APPENDIX E

Quality Assurance Project Plan

Lower Duwamish Waterway Group

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

QUALITY ASSURANCE PROJECT PLAN

Enhanced Natural Recovery/Activated Carbon Pilot Study

Lower Duwamish Waterway

FINAL

Prepared for:

The U.S. Environmental Protection Agency
Region 10
Seattle, Washington

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

Prepared by:

Amec Foster Wheeler Environment & Infrastructure, Inc.
Dalton, Olmsted & Fuglevand, Inc.
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TITLE AND APPROVAL PAGE
ENHANCED NATURAL RECOVERY/ACTIVATED CARBON PILOT STUDY
QUALITY ASSURANCE PROJECT PLAN

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DISTRIBUTION LIST

This list identifies all individuals to receive a copy of the approved Quality Assurance Project Plan, either in hard copy or electronic format, as well as any subsequent revisions.

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APPENDICES

ABBREVIATIONS AND ACRONYMS

AC	activated carbon
Alpha	Alpha Analytical Laboratory
AOC	Administrative Order on Consent for Remedial Investigation/Feasibility Study
CD	compact disc
CF	correction factor
CFPRC	correction factor for a performance reference compound
COC	chain of custody
CQAPP	construction quality assurance project plan
°C	degrees Celsius
DGPS	digital global positioning system
DOT	U.S. Department of Transportation
DQO	data quality objective
DVD	digital video disc
Ecology	Washington State Department of Ecology
EDD	electronic data deliverable
EIM	Environmental Information Management
ENR	enhanced natural recovery
ENR+AC	enhanced natural recovery amended with activated carbon
EPA	U.S. Environmental Protection Agency
FC	field coordinator
FGW	field-generated waste
Frontier	Frontier Analytical Laboratory
GAC	granular activated carbon
GPS	global positioning system
L	liter
LCS	laboratory control sample
LDW	Lower Duwamish Waterway
LDWG	Lower Duwamish Waterway Group
LOD	limit of detection
LOQ	limit of quantification
µg/kg	micrograms per kilogram
MDL	method detection limit
mg/kg	milligrams per kilogram

ABBREVIATIONS AND ACRONYMS (Continued)

mg/kg-OC	milligrams (of chemical) per kilogram of organic carbon (in soil)
mL	milliliter
MLLW	mean lower low water
MS	matrix spike
MSD	matrix spike duplicate
ng	nanogram
Order Amendment	Second Amendment (July 2014) to the Administrative Order on Consent for Remedial Investigation/Feasibility Study
PCB	polychlorinated biphenyl
PDMS	polydimethylsiloxane
pg	picogram
PPE	personal protective equipment
PM	project manager
PRC	performance reference compound
PSEP	Puget Sound Estuary Program (protocols)
QA	quality assurance
QAO	quality assurance officer
QAC	quality assurance criterion (criteria)
QAPP	quality assurance project plan
QC	quality control
redox	oxidation-reduction
RL	reporting limit
RPD	relative percent difference
RSD	relative standard deviation
SMS	Sediment Management Standards
SOP	standard operating procedure
SPI	sediment profile imagery
SPME	solid-phase microextraction
SVOC	semivolatile organic compound
TOC	total organic carbon

QUALITY ASSURANCE PROJECT PLAN
Enhanced Natural Recovery/Activated Carbon Pilot Study
Lower Duwamish Waterway

1.0 PROJECT DESCRIPTION AND OBJECTIVES

The Lower Duwamish Waterway Group (LDWG) will conduct a pilot study of an innovative sediment technology in the field to evaluate the potential effectiveness of the technology in the Lower Duwamish Waterway (LDW). The study will determine whether enhanced natural recovery (ENR) amended with activated carbon (AC) can be successfully used to decrease bioavailability of contaminants in sediment in the LDW. The study will compare the effectiveness of ENR amended with AC (ENR+AC) against that of ENR without added AC. This will be tested in three habitat types: the subtidal, the intertidal, and an area where vessel scour is possible. For the purposes of this project, ENR involves the placement of a thin layer of clean material over subtidal or intertidal sediments. ENR+AC involves the placement of a thin layer of clean material augmented with AC over subtidal or intertidal sediments.

This pilot study was specified under the Second Amendment (July 2014) to the Administrative Order on Consent for Remedial Investigation/Feasibility Study (AOC) for the Lower Duwamish Waterway, CERCLA Docket No. 10-2001-0055, issued on December 20, 2000. The Second Amendment to the AOC, which is referred to as the Order Amendment, included a statement of work for the pilot study, including a general overview of the work to be performed, a list of study steps/tasks, and a schedule for deliverables.

The goals of the pilot study, as stated in the Order Amendment, are the following:

- Verify that ENR amended with AC (ENR+AC) can be successfully applied in the LDW by monitoring physical placement success (uniformity of coverage and percent of carbon in a placed layer).
- Evaluate performance of ENR+AC compared to ENR alone in locations with a range of polychlorinated biphenyl (PCB) concentrations.
- Assess potential impacts to the benthic community in ENR+AC compared to ENR alone.
- Assess changes in bioavailability in ENR+AC compared to ENR alone.
- Assess the stability of ENR and ENR+AC in scour areas (such as berthing areas).

This quality assurance project plan (QAPP) briefly describes the pilot study plot locations and treatment design, discusses the data quality objectives (DQOs) for the study, describes the overall monitoring design, and provides details of the methods and procedures for the measurement tools used in the study.

1.1 PLOT DESIGN, LOCATIONS, AND SUMMARY OF CONDITIONS

Consistent with the AOC and the Order Amendment, the ENR and ENR+AC layers will be placed on sediments in plots that represent three habitat types: a subtidal, an intertidal, and a subtidal area that may be influenced by propeller wash, which is referred to as the scour plot. Because the goal of the pilot study is to evaluate the performance of ENR augmented with AC as compared with that of ENR alone, the pilot study will evaluate side-by-side subplots. At each of the three plot locations, a 6- to 9-inch-thick layer of sand or gravelly sand will be added. Both subplots will receive the same material, at the same thicknesses. In one subplot, granular activated carbon (GAC) will be added at 4 percent (by weight) GAC/mass of gravelly sand or sand. Details of the ENR and ENR+AC layer addition and specifications are provided in the Narrative Design Report and the plans and specifications for the pilot study. This QAPP is an attachment to the Narrative Design Report.

The selection of the specific plot locations is described in the Plot Selection Memorandum (LDWG 2015), which is included as an appendix of the Narrative Design Report. These locations were approved by the U.S. Environmental Protections Agency (EPA) and the Washington State Department of Ecology (Ecology) on February 11, 2015. The three plots are shown in Figures 1.1 through 1.3, and each plot area is described in the following subsections. The plot selection memorandum provides sediment results for all contaminants of concern for the LDW, a physical description of the plot, and provides the selection rationale.

The selection of these plots for the pilot study met the study goal to evaluate performance of ENR+AC compared to ENR alone in locations with a range of PCB concentrations.

1.1.1 Subtidal Plot (River Mile 1.2)

The subtidal plot represents subtidal conditions in the LDW Superfund site. The location and bathymetry of the subtidal plot, the layout of its two subplots, and the surface-sediment PCB concentrations are shown in Figure 1.1. This plot is divided into two longitudinal subplots called the East Lanes and the West Lane, for the ENR and ENR+AC applications, respectively.

PCB concentrations in surface sediments at this plot range from approximately 4 milligrams per kilogram of organic carbon (mg/kg-OC) to 180 mg/kg-OC.

1.1.2 Scour Plot (River Mile 0.1)

The scour plot is representative of areas throughout the site that may experience scour in berthing areas. The location and bathymetry of the scour plot, the layout of its two subplots, and the surface-sediment PCB concentrations are shown in Figure 1.2. This plot is divided into two almost square subplots called the upstream and downstream subplots, for the ENR and ENR+AC applications, respectively.

PCB concentrations in surface sediments at this plot range from approximately 7 to 180 mg/kg-OC.

1.1.3 Intertidal Plot (River Mile 3.9)

The intertidal plot represents intertidal conditions throughout much of the site. Consistent with previous documents, the intertidal area in the LDW is defined as sediments above -4 feet mean lower low water (MLLW). The location and bathymetry of the intertidal plot, the layout of its two subplots, and the surface-sediment PCB concentrations are shown in Figure 1.3.

PCB concentrations at this plot range from approximately 7 to 150 mg/kg-OC.

1.2 DATA QUALITY OBJECTIVES

This section presents the data quality objectives (DQOs) for the pilot study monitoring program. The DQO process defines criteria that will be used to establish the final data collection design (U.S. EPA 2006). Based on the study goals listed in Section 1.0, the DQOs were developed to support the selection of sampling and analysis methods and an overall study design that leads to data appropriate to answer the study questions. The DQOs developed for the pilot study, the data types, and the analytical approaches are presented in the following subsections. Specific performance goals, referred to as Data Quality Indicators, for the individual analytical methods are discussed in Section 3.0 after the methods have been introduced.

The DQOs were developed with the recognition that ENR (and ENR+AC) are technologies that inherently work with natural recovery processes that are ongoing in the LDW surface sediments. These include vertical mixing by bioturbation, redistribution and vertical mixing of surface sediments by waves and currents, sedimentation and minor erosion, and minor anthropogenic disturbances such as small boat anchors. ENR is not an engineered containment layer and the placed ENR layer is expected to physically change over time as a result of these riverine processes.

1.2.1 DQO-1: Verify the Placement of the ENR and ENR+AC Materials

The first DQO is to determine whether the ENR and ENR+AC layers can be placed in the subtidal, intertidal, and scour plots within the targeted specifications. This first DQO establishes the initial

physical conditions of the ENR and ENR+AC layers immediately after placement and is used to support subsequent monitoring. This DQO addresses the thickness and evenness of the ENR and ENR+AC layers, the constructed AC content in the ENR+AC layer, and the distribution of carbon in the ENR+AC layer.

Investigative methods to measure the thickness and evenness of the layers will include physical assessment by the contractor during placement using tools such as bathymetric survey and breakaway stakes. The QA/QC requirements for the tools used by the contractor and LDWG team during construction are described in the Construction Quality Assurance Project Plan (CQAPP). The QC by the contractor will be augmented by QA checks by the LDWG team using visual observation by divers, sediment profile imagery (SPI), and collection, logging, and analysis of shallow cores.

The achieved concentration of AC in the ENR+AC subplots will be based on measures of post placement carbon content using methods for both total organic carbon (TOC) and black carbon. The general distribution of AC within the ENR+AC layer will be based on visual observations using diver-collected cores and SPI. Measurements supporting DQO-1 will be made within 30 days of placement at each subplot.

A baseline event to collect information on the bathymetry, grain size, and carbon content of the *in-situ* sediments will also be conducted 60 to 90 days before placement to assist in assessing the success of the placement.

1.2.2 DQO-2: Evaluate the Stability of ENR and ENR+AC Materials

The second DQO addresses the stability of the ENR materials and the stability of the AC material in the ENR matrix in the scour plot. Loss of ENR and ENR+AC materials may occur as a result of erosional forces, such as propeller wash. Depending upon the nature of the turbulence in the berthing areas, there is also the potential for an increase in stability from the deposition of riverine sediments or for integration of the ENR and ENR+AC layers into the underlying sediment. Changes in ENR+AC stability will be evaluated during post placement monitoring events in Years 1, 2, and 3 using visual observations (diver survey and SPI), and diver-collected cores.

Winnowing of the AC materials from the ENR layer can occur when the ENR material becomes suspended in the water column by erosional forces such as propeller wash in the scour plot. When the ENR matrix re-deposits on the riverbed, the more buoyant AC can be lost to the water column and potentially transported out of the plot. Combined visual observations (diver-collected cores and SPI) and measurements of black carbon will be used to evaluate the distribution and concentration of AC in the ENR+AC layer. AC measurements in the ENR+AC layer will be

evaluated in Years 1, 2, and 3 after initial placement of the ENR+AC layer and compared to the conditions seen in Year 0.

1.2.3 DQO-3: Assess Changes in Bioavailability in ENR+AC Compared to ENR Alone

The third DQO assesses the potential changes in PCB bioavailability in ENR+AC compared to ENR alone. For the purposes of the Pilot Study, changes in bioavailability will be based on measurements of the bioavailable fraction of PCBs as represented by the porewater PCB concentrations.

Sediment and porewater concentrations collected prior to placement of the ENR layers will be used to establish a baseline partitioning relationship between sediment (normalized for carbon content) and porewater. The same types of data (sediment and porewater PCBs, TOC, and AC) will be collected in Years 1, 2, and 3 monitoring events (post placement). These data will be analyzed to see if the addition of AC to the ENR matrix results in different partitioning of PCBs into porewater relative to ENR alone. If the addition of AC causes the PCBs to remain in the sediment matrix (adhered to the increased carbon content), then the amount of PCBs dissolved in porewater will be less, and the availability of PCBs to aquatic organisms will be less.

Porewater PCB concentrations will be measured using Solid-Phase Microextraction (SPME) fibers deployed in the top 10 cm of the sediment surface. Secondary measurements supporting interpretation of bioavailability will include measurements of grain size, carbon content, and bulk sediment PCB congeners in the top 10 cm of the sediment.

Porewater PCB concentrations will also be measured at the top 1 cm of the sediment (approximate sediment-water interface) in Years 2 and 3 to assess temporal variability at the sediment surface and the effect of recently deposited sediment on the effectiveness of ENR and ENR+AC. LDWG may request to EPA and Ecology that the sediment-water interface PCB porewater measurement at Year 3 be omitted in the scour plot if evidence indicates that there is no sediment accumulation in Years 2 and 3 and Year 2 data indicate there is no difference in sediment-water interface SPME PCB concentrations in the ENR+AC versus ENR plots.

1.2.4 DQO-4: Assess the Potential Impacts of AC on Benthic Communities

The fourth DQO addresses the potential impacts of AC on benthic communities in the LDW. Although laboratory and field studies have generally shown few adverse effects on benthic organisms after the application of AC to contaminated sediments, effects have been associated with the use of small particle sizes (powdered activated carbon) or higher applications rates (generally greater than 5 percent AC).

To determine whether the use of AC, as proposed in the pilot study, could adversely affect the benthic communities in the LDW, a benthic survey will be conducted in Year 3. The benthic communities established in each of the ENR+AC subplots of the subtidal, intertidal, and scour plots will be compared to the benthic communities in their respective ENR subplots.

1.3 PROJECT SCHEDULE

As discussed in further detail in the next section, data for this project will be collected in five events. The first event, referred to as the baseline event, will occur 60 to 90 days before placement of the ENR and ENR+AC layers. The second event, Year 0, will occur within 30 days post placement at each plot; and the next three events will occur annually approximately 1, 2, and 3 years after the Year 0 event.

All in-water construction work for ENR and ENR+AC placement is planned to be conducted during the authorized 2016–2017 in-water work window for the LDW, when salmonid species listed under the Endangered Species Act are least likely to be present. It is anticipated that the construction would occur in December 2016, after the completion of the Muckleshoot Indian Tribe's net fishery season. Baseline sampling, scheduled to precede placement by 60 to 90 days, would occur in September or October 2016, with Year 0 sampling occurring in January or February 2017. The Narrative Design Report and its appendices contain more details on the scheduling of the placement of the ENR and ENR+AC layers.

The Year 1, 2, and 3 Monitoring Events are anticipated to occur in the spring (March to May) of 2018, 2019, and 2020. Shifting the annual events from January (Year 0) to the spring increases the number of daylight hours available for the field staff to collect and process samples and should be during a time of relative stability in the benthic populations in Year 3 (prior to late spring recruitment which add extra variability to the conditions.

1.4 QAPP ORGANIZATION

This QAPP is organized into the following sections:

- Section 1 – Project Description and Objectives
- Section 2 – Project Organization and Responsibility
- Section 3 – Data Generation and Acquisition
- Section 4 – Sampling Handling and Custody Documentation
- Section 5 – Assessment and Oversight
- Section 6 – Reporting

- Section 7 – References

The representative field forms are included as Attachment A. Attachment B is a technical memorandum that includes additional detail on the use of the SPME fibers for porewater sampling. Attachment C contains the preliminary requirements for the electronic data deliverables file from the laboratories.

Separate health and safety plans are being prepared for construction and monitoring. These plans are an appendix to the Narrative Design Report. A separate Dive Plan will be available for tasks requiring diver support as described in Section 4.2.6 of Appendix G of the Narrative Design Report.

2.0 PROJECT ORGANIZATION AND RESPONSIBILITY

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

2.1 MANAGEMENT RESPONSIBILITIES

Figure 2.1 shows the overall project organization for the activities described in this QAPP, along with contact information (telephone numbers and email addresses) for key staff. Responsibilities of project team members and laboratory project managers are described in the following sections.

2.1.1 Project Management

LDWG is the lead for conducting this work for EPA and Ecology and, as such, will be involved in all aspects of this project. EPA and Ecology as oversight agencies will review and approve the QAPP as well as perform oversight on any field activities, as needed. EPA and Ecology will be represented by their project managers (PMs) for this project, Elly Hale and Ron Timm, respectively.

Cliff Whitmus of AMEC Foster Wheeler will serve as the consultant team PM, responsible for overall project coordination and providing oversight related to planning and coordination, work plans, project deliverables, and performance of the administrative tasks needed to ensure timely and successful completion of the project. He also will be responsible for coordinating with LDWG, EPA, and Ecology on schedule, deliverables, and other administrative details. Mr. Whitmus can be reached as follows:

Cliff Whitmus
AMEC Foster Wheeler
3500 188th Street SW, Suite 601

Lynwood, WA 98037
Tel: 425.921.4023
cliff.whitmus@amecfw.com

2.1.2 Project Engineer

Rob Webb of Dalton, Olmsted & Fuglevand, Inc. (DOF) will serve as the project engineer (PE); his responsibilities are focused on the design and placement of the ENR layers, including construction quality assurance/quality control (QA/QC). The CQAPP outlines the QA/QC elements for the placement of the ENR layers and includes testing performed by the contractor to demonstrate that the requirements of the construction contract have been met. The PE is responsible for overseeing contractor QC elements and conducting QA elements associated with construction, including acceptability of placed materials and verification of placement in Year 0 Events.

The PE reports to the PM. However, coordination, between the PE and his CQAPP and this QAPP, is needed during, the baseline and Year 0 events, as follows:

- As part of the baseline event, the materials that will be used for the ENR layers will be tested for all Sediment Management Standards (SMS) benthic chemicals of concern and the GAC will be tested for PCB congeners. Requirements for this testing are part of this QAPP and will be performed by the consultant team and not the contractor. This testing will be scheduled by the PE to occur early enough in the process to allow for alternative sources of materials to be identified if contamination is found to be a problem.
- For the Year 0 event, the PE will notify rest of the team when the contractor is done with the verification of physical placement of the layers (as discussed in the CQAPP). The monitoring team will then schedule Year 0 sampling of the new layers as described in this QAPP to occur within 30 days of notification for each Plot.

Mr. Webb can be reached as follows:

Rob Webb, PE
Dalton, Olmsted & Fuglevand, Inc.
1236 NW Finn Hill Road
Poulsbo, WA 98370
Tel: 360.394.7917
rwebb@dofnw.com

2.1.3 Monitoring Lead

Dr. Victor Magar of Ramboll Environ US Corporation (Ramboll Environ) will serve as the monitoring lead (ML), responsible for the overall design and implementation of the monitoring program. The

monitoring team reports to the ML. The Quality Assurance Officer (see next section) reports to both the ML and PM any out-of-compliance event with the potential to affect data quality or project objectives. The ML reports to the PM.

Dr. Magar can be reached as follows:

Victor Magar, PhD, PE
Ramboll Environ
333 West Wacker Drive, Suite 2700
Chicago, IL 60606
Tel: 312.288.3840
vmagar@ramboll.com

2.2 QUALITY ASSURANCE RESPONSIBILITIES

The overall goal of the QA program is to develop and implement procedures that will ensure the collection of representative data of known, acceptable, and defensible quality and can be used to achieve the DQOs in Section 1.2.

Dr. Teri Floyd of Floyd|Snider will serve as the QA officer (QAO) for the monitoring program. This will include being the analytical lead responsible for laboratory coordination, overall QA/QC of the monitoring, and supervision of data validation, database management, and electronic data reporting. The QAO will report any QA/QC problems to the PM and the ML immediately, propose resolutions, and see that they are implemented. Dr. Floyd can be reached as follows:

Teri Floyd, PhD
Floyd|Snider
601 University Street, Suite 600
Seattle, WA 98101
Tel: 206.292292-2078
teri.floyd@floydsnider.com

Dr. Floyd is supported by Dr. Gretchen Heavner (of Floyd|Snider) for field-to-laboratory coordination and by Cari Sayler of Sayler Data Solutions, who will provide an independent third-party review and validation of analytical chemistry data. Ms. Sayler will also manage the project database (using the existing LDWG template), apply qualifiers, perform the calculations for calculated results, import data from electronic laboratory deliverables, and produce any electronic data deliverables (EDDs). She can be reached as follows:

Cari Sayler
Sayler Data Solutions
14257 93rd Court NE
Kirkland, WA 98034
Tel: 425.820.7504
cari@saylerdata.com

Significant deviations from this QAPP will be reported in a timely manner to representatives of LDWG, EPA, and Ecology.

