Lower Duwamish Waterway Group

Port of Seattle / City of Seattle / King County / The Boeing Company

QUALITY ASSURANCE PROJECT PLAN: BENTHIC INVERTEBRATE SAMPLING OF THE LOWER DUWAMISH WATERWAY

FINAL

For submittal to

The US Environmental Protection Agency
Region 10
Seattle, WA

The Washington State Department of Ecology
Northwest Regional Office
Bellevue, WA

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TITLE AND APPROVAL PAGE
LDW BENTHIC INVERTEBRATE
QUALITY ASSURANCE PROJECT PLAN

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Acronyms

ACRONYM	Definition
%RSD	percent relative standard deviation
ACG	analytical concentration goal
Axys	Axys Analytical Services, Ltd
CAS	Chemical Abstracts Services
COC	chain-of-custody
Columbia	Columbia Analytical Services, Inc.
COPC	chemical of potential concern
cPAH	carcinogenic polycyclic aromatic hydrocarbon
CPUE	catch per unit effort
CSL	cleanup screening level
DQI	data quality indicator
DQO	data quality objective
Ecology	Washington Department of Ecology
EPA	US Environmental Protection Agency
EPC	exposure point concentration
ERA	ecological risk assessment
FC	field coordinator
Frontier	Frontier Geosciences, Inc.
GPS	global positioning system
HHRA	human health risk assessment
HPAH	high-molecular-weight polycyclic aromatic hydrocarbon
HSP	Health and Safety Plan
ITIS	Integrated Taxonomic Identification System
LCS	laboratory control standard
LDW	Lower Duwamish Waterway
LDWG	Lower Duwamish Waterway Group
LPAH	low-molecular-weight polycyclic aromatic hydrocarbon
MDL	method detection limit
MHHW	mean higher high water
MLLW	mean lower low water
NOAA	National Oceanic and Atmospheric Administration
OC	organic carbon
OSHA	Occupational Health and Safety Administration

ACRONYM	Definition
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
RI	Remedial Investigation
ROC	receptor of concern
RPD	relative percent difference
SD	standard deviation
SDG	sample delivery group
SQS	Washington State Sediment Quality Standards
SRM	standard reference material
SVOC	semivolatile organic compound
T-117	Terminal 117
TM	task manager
TOC	total organic carbon
TBT	tributyltin
Windward	Windward Environmental LLC
UCL	upper confidence limit
WQA	Water Quality Assessment

1.0 Introduction

This quality assurance project plan (QAPP) describes the quality assurance (QA) objectives, methods, and procedures both for conducting a qualitative benthic invertebrate community characterization, and for collecting and analyzing benthic invertebrate tissue and co-located sediment in the Lower Duwamish Waterway (LDW). Data from these studies will be used to support the ecological and human health risk assessments for Phase 2 of the LDW Remedial Investigation (RI), as described in the Phase 2 RI work plan (Windward 2004c). Section 3.1.5 of the Phase 2 work plan presented a preliminary study design for benthic invertebrate community characterization and sampling and chemical analyses of co-located benthic invertebrate tissue and sediment to provide all stakeholders with a common understanding of the objectives, background, and general study design. This QAPP presents the study design, including details on project organization, field data collection, laboratory analysis, and data management. This QAPP was prepared in accordance with guidance for preparing QAPPs from the US Environmental Protection Agency (EPA) (2002).

Four benthic invertebrate studies are described in this QAPP:

- collection and analysis of "market basket"[1] benthic invertebrate tissue samples and co-located surface sediment samples
- qualitative benthic community characterization
- collection and analysis of gastropod tissue samples and co-located surface sediment samples
- collection and analysis of clam tissue samples and co-located surface sediment samples

This plan is organized into the following sections:

- 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 – oversize figures

A health and safety plan (HSP) designed for the protection of on-site personnel from physical, chemical, and other hazards posed during field sampling activities is

[1] In the market basket approach, all benthic invertebrates (except bivalves and epibenthic crustaceans larger than 2 cm) are collected within a targeted sampling area and combined into a single composite sample.

included as Appendix A. Field collection forms are included as Appendix B. The derivation of risk-based analytical concentration goals for tissue is presented in Appendix C. The derivation of analytical concentration goals for sediment collected at clam sampling locations is presented in Appendix D. The derivation of salinity ranges in the LDW used in the benthic community characterization is presented in Appendix E.

An addendum to this QAPP will be prepared and submitted (in draft) to EPA and Ecology June 17, 2005 presenting specific locations where gastropods will be collected to directly assess the imposex endpoint. These locations will be based on TBT concentrations in surface sediment to be sampled in the winter/spring of 2004-2005.

2.0 Project Management

This section describes the overall management of the project, including key personnel, project description, problem definition and background, quality objectives and criteria, special training requirements and certification, and documents and record keeping.

2.1 Project Organization and Team Member Responsibilities

Figure 2-1 shows the overall project organization for the four Phase 2 benthic invertebrate studies described in this QAPP. Responsibilities of project team members, as well as those of the laboratory project managers, are described in the following sections.

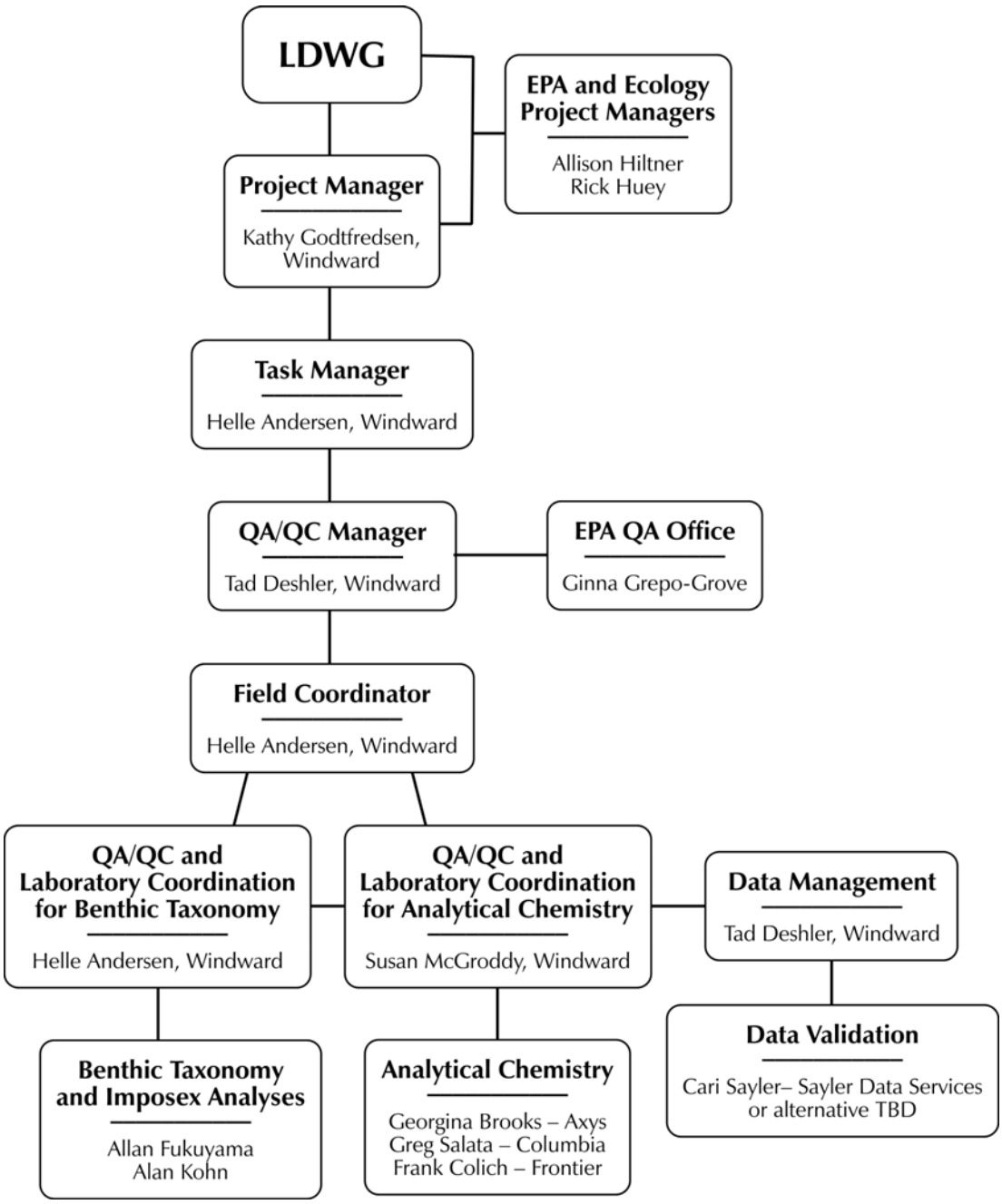

Figure 2-1. Project organization

2.1.1 Project management

The Lower Duwamish Waterway Group (LDWG), EPA, and the Washington Department of Ecology (Ecology) will be involved in all aspects of this project, including discussion, review, and approval of the QAPP, and interpretation of the results of the investigation. EPA and Ecology will be represented by their Project Managers (PMs) for this project, Allison Hiltner and Rick Huey, respectively.

Kathy Godtfredsen will serve as the Windward PM, 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 LDWG, EPA, and Ecology on schedule, deliverables, and other administrative details. Dr. Godtfredsen can be reached as follows:

Kathy Godtfredsen
Windward Environmental LLC
200 W. Mercer St., Suite 401
Seattle, WA 98119
Telephone: 206.577.1283
Facsimile: 206.217.0089
Email: kathyg@windwardenv.com

Helle Andersen 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 LDWG, EPA, and Ecology. Ms. Andersen can be reached as follows:

Helle Andersen
Windward Environmental LLC
200 W. Mercer St., Suite 401
Seattle, WA 98119
Telephone: 206.577.1287
Facsimile: 206.217.0089
Email: hellea@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 general field quality assurance/quality control (QA/QC) oversight. She will ensure that appropriate protocols for sample collection, preservation, and holding times are observed and oversee delivery of environmental samples to the designated laboratories for chemical and taxonomic analyses.

2.1.3 Quality assurance/quality control

Tad Deshler of Windward will serve as QA/QC manager for the project. As the QA/QC manager, he will provide oversight for the coordination of the field sampling and laboratory programs, and will supervise data validation and project QA coordination, including coordination with the EPA QA officer, Ginna Grepo-Grove.

Mr. Deshler can be reached as follows:

Tad Deshler
Windward Environmental LLC
200 W. Mercer St., Suite 401
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Facsimile: 206.217.0089
Email: tad@windwardenv.com

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US Environmental Protection Agency, Region 10
1200 6th Avenue
Seattle, WA 98101
Telephone: 206.553.1632
Email: grepo-grove.gina@epa.gov

Susan McGroddy of Windward will serve as the QA/QC coordinator for chemical analyses. Dr. McGroddy can be reached as follows:

Susan McGroddy
Windward Environmental LLC
200 W. Mercer St., Suite 401
Seattle, WA 98119
Telephone: 206.577.1292
Facsimile: 206.217.0089
Email: susanm@windwardenv.com

Helle Andersen of Windward will also serve as the QA/QC coordinator for benthic taxonomy. The QA/QC coordinators will ensure that samples are collected and documented appropriately and coordinate with the analytical and taxonomy laboratories to ensure that QAPP requirements are followed. Independent third-party chemical data review and validation will be provided by Cari Sayler of Sayler Data Solutions, Inc (or a suitable alternative). Ms. Sayler can be reached as follows:

Cari Sayler
Sayler Data Solutions, Inc.
14257 93rd Court NE
Bothell, WA 98011
Telephone: 425.820.7504
Email: cari@saylerdata.com

The benthic taxonomy data will be validated by expert taxonomists (see Section 3.5.2) as part of the taxonomic identification process performed by the laboratory. Windward will review the data by comparing the raw data from the primary taxonomists with the electronic data provided by the laboratory.

2.1.4 Laboratory project management

Susan McGroddy of Windward will serve as the laboratory coordinator for the analytical chemistry laboratories, and Helle Andersen of Windward will serve as the laboratory coordinator for the benthic taxonomy laboratory. Columbia Analytical Services Inc. (Columbia), Frontier Geosciences Inc. (Frontier), and Axys Analytical Services Ltd. (Axys) will perform chemical analyses on the tissue and sediment samples. The laboratory PM at Columbia can be reached as follows:

Greg Salata
Columbia Analytical Services, Inc.
1317 S 13th Avenue
Kelso, WA 98626
Telephone: 360. 577. 7222
Facsimile: 360. 636.1068
Email: gsalata@kelso.caslab.com

The laboratory PM at Frontier can be reached as follows:

Frank Colich
Frontier Geosciences, Inc.
414 Pontius Ave N
Seattle, WA 98109
Telephone: 206.622.6960
Facsimile: 206.622.6870
Email: frankc@frontiergeosciences.com

The laboratory PM at Axys can be reached as follows:

Georgina Brooks
Axys Analytical Services, Ltd.
PO Box 2219
2045 Mills Road
Sidney, British Columbia V8L 3S8
Canada
Telephone: 250.656.0881
Facsimile: 250.656.4511
Email: gbrooks@axys.com

Allan Fukuyama's taxonomy laboratory will perform invertebrate identification and enumeration on the benthic community samples. Dr. Fukuyama can be reached as follows:

Allan Fukuyama
7019 157th St. SW
Edmonds, WA 98026
Telephone: 425.745.3349
Email: allanf@u.washington.edu

Alan Kohn will perform the imposex analysis of the gastropods. Dr. Kohn can be reached as follows:

Alan Kohn
Professor Emeritus, Zoology
Box 351800
410 Kincaid
Seattle, WA 98195
Telephone: 206.616.4383
Email: kohn@u.washington.edu

The laboratories will accomplish the following:

- adhere to the methods outlined in this QAPP, including those 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 the QAPP
- allow EPA and the QA/QC third-party auditors to perform laboratory and data audits

2.1.5 Data management

Tad Deshler will oversee data management to ensure that analytical data are incorporated into the LDWG database with appropriate qualifiers following acceptance of the data validation. QA/QC of the database entries will ensure accuracy for use in Phase 2.

2.2 PROBLEM DEFINITION/BACKGROUND

The Phase 2 RI work plan (Windward 2004a) identified the need for additional benthic invertebrate community data and the collection of co-located benthic invertebrate tissue and surface sediment samples for chemical analyses. This section presents the objectives and background information for four studies to address these data needs. These studies include the benthic community characterization, an evaluation of imposex in gastropods, and studies involving collection of co-located sediment and two different types of benthic invertebrate tissue samples (market basket and clams). An overview of each study and its schedule is presented in Section 2.3, and detailed sampling designs are presented in Section 3.1.

2.2.1 Market basket benthic invertebrate tissue and sediment samples

Benthic invertebrates are important prey items for many fish species in the LDW, including juvenile chinook salmon, Pacific staghorn sculpin, and English sole, which were selected as fish receptors of concerns (ROCs) for the Phase 2 Ecological Risk Assessment (ERA) (see Section 3.1.1). Benthic invertebrates are also key prey items for spotted sandpiper, a Phase 2 wildlife ROC. Risks to these fish and wildlife ROCs will be assessed, in part, through exposure to chemicals in their diet. However, sufficient data are not available regarding the concentrations of chemicals in key prey items collected from the LDW. Therefore, the objective of this study is to collect composite samples of benthic invertebrates and co-located sediment samples to evaluate the dietary exposure of fish and wildlife ROCs to sediment-associated chemicals, including those identified as chemicals of potential concern (COPCs) in Phase 1. Another objective of these data is to support a food web model, as described in Section 3.1.2.

To date, one study has been conducted in the LDW to characterize chemical concentrations in benthic invertebrate tissue samples. The King County WQA (King County 1999a) collected four composite tissue samples of approximately 2,000 amphipods (*Corophium* and *Eogammarus* spp.) each near Kellogg Island. These tissue samples were associated with sediment samples collected in the general vicinity of the island. These tissue samples were analyzed for metals, tributyltin (TBT), semivolatile organic compounds (SVOCs), and polychlorinated biphenyls (PCBs). Additional data are needed to characterize the concentrations of chemicals in benthic invertebrate tissues throughout the LDW over a range of chemical concentrations in sediment.

2.2.2 Benthic community characterization

The benthic invertebrate community is one of the ROCs identified in the Phase 1 ERA (Windward 2003) and will also be a Phase 2 ROC. In addition, benthic invertebrates are important prey items for fish and wildlife that forage in the LDW. Risk to the benthic community will be primarily assessed through comparison of sediment chemical concentrations to Washington State Sediment Management Standards and by conducting laboratory sediment toxicity tests (Windward 2004c), and will be described in the upcoming surface sediment QAPP. The primary objectives of this benthic community characterization are to collect additional data within representative LDW habitats on the general composition, relative abundance, and distribution of the diverse group of animals in the benthic community, and to provide this information in areas targeted for market basket samples.

The LDW benthic community has been characterized in selected areas in the past. Most existing benthic community data from the LDW were collected in the region between Kellogg and Harbor Islands, with only a few samples collected upstream of

Kellogg Island (Figure 2-2) (oversize figure; see Section 7.0). Five studies[2] have been conducted in the LDW examining benthic community, three of which were conducted in the last ten years:

- Cordell et al. (1996, 1997, 1999, 2001) evaluated the intertidal communities in both vegetated and non-vegetated areas throughout the LDW, primarily associated with restoration sites
- Three stations located in the LDW were evaluated as part of the sediment quality reconnaissance study for central Puget Sound (Ecology 2000)
- The subtidal communities around the Diagonal/Duwamish combined sewer overflow (CSO) outfall and the northern tip of Kellogg Island were evaluated during King County's water quality assessment (WQA) for the Duwamish River (King County 1999b)
- Epibenthic samples were collected along seven transects near Kellogg Island as part of an evaluation of the intertidal habitats (Williams 1990)
- Leon (1980) evaluated the benthic invertebrate communities at nine intertidal and five subtidal stations in the lower portion of the LDW (river mile [RM] 0.1-1.5)

Table 2-1 summarizes general sampling information from the three most recent studies; station locations from all existing studies are shown in Figure 2-2 (oversize figure; see Section 7.0). These data are of acceptable quality for qualitative use as a result of the use of standard methods, reputable taxonomy laboratories, and sufficient documentation, and thus provide useful information for a number of habitat types and locations within the LDW. However, some of the methods (i.e., sampling season, sampling gear, sieve size) differ among the surveys. Thus, direct comparison of these results to e benthic community data collected as part of the study outlined in this QAPP is somewhat uncertain. In addition, existing data are not available from all habitat types in the LDW. Therefore, additional data are needed; these data will be used to further qualitatively define the benthic community in the LDW from a resource perspective. Additional benthic community data are also needed because there is a desire to have information regarding the benthic community collected synoptically with market basket tissue chemistry samples.

[2] Cordell et al. (1996, 1997, 1999, 2001) is counted as a single study.

Table 2-1. Sample information available from the three most recent benthic community studies in the LDW

Study	Sampling Device	Sieve	Sampling Season	# of Replicate Samples	Taxonomy Coordinator	Station	RM	% Fines	Elevation (ft, MLLW)
Ecology 2000	0.1-m^2 grab	1.0- and 0.5-mm (nested)	June 1998	3	Kathy Welch	Duwamish Station 203	0.5	63	approx -13
				3		Duwamish Station 204	0.5	24	approx -15
				3		Duwamish Station 205	1.8	56	approx -24
King County 1999a	0.1-m^2 grab	1.0-mm	September 1997	5	Allan Fukuyama	DDS-1	0.6	14.6	-9.4
				5		KI-1	0.6	90.6	-41
				5		DDS-3	0.6	81.2	-25
				5		DDS-5	0.6	85.2	-40
				5		KI-2	0.7	93.2	-24
				5		KI-4	0.7	24.7	-11
Cordell et al. 1996-2001[a]	0.0024-m^2 core	0.5-mm	August 1993	5	Kathy Welch	Duwamish bench	0.0	6.3	0.0
			May 1995	5		T-105 restoration site	0.1	4.8	0.0
			April, May, June 1996	5		*Scirpus* patch	0.5	< 20[b]	0.0
			April, May, June 1997	5		Benthic reference site	0.7	approx. 75[b]	0.0
			March, April, May, June 1999	5		Kellogg Island	0.8	59.7	0.0
				5		GSA bench	1.1	4.0	0.0
				5		GSA *Scirpus* site	1.2	approx. 50[b]	0.0
				5		*Carex* site 3	3.0	na	0.0
				5		*Carex* site 2	4.0	na	0.0
				5		benthic reference site	4.7	45.8	0.0
				5		benthic restoration site	4.7	47.2	0.0
				5		*Carex* site 1	4.9	na	0.0

[a] Baseline studies prior to restoration were performed in August 1993. Restoration was performed in late 1993 and 1994, followed by the studies listed above.

[b] Percent fines taken from grain size distribution graphs (Cordell et al. 2001)

DDS – Diagonal Duwamish Study

GSA – General Services Administration

KI – Kellogg Island

MLLW – mean lower low water

RM – river mile relative to the southern tip of Harbor Island

na – not available

2.2.3 Gastropod samples

TBT was identified in the Phase 1 ERA as a COPC for benthic invertebrates and will be evaluated using a tissue-based approach in the Phase 2 ERA. Therefore, benthic invertebrate tissue data are needed to assess the risk of TBT to benthic invertebrates in the LDW. Based on the scientific literature, the benthic invertebrates most sensitive to TBT that are found in the LDW are snails, specifically neo- and mesogastropods (Meador et al. 2002). At sufficiently high tissue concentrations, TBT is known to cause the development of male sexual organs (a condition known as imposex) in female neo- and mesogastropods, which, if sufficiently pronounced, can interfere with reproduction and potentially result in population-level effects (Gibbs and Bryan 1996). However, little is known regarding the site use of gastropods in the LDW, and no data exist regarding the concentrations of TBT in gastropod tissues. Thus, the objectives of this study are fourfold:

- to assess the presence and general distribution of gastropods (particularly neo- and mesogastropods) in the LDW
- to conduct a preliminary assessment of whether field-collected gastropods show signs of imposex, a direct measure of the endpoint of concern
- to assess the feasibility of collecting a sufficient number of gastropods (or a surrogate taxon) for chemical analysis
- to collect co-located tissue and sediment samples for chemical analysis of TBT to assess risk to benthic invertebrates

The first three objectives will be addressed through a gastropod pilot survey.[3] This survey will be conducted at numerous intertidal and subtidal locations with a range of TBT concentrations in sediment using different sampling techniques. Based on the results of this survey, the appropriate benthic invertebrate tissue type for collection and chemical analysis of TBT will be selected.

Relatively few data exist regarding the abundance and distribution of gastropods in the LDW, and the studies that do exist were not specifically designed to provide this information (e.g., they may not have included sampling in areas with the most appropriate substrate; sampling devices may not have been the most appropriate for collecting gastropods). King County (1999a) reported numerous gastropods, including neo- and mesogastropods, in the downstream reaches of the LDW, with the greatest abundance in the area between the southern tip of Harbor Island and Kellogg Island (river mile [RM] 0 to RM 0.5). At stations near Kellogg Island, Leon (1980) collected two individuals each of two different neogastropod species, *Nassarius* sp. and *Mitrella gouldii*, and one individual mesogastropod, *Barleeia* sp.,

[3] Survey methods for the gastropod pilot survey are presented in the Gastropod Pilot Survey Results Technical Memorandum(Windward 2004d), which was approved by EPA and Ecology on June 4, 2004. The results of the pilot survey will be presented in a separate technical memorandum and discussed at a July 15, 2004 meeting with EPA and Ecology.

using a 0.5-m^2 van Veen grab sampler. Williams (1990) collected a single unidentified mesogastropod larva using a 0.018-m^2 plankton pump in the subtidal area at the south end of Kellogg Island. No gastropods were reported in Cordell et al. (1996, 1997, 1999, 2001) or Ecology (2000). Table 2-2 presents the abundance of gastropods previously collected in the LDW, and Figure 2-2 (oversize figure; see Section 7.0) shows the station locations of previous investigations of benthic communities, including the stations where gastropods were found.

Also, few data exist regarding TBT concentrations in benthic invertebrate tissues collected from the LDW. As noted in Section 2.2.2, the only TBT data available for benthic invertebrate species in the LDW are from four composite tissue samples of amphipods (mixed *Corophium* and *Eogammarus* sp.) collected near Kellogg Island, with associated sediment samples (King County 1999a).

Thus, additional data are needed to assess TBT risk to benthic invertebrates in the LDW by assessing site use of the LDW by neo- and mesogastropods, measuring imposex in gastropods, and analyzing TBT in the appropriate benthic invertebrate tissues.

2.2.4 Clam tissue and sediment samples

Clams may be consumed by both people and wildlife. However, clams were not included as prey items for wildlife or as a food source for people in the Phase 1 risk assessments because no chemical data were available in clam tissues and because few data were available documenting the abundance of clams within the LDW. To address the lack of abundance data, a clam abundance survey was conducted in August 2003. The results of the survey (Windward 2004a) indicated that the abundance of clams at multiple intertidal locations in the LDW is sufficient to support some consumption by people. Therefore, the primary objective of the clam study is to collect composite samples of clams from intertidal areas where clams could be harvested by people. These clam tissue samples will be chemically analyzed and the data will be used in the Phase 2 risk assessments to estimate exposure to people who could consume clams collected from the LDW, and to estimate exposure of otters, a wildlife ROC that may consume clams as a part of their diet. Another objective of this study is to collect co-located sediment data to evaluate the relationship between chemical concentrations in clams and sediment (see Section 3.1.4).

No chemical data exist for clams collected from the LDW. The only existing chemical concentration data in bivalves are the mussel tissue data collected as part of the King County WQA (King County 1999a). As part of that study, 22 composite mussel tissue samples were collected from the LDW and analyzed for SVOCs, PCBs, metals, and TBT, and half of the samples were also analyzed for chlorinated pesticides. Thus, additional data are needed to characterize the concentrations of chemicals in clams collected from intertidal areas of the LDW.

Table 2-2. Summary of existing data for gastropods collected in the LDW

Order	Taxon	Abundance (number of organisms)	Maximum Shell Height (cm)	Estimated weight [a] (g)	Location	River Mile	Substrate	Sampling Device	Study
Neogastropoda	*Nassarius* sp.	2	1.8-4.7	0.5-9.5	Stations 9 and 12	0.5 and 0.7	sandy mud	0.05-m^2 grab	Leon 1980
	Alia carinata	1	1.0	0.09	DDS-3	0.4	81.2% fines	0.1-m^2 grab	King County 1999a
	Mitrella gouldii [b]	20	2.5	1.4	DDS-3, DDS-5, KI-1, KI-2	0.4–0.6	81.2-93.2% fines	0.1-m^2 grab	King County 1999a
		2	2.5	1.4	Stations 10 and 11	0.9	sandy mud	0.05-m^2 grab	Leon 1980
Mesogastropoda	*Epitonium* sp.	98	1.5-3.2	0.3-3.0	DDS-3, DDS-5, KI-1, KI-2	0.4 – 0.5	81.2-93.2% fines	0.1-m^2 grab	King County 1999a
	Mellanella sp. [c]	1	na	na	DDS-3	0.4	81.2% fines	0.1-m^2 grab	King County 1999a
	Alvania compacta	30	0.3	0.002	DDS-1 DDS-3, DDS-5, KI-1, KI-2	0.4 – 0.5	14.6 (DDS-1) and 81.2-93.2% fines	0.1-m^2 grab	King County 1999a
	Barleeia sp.	1	0.3-0.4	0.002-0.01	Station 12	0.7	mud with wood chips	0.05-m^2 grab	Leon 1980
	Tachyrhynchus sp.	1	2.0-3.0	0.7-2.4	DDS-3	0.4	81.2% fines	0.1-m^2 grab	King County 1999a
	unidentified larva	1	na	na	south end Kellogg Island	0.9	very fine sediment	0.018-m^2 area plankton pump	Williams 1990
Opisthobranchia [d]	*Odostomia* sp.	4	0.6-1.0	0.02-0.5	DDS-3, DDS-5, KI-2	0.4 – 0.5	81.2-93.2% fines	0.1-m^2 grab	King County 1999a
Nudibranchia	Aeolidacea	1	na	na	DDS-3	0.4	81.2% fines	0.1-m^2 grab	King County 1999a
Cephalaspidea	*Gastropteron pacificum*	10	na	na	KI-1, KI-2	0.5	90.6-93.2% fines	0.1-m^2 grab	King County 1999a
	Melanochlamys diomedea	9	na	na	DDS-5, KI-1, KI-2	0.4 – 0.5	85.2-93.2% fines	0.1-m^2 grab	King County 1999a

[a] Total dry weight of tissue (shell excluded) for all individuals collected, estimated as a function of measured shell height, based on Tokeshi et al. (2000) and an assumed gastropod tissue moisture content of 80%

[b] Also known as *Nitidella gouldii*

[c] Small parasite on sea cucumbers

[d] Subclass of Mollusca; other taxa in this column are orders of Mollusca

na – not available

DDS – Diagonal Duwamish Study; KI – Kellogg Island

2.3 PROJECT/TASK DESCRIPTION AND SCHEDULE

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

2.3.1 Market basket benthic invertebrate tissue and sediment samples

Co-located market basket benthic invertebrate tissue and surface sediment samples will be collected in intertidal and subtidal areas from August 9 to 20, 2004. Sampling in August is appropriate because although abundance, diversity, and benthic invertebrate biomass vary seasonally and spatially, the highest subtidal benthic invertebrate abundance and biomass were reported in late summer in Elliott Bay (Dexter et al. 1981). Each market basket benthic invertebrate tissue sample will be organized into major taxonomic groups at Windward, photographed, weighed, and re-combined into composite samples (see Section 3.2.3). These composite samples will then be submitted to Columbia and Axys for chemical analyses (see Section 3.4.2.1). Chemical analysis of the samples, as described in Section 3.4.2, should be completed in September 2004. A draft report presenting the chemical data from all the benthic invertebrate tissue and co-located sediment samples will be submitted to EPA and Ecology on November 19, 2004.

2.3.2 Benthic community characterization

Benthic community samples will be collected synoptically with market basket samples from August 9 to 20, 2004 to provide additional information on the general composition, relative abundance, and distribution of benthic invertebrates from representative habitats throughout the LDW and at market basket locations. Representative habitats were defined based primarily on sediment elevation, grain size, and salinity (see Section 3.1.1). At the taxonomy laboratory, the benthic invertebrates will be divided into major taxonomic groups (i.e., Annelida, Crustacea, Mollusca, Echinodermata, and miscellaneous phyla), photographed, weighed, and enumerated (see Section 3.4.1.1). The sorted organisms will then be identified and keyed to the lowest taxonomic level practical, generally the species level, by an experienced taxonomist. Numerical abundance data will be reported for each sample both by the lowest taxa practical and by major taxonomic groups. Taxonomic analyses should be completed in November 2004, and a draft data report will be submitted to EPA and Ecology on January 24, 2005.

2.3.3 Gastropod samples

A gastropod pilot survey was conducted in mid-June 2004 to assess the feasibility of collecting gastropods for chemical analyses of TBT over a range of TBT concentrations in sediment and to conduct a preliminary assessment of imposex in field-collected

gastropods. A technical memorandum was approved by EPA and Ecology on June 4, 2004 outlining which areas were to be surveyed and the sampling techniques that were to be used to assess the feasibility of collecting gastropods or a surrogate taxon (Windward 2004d). Results of the gastropod pilot survey were summarized in a technical memorandum (Windward 2004f), and discussed at a meeting with EPA and Ecology on July 15, 2004. At the meeting, it was agreed that additional gastropod collection will be conducted in summer 2005 at locations to be specified in a June 17, 2005 draft addendum to this QAPP based on the results of the surface sediment sampling specified in the surface sediment QAPP.

Risks to gastropods from TBT will be assessed directly through the measurement of imposex in field-collected gastropods from areas representing a range of TBT concentrations in surface sediment in the lower one mile (approximately RM 0.0 to 1.0) of the LDW where concentrations of TBT in surface sediment are highest. A QAPP addendum will be submitted to EPA and Ecology June 17, 2005 describing in detail the locations of gastropod collection and the imposex analysis methods to be used (methods likely to be similar to those used in the gastropod pilot survey). As many neo- and meso-gastropod species as possible will be assessed as part of this effort. Risks to the rest of the benthic community from TBT will be assessed by analyzing TBT in market basket benthic invertebrate tissue samples (see Section 3.1.1), and comparing the TBT concentrations to survival, growth, and reproduction endpoints (excluding the imposex endpoints for gastropods, which will be assessed directly).

2.3.4 Clam tissue and sediment samples

Co-located clam and surface sediment samples will be collected from intertidal areas in the LDW from August 24 to 30, 2004 when the tides are lowest. Intertidal areas, primarily associated with high quality clam habitat in the 2003 survey (Windward 2004a), will be sampled over a range of chemical concentrations in sediment. Chemical analyses of these tissue samples, described in Section 3.4.2, will be completed in late September or early October 2004. A draft report presenting the chemical data for all the benthic invertebrate tissue and co-located sediment samples will be submitted to EPA and Ecology on November 19, 2004.

2.4 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.

2.5 SPECIAL TRAINING/CERTIFICATION

The Superfund Amendments and Reauthorization Act of 1986 required 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 personal health. All sampling personnel will have completed the 40-hour HAZWOPER training course and 8-hour refresher courses, as necessary, to meet the OSHA 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:

- surface sediment collection form
- benthic community collection form
- market basket benthic invertebrate collection form
- clam tissue collection form
- protocol modification form
- corrective action form

2.6.2 Laboratory records

The various laboratory record requirements for the benthic community characterization data and the co-located tissue and sediment chemistry data are described below.

2.6.2.1 Benthic community data

The benthic taxonomy laboratory will be responsible for internal checks on sample handling and analytical data reporting, and will correct errors identified during the QA review (see Sections 3.4.1 and 3.5.2). Close contact will be maintained with the

laboratory to resolve any QC problems in a timely manner. 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 the identification process. The summary will include, but not be limited to, discussion of quality control, sample shipment, and identification difficulties.
- **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, including shipment of the voucher collection and the subset of samples to the secondary taxonomists.
- **Sample results**: The data package will summarize the results for each sample analyzed. The summary will include the following information:
  - field sample identification code and the corresponding laboratory identification code
  - name, count, and Integrated Taxonomic Identification System (ITIS; www.itis.usda.gov) taxonomic number of each taxon observed
- **QA/QC summary:** The summary will contain the results of the QA/QC procedures, including the re-sorting and re-identification of samples, voucher collection, and any corrective actions required.

An example of the acceptable organization of the electronic deliverable for taxonomic data is provided in Table 2-3.

Table 2-3. Example of acceptable organization of electronic deliverable for taxonomic data

FIELD NAME	REQUIRED OR OPTIONAL
Event name	required
Chain of custody ID	required
Laboratory sample ID	required
Sample collection date/time	required
Taxon	required
Integrated taxonomic information system (ITIS) number	required
Taxon abundance	required
Laboratory notes	optional
Laboratory	required

2.6.2.2 Chemistry data for co-located tissue and sediment studies

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, discussion of quality control, 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 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, when 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 and reporting limits
  - 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 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 (RPD), and the retention time for each analyte will be listed, as appropriate. Results for standards to indicate 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 recovery summary will report the matrix spike or matrix spike/matrix spike duplicate 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 matrix spike and matrix spike duplicate analyses will be reported.
- The matrix duplicate summary will report the RPD for all matrix duplicate 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 3.4.2.2, for each analyte.
- The laboratory control analysis summary will report the results of the analyses of laboratory control samples. 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 refrigerator temperature logs
  - sample extraction/digestion, preparation, and cleanup logs
  - instrument specifications and analysis logs for all instruments used on days of calibration and analysis
  - reconstructed ion chromatograms for all samples, standards, blanks, calibrations, spikes, replicates, laboratory control samples, and standard reference materials
  - final gas chromatograph-electron capture detection (GC-ECD) chromatograms used in the quantification of the sample
  - enhanced spectra of detected compounds with associated best-match spectra for each sample

- printouts and quantitation reports for each instrument used, including reports for all samples, standards, blanks, calibrations, spikes, replicates, and laboratory control samples, and SRMs
- original data quantification reports for each sample

The contract laboratories for this project will submit data electronically, in Microsoft Excel® or delimited-text format. Guidelines for electronic data deliverables for chemical data are as follows:

- Each row of data will contain only one analyte for a given sample. Therefore, one complete sample will require multiple rows.
- Each row should contain the following information at a minimum: Windward sample identifier, sample matrix, laboratory sample identifier (if used), date of sampling, date of laboratory analysis, laboratory method, analyte name, measured result, laboratory qualifiers, units, and measurement basis.
- If using a spreadsheet file to produce the electronic deliverable, the value representing the measured concentration or detection limit will be rounded to show the correct number of significant figures and will not contain any trailing digits that are hidden in the formatting.
- If using a database program to produce the electronic deliverable, the value representing the measured concentration or detection limit will be stored in a character field, or a field in addition to the numeric result field will be provided to define the correct number of significant figures.
- If a result for an analyte is below the detection limit, the laboratory qualifier will be U, and the value in the result column will be the sample-specific detection limit.
- Analytical results of laboratory samples for QA/QC will be included and clearly identified in the file with unique laboratory sample identifiers. Additional columns may be used to distinguish the sample type (e.g., matrix spike, matrix spike duplicate).
- If replicate analyses are conducted on a submitted field sample, the laboratory sample identifier must distinguish among the replicates.
- Wherever possible, all analytes and replicates for a given sample will be grouped together.

An example of the acceptable organization of the electronic deliverable for chemical data is provided in Table 2-4.

Table 2-4. Example of acceptable organization of electronic deliverable for chemical data

FIELD NAME	REQUIRED OR OPTIONAL
Event name	required
Chain of custody ID	required
Laboratory sample ID	required
Matrix	required
Sample collection date/time	required
Requested analysis	required
Analyte	required
Chemical Abstracts Services (CAS) registry number	required
Date/time analyzed	required
Detection limit	required
Reporting limit	required
Reporting limit type	required
Sample result	required
Units	required
ResultSigFig	required
Laboratory qualifier	required [a]
Analysis batch	required
True value/spiked amount	optional
Percent recovery	required [a]
Upper limit	optional
Lower limit	optional
Analyst	required
Dilution	required
Extraction batch	required
Extraction date/time	required
Extraction method	required
Percent moisture	required [a]
Laboratory notes	optional
Laboratory	required

[a] Required when available. Not all samples are qualified. Blanks and laboratory control standards (LCSs) have no percent moisture. Field samples have no percent recovery.

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 analysis of the data. 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 PM, the Windward PM, the Project

QA/QC Coordinator, and independent 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 documenting 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 invertebrates samples (either as pictures in the report or submitted on a CD)
- summary spreadsheet containing information from field forms
- sediment and invertebrate sampling locations 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
- results from the analysis of field samples, both as summary tables in the main body of the report and appendices with data forms submitted by the laboratories and cross-tab tables produced from Windward's database

Data will be validated within five weeks of receiving data packages from the respective laboratories. A draft data report will be submitted to EPA and Ecology eight weeks after receipt of the validated analytical results. A final data report will be submitted to EPA and Ecology approximately four weeks after receiving comments on the draft report (see Section 2.3). Once the data report has been approved by EPA and Ecology, a database export will be created from Windward's database. The data will be exported in SEDQUAL format as well as the format used to export the historical chemistry data in Phase 1, which consists of separate tables for events, locations, samples, and results.

3.0 Data Generation and Acquisition

This section describes the collection and processing of benthic invertebrate community samples, benthic invertebrate tissue samples, and sediment samples for chemical analysis. Elements include sampling design, sampling methods, sample handling and custody requirements, analytical methods, quality assurance/quality control, instrument/equipment testing and frequency, inspection and maintenance, instrument calibration, supply inspection/acceptance, non-direct measurements, and

data management. Each of the four studies detailed in this QAPP (i.e., benthic community characterization, and the market basket, gastropod, and clam tissue studies) is described separately in the sampling design and sampling methods sections.