2.3 FIELD WORK

Field work and sample collection roles are identified in this section.

2.3.1 Field Coordinator

Bill Gardiner of Ramboll Environ will serve as the field coordinator (FC). The FC is responsible for managing field activities and performing field QA/QC oversight. Mr. Gardiner will ensure that appropriate protocols for sample collection, preservation, and holding times are observed and will oversee delivery of environmental samples to the designated laboratories for chemical and benthic macroinvertebrate analyses. Deviations from this QAPP will be reported to the PM, with concurrent notification to the ML and QAO for consultation.

For the benthic survey in Year 3, Mr. Gardiner, in his role as FC, will collect and stabilize the benthic samples and, in his role as Manager of the Ramboll Environ lab (section 2.5), will lead the benthic macro-invertebrate analysis. If problems are encountered in the benthic work, Mr. Gardiner will assess the situation, report it immediately to the PM, ML, and QAO, propose solutions, and implement corrective measures if needed.

Mr. Gardiner is supported by Dr. Jack Word (of Ramboll Environ) who act as a benthic expert assisting with sampling design and benthic data interpretation.

Mr. Gardiner can be reached as follows:

William Gardiner
Ramboll Environ
P.O. Box 216
4729 NE View Drive
Port Gamble, WA 98364
Tel: 360.297.6080
bgardiner@ramboll.com

Significant deviations from the monitoring program will be reported to representatives of LDWG, EPA, and Ecology.

2.3.2 Field Support

The FC is supported in the field by staff from the consultant team, by experts such as Drs. Jason Conder and Jack Word (discussed below) and by vendors with specialized equipment or expertise.

2.4 SPECIALIZED EXPERTISE

Dr. Jason Conder of Geosyntec Consultants is an expert in the use of SPME sampling techniques for in situ porewater analyses. This expertise includes preparation of the fibers in the laboratory, the addition of special internal standards, deployment and retrieval of the fibers in the field, and extraction of the fibers before analysis, and interpretation of the results. Dr. Conder will work closely with the QAO during the preparation and extraction steps and then will transfer custody of the extracts to the FC for transportation to the analytical laboratory. During the deployment and retrieval of the fibers, he will work closely with the FC. Dr. Conder can be reached as follows:

Jason Conder, PhD
Geosyntec Consultants
2100 Main Street, Suite 150
Huntington Beach, CA 92648
Tel: 714.465.1226
JConder@Geosyntec.com

2.5 LABORATORY RESPONSIBILITIES

Dr. Teri Floyd of Floyd|Snider will serve as the overall laboratory coordinator for the monitoring program. Each of the laboratories utilized 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 reporting requirements
- Deliver electronic data files as specified in this QAPP
- Meet turnaround times for deliverables as described in this QAPP
- Allow EPA and the QA/QC third-party auditors to perform laboratory and data audits

2.5.1 SPME Preparation Laboratory (Ramboll Environ Laboratory)

Dr. Jason Conder will oversee the preparation of the SPME fibers before deployment and the extraction of the fibers after deployment. This work will be performed in the Ramboll Environ Laboratory in Port Gamble, Washington. The preparation procedures are presented in Appendix B and discussed in Section 3.0. The laboratory PM is Bill Gardiner, who is also the Field Coordinator for this study.

2.5.2 Benthic Infauna Laboratory

Bill Gardiner will oversee laboratory and field preparations for the benthic infauna analyses prior to field collection of benthic sediment samples. Benthic infaunal counts will be performed in the Ramboll Environ Lab in Port Gamble, Washington. The laboratory PM is Bill Gardiner, who is also the Field Coordinator for this study.

2.5.3 Analytical Testing Laboratories

Dr. Teri Floyd of Floyd|Snider will serve as the laboratory coordinator for the analytical chemistry laboratories. She is also the QAO for the monitoring program. The analytical laboratories are not yet under contract, and may change. If the analytical laboratories change, the affected pages of the QAPP will be resubmitted for review and approval. At this time, it is expect that Frontier Analytical Laboratory (Frontier) in El Dorado Hills, California will perform the PCB congener analyses of the SPME extracts and sediment samples. Likewise, it is expected that Alpha Analytical Laboratory (Alpha) will perform the other analyses on the sediment samples. The Frontier laboratory PM can be reached as follows:

Dr. Brad Silverbush
Frontier Analytical Laboratory
5172 Hillsdale Circle
El Dorado Hills, CA 95762
Tel: 916.934.0900
brads@frontieranalytical.com

The Alpha laboratory PM can be reached as follows:

Liz Porta
Alpha Analytical Laboratory
8 Walkup Drive
Westborough, MA 01581
Tel: 508.844.4100
eporta@alphalab.com

2.6 SPECIAL TRAINING AND 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 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 (Code of Federal Regulations, Title 29, Section 1910.120 [29 CFR 1910.120]). All sampling personnel will have completed the 40-hour HAZWOPER training course and 8-hour refresher courses, as necessary, to satisfy the requirements of the Occupational Safety and Health Administration regulations.

2.7 DOCUMENTS AND RECORDS

The following documents and records specific to this QAPP will be retained for this study and incorporated in the Administrative Record for the LDW Superfund sites:

- Final QAPP, which covers baseline and long-term monitoring for the pilot study. If it is necessary to amend this QAPP in the future, those amendments will also be included.
- Field sampling forms and records (as discussed in Section 3.0) will be presented on electronic media (compact disc [CD] or digital video disc [DVD]) as an appendix to the reports, as discussed in Section 6.0, Reporting. This will include the reporting of any deviations that occurred in the field and during sample preparation for laboratory submittal.
- Final laboratory reports, including the Laboratory Information Management System (LIMS) data necessary for data validation, will be presented on electronic media (CD or DVD) as an appendix to the reports, as discussed in Section 6.0. This will include the reporting of any deviations that occurred in the laboratory, and the identification of out-of-control events, if any, and their resolution.
- Final validated data will be submitted to Ecology's Environmental Information Management (EIM) system, in the format required by Ecology for data submittals. A printed summary of the data will also be included in the reports, as discussed in Section 6.0.

3.0 DATA GENERATION AND ACQUISITION

This section describes the collection and handling of porewater, sediment, and biological samples for analysis. Elements include sampling events, sampling design, station location, sampling and analysis methods, QA/QC, and data custody and management.

3.1 OVERVIEW OF THE MONITORING PROGRAM

This section describes the sampling events, the design of the monitoring program, and the sequencing of the work.

3.1.1 Sampling Events

There will be a total of five sampling events in support of the pilot study monitoring program. The events begin with a baseline event before ENR and ENR+AC placement, a Year 0 event immediately after ENR and ENR+AC placement, and three annual events after the Year 0 event at intervals of one year (i.e., Years 1, 2, and 3). The types of samples and the DQOs supported by the activities performed during each of these events are described in this section and summarized in Table 3.1. Additional details of sampling design and measurement tools are provided throughout Sections 3.0 and 4.0.

3.1.1.1 Baseline Event

Baseline sampling will be conducted to establish the conditions in sediment and porewater within each plot prior to placement. Data collected during the baseline sampling event will include concentrations of PCB congeners in porewater and bulk sediment; bulk sediment grain size, TOC, and black carbon[1]; porewater salinity; and visual observations of benthic community successional stages using sediment profile imagery (SPI). The data will be collected 30 to 60 days before placement of the layers.

As part of the baseline event, the sand and gravelly sand that will be used for the ENR layers will be tested the chemicals listed below; the GAC will be tested for PCB congeners. The sampling and analysis consists of the following:

- Three to five grab samples will be collected by the contractor of each material intended for use as ENR layer materials (sand and gravelly sand) from material that is representative of the materials to be used in the project. The samples will be given under chain-of-custody paperwork to the PE, who will relay them to the FC, for transportation to the lab. The samples should be placed in 8-ounce wide-mouth jars with Teflon-lined lids, but zip lock bags are acceptable. The samples will be tested for all chemicals listed in Lower Duwamish Waterway Record of Decision (U.S. EPA, 2014) Tables 19 and 20, TOC, and grain size as discussed in Section 3.5.

- One representative sample of the GAC material that will be used in this project will be tested for PCB congeners. The sample will be acquired by the contractor from the Vendor for this testing and shipped directly to the FC for transportation to the lab. The sample must be collected from the same "batch" of GAC intended for use in this pilot

1 Black carbon is the name of the analytical method that is used to quantify the activated carbon content of the sediments. It includes both the added GAC and naturally occurring carbon with a high sorption capacity such as soot.

study. The sample must be received from the vendor in a 4-ounce (or larger) wide-mouth glass jar with a Teflon-lined lid accompanied with documentation of material batch number(s).

This testing will be scheduled by the PE to occur early enough in the process to allow for alternative sources of materials to be identified if contamination is found to be a problem.

3.1.1.2 Placement Confirmation (Year 0)

Post placement monitoring will occur within 30 days after the placement of the ENR layer in each plot. This event is separate from and follows contractor's performance verification requirements specified in the CQAPP. This event is intended to document the thickness and evenness of the ENR and ENR+AC layers and the distribution and content of the AC in the placed ENR+AC layer.

Measurements collected during this event will be limited to physical sediment properties (grain size, TOC, and black carbon) and visual observations of the thickness and general condition of the ENR and ENR+AC layers, using diver observations and SPI.

3.1.1.3 Post Placement Events – Year 1 and Year 2

These two events are intended to gather data on the stability and performance of the ENR+AC layer over time relative to the ENR layer. The sampling is intended to be conducted during the same time of year to limit seasonal variations and to be conducted 1 year apart for 2 years after layer placement. The events are expected to occur between March and May of 2018 and 2019.

Data collected during these monitoring events will include measurements of PCB congeners in porewater and bulk sediment; an evaluation of conventional sediment properties (TOC, BC, and grain size); measurement of porewater salinity; observations of ENR layer stability; and an assessment of the extent of overlying sediment deposition using SPI images, diver observations, and physical logging of the shallow sediment cores. Year 2 monitoring will also include measurement of PCB congeners in sediment-water interface porewater. SPI and plan view images will also be used during Years 1 and 2 to assess the benthic community recolonization in the ENR/AC layers over time.

3.1.1.4 Post Placement Events – Year 3

The final monitoring event will occur 3 years after construction and is intended to gather data on the stability and performance of the ENR+AC layer over time relative to the ENR layer (similar to Years 1 and 2) and the potential effects of AC on the benthic communities. Year 3 monitoring will occur during the same season as Year 1 and 2 monitoring events (between March and May of

2020). The March time period should represent a period of low inherent variability in the benthic communities.

Data collected during the Year 3 monitoring event will include measurements of PCB congeners in porewater and bulk sediment; an evaluation of conventional sediment properties (TOC, BC, and grain size); measurement of porewater salinity; observations of ENR layer stability; an assessment of the extent of overlying sediment deposition; and an assessment of the benthic communities. Year 3 monitoring will include measurement of PCB congeners in sediment-water interface porewater. LDWG may request to EPA and Ecology that the sediment-water interface PCB porewater measurement at Year 3 be omitted in the scour plot if evidence indicates that there is no sediment accumulation in Years 2 and 3 and Year 2 data indicate there is no difference in sediment-water interface SPME PCB concentrations in the ENR+AC versus ENR plots.

A tissue study is proposed for Year 3 to evaluate potential differences in PCB uptake into benthic infaunal tissues between the two plot types. The nature and scope of this phase of the investigation is being developed and an amendment to this QAPP will be prepared to address the tissue investigations.

3.1.2 Sampling Design

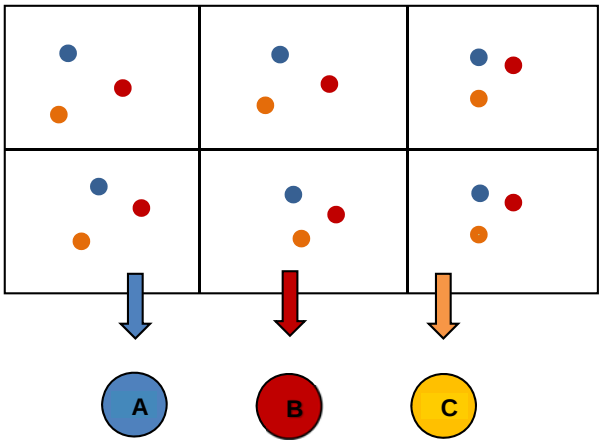
This section describes the sampling design developed to meet the data needs supporting the objectives defined in Section 1.2. The sampling design includes the number of samples and the sampling locations for individual samples, as well as the compositing strategies to generate analytical samples. Section 3.3 discusses future conditions that could warrant changes in the design of the monitoring program.

For 0 to 10 cm sediment porewater, sediment-water interface porewater (0 to 1 cm), and bulk sediment sample collection, a subplot will be represented by three composite samples made up of sediment or porewater from six locations. Each composite will be considered to be "representative" of the subplot and the use of three composites will allow for a measure of the variability within the subplot. To form the composites, each subplot is divided into six grid cells to ensure that there is good sampling coverage throughout the subplot. To avoid sampling in areas potentially influenced by untreated sediments and to avoid influence from the adjacent subplot, no samples will be collected from locations within 5 feet of the edge of a subplot, and a 15-foot buffer will be maintained between the ENR and ENR+AC subplots.

The location of the subplots and the grid cells within the subplots are shown in Figures 3.1, 3.2, and 3.3. Each grid cell has been further divided into approximately 24 locations. This division into 24 locations results in small rectangular "location" cells that are approximately 10 by 10 ft. This

size is large enough to collect multiple samples without removing too much of the ENR layer as part of sampling and large enough to use hand-held GPS to confirm that the diver is at one location and not an adjacent one. A random number generator was used to identify 3 locations within each of the six grid cells for a total of 18 locations per subplot. Figures 3.1, 3.2, and 3.3 show this for one of the events; Table 3.2 lists the locations that have been randomly selected for each event. In each event, there will be 18 locations identified in a subplot, but the specific locations within a grid cell will change for each event so that the area is not oversampled (too much material removed or disturbed) during the study.

In each subplot, six of the locations have been assigned the letter A, six the letter B, and six the letter C. The sediment (or SPME fibers deployed in the top 10 cm of the surface layer, or the SPME fibers deployed at the sediment-water interface) collected from each of the "A" locations within a subplot will be composited for the "A" composite for that subplot; likewise for the sediment from the "B" and "C" locations will be composited to form the "B" and "C" composites, respectively. Conceptually, it works like the schematic below.



This sampling design was derived using a statistical power analysis based on variability in the concentrations of total PCBs in sediment samples collected during remedial investigation and candidate plot identification process (Windward, 2010; LDWG, 2014). The design enables the detection of approximately a 50% or more reduction in concentrations of PCBs in porewater as a result of the treatment.

In the baseline event and the annual events in Years 1 through 3, the three composited sediment samples will be analyzed for PCB congeners, TOC, black carbon, and grain size. During those same events, three composited SPME porewater samples deployed in the top 10 cm layer will be analyzed for PCB congeners. In addition, during Years 2 and 3, three composited SPME porewater samples deployed at the sediment-water interface (0 to 1 cm) will also be analyzed for PCB congeners. Visual observations (by divers) will be recorded at each of the 18 locations (A, B, and C locations) sampled in each of the subplots during years 0 through 3.

During the baseline event, two additional composite SPME porewater samples (deployed in the top 10 cm layer) will be collected from each subplot (D and E locations - see Table 3.2). These samples will be processed and stored as described below, and may be analyzed pending an analysis and review of the statistical power indicated by the analysis of the three baseline composite SPME porewater samples. Measurements of PCBs in porewater in the top 10 cm layer for Years 1 through 3 will be based on three composites, unless the statistical power evaluation from the Baseline Event indicates that additional composites are needed to attain the desired level of statistical power. Additionally, measurements of PCBs in porewater at the sediment-water interface (Years 2 and 3) will also be based on the same number of composites required for the top 10 cm samples (three composites, unless the top 10 cm power analysis indicates more samples are needed).

Sediment conditions at each of the sediment sampling locations will be logged and porewater salinity will be measured. Salinity measurements will be made using a field probe of porewater collected approximately 10 cm below mudline during the Baseline Event; and 10 to 20 cm below mudline in subsequent events to assess the salinity of upwelling water. If salinities are consistently saline within a plot (greater than 20 parts per thousand), then LDWG may request to EPA and Ecology that the number of salinity measurements be reduced for that plot in future events.

SPI and plan view images will be collected from 6 locations per subplot (the A locations) during the baseline sampling to provide a general sense of the substrate and benthic community (e.g., successional stages) prior to ENR/AC placement; the SPI images are collected as triplicate images. In Year 0 through 3, SPI images (in triplicate) are collected at 12 locations per subplot (the A and B locations).

In Year 0, the primary DQO is to understand how the AC is distributed in the ENR+AC subplots. Bioavailability of PCBs is not of interest because the ENR and ENR+AC layers will not have had time to come into steady state with their surroundings. For this reason, only TOC, black carbon, and grain size are being analyzed. The sediment composites from each subplot will be analyzed for TOC, BC, and grain size. In the ENR+AC subplots, each of the 18 locations (6 per subplot) will be analyzed separately for BC to gather additional information about the distribution of the AC in the ENR+AC subplots. No porewater samples will be collected.

The benthic macro-invertebrate survey in Year 3 will not employ the compositing scheme described in 3.1.2.1; instead it will be performed on sediment grab samples collected specifically for the benthic survey. Five samples will be collected from each subplot; the locations were chosen using a random number generator as with the sediment and porewater locations. The selected locations are shown on Figures 3.1, 3.2, and 3.3.

3.1.3 Sequencing of Tasks within an Event

The following sequence of field activities will be used in the events.

1. SPI and plan view camera images will be collected first. They will be processed and used to gather a preliminary overview of current conditions at each subplot.
2. SPME fibers will be deployed using a diver as described later in Section 3.2.
3. Four weeks later (see Section 3.2.5), the SPME fibers will be retrieved by a diver, who will also collect the shallow sediment cores at the same location.
4. Benthic grab samples collected in Year 3 will be collected after the SPI and SPME retrieval.

The SPI, SPME, and sediment cores are co-located within location cells that are approximately 10- by 10-foot areas; the SPMEs and sediment cores are then composited as described in the Sampling Design above, and in more detail in Section 3.2 below.

3.2 SAMPLING METHODS

This section describes the sampling methods utilized in the monitoring program. Section 3.3 describes the analysis methods.

3.2.1 ENR Material Testing

As part of the baseline event, materials intended for use as ENR will be tested. The material samples will be collected by the Contractor (see Section 3.1.1) and submitted to the PE who will relay the materials to the FC for packaging and submittal to the analytical labs. The FC will place the sand and gravelly sand samples into the jars listed below; the sample jars (two jars per sample for the sand and gravelly sand) will be transferred to the sediment laboratory under chain-of-custody. Preservation or chilling is not required.

Jar Order	Analysis	Laboratory	Jar Size
1	SMS Metals, SVOCs Total solids Total organic carbon Black carbon	Sediment Laboratory	16 oz.
2	Grain size	Sediment Laboratory	8 oz. (full)
3	PCB congeners Dioxins/Furans	Congener Laboratory	4 oz

A sample of GAC will also be acquired by the PE (see Section 3.1.1) and given to the FC for packaging and submittal to the analytical laboratory. The GAC will be tested for PCB congeners

by the PCB congener laboratory. It will be submitted to the lab in a wide-mouth amber 4-ounce glass jar with a Teflon liner; the jar will be supplied by the PCB congener laboratory. A sample of the GAC will be placed in the jar and shipped to the laboratory under chain-of-custody. Preservation or chilling is not required.

3.2.2 Location Positioning

The center of the locations presented in Table 3.2 (and shown in Figures 3.1, 3.2, and 3.3 for one of the events) will be converted to digital global positioning system (DGPS) coordinates georeferenced to the datum used by the DGPS equipment. This information will be available to the field team at the beginning of each event.

The field team may relocate to another location within a grid cell if the location in Table 3.2 is found to have been adversely affected by conditions that are not intended to be part of the study. Such conditions could include spud holes created during construction, debris that has settled on the site, etc. – first preference would be to remain at the "location" but position the sample to avoid the problem, but if the adverse condition is more wide-spread (typically greater than 5-feet across), then a new location may be selected. The field staff will be given three additional locations per grid cell to those in listed in Table 3.2 as "contingent" locations; the contingent locations will also have been selected randomly. Finally, it also acceptable to adjust locations if localized areas of ENR loss (scour) occur; if the scour is wide-spread across the plot, then Section 3.3 should be consulted.

Station positioning for diver-deployed sampling will use temporary marker buoys for deployment. Immediately before sampling, the stations will be located using the vessel's DGPS. Once the designated coordinates have been reached, the station will be marked with a weighted marker buoy. The station location will be recorded once the marker buoy is in place. The DGPS receiver will be capable of accurately surveying positions to within 2 meters. A similar approach is used for the intertidal plot although the diver may be wading and/or walking along the mudflat during part of the sampling.

For vessel-deployed work (SPI and plan view images and benthic sample collection), the DGPS receiver will be placed above the deployment boom of the sampling device to accurately record the position of the sampling device. At surface sediment grab stations, once the sampling device has been deployed, the actual position will be recorded when the device reaches the sediment surface. At that point, there is typically less than 5 degrees of wire angle.