3.1 SAMPLING DESIGN

Separate sampling designs have been developed for each of the four benthic invertebrate studies, as described below. These studies have been designed to address the study objectives defined in Section 2.2.

3.1.1 Market basket benthic invertebrate tissue and sediment samples

This section presents the process for selecting locations where co-located market basket benthic invertebrate tissue and surface sediment samples will be collected. Composite samples for benthic community characterization will also be collected at these locations (see Section 3.1.2). In the market basket approach, benthic invertebrates less than 2 cm are collected within a given sampling area and combined into a single composite sample. A size threshold of 2 cm was selected based on the beak size of spotted sandpipers (2.4 cm in length) and the size of prey preferred by various fish species. Chemical analyses of samples collected using this sampling approach provide an estimate of chemical concentrations in benthic invertebrates available for ingestion by fish and wildlife. These data will be used in the Phase 2 ERA to assess the dietary exposure of Phase 2 ROCs that consume benthic invertebrates: juvenile chinook salmon, English sole, Pacific staghorn sculpin, and spotted sandpiper. These data will also support the food web model to link concentrations of risk-driving, bioaccumulative chemicals in fish tissue (English sole, sculpin, perch) and crabs to concentrations of these chemicals in sediment. The market basket samples will be an important component of the model for fish.

Likely prey items for fish ROCs in the LDW, other than juvenile chinook salmon, can be identified from studies conducted in Puget Sound. Three studies (Fresh et al. 1979; Miller et al. 1977; Wingert et al. 1979) examined the stomach contents of English sole, Pacific staghorn sculpin, shiner surfperch, striped perch, and pile perch collected from Puget Sound (Table 3-1).

Table 3-1. Summary of prey preference studies for English sole, Pacific staghorn sculpin, and perch

Species	Fresh et al. (1979)			Wingert et al. (1979)			Miller et al. (1977)		
	n	Dominant Food Items	Fish % IRI	n	Dominant Food Items	Fish % IRI	n	Dominant Food Items	Fish % IRI
English sole	63	polychaetes, gammarid amphipods, bivalve siphons	0	99	polychaetes, gammarid amphipods, bivalves	0	46	cumaceans, polychaetes, gammarid amphipods	0

Species	Fresh et al. (1979)			Wingert et al. (1979)			Miller et al. (1977)		
	n	Dominant Food Items	Fish % IRI	n	Dominant Food Items	Fish % IRI	n	Dominant Food Items	Fish % IRI
Pacific staghorn sculpin	57,[a] 85[b]	benthic and epibenthic crustaceans (gammarid amphipods, shrimp, brachyuran crabs, mysids), fish	29.1,[a] 1.2[b]	25	gammarid amphipods, fish, crabs	17.5	51	polychaetes, isopods, bivalve siphons, crabs, fish (including juveniles and larvae)	3.2-51.7
Shiner surfperch	24	epibenthic and planktonic invertebrates (copepods, amphipods)	0	10	gammarid and caprellid amphipods, copepods	0	31	gammarid and caprellid amphipods, polychaetes, cumaceans	0
Striped perch	2	amphipods, polychaetes, shrimp, and crabs	0	18	gammarid and caprellid amphipods	0	6	gammarid amphipods, isopods, crabs and shrimp	0
Pile perch	--	--	--	--	--	--	8	isopods, bivalves, crabs, gammarid amphipods	0

[a] Samples collected in 1977

[b] Samples collected in 1978

IRI – index of relative importance. IRI = % frequency of occurrence of prey group x (% stomach content by number items from prey group + % stomach content by weight of all items from prey group). The fish % IRI is the percent of the total IRI made up of fish.

These studies suggest that prey for English sole in the LDW would most likely consist of gammarid amphipods, polychaetes, and, to a lesser extent, bivalves. English sole are noted to be opportunistic foragers, and would likely consume numerically dominant benthic prey in the LDW that are small enough for them to eat. No data were identified on the size of prey consumed by English sole. However, prey similar in size to gammarid amphipods would likely be preferred. Pacific staghorn sculpin are also opportunistic foragers. Although larger sculpin may be primarily piscivorous, sculpin may also ingest gammarid amphipods, shrimp, small brachyuran crabs (*Cancer* crabs and their relatives), and, to a lesser extent, polychaetes (Table 3-1). Shiner surfperch[4] consume a mix of epibenthic and planktonic invertebrates; amphipods (gammarids and caprellids) were the most common prey of shiner surfperch in all three nearshore surveys of Puget Sound (Fresh et al. 1979; Miller et al. 1977; Wingert et al. 1979). Polychaetes, copepods, and *Cumacea* sp. were also locally abundant prey items for shiner surfperch (Table 3-1). Most amphipods, polychaetes, and *Cumacea* sp. are epibenthic invertebrates, but copepods tend to be more pelagic (Brusca and Brusca 2003). Therefore, a market basket collection of benthic invertebrate species

[4] Striped and pile perch may also be collected, chemically analyzed, and modeled if a sufficient number of fish are found. These perch species consume primarily epibenthic organisms (Table 3-1); pile perch tend to consume more hard-shelled organisms (e.g., bivalves and crabs) than striped perch (Laur and Ebeling 1983).

(amphipods, small crabs, polychaetes) would likely be representative of dietary prey preferences associated with sediment for English sole, sculpin, and perch.

For juvenile chinook salmon, likely prey items can be identified from studies performed in the LDW. Gut content analyses showed that in April/May, juvenile chinook salmon from the LDW consume predominantly benthic species, such as *Corophium* spp. (amphipods) and *Cumella vulgaris* (a cumacean), and drift species such as adult dipterans (Cordell et al. 1997, 1999). Gut content analysis also showed that in late May and June, juvenile chinook salmon primarily consume drift organisms such as wasps and ants (Cordell et al. 1997, 1999). Other prey constituting over 25% of prey weight for any single site included collembolans, fish larvae, bivalve (clam) siphons, dipteran flies, polychaete and oligochaete annelid worms, and barnacle nauplius larvae (Cordell et al. 1997). These results are consistent with studies of juvenile chinook salmon from other areas that show similar prey preferences (Macdonald et al. 1987; Meyer et al. 1981). The benthic invertebrate component of the juvenile chinook salmon diet (clam siphons, polychaetes, and oligochaetes) that are closely associated with sediments will be represented by the market basket composite samples collected from the LDW.

Spotted sandpipers feed on insects, small crustaceans and mollusks, worms, and other invertebrates, and rarely on seeds and berries. Spotted sandpipers feed occasionally on small fish and carrion (Oring et al. 1983). Sandpipers were observed during the sandpiper presence and habitat survey (Windward 2004e) to feed in the intertidal mudflats along the LDW. The benthic invertebrate component of their diet (small crustaceans and mollusks, worms, and other invertebrates) that would be most closely associated with sediments will be represented by the market basket composite samples.

To support data needs associated with the ERA, human health risk assessment (HHRA), and food web model linking tissue and sediment, co-located benthic invertebrate tissue and sediment samples will be collected throughout the LDW. Benthic invertebrates are expected to be present site-wide, but their abundance and diversity are expected to vary both temporally and spatially. Sampling in August is appropriate based on the results presented in Dexter et al. (1981) in which the highest subtidal benthic invertebrate biomass and abundance was reported in late summer in Elliott Bay. Benthic invertebrate tissue sampling will occur in late summer, when abundance and diversity are expected to be highest. The tissue sampling approach for benthic invertebrates will address spatial diversity, with a focus on:

- the spatial distribution of sediment concentrations of selected Phase 1 COPCs for spotted sandpipers and fish
- preferred fish and wildlife habitats, to the extent known[5]

[5] The results of the sandpiper presence and habitat survey were used to ensure that market basket samples are collected in important sandpiper habitat (see Table 3-2).

Co-located market basket benthic invertebrate tissue and surface sediment samples will be collected over the range of selected Phase 1 COPC concentrations in sediment. An accumulation factor will be developed for each chemical based on these co-located data, which will relate tissue concentration of the chemical to sediment concentration. These factors will be used to estimate chemical concentrations in benthic invertebrate tissue in areas where only sediment data have been collected. Application of these factors will be made in consultation with EPA and Ecology in the Phase 2 ERA.

Co-located sediment and tissue data for bioaccumulative risk-driving COPCs (such as PCBs) will also be used in the food web model to predict concentrations of these chemicals in fish tissues following various remedial activities (e.g., early actions) and to back-calculate risk-based goals for sediment remediation based on Phase 2 ecological and human health risks. The food web model methodology will be described in detail in a memorandum scheduled for submittal to EPA and Ecology in March 2005.

As noted above, sample locations for the collection of co-located market basket benthic invertebrate tissue and sediment were selected to cover the range of existing sediment concentrations of PCBs and other COPCs recommended in the Phase 1 ERA for additional evaluation based on dietary exposure (i.e., arsenic, copper, and polycyclic aromatic hydrocarbons [PAHs] for fish, and lead for spotted sandpiper). To ensure adequate spatial coverage of these chemicals, the cumulative percent of the total LDW area at a given chemical concentration was estimated using Thiessen polygons. The sampling locations were then selected based on these estimates. This approach was used to ensure that the sampling locations were placed throughout the range of key chemical concentrations.

Because fish and sandpipers integrate their exposure over their home ranges, averaged concentrations of risk-driving chemicals in their prey over their home range are the most relevant data for assessing risk from prey ingestion. To calculate this average concentration, the relationship between selected chemical concentrations in tissue and sediment will be evaluated to assess the strength of the relationship, and to determine whether this relationship varies as a function of concentration in sediment within the concentration range of these chemicals in LDW sediments. If a strong relationship is found, co-located sediment and tissue concentrations could be used to calculate an average concentration of chemicals in benthic invertebrate tissues for risk assessment purposes. This average concentration would be calculated using spatially weighted concentrations of chemicals in sediment and chemical-specific accumulation factors. The co-located data could also be used in the food web model to relate the concentrations of risk-driving bioaccumulative chemicals in fish tissue with concentrations in sediment.

The distribution of preferred habitat for fish and sandpiper was also considered in the placement of the samples. The preferred habitat for English sole and sculpin includes both intertidal and subtidal locations (Jones 1962; Lassuy 1989), although adult English

sole primarily reside in subtidal habitat (Day 1976). Intertidal habitat is generally assumed to be preferred by juvenile chinook salmon (Beauchamp et al. 1983)). Spotted sandpiper forage in intertidal habitats, with an estimated foraging range of about 1.5 km along the LDW (Norman 2002). Therefore, the primary foraging habitat of spotted sandpipers is expected to be in areas within about 0.75 km of their nesting sites, which have been observed historically on Kellogg Island (Canning et al. 1979).

A sandpiper survey was conducted June 3-11, 2004. Four general areas within the LDW were classified as nesting habitat: Kellogg Island and nearby downstream areas on the western shoreline, beneath the First Avenue South Bridge, the Hamm Creek restoration site, and the Turning Basin restoration site. Sandpiper and killdeer were observed foraging in salt marsh and mudflat habitats, and to a lesser extent in riprap habitats within 0.53 mi of identified nesting habitats.

Based on the considerations discussed above, ten intertidal sampling locations were placed throughout the LDW, with seven of the ten locations placed in areas associated with spotted sandpipers (either areas classified as suitable habitat, or areas where spotted sandpiper were observed foraging). Also, ten subtidal sampling locations were placed in the channel and on the bench to ensure that both habitats would be sampled. To demonstrate that the concentration ranges of PCBs and Phase 1 COPCs identified for fish and sandpiper (based on their prey) are represented by the selected sampling locations, frequency distributions of these chemicals (PCBs, arsenic, and lead)[6] were created. The frequency distributions for PCBs, arsenic, and lead are presented, along with station identifiers, in Figures 3-1, 3-2, and 3-3. Specific intertidal locations and corresponding concentrations of lead, PCBs, and arsenic are summarized in Table 3-2, while specific subtidal locations and corresponding concentrations of PCBs and arsenic are summarized in Table 3-3. Coordinates for the selected stations are presented in Table 3-4, and the locations of these stations are shown in Figure 3-4 (oversize figure; see Section 7.0).

[6] Station locations selected based on the frequency distributions for PCBs, arsenic, and lead were also plotted on frequency distributions for copper and PAHs to ensure adequate concentration coverage for these Phase 1 COPCs. Copper and PAHs were considered to be secondary drivers because the Phase 1 risk estimates for PAHs were lower (the no-effects hazard quotient was just over 1), and the risk estimates for copper are likely to be lower in Phase 2 based on new toxicity information (Erickson et al. 2003; Hocket et al. 2003).

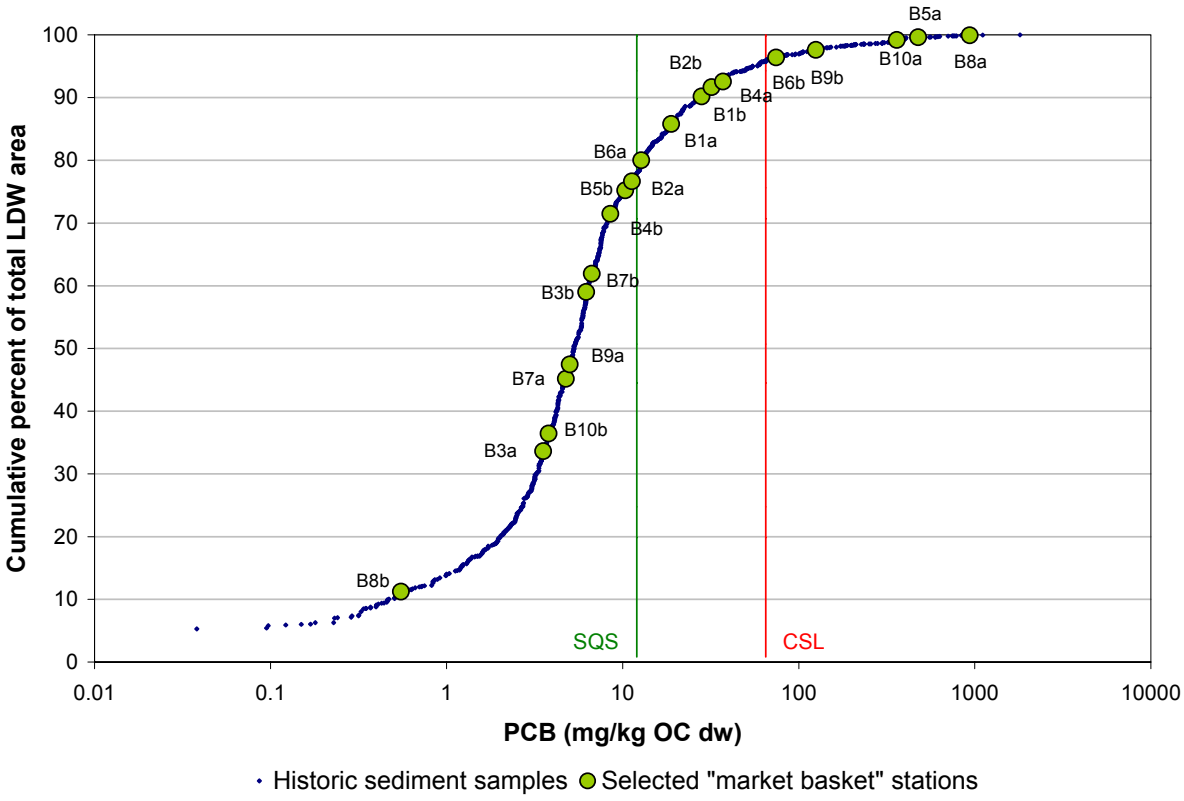

Figure 3-1. Cumulative frequency distribution of historical surface sediment PCB concentrations in the LDW and selected market basket sampling locations

Note: Intertidal stations are designated with an “a” and subtidal stations are designated with a “b.”

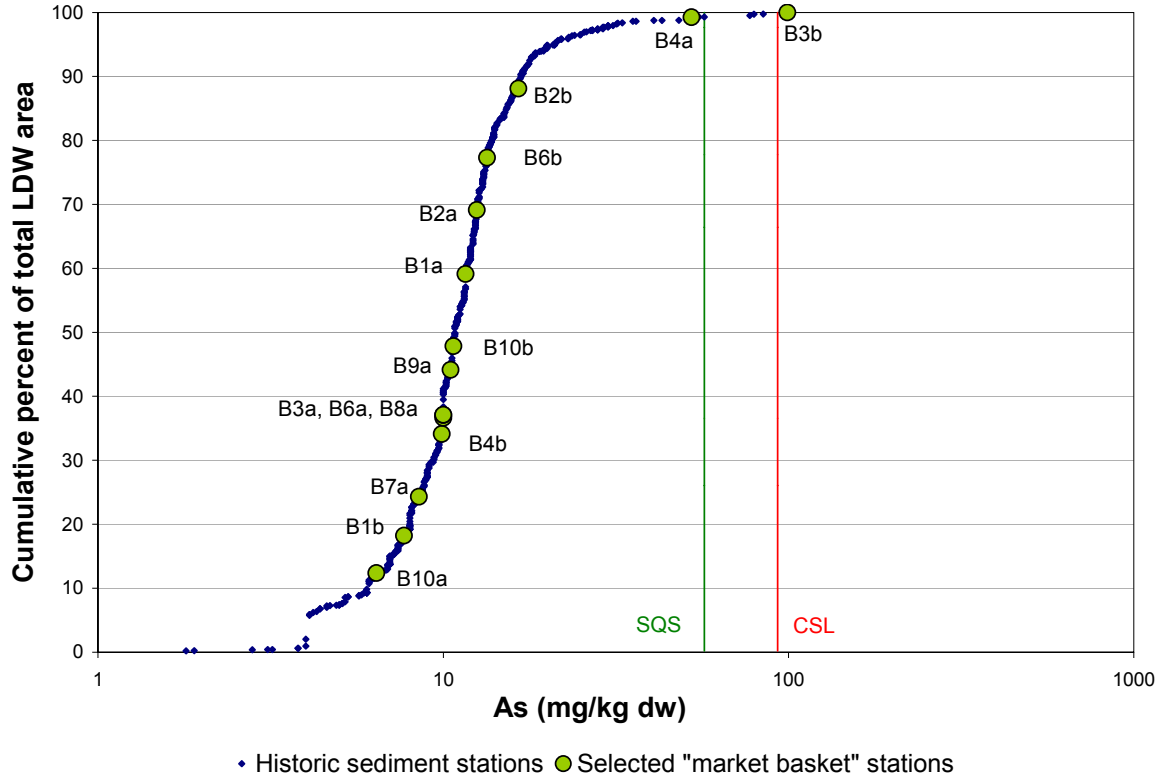

Figure 3-2. Cumulative frequency distribution of historical surface sediment arsenic concentrations in the LDW and selected market basket sampling locations

Note: Arsenic concentrations in surface sediment were not available for all the selected stations; hence, only 15 of the selected 20 stations are shown. Intertidal stations are designated with an "a" and subtidal stations are designated with a "b."