Before field work is initiated, a control checkpoint such as a dock or piling that can be accessed by the sampling vessel will be established. At the beginning and end of each day, the coordinates

and elevation of the checkpoint will be determined from the vessel, averaged, and compared to the known coordinates and elevation. The two position readings should agree within the limits of survey vessel's operational mobility and the instrument specifications.

Horizontal coordinates will be projected to the Washington State Plane (North) coordinate system under the North American Datum of 1983 (NAD 83). The vertical datum will be the National Ocean Service MLLW datum. Vertical control measured by the vessel depth finder will be corrected for tidal influence after the field activities are completed (Ecology, 2008). Tidal elevation will be determined by calling the National Ocean Service for data from its automated tide gage located at Pier 54 (206.749.9218).

Water depth will be measured during all sampling events using the vessel fathometer, the diver depth gauges, or a traditional lead line.

For diver-collected samples (SPME and sediment cores), depth will be determined by diver depth gauges. Divers will note the water depth and time at the sampling location while placing or retrieving the SPME fibers. The water depth from the diver's depth gauge and the tide at the time of sampling will be recorded on the field log. Tides will be converted to MLLW by subtracting the tidal height from the measured water depth.

For benthic grab samples, a lead line or vessel fathometer will be used to measure water depth. For lead-line readings, the line will be lowered to the sediment mudline. Once the lead line has reached the sediments, the distance to the surface of the water will be recorded, as well as the tide and time of the recorded depth. Tides will be corrected to MLLW by subtracting the tidal height from the measured water depth.

Forms: Location information will be recorded on a sampling station location log that may be a Microsoft Excel® table. The table will include information on the weather and waterway conditions; position checks with the fixed control checkpoint; and station-specific information (DGPS coordinates, water depth, date, and time). If the station is occupied for more than 1 hour or for the collection of more than one type of sample, the information will be measured and recorded again for the additional samples so that no more than 1 hour passes between measurements.

3.2.3 Sediment Profile Imaging and Plan View Imagery

SPI will be used to evaluate the thickness and physical characteristics of the ENR and ENR+AC layers, the thickness of newly deposited material (if any), the oxidation-reduction (redox) conditions, and the establishment of biological communities. Plan view images will be used to

assist in understanding surface conditions, erosion and deposition and the nature of the biological communities.

The SPI camera will provide semi-quantitative data regarding sediment type, mixing of the AC, presence of depositional layers, and benthic community characteristics. In some cases, SPI data collection may be limited by penetration depth in firm substrates or substrates with heavy debris, and may be unable to show the interface with the ENR/AC layer and the native sediment. Furthermore, benthic community data will be limited in scope and only provides an indication of benthic community recolonization and successional stage, but does not provide quantitative data on benthic taxa (e.g., abundance, diversity). Both SPI and plan view imagery will be considered as a line of evidence used in conjunction with other data types collected during the field investigations.

3.2.3.1 Image Collection

The in-water camera work will be performed by a specialty vendor under the direction of the FC. The SPI operator will deploy SPI camera from a marine sampling vessel owned and operated by Research Support Services, using a prism-mounted camera system that is lowered into the sediment surface. The camera produces a cross-sectional photograph of the sediment/water interface and near-surface sediment (a 15- by 20-centimeter area). The SPI camera consists of a wedge-shaped prism with a Plexiglas faceplate and a back mirror mounted at a 45-degree angle. Light is provided by an internal strobe. The back mirror reflects the image of the sediment/water interface profile to a digital camera mounted on top of the prism. Plan view images will also be collected for each station using a down-looking underwater camera mounted on the SPI camera frame.

SPI surveys will be conducted in all three plots during the baseline and Year 0 through 3 monitoring events. Because SPI sample collection disturbs the surface sediments, the station locations listed in Table 3.2 actually represent an area of approximately 10 by 10 feet (they differ slight from plot type to plot type due to the geometry of the plots); samples collected within the cell are considered co-located. The actual locations will be tabulated as discussed in the previous section.

At each location the SPI camera will be lowered to the sediment surface. Immediately prior to making contact, a plan-view image of the sediment surface will be collected. Once the SPI frame is resting on the bottom, a hydraulic piston will push the camera prism into the surface sediments. To minimize the disturbance of the sediment-water interface, the rate of descent of the prism will be limited to 6 centimeters/second. After an image is collected, the camera will be raised from the sediment; a wiper blade automatically cleans off sediment adhering to the prism faceplate. The camera is raised several feet above the riverbed and the winch moved laterally. The camera is

then lowered to the sediment surface to collect a replicate plan-view and SPI image. A total of three replicate images for analysis will be collected at each location.

The SPI and plan view images will be labeled with sample IDs (see Section 4.1.1 for naming protocols) along with the date and time.

Forms: A photograph log (Appendix A) will be completed in the field. The log will tie the SPI and plan view images to the time, date, and station where they were recorded.

3.2.3.2 Image Analysis

The images will be processed by SPI operator and Ramboll Environ staff. The primary focus of the analysis of the SPI images is to determine the thickness of the ENR and ENR+AC layers, the distribution of GAC within the ENR+AC layers, and the presence of organisms in surface sediments. For each of the three replicate images at each location, a computer-based image analysis system will be used to measure the following parameters:

- Prism penetration depth and thickness of the ENR and ENR+AC layers
- Distribution of GAC, if observable
- Apparent redox potential discontinuity
- Quantity and relative size of feeding voids at three depths (0 to 2 centimeters, 2 to 5 centimeters, and 5 to 10 centimeters)

The prism penetration depth of the SPI camera is determined by measuring both the largest and the smallest linear distance between the sediment-water interface and the bottom of the SPI image. Camera prism penetration depths provide a qualitative, relative measure of sediment-bearing capacity. The thickness of the ENR and ENR+AC layers will be determined on the basis of the largest and smallest linear distance between the sediment-water interface and the bottom of the ENR material. If possible the bottom of the ENR and ENR+AC layers will be noted by a transition to areas of unconsolidated, water-rich, fine-grained sediments.

When observable, the distribution of GAC will be noted. GAC may appear as dark particles or layers of particles in the ENR+AC layers.

The apparent redox potential discontinuity estimates the depth of oxygenation in the upper sediment column and can be considered the depth of biological mixing by infaunal organisms. The upper surface of aerobic fine-grained sediments has a higher light reflectance value than the underlying hypoxic or anoxic sediments. This is apparent in SPI images and is due to oxidized

surface sediment that contains minerals in an oxidized state (typically an olive color), and the reduced sediments below this oxygenated layer are generally dark gray or black. The boundary between these layers is called the apparent redox potential discontinuity, which provides an estimate of the biogenic sediment mixing depth because bioturbating organisms mix the oxidized sediment particles downward into the sediment column. Bioturbation also vertically transports buried reduced compounds to the sediment surface and exposes them to an oxidized water column (Aller, 1982).

SPI images can assist in understanding how recolonization of the ENR and ENR+AC layers differ over the first three years after placement, and support the more definitive benthic macroinvertebrate survey planned for Year 3. Benthic infaunal communities generally follow a three-stage succession after a disturbance of the seafloor (Pearson and Rosenberg, 1978; Rhoads and Germano, 1986). Stage I infauna typically are the first organisms to colonize the sediment surface. These opportunistic organisms may consist of small, tubicolous, surface-dwelling polychaetes. Stage II organisms typically are shallow-dwelling bivalves or tube-dwelling amphipods. Stage II communities are considered a transitional community before reaching Stage III, the high-order successional stage consisting of long-lived, infaunal deposit-feeding organisms. Stage III invertebrates may feed at depth in a head-down orientation and create distinctive feeding voids that are visible in SPI images. The evaluation of SPI survey results may be used by a trained biologist to qualitatively identify the presence of Stage I, II, and III communities after construction.

Feeding voids observed in SPI images will provide an indication of the presence of head-down, deposit feeding, bioturbating organisms in surface sediments. The quantity and relative size of the feeding voids will be determined at three depth intervals for each SPI image: 0 to 2 centimeters, 2 to 5 centimeters, and 5 to 10 centimeters. The relative size classifications for the feeding voids will be based on the approximate height of the feeding voids: small voids (height less than 0.15 centimeters), medium voids (0.16 to 0.50 centimeters), and large voids (greater than 0.51 centimeters).

The plan view images will be used to assist in understanding the ENR/AC layer conditions, sediment erosion/deposition, and recolonization of the benthic community. Plan view images will be scored for surface smoothness, sediment type, and surface features (e.g., sand waves, soft deposits, detritus and/or wood). Evidence of biological activity will include the presence/absence of epifauna (e.g., demersal fish and invertebrates), burrows, tracks, tubes, and mudclasts.

3.2.4 Sediment Core Collection and Field Processing

The physical and chemical characteristics of the bulk sediment will be measured in sediment composites generated from hand-collected sediment cores.

3.2.4.1 Core Collection and Logging

As indicated in Section 3.1, 18 locations have been defined in each subplot to form a total of three composites made up of material from up to 6 locations each, labeled A, B, and C, which will be analyzed for PCB congeners, TOC, black carbon, and grain size.

Shallow sediment core samples will be collected from the subtidal and intertidal plots by divers (who may be wading during intertidal plot sampling), using a precleaned 2- to 4-inch-diameter, 1 to 2-foot-long cellulose acetate butyrate (CAB) core liner. The core tubes will be marked on the top with brightly colored duct tape or electrical tape. The core liner will also be marked to indicate the depth of insertion. Before deployment, the core liners will be decontaminated with warm soapy water using laboratory-grade detergent (e.g., Alconox), triple-rinsed with deionized water, and then sealed to prevent contamination.

To collect the sediment core, a core liner will be unsealed and then inserted directly into the sediment surface and gently pushed down into the sediment until the mark is flush with the sediment surface. The target depth for core collection will be 12 inches. This sampling depth allows an evaluation of presence of a deposition layer and the depth of the ENR layers. Even though only the upper 10 cm will be composited, the whole depth of the core will be described on the sediment core log.

The core liner will not be tilted back and forth into the sediment, although gentle vertical twisting of the core liner into the sediment is acceptable. If the core liner cannot penetrate the sediment, the diver may move the location slightly until the target penetration can be reached. If the target penetration cannot be reached after two tries, a new location will be selected using the procedures in Section 3.2.2. Once the core liner has been inserted to the target depth, the diver will retrieve the core by pulling the core liner out of the sediment and immediately capping the bottom the liner, preventing the release of sediment from the bottom of the core liner. A hand may be placed on the bottom of the core to prevent sediment from being released until the bottom of the core has been capped. A cap will then be placed on the top of the core liner. If necessary, the top cap of the core liner may be pierced to increase the ease of cap placement. For diver safety, this hole would need to be created in the cap before the diver enters the water. The diver must keep the core upright after collection and while bringing it to the surface of the water.

In order to get enough sample volume, co-located cores will likely need to be collected as follows:

- In the ENR and ENR+AC layers using sand, one 4-in core or two 2-in cores should provide sufficient material for the composite.
- In the ENR and ENR+AC layers using gravelly sand, one 4-in core or three 2-in cores should provide sufficient material for the composite.

Once the core has been brought to the water surface, the on-board crew will inspect the retrieved core length to ensure that the core fully penetrated the ENR layer and that the upper 10-centimeter layer is intact. If the percent recovery of a short core is not acceptable or the core shows significant disturbance during sampling, the core will be recollected in an adjacent location using a new core tube. Once the core has been accepted, a hole will be drilled into the core liner above the top of the sediment to drain any overlying water; and care will be taken not to disturb the surface of the core sample and suspended sediment will be allowed to settle before the overlying water is drained. The core caps at both ends and any drain holes will then be sealed with electrical/duct tape. The core sample will be labeled with the sample ID (see Section 4.1.1 for naming protocols), date and time, and an arrow pointing toward the top of the core. Intact sediment cores will be stored upright in an ice-filled container (e.g., a cooler) or refrigerator (4 degrees Celsius [C]) before processing.

Form: The field technician will complete a surface sediment core sample collection form (QAPP Attachment A) for each core collected. Photographs will be recorded on the photograph log form and cross-referenced to the surface sediment core sample collection form.

3.2.4.2 Porewater Salinity Measurements

Porewater salinity measurements will be made by the diver at the time of the collection of sediment cores from a co-located position. The measurement will be made using a field probe to measure specific conductance that has been calibrated to salinity. The measurement will be made at approximately 10 cm below mudline during the Baseline Event; and 10 to 20 cm below mudline in subsequent events. This depth was selected to assess the salinity of upwelling water.

Measurements will be made using an underwater probe that can be inserted directly into the sediments. If the probe is unable to penetrate the sediments, then a porewater sample will be collected by the diver using a stainless-steel syringe, and the porewater will be measured in the boat using a standard specific conductance or salinity meter.

If salinities are uniform within a plot, then the number of salinity measurements maybe reduced for that plot in future events.

3.2.4.3 Bulk Sediment Processing and Compositing

Core processing, compositing, and subsampling for chemical analysis will be performed in the field, either on board the sampling vessel or in a land-based work area. All cores will be stored in the dark at 4°C (±2°C) before processing. The core samples from each subplot will be organized into groups of six core samples labeled by letter "A," "B," or "C" (one core sample from each grid cell).

Before compositing, each A core sample (a total of six from each subplot) will be split vertically to evaluate stratigraphy and the distribution of carbon in the ENR+AC subplot. To split the core, electrical tin snips will be used to remove a strip of the core liner vertically from the bottom to the top. The core will be carefully rotated 180 degrees, and a strip of the core liner will be removed from the other side. The core will be carefully divided in half with a stainless-steel spatula. The core will be photographed and characterized in terms of its length and visual geotechnical characteristics (presence of depositional layers, depth of ENR+AC layer, grain size, and presence of carbon).

To form the composite, sediment from the top 10 centimeters will be removed from both halves of the core liner with clean stainless-steel utensils and placed in a clean, stainless-steel mixing bowl for homogenization. Care will be taken not to scrape the core liner to avoid getting liner material in the sample. In the same manner, sediment cores from the other subplots will be placed in the stainless-steel bowl for processing. A similar volume from each of the six samples will be composited.

Each composite sample will be homogenized until uniformity throughout the sample has been achieved. The sample jars for grain size analysis and the archive sample will then be filled. Then the weight of the bowl and sediment will be recorded. If gravel is present, the composite (after the removal of the samples for grain size and archiving) will be press-sieved with a 3/8-inch stainless-steel mesh to remove large gravel. (The scour and intertidal plots are expected to have gravel because of the use of gravelly sand; no gravel is expected in the subtidal plot where sand will be used.) The bowl and sieved sediment will be reweighed and the difference will be recorded and assumed to be the weight of the removed gravel.

The sediment will be used to fill the jars at least half full, in the order shown below:

Jar Order	Analysis	Laboratory	Jar Size
1	Grain size	Sediment Laboratory	8 oz. (full)
2	Archive	PCB Laboratory	8 oz.

Jar Order	Analysis	Laboratory	Jar Size
Sample composite is now field sieved to remove gravel			
3	PCB congeners Total solids	PCB Laboratory	8 oz.
4	Total organic carbon Black carbon	Sediment Laboratory	4-oz.

Unused sediment material including the gravel will be disposed appropriately (see Section 3.2.8).

The work surface cover will be changed between the preparations of each composite sample, and all tools and utensils that come in contact with the core sample will be cleaned with detergent and rinsed with laboratory-provided deionized water; to the extent practicable, disposable materials will be used for sampling to minimize potential cross-contamination. The sample container will be maintained on ice or in a refrigerator (4°C) until it is shipped to the analytical laboratories in accordance with the procedures in Section 4.3.1.

Forms: Compositing information will be recorded on the Sediment Composite Log. Chain-of-custody forms will also be completed for transfer of the sample jars to the laboratories under custody (see Section 4.3.1).

3.2.5 Porewater Sampling

Dissolved PCB congeners in sediment porewater will be measured with the use of SPME fibers using a method that has been successfully applied to measure PCB availability before and after an AC amendment at a site in Puget Sound (Conder et al., 2013; Conder et al., 2015). The method is based on the work of Conder et al. (2003), You et al. (2007), Yang et al. (2008), Lu et al. (2011), Oen et al. (2011), and Harwood et al. (2012).

The SPME sampler consists of a steel-mesh envelope containing SPME fibers that is attached to a steel plate to allow its insertion into the sediment. As described in the following subsections, SPME samplers will be deployed in situ within surface sediments and at the sediment-water interface at the plots, providing a surface onto which PCBs present in porewater will sorb. The fibers will be retrieved, extracted, and analyzed for PCBs. PCB concentrations in the SPME fibers will be used to calculate the concentrations of dissolved PCBs present in porewater during the in situ exposure. The remainder of this section details SPME sampler preparation, deployment, retrieval, and fiber extraction (to recover the sorbed PCBs). Section 3.5 will discuss the analysis of PCBs in the extracts; and the estimation of dissolved PCB concentrations in sediment porewater.

3.2.5.1 SPME Porewater Sampler Preparation

SPME fibers are commercially available optical fibers composed of a 10-micrometer-thick polydimethylsiloxane (PDMS) coating around a 210-micrometer-diameter silica core (Fiber-guide Industries, Stirling, New Jersey). The fibers will be cut to 10-centimeter lengths (±0.5 centimeters). For each sample station, eight fibers (80 centimeters total) will be placed in a 2-by-11-centimeter steel-mesh envelope (with 110-micrometer mesh openings) to protect the fibers from loss and breakage (Figure 3.4). The SPME envelopes (containing SPME fibers) will be rinsed in a 50:50 solution of acetonitrile and water, followed by three rinses with ultrapure water to remove trace impurities.

The cleaned SPME envelopes will be placed in a solution containing performance reference compounds (PRCs). Because of the duration of time needed for the SPME fibers to reach full equilibrium for all congeners, PRCs are used to allow non-equilibrium conditions to be quantified between the porewater and the SPME medium. With the use of PRCs, the SPME envelope can be deployed for shorter time periods, which has been found to decrease the risk of lost or destroyed fibers and biological fouling. Details of the PRCs and how they are used for quantitation are provided in more detail in QAPP Attachment B. The PRCs include one to two PCB congeners from each of the tri-, tetra-, penta-, hexa-, hepta-, and octa-chlorinated biphenyl homolog series. As discussed in the attachment, the selected PRCs will be PCBs that are not routinely detected in the LDW. After a period of time sufficient to allow the PRCs to sorb to the PDMS coating on the SPME fibers (24 hours), the SPME envelopes will be blotted dry, wrapped separately in rinsed aluminum foil, and stored at 4°C until deployment. The envelopes will be deployed within 2 weeks of preparation.

Forms: The analyst will complete a SPME preparation form (QAPP Attachment A) for each batch of SPME fibers. The form will document the source of the base fibers, their purchase date, reference vendor-supplied information, reference to the analysis of the cleaned fiber, a list of the PRCs used and their concentrations in the soaking solutions, and a reference to the analysis of the PRC-loaded fiber.

3.2.5.2 SPME Porewater Sampler Deployment and Retrieval

Immediately, but no more than 15 minutes before deployment, the SPME envelopes will be removed from cold storage, unwrapped from their aluminum foil layers, and attached to a corrosion-resistant steel plate (Figure 3.4). Three samplers will be labeled with the same grid cell number, and a reflective, fluorescent marker or small buoy will be attached to the sampler's steel plate. The three samplers will be placed in a labeled gallon-sized sealable plastic bag and handed to a diver. Within each grid cell in a subplot, the diver will go to the locations listed in Table 3.2 and

insert the steel plates vertically into the sediment so that the tops of the SPME envelopes are just below the sediment-water interface and the bottoms of the SPME envelopes are approximately 10 centimeters (±1 centimeter) below the sediment-water interface.

For the Years 2 and 3 monitoring events, an additional SPME envelope will be attached to the steel plate (via an additional smaller steel plate or support as necessary) to enable measurement of PCBs in porewater at the sediment-water interface. This additional SPME envelope will be attached to the upper portion of the steel plate in a horizontal/landscape orientation (i.e., oriented perpendicularly to the primary SPME envelope that will be exposed to the 0 to 10 cm layer). The resulting design will be a steel plate with two SPME envelopes attached. This "Year 2 and 3" sampler configuration will be inserted into the sediment such that one SPME envelope will be exposed vertically to the top 10 cm of sediment (as in the previous Baseline and Year 1 events), while the second SPME envelope will be exposed horizontally to the sediment-water interface, approximately 1 cm below the sediment surface.

This deployment of SPME samplers at three pre-selected locations will be repeated in each of the six grid cells in a subplot. In every monitoring event, extra samplers may be deployed in some grid cells as a contingency for the potential loss of samplers. Additionally, during the baseline sampling event, five (not three) SPME samplers will be deployed in each of the six grid cells in a subplot.

Figure 3.4. SPME Porewater Sampler

The SPME samplers will remain embedded in situ for a 4-week/28-day period, during which PCBs from the surrounding sediment porewater will sorb to the PDMS coating of the fiber, while the PRCs contained within the PDMS will desorb from the fiber coating. A 4-week exposure period is an optimal balance of providing the adequate time period required for the PCBs in porewater to come to a sufficient proportion of equilibrium (approximately 20 percent or greater) and minimizing the risk of sampler loss, fouling, or vandalism, which is likely with longer deployment periods. After the 4-week exposure period, divers will return to each sampler location, remove the sampler plate from the sediment, place the sampler plate in an individual sealable plastic bag, and return it to the surface. If the SPME has been disturbed during its deployment and this is visible to the diver, this will be noted on the field record. At the surface, the samplers will be immediately removed from the plastic bags. The SPME envelope(s) will be removed from the steel plate, wrapped individually in a layer of aluminum foil, placed in individual labeled sealable plastic bags, and stored at 4°C

until processing and extraction. The SPME envelopes will be labeled with the sample ID (see Section 4.1.1 for naming protocols) and the date and time of collection. The SPME envelopes will be placed inside a protective box in the cooler (e.g., Tupperware or similar container) to protect the SPME envelopes from breakage when contacting bags of ice or reusable ice packs.

For the Baseline, Year 1, Year 2, and Year 3 events, eighteen (18) SPME envelopes exposed to the 0-10 cm layer will be obtained from each subplot during each monitoring event; these 18 SPME envelopes will be composited to yield three six-point composite samples per subplot. In the baseline monitoring event, an additional twelve (12) baseline contingency SPME envelopes will also be obtained from each subplot to yield a total of five six-point composite samples per subplot. The same locations that were composited to form the A, B, and C surface sediment composites (per subplot) will be used to form the SPME composites. The additional 12 SPME samples will be composited into 2 composites of 6 samples and will be stored until the first three composites have been analyzed, a power analysis completed, and EPA and Ecology have concurred on whether the additional composites are required. Any samplers that were deployed to account for possible sample losses that are not necessary for the 3 to 5 composite samples will be retrieved but not retained.

For Year 2 an additional eighteen (18) SPME envelopes exposed to the sediment-water interface will be obtained from each subplot; these 18 SPME envelopes will be composited to yield three six-point composite samples per subplot. However, if the power analysis conducted on the SPME envelopes exposed to the 0-10 cm layer in the baseline event indicates that more samples are needed, the same number of SPME envelopes will be used at the sediment-water interface as for the 0-10 cm layer. The same locations that were composited to form the A, B, and C surface sediment composites and the 0-10 cm SPMEs (per subplot) will be used to form the sediment-water interface SPME composites. The same compositing approach will be repeated for Year 3 if no modifications are made following review of Year 2 results.

Trip blanks will be collected and analyzed with SPME samples to ensure that the samples do not become contaminated prior to or after deployment. The use of trip blanks as a field quality control procedure is described in Section 3.5.1 – Field Quality Control Procedures.

Forms: SPME deployment and recovery forms (Appendix A) will be used to record the batch ID, discrete and composite sample IDs, SPME type (i.e., 0-10 cm deployment or sediment-water interface deployment, coordinates, dates and times of deployment and retrieval, water depths, depth of ENR or ENR/AC and diver observations for each sample.

3.2.5.3 SPME Fiber Compositing, Processing, and Extraction

The SPME fibers will be processed as soon as possible after the termination of deployment but no later than 2 weeks after their retrieval. Under clean conditions in a laboratory, the SPME envelopes exposed to the 0-10 cm layer from each subplot will be separated into three groups of six samples (six samples from the "A" location for the A-composite, six samples from the "B" location for the B-composite, etc.). Fibers from the six SPME envelopes used for each composite sample will be removed from the plastic bags, the steel-mesh envelopes will be unfolded, and the SPME fibers will be removed from the envelopes. The fibers will be gently wiped with moistened lint-free tissue (e.g., Kimwipes®) to remove any fine particulate matter, cut into small (e.g., 1-centimeter pieces), and placed in a labeled, pre-weighed 2-milliliter (mL) amber glass vial. Clean, power- and dust-free nitrile gloves will be used during the handling of the SPME fibers.

Each vial will contain fiber from all six SPME envelopes for each respective composite and will represent a composite sample of approximately 480 centimeters (80 centimeters per envelope multiplied by six envelopes) of SPME fiber—the loss of some fibers during deployment may result in less than 480 centimeters in some vials, which will be noted in the laboratory logbook. The vial will be reweighed to determine the total weight of the fiber in the vial, and this fiber mass measurement will be used to infer the total length of the SPME fiber present in the composite sample. Hexane (1.8 mL) will be added to the vial, and the vial will be stored and shipped to the analytical laboratory and stored at 4°C ± 2°C until further extract processing and analysis occurs at the analytical laboratory. Baseline contingency SPME extracts will not receive additional processing and analysis steps until the decision is made to proceed with the full PCB analysis of these samples. This decision will be made after a review of the data provided by analysis of the primary baseline SPME samples.

The SPME envelopes exposed to the sediment-water interface from each subplot will be separated into three groups of six samples (six samples from the "A" location for the A-composite, six samples from the "B" location for the B-composite, etc.) and processed separately in an manner analogous to the SPMEs exposed to the 0-10 cm layer in all monitoring events.

Forms: The compositing step will be documented on the SPME extraction and compositing form (QAPP Attachment A).

3.2.6 Benthic Macroinvertebrate Survey Surface Sediment Collection and Field Processing

At the end of the 3-year pilot study, a benthic macroinvertebrate survey will be used to compare the benthic communities that are established in each of the ENR+AC subplots to the benthic communities in the corresponding ENR subplots. Five replicate surface-sediment samples will be

collected from each subplot for benthic analysis using a 0.1-square-meter van Veen grab sampler. At each plot, the observations during the benthic macroinvertebrate survey will be compared between the two subplots.

Sediment for benthic macroinvertebrate analysis will be collected using a van Veen grab sampler deployed with a hydraulic winch. Before sampling begins, the grab sampler will be cleaned with a non-phosphate laboratory soap (e.g., Alconox) and rinsed with site water. The sampler will be attached to the winch cable by a ball-bearing swivel and shackles. If necessary, weights may be attached to the sampler to achieve proper sampling depth. The grab sampler will then be cocked and lowered through the water column at a rate that is slow enough (approximate 1 meter per second) to prevent bow wake disturbance of surface sediments. Once the grab sampler has reached the bottom, the time and location of the sample will be recorded. The grab sampler will be closed slowly and lifted to the surface. Once at the surface, the grab sampler will be lowered into its stand, secured, and visually inspected for acceptability. An acceptable grab sample is one with relatively level, intact sediment over the entire area of the grab and, generally, a sediment depth at the center of the sampler in excess of the depth required to sample more than 90 percent of the species and individuals in the upper 10 centimeters of sediment. Grabs containing no sediment, partially filled grab samplers, grabs with grossly slumped surfaces, or grabs that leak are unacceptable. Grabs that completely fill the sampler to the top, where the sediment is pushed through the door screens, may also be unacceptable.

Once a grab sample has been accepted, a description of the collected material will be recorded in field sampling forms, including such information as penetration depth, color, texture, odor, biological structures, and any other notable features.

The sediment from each grab will be processed in the field. The samples will be sieved on board through a 1.0-millimeter screen. The water used to sieve the organisms from the sediments will be obtained from the LDW and filtered to remove organisms that might have been picked up from the water column. Organisms and debris that are collected on the screen will be placed in a magnesium sulfate solution to relax the organisms, and then this material will be preserved using seawater-buffered formalin solutions of at least 8 to 10 percent. The samples will be labeled internally and externally and placed in a container appropriate for the volume of the sample. Samples with a volume less than100 mL will be placed in plastic Whirl-Pak® bags. Larger samples will be placed in larger containers made of either glass or plastic. Each sample or each group of samples from a single grab will be stored together in a separate container. Field notes and chain-of-custody (COC) records will be maintained to indicate the number and size of sample containers obtained from each grab sample. Samples will be sent by courier to Ramboll Environ's benthic laboratory (Port Gamble, Washington) for further analysis and archiving. The sample

containers can be stored at ambient temperature. The grab sampler, sieve, and utensils should be rinsed with site water between sampling locations.

Forms: Information related to the collection of the grab samples for benthic macroinvertebrate analysis will be recorded on the Sediment Grab Log. Chain-of-custody forms will be completed for transfer of the sample jars to the Ramboll Environ laboratory. Benthic taxa identified during the sorting and identification will be recorded on "infaunal sample identification and sorting" sheets.

3.2.7 Decontamination Procedures

Working surfaces, utensils, tools, equipment, mixing bowls, and other items that come in contact with the sample must have been cleaned before use, between composite samples, and between sampling events involving samples collected for chemical data. The decontamination procedure is as follows:

1. Prewash rinse with tap or site water.
2. Wash with solution of warm tap water or site water and detergent (e.g., Alconox).
3. Rinse with tap or site water.
4. Rinse thoroughly with laboratory-provided deionized water.
5. Store in a clean, closed container.

All dilute detergents, residual solvent (from the benthic sampling), and deionized rinsate will be captured separately at each location and handled according to the procedures described in Section 3.2.8.

3.2.8 Field-Generated Waste Disposal

EPA mandates the management of field-generated waster (FGW) to ensure the protection of the environment and of human health. FGW from this project may include the following:

- Used personal protective equipment (PPE): sampling gloves, Tyvek® suits, and shoe covers
- Packaging and storage materials, plastic bags, foil, and deionized water containers
- Liquids or solids from field decontamination procedures

The field team will manage the individual waste streams in a similar manner, with the goal of minimizing the volume of FGW. The following procedures will be used for waste.

Used PPE, disposable sampling equipment, and packaging materials will be managed together and minimized whenever possible. These wastes are not considered hazardous and can be sent to a municipal landfill. These wastes will be stored in heavy-duty, rip-stop trash bags until the bags are filled to 80 percent capacity. The bags will be compacted by manual pressure; standing air will be removed to the extent practical and the bags will be taped shut. If a bag contains sharp objects or there is a potential for the bag to rip, the bag will be isolated with an outer over-pack bag.

Decontamination fluids will include residual solvents, deionized water, a dilute solution (2 to 5 percent) of Alconox non-phosphate detergent, water from the LDW, and sediment (both solids and porewater). They will be handled as follows:

- Fluids contain residual solvents (from benthic sampling) will be captured at each plot, returned to the shore for storage, testing, and disposal (based on the test results).
- Deionized water, dilute Alconox, water from the LDW and residual sediment and porewater mixed with them will be returned to the waterway at the downgradient edge of the plot.

Excess sediment that is collected in cores and van Veen samplers that is not used for analysis will also be returned to the waterway at the downgradient edge of each plot.

3.3 CONTINGENT SAMPLING DESIGN MODIFICATION

As the pilot study progresses two potential conditions have been identified that could require modification to the monitoring design. Other conditions could occur in the future that would also require an evaluation of the study DQOs and design.

3.3.1 Significant Deposition of New Sediment

If a significant buildup of fresh sediment occurs at a plot as a distinct layer rather than mixing in with the ENR and ENR+AC layer, this material could impact the study results. Minor buildup is considered a normal condition and not a concern, although it will be noted on SPI interpretations and the surface sediment core logs if encountered. Isolated deposition, such as in-filling of the spud holes created during construction, will be avoided whenever possible. For example, the spud holes will be designated with DGPS coordinates and would result in the moving of locations in Table 3.2 to avoid the locations with spud effects.

If a significant buildup of fresh sediment occurs across a plot, a composite of the material (one per subplot) will be collected and tested for PCB congeners, TOC, black carbon, and grain size. The physical observations of the depositional layer and the chemistry results will be shared with the EPA and Ecology and the DQOs reviewed. If appropriate, modifications may be suggested, approved, and implemented in subsequent monitoring events based on this discussion.

3.3.2 Significant Scour of ENR Layer

If significant loss of ENR layers has occurred such that the results would no longer be relevant for achieving the DQOs, further testing of that plot may not be useful and a request may be made to terminate testing in that plot or to modify the sampling plan to avoid the eroded area. Termination in one plot would not affect the decision to continue or terminate in another plot. Termination of the study in a plot would require concurrence from EPA and Ecology.

3.4 ANALYTICAL METHODS

The analyses to be performed are summarized in Table 3.3. As discussed above there are four sample matrices that are being analyzed: a sand and gravelly sand matrix that represent ENR substrate, an activated carbon matrix that represents the GAC being added the ENR substrate for the ENR+AC subplots, the sediment matrix, and the SPME extracts. Table 3.3 lists the methods, the sample preservation, the holding times, the minimum sample size, and the sample container preferred for shipment and storage.

Tables 3.4 through 3.6 summarize the quality assurance goals (QAGs) for the solid samples (ENR substrate, GAC, surface sediment) collected for chemical analysis are described in this section.

3.4.1 ENR and GAC Material Analysis

The sand and gravelly sand samples are to be analyzed for all chemicals listed in Lower Duwamish Waterway Record of Decision (U.S. EPA, 2014) Tables 19 and 20, percent solids, TOC, black carbon, and grain size. Detection limits will be low enough for the materials to be compared the lowest cleanup levels shown in the Lower Duwamish Waterway Record of Decision (U.S. EPA, 2014) Tables 19 and 20. The methods are listed in Table 3.3. Tables 3.4 and 3.6 contain the quality assurance criteria that the sediment laboratory is to meet for each of the conventional, and SMS chemical analytical methods.

The GAC material will be analyzed for PCB congeners only; analysis will use EPA Method 1668C. Because the GAC is expected to contain particles that are larger than 1 mm, the sample will require grinding and compositing as part of EPA Method 1668. This will be performed at the laboratory using clean equipment intended for the processing of PCB congener samples. Table 3.5 contains the QAC that are applicable to sediment samples for the PCB congeners. Because of the strong sorption capacity of the GAC, it is possible that the quality assurance recoveries targeted for sediment samples may not be met with the GAC. Therefore, laboratory has been directed to take reasonable measures to meet the QACs for the GAC sample, and will specify any necessary modifications in the narrative section of the laboratory report for the analysis.

Table 3.7 and Section 3.5 identify the laboratory QA samples that will be used for the analyses.

3.4.2 Bulk Sediment Preparation and Analyses

The bulk sediment samples will have been composited in the field before shipment to the analytical laboratories as discussed in Section 3.2.4. Sediment composite samples for grain size and archiving will represent material "as-is" from the subplot; the sediment composite samples for PCB congeners, TOC, and black carbon will have been press sieved in the field to remove gravel greater than 3/8-inch; however, smaller gravel and coarse sand will remain in the samples from the scour and intertidal plots. The small sample volumes used for the analysis give rise of the following concerns and their proposed solutions:

- Will the ENR+AC layer in Year 0 (and maybe Year 1) contain GAC that has not had the opportunity to disperse and is still somewhat clumpy? If so, there is a potential to introduce a significant error in the laboratory when removing a small aliquot (10-20 grams) from the sample for analysis of black carbon and TOC. If this situation is observed in the field during sample compositing (or later during the laboratory sample preparation), then the laboratory will be instructed to take a larger sample (~100 grams), crush it, homogenize the result, and then sample the smaller aliquot for the analysis. This can be performed on a damp or dry sample, depending on the requirements of the underlying analytical method. If this is still a problem in Year 1, then the sample aliquot for PCB congeners (not performed in Year 0), will undergo the same process. The PCB congener method includes instructions for crushing and handling the sample.

- Will the ENR and ENR+AC layers that are using gravelly sand contain a significant amount of material in the fraction between coarse sand and 3/8-inch gravel (the sieve size used in the field for press-sieving prior to compositing)? If so, the laboratories will be instructed to handle the sample as described in item 1 above. This will apply to PCB congeners, TOC, and black carbon. This crushing and sample handling will comply with the requirements in Method 1668C.

3.4.2.1 Total Organic Carbon, Grain Size, and Other Physical Analyses

The sediment samples will be analyzed for TOC by SW-846 9060, for black carbon by Gustafsson et al. (1997), and for grain size by ASTM D422. Black carbon refers to the analytical method used to measure the more sorptive forms of carbon in the sediments. The black carbon measurement will include both the GAC added to the ENR material and any naturally occurring active carbon present (such as soot in the existing sediments).

In order to understand whether there has been a preferential loss of fine-sized carbon, TOC will be measured in both the bulk sediment and in the material passing a #50 sieve (300 microns). The measurements passing the #50 sieve will be made in the Year 0 Event (just after placement) and

in the Year 3 Event. If there is too little material passing the #50 sieve for the analysis, then a #40 sieve may be used instead.

Table 3.7 in Section 3.5 identifies the laboratory QA samples that will be used for the analyses. Because the precision and reproducibility of the black carbon method is not as well understood as the other methods, one of the composite samples in each of the ENR+AC subplots will be analyzed in triplicate (two laboratory duplicates) in the Year 0 event.

3.4.2.2 PCB Congener Analysis

The sediment composite samples will be analyzed for PCB congeners by EPA Method 1668C. Method 1668 defines quality assurance goals for a subset of congeners rather than for all 209 congeners. All 209 congeners will be reported in this project. Meeting the requirements for the subset of congeners is deemed by the method as sufficient to demonstrate acceptable performance for all 209 congeners. Per the method, internal standards and recovery standards will be used by the analytical laboratory for calibration to account for analyte loss during analysis. Laboratory QA/QC requirements are presented in Table 3.7 and provided in Section 3.5. EPA Method 1668C contains extensive requirements for laboratory QC. These will be performed as required by the method and reported as part of the laboratory report (and in the EDD).

3.4.2.3 Archived Sediment Composites

In addition to the analyses specified, additional sediment from each sediment composite will be archived (at the temperatures indicated in Table 3.4) for 6 months after the final data package is received from the laboratory for that event.

3.4.3 SPME Porewater Sampler Extract Processing and PCB Congener Analysis

At the PCB congener laboratory, the 1.8-mL hexane extracts will be spiked with radio-isotope labeled-PCB analytical recovery standards and internal standards, and the extracts will be concentrated to a volume of approximately 100 microliters under a stream of nitrogen. This concentrated extract will be analyzed for PCB congeners, including the radio-isotope labeled congeners, using EPA Method 1668C. Because Method 1668 involves a significant amount of sample handling, reported concentrations are quantified using a combination of isotope dilution and internal standard correction. Details are contained in the method. Additional information on laboratory performance, QC, and reporting is provided in Section 3.5.

3.4.4 Benthic Infauna Analysis

Benthic sorting and identification will be conducted at the Ramboll Environ benthic laboratory.

Within 2 weeks of preservation, the samples will be transferred to 70 percent ethanol for storage. Each sample will be poured into an appropriately sized sieve (500 microns or less) over a bowl or pan to collect the formalin. The formalin will then be disposed in a hazardous waste drum. The sample will then be washed gently with tap or distilled water, as will the sample container. Care should be taken not to splash the sample. Once the rinse water has drained from the sieve, the sample will be rinsed gently with 70 percent ethanol from a squirt bottle and returned to the sample container. The sieve will be checked to ensure that the entire sample has been returned to the jar. The sample container will then be filled to ~90 percent of its capacity with 70 percent ethanol, sealed, and gently shaken and inverted to ensure proper mixing.

Before removal and sorting of the organisms, the alcohol will be rinsed from the samples, and the retained organisms will be placed in water. The removal and sorting will be performed under a dissecting microscope using ~10 to 20X amplification and small quantities of sample (~5 mL). The organisms removed from the sample will be sorted into major taxonomic categories (e.g., mollusks, arthropods, annelids, echinoderms, and miscellaneous phyla). The organisms will be preserved in 70 percent ethyl alcohol with 5 percent glycerin added for longer term storage. The sorting efficiency is expected to be at least 95 percent. Samples with sorting rates falling below that rate will be resorted, and a second outside QA review will be performed.

The percent sorting efficiency will be calculated as follows:

$$\% \text{ sorting efficiency} = [1 - (\#\text{ in QA resort}/(\#\text{ sorted originally} + \#\text{ in QC resort})] \times 100$$

Organisms will be identified to the lowest practicable taxonomic level, generally species level, by qualified taxonomists with specialized expertise in each of the major taxonomic categories. Most of these identifications will be made by Ramboll Environ with additional help from taxonomists with key specialties for specific groups of species. Two forms of QA will occur. A reference collection of representative individuals for each of the identified species will be submitted for verification by Biological Environmental Services of Victoria, British Columbia, Canada, and other outside taxonomists from British Columbia, Alaska, Washington, Oregon, and California. Secondly, to maintain internal consistency with historical sets and ensure the current taxonomic conventions, the LDW data set will be evaluated to ensure consistent naming conventions for each species among the various taxonomic groups. All of the identified individuals, their abundance, and biomass will be entered into a Microsoft Excel® workbook.

All identified organisms from a discrete sample will be held in labeled glass vials containing 70 percent ethyl alcohol and 5 percent glycerin for storage (for 1 year after EPA and Ecology approval of the Year 3 data report).

3.4.5 Quality Assurance Criteria

The parameters used to assess data quality are precision, accuracy, representativeness, comparability, completeness, and sensitivity. The specific QAGs for laboratory chemical analyses of sediment samples are shown in Tables 3.4 through 3.6. These parameters are discussed in more detail in the following subsections.

The analysis of a regional reference material for PCB congeners is not included as part of this pilot study. Frontier does run reference materials from Puget Sound on a routine basis, and this information is available on request, and their record of successful analyses was considered in selecting them to perform the PCB congener analyses for the Pilot Study.