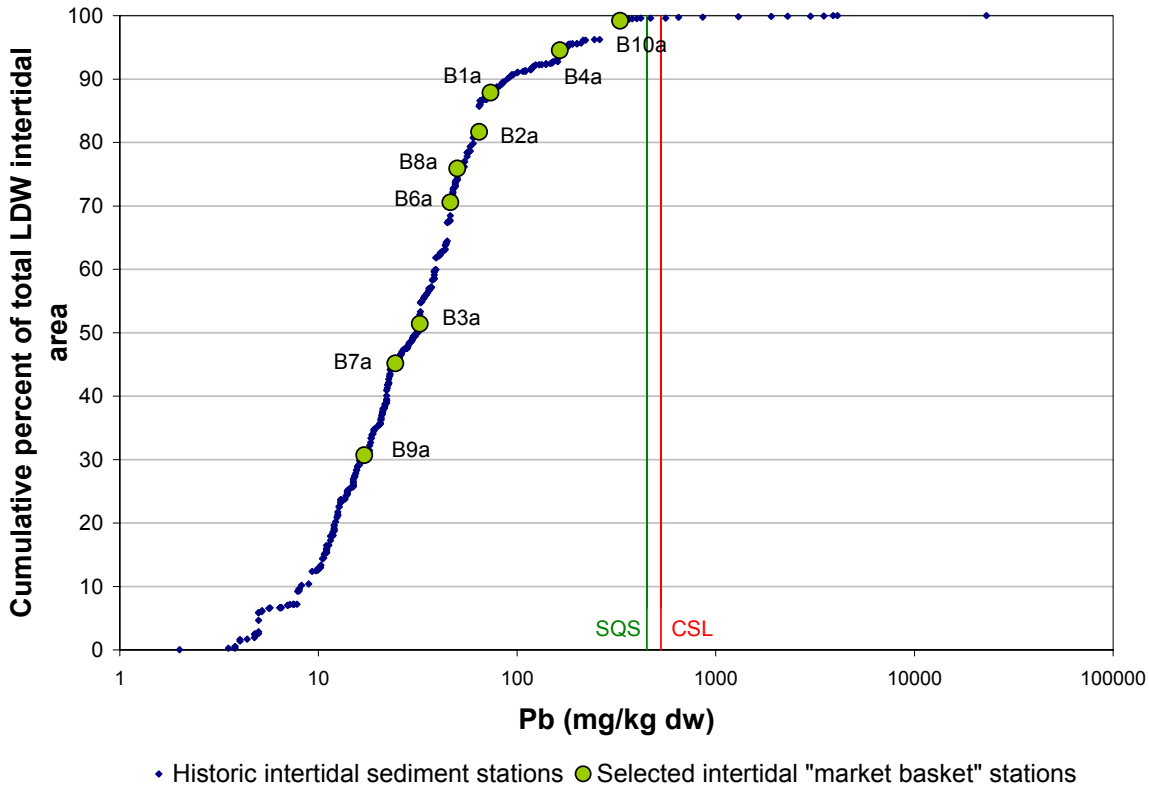

Figure 3-3. Cumulative frequency distribution of historical surface sediment lead concentrations from intertidal areas in the LDW and selected intertidal market basket sampling locations

Note: Lead concentrations in surface sediment were not available for all the selected intertidal stations; hence, only 9 of the selected 10 intertidal stations are shown. Subtidal stations are not shown for lead because lead is a contaminant of potential concern only for sandpipers, and sandpipers do not forage in subtidal habitats.

Table 3-2. Sampling locations for intertidal market basket benthic invertebrate tissue and sediment sampling

ID	Location	Sandpiper Occurrence and Habitat	Lead[a]		PCBs[a]		Arsenic[b]	
			Conc. in Sed (mg/kg dw)	% of Intertidal Area Below Conc[b]	Conc. in Sed (mg/kg OC)	% of Intertidal Area Below Conc[b]	Conc. in Sed (mg/kg dw)	% of Intertidal Area Below Conc[b]
B1a	RM 0.2, western shoreline	yes[c,d]	73.6	88	18.9	78	11.6	72
B2a	RM 0.8-0.9, west channel around Kellogg Island	yes[c,d,e]	64.4	82	11.3	68	12.5	79
B3a	RM 0.7, eastern shoreline of Kellogg Island	yes [c,d,e]	32.4	51	3.54	40	10.0	50
B4a[f]	RM 1.5, western shoreline, in off-channel area near cement plant	no	164	95	37.2	88	52.4	99
B5a	RM 2.25, western shoreline, within early action area	yes[c]	no data	no data	477	99	no data	no data
B6a	RM 2.1, western shoreline, under 1st Ave. S. Bridge	yes[c,d,e]	46.2	71	12.7	71	10	50
B7a	RM 3.1, western shoreline (across from Boeing)	no	24.4	45	4.76	49	8.5	36
B8a	RM 3.5, eastern shoreline near Boeing Plant 2	no	50	74	938	99	10	50
B9a	RM 4.3-4.4, eastern shoreline, south of Slip 6	yes[c]	17.0	31	5.01	50	10.5	59
B10a	RM 4.7, southern shore of Turning Basin, near inlet	yes[c,d,e]	330	99	360	99	6.4	17

Note: Benthic community characterization samples will also be collected at all of these locations (see Section 3.1.2)

[a] Coordinates for the existing station locations used to estimate lead, total PCB, and arsenic concentrations are given in Table 3-4

[b] Cumulative percent of LDW intertidal area with chemical concentrations below those shown

[c] Sandpiper or killdeer were sighted foraging in this area in June 2004 as part of the sandpiper survey (Windward 2004e)

[d] Near potential sandpiper nesting habitat (Windward 2004e)

[e] Cordell et al. (1996-2001) reported sandpiper sightings in this area

[f] This station may have potential access issues; sediment at this location is very soft during low tide, and pier clearance may not be possible at high tide

Table 3-3. Sampling locations for subtidal market basket benthic invertebrate tissue and sediment sampling

ID	Location	Channel or Bench	PCBs[a]		Arsenic[a]	
			Sed Conc. (mg/kg OC)	% of Subtidal Area Below Conc. [b]	Sed Conc. (mg/kg dw)	% of Subtidal Area Below Conc. [b]
B1b	RM 0.1, south of most SW corner of Harbor Island	channel	28.1	93	7.70	14
B2b	RM 0.9, mid-channel, off of S corner of Kellogg Island	channel	32.0	94	16.5	88
B3b	RM 1.0, SE corner of Slip 1	bench	6.21	60	99.3	100
B4b	RM 1.3, mid-channel	channel	8.52	71	9.9	34
B5b	RM 1.5, east side of channel	bench	10.3	78	no data	no data
B6b	RM 2.2, east side of channel	bench	74.5	98	13.4	72
B7b	RM 2.7, mid-channel	channel	6.67	64	no data	no data
B8b	RM 4.2, mouth of Slip 6	bench	0.55	11	no data	no data
B9b	Between RM 3.9 and 4.0, east side of channel	bench	125	99	no data	no data
B10b	RM 4.3, mid-channel	channel	3.80	36	10.7	48

Note: Benthic community characterization samples will also be collected at all of these locations (see Section 3.1.2)

[a] Coordinates for the existing station locations used to estimate total PCB and arsenic concentrations are given in Table 3-4

[b] Cumulative percent of LDW subtidal area with chemical concentrations below those shown

Table 3-4. Coordinates for Phase 2 market basket benthic invertebrate tissue sampling locations

Location ID	Easting (X)	Northing (Y)	Historical Sample Identification [a]		
			Event ID	Location ID	Sample ID
B1a	1266062	210471	EPA SI	DR034	SD-DR034-0000
B2a	1266314	206701	EPA SI	DR047	SD-DR047-0000
B3a	1266791	207436	EPA SI	DR046	SD-DR046-0000
B4a	1267968	203890	EPA SI	DR123	SD-DR123-0000
B5a	1270188	200290	NOAA SiteChar	WIT280	WID11-01
B6a	1269785	200986	EPA SI	DR135	SD-DR135-0000
B7a	1273645	197211	EPA SI	DR199	SD-DR199-0000
B8a	1275334	196152	Plant 2 RFI-2	SD-DUW13	SD2B-DUW13-0000C
B9a	1276941	191740	Boeing SiteChar	R65	SD0036
B10a	1277573	189995	EPA SI	DR271	SD-DR271-0000
B1b	1266250	210819	Harbor Island RI	K-06	K-06
B2b	1267392	207054	EPA SI	DR085	SD-DR085-0000
B3b	1268450	206549	EPA SI	DR020	SD-DR020-0000
B4b	1268470	204607	EPA SI	DR028	SD-DR028-0000
B5b	1268706	204114	NOAA SiteChar	EIT082	EIT11-01
B6b	1270429	200851	EPA SI	DR113	SD-DR113-0000-CC
B7b	1272080	198904	NOAA SiteChar	CH0021	CH06-02
B8b	1276632	192760	NOAA SiteChar	EST135	EST07-07
B9b	1276329	193933	NOAA SiteChar	EST144	EST09-04
B10b	1276508	191854	EPA SI	DR286	SD-DR286-0000-CC

[a] The target coordinates for the Phase 2 sampling locations are identical to coordinates of historical sampling locations identified here by event, location, and sample ID. The actual coordinates will depend on the number and location of the grab samples necessary to obtain the target weight of invertebrate tissue, as described in Section 3.2.4.

The intertidal sampling locations were placed throughout the waterway from RM 0.2-RM 4.7. The sediment concentration ranges represented by the intertidal sampling locations for the three COPCs[7] are 17.0-330 mg/kg dw for lead, 3.54-938 mg/kg OC for PCBs, and 6.4-52.4 mg/kg dw for arsenic. The subtidal sampling locations are placed throughout the waterway from RM 0.1-4.3. The sediment concentration ranges represented by the subtidal sampling locations for the two COPCs are 0.55-125 mg/kg OC for PCBs and 7.7-99.3 mg/kg dw for arsenic.

[7] The distributions of lead, PCBs, and arsenic sediment concentrations were considered in placing sampling locations within intertidal areas to address sandpiper and fish foraging habitat; the distributions of PCB and arsenic sediment concentrations were considered in placing sampling locations within intertidal and subtidal fish habitat.

At each of the 10 intertidal and 10 subtidal sampling locations, a market basket benthic invertebrate tissue sample will be collected. In this approach, all benthic invertebrates[8] collected within each targeted sampling location will be combined into a single composite sample for chemical analyses. Prior to chemical analyses, the composition of each market basket composite sample will be documented qualitatively based on field notes, a photograph, and wet weight measurement of the invertebrates after sorting into major taxonomic groups (Section 3.2.4). A full enumeration of major taxonomic groups will not be conducted in these specific samples; however, co-located samples will be collected for benthic community enumeration, as described in Section 3.1.2. The proximity of the benthic community samples as well as the qualitative characterization of both market basket and benthic community samples (i.e., photos and weights of major taxonomic groups) will provide sufficient information to ensure the representativeness of the composition of the market basket benthic invertebrate samples, particularly for use in the food web modeling. The complementary benthic community analyses may also be useful in interpreting chemical uptake by invertebrates in the market basket samples.

3.1.2 Benthic community characterization

This section presents the sampling design for the qualitative benthic invertebrate community characterization. This characterization will provide information within representative LDW habitats regarding the general composition, relative abundance, and distribution of this diverse group of organisms. Data from these samples will also be useful in assessing, in a more quantitative fashion, the genus/species composition of the market basket samples.

Benthic communities are influenced by physical, chemical, and biological factors such as water depth, salinity range, sediment grain size, sediment quality, total organic carbon (TOC), temperature, dissolved oxygen (DO), and physical disturbance (Gray 1974, 1981). All these factors vary spatially within the LDW, potentially resulting in large spatial differences in the benthic community composition. To guide the placement of sampling locations, the variables deemed most influential to benthic community composition in the LDW were used to create a matrix, with each cell representing a combination of specific benthic habitat characteristics. Each cell was then assigned the percent of the total area of the LDW that it represents, as described below.

The primary variables selected to characterize benthic community habitats were salinity, sediment elevation relative to MLLW (mean lower low water), and grain size. Sediment chemistry (as compared to Washington's Sediment Quality Standards (SQS) was considered as a secondary variable. Within each sediment elevation/salinity/grain-size combination, a station was placed in either the < SQS or

[8] Epibenthic crustaceans and bivalves larger than 2 cm will not be included in the market basket samples.

the > SQS category. Overall, half of the new or existing benthic community locations were placed in locations with no exceedances of SQS (< SQS), and half were placed in locations with at least one exceedance of SQS (> SQS).

Although TOC was also considered an important factor potentially influencing benthic community composition, it was deemed less important in the LDW because TOC concentrations are generally less than 3% (mean 1.86%, standard deviation 0.96%) and fairly uniform throughout the study area (Figure 3-5) (oversize figure; see Section 7.0). Temperature and DO were also considered of secondary importance because these variables are likely to vary in relation to the mixing of fresh and marine water, which is captured by the salinity variable. Physical disturbance was considered because it may be important at specific locations within the LDW, particularly where sediment has been dredged within the past 2 years. Because the benthic community characterization is designed to provide information regarding mature benthic communities, no stations were selected within areas recently dredged.

To place stations for benthic community characterization in different habitat types, a matrix-based table was constructed, displaying combinations of the primary variables listed above (salinity, sediment elevation, and grain size), and also showing sediment chemistry information (Table 3-5). A geographic information system (GIS) was used to calculate the percent of the total LDW area within each matrix cell to show the relative areal importance of each habitat type.

Table 3-5. Percent area estimates based on sediment elevation, salinity, grain size, and sediment quality

Elevation (ft MLLW)	Grain Size (% fines)	Salinity (percent of time below 5 ppt)					
		0-30%		30-70%		70-84%	
		≤SQS	>SQS	≤SQS	>SQS	≤SQS	>SQS
≥ - 5[a]	<40%	1.1	0.4	3.7	5.6	9.0	3.2
≥ - 5[a]	40-80%	5.4	3.2	12.5	15.4	14.3	6.7
≥ - 5[a]	>80%	1.9	0.6	4.7	1.3	8.6	2.4
< -5 to > -15[b]	<40%	2.1	1.5	1.4	0.1	na	na
< -5 to > -15[b]	40-80%	5.8	5.0	6.0	0.4	na	na
< -5 to > -15[b]	>80%	5.6	1.7	3.9	0.0	na	na
≤ -15[b]	<40%	3.9	3.4	0.0	na	na	na
≤ -15[b]	40-80%	17.1	11.0	0.3	na	na	na
≤ -15[b]	>80%	24.5	6.0	0.3	na	na	na

Note: Area estimates based on available bathymetry data - some areas (mostly intertidal) were unavailable for bathymetry measurements due to obstruction by piers, barges etc., which would have underestimated total intertidal area

[a] Areas reported as percent of total intertidal area, which is approximately 22% of the total LDW area

[b] Areas reported as percent of total subtidal area, which is approximately 78% of the total LDW area

≤SQS - All chemicals analyzed were present at concentrations less than or equal to their respective SQS values

>SQS - At least one chemical analyzed was present at a concentration above its SQS value

na – not applicable; no area in the LDW occurred in this category

Information from the King County WQA (King County 1999b) was used to define the different salinity environments of the LDW based on the percent of time surface sediment would be in contact with overlying water (i.e., the water just above the sediment) of that salinity regime. Water salinities were divided into three categories:

- saline environments with overlying water salinity less than 5 parts per thousand (ppt)[9] 0-30% of the year
- mid-salinity environments with overlying water salinity less than 5 ppt 30-70% of the year
- low-salinity environments with overlying water salinity less than 5 ppt 70-84% of the year

The selection of these three salinity ranges, and the derivation of the sediment areas of the LDW that are associated with them, are described in Appendix E.

Sediment elevations are based on the results from the 2003 bathymetry survey (Figure 3-6; oversize figure located in Section 7.0). Three sediment elevation ranges relative to MLLW were selected to represent intertidal, shallow subtidal, and deeper subtidal areas.

Sediment grain size was evaluated based on surface sediment data from the Phase 1 RI. The upper (> 80% fines) and lower (< 40% fines) grain size ranges were selected because these ranges are more likely to influence benthic community composition than the intermediate range. Many benthic invertebrates are tolerant of grain size differences within the intermediate range of sediment grain sizes (Gray 1974). Sediment grain size for the LDW is presented in Figure 3-7 (oversize figure; see Section 7.0).

Areas within sediment elevation/grain size/ salinity combinations were further divided into areas with at least one chemical exceeding its corresponding SQS and areas with no SQS exceedances. Under the provisions of the SMS, surface sediments with chemical concentrations equal to or less than all the SQS are designated[10] as having no adverse effects on biological resources, although there is some uncertainty in the prediction of effects based solely on comparison with SQS because of the way the SQS are derived. Sediment quality was based on surface sediment chemistry data used in the Phase 1 RI.

The combinations in Table 3-5 form a single sample design matrix used to identify habitat types in the LDW where benthic community samples may be collected. Based on the matrix, 27 different habitat types (i.e., 3 sediment elevation intervals by 3 grain-size ranges by 3 salinity ranges) were identified in the LDW based on salinity, sediment elevation, and grain size. Eleven of these habitat types are represented by the

[9] King County modeled 5 ppt because this salinity is generally associated with stress to marine benthic invertebrates (King County (1999a).

[10] WAC 173-204-310(1)(a)

market basket sample locations selected in Section 3.1.1. At these locations (designated as B1a-B10a and B1b-B10b), samples will be collected for both market basket composite samples for chemical tissue analyses and benthic community characterizations. Six benthic community sampling locations, designated BCA1 to BCA6 in Table 3-6, will be sampled as part of this study to represent six additional habitat types in the benthic community habitat characteristics matrix.

Recent benthic community data (1995-2001), summarized in Table 2-1, were reviewed to determine whether any of the existing data[11] could be used to fill any of the other habitat types identified in Table 3-5. One historical sampling location met all the conditions specified (i.e., appropriate salinity, sediment elevation, grain size, and sampling technique consistent with this study) for a given habitat type. The remaining nine habitat types did not represent sufficient area (i.e., <1%) to warrant placement of sampling locations.

Table 3-6. Sampling locations for LDW benthic invertebrate communities using a matrix-based approach

Elevation (ft MLLW)	Grain Size (% fines)	Salinity (percent of time below 5 ppt)					
		0-30%		30-70%		70-84%	
		≤SQS	>SQS	≤SQS	>SQS	≤SQS	>SQS
≥ - 5	<40%	ns-c	BCA4	BCA5	ns-c	ns-c	B8a, B10a
≥ - 5	40-80%	B3a	B1a	B7a	B2a, B4a, B5a, B6a	BCA6	ns-c
≥ - 5	>80%	BCA1	nc-c	BCA3	ns-c	B9a	ns-c
< -5 to > -15	<40%	B5b	ns-c	B8b[a]	ns-c	na	na
< -5 to > -15	40-80%	B7b	B3b	B10b[b]	ns-c	na	na
< -5 to > -15	>80%	ns-c	B6b	B9b	ns-c	na	na
≤ -15	<40%	ns-c	204[c]	ns-a	na	na	na
≤ -15	40-80%	B4b	B1b, B2b	ns-a	na	na	na
≤ -15	>80%	BCA2		ns-a	na	na	na

B1a-B10a – intertidal locations for both market basket benthic invertebrate tissue samples and benthic community analyses

B1b-B10b – subtidal locations for both market basket benthic invertebrate tissue samples and benthic community analyses

BCA1-BCA3 – locations for benthic community analyses only (no market basket benthic invertebrate tissue samples)

na – cell characteristics not present in LDW

ns-c – not sampled because there is either a historical sample or a proposed sample in the other SQS category for the same depth, salinity regime, and grain size range

ns-a – not sampled because this category (including both < SQS and >SQS) represented less than 1% of either the total intertidal area or total subtidal area within the LDW

[a] the grain size was slightly higher that 40%

[b] the grain size was slightly higher than 80%

[c] Ecology (2000)

≤SQS – All chemicals analyzed were present at concentrations less than or equal to their respective SQS values

>SQS – At least one chemical analyzed was present at a concentration above its SQS value

[11] Only recent data deemed acceptable based on methods, taxonomy laboratory, and documentation were used.

Table 3-7 provides a summary of the characteristics of proposed sampling locations. For both the intertidal and subtidal samples, a preliminary determination of the grain size will be performed in the field using the methods specified in PSEP (1997) to ensure that the sample is collected in the appropriate grain size range as described in Table 3-6. Due to variability in the field, an acceptable grain size will be ±20% of the targeted percent fines.

Table 3-7. Characteristics of Phase 2 benthic invertebrate community sampling locations

Location ID	Location	Elevation (ft MLLW)	Salinity (% of time below 5 ppt)	Grain Size (% fines, dw)	Exceedance of SQS?
B1a	RM 0.2, western shoreline	≥ -5	0-30%	60.8	yes
B2a	RM 0.8-0.9, west channel around Kellogg Island	≥ -5	30-70%	48.2	yes
B3a	RM 0.7, eastern shoreline of Kellogg Island	≥ -5	0-30%	66.7	no
B4a	RM 1.5, western shoreline, in off-channel area near cement plant	≥ -5	30-70%	74.8	yes
B5a	RM 2.25, western shoreline, within early action area	≥ -5	30-70%	66.0	yes
B6a	RM 2.1, western shoreline, under 1st Ave. S. Bridge	≥ -5	30-70%	48.0	yes
B7a	RM 3.1, western shoreline (across from Boeing)	≥ -5	30-70%	54.1	no
B8a	RM 3.9, eastern shoreline near Boeing Plant 2	≥ -5	70-84%	39.0	yes
B9a	RM 4.3-4.4, eastern shoreline, south of Slip 6	≥ -5	70-84%	81.0	no
B10a	RM 4.7, southern shoreline of Turning Basin, near inlet	≥ -5	70-84%	36.4	yes
B1b	RM 0.1, south of most SW corner of Harbor Island	≤ -15	0-30%	69.4	yes
B2b	RM 0.9, mid-channel, off of S corner of Kellogg Island	≤ -15	0-30%	61.2	yes
B3b	RM 1.0, SE corner of Slip 1	< -5 to > -15	0-30%	78.1	yes
B4b	RM 1.3, mid-channel	≤ -15	0-30%	70.3	no
B5b	RM 1.5, east side of channel	< -5 to > -15	0-30%	21.9	no
B6b	RM 2.2, east side of channel	< -5 to > -15	0-30%	100	yes
B7b	RM 2.7, mid-channel	< -5 to > -15	0-30%	44.8	no
B8b	RM 4.2, mouth of Slip 6	< -5 to > -15	30-70%	41.5	no
B9b	Between RM 3.9 and 4.0, east side of channel	< -5 to > -15	30-70%	89.2	no
B10b	RM 4.3, mid-channel	< -5 to > -15	30-70%	80.7	no
BCA-1	RM 0.6, western shoreline, north of Kellogg Island	≥ -5	0-30%	89.0	no

Location ID	Location	Elevation (ft MLLW)	Salinity (% of time below 5 ppt)	Grain Size (% fines, dw)	Exceedance of SQS?
BCA-2	RM 1.8, mid-channel off mouth of Slip 2	≤ -15	0-30%	82.8	no
BCA-3	RM 2.9, western shoreline, south of Slip 4	≥ -5	30-70%	80.0	no
BCA-4	RM 0.6, eastern shoreline north of Kellogg Island	<-5 to >-15	0-30	78.46	yes
BCA-5	RM 1.5, eastern shoreline	<-5 to >-15	30-70	21.93	no
BCA-6	RM 4.6, western shoreline of Turning Basin 3	<-5 to >-15	70-84	28.81	no

B locations were co-located with locations of existing sediment data. Coordinates for these locations are summarized in Table 3-8. The specific locations for Stations BCA-1 to BCA-3 were determined based on salinity data from the King County WQA (see Appendix E), bathymetry data from the 2003 survey, and surface sediment chemistry data used in Phase 1. Locations for all market basket and benthic community characterization stations are shown in Figure 3-4 (oversize figure; see Section 7.0).

Table 3-8. Coordinates of Phase 2 benthic invertebrate community sampling locations

Location ID	Easting (x)	Northing (y)	Historical Sample Identification [a]		
			Event ID	Location ID	Sample ID
B1a	1266062	210471	EPA SI	DR034	SD-DR034-0000
B2a	1266314	206701	EPA SI	DR047	SD-DR047-0000
B3a	1266791	207436	EPA SI	DR046	SD-DR046-0000
B4a	1267968	203890	EPA SI	DR123	SD-DR123-0000
B5a	1270188	200290	NOAA SiteChar	WIT280	WID11-01
B6a	1269785	200986	EPA SI	DR135	SD-DR135-0000
B7a	1273645	197211	EPA SI	DR199	SD-DR199-0000
B8a	1275476	196120	Plant 2 RFI-1	SD-04905	SD-04905-0000
B9a	1276941	191740	Boeing SiteChar	R65	SD0036
B10a	1277573	189995	EPA SI	DR271	SD-DR271-0000
B1b	1266250	210819	Harbor Island RI	K-06	K-06
B2b	1267392	207054	EPA SI	DR085	SD-DR085-0000
B3b	1268450	206549	EPA SI	DR020	SD-DR020-0000
B4b	1268470	204607	EPA SI	DR028	SD-DR028-0000
B5b	1268706	204114	NOAA SiteChar	EIT082	EIT11-01
B6b	1270429	200851	EPA SI	DR113	SD-DR113-0000-CC
B7b	1272080	198904	NOAA SiteChar	CH0021	CH06-02
B8b	1276632	192760	NOAA SiteChar	EST135	EST07-07
B9b	1276329	193933	NOAA SiteChar	EST144	EST09-04
B10b	1276508	191854	EPA SI	DR286	SD-DR286-0000-CC
BCA-1	1266009	208064	Seaboard-Ph2	SD-1	SD-1

Location ID	Easting (X)	Northing (Y)	Historical Sample Identification [a]		
			Event ID	Location ID	Sample ID
BCA-2	1269023	202713	Hardie Gypsum	5.2	5
BCA-3	1272952	197792	NOAA Site Char	WIT269	WIT08-01
BCA-4	1267131	208314	EPA SI	DR011	SD-DR011-0000
BCA-5	1268664	203993	EPA SI	DR091	SD-DR091-0000
BCA-6	1276822	190328	EPA SI	DR269	SD-DR269-0000

[a] The target coordinates for the Phase 2 sampling locations are identical to the coordinates of previously sampled locations identified here by event, location, and sample ID. The actual coordinates will depend on the results of preliminary sediment grain size determination in the field, as described in Section 3.2.4.

At each benthic community station (both intertidal and subtidal), five samples will be collected and composited into one sample (see Section 3.2.4 for sampling methods). Replicates will not be collected at each station because the data will be used qualitatively in the Phase 2 ERA (see Section 3.1.5.1 of the Phase 2 work plan). At the taxonomy laboratory, benthic invertebrates will be divided into the major taxonomic groups (i.e., Annelida, Crustacea, Mollusca, Echinodermata, and miscellaneous phyla), photographed and weighed (wet weight) in these groups, and then enumerated (see Section 3.4.1.1). The sorted organisms will then be identified and keyed to the lowest taxonomic level practical, generally the species level, by an experienced taxonomist. Numerical abundance data will be reported for each sample both by the lowest taxa practical and by major taxonomic groups.

3.1.3 Gastropod samples

Following the gastropod pilot survey, a meeting was held on July 15, 2004 with EPA and Ecology to determine:

- which tissue type will be collected for TBT analysis (i.e., gastropods, surrogate taxon, or market basket benthic invertebrate samples)
- where and how many samples will be collected to cover the general range of TBT concentrations in sediment while collecting a sufficient mass of tissue for TBT analysis
- which methods are most appropriate to collect the co-located tissue and surface sediment samples

Based on this meeting, it was determined that were sufficient numbers and species of gastropods to assess risks directly to gastropods by assessing the imposex endpoint in field-collected gastropods. Therefore, neither gastropod tissue nor a surrogate taxon need to be collected. Risks to other benthic community organisms will be assessed by measuring TBT in market basket benthic invertebrate tissue samples at locations described in Section 3.1.1. These locations are likely to represent a range of TBT concentrations in sediment, based on existing data at 5 of the 20 locations (Figure 3-8).

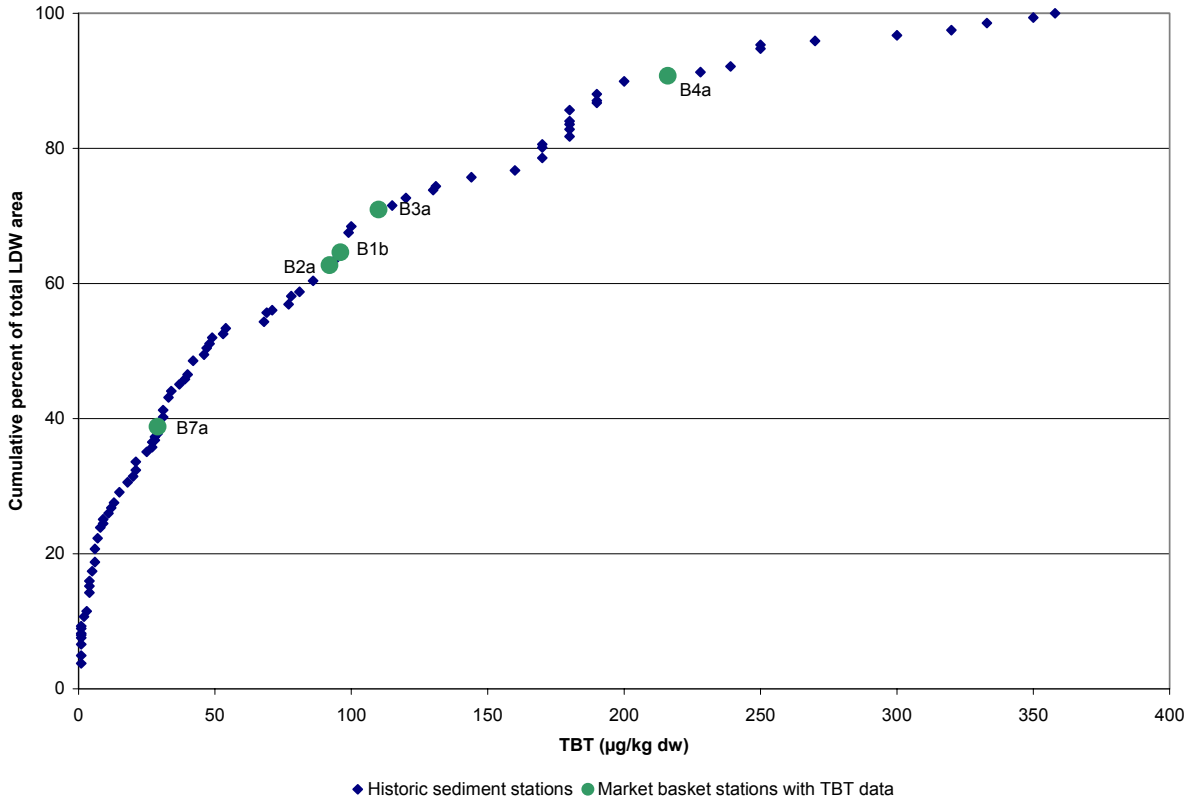

Figure 3-8. Cumulative frequency distribution of historical surface sediment TBT concentrations in the LDW and market basket sampling locations

As part of the market basket study (Section 3.1.1), co-located market basket benthic invertebrate tissue and sediment samples will be collected across a range of TBT concentrations in sediment. The tissue data will be used to assess risks to benthic invertebrates. The relationship between tissue chemical concentrations and co-located sediment chemical concentrations may be used to estimate TBT tissue concentrations if higher TBT concentrations in sediment are identified in areas not sampled for co-located tissue and sediment; see Phase 2 work plan (Windward 2004c), Appendix B. Also, if benthic invertebrate risks from TBT are above levels of concern, the co-located data may be used to back calculate risk-based sediment remediation goals for TBT as part of the Phase 2 RI.

3.1.4 Clam tissue samples

This section presents the sampling design for selecting locations where co-located clam tissue and surface sediment samples will be collected. These tissue data will be used in the Phase 2 risk assessments to assess the dietary exposure of humans and otters. Clam tissue samples will also be collected from background locations, as described in Appendix E of the fish and crab chemistry QAPP (Windward 2004b).

Thus, sampling locations were placed in known clam habitat areas to cover the concentration range of PCBs, carcinogenic PAHs (cPAHs), and arsenic in sediment, and to collect sufficient data to develop representative exposure point concentrations (EPCs). PCBs and arsenic were selected to guide the placement of clam sampling locations because they had the highest risk estimates for humans and otters in the Phase 1 risk assessments. Human health risk estimates for cPAHs were of similar magnitude to risk estimates for PCBs, but because the highest concentrations of cPAHs in sediment tended to be at the same intertidal areas as the highest concentrations of PCBs, the distribution of cPAH concentrations did not influence the study design.

Co-located clam tissue and surface sediment data will be collected to determine if chemical concentrations are correlated in these two matrices. If highly correlated, these data could be used to calculate risk-based goals for sediment, if risks from clam consumption are sufficiently high.

Intertidal areas were selected for clam collection based, in part, on the results of the August 2003 clam habitat (Windward 2004a). In that survey, 26 intertidal areas in the LDW were identified as potential clam habitat and grouped into three categories: high-, medium-, and low-quality habitat. Overall, eight intertidal areas were ranked as high, five intertidal areas were ranked as medium, and 13 intertidal areas were ranked as low-quality clam habitat. High-quality clam habitats are likely to have a higher abundance of clams, and thus potentially be targeted by humans. Because the highest PCB and arsenic concentrations are not limited to high-quality clam habitats, lower quality habitats were also targeted for sampling to evaluate the relationship between chemical concentrations in clams and sediments across the expected range of PCB and arsenic concentrations in sediment. Therefore, concentrations of PCBs and arsenic in intertidal surface sediment at eight high-quality and two low-quality clam habitats were evaluated to determine whether sampling these areas would cover the range of PCB and arsenic concentrations in LDW intertidal sediments. The selected clam habitats in the LDW are shown in Figure 3-9 (oversize figure; see Section 7.0).

As shown in Table 3-9, PCB concentrations at the ten intertidal areas varied. PCB concentrations at C1, C2, and C5 were low, while maximum PCB concentrations at C7, C8, and C10 were among the highest PCB concentrations in LDW sediments. All three of these locations are in early action areas (C7 and C8 are in Slip 4; C10 is adjacent to Terminal 117 [T-117]). Thus, clam sampling at C7, C8, and C10 will cover areas known to have the highest PCB concentrations in intertidal areas of the LDW. Based on existing data, sampling will initially focus on the northern segment of C10 because this portion of the intertidal area is within the T-117 early action area. Sampling at C7, which is entirely contained within the Slip 4 early action area, will initially be focused in the southern segment based on existing data. If a sufficient number of clams cannot be collected from these targeted areas, the collection area will be expanded within the limits of the clam sampling areas shown in Figure 3-10 (oversize figure; see Section 7.0). Additional sediment samples were collected for chemical analyses at both the T-117 and Slip 4 early action areas in the first half of 2004. When available, these

data will be reviewed to refine specific sampling areas within C7, C8, and C10 to focus sampling within segments with higher PCB concentrations.

Table 3-9. Clam tissue sampling locations

Location #	Clam Intertidal Area #	Clams/ ft^2	Clam Habitat Quality	Mean CPUE (g/pers/ hr) [a]	Phase 1 Sediment PCB Concentration Range (µg/kg dw)	Phase 1 Sediment Arsenic Concentration Range (mg/kg dw)	# Compo-site Samples/ Area	RM
C1	1a	0.28	high	1,572	3.6	no data	1	0.2
C2	2a island	1.0	high	1,697	6.0-37	no data	2	0.6 -0.9
C3	2a and b mainland	0.68	high	492	9.9-770	14	2	0.6-0.7
C4	5	na	low	na	98-900	13.4-52.4	1	1.5
C5	7	0.46	high	na	45	no data	1	1.8
C6	8	0.94	high	712	no data	no data	1	2.1
C7	13a	0.47	high	na	1,300-16,400	7.30-14.8	2	2.8
C8	13b	na	low	na	3,300-25,000	16.3	1	2.8
C9	12	0.71	high	na	no data	no data	1	2.8
C10	16	0.18	high	na	7.1-12,000	9.6-15.9	2	3.5-3.9

[a] Biomass of *Mya* sp. only. Catch per unit effort (CPUE) and the clam/ft^2 data are from Windward (2004b).

na: not available; no survey or CPUE exercise conducted at these intertidal areas

Arsenic has been analyzed less frequently than PCBs at the ten intertidal areas targeted for sampling (Table 3-9). No intertidal sediment samples from five of the ten intertidal areas have been analyzed for arsenic; thus, the arsenic concentration range in sediment from high quality clam habitat is unknown. The arsenic concentration range at the five intertidal areas with sediment data was 7.3-52.4 mg/kg dw. The maximum arsenic concentration within C4 (52.4 mg/kg dw) is higher than all other arsenic concentrations measured in any of the 26 clam habitat areas identified in the 2003 survey (Windward 2004a). Therefore, it is expected that the upper range of sediment arsenic concentrations will be captured in the study design. Stations C4 and C8 were included in the study design because of the high arsenic and PCB concentrations, respectively, at these low quality clam habitat areas. However, clams are not expected to be as abundant in these areas, so it may be difficult to obtain a sufficiently large composite clam tissue sample at these locations.

The data collected at these ten locations will be used in the HHRA and ERA to estimate the risks to potential clam consumers over the entire LDW. In addition, risks for smaller areas than the entire LDW may be evaluated in the uncertainty assessment of the HHRA. The exposure point concentrations (EPCs) needed for risk estimates are typically based on a 95% upper confidence limit (UCL) on the mean concentration. At least 6 samples are preferred for calculating a 95% UCL on the mean. The study described here is designed to collect enough samples to calculate two separate EPCs, one for the northern LDW (RM 0 to 2.5) and one for the southern LDW (RM 2.6 to 5.0).

One or two composite clam tissue sample will be collected at each intertidal area in the northern LDW (two each from C2 and C3; one each from C1, C4, C5, and C6), for a total of eight samples. Two composite samples will be collected at C2 and C3 because they are larger than the other sampling areas. Six composite samples will also be collected in the southern LDW (C7 to C10), but they will be from only four locations. Available data regarding clam habitat availability (Figure 3-9) suggest that there are no more than four locations in the southern LDW where clams are sufficiently abundant to support sampling. Two composite clam tissue samples will be collected at C7 and one at C8; these locations are adjacent to each other in Slip 4. C7 was selected for two composite samples because 1) clam habitat there was qualified as high in the clam survey (Windward 2004a), thus increasing the chance of finding sufficient numbers of clams; and 2) historical surface sediment PCB concentrations were high in this area. One composite sample will be collected at C9 and two composite samples will be collected at C10. C10 was selected for two samples because it is much larger than the Slip 4 locations, so there is more available habitat to sample.

If clams are sufficiently abundant, the two composite samples collected from C7 and C10 will be collected from separate locations within those areas. If clams are not sufficiently abundant at either C7 or C10 to collect two composite samples at each location within the level of effort described in Section 3.2.6, a single composite sample will be collected at each site and the total number of composite clam tissue samples will be reduced from 14 to 12 or 13. If only one of three samples can be collected from Slip 4 areas C7 and C8 combined, then a sample will be collected from another location with high PCB concentrations in the intertidal zone (e.g., RM 3.4 – 3.5, eastern shoreline). This location will be determined in consultation with EPA and Ecology. The sampling locations and corresponding summary information are presented in Table 3-9, and the station locations are shown in Figure 3-10 (oversize figure; see Section 7.0). Sampling locations are placed throughout most of the waterway from RM 0.1–RM 3.9.

3.2 SAMPLING METHODS

The sampling methods for each of the four studies are described in separate sections below. There may be contingencies during field activities that require modification of the general procedures outlined below. Modification of procedures will be at the discretion of the FC after consultation with the Windward PM and the boat operator, if applicable. EPA and Ecology 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 sampling location will be assigned a unique alphanumeric location ID number. The first three characters of the location ID are "LDW" to identify the Lower Duwamish Waterway project area. The next characters indicate the type of samples to

be collected (B, BCA, G, or C), followed by a consecutive number identifying the specific location within the LDW area. The 20 locations designated with a B will be sampled for market basket invertebrates, benthic community, and sediment. The 20 locations are divided into intertidal and subtidal groups of 10. Each group is numbered independently. The intertidal locations are numbered B1a (northernmost) to B10a (southernmost). The subtidal locations are numbered B1b (northernmost) to B10b (southernmost). Six other locations designated with BCA will be sampled only for benthic community analysis. The gastropod collection locations will be numbered from G1. The 10 clam tissue and sediment sampling locations are numbered C1 (northernmost) to C10 (southernmost).