3.4.5.1 Precision

Precision is the measure of the reproducibility among individual measurements of the same property, usually under similar conditions, such as multiple measurements of the same sample. Precision is assessed by performing multiple analyses on a sample and is expressed as a relative percent difference (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, MSDs, and laboratory control sample [LCS] duplicates) for all parameters. When duplicate samples are not available or spiking of the matrix is inappropriate, precision is assessed by the analysis of laboratory triplicate analyses (e.g., TOC). Precision measurements can be affected by the nearness of a chemical concentration to the method detection limit (MDL), where the percent error (expressed as either % RSD or RPD) increases. The QAG for precision varies depending on the analyte (Table 3.4 through 3.6). The equations used to express precision are as follows:

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

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

where:

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

SD = standard deviation
D = sample concentration

Dave = average sample concentration
n = number of samples

3.4.5.2 Accuracy

Accuracy is an expression of the degree to which a measured or computed value represents the true value. Accuracy is expressed as a percent recovery for MS, surrogate spike, and LCS analyses. The QAG for accuracy varies, depending on the analyte (Table 3.4 through 3.6). The equation used to express accuracy for spiked samples is as follows:

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

3.4.5.3 Representativeness

Representativeness expresses the degree to which data accurately and precisely represent an environmental condition. The sampling approach was designed to address the specific data needs described in Section 1.2. Assuming that those needs are met, the collected samples should be considered adequately representative of the environmental conditions they are intended to characterize.

3.4.5.4 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 Puget Sound Estuary Program (PSEP) QA/QC procedures (PSWQAT, 1997) and EPA and PSEP analytical protocols.

3.4.5.5 Completeness

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

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

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

3.4.5.6 Sensitivity

Analytical sensitivity is a measure of both the ability of the analytical method to detect the analyte and the concentration that can be reliably quantified. The minimum concentration of the analyte that can be detected is the MDL, or limit of detection (LOD). The minimum concentration that can be reliably quantified is the reporting limit (RL), or limit of quantification (LOQ).

Frontier will report detected concentrations greater than the RL/LOQ without qualification and will report detected concentrations between the MDL/LOD and the RL/LOQ with a "J" qualifier, indicating that the concentration is estimated. The RLs/LOQs and MDLs/LODs are presented in Tables 3.4 through 3.6.

3.4.6 Laboratory Records, Reports, and Electronic Deliverables

This section describes the various laboratory record requirements for the sediment chemistry data. The laboratories selected for the various analytical methods are accredited for those methods that are accredited by Ecology. Specifically, Frontier is accredited for PCB congeners in water and sediments, and Alpha is accredited for sediment analyses using the methods referenced in Ecology's Sediment Cleanup User's Manual. There are no accreditation programs for the black carbon method and the preparation and extraction method for SPME fibers; however, these methods will follow available SOPs for peer-reviewed methods being used at laboratories that are accredited for other methods.

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 the analysis. The summary will include, but not be limited to, a discussion of QC, sample shipment, sample storage, and analytical difficulties. 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
  - Total solids in the samples
  - Identification of the instruments used for analysis
  - Identification of cleanup procedures used on sample extracts
  - MDLs/LODs and LOQs/RLs
  - All data qualifiers and their definitions

- **QA/QC summaries** – These summaries will contain the results of all QA/QC procedures. Each QA/QC sample analysis will be documented with the same information required for the sample results (see above). The laboratory will make no recovery corrections other than those required in EPA Method 1668. The laboratory will make no corrections for blank contamination or SPME equilibrium. The contents of the required QA summaries are included in QAPP Attachment C, Laboratory Deliverables.

The contract laboratories for this project will submit data electronically, in Microsoft Excel® or delimited-text format. The guidelines for EDDs for chemical data are also included in QAPP Attachment C, Laboratory Deliverables.

3.5 QUALITY ASSURANCE/QUALITY CONTROL PROCEDURES

This section presents an overview of the QA/QC information that will be used to track procedures in the field and lab. Table 3.7 summarizes the QA/AC samples by methods, but is not intended to capture to full level of detail that is contained within the methods.

3.5.1 ENR and GAC Materials Testing

Prior to the placement of ENR material, samples of the materials to be used during construction, sand and gravelly sand samples, as well as GAC samples will undergo analytical testing to ensure that the initial physical and chemical composition and quality of the samples are known prior to placement. The analyses to be performed on the ENR materials are discussed in Section 3.4.1, and the QA/QC requirements are shown in Table 3.7.

The ENR material samples are “clean” quarry rock and the SDG will consist of only a few samples, which means that it is likely that they will be batched with other samples for analysis. The MS/MSD, where required, may be performed on a sample other than the ENR material sample. For the GAC sample analyzed for PCB congeners, the method performs recovery correction using standards that are added to each sample, allowing for correction of matrix effects.

3.5.2 Field QC for Collection of Sediment and SPME Samples

3.5.2.1 Bulk Sediment

The three composites per subplot are equivalently representative of the subplot and, therefore, act as field replicates and provide data regarding site heterogeneity and variability from sample handling. Additional sample volume will not be collected for matrix spike/matrix spike duplicates because EPA Method 1668 uses isotope dilution to measure the congener recovery from the matrix and as the sample moves through sampling handling steps. This is discussed more in Section 5.4.3.

3.5.2.2 SPME Porewater Sampling

As with the sediment composites, the three composite samples per subplot act as field replicates; therefore, no additional field duplicate will be necessary. Matrix spike and matrix spike duplicates are also not needed because of a combination of the PRCs used to access recovery from the fiber and the use labeled congeners in EPA Method 1668 to monitor congener recoveries. As described below, two types of QC samples will be collected for SPMEs: material and trip blanks.

Material QC: For each deployment, a sample of the SPME fiber after initial cleaning (before exposure to the PRCs) will be analyzed for PCB congener, and the results will be attached to the SPME preparation form. Cleaned fiber is not expected to contain PCBs. This sample will serve as a SPME fiber blank and be used to identify any artifacts of fiber handling, storage, or shipping, prior to preparation for deployment (where the trip blank is used).

SPME Trip Blanks: Trip blanks are needed for the SPME fibers because their high sorption capacity makes field contamination prior to and after deployment a concern. For each deployment and at each plot, a trip blank composite will be created from six trip blanks. The trip blanks are created at the same time and using the same methods as the SPME samplers. These trip blanks will be transported to the plot during deployment of the SPME samplers, unwrapped from their foil, and exposed to air for approximately 5 minutes. After exposure, the envelope will be wrapped in rinsed aluminum foil and stored at 4°C ± 2°C. Within 2 weeks, the trip blank fibers will be processed and extracted.

3.5.3 Sample Delivery Group

Traditionally, a sample delivery group (SDG) is defined as no more than 20 samples or a group of samples received at the laboratory within a 2-week period. For this project, the following SDGs are defined:

Event	Basis for SDG	Expected Sample Count
Baseline	1 SDG for construction materials (ENR substrate)	3 to 5
	1 SDG for GAC	1
	1 SDG for composite sediment samples	18
	1 SDG for composite SPME extracts from subtidal and scour plots	12 + TBs
	1 SDG for composite SPME extracts from intertidal plot	6 + TBs
Years 0 through 3	1 SDG for composite sediment samples	18
	1 SDG for composite SPME extracts from subtidal and scour plots	12 + TBs
	1 SDG for composite SPME extracts from intertidal plot	6 + TBs

Note: If conditions in the field cause a time lag of more than a week between sampling at the different plots, then smaller, more frequent SDGs will be used for the composite sediment samples. All composites from a plot will be in the same SDG.

3.5.4 Laboratory QA/QC Criteria

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

The following subsections summarize the procedures that will be used to assess data quality throughout the sample analysis. The QC procedures and sample analyses to be performed by the laboratory are summarized in Table 3.7. The associated control limits for precision and accuracy are summarized in Table 3.4 through 3.6.

In addition to the QC samples discussed in Table 3.7, the PCB Congener Laboratory has analyzed the Puget Sound CRM for other projects and their results for the CRM are available.

EPA Method 1668C contains extensive requirements for laboratory QC. These will be performed as required by the method and reported as part of the laboratory report (and in the EDD). Additionally, PRCs added to the SPME fibers, while not a laboratory QC component, will be analyzed and reported by the laboratory using the protocols in EPA Method 1668C because they are a critical part of the QC of the SPME absorption and extraction steps.

3.5.4.1 Definitions

Matrix Replicates (including Lab Duplicates)

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.

Matrix Spikes and Matrix Spike Duplicates

The analysis of MS samples provides information on the extraction efficiency of the method on the sample matrix. By performing duplicate MS analyses, information on the precision of the method is also provided for organic analyses. These are not necessary when using isotope dilution.

Method Blanks

Method blanks are analyzed to assess possible laboratory contamination at all stages of sample preparation and analysis.

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, except for PCB congener analysis. PCB congener analyses will be performed using isotope dilution methods, which does recovery correct the concentrations of the congeners.

Laboratory Control Samples

LCSs are analyzed as a measure of the accuracy of the analyses. LCS recoveries will be reported by the laboratories; however, no sample results will be corrected for recovery using these values.

3.5.5 Estimated MDLs/LOQs for PCB Congeners in Porewater Using SPME

A list of the PCB congeners that will be quantified by means of this method is provided in Table 3.5. In Table 3.8, expected MDLs/LODs are calculated for porewater using the SPME fibers for sample collection.

Lowest Achievable MDL in Porewater at Complete Equilibrium Exposure

The lowest possible MDL in porewater for the SPME experimental design proposed in this study can be calculated based on the following information: (1) the lowest mass of PCBs that the analytical instrument can detect (0.50 ng), the volume of the PDMS layer on the SPME fiber (34 µL for 480 cm of fiber in a composite), and the partitioning coefficient between seawater and the PDMS layer (from Smedes et al., 2009). This results in porewater concentrations between 0.4 and 58 pg/L, depending on congener.

Effective MDL in 4-week Exposure Study

The study proposed has only a 4-week exposure, which is not long enough for full equilibrium to be reached for all congeners; therefore, the effective MDLs in the shorter study will be lower. In the pilot study, measured responses of the PRCs will be used to track how close to equilibrium the study was able to reach and will be used to calculate actual MDLs. Since this information is not yet available, the percent to equilibrium from the recent work at Bremerton, Washington was used; their study design is very similar with respect to SPME exposures and PCBs congeners. When these rates are applied in Table 3.8, the effective MDLs for PCB congeners in porewater decreases to 2.7 to 66 pg/L, depending on the congener. Concentrations of octa-chlorinated biphenyls may be designated as "estimated" because these compounds may not reach at least 20% of steady state concentrations during the 4-week exposure time.

Comparison to Expected Baseline Conditions

To access whether the effective MDLs are sufficient for this study, the MDLs were compared first to likely existing porewater concentrations in the LDW near the test plots. The data used to estimate these concentrations are presented in QAPP Attachment B, which contains details on the SPME method development and its assumptions. Since there are no PCB congener results for porewater samples, they were estimated from sediment PCB congener results and default equilibrium partitioning coefficients for organic carbon. The resultant estimated porewater concentrations under current (baseline) conditions are shown in Table 3.8. In general, the MDLs are 5 to 100 times lower than the predicted baseline concentrations in porewater, indicating that the SPME fibers should be able to quantify PCB congeners in porewater under baseline conditions.

Comparison to Expected Study Conditions

Once the ENR layers (with and without AC) have been applied, the concentrations of PCBs in surface sediment will decrease to very low levels because the ENR substrate is not expected to have PCBs in its matrix. Over time, the ENR layers will interact with underlying sediment, porewater, newly deposited sediment, and the water column such that concentrations of PCBs in the layer will reach measureable concentrations. Rather than make a series of rough assumptions

about when this would occur, a different question was asked: if the application of ENR (with or without AC) were to reduce estimated baseline porewater concentrations by a factor of 80 to 90% would the SPME method proposed in this study be able to detect the concentrations? The final columns in Table 3.8 indicate the effective MDLs will allow detections of PCBs and will support being able to measure an 85 to 95% reduction in porewater concentrations from the predicted baseline concentrations.

If baseline or Year 1 measurements indicate that a 4 week duration and amount of SPME fiber is not sufficient to approximate the MDLs on which Table 3.8 is based, a modification of the SPME method may be considered for subsequent monitoring events. If this occurs, this will be discussed with the Agencies at the time when the data are delivered to the Agencies.

3.6 FIELD INSTRUMENT/EQUIPMENT TESTING, INSPECTION, AND MAINTENANCE

Field equipment will be inspected before each field event to ensure proper maintenance and operation. This includes, but is not limited to, grab sampling devices, core sampling devices, electrical tin snips, GPS units, and digital cameras.

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 Section 3.7.

3.7 LABORATORY INSTRUMENT/EQUIPMENT CALIBRATION AND FREQUENCY

Laboratory instrument calibration will be conducted in accordance with the QC requirements identified in the manufacturers' instructions and the laboratory SOPs. General requirements are discussed the following subsections.

3.7.1 Laboratory Instruments

Calibration of all analytical instrumentation is required to ensure that the analytical system is operating correctly and functioning at the sensitivity required to meet the project objectives. Each instrument will be calibrated with standard solutions appropriate for the instrument and analytical method, in accordance with the method specified and at the QC frequency specified in the laboratory SOPs.

The calibration and maintenance history of the fixed laboratory instrumentation is an important aspect of the project's overall QA/QC program. As such, all initial and continuing calibration procedures will be implemented by trained personnel in accordance with the manufacturer's

instructions and applicable EPA protocols to ensure the equipment is functioning within the tolerances established by the manufacturer and the method-specific analytical requirements.

3.7.2 Standard Solutions

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 in a multitude of ways. Second-source calibration verifications are run (i.e., same standard, two different vendors) for calibrations. New working standard mixes (e.g., calibrations and spikes) are verified against the results of the original solution and must be within 10 percent. Newly purchased standards are verified against current data. Any impurities found in the standard will be documented.

The laboratories will maintain a written record of the supplier, lot number, purity/concentration, receipt/preparation date, preparer's name, method of preparation, expiration date, and all other pertinent information for all standards, standard solutions, and individual standard preparation logs.

Reagents will be examined for purity by subjecting an aliquot or subsample to the corresponding analytical method as well.

3.8 INSPECTION/ACCEPTANCE OF SUPPLIES AND CONSUMABLES

The FC will be responsible for ensuring that all supplies necessary to conduct the sampling, including collecting, processing, and transporting samples, are available and in good working order at the beginning of the field work. The FC will monitor supplies and equipment throughout the sampling and replenish or replace them as necessary.

Likewise, the laboratory managers are responsible for ensuring that all supplies necessary to perform the analyses are available and uncontaminated, that equipment is in good working order and conforms to the QA protocols, and that the procedures, including the laboratory's QA plan are documented and followed.

3.9 DATA REDUCTION

Data reduction is the process by which original data are converted or reduced to a specified format or unit to the facilitate analysis of the data. For example, a final analytical concentration may need to be calculated from a diluted sample result. 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 consultant team PM, the project QAO, 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 produce accurate calculations that are free from unacceptable error.

3.9.1 Samples with Multiple Dilutions

During chemical analysis, samples are occasionally diluted after the initial analysis if the estimated concentration curve for one or more of the target analytes is above the calibration curve. In these instances, concentrations from the initial analysis will be identified as the "best result" for all target analytes other than the chemical that was originally above the calibration range. The "best result" for this qualified analyte will be taken from the diluted sample. The data validator may overrule this approach but, if so, must include an explanation in the data validation report. The results that are not used will be qualified as "R1," indicating that they have been rejected in favor of a more accurate value.

3.9.2 Summation and Normalization

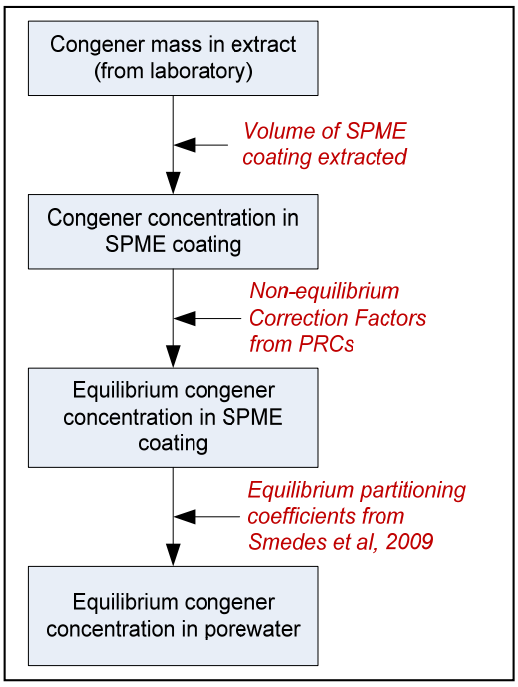
After third-party data validation, total PCBs will be calculated using only detected values for the 209 congeners. For individual samples in which none of the 209 congeners are detected, total PCBs will be given a value equal to the highest RL of the 209 congeners and assigned a U-qualifier, indicating the lack of detected concentration by the laboratory. Consistent with EPA Region 10 rules for data validation of PCB congeners, congeners that did not meet QA requirements and were reported as estimated maximum possible concentrations (qualified with either the K or EMPC qualifier), will be qualified as not detected ("U") not be included in the summation.

PCB concentrations will be reported as dry weight for sediment and as solution concentrations for porewater. Carbon normalization of the sediment data will be evaluated following the methods of the Washington State SMS, but may include modification to incorporate the following: samples from the ENR+AC subplots may have TOC contents higher than 4% due to the addition of GAC. For these samples the normal 4 percent cutoff used in Washington State is not appropriate and normalization will be performed at the higher TOC levels. Additionally, carbon normalization using the black carbon value, rather than the TOC, may yield results that are more predictive of porewater concentrations and bioavailability; therefore, normalization by black carbon content will also be evaluated.

3.9.3 Significant Figures

The laboratories report results with different numbers of significant figures, depending on the instrument, the parameter, and the concentration relative to the RL. The reported (or assessed) precision of each observation is explicitly stored in the project database as a record of the number of significant figures assigned by the laboratory. However, due to inherent field and laboratory variability, the data are rarely precise to more than plus or minus 20 percent. When a calculation involves addition, such as totaling PCBs, the calculation is only as precise as the least precise number that went into the calculation. For example (assuming two significant figures), 210 + 19 = 229. However, this would be reported as 230 because the number 19 is reported only to two significant figures, and the enhanced precision of the trailing zero in the number 210 is not significant.

When a calculation involves multiplication or division, such as the calculation used in carbon normalization, the original significant figures for each were carried through the calculation. That is, individual values will not be adjusted to a standard number of significant figures; instead, the appropriate adjustment will be made to the resultant value at the end of the calculation. The result will be rounded at the end of the calculation to reflect the value used in the calculation with the fewest significant figures. For example, 59.9 x 1.2 = 71.88 would be reported as 72 because there are two significant figures in the number 1.2.



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

3.9.4 Sediment Porewater Data Reduction

When the PCB congener laboratory reports the “SPME” data they are reporting the concentration of the PCB congeners in the extract, not in the porewater. This is appropriate because the laboratory receives an “extract” not a porewater sample to analyze.

The conversion of the extract concentration to the porewater concentration is performed by the SPME Expert, Dr. Jason Conder, and reviewed as part of data validation by Cari Sayler. The following paragraphs describe how the conversion from extraction concentrations to porewater concentrations occurs. Attachment B, Passive Sampling Method

Development, contains additional detail on the congener distribution in the Lower Duwamish Waterway, on the reporting of PCB congener data, and on calculations used to convert SPME extract results into porewater results. It contains additional details not presented below that may be of interest to some readers.

The PCB congener laboratory reports the concentration of each PCB congener in the SPME extracts. By knowing the volume of the extract (100 microliters) and the radio-isotope labeled internal and recovery standards added to the extract, the laboratory calculates the mass of the PCB congener extracted from the fiber. This value is reported by the laboratory.

This mass of PCB congeners in the extract is converted to a porewater concentration in three major steps as shown below.

In Step 1, the measured mass of fiber present in the vial before hexane extraction and the manufacturer's information on coating thickness is used to calculate the volume of PDMS coating that was extracted. Dividing the mass of PCB congener extracted by the volume of the coating results in concentration of PCBs present in the PDMS (i.e., nanograms of PCBs per microliter of PDMS [ng PCBs/µL PDMS]).

In Step 2: The concentration in the coating is corrected for non-equilibrium concentrations using methods used by Tomaszewski and Luthy (2008), Oen et al. (2011), Lohmann (2012). Correction is necessary because the 4-week deployment is unlikely to be sufficient for the PDMS coating to reach steady-state equilibrium with the porewater for all congeners.

First, the concentrations of PRCs in the PDMS coating of the SPME fibers will be used to calculate elimination rate constants for each PRC (PRC k_es) using the following equation (Lohmann, 2012):

$$PRC\ \ k_e = \ln\left(\frac{[PDMS_{t=0}]}{[PDMS_{t=28}]}\right) \div 28\ days$$

where:

$PDMS_{t = 28}$ = the concentration of the PRC in the PDMS after the 28-day field deployment (obtained from the SPME sampler exposed in situ for 28 days), and

$PDMS_{t = 0}$ = the average concentration of the PRC in the PDMS at the beginning of the field exposure (obtained from measurement of the trip blanks)

k_es for each of the PCB analyte congeners[2] (non-PRCs) detected in the field-deployed SPME samplers will be calculated from a linear regression model of the sampler-specific PRC k_es versus PDMS-solution partition coefficients (both values Log_{10}-transformed, per Tomaszewski and Luthy, 2008).

As a default, predicted k_es less than 0.008 d^{-1} will result in analytical results that will be flagged as "estimated" (J-qualified) due to analytical limitations (PDMS did not come to sufficient equilibrium with porewater). For example, k_es less than 0.008 d^{-1} indicate the concentration of the PRC at the end of the 28-day deployment period was 80 percent (or greater) of the initial (pre-deployment) concentration. Because the two analytical results are only 20 percent different (or less), the two measurements may be within the range of measurement variability for PCB quantification and, therefore, may not be truly different. In these cases, the results fail to indicate any measurable loss of PRCs from the SPME PDMS during the 28-day deployment and/or a possible overestimation of the steady-state equilibrium concentrations of non-PRC PCBs due to analytical variability. This criterion may be adjusted based on a statistical evaluation of actual measurement variability in PRC results during the study. For example, if PRC analytical variability is sufficiently precise as to suggest that measurements with differences of 10% are likely distinct, a k_e criterion value of 0.004 d^{-1} may be applied.

Sampling rate correction factors (CFs) for each PCB in the composited sample will be calculated via the following equation, adapted from Lohmann (2012):

$$CF = \frac{1}{1 - e^{-k_e \times 28\ days}}$$

CFs will be multiplied by the concentration of PCB congeners in the PDMS of each SPME composite to determine the steady-state concentration of PCBs present in the PDMS coating of the SPME fibers (i.e., ng PCBs/L PDMS).

In Step 3: the steady-state concentrations of PCBs in the PDMS coating of the SPME fibers will be divided by PCB congener-specific PDMS-solution partition coefficients (Smedes et al., 2009) to provide a concentration of dissolved PCBs in sediment porewater (e.g., picograms (pg) of

2 The term used here "analyte congeners" refers to all of the other congeners that were not used as PRC and can therefore be quantified in porewater. The PRC used for this study are specific PCB congeners that are rarely found in sediment and tissue, including those in Puget Sound. These are identified in QAPP Attachment B. Once they are used as PRCs, their concentrations are controlled by the spiked concentration.

dissolved PCBs/L porewater). At this stage, the PCB congener results for each SPME composite are now expressed as PCB congener porewater concentrations in contact with the SPME fibers.

The concentrations of dissolved tri-, tetra-, penta-, hexa-, hepta-, and octa-chlorinated biphenyls will be summed to estimate total dissolved PCBs in sediment porewater. The tri- to octa-chlorinated biphenyls include 99.7 percent of the bioavailable PCB congeners detected in tissue samples obtained from the LDW (QAPP Attachment B). Quantification of mono-, di-, nona-, and deca-chlorinated biphenyls is not practical with the SPME method that will be applied in this pilot study due to the low accumulation rates for these congeners. As noted in the QAPP Attachment B quantification of dissolved octa-chlorinated biphenyls in sediment porewater may be reported as "estimated" (J-qualified) values due to the low proportion of steady state obtained in the sampling time (i.e., the absorption of octa-chlorinated biphenyls and desorption of the octa-chlorinated PRC during the allotted sampling period may be too minimal to be reliably measured). Octa-chlorinated biphenyls are estimated to represent only 0.03 percent of the total available PCB homologs in porewater within the plot areas; therefore, the effect of including or excluding octa-chlorinated biphenyl in the summation of dissolved PCBs in sediment porewater will be minimal and within the range of standard analytical measurement variation.

3.10 DATA AND RECORDS MANAGEMENT

This section discusses data recording and data management.

3.10.1 Field Observations and Measurements

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. 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.

In addition to the field logbook, many of the field steps used specific forms for that collecting field information. These were discussed in Section 3.2 and representative forms are included in QAPP Attachment A.

Complete copies of the completed field forms, including the chain-of-custody forms, and all completed pages of the field logbook will be maintained at AMEC Foster Wheeler offices (as the Prime for the project team) for 10 years.

3.10.2 Photographs (including SPI)

Photographs will be assigned a unique identifier using procedures similar to those for the sediment samples and SPME fibers. They will be logged into the photograph log, with the date, time, and location (DGPS, verbal description, or sample station ID and replicate, depending on the purpose and type of the photograph), as well as a brief description of the intent or subject of the photograph.

An accurate and complete set of the photographs and associated logs will be maintained at AMEC Foster Wheeler offices (as the Prime for the project team) for 10 years.

3.10.3 Laboratory Records Retention and Management

A full record of laboratory analyses of samples for this project will be maintained and available for review for ten years from the time of analysis of the samples. The records must document no only the analyses of the samples, but the QA systems that support them. Information for each of the laboratories are given below.

3.10.3.1 Frontier Analytical

Frontier Analytical retains records of all raw data, derived data, test reports, logbook sheets, certificates, calibration and maintenance records for at least 5 years. After 5 years, hardcopy documents will be destroyed unless specifically requested by a client. A permanent record will be maintained on their server and a portable USB drive. Their record keeping system is described in Section 5.0 of their Quality Systems Manual, last revised on December 12, 2014. This document, along with laboratory standard operating procedures and related components of their QA system are available for review.

3.10.3.2 Alpha Analytical

Alpha Analytical has a record system that produces accurate records, which document all laboratory activities. The laboratory retains records of all original observations, calculations and derived data, calibration records and a copy of the test for ten years minimum. Their record keeping system is described in Section 12 of their Quality Systems Manual, last revised on April 1, 2015. This document, along with laboratory standard operating procedures and related components of their QA system are available for review.

3.10.3.3 Ramboll Environ Laboratory for Sample Preparation

Archived information and access logs are protected against fire, theft, loss, environmental deterioration, vermin, and in the case of electronic records, electronic or magnetic sources. All electronic records are backed-up daily (onsite) and weekly (offsite storage). Access to protected

records is limited to laboratory management or their designees to prevent unauthorized access or amendment. Records are disposed according to applicable regulation, client request, or after five years. For this project, the SPME processing records will be transferred AMEC Foster Wheeler as part of the "field" records for the project.

3.10.3.4 Ramboll Environ Laboratory for Benthic Macroinvertebrate Analysis

Archived information and access logs are protected against fire, theft, loss, environmental deterioration, vermin, and in the case of electronic records, electronic or magnetic sources. All electronic records are backed-up daily (onsite) and weekly (offsite storage). Access to protected records is limited to laboratory management or their designees to prevent unauthorized access or amendment. Records are disposed according to applicable regulation, client request, or after five years. For this project, the contract with the laboratory will require that records be retained for 10 years.

4.0 SAMPLE HANDLING AND CUSTODY DOCUMENTATION

This section discusses sample handling and chain of custody documentation, including sample nomenclature; sample chain of custody; sample preservation, handling, and transport; and sample receipt procedures.

4.1 SAMPLE NOMENCLATURE

Sample nomenclature is defined for the SPME porewater samples, the surface sediment cores, and the benthic macroinvertebrate samples.

4.1.1 SPME Porewater and Surface Sediment Samples

Each sample will be assigned a unique alphanumeric ID number that will consist of seven to nine components identifying various aspects of the sample, with each component separated by a hyphen ("-"). The hyphen will allow for ease in electronic data entry from the field forms into the database.

The sample ID components are summarized in Table 4.1.

Table 4.1 SPME Porewater, SPI, and Surface Sediment Sample ID Components

Order	Component	Definition
1st	Project area	"LDW" = Lower Duwamish Waterway
2nd	Monitoring event	"BA" = baseline "Y0" = Year 0 after layer placement "Y1" = Year 1 (one year after placement) "Y2" = Year 2 (two years after placement) "Y3" = Year 3 (three years after placement)
3rd	Plot type	"SU" = subtidal plot "SC" = scour plot "IN" = intertidal plot
4th	Subplot	"ENR" = enhanced natural recovery only "ENR+AC" = enhanced natural recovery with activated carbon
5th	Grid cell number	A single number between 0 and 6: "0" = composite "1" to "6" = indicates a un-composited sample collected from the grid cell indicated by the number
6th	Location or composite number	If the sample is a composite, this is a two-character code for the composite number: "CA," "CB," or "CC." If the sample is a grab sample, this is the location (generally between 1 and 30) within the grid cell from which the sample was collected.
7th	Sample medium	"CORE" = short sediment core tube (used for chain of custody between sampler and compositing) "S010" = SPME fibers in envelopes and vials collected from 0 to 10 cm (used for chain of custody between sampler and preparation laboratory) "SSWI" = SPME fibers in envelopes and vials collected from the surface water interface (0 to 1 cm) (used for chain of custody between sampler and preparation laboratory) "SS" = surface sediment to be analyzed for conventionals or PCB congeners (used for samples to be sent to analytical laboratories) "SPI" = Sediment Profile Imagery
8th (as needed)	Collocated sample	Single-digit numbers from 1 to 5, if needed to ensure that enough volume is available for analysis, collocated cores or SPME envelopes may be collected.
9th (as needed)	Field QC sample	"FD" = field duplicate (TOC and BC) "TB" = trip blank (SPME) "R1" to "R5" = field replicates for BC in Year 0

Abbreviations:

BC Black carbon
SPME Solid-phase microextraction
TOC Total organic carbon

The first component of the sample ID will represent the LDW project area ("LDW"). The second component will represent the monitoring event. The third through sixth components will represent the location (plot and subplot) and the type of sample (grab, core, or composite). The seventh component will represent the sample medium. The field sample collector (dive team) will use

"SPME" and "CORE" on the sample collection forms, as discussed in Section 3.3. The sample preparation team will then use the "CORE" surface sediment samples to prepare the surface sediment composites ("SS") in the field for placement in the jars and shipment to the analytical laboratories. Likewise, the "SPME" fibers will be composited and extracted, and the extract will be shipped to the analytical laboratories as porewater ("PW").

The last two ID components will be needed only under certain conditions. The eighth component will allow the collection of collocated sediment cores or SPME fibers to increase the sample volume, and the ninth component will represent the field QC samples.

The sediment core tubes will also be marked with electrical tape to indicate the top of the core (see Section 3.3 for details).

Attachment A, which contains the field forms, includes a table with several examples of the naming protocols to help clarify how they are to be used.

4.1.2 Benthic Macroinvertebrate Community Survey

Each sample will be assigned a unique alphanumeric ID number will consist of six components identifying various aspects of the sample, with each component separated by a hyphen ("-"). The hyphen will allow for ease in electronic data entry from the field forms into the database.

The sample ID components are summarized in Table 4.2, and follow the same general approach as that used for the sediment and porewater samples. The first component of the sample ID will represent the LDW project area ("LDW"). The second component will represent the monitoring event. The third through five components will represent the location, and the sixth component represents the sample medium.

Table 4.2 Benthic Macroinvertebrate Survey Sample ID Components

Order	Component	Definition
1st	Project area	"LDW" = Lower Duwamish Waterway
2nd	Monitoring event	"Y3" = Year 3 (three years after placement)
3rd	Plot type	"SU" = subtidal plot "SC" = scour plot "IN" = intertidal plot
4th	Subplot	"ENR" = enhanced natural recovery only "ENR+AC" = enhanced natural recovery with activated carbon
5th	Location number	A single-digit number between 0 and 5 that corresponds to a location on Figures 3.1 through 3.3
6th	Medium	"BEN" = benthic macroinvertebrate survey

4.2 SAMPLE CHAIN-OF-CUSTODY

Samples will be collected, handled, and shipped in accordance with COC procedures. These procedures document the transfer of the custody of samples from the point of collection in the field to the laboratory. 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 or seals 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 analyses, and for all data and data documentation whether in hard copy or electronic format.

Each sample sent to the laboratory for analysis will be recorded on a COC form, which will include instructions to the laboratory for analytical services and special turnaround times. The COC form will be a triplicate carbon copy form. The form will include, at a minimum, the following information:

- Project name
- Unique sample identifier
- Sampling location
- Collection date and time
- Collector name and initials
- Date sent to the laboratory
- Number of sample containers
- Sample matrix
- Analyses required
- Remarks, including preservatives, special conditions, or specific QC measures
- Turnaround time and person to receive laboratory report
- Release signature of sampler(s) and signatures of all people assuming custody
- Condition of samples, including temperature, when received by laboratory
- Shipping company and waybill number

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. The time and date at the time of custody transfer to the laboratory or shipping will be noted on the forms. The original COC form will accompany the

sample containers to the analytical laboratory. The shipping company (e.g., Federal Express or UPS) will not sign the COC forms as a receiver; instead the laboratory will sign as a receiver when the samples are received. A duplicate copy of the COC form will be retained for the project records and included as appendices to QA/QC reports and data reports. The COC form will be sealed inside a plastic sealable bag within the ice chest, and the chest will be sealed with custody tape that has been signed and dated by the last person listed on the COC form. Blank spaces on the COC form will be crossed out and initialed by the sampler between the last sample listed and the signatures at the bottom of the form.

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 the COC forms before removing the samples from the sampling area. At the end of each day, and before transfer, COC entries will be made for all samples. The information on the labels will be checked against the sample log entries and the sample tracking forms, and a final sample jar count made before sealing the cooler for transport. The FC will ensure that the laboratory has accepted delivery of the shipment at the specified time.

Upon receipt of the samples, the laboratories will ensure that the COC forms have been properly signed and will note questions or observations concerning the sample integrity on the COC forms. The laboratories will contact the FC and QAO immediately if a discrepancy between the COC form and the sample shipment is discovered upon receipt of the samples.

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 individuals responsible for performing the analyses, dates of sample extraction/preparation and analysis, and the types of analyses performed.

4.3 SAMPLE PRESERVATION, HANDLING, AND TRANSPORT

Sample preservation, handling, and transport includes discussion of surface sediment core samples for bulk PCB analysis, SPME samples for porewater PCB analyses, and benthic macroinvertebrate samples.

4.3.1 Surface Sediment Composites

Samples will be placed in pre-cleaned, laboratory-provided 8-oz wide-mouth amber glass jars leaving a minimum of approximately 1 centimeter of headspace to prevent breakage during shipping and storage. The sample containers will be stored cool (not frozen) in a refrigerator or cooler with ice at less than or equal to 4°C until received by the laboratory.

Samples jars must be appropriately labelled with waterproof, self-adhering labels. Each sample label will contain the project number, sample identification (Section 4.1), preservation technique, analyses, date, and time of collection, and initials of the person(s) filling the sample jar. A completed sample label will be affixed to each sample container. The labels will be covered with clear tape immediately after their completion to protect them from stains or deterioration due to water and sediment.

Samples will be shipped in accordance with state and federal regulations as well as U.S. Department of Transportation (DOT) standards. They must be packed securely for shipment, according to the following guidelines:

- Using duct tape, secure the outside and inside the drain plug at the bottom of the cooler that is used for sample transport.
- Place 1 to 2 inches of bubble wrap or other cushioning material at the bottom of the cooler.
- Individually wrap each sample jar in bubble wrap or other cushioning material and place securely in the cooler.
- Place ice on top of and in between sample containers. Package wet ice in sealable plastic bags. When packing ice, leave space for the addition of sufficient cushioning material.
- Fill the remaining space in the cooler with cushioning material.
- Close the cooler Place the completed COC forms in a sealable plastic bag and tape the forms to the inside of the cooler lid.
- lid and fasten with duct tape.
- Wrap duct tape around both ends of the cooler at least twice.
- Mark the cooler on the outside with the following information: return address, “Fragile” labels on the top and on one side, and arrows indicating “This Side Up” on two adjacent sides.
- Include temperature blanks as applicable.

Environmental samples will be shipped via an express carrier, overnight or within 24 hours, to ensure that the samples are retained at the appropriate temperature. If samples are unable to be shipped daily, samples will be held in the dark at 4°C ±2°C prior to shipping.

4.3.2 SPME Extracts for PCB Analysis

The transport of SPME fibers from the field to the extraction laboratory is discussed in Section 3.3. This section discusses the shipment of the extracts to the analytical laboratory for PCB congener analysis.

The 2 mL vials with fibers and 1.8 mL of hexane will be wrapped in bubble wrap and shipped in a cooler containing double-bagged wet ice at 4°C with sufficient cushioning material. The samples will be shipped in accordance with state and federal regulations as well as DOT standards using the same procedures as those for the sediment samples.

4.3.3 Benthic Macroinvertebrate Survey Grab Samples

Benthic macroinvertebrate samples will be preserved in 10 percent buffered formalin solution. Samples will be maintained at ambient air temperatures once preserved in formalin solution.

Samples will be appropriately labelled with waterproof, self-adhering labels. A completed sample label will be affixed to each sample container. The labels will be covered with clear tape immediately after their completion to protect them from stains or deterioration due to water and sediment. An internal sample label made of waterproof paper will also be placed in each sample container. This internal label will be used by the taxonomic laboratory to identify samples in addition to the external label on the sample container.

Samples will be packed securely for transport by field personnel or a courier. Samples will be individually wrapped in bubble wrap or other cushioning material and placed securely in the cooler. The completed COC forms will be placed in a sealable plastic bag and taped to the inside of the cooler lid. The lid should be tightly sealed.

4.4 SAMPLE RECEIPT

Upon arrival at the laboratory, the samples will be logged into the inventory system, and the sample numbers will be verified with the COC form. Any discrepancies will be resolved at this point. In most cases, when samples are sent to a testing laboratory, an Acknowledgment of Sample Receipt form is faxed to the project QAO the day the samples are received by the laboratory. The person receiving this form is responsible for reviewing it, making sure that the laboratory has received all the samples that were sent, and verifying that the correct analyses were requested. If an error is found, the QAO will call the laboratory immediately and document any decisions made during the telephone conversation, in writing, on the Acknowledgment of Sample Receipt form. In addition, the COC form will be corrected as needed and faxed to the laboratory to document the decisions made.

The Acknowledgment of Sample Receipt and COC forms, including any modifications, become part of the project documents as discussed in Section 6.1.

5.0 ASSESSMENT AND OVERSIGHT

EPA, Ecology, or their designees may observe field activities during each sampling event, as needed. If situations arise in which there is an inability to follow the QAPP methods, the PM will determine the appropriate actions and/or consult EPA and Ecology if the issue is significant.

5.1 COMPLIANCE ASSESSMENTS

Laboratory and field performance assessments consist of on-site reviews conducted by EPA or Ecology of QA systems and equipment for sampling, calibration, and measurement. EPA or Ecology personnel may conduct a laboratory audit before sample analysis. Pertinent laboratory audit reports will be made available to the project QAO. Analytical laboratories are required to have written procedures addressing internal QA/QC; these procedures will be submitted for review by the QAO to ensure compliance with the QAPP. All laboratories and the QAO are required to ensure that all personnel engaged in sampling and analysis tasks have appropriate training.

5.2 RESPONSE ACTIONS FOR FIELD SAMPLING

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

5.3 CORRECTIVE ACTION FOR LABORATORY ANALYSES

Analytical laboratories are required to comply with the SOPs previously submitted to the QAO. Laboratory SOPs that implement EPA Methods are required to be consistent with the EPA Methods. The laboratory PMs will be responsible for ensuring that appropriate corrective actions are initiated as required for conformance with this QAPP, their internal QA program, their SOPs, and the EPA Method (where appropriate). All laboratory personnel will be responsible for reporting problems that may compromise the quality of the data.

The QAO will be notified immediately if any QC sample exceeds the project-specified data quality indicators (Tables 3.4 through 3.7). 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 that will be submitted to the QAO within 5 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, or re-extraction) will be submitted by the QAO with the data package using the protocol modification form.

5.4 REPORTS TO MANAGEMENT

After each monitoring event, the FC will prepare a summary documenting the sample coordinates and whether any QAPP deviations occurred in the field. When the analyses have been completed, the QAO will also prepare a summary documenting any laboratory deviations.

5.5 DATA VALIDATION

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 laboratory performs an initial qualification of the data, applying laboratory qualifiers.

Data are not considered final until validated. Data validation will be conducted following EPA National and Region 10 guidance (U.S. EPA 1995, 2008, 2010, 2011, 2014a and 2014b). This review will be performed in accordance with the QA requirements of the project and the technical specifications of the analytical methods indicated in Table 3.4 through 3.7. The EPA PM may have EPA peer review the third-party validation or perform data assessment/validation on a percentage of the data.

The QAO is responsible for checking to see that all analyses performed by the laboratories are correct, properly documented, and complete, and that they comply with the project QAGs specified in this QAPP to the extent possible, and that deviations are identified and documented.

Independent third-party data validation will be conducted by Cari Sayler of Sayler Data Solutions, including the following based on levels defined in EPA's Guidance for Labelling Externally Validated Laboratory Analytical Data for Superfund Use (EPA 2009):

6. Data review and compliance screening (Stage 2a) validation of TOC, black carbon, and grain size for all sediment samples, and TOC, black carbon, grain size, and benthic SMS constituents for the ENR fill materials.
7. PCB congeners by EPA Method 1668C in sediment and porewater extracts will be validated using Stage 4 validation. The calculations checks will focus on the dioxin-like PCBs congeners and 10 of the most commonly detected PCBs congeners. These

calculations will include representative congeners that are quantified using isotope dilution as well as those quantified using internal standards.

8. A calculation verification check on the conversion of SPME extracts to porewater concentrations using PRCs (see Section 3.9.4).

Taxonomic identification for benthic samples will be conducted by Ramboll Environ. At least one specimen for each species identified will be placed in a vial with 70 percent ethanol for outside validation. Once all of the organisms from all of the samples have been identified, the library of specimens will be verified by Biological Environmental Services of Victoria, British Columbia, Canada, and other outside taxonomists from British Columbia, Alaska, Washington, Oregon, and California.