Composite samples of organisms will be collected from each of the locations described above. In addition, composited samples of surface sediment will be collected at all locations except for the six locations sampled only for benthic community. The type of sample will be identified using a C suffix for community samples, an S suffix for sediment samples, or a T suffix for tissue samples. A single sample of a given type will be collected at most locations, thus no numeric suffix is generally necessary. Two clam and sediment samples may be collected at locations C2, C3, C7, and C10; IDs for these samples will include additional numeric suffixes as follows: S1 and S2 for sediment, and T1 and T2 for clams. Field duplicates will be identified with an additional suffix (e.g., LDW-C7-SFD1 and LDW-C7-SFD2). Blanks will be identified with a FB suffix. Several examples of sample IDs are provided below:

- The composite sample created for benthic community characterization at location B7a would be called LDW-B7a-C.
- The composite market basket benthic invertebrate tissue sample collected at intertidal location B7a would be called LDW-B7a-T.
- The composite surface sediment sample associated with the clam sampling location C9 would be called LDW-C9-S.

3.2.2 Location positioning

Locations identified for sampling will be located by global positioning system (GPS). A handheld GPS unit will be used during sampling in the intertidal areas and a GPS unit mounted on the winch arm will be used during sampling with the van Veen grab sampler. The GPS unit will receive GPS signals from satellites to produce positioning accuracy to within 3 m. Washington State Plane coordinates North (NAD 83) will be used for the horizontal datum.

3.2.3 Market basket benthic invertebrate tissue and co-located sediment collection

Benthic invertebrates, as market basket tissue samples, will be collected at both intertidal and subtidal stations in accordance with standardized procedures for the Puget Sound area that have been developed by PSEP (1997a), as described below.

At intertidal stations, samples will be collected along transects running perpendicular to the waterline between MLLW and mean higher high water (MHHW). Elevation will be estimated to the nearest foot using two staff gages, one positioned at the top of the sampling area and one at the waterline. A third staff member will estimate the change in elevation from a distance and the approximate elevation of the top of the sampling area, relative to the waterline, and the time measured will be recorded on the field form. Actual elevation of the top of the sampling area will be adjusted later to the known elevation of the waterline at the time of measurement. A transect will be placed over the GPS position, and five sample locations will be placed evenly along the transect. If the required biomass of 20 g[12] is not collected after collection of the five grab samples, another transect will be placed at a distance of 10 m from the first transect and five additional sample locations will be placed evenly along the second transect. If the biomass still has not been achieved, a third transect will be placed on the other side of the primary transect at a distance of 10 m and five additional sample locations will be placed evenly along the third transect. If sufficient tissue mass for chemical analyses is not obtained after 15 samples have been collected along the three transects at each station, EPA and Ecology will be consulted to determine a course of action.

At intertidal stations, a 0.1-m^2 stainless-steel transect frame[13] will be placed at each sample location, and approximately 200 mL of sediment, up to a depth of 10 cm, will be removed from each location for chemical analyses using a stainless-steel spoon prior to the collection of organisms. The volume of sediment collected will be estimated using a 200-mL beaker. The benthic invertebrates in the remaining sediment will be collected by digging the sediment from the frame to a depth of 10 cm and transferring it to a 0.5-mm mesh sieve.

A minimum of 1 L of sediment will be collected at each market basket benthic invertebrate tissue collection area. Sediment composite samples will consist of a minimum of five 200-mL samples taken from the five intertidal samples or from the five van Veen grabs from subtidal locations. The sediment subsamples from each station will be transferred to a stainless-steel bowl and stirred with a clean, stainless-steel spoon or spatula until textural and color homogeneity are achieved (PSEP 1997). Homogenized sediment will then be split into the appropriate sample containers as described in Section 3.3.1. Excess sediment will be returned to the sampling location. For decontamination procedures between collection activities, see Section 3.3.2.

At subtidal stations, organisms will be collected with a double 0.1-m^2 van Veen grab sampler, [14] as described in Section 3.2.3. Prior to transferring the sediment to the sieve, approximately 200 mL of sediment will be removed for chemical analyses from each grab (see above). The remaining sediment with the benthic invertebrates will be

[12] The required biomass of each market basket benthic invertebrate tissue sample is 20 g.
[13] This frame has the same surface area as the double vanVeen grab samples collected in the subtidal.
[14] Each half of the double van Veen samples an area of 0.1 m^2.

transferred directly to a 0.5-mm mesh sieve. Five van Veen grab samples will be collected within 3 m of each pre-identified sampling location and composited. If the required biomass of 20 g is not collected from the five composite samples, additional samples will be collected at nearby locations with a maximum distance of 10 m from the primary sampling location. If sufficient tissue mass is not collected after 10 grabs per station, EPA and Ecology will be consulted to determine a course of action. For decontamination procedures between collection activities, see Section 3.3.2.

The sediment in the sieve will be broken up with a gentle spray of LDW water and rinsed to separate the organisms from sediment and organic matter. All organisms except larger mollusks or crustaceans (defined as larger than approximately 2 cm) will be used for the market basket benthic invertebrate tissue samples. Once the sieving is complete, the material retained on the sieve will be rinsed into wide-mouthed plastic jars and stored on ice.

The samples will be transported to the Windward laboratory for rough sorting into major taxonomic groups, weighing, and documentation with photography. Each group will be weighed on a pre-tared, clean sample container to minimize the potential for sample contamination. After the invertebrate composition has been photographed and the groups have been weighed, the organisms will be returned to the jars, stored on ice, and shipped to the analytical laboratory. Care will be taken both in the field and in the sorting laboratory to avoid contaminating tissue specimens during sample processing. The technicians will be wearing nitrile powder-free examination gloves, and all sampling and laboratory equipment will be stainless steel and cleaned between samples. For decontamination procedures of laboratory equipment, see Section 3.3.2.

3.2.4 Benthic community characterization

Benthic invertebrates will be collected and processed in accordance with standardized procedures for the Puget Sound area that have been developed by the Puget Sound Estuary Program (PSEP) (1987). Benthic invertebrates will be collected from each intertidal station using a 0.0024-m^2 PVC core sampler coupled with a 0.1-m^2 transect frame, and from each subtidal station using a double van Veen grab sampler. At all stations, five grab samples will be collected within a 3-m radius and composited into one sample either before or after sieving, depending on the sediment volume. All stations will be located using GPS. Different sampling gear is proposed for the two zones because intertidal areas are expected to have much higher organism abundances than subtidal areas. Hence, the smaller sampling area with the core sampler will yield a sufficient number of organisms that are representative of the area.

The intertidal benthic invertebrates will be collected during minus tides. The areas will be accessed by boat, and the field crew will walk to the sample location. The core sampler will be placed directly into the sediment at approximately (within 3 m) the same five locations sampled for market basket samples and driven to a depth of 10 cm by hand, and the sample will be transferred directly to a 0.5-mm mesh sieve. The

sample from within the 0.1-m^2 frame will be collected to a depth of 10 cm at approximately (within 3 m) the same five locations within 3 m and sieved through a 2-mm sieve to collect larger organisms that may not be sampled by the smaller core.

The subtidal benthic invertebrates will be collected using a double van Veen grab sampler as described in the following steps:

1. Maneuver the sampling vessel to the pre-identified sampling location (within 1-2 m of the intended station) using GPS. The GPS is located on the winch arm right over the grab sampler.
2. Open the grab sampler jaws into the deployment position.
3. Guide the sampler overboard until it is clear of the vessel.
4. Lower the sampler through the water column to the bottom at approximately 0.3 m/s.
5. Record the GPS location of the boat when the sampler reaches bottom.
6. Retrieve the sampler and raise it at approximately 0.3 m/s.
7. Guide the sampler aboard the vessel and place it on the work stand on the deck, using care to avoid jostling that might disturb the integrity of the sample.
8. Examine the sample using the following sediment acceptance criteria:
    - Sediment is not extruded from the upper face of the sampler such that organisms may have been lost.
    - Overlying water is present (indicating minimal leakage).
    - The sediment surface is relatively flat (indicating minimal disturbance or winnowing).
    - The entire surface of the sample is included in the sampler.
    - The following penetration depths are achieved at a minimum:
        - 4-5 cm for medium-coarse sand
        - 6-7 cm for fine sand
        - ≥ 10 cm for muddy sediment

If these sample acceptance criteria are not achieved, the sample will be rejected.

After sample acceptance, the following observations will be noted in the field logbook:

- station GPS location
- depth as read by the boat's depth sounder
- gross characteristics of the surficial sediment including texture, color, biological structures, odor, and presence of debris and oily sheen

- gross characteristics of the vertical profile (i.e., changes in sediment characteristics and redox layer, if visible)
- maximum penetration depth (nearest 0.5 cm)
- comments relative to sample quality

The entire sample will be transferred from the core sampler or van Veen grab sampler directly to a 0.5-mm mesh sieve.

The sediment collected either by core sampler or van Veen grab and placed in the sieve will be broken up with a gentle spray of LDW water and rinsed to separate the organisms from sediment and organic matter. Once the sieving is complete, the remaining invertebrates and material will be rinsed into wide-mouthed plastic jars, a buffered preservative (7-10% formalin) will be added, and the sample will be mixed gently. The samples will be transported to the laboratory where they will be transferred from formalin into alcohol.

3.2.5 Gastropod samples

Gastropods will be collected using a sledge from subtidal locations within the lower one mile of the LDW during summer 2005. These gastropods will be identified to species, and neo- and meso-gastropods of sufficient size[15] will be examined for imposex. An addendum to the QAPP will be submitted to EPA and Ecology June 17, 2005 detailing collection locations and specific sampling methods, imposex methods, and other considerations, such as quality control of the imposex analyses.

3.2.6 Clam tissue and co-located sediment collection

Clams will be collected for chemical analyses at low tide[16] following the CPUE method used in 2003 (Windward 2004a). This method involves three field crew members actively searching and collecting clams from areas within the intertidal area with the highest clam abundance, as determined by evidence of shows. At each intertidal area, a total of one or two composite tissue samples (see Section 3.1.4 for the number of composite samples to be collected at each intertidal area) consisting of at least 81 g of clam tissue (excluding shells) will be collected. This composite sample will consist of at least 20 clams. Only clams with shells at least 2 cm in width will be included in the composite samples.[17] Clams smaller than 2 cm were observed during the 2003 survey, but clams of this size are less likely to be retained for consumption by clam harvesters. Although no published references to a specific minimum harvestable size could be

[15] The minimum size will be determined by Dr. Alan Kohn and may be smaller than the 1 cm size threshold used in the gastropod pilot survey.

[16] The lowest tides during this period occur in the mornings of August 12 and 13, and mid-day on August 16 and 17.

[17] Market basket samples, discussed in Section 3.1.1, will include benthic invertebrates (including clams) smaller than 2 cm; the fish and avian exposure assessment will thus include exposure to these smaller clams.

located, the 2 cm threshold represents a practical limit. Clams smaller than 2 cm would likely constitute a small fraction of the total weight of a composite sample containing much larger clams. Species that can be included in the composited samples are *Mya arenaria*, *Macoma nasuta*, and *Protothaca staminea*. Other edible clams such as *Protothaca tenerrima*, *Tapes japonica*, and *Clinocardium* sp. will be included in the samples if found. Broken clams will not be included in the samples. The clams will be rinsed, placed in a wide-mouth plastic jar, and stored on ice. Removal of the clam tissue from the shell will be performed by the analytical laboratory. The technicians will wear nitrile powder-free examination gloves; all sampling equipment will be stainless steel, and will be cleaned between samples to avoid contaminating tissue specimens during collection and handling.

The maximum level of effort for each of the ten sampling areas is 2 hours for the three-person crew. The level of effort is based on the results from the August 2003 focused clam sampling effort (Windward 2004a). During that survey, three-person sampling teams collected enough clams for a single composite sample in approximately one hour at each of four high quality areas (C1, C2, C3, and C6). Thus, two hours would likely be a sufficient amount of time to collect either one or two composite samples at the high quality areas. Because the 2003 clam survey did not focus on low quality areas, the likelihood of obtaining the target number of clams at the two low quality areas (C4 and C8) is unknown. A two-hour cap on the level of effort for each of these areas is also appropriate because the size of these areas can be comprehensively sampled by the crew during this time. If an insufficient number of clams are obtained during the two-hour period, the abundance of clams in that area would appear to be inadequate for collecting the target number of clams. Thus, it is doubtful that additional level of effort would yield any more success at these areas.

At each clam tissue collection location, 50 mL of the first shovelful of sediment will be collected for chemical analyses. If an unbroken clam is collected, the sediment will be retained; otherwise it will be discarded. A minimum of twenty 50-mL sediment subsamples will be composited into each 1 L sediment sample per location. As indicated in Section 3.1.4, an attempt will be made to limit the PCB chemical gradient per area over which composite sediment samples will be formed by initially focusing the clam sampling, and consequently the sediment sampling, on areas where expected PCB concentrations are highest if a large chemical gradient has previously been found at that location (i.e., C7 and C10). The volume of collected sediment will be estimated using a 50-mL beaker, and the sediment samples will be collected to a depth of 10 cm. For decontamination procedures between collection activities, see Section 3.3.2.

3.2.7 Field equipment

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

- QAPP
- field sample sheets

- study area maps
- tide tables
- COC forms
- field notebooks and pens/pencils/Sharpies
- digital camera
- GPS
- batteries
- 200-mL beaker
- wide-mouth plastic jars for benthic organisms
- 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 needs for the four studies are summarized in Table 3 - 10. 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).

Table 3-10. Additional field equipment needs for each of the four studies

STUDY	SAMPLING DEVICES	PRESERVATIVE	OTHER ITEMS
Market basket tissue and sediment collection	double 0.1-m^2 van Veen grab sampler, stainless-steel shovels	wet ice	0.1-m^2 stainless-steel transect frame; 0.5-mm mesh sieves
Benthic community characterization	0.0024-m^2 PVC core, double 0.1-m^2 van Veen grab sampler	7-10% formalin	0.1-m^2 stainless-steel transect frame; 0.5-mm and 2.0-mm mesh sieves; stainless steel shovels
Gastropod collection	sledge	saltwater	sieves
Clam tissue and sediment collection	stainless-steel shovels	wet ice	clam identification key

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 analyses. In addition, this section describes decontamination procedures, 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

Samples for benthic community characterization will be placed in wide-mouthed plastic jars. Sediment and tissue samples for chemical analyses will be placed in appropriately sized, certified-clean, wide-mouth glass jars and capped with Teflon®-lined lids (Tables 3-11 and 3-12). All sediment sample containers will be filled leaving a minimum of 1 cm of headspace to prevent breakage during shipping and storage. Prior to shipment, each glass container will be wrapped in bubble wrap and placed in a cooler with wet ice. Each jar will be sealed, labeled, and stored under appropriate conditions, as outlined in Section 3.4.2.1. Tissue samples will be homogenized at Columbia according to their standard operating procedures.

Table 3-11. Sample containers and laboratory conducting chemical analyses of tissue samples

PARAMETER	CONTAINER	LABORATORY
PCBs (as Aroclors), organochlorine pesticides, SVOCs	glass jar	Columbia
PCB congeners	glass jar	Axys[a]
Metals, TBT	glass jar	Columbia
Inorganic arsenic	glass jar	Frontier[b]

[a] Tissue will be homogenized and archived frozen at Columbia, and sent to Axys when specific samples for PCB congener analyses have been identified based on the Aroclor data

[b] Following tissue homogenization at Columbia, a frozen subsample of clam tissue will be sent to Frontier for analysis of inorganic arsenic

Table 3-12. Sample containers and laboratory conducting chemical analyses of sediment samples

PARAMETER	CONTAINER	LABORATORY
PCBs (as Aroclors), organochlorine pesticides, SVOCs	16 oz glass jar	Columbia[a]
PCB congeners	8 oz glass jar	Axys
Metals, TBT	8 oz glass jar	Columbia
Grain size, TOC, total solids	16 oz glass jar	Columbia

[a] Sediment will be homogenized and archived frozen at Columbia, and sent to Axys when specific samples for PCB congener analyses have been identified based on the Aroclor data

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 spoiled from water and sediment.

At each laboratory, a unique sample identifier will be assigned to each sample (using either project ID or laboratory ID). The laboratory will ensure that a sample tracking record follows each sample through all stages of laboratory processing. The sample tracking record must contain, at a minimum, the name/initials of responsible individuals performing the analyses, dates of sample extraction/preparation and analysis, and the type of analysis being performed.

3.3.2 Decontamination procedures

All sediment sampling and homogenizing equipment, including the mixing bowl and stainless-steel implements, will be decontaminated following PSEP (1997a) guidelines 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 and invertebrates, generated equipment rinsates, and decontamination water will be returned to each sampling location after sampling is completed for 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 heavyweight 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, and for all data and data documentation whether in hard copy or electronic format. Custody procedures will be initiated during sediment 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:

- sample location, project name, and unique sample number
- sample collection date and time
- any special notations on sample characteristics or problems
- initials of the person 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 QA/QC reports and data reports. Tissue and sediment samples will be shipped in sealed coolers to the analytical laboratories.

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 forms. The laboratories will contact the FC and 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. The sample-tracking records for benthic invertebrate characterization samples must contain, at a minimum, the name/initials

of individuals responsible for sorting the sample and the taxonomists identifying each of the major taxonomic groups.

3.3.5 Shipping requirements

Sample coolers containing market basket benthic invertebrate tissue samples will be transported directly to the Windward laboratory. After the assessment of major taxonomical groups, the samples will be shipped overnight to Columbia. Sample coolers containing all other samples for chemical and grain-size analyses will be shipped overnight to the analytical laboratory. Sample coolers containing samples for benthic invertebrate community characterization will be transported directly to Allan Fukuyama's taxonomy laboratory. Samples for imposex analyses will be transported by Windward to Alan Kohn.

The temperature inside the cooler(s) containing chemistry samples will be checked upon receipt of the samples. The laboratories 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.

Samples will be assigned a specific storage area within the laboratory and will be kept there until analyzed. The analytical laboratory will not dispose of the environmental samples for this project until notified in writing by the QA/QC coordinator. After completion of the taxonomic identification, the samples will be returned to Windward and stored in alcohol at room temperature.

3.4 ANALYTICAL METHODS

A summary of the analyses to be conducted for each of the four studies is presented in Table 3-13. This section discusses standard methods and data quality indicators for the imposex, taxonomic, and chemical analyses.

Table 3-13. Summary of number of tissue and sediment samples and analyses for the four studies

STUDY	# TISSUE	# SEDIMENT	SAMPLING GEAR	ANALYSES
Market basket tissue and sediment collection	10 intertidal tissue samples 10 subtidal tissue samples	10 co-located intertidal sediment samples 10 co-located subtidal sediment samples	transect van Veen grab sieves	**All samples:** SVOCs, alkylated and nonalkylated PAHs, metals, PCBs (as Aroclors), mercury, organochlorine pesticides, TBT **All sediment samples:** moisture content, TOC, and grain size **All tissue samples:** lipids; photos and weights of major taxonomic groups **7 tissue and 7 co-located sediment samples**: PCB congeners
Benthic community characterization	15 intertidal benthic community samples 11 subtidal benthic community samples	none	transect, PVC core van Veen grab sieves	taxonomic identification, enumeration photos and weights of major taxonomic groups
Gastropod and sediment collection	number and location of collection areas will be described in a QAPP addendum to be submitted in 2005	none	sledge	taxonomic identification and imposex assessment
Clam tissue and sediment collection	14[a] intertidal tissue samples (from 10 locations)	14[a] co-located intertidal sediment samples (from 10 locations)	shovel, beaker	**All samples:** SVOCs, PCBs (as Aroclors), metals (including total arsenic), mercury, organochlorine pesticides, TBT **All sediment samples:** moisture content, TOC, and grain size **All tissue samples:** low-level PAHs, lipids **8 tissue samples**: inorganic arsenic **8 tissue and 8 co-located sediment samples**: PCB congeners

[a] Total number will be dependent on the ability to collect sufficient tissue mass within the specified level of effort (see Section 3.2.6).

3.4.1 Benthic community characterization methods

Laboratory methods, sample handling, and data quality indicators for the benthic community samples are described in this section.