5.6 DATA USABILITY STATEMENT

The data usability assessment considers four questions:

1. Are the data from a known source with adequate documentation to evaluate their relevance and quality?
2. Are the analytical methods and detection limits sensitive and selective enough for the data to be usable for their intended purpose?
3. Were the QAGs met, and if not, can the error or bias be quantified sufficiently for the data to still be usable?
4. Does a review of the data collection and laboratory analyses steps, including any reports to the QAO, indicate that the data are not representative of the conditions that were intended to be measured?

The purpose of this QAPP is to collect data that satisfy the first two requirements. The data validation step is intended to identify any issues that need to be considered for the third question. The consistent use of field forms by qualified and experienced staff is intended to address the last question. At the end of each field event, a short usability evaluation will be performed and included in the data report, as specified in Section 6.0. Special consideration will be given to rejected data, if any, and their consequences; to whether estimated data have a known bias and their potential consequence; and to whether field conditions indicate that the data are not representative of the conditions intended to be tested. The last condition may occur if significant sedimentation occurs at one of the pilot plots and covers the ENR layer.

5.7 RECONCILIATION WITH DATA QUALITY OBJECTIVES

A meaningful usability assessment is based on an understanding of the DQOs of the study; therefore, the usability assessment will consider the DQOs defined in Section 1.2.

6.0 REPORTING AND RECORD RETENTION

6.1 DATA SUBMITTALS AND MONITORING REPORTS

Reporting associated with this pilot study will evaluate the performance of ENR+AC compared to ENR alone in locations with a range of PCB concentrations and under three conditions representative of the waterway (i.e., intertidal, subtidal, and scour).

Validated sampling data will be provided to EPA and Ecology within 75 days after the completion of each sampling event (90 days after the Year 3 event). The validated sampling data will be provided in two formats: (1) printed compilation and (2) LWDG database format. The LDWG database format will contain the sample coordinates cross referenced against the sample location and sample IDs. The data report will include a short description of the event, a tabulated analytical schedule for the event, and a tabulated definition of data qualifiers (which is consistent across all events, but may vary by analysis type).

Two monitoring reports will be prepared; one after the Year 1 event and the other after the Year 3 event, consistent with the reporting requirements from the Order Amendment. The monitoring reports will be submitted to EPA and Ecology initially in draft form for their review. The reports will be revised and finalized and approved according to the following schedule:

Year 1 draft monitoring report	Submitted 90 days after data validation of the Year 1 monitoring event.
Year 1 final monitoring report	Submitted 30 days from the receipt of EPA/Ecology comments.
Year 3 draft monitoring report	Submitted 90 days after data validation of the Year 3 monitoring event.
Year 3 final monitoring report	Submitted 30 days from the receipt of EPA/Ecology comments.

The Year 1 monitoring report will include the baseline data, the construction completion details, the Year 0 results immediately after construction, and the Year 1 monitoring results. The focus of the report will be on the placement of the ENR layers, their stability, and their impact on PCB bioavailability, as measured by PCB concentrations in porewater.

The Year 3 monitoring report will include the results from the Year 2 and Year 3 monitoring events and will focus on longer term assessments of ENR layer stability and PCB bioavailability and on any potential impacts of AC on the benthic communities.

6.2 RECORD MAINTENANCE AND STORAGE

All documents relating to the project will be controlled to ensure proper distribution, filing, and retrieval.

Project records will be stored and maintained by LDWG. The task manager and office staff are responsible for organizing, storing, and cataloging all project information and for collecting records and supporting data from project team members. Once project records have been catalogued, LDWG will ensure that they are appropriately filed by category in the correct project file. Filed documents will be available to LDWG staff through the checkout procedures developed to ensure the integrity of the project file. Individual project team members may maintain separate files or notebooks for individual tasks. These files or notebooks will be transferred to the task manager as part of project closeout. The archived files will be stored and maintained by LDWG.

Field sampling forms and logs, daily field notes, laboratory deliverables, laboratory electronic deliverables, the chemical database, the calculation spreadsheets, and an abbreviated data dictionary will be placed saved on DVDs for long-term storage as readable, searchable Adobe Acrobat files. They will be maintained by AMEC Foster Wheeler.

7.0 REFERENCES

AECOM. 2012. Final feasibility study, Lower Duwamish Waterway. Prepared for Lower Duwamish Waterway Group. AECOM, Seattle, WA.

Aller, R.C. 1982. The effects of macrobenthos on chemical properties of marine sediments and overlying water. In: McCall, P.L., and Tevesz, M.J.S. (Eds.), Animal–Sediment Relations. Plenum Press, New York, pp. 53–102

ASTM. 2001. Standard practice for classification of soils for engineering purposes (unified soil classification system). D-2487-00. ASTM annual book of standards. Vol 04.08. American Society for Testing and Materials, Consohocken, PA.

Conder, J.M., La Point, T.W., Lotufo, G.R., and Steevens, J.A. 2003. Nondestructive, minimal-disturbance, direct-burial solid phase microextraction fiber technique for measuring TNT in sediment. Environ. Sci. Technol. 37:1625-1632.

Conder et al. 2013. Interim Report – Project ER-201131. Short-Term Performance of an Activated Carbon Amendment to Reduce PCB Bioavailability at an Active Naval Shipyard. August 2014. Submitted to Environmental Security Technology Certification Program.

Conder, J.M., Grover, M., Rosen, G., Kirtay, V., Chadwick, D.B., and Magar, V.M. 2015. Evaluation of PCBs Availability in Sediment after Application of an Activated Carbon Amendment at an Active Naval Shipyard. Battelle Eighth International Conference on Remediation of Contaminated Sediments, New Orleans, LA. January.

Ecology. 2008. Guidance on the Development of Sediment Sampling and Analysis Plans Meeting the Requirements of the Sediment Management Standards (Chapter 173-204 WAC). Ecology Publication No. 03-09-043. February. Sediment Sampling and Analysis Plan Appendix.

Gustafsson, Ö., Haghseta, F., Chan, C., MacFarlane, J., and Gschwend, P.M. 1997. Quantification of the dilute sedimentary soot phase: Implications for PAH speciation and bioavailability. Environ. Sci. Technol. 31: 203-209.

Harwood, A.D., Landrum, P.F., and Lydy, M.J. 2012. A comparison of exposure methods for SPME-based bioavailability estimates. Chemosphere 86: 506-511.

LDWG. 2014. Candidate plot locations for enhanced natural recovery-activated carbon pilot study. Lower Duwamish Waterway Group, Seattle, WA.

Lohmann, R. 2012. Critical review of low-density polyethylene's partitioning and diffusion coefficients for trace organic contaminants and implications for its use as a passive sampler. Environ. Sci. Technol.: 46:606-618.

Lu, X., Skwarski, A., Drake, B., and Reible, D.D. 2011. Predicting bioavailability of PAHs and PCBs with porewater concentrations measured by solid-phase microextraction fibers. Environ. Toxicol. Chem. 30: 1109-1116.

Oen, A.M.P., Janssen, E.M.L., Cornelissen, G., Breedveld, G.D., Eek, E., and Luthy, R.G. 2011. In situ measurement of PCB pore water concentration profiles in activated carbon-amended sediment using passive samplers. Environ. Sci. Technol. 45: 4053-4059.

Pearson, T.H., and Rosenburg, R. 1978. Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. Oceanogr Mar Biol Annu Rev 16:229-311.

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

PSEP. 1997. Recommended guidelines for sampling marine sediment, water column, and tissue in Puget Sound. Prepared for the Puget Sound Estuary Program, US Environmental Protection Agency, Region 10. King County (METRO) Environmental Laboratory, Seattle, WA.

PSWQAT. 1997. Recommended quality assurance and quality control guidelines for the collection of environmental data in Puget Sound. Prepared for U.S. Environmental Protection Agency Region 10. Puget Sound Water Quality Action Team, Olympia, WA.

Rhoads, D.C., and Germano, J.D. 1986. Interpreting long-term changes in benthic community structure: a new protocol. Hydrobiologia 142:291-308.

Smedes, P., Geerstma, R. W., van der Zande, T., and Booij, K. 2009. Polymer-water partition coefficients of hydrophobic compounds for passive sampling: Application of cosolvent models for validation. Environ. Sci. Technol. 43:7047-7054.

Tomaszewski, J.E., and Luthy, R.G. 2008. Field deployment of polyethylene devices to measure PCB concentrations in pore water of contaminated sediment. Environ. Sci. Technol. 42:6086-6091.

USEPA. Ecology. 2000. Administrative Order on Consent for Remedial Investigation/Feasibility Study, Lower Duwamish Waterway; Port of Seattle, King County, City of Seattle, The Boeing Company, respondents. US EPA docket no. CERCLA-10-2001-0055; Ecology docket no. 00TCPNR-1895. US Environmental Protection Agency, Region 10, Seattle, WA; State of Washington Department of Ecology, Olympia, WA.

USEPA. Ecology. 2014. Second Amendment to the Administrative Order on Consent for remedial investigation/feasibility study (AOC) for the Lower Duwamish Waterway (LDW), CERCLA-10-2001-0055. US Environmental Protection Agency, Region 10, Seattle, WA; State of Washington Department of Ecology, Olympia, WA.

USEPA. (U.S. Environmental Protection Agency). 1995. Region 10 SOP For the Validation of Method 1668 Toxic, Dioxin-like, PCB Data EPA Region EPA Region 10, Environmental Services Division, 1200 Sixth Avenue Seattle, WA 98101, Revision 1.0, December 8.

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

USEPA. 2004. Region III Interim Guidelines for the Validation of Data Generated Using Method 1668 PCB Congener Data EPA Region III Quality Assurance Team Environmental Science Center Ft. Meade, MD Revision 0, April 21.

USEPA. 2006. Guidance on Systematic Planning Using the Data Quality Objectives Process EPA QA/G-4. EPA/240/B-06/001. February 2006.

USEPA. 2008. USEPA Contract Laboratory Program National Functional Guidelines for Superfund Organic Methods Data Review (SOM01.2). OSWER 9240.1-48; EPA-540-R-08-01. Office of Superfund Remediation and Technology Innovation. June 2008

USEPA. 2009. Guidance for Labeling Externally Validated Laboratory Analytical Data for Superfund Use. OSWER No 9200.1-85, EPA 540-R-08-005, 13 Jan 2009.

USEPA. 2010. USEPA Contract Laboratory Program National Functional Guidelines for Inorganic Superfund Data Review (ISM01.2). OSWER 9240.1-51; EPA 540-R-10-011. Office of Superfund Remediation and Technology Innovation. January 2010.

USEPA. 2010. Method 1668C, Chlorinated Biphenyl Congeners in Water, Soil, Sediment, Biosolids, and Tissue by HRGC/HRMS, April 2010, U.S. Environmental Protection Agency, Office of Water Office of Science and Technology, Engineering and Analysis Division (4303T) 1200 Pennsylvania Avenue, NW Washington, DC 20460. EPA-820-R-10-005.

USEPA. 2011. USEPA Contract Laboratory Program (CLP) National Functional Guidelines for Chlorinated Dibenzo-p-Dioxin (CDDs) and Chlorinated Dibenzofurans (CDFs) Data Review. OSWER 9240.1-53; EPA-540-R-11-016. Office of Superfund Remediation and Technology Innovation. September 2011.

USEPA. 2014a. National Functional Guidelines for Superfund Organic Methods Data Review (SOM02.2). OSWER 9355.0-132; EPA 540-R-014-002. Office of Superfund Remediation and Technology Innovation. August 2014.

USEPA. 2014b. National Functional Guidelines for Inorganic Superfund Data Review (ISM02.2). OSWER 9355.0-131; EPA 540-R-013-001. Office of Superfund Remediation and Technology Innovation. August 2014.

Windward (Windward Environmental, LLC). 2010. Final Lower Duwamish Waterway Remedial Investigation Report. Prepared for Lower Duwamish Waterway Group. Windward, Seattle, WA.

Yang, Z., Maruya, K.A., Greenstein, D., Tsukada, D., and Zeng, E.Y. 2008. Experimental verification of a model describing solid phase microextraction (SPME) of freely dissolved organic pollutants in sediment porewater. Chemosphere 72: 1435-1440.

You, J., Pehkonen, S., Landrum, P.F., and Lydy, M.J. 2007. Desorption of hydrophobic compounds from laboratory-spiked sediments measured by Tenax absorbent and matrix solid-phase microextraction. Environ. Sci. Technol. 41: 5672-5678.

TABLES

Table 3.1
Subplot Analytical Schedule and DQOs by Monitoring Event and Subplot

Analytical Schedule by Event (Counts per Subplot)								
		Surface Sediment Cores			Porewater			Benthic Survey
					PCB Congeners by SPME		Salinity by	
Events	Sediment Profile Image Locations	Physical Description[1]	PCB Congeners[2]	TOC, BC, and GS[3]	0 to 10 cm	0 to 1 cm	Probe	Benthic Counts
Baseline[4]	6 ("A" locations)	18	3 composites	3 composites	3-5 composites[6]		18 [9]	
Year 0	12 ("A" and "B" locations)	18		9 grab samples[5]				
Year 1	12 ("A" and "B" locations)	18	3 composites	3 composites	3 composites[7]		18 [9]	
Year 2	12 ("A" and "B" locations)	18	3 composites	3 composites	3 composites[7]	3 composites[8]	18 [9]	
Year 3	12 ("A" and "B" locations)	18	3 composites	3 composites	3 composites[7]	3 composites[8]	18 [9]	5 grab samples
DQOs Addressed in Each Event by Data Collected								
Baseline		1 & 2	3	1, 2 & 3	3			
Year 0	1 & 2	1 & 2		1, 2 & 3				
Year 1	1, 2 & 4	2	3	2 & 3	3			
Year 2	1, 2 & 4	2	3	2 & 3	3			
Year 3	1, 2 & 4	2	3	2, 3 & 4	3			4

Notes:

This table addresses analyses on samples from the test plots. Section 3.1.1.1 also includes testing of the ENR materials during the Baseline Event prior to acceptance for use.

1. The physical description includes diver observations, that will be recorded on the diver core log.
2. The composited sediment samples will also be analyzed for total solids.
3. The composited sediment samples from the intertidal plots will also be analyzed for salinity.
4. Prior to construction, the ENR sand and gravelly sand fill will be tested for all chemicals listed in Lower Duwamish Waterway Record of Decision (U.S. EPA, 2014) Tables 19 and 20, and the granulated activated carbon will be tested for PCB congeners.
5. In year 0, individual samples will be tested for TOC, BC, and grain size to document the success of layer placement and how uniform the layer.
6. During Baseline, five composites will the collected. Initially, three composites will be analyzed and two composites will be archived. If power analysis using results from the three Baseline composites indicates that more than three composites are needed, the additional two samples will be analyzed. See text for details.
7. Three composites are currently planned, although more composites may be required, pending analyses of the Baseline data. See text for details.
8. In Years 2 and 3, SPMEs will also be collected to the 0 to 1 cm depth to represent the sediment to surface water interface. These samples are in addition to the 0 to 10 cm samples. See text for details.
9. Salinity measurements will be made using a field probe of porewater collected approximately 10 cm below mudline during the Baseline Event; and 10 to 20 cm below mudline in subsequent events to assess the salinity of upwelling water.

DQOs:

DQO 1	Initial placement
DQO 2	Stability
DQO 3	PCB bioavailability
DQO 4	Effects on benthic

Abbreviations:

BC	Black carbon
DQO	Data quality objective
ENR	Enhanced natural recovery
GS	Grain size
PCB	Polychlorinated biphenyl
SMS	Sediment Management Standards
SPI	Sediment profile Image
SPME	Solid-phase microextraction
TOC	Total organic carbon

Table 3.2
Location-Specific Information by Monitoring Event

Subtidal Plot: East Lane						Subtidal Plot: West Lane					
Treatment: ENR						Treatment: ENR+AC					
Baseline	Comp A	Comp B	Comp C	Comp D	Comp E	Baseline	Comp A	Comp B	Comp C	Comp D	Comp E
Cell 1	19	6	12	18	11	Cell 1	23	16	6	21	20
Cell 2	13	11	9	16	10	Cell 2	10	23	2	13	18
Cell 3	19	9	7	12	13	Cell 3	10	7	24	11	20
Cell 4	19	4	3	11	13	Cell 4	6	18	3	5	22
Cell 5	9	14	2	24	12	Cell 5	18	11	12	19	9
Cell 6	12	8	11	3	9	Cell 6	18	1	22	19	8
Year 0	Comp A	Comp B	Comp C	Comp D	Comp E	Year 0	Comp A	Comp B	Comp C	Comp D	Comp E
Cell 1	10	24	13	5	7	Cell 1	7	13	4	19	12
Cell 2	23	6	18	8	19	Cell 2	11	12	22	1	24
Cell 3	6	21	23	5	14	Cell 3	4	16	6	23	22
Cell 4	1	20	18	2	12	Cell 4	10	15	21	13	16
Cell 5	16	11	21	23	19	Cell 5	6	4	15	7	23
Cell 6	6	5	23	16	22	Cell 6	10	9	13	23	17
Year 1	Comp A	Comp B	Comp C	Comp D	Comp E	Year 1	Comp A	Comp B	Comp C	Comp D	Comp E
Cell 1	15	20	1	9	16	Cell 1	8	5	9	15	11
Cell 2	20	7	15	3	2	Cell 2	9	8	15	20	7
Cell 3	3	22	18	16	20	Cell 3	5	9	8	18	14
Cell 4	16	22	5	23	7	Cell 4	9	12	8	24	7
Cell 5	7	20	15	1	5	Cell 5	8	13	20	17	14
Cell 6	20	2	13	24	1	Cell 6	4	2	24	15	12
Year 2	Comp A	Comp B	Comp C	Comp D	Comp E	Year 2	Comp A	Comp B	Comp C	Comp D	Comp E
Cell 1	21	8	23	7	4	Cell 1	7	17	1	2	18
Cell 2	1	12	5	6	14	Cell 2	4	20	3	17	19
Cell 3	11	8	10	8	1	Cell 3	1	21	14	12	19
Cell 4	14	10	17	12	21	Cell 4	20	11	19	14	6
Cell 5	10	4	3	8	4	Cell 5	16	2	10	24	10
Cell 6	15	24	10	21	14	Cell 6	6	20	16	7	14
Year 3	Comp A	Comp B	Comp C	Comp D	Comp E	Year 3	Comp A	Comp B	Comp C	Comp D	Comp E
Cell 1	2	14	22	17	3	Cell 1	3	24	22	14	10
Cell 2	17	21	4	22	24	Cell 2	5	16	21	6	14
Cell 3	17	24	2	4	15	Cell 3	3	13	15	2	17
Cell 4	24	15	6	9	8	Cell 4	2	4	1	17	23
Cell 5	13	6	17	22	18	Cell 5	22	5	1	21	3
Cell 6	4	19	17	18	7	Cell 6	3	5	11	21	16

Scour Plot: Upstream Subplot						Scour Plot: Downstream Subplot					
Treatment: ENR						Treatment: ENR+AC					
Baseline	Comp A	Comp B	Comp C	Comp D	Comp E	Baseline	Comp A	Comp B	Comp C	Comp D	Comp E
Cell 1	3	24	1	6	9	Cell 1	11	7	21	12	24
Cell 2	10	12	19	17	3	Cell 2	8	14	20	13	11
Cell 3	6	10	19	9	23	Cell 3	20	8	19	15	23
Cell 4	7	9	13	1	15	Cell 4	1	7	15	8	14
Cell 5	1	12	4	20	18	Cell 5	17	8	11	6	5
Cell 6	20	3	6	23	8	Cell 6	2	6	7	1	23
Year 0	Comp A	Comp B	Comp C	Comp D	Comp E	Year 0	Comp A	Comp B	Comp C	Comp D	Comp E
Cell 1	12	20	14	23	7	Cell 1	10	4	6	9	17
Cell 2	15	9	1	7	2	Cell 2	5	18	24	4	21
Cell 3	2	12	24	8	3	Cell 3	21	2	13	1	10
Cell 4	24	3	21	5	23	Cell 4	19	9	4	11	24
Cell 5	23	14	9	15	21	Cell 5	12	9	1	16	3
Cell 6	22	11	7	24	14	Cell 6	9	21	12	22	24
Year 1	Comp A	Comp B	Comp C	Comp D	Comp E	Year 1	Comp A	Comp B	Comp C	Comp D	Comp E
Cell 1	11	19	13	8	2	Cell 1	23	1	8	5	3
Cell 2	21	23	6	11	24	Cell 2	19	23	7	1	12
Cell 3	14	7	5	18	20	Cell 3	14	4	24	18	17
Cell 4	6	14	20	11	19	Cell 4	2	6	18	13	10
Cell 5	3	8	11	6	13	Cell 5	24	4	2	18	23
Cell 6	5	16	10	2	19	Cell 6	8	17	10	18	14
Year 2	Comp A	Comp B	Comp C	Comp D	Comp E	Year 2	Comp A	Comp B	Comp C	Comp D	Comp E
Cell 1	15	18	21	4	5	Cell 1	19	15	20	18	14
Cell 2	4	8	14	22	2	Cell 2	16	15	20	6	9
Cell 3	8	11	13	22	21	Cell 3	3	15	16	7	12
Cell 4	18	8	8	4	16	Cell 4	23	22	16	12	6
Cell 5	16	18	7	10	17	Cell 5	3	12	17	5	9
Cell 6	4	13	18	15	9	Cell 6	13	20	4	19	16
Year 3	Comp A	Comp B	Comp C	Comp D	Comp E	Year 3	Comp A	Comp B	Comp C	Comp D	Comp E
Cell 1	22	10	17	4	16	Cell 1	13	20	22	2	16
Cell 2	18	5	20	13	16	Cell 2	3	17	22	10	2
Cell 3	1	17	4	15	16	Cell 3	9	6	5	22	11
Cell 4	2	22	12	17	10	Cell 4	3	21	17	20	5
Cell 5	24	5	22	19	2	Cell 5	24	10	9	10	8
Cell 6	12	13	1	17	21	Cell 6	3	11	15	5	16