3.4.1.1 Laboratory methods and sample handling

The benthic invertebrate samples collected for benthic community characterization will be processed in the taxonomy laboratory in accordance with standardized procedures for the Puget Sound area that have been developed by PSEP (1987). The samples will be transferred into ethanol three to seven days after collection to ensure proper fixation in the formalin. Each composited sample will be sorted to remove the benthic organisms. The entire composite sample will be emptied into a 0.5-mm mesh sieve and then washed into a shallow pan of water. Large pieces of debris will be inspected for attached invertebrates and then removed from the sample. The sample will be gently agitated to separate organic matter from inorganic sediments, and the lighter organic matter will be poured back into the 0.5-mm sieve. The inorganic material remaining in the pan will be repeatedly washed and decanted until no organic material remains. It will then be visually inspected under a dissecting microscope for any remaining invertebrates. This sorting method is best suited for coarser sediment grains containing small amounts of organic matter. If this sorting method is deemed unsuitable, small amounts of the samples will be placed into a Petri dish and the laboratory technician will systematically sort through the samples removing each organism with a pair of fine forceps. Each dish will be sorted twice to ensure that all organisms have been removed. Each organism removed from the sample will be placed in one of the following major taxonomic groups: Annelida, Crustacea, Mollusca, Echinodermata, and miscellaneous phyla. The organisms will be preserved with 95% ethanol, with the objective of achieving a final concentration of 70–80% ethanol (water entrained in the sample will dilute the preservative). The actual volume of ethanol added to each sample may vary, depending on sample characteristics. In general, a 1:1 ratio (by volume) of preservative to sample material will achieve the desired concentration.

Sorted organisms will be identified and keyed to the lowest taxonomic level practical, generally the species level, by an experienced taxonomist. Only those taxonomic keys that have been peer-reviewed and are available to other taxonomists will be used. Once the identification process is completed, the organisms will be returned to the original vial. Numerical abundance data will be reported for each sample by the lowest taxa practical and by major taxonomic groups (i.e., Annelida, Crustacea, Mollusca, Echinodermata, and miscellaneous phyla). The major taxonomic groups from each sample will be photographed, and the biomass of those groups will be determined to the nearest 0.1 g (wet weight) and reported. See Section 3.5.2 for the verification process using in the identification of organisms and other QC procedures.

3.4.1.2 Data quality indicators

Data quality indicators (DQIs) for benthic community characterization samples are based on sorting and identification accuracies. The sorting process for each benthic invertebrate community sample will meet the recommended 95% sorting accuracy of total number of individuals, as recommended in the PSEP protocols (PSEP 1987), or a

complete re-sorting of the sample will be conducted. The organisms from each of the major taxonomic groups (i.e., Annelida, Crustacea, Mollusca, Echinodermata, and miscellaneous phyla) will be identified by an experienced taxonomist. The accuracy of the primary taxonomist's identifications will be assessed in two ways. Five percent of the total number of animals will be re-identified by a second (expert) taxonomist, and a species reference collection created by the primary taxonomist will be verified by the expert taxonomist. At least 95% of the two species identifications should be in agreement. If any discrepancies are identified, it is the responsibility of the expert taxonomist to reach resolution on the proper identification(s) and to ensure that any inconsistency is corrected throughout the data set.

3.4.2 Co-located benthic invertebrate tissue and sediment methods

Laboratory methods, sample handling, and data quality indicators for the sediment and tissue samples collected for chemical analyses are described in this section.

3.4.2.1 Laboratory methods and sample handling

Chemical analyses of the tissue and sediment samples will be conducted at three different laboratories. Analyses to be conducted at each laboratory are presented in Table 3-14.

Table 3-14. Procedures to be conducted at each analytical laboratory

COLUMBIA	AXYS	FRONTIER
Homogenization	PCB congeners	inorganic arsenic
PCB Aroclors	dioxins and furans[a]	
organochlorine pesticides		
SVOCs		
metals		
TBT		
mercury		
moisture		
TOC (sediments)		
lipids (tissue)		
Sample archiving		

[a] Tissue mass or a portion of the extract from samples analyzed for PCB congeners will be heat-sealed and frozen for potential dioxin/furan analysis

Market basket benthic invertebrate tissue samples will first be transported to Windward laboratory for assessment of the major taxonomic groups. After the assessment, the samples will be shipped to Columbia. Clam tissue and co-located sediment samples, as well as the market basket benthic invertebrate tissue samples and co-located sediment samples will be shipped directly to Columbia after field collection. All tissue and sediment samples will be homogenized at Columbia following their laboratory standard operating procedure. A frozen subsample of

homogenized clam tissue samples will be sent to Frontier for inorganic arsenic analysis. Columbia will store remaining tissue and sediment samples frozen. A subsample of the frozen, homogenized market basket benthic invertebrate tissue, clam tissue, and associated sediment samples will be sent to Axys for analysis of PCB congeners and potentially for dioxin/furan analysis.

Market basket benthic invertebrate tissue samples will be analyzed for SVOCs,[18] metals,[19] PCBs as Aroclors, mercury, organochlorine pesticides, lipids, moisture content, and TBT. All 209 PCB congeners will be analyzed in a subset (one third) of the market basket benthic invertebrate tissue samples using a tiered approach (Windward 2004c). In this approach, all market basket 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, a subset (7 of the 20 samples) will be selected for PCB congener analysis to cover the range of total PCB concentrations (Aroclor sum) and to provide spatial coverage within the LDW. Based on this dataset, the relationships between total PCBs (congener sum), dioxin-like PCB congeners toxic equivalency quotients (TEQs), sum of selected peaks, and total PCBs (Aroclor sum) will be assessed to determine the ability of the Aroclor sum to estimate the total PCB concentration in tissue. If the Aroclor sum underestimates the total or the relationship between Aroclor and total congener sums is not consistent enough to be useful, and the data suggest that an increased sample size will improve the fit, the remaining 13 market basket benthic invertebrate tissue samples will be analyzed for all 209 PCB congeners.

Tissue samples will also be archived for potential dioxin/furan analysis. Market basket benthic invertebrate tissue samples will be analyzed for dioxins/furans if the results of the Phase 2 urban background analysis in surface sediments indicate that quantitative risk characterization is needed (the sampling approach will be described as part of the surface sediment QAPP). Subsamples will be archived frozen for potential dioxin/furan analysis at Columbia.

Clam samples will be analyzed for SVOCs,[20] metals,[21] PCBs as Aroclors, mercury, organochlorine pesticides, lipids, moisture content, and TBT. All 209 PCB congeners will be analyzed in a subset of the clam samples using the same tiered approach described above. Eight of the 14 composite clam tissue samples will initially be analyzed for PCB congeners. For the HHRA, eight of the 14 composite clam tissue samples will be analyzed for both total arsenic and total inorganic arsenic to determine the fraction of inorganic arsenic in the sample. Composite clam tissue samples will also be archived for potential dioxin/furan analysis, as described above.

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[18] SVOC analyses for market basket samples will include both alkylated and non-alkylated PAHs.

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

[20] SVOCs will include nonalkylated PAHs. Alkylated PAHs are not relevant for the human health or mammalian exposure assessments because toxicological data for these chemicals are not available.

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

The co-located sediment samples for market basket and clam samples will be analyzed for TOC, moisture content, grain size, SVOCs, metals, PCBs as Aroclors, mercury, TBT, and organochlorine pesticides. Nonalkylated PAHs will be analyzed, as part of the SVOC analysis, in sediment samples co-located with market basket and clam samples. Alkylated PAHs will also be analyzed in sediment samples co-located with market basket samples. Seven of the twenty co-located sediment samples will also be analyzed for dioxin-like and principal PCB congeners.[22] The sediment samples to be analyzed for PCB congeners will be co-located with the tissue samples analyzed for PCB congeners. Six principal congeners were selected because these congeners were present in the highest concentrations relative to the other congeners in historical datasets (SAIC 2004)). In sum, the concentrations of these congeners make up approximately 20-60% of the total PCB concentration. Data for the individual dioxin-like and principal PCB congeners will enable assessments to be made regarding risk and congener-specific food web model analyses, as appropriate for calibration or other purposes. Additional sediment from each market basket location will be archived in case additional PCB congener analyses are required.

Analytical methods and sampling handling requirements for tissue samples are presented in Tables 3-15 and 3-16, respectively.

Table 3-15. Laboratory analytical methods and sample handling requirements for tissue samples

PARAMETER	METHOD	REFERENCE	SAMPLE HOLDING TIME[a]	PRESERVATIVE
PCBs as Aroclors	GC/ECD	EPA 8082A[b]	1 year to extract, 40 days to analyze	freeze/-20°C
PCB congeners	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
DDTs and other organochlorine pesticides[c]	GC/ECD[d]	EPA 8081A	1 year to extract, 40 days to analyze	freeze/-20°C
PAHs (and alkylated PAH homologues)[e,f]	GC/MS	EPA 8270-SIM[g]	1 year to extract, 40 days to analyze	freeze/-20°C
SVOCs	GC/MS	EPA 8270-SIM	1 year to extract, 40 days to analyze	freeze/-20°C
Arsenic (inorganic)[h]	HG-AFS	EPA 1632	6 months	freeze/-20°C
Chromium[i]	ICP-AES	EPA 6010	6 months	freeze/-20°C
Mercury	CVAA	EPA 7471	60 days	freeze/-20°C
Selenium[i]	BHR-AA	EPA 7742	6 months	freeze/-20°C
Other metals[j]	ICP-MS	EPA 6020	6 months	freeze/-20°C
TBT, DBT, MBT (as ions)	GC/FPD	Stallard et al. (1988)	1 year to extract, 40 days to analyze	freeze/-20°C
Lipids	DCM extraction gravimetric	NOAA (1993)	1 year	freeze/-20°C
Moisture	freeze-dried	PSEP	6 months	freeze/-20°C

[22] 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.

[a] All sample extracts will be archived frozen at the laboratory until the Windward PM authorizes their disposal

[b] If more than one Aroclor is detected in a sample, the laboratory will choose unique peaks to quantitate 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, gamma-BHC, chlordane, 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 if necessary to meet project needs

[e] Target PAHs include: anthracene, pyrene, dibenzofuran, dibenzothiophene, benzo(g,h,i)perylene, benzo(e)pyrene, indeno(1,2,3-cd)pyrene, perylene, benzo(b)fluoranthene, fluoranthene, benzo(k)fluoranthene, acenaphthylene, chrysene, benzo(a)pyrene, dibenz(a,h)anthracene, benz(a)anthracene, acenaphthene, phenanthrene, fluorene, 1-methylnaphthalene, naphthalene, 2-methylnaphthalene, and biphenyl. Target alkylated PAH homologs include: C1-chrysenes, C2-chrysenes, C3-chrysenes, C4-chrysenes, C1-dibenzothiophenes, C2-dibenzothiophenes, C3-dibenzothiophenes, C1-fluoranthenes/pyrenes, C1-fluorenes, C2-fluorenes, C3-fluorenes, C1-phenanthrenes/anthracenes, C2-phenanthrenes/anthracenes, C3-phenanthrenes/anthracenes, C4-phenanthrenes/anthracenes, C2-naphthalenes, C3-naphthalenes, C4-naphthalenes

[f] Alkylated PAHs will be analyzed in the market basket benthic invertebrate tissue samples only

[g] The alkylated PAHs will be quantitated using a Columbia in-house selective ion monitoring (SIM) method because no EPA method has been promulgated for these compounds

[h] Inorganic arsenic will be quantified in the clam tissue samples

[i] Chromium and selenium cannot be analyzed in tissue using EPA Method 6020 due to matrix interferences, although they can be analyzed in sediment using EPA method 6020

[j] Antimony, cadmium, cobalt, copper, lead, molybdenum, nickel, silver, thallium, vanadium, and zinc

BHR-AA – borohydride reduction atomic absorption

CVAA – cold vapor atomic absorption

DCM – dichloromethane

GC/ECD – gas chromatography electron capture detection

GC/FPD – gas chromatography flame photometric detection

GC/MS – gas chromatography mass spectrometry

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

SIM – select ion monitoring

Table 3-16. 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[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
DDTs and other organochlorine pesticides[d]	GC/ECD	EPA 8081A	14 days[b]	cool/4°C
PAHs (and alkylated PAH homologues)[e, f]	GC/MS	EPA 8270C-SIM[g]	14 days[b]	cool/4°C
SVOCs	GC/MS	EPA 8270C-SIM	cool/4°C	cool/4°C
Mercury	CVAA	EPA 7471	28 days	cool/4°C

PARAMETER	METHOD	REFERENCE	SAMPLE HOLDING TIME[a]	PRESERVATIVE
Other metals[h]	ICP-MS	EPA 6020	1 year	cool/4°C
TBT, DBT, MBT (as ions)	GC/FPD	Krone et al. (1989)	40 days	cool/4°C
grain size	sieve/pipette	PSEP (1986)	6 months	cool/4°C
TOC	combustion	Plumb (1981)	28 days	cool/4°C
Moisture	oven-dried	PSEP (1986)	7 days	cool/4°C

[a] All sample extracts will be archived frozen at the laboratory until the Windward PM authorizes their disposal

[b] 14 days until extraction, 40 days from time of extraction; sediment can also be frozen to increase the holding time to 1 year

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

[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, gamma-BHC, chlordane, dieldrin, endosulfan, endosulfan sulfate, endrin, heptachlor, heptachlor epoxide, hexachlorobenzene, methoxychlor, mirex, and toxaphene

[e] Target PAHs include: anthracene, pyrene, dibenzofuran, dibenzothiophene, benzo(g,h,i)perylene, benzo(e)pyrene, indeno(1,2,3-cd)pyrene, perylene, benzo(b)fluoranthene, fluoranthene, benzo(k)fluoranthene, acenaphthylene, chrysene, benzo(a)pyrene, dibenz(a,h)anthracene, benz(a)anthracene, acenaphthene, phenanthrene, fluorene, 1-methylnaphthalene, naphthalene, 2-methylnaphthalene, and biphenyl. Target alkylated PAH homologs include: C1-chrysenes, C2-chrysenes, C3-chrysenes, C4-chrysenes, C1-dibenzothiophenes, C2-dibenzothiophenes, C3-dibenzothiophenes, C1-fluoranthenes/pyrenes, C1-fluorenes, C2-fluorenes, C3-fluorenes, C1-phenanthrenes/anthracenes, C2-phenanthrenes/anthracenes, C3-phenanthrenes/anthracenes, C4-phenanthrenes/anthracenes, C2-naphthalenes, C3-naphthalenes, C4-naphthalenes

[f] Alkylated PAHs will be analyzed in sediment samples co-located with the market basket benthic invertebrate tissue samples only

[g] The alkylated PAHs will be quantitated using a Columbia in-house selective ion monitoring (SIM) method because no EPA method has been promulgated for these compounds.

[h] Arsenic, antimony, cadmium, chromium, cobalt, copper, lead, molybdenum, nickel, selenium, silver, thallium, vanadium, and zinc

CVAA – cold vapor atomic absorption

GC/ECD – gas chromatography electron capture detection

GC/FPD – gas chromatography flame photometric detection

GC/MS – gas chromatography mass spectrometry

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

SIM – select ion monitoring

3.4.2.2 Data quality indicators

The parameters used to assess data quality are precision, accuracy, representativeness, comparability, completeness, and sensitivity. Tables 3-17 and 3-18 list specific DQIs for laboratory analyses of tissue and sediment samples. These parameters are discussed in more detail in the following sections.

Table 3-17. Data quality indicators for tissue analyses

Parameter	Units	Precision	Accuracy	Completeness	Sensitivity (Method Detection Limit)[a]
PCBs as Aroclors	µg/kg ww	±50%	38-150%	95%	0.76-4.7
PCB congeners	ng/kg ww	±50%	50-150%	95%	1.0
Dioxins and furans	ng/kg ww	±50%	50-150%	95%	0.04
DDTs and other organochlorine pesticides[b]	µg/kg ww	±50%	30-150%	95%	0.099-5.8
PAHs (and alkylated PAH homologues)[c, d]	µg/kg ww	±50%	20-130%	95%	0.045-0.26[e] 2.8-8.2[f]
SVOCs	µg/kg ww	±50%	20-130%	95%	1.3-5,000[g]
Arsenic (inorganic)[h]	mg/kg ww	±25%	75-125%	95%	0.004[i]
Other metals[j]	mg/kg ww	±30%	60-130%	95%	0.002-1.0[h]
Tributyltin, dibutyltin, monobutyltin (as ions)	µg/kg ww	±50%	20-130%	95%	0.33-0.38
Lipids	% ww	±30%	na	95%	0.1
Moisture	% ww	±20%	na	95%	0.1

[a] Method detection limits for individual chemicals are presented in Appendix C, Table C-6

[b] 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, gamma-BHC, chlordane, dieldrin, endosulfan, endosulfan sulfate, endrin, heptachlor, heptachlor epoxide, hexachlorobenzene, methoxychlor, mirex, and toxaphene

[c] Target PAHs include: anthracene, pyrene, dibenzofuran, dibenzothiophene, benzo(g,h,i)perylene, benzo(e)pyrene, indeno(1,2,3-cd)pyrene, perylene, benzo(b)fluoranthene, fluoranthene, benzo(k)fluoranthene, acenaphthylene, chrysene, benzo(a)pyrene, dibenz(a,h)anthracene, benz(a)anthracene, acenaphthene, phenanthrene, fluorene, 1-methylnaphthalene, naphthalene, 2-methylnaphthalene, and biphenyl. Target alkylated PAH homologs include: C1-chrysenes, C2-chrysenes, C3-chrysenes, C4-chrysenes, C1-dibenzothiophenes, C2-dibenzothiophenes, C3-dibenzothiophenes, C1-fluoranthenes/pyrenes, C1-fluorenes, C2-fluorenes, C3-fluorenes, C1-phenanthrenes/anthracenes, C2-phenanthrenes/anthracenes, C3-phenanthrenes/anthracenes, C4-phenanthrenes/anthracenes, C2-naphthalenes, C3-naphthalenes, C4-naphthalenes

[d] Alkylated PAHs will be analyzed in the market basket benthic invertebrate tissue samples only

[e] MDLs for ultra low PAH method to be used for clam tissue samples

[f] MDLs for standard EPA 8270-SIM to be used for market basket benthic invertebrate tissue samples.

[g] MDLs for SVOCs other than PAHs

[h] Inorganic arsenic will be quantified in the clam tissue samples

[i] MDL represents an estimated value based on previous studies. MDL for this study will be calculated based on analysis of instrument blanks at the time of analysis.

[j] Arsenic, antimony, cadmium, chromium, cobalt, copper, lead, mercury, molybdenum, nickel, selenium, silver, thallium, vanadium, and zinc

Table 3-18. Data quality indicators for sediment analyses

Parameter	Units	Precision	Accuracy	Completeness	Sensitivity (Method Detection Limit)
PCBs as Aroclors	µg/kg dw	±50%	50-150%	95%	1.0-4.0
PCB congeners	ng/kg dw	±50%	50-150%	95%	1.0
Dioxins and furans	ng/kg dw	±50%	50-150%	95%	0.059

PARAMETER	UNITS	PRECISION	ACCURACY	COMPLETENESS	SENSITIVITY (METHOD DETECTION LIMIT)
DDTs and other organochlorine pesticides[a]	µg/kg dw	±50%	50-150%	95%	0.19-38
PAHs (and alkylated PAH homologues)[b,c]	µg/kg dw	±50%	40-130%	95%	0.10-0.21
SVOCs	µg/kg dw	±50%	40-130%	95%	4.8-5,000[d]
Mercury	mg/kg dw	±30%	55-137%	95%	0.01
Other metals[e]	mg/kg dw	±30%	70-130%	95%	0.006-0.2
Tributyltin, dibutyltin, monobutyltin (as ions)	µg/kg dw	±50%	20-130%	95%	0.041-0.16
grain size	% dw	±30%	na	95%	na
TOC	% dw	±30%	na	95%	0.01
Moisture	% ww	±20%	na	95%	0.1

NOTE: MDLs for all chemicals are presented in Table D-1 in Appendix D.

[a] 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, gamma-BHC, chlordane, dieldrin, endosulfan, endosulfan sulfate, endrin, heptachlor, heptachlor epoxide, hexachlorobenzene, methoxychlor, mirex, and toxaphene

[b] Target PAHs include: anthracene, pyrene, dibenzofuran, dibenzothiophene, benzo(g,h,i)perylene, benzo(e)pyrene, indeno(1,2,3-cd)pyrene, perylene, benzo(b)fluoranthene, fluoranthene, benzo(k)fluoranthene, acenaphthylene, chrysene, benzo(a)pyrene, dibenz(a,h)anthracene, benz(a)anthracene, acenaphthene, phenanthrene, fluorene, 1-methylnaphthalene, naphthalene, 2-methylnaphthalene, and biphenyl. Target alkylated PAH homologs include: C1-chrysenes, C2-chrysenes, C3-chrysenes, C4-chrysenes, C1-dibenzothiophenes, C2-dibenzothiophenes, C3-dibenzothiophenes, C1-fluoranthenes/pyrenes, C1-fluorenes, C2-fluorenes, C3-fluorenes, C1-phenanthrenes/anthracenes, C2-phenanthrenes/anthracenes, C3-phenanthrenes/anthracenes, C4-phenanthrenes/anthracenes, C2-naphthalenes, C3-naphthalenes, C4-naphthalenes

[c] Alkylated PAHs will be analyzed in sediment co-located with the market basket benthic invertebrate tissue samples only

[d] MDLs for SVOCs other than PAHs

[e] Arsenic, antimony, cadmium, chromium, cobalt, copper, lead, molybdenum, nickel, selenium, silver, thallium, vanadium, and zinc

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 a percent relative standard deviation (% RSD) when more than two analyses are performed on the same sample (e.g., triplicates). Precision is assessed by laboratory duplicate analyses (duplicate samples, matrix spike duplicates, LCS duplicates) for all parameters. Precision is assessed by laboratory duplicate analyses 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 (Tables 3-17 and 3-18). The equations used to express precision are as follows:

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

$$\%RSD = (SD/D_{ave}) \times 100$$

where

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

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

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 matrix spike and laboratory control sample analyses. The DQI for accuracy varies, depending on the analyte (Tables 3-17 and 3-18). Below is the equation used to express accuracy for spiked samples:

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

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.

Comparability

Comparability expresses the confidence with which one data set can be evaluated in relation to another data set. The 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.

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:

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

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.

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. For this study, MDLs will be used as the measure of sensitivity of each measurement process. Results will be reported at or below the target detection limits presented in Tables 3-17 and 3-18. Appendix C presents a detailed evaluation of whether MDLs for tissue samples are sufficiently sensitive to meet the needs of the Phase 2 ecological and human health risk assessments. Based on that evaluation, the analytical MDLs specified in Table 3-17 for all chemicals, except selenium, are sufficiently sensitive for market basket benthic invertebrate, clam, and gastropod tissue samples to meet the needs of the ERA. MDLs for 22 analytes in clam tissue exceed risk-based analytical concentration goals (ACGs) for the protection of human health across a range of consumption rates from 58 to 98 g/day. These MDLs include those for seven SVOCs, five PCB Aroclors, one PCB congener, four pesticides, arsenic (total and inorganic), chromium, selenium, and 2,3,7,8 TCDD. These MDLs are the lowest that can be obtained using standard methods. Six additional chemicals have ACGs less than their corresponding MDLs if a total seafood consumption rate of 98 g/day is assumed; ACGs are greater than their MDLs if a clam consumption rate of 58 g/day is assumed. These additional chemicals include two SVOCs, a PCB Aroclor, mercury, and two pesticides.

Elevated MDLs relative to ACGs are only problematic when chemicals are not detected. The laboratory will make additional efforts to achieve ACGs for Aroclors in samples if no Aroclors are detected in a sample. The lab will also make additional efforts to achieve the ACG based on a consumption rate of 58 g/day for PCB congener 126 if it is not detected in a sample. Additional efforts may include additional sample clean-up, extracting more sample, using a lower concentration for the lowest standard in the initial calibration, adjusting the final volume, or adjusting the amount of extract injected into the instrument. For the other chemicals with MDLs above the risk-based ACGs, the ramifications for the Phase 2 HHRA will be discussed in the uncertainty assessment.

Standard tissue mass requirements are specified to meet MDLs for each particular analytical method. Because collecting the standard tissue mass may be difficult for market basket benthic invertebrate or gastropod tissue samples,[23] an analysis was

[23] The analysis to determine the minimum weight of gastropod for the analysis of TBT was conducted for the gastropod pilot survey which evaluated, as one of its objectives, the feasibility of collecting gastropods for tissue analysis of TBT. Based on the July 15, 2004 meeting, however, TBT will not

conducted to determine if a lower tissue mass could be collected and still meet the risk-based ACGs described in Appendix C. Based on this analysis, market basket benthic invertebrate tissue mass can be reduced to 20 g and gastropod tissue mass can be reduced to 2 g (see Appendix C for determination of required tissue mass). [24] Clam tissue mass[25] cannot be reduced below the standard requirements because of the low MDLs needed to meet ACGs; 81 g of clam tissue mass will be required per sample. Table 3-19 summarizes the tissue mass needed for each sample type.

Table 3-19. Minimum tissue mass required per sample type

Analyte	Minimum tissue mass (g)		
	Clam	Market Basket	Gastropod
PCB congeners and dioxins/furans	25[a]	10[a]	na
PCB Aroclors and organochlorine pesticides	20[b]	2[b]	na
SVOCs	10	2	na
PAHs (ultra low extraction)	10	na	na
Mercury	2	2	na
Other metals	2[c]	2[c]	na
Inorganic arsenic	2[d]	na	na
TBT	10	2	2
Total Mass	**81**	**20**	**2**

na – not analyzed

[a] Tissue mass will be archived for samples not initially analyzed for PCB congeners. Also, a portion of the extract from samples analyzed for PCB congeners will be heat-sealed and frozen for potential dioxin/furan analysis.

[b] A portion of the sample extract will be used for lipid analysis. Therefore, no additional tissue mass is required for lipid determination.

[c] Tissue mass if sufficient for metals to be analyzed with EPA Methods 6010, 6020, and 7742

[d] Inorganic arsenic will be analyzed in 6 of 14 clam samples.

The purpose of collecting the sediment samples at clam sampling locations is to explore the relationship between detected concentrations of chemicals of concern in co-located sediments and clams. Appendix D discusses ACGs for the co-located sediment samples to be collected at clam sampling locations. The ACGs are generally higher than the MDLs shown in Table 3-18, with the exception of arsenic, cadmium, six PCB Aroclors, and two pesticides (aldrin and dieldrin). Elevated MDLs relative to ACGs are only problematic when chemicals are not detected. The laboratory will made additional efforts to lower the MDL on a per sample basis if no Aroclors are detected in a sample. Aldrin and dieldrin have rarely been detected in LDW sediments

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analyzed in gastropod tissue. Instead, TBT will be analyzed in market basket benthic invertebrate samples.

[24] Standard and modified tissue mass requirements do not include the amount needed for laboratory quality control samples; thus, an additional 10 g of tissue mass will need to be collected for each matrix spike and matrix spike duplicate sample (i.e., one of each for every 20 field samples).

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

(i.e., out of 262 samples, aldrin was undetected in 260 and dieldrin was undetected in 237 samples), and have never been detected in LDW tissue samples. However, existing pesticide data in tissue and sediment are limited and may not be representative of Phase 2 results. Arsenic and cadmium were detected in 869 and 715, respectively, of the over 900 samples in which they were analyzed.

3.5 QUALITY ASSURANCE/QUALITY CONTROL

The QA/QC criteria for the field and laboratory analyses are described below.

3.5.1 Field quality control samples

Although data validation guidelines have not been established for field quality control samples, the data resulting from the analyses of these samples is useful in identifying possible problems resulting from sample collection or sample processing in the field. All field quality control samples will be documented in the field logbook and verified by the project QA/QC coordinator or a designee.

Field QA/QC samples will be used to evaluate the efficiency of field decontamination procedures and variability attributable to sample handling. Two types of field QA/QC samples will be collected during each sampling event: a field blank for the sampling equipment and a field duplicate. These two sample types are further described below. Locations for collection of field QA/QC samples will be selected in the field by the FC.

3.5.1.1 Field blanks

Field blanks are used to assess whether and to what degree contamination is occurring during sample collection. A field blank will be created by wiping the sample collection device with filter paper following decontamination procedures. The filter paper will be collected in an appropriate clean jar for SVOCs and metals analyses. A minimum of one field blank for every 20 samples collected with a sampling device will be submitted for chemical analyses. If any chemicals are detected in field blanks, sample results may be qualified or rejected depending on the magnitude of the detected concentration.

Field blanks will not be collected from the van Veen grab sampler or the transect frame because no sediment in contact with the sampler walls will be included in the sample. Field blanks will be collected from sieves used to isolate benthic invertebrate market basket tissue samples.

3.5.1.2 Field duplicate samples

Two field duplicate sediment samples will be collected. One duplicate sample will be collected from the sediment homogenized at a subtidal market basket sampling location, and the other will be collected from an intertidal clam sampling location. The criterion for field duplicate RPDs is ±75%.

3.5.2 Benthic community characterization quality control criteria

The organisms from each of the major taxonomical groups (i.e., Annelida, Crustacea, Mollusca, Echinodermata, and miscellaneous phyla) will be identified by an experienced taxonomist. The accuracy of the primary taxonomist's species identifications will be assessed in two ways. The organisms in 5% percent of the total number of samples as required in PSEP (1987) will be re-identified by a second expert taxonomist, and a species reference collection created by the primary taxonomist will be verified by the expert taxonomist. At least 95% of the two species identifications should be in agreement. It is the responsibility of the expert taxonomist to decide on the proper identification(s) and to ensure that any inconsistency is corrected throughout the data set. In addition, 20% percent of each sample will be re-sorted by a different laboratory technician. If the sample does not meet the 95% removal criterion (PSEP 1987), the whole sample will be resorted. Upon completion of sample identification and QC, the archived and reference specimen vials (grouped by station and date) will be placed in jars with a small amount of 70% ethanol and tightly capped.

3.5.3 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 of interest, and establish an initial calibration curve for all analytes. The laboratory must demonstrate their continued proficiency by participation in inter-laboratory comparison studies and through repeated analysis of certified reference materials, calibration checks, laboratory reagent blanks, and spiked samples.

3.5.3.1 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 40 CFR §136, where seven 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 a factor of 3.14.

3.5.3.2 Sample delivery group

Project- and/or method-specific quality control measures such as matrix spikes and matrix spike duplicates will be analyzed per sample delivery group (SDG) or sample batch. An SDG is defined as no more than 20 samples or a group of samples received at the laboratory within a two-week period. Although a SDG may span two weeks, all holding times specific to each analytical method will be met for each sample in the SDG.

3.5.3.3 Laboratory quality control criteria

The analyst will review results of QC analyses (described below) from each sample group immediately after a sample group has been analyzed. The QC sample results will then be evaluated to determine whether control limits have been exceeded. If control limits are exceeded in the sample group, the project QA/QC coordinator will be contacted immediately, and corrective action, such as method modifications followed by reprocessing of the affected samples, will be initiated before processing a subsequent group of samples.

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 will be verified by comparison with an independent standard. Laboratory QC standards are verified a multitude of ways. Second-source calibration verifications are run (i.e., same standard, two different vendors) for calibrations. New working standard mixes (calibrations, spikes, etc.) are verified against the results of the original solution and must be within 10%. Newly purchased standards are verified against current data. Any impurities found in the standard will be documented. The following sections summarize the procedures that will be used to assess data quality throughout sample analysis. Table 3-20 summarizes the QC procedures to be performed by the laboratory. The associated control limits for precision and accuracy are summarized in Tables 3-17 and 3-18.

Table 3-20. Laboratory quality control sample analysis summary

Analysis Type	Initial Calibration	Continuing Calibration	Field Duplicate/ Triplicate	Matrix Spikes	Matrix Spike Duplicates	Method Blanks	Standard Reference Material	Surrogate Spikes
PCB Aroclors	prior to analysis	every 10-20 analyses or 12 hrs	1 per batch or SDG	1 per batch or SDG	1 per batch or SDG	each batch or SDG	na	Each sample[a]
PCB congeners and dioxins/furans	prior to analysis	every 10-20 analyses or 12 hrs	na	1 per batch or SDG	1 per batch or SDG	each batch or SDG	each batch or SDG	Each sample
Organochlorine pesticides[b]	prior to analysis	every 10-20 analyses or 12 hrs	1 per batch or SDG	1 per batch or SDG	1 per batch or SDG	each batch or SDG	each batch or SDG	Each sample
Mercury	prior to analysis	every 10 samples	1 per batch or SDG	1 per batch or SDG	1 per batch or SDG	each batch or SDG	each batch or SDG	na
Other metals	prior to analysis	every 10 samples	1 per batch or SDG	1 per batch or SDG	na	each batch or SDG	each batch or SDG	na
SVOCs, including PAHs	prior to analysis	every 10-20 analyses or 12 hours	1 per batch or SDG	1 per batch or SDG	1 per batch or SDG	each batch or SDG	each batch or SDG	Each sample
TBT	prior to analysis	every 10 samples	1 per batch or SDG	1 per batch or SDG	1 per batch or SDG	each batch or SDG	Each batch or SDG	Each sample
Grain size	na	na	1 per 20 samples	na	na	na	na	na
TOC	daily	every 10 samples	1 per 20 samples	1 per 20 samples	na	each batch or SDG	na	na
Percent solids	na	na	1 per 20 samples	na	na	na	na	na
Lipids	na	na	1 per 20 samples	na	na	na	na	na

[a] 2,3,6,7-tetrachloroxanthene and decachlorobiphenyl will be used as surrogates for all Aroclor analyses

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

na – not applicable

SDG – sample delivery group

Field Duplicates

Field duplicates provide information on the precision of the analysis and are useful in assessing potential sample heterogeneity and matrix effects. Field duplicates are taken from the same homogenized material as the original sample and analyzed as a separate sample. A minimum of one field duplicate will be analyzed for each sample group or for every 20 samples, whichever is more frequent.

Matrix Replicates

Analytical replicates provide information on the precision of the analysis and are useful in assessing potential sample heterogeneity and matrix effects. Analytical 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 replicate will be analyzed for each sample group or for every 20 samples, whichever is more frequent.

Matrix Spikes and Matrix Spike Duplicates

The analysis of matrix spike samples provides information on the extraction efficiency of the method on the sample matrix. By performing duplicate matrix spike analyses, information on the precision of the method is also provided for organic analyses. A minimum of one matrix spike and matrix spike duplicate will be analyzed for each sample group or for every 20 samples, whichever is more frequent, when possible.

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 sample group or for every 20 samples, whichever is more frequent.

Surrogate Spikes

All project samples analyzed for organic compounds will be spiked with appropriate surrogate compounds as defined in the analytical methods. Surrogate recoveries will be reported by the laboratories; however, no sample results will be corrected for recovery using these values.

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) will be run with single-component pesticides in the initial calibration. Additional

Aroclors will be run if they are detected in sediment or tissue samples. The resulting data will be reviewed by data validators in order to assess potential coelution issues affecting the reported pesticide results.

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 used, including the GPS 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. The methods used in calibrating the analytical instrumentation are described in the following section.

3.7 INSTRUMENT/EQUIPMENT CALIBRATION AND FREQUENCY

Multipoint initial calibration will be performed on each instrument at the start of the project, after each major interruption to the analytical instrument, and when any continuing calibration does not meet the specified criteria. The number of points used in the initial calibration is defined in each analytical method. Continuing calibrations 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.

In addition, if an Aroclor is detected in a sample, then the standard for that Aroclor must be analyzed in the continuing calibration within 72 hrs of the original detection of the Aroclor. Gel permeation chromatography (GPC) 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.

Calibration of analytical equipment used for chemical analyses includes instrument blanks or continuing calibration blanks, which provide information on the stability of the baseline established. Continuing calibration blanks will be analyzed immediately after the continuing calibration verification at a frequency of one blank for every 10 samples analyzed for inorganic analyses and one blank for every 12 hours for organic analyses. If the continuing calibration does not meet the specified criteria, the analysis must stop. Analysis may resume 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 AND CONSUMABLES

The field team leaders for each sampling event will have a checklist of supplies required for each day in the field (see Section 3.2.7). The FC will gather and check these supplies daily for satisfactory conditions before each field event. Batteries used in the GPS unit and digital camera will be checked daily and recharged as necessary. Supplies and consumables 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 the correct size and quantity and were not 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), which provides daily tide tables for a station at the Lockheed Shipyard on Harbor Island, Seattle, WA.

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. After sampling is completed, all data from field forms will be entered into a Microsoft Excel® spreadsheet. A QC check will be done within 24 hours 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 drive, which is backed up daily. Field forms will be archived in the Windward library. All photographs will be transferred to a CD each day.

Both analytical and taxonomy laboratories are expected to submit data in an electronic format as described in Section 2.6.2, Tables 2-3 and 2-4. 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.

4.0 Assessment and Oversight

4.1 COMPLIANCE ASSESSMENTS AND RESPONSE ACTIONS

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

4.1.1 Compliance assessments

Laboratory and field performance assessments consist of on-site reviews conducted by EPA 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 addressing internal QA/QC; these procedures will be submitted for review by the project QA/QC coordinator 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 and taxonomy laboratories are required to comply with the standard operating procedures previously submitted to the project QA/QC coordinator. The laboratory PMs will be responsible for ensuring that appropriate corrective actions are initiated as required for conformance with this QAPP. All laboratory personnel will be responsible for reporting problems that may compromise the quality of the data.

The project QA/QC coordinator will be notified immediately if any QC sample exceeds the project-specified control limits (Tables 3-17 and 3-18). The analyst will identify and correct the anomaly before continuing with the sample analysis. The laboratory PM will document the corrective action taken in a memorandum submitted to the project QA/QC coordinator within five days of the initial notification. A narrative describing the anomaly, the steps taken to identify and correct the anomaly, and the treatment of the relevant sample batch (i.e., recalculation, reanalysis, reextraction) will be submitted with the data package using a corrective action form.

4.2 REPORTS TO MANAGEMENT

Progress reports will be prepared by the FC for LDWG 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 analyses, 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.

5.0 Data Validation and Usability

5.1 DATA VALIDATION

Data are not considered final until validated. Data validation will be conducted following EPA (1999 and 2002) guidance.

The data validation process begins within the laboratory with the review and evaluation of data by supervisory personnel or QA specialists. 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 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.

Independent third-party data review and summary validation of the analytical chemistry data will be conducted by Cari Sayler of Sayler Data Solutions, Inc. (or a suitable alternative). A minimum of 20% or a single sample delivery group 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
- matrix spike recoveries
- matrix spike/matrix spike duplicate RPDs
- compound identifications
- compound quantitations
- instrument performance check (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, then validation can proceed as a summary validation on the rest of the data using all the QC forms submitted in the laboratory data package. Quality assurance 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 3-15, 3-16, 3-17, and 3-18, and EPA (1999, 2002) guidance for organic and inorganic data review. 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. All contacts with the laboratories will be documented in a communication report. 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 general use.

5.2 RECONCILIATION WITH DATA QUALITY OBJECTIVES

Data quality assessment will be conducted by the project QA/QC coordinator in consultation with EPA guidelines. 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.

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7.0 Oversize Figures

Figure 2-2. Historical benthic invertebrate community sampling locations in the Lower Duwamish Waterway

(separate file in MS Word® version)

Figure 3-4. Market basket benthic invertebrate/sediment chemistry locations and SQS/SL and CSL/ML exceedances for any chemical

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Figure 3-5. Percent total organic carbon by Thiessen polygon in LDW surface sediment

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Figure 3-6. Lower Duwamish Waterway bathymetry

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Figure 3-7. Percent fines by Thiessen polygon in LDW surface sediment

(separate file in MS Word® version)

Figure 3-9. Clam habitat quality for the Lower Duwamish Waterway

(separate file in MS Word® version)

Figure 3-10. Total PCB concentrations in LDW surface sediment and clam tissue/co-located sediment sampling areas

(separate file in MS Word® version)

Appendix A. Health and Safety Plan

(Appendices are contained in separate file in MS Word® version)

Appendix B. Field Collection Forms

(Appendices are contained in separate file in MS Word® version)

Appendix C. Risk-based Analytical Concentration Goals

(Appendices are contained in separate file in MS Word® version)

Appendix D. Analytical Concentration Goals for Sediment Collected at Clam Sampling Locations

(Appendices are contained in separate file in MS Word® version)

Appendix E: Derivation of Salinity Ranges and Calculation of Areal Percentages for Each Range

(Appendices are contained in separate file in MS Word® version)