Intertidal Plot: Upstream Subplot						Intertidal Plot: Downstream Subplot					
Treatment: ENR						Treatment: ENR+AC					
Baseline	Comp A	Comp B	Comp C	Comp D	Comp E	Baseline	Comp A	Comp B	Comp C	Comp D	Comp E
Cell 1	23	22	1	21	15	Cell 1	11	23	20	6	5
Cell 2	23	22	20	14	17	Cell 2	21	12	10	7	2
Cell 3	3	17	7	1	9	Cell 3	22	23	3	14	10
Cell 4	8	2	3	4	10	Cell 4	1	23	19	5	17
Cell 5	7	14	22	17	10	Cell 5	3	5	1	12	23
Cell 6	21	22	18	24	16	Cell 6	18	2	14	17	12
Year 0	Comp A	Comp B	Comp C	Comp D	Comp E	Year 0	Comp A	Comp B	Comp C	Comp D	Comp E
Cell 1	17	16	4	8	10	Cell 1	21	8	16	9	12
Cell 2	13	3	1	18	10	Cell 2	1	14	9	23	24
Cell 3	20	15	12	2	10	Cell 3	20	17	1	6	19
Cell 4	7	5	6	1	9	Cell 4	18	24	22	12	4
Cell 5	6	2	15	4	1	Cell 5	24	16	18	17	21
Cell 6	14	12	8	17	5	Cell 6	16	11	21	23	20
Year 1	Comp A	Comp B	Comp C	Comp D	Comp E	Year 1	Comp A	Comp B	Comp C	Comp D	Comp E
Cell 1	12	3	14	13	2	Cell 1	7	10	15	1	2
Cell 2	16	8	9	12	15	Cell 2	3	20	15	4	13
Cell 3	11	21	5	19	23	Cell 3	12	18	11	5	9
Cell 4	5	13	1	6	13	Cell 4	10	6	16	9	13
Cell 5	21	24	9	12	18	Cell 5	15	19	13	14	7
Cell 6	10	9	20	4	3	Cell 6	3	10	24	9	6
Year 2	Comp A	Comp B	Comp C	Comp D	Comp E	Year 2	Comp A	Comp B	Comp C	Comp D	Comp E
Cell 1	6	21	18	11	20	Cell 1	9	24	4	17	14
Cell 2	7	19	23	2	11	Cell 2	6	18	8	22	8
Cell 3	18	18	16	14	13	Cell 3	2	7	24	21	15
Cell 4	10	6	2	4	7	Cell 4	24	8	11	21	15
Cell 5	24	3	18	23	5	Cell 5	2	22	6	8	11
Cell 6	1	13	19	12	2	Cell 6	4	5	8	1	13
Year 3	Comp A	Comp B	Comp C	Comp D	Comp E	Year 3	Comp A	Comp B	Comp C	Comp D	Comp E
Cell 1	19	7	24	9	5	Cell 1	22	19	3	13	18
Cell 2	21	5	6	24	4	Cell 2	5	19	16	17	11
Cell 3	22	8	6	24	4	Cell 3	16	8	7	4	13
Cell 4	13	10	5	6	1	Cell 4	3	7	14	20	2
Cell 5	11	16	5	8	3	Cell 5	8	10	20	4	9
Cell 6	11	7	15	23	6	Cell 6	19	15	5	7	22

Notes:

1. Locations were selected by dividing the subplot into a 4-by-6 grid, numbering the grid cells 1 through 24, and then using a random number generator to select the location of each sample. The GPS coordinates of the center of the selected cell will be presented in the database expressed as Northings and Eastings in state plane coordinates according to the procedures in Section 3.0.
2. During Baseline, five composites will the collected; three will be analyzed (A, B, and C); two will be archived (D and E). If the Power Analysis during baseline indicates that more than three composites are needed, subsequent events will be modified to reflect the change. See text for details.

Abbreviations:

Comp	Composite
ENR	Enhanced natural recovery
ENR+AC	Enhanced natural recovery amended with activated carbon
GPS	Global positioning system

Table 3.3
Analytical Parameters, Methods, Laboratories, Sample Containers, and Sample Preservation

Parameter	Analytical Method	Laboratory	Sample Preservation	Technical Holding Time	Minimum Sample Size	Sample Container(s)
Surface Sediment Composites (Baseline Event and Years 1, 2, and 3) and GAC Sample (Baseline Event Only)						
PCB congeners	EPA 1668C	Frontier	Transport: less than 6°C. Storage: less than -10°C.	1 year	20 grams	8-oz. AWMG jar
Total solids					10 grams	
ENR Substrate (Baseline Event Only)						
SMS Metals (except Hg)	EPA 6020A	Alpha	Transport: less than 6°C. Storage: less than -10°C.	180 days	10 g	16-oz. AWMG jar
SMS Hg	EPA 7474			28 days	5 g	
SMS SVOCs	SW-846-8270D			Extract w/in 14 days of collection; analyze w/in 40 days of extraction	50 g dry wt.	
PCB congeners	EPA 1668C	Frontier		1 year	20 g	4-oz. AWMG jar
Dioxins/Furans	EPA 1613		Transport: less than 4°C. Storage: less than -10°C.	1 year	10 g	
Sediment (Baseline Event and Years 0, 1, 2, and 3) and ENR Substrate (Baseline Event Only)						
Total organic carbon	EPA 9060	Alpha	Cool to 4°C ± 2°C.	28 days	20 grams	4-oz. AWMG jar
Black carbon	Gustafsson et al. (1997)			28 days	20 grams	
Grain size	ASTM D422		None	6 months	200 grams	8-oz. AWMG jar
Salinity	EPA 9050A (field version)	Field	None	NA	NA	None
SPME Fiber Extracts (Baseline Event and Years 1, 2, and 3)						
PCB congeners	EPA 1668C	Frontier	Transport: less than 6°C. Storage: less than 4°C.	1 year	Entire hexane extract	2-mL amber glass vial

Abbreviations:

Alpha	Alpha Analytical Laboratory
AWMG	Amber, wide-mouth glass with teflon-lined lid
ASTM	American Society for Testing Materials
°C	Degrees Celsius
EPA	U.S. Environmental Protection Agency
Frontier	Frontier Analytical Laboratory
PCB	Polychlorinated biphenyl
SPME	Solid-phase microextraction
SIM	Selective Ion Monitoring
ENR	Enhanced Natural Recovery

Table 3.4
Methods and Acceptable Quality Assurance Goals for Conventionals in Sediment Samples

Parameter	Analytical Method	Lab	Expected Range	Units	Sensitivity [1]		Precision[2]	Accuracy[3]	Completeness[4]
					RL/LOQ	MDL/LOD			
Black carbon	Gustafsson et al. (1997)	Alpha	0.1 to 4.0	%	0.01	0.01	±25%	75 - 125%	95%
Grain size	ASTM D422	Alpha	Clay to gravel	%	NA	NA	±25%	NA	95%
Salinity	EPA 9050	Field	1 to 32	SU	0.01	0.005	±20%	80 - 120%	95%
TOC	SW-846 9060	Alpha	1 to 6	%	0.01	0.01	±25%	75 - 125%	95%

Notes:

1. Sensitivity is assessed by the use of initial and continuing calibration and laboratory control samples.
2. Precision is assessed by the use of laboratory control samples and laboratory duplicates.
3. Accuracy is assessed by calibration, laboratory control samples, and matrix spikes (TOC and black carbon only). For TOC, the laboratory control sample is NIST standard reference material with a certified value of 4.4% TOC.
4. Completeness is measured as the number of results that are acceptable for use vs. the number of samples analyzed.

Abbreviations:

Alpha	Alpha Analytical Laboratory
ASTM	American Society for Testing Materials
EPA	U.S. Environmental Protection Agency
Frontier	Frontier Analytical Laboratory
LOD	Limit of detection
LOQ	Limit of quantification
MDL	Method detection limit
NA	Not applicable
NIST	National Institute of Standards and Technology
PCB	Polychlorinated biphenyl
RL	Reporting limit
SU	Salinity Unit
TOC	Total organic carbon

Table 3.5
Methods and Acceptable Quality Assurance Goal for PCB Congeners in Sediment and SPME Extracts

PCB Congener by Frontier Using EPA 1668C		Sediment Samples					Acceptance Criteria for Native PCBs					Acceptance Criteria for Labeled PCBs					
			Sensitivity: Analysis of 5-Gram Sample[2]		Sensitivity: Analysis of 10-Gram Sample				IPR					IPR			
	Co-elution[2]	Units	RL/LOQ	MDL/LOD	RL/LOQ	MDL/LOD	Test Conc.	VER Recovery	RSD	Mean Recovery	OPR Recovery	Test Conc.	VER Recovery	RSD	Mean Recovery	OPR Recovery	Sample Recovery
PCB-1	NA	pg/g	4	0.06	2	0.03	50	75 - 125%	25%	70 - 130%	60 - 135%	100	50 -145%	70%	20 - 135%	15 - 145%	5 - 145%
PCB-3	NA	pg/g	4	0.06	2	0.03	50	75 - 125%	25%	70 - 130%	60 - 135%	100	50 -145%	70%	20 - 135%	15 - 145%	5 - 145%
PCB-4	NA	pg/g	4	0.39	2	0.19	50	75 - 125%	25%	70 - 130%	60 - 135%	100	50 -145%	70%	20 - 135%	15 - 145%	5 - 145%
PCB-15	NA	pg/g	4	0.22	2	0.11	50	75 - 125%	25%	70 - 130%	60 - 135%	100	50 -145%	70%	20 - 135%	15 - 145%	5 - 145%
PCB-19	NA	pg/g	4	0.15	2	0.077	50	75 - 125%	25%	70 - 130%	60 - 135%	100	50 -145%	70%	20 - 135%	15 - 145%	5 - 145%
PCB-28	NA	pg/g	4	0.11	2	0.056	50	75 - 125%	25%	70 - 130%	60 - 135%	100	65 -135%	70%	20 - 135%	15 - 145%	5 - 145%
PCB-37	NA	pg/g	4	0.089	2	0.044	50	75 - 125%	25%	70 - 130%	60 - 135%	100	50 -145%	70%	20 - 135%	15 - 145%	5 - 145%
PCB-54	NA	pg/g	4	0.099	2	0.049	50	75 - 125%	25%	70 - 130%	60 - 135%	100	50 -145%	70%	20 - 135%	15 - 145%	5 - 145%
PCB-77	NA	pg/g	4	0.11	2	0.056	50	75 - 125%	25%	70 - 130%	60 - 135%	100	50 -145%	50%	45 - 135%	40 - 145%	10 - 145%
PCB-81	NA	pg/g	4	0.13	2	0.064	50	75 - 125%	25%	70 - 130%	60 - 135%	100	50 -145%	50%	45 - 135%	40 - 145%	10 - 145%
PCB-104	NA	pg/g	4	0.12	2	0.062	50	75 - 125%	25%	70 - 130%	60 - 135%	100	50 -145%	50%	45 - 135%	40 - 145%	10 - 145%
PCB-105	NA	pg/g	4	0.11	2	0.057	50	75 - 125%	25%	70 - 130%	60 - 135%	100	50 -145%	50%	45 - 135%	40 - 145%	10 - 145%
PCB-106	118	pg/g	4	0.12	2	0.06	50	75 - 125%	25%	70 - 130%	60 - 135%	100	50 -145%	50%	45 - 135%	40 - 145%	10 - 145%
PCB-111	115	pg/g	4	0.12	2	0.058	50	75 - 125%	25%	70 - 130%	60 - 135%	100	75 -125%	50%	45 - 135%	40 - 145%	10 - 145%
PCB-114	NA	pg/g	4	0.13	2	0.066	50	75 - 125%	25%	70 - 130%	60 - 135%	100	50 -145%	50%	45 - 135%	40 - 145%	10 - 145%
PCB-118	106	pg/g	4	0.12	2	0.06	50	75 - 125%	25%	70 - 130%	60 - 135%	100	50 -145%	50%	45 - 135%	40 - 145%	10 - 145%
PCB-123	NA	pg/g	4	0.13	2	0.063	50	75 - 125%	25%	70 - 130%	60 - 135%	100	50 -145%	50%	45 - 135%	40 - 145%	10 - 145%
PCB-126	NA	pg/g	4	0.091	2	0.045	50	75 - 125%	25%	70 - 130%	60 - 135%	100	50 -145%	50%	45 - 135%	40 - 145%	10 - 145%
PCB-155	NA	pg/g	4	0.11	2	0.053	50	75 - 125%	25%	70 - 130%	60 - 135%	100	50 -145%	50%	45 - 135%	40 - 145%	10 - 145%
PCB-156	NA	pg/g	4	0.11	2	0.057	50	75 - 125%	25%	70 - 130%	60 - 135%	100	50 -145%	50%	45 - 135%	40 - 145%	10 - 145%
PCB-157	NA	pg/g	4	0.13	2	0.066	50	75 - 125%	25%	70 - 130%	60 - 135%	100	50 -145%	50%	45 - 135%	40 - 145%	10 - 145%
PCB-167	NA	pg/g	4	0.12	2	0.06	50	75 - 125%	25%	70 - 130%	60 - 135%	100	50 -145%	50%	45 - 135%	40 - 145%	10 - 145%
PCB-169	NA	pg/g	4	0.089	2	0.045	50	75 - 125%	25%	70 - 130%	60 - 135%	100	50 -145%	50%	45 - 135%	40 - 145%	10 - 145%
PCB-178	NA	pg/g	4	0.19	2	0.093	50	75 - 125%	25%	70 - 130%	60 - 135%	100	75 -125%	50%	45 - 135%	40 - 145%	10 - 145%
PCB-188	NA	pg/g	4	0.11	2	0.056	50	75 - 125%	25%	70 - 130%	60 - 135%	100	50 -145%	50%	45 - 135%	40 - 145%	10 - 145%
PCB-189	NA	pg/g	4	0.083	2	0.042	50	75 - 125%	25%	70 - 130%	60 - 135%	100	50 -145%	50%	45 - 135%	40 - 145%	10 - 145%
PCB-202	NA	pg/g	4	0.11	2	0.054	50	75 - 125%	25%	70 - 130%	60 - 135%	100	50 -145%	50%	45 - 135%	40 - 145%	10 - 145%
PCB-205	NA	pg/g	4	0.06	2	0.03	50	75 - 125%	25%	70 - 130%	60 - 135%	100	50 -145%	50%	45 - 135%	40 - 145%	10 - 145%
PCB-206	NA	pg/g	4	0.098	2	0.049	50	75 - 125%	25%	70 - 130%	60 - 135%	100	50 -145%	50%	45 - 135%	40 - 145%	10 - 145%
PCB-208	NA	pg/g	4	0.068	2	0.034	50	75 - 125%	25%	70 - 130%	60 - 135%	100	50 -145%	50%	45 - 135%	40 - 145%	10 - 145%
PCB-209	NA	pg/g	4	0.049	2	0.024	50	75 - 125%	25%	70 - 130%	60 - 135%	100	50 -145%	50%	45 - 135%	40 - 145%	10 - 145%

Notes:

1. Method 1668 defines quality assurance goals for the subset of congeners above rather than for all 209 congeners. All 209 congeners will be reported in this project. Meeting the requirements for the congeners tabulated above is deemed by the method as sufficient to demonstrate acceptable performance for all 209 congeners.
2. Chromatographic co-elution occurs when two (or more) compounds do not chromatographically separate due to the fact that both species have retention times that differ by less than the resolution of the method. The concentration is reported for the first co-eluting congener only. All co-eluting congeners receive a qualifier that indicates the congener that receives the value.

Abbreviations:

Conc. Concentration
EPA U.S. Environmental Protection Agency
IPR Initial precision and recovery
LOD Limit of detection
LOQ Limit of quantification
MDL Method detection limit
NA Not applicable
OPR Ongoing precision and recovery
PCB Polychlorinated biphenyl
pg/g Picograms per gram
RL Reporting limit
RSD Relative standard deviation
SPME Solid-phase microextraction
VER Calibration verification

Table 3.6
Methods and Acceptable Quality Assurance Criteria for Chemistry in Sediment Samples

Parameter	Analytical Method	Lab	Units	Sensitivity [1]		Precision[2]	Accuracy[3]	Completeness[4]
				RL/LOQ	MDL/LOD			
Metals								
Arsenic	EPA 6020A	Alpha	mg/kg dw	0.05	0.0062	20%RPD	75-125%R	95%
Cadmium	EPA 6020A	Alpha	mg/kg dw	0.02	0.0026	20%RPD	75-125%R	95%
Chromium	EPA 6020A	Alpha	mg/kg dw	0.2	0.047	20%RPD	75-125%R	95%
Copper	EPA 6020A	Alpha	mg/kg dw	0.2	0.011	20%RPD	75-125%R	95%
Lead	EPA 6020A	Alpha	mg/kg dw	0.06	0.019	20%RPD	75-125%R	95%
Mercury	EPA 7474	Alpha	mg/kg dw	0.013	0.0016	20%RPD	80-120%R	95%
Silver	EPA 6020A	Alpha	mg/kg dw	0.05	0.0011	20%RPD	75-125%R	95%
Zinc	EPA 6020A	Alpha	mg/kg dw	1	0.26	20%RPD	75-125%R	95%
Organic Compounds								
4-methylphenol	EPA 8270D	Alpha	µg/kg dw	33	4	30%RPD	30-130%	95%
2,4-dimethylphenol	EPA 8270D	Alpha	µg/kg dw	33	5	30%RPD	30-130%	95%
Benzoic acid	EPA 8270D	Alpha	µg/kg dw	2000	420	30%RPD	40-140%	95%
Benzyl alcohol	EPA 8270D	Alpha	µg/kg dw	67	22	30%RPD	40-140%	95%
Pentachlorophenol	EPA 8270D	Alpha	µg/kg dw	200	60	30%RPD	30-130%	95%
Phenol	EPA 8270D	Alpha	µg/kg dw	33	3	30%RPD	30-130%	95%
Acenaphthene	EPA 8270D	Alpha	µg/kg dw	33	3	30%RPD	40-140%	95%
Anthracene	EPA 8270D	Alpha	µg/kg dw	33	2	30%RPD	40-140%	95%
Benzo(a)pyrene	EPA 8270D	Alpha	µg/kg dw	33	2	30%RPD	40-140%	95%
Benz(a)anthracene	EPA 8270D	Alpha	µg/kg dw	33	2	30%RPD	40-140%	95%
Total benzofluoranthenes	EPA 8270D	Alpha	µg/kg dw	33	3	30%RPD	40-140%	95%
Benzo(g,h,i)perylene	EPA 8270D	Alpha	µg/kg dw	33	3	30%RPD	40-140%	95%
Chrysene	EPA 8270D	Alpha	µg/kg dw	33	2	30%RPD	40-140%	95%
Dibenz(a,h)anthracene	EPA 8270D	Alpha	µg/kg dw	33	3	30%RPD	40-140%	95%
Indeno(1,2,3-cd)pyrene	EPA 8270D	Alpha	µg/kg dw	33	3	30%RPD	40-140%	95%
Fluoranthene	EPA 8270D	Alpha	µg/kg dw	33	3	30%RPD	40-140%	95%
Fluorene	EPA 8270D	Alpha	µg/kg dw	33	2	30%RPD	40-140%	95%
Naphthalene	EPA 8270D	Alpha	µg/kg dw	33	2	30%RPD	40-140%	95%

Table 3.6
Methods and Acceptable Quality Assurance Criteria for Chemistry in Sediment Samples

Parameter	Analytical Method	Lab	Units	Sensitivity [1]		Precision[2]	Accuracy[3]	Completeness[4]
				RL/LOQ	MDL/LOD			
Organic Compounds (continued)								
Phenanthrene	EPA 8270D	Alpha	µg/kg dw	33	2	30%RPD	40-140%	95%
Pyrene	EPA 8270D	Alpha	µg/kg dw	33	3	30%RPD	40-140%	95%
Bis(2-ethylhexyl)phthalate	EPA 8270D	Alpha	µg/kg dw	33	9	30%RPD	40-140%	95%
Butyl benzyl phthalate	EPA 8270D	Alpha	µg/kg dw	33	7	30%RPD	40-140%	95%
Dimethyl phthalate	EPA 8270D	Alpha	µg/kg dw	33	3	30%RPD	40-140%	95%
1,2-dichlorobenzene	EPA 8270D	Alpha	µg/kg dw /kg OC	33	7	30%RPD	40-140%	95%
1,4-dichlorobenzene	EPA 8270D	Alpha	µg/kg dw	33	7	30%RPD	40-140%	95%
1,2,4-trichlorobenzene	EPA 8270D	Alpha	µg/kg dw	33	2	30%RPD	40-140%	95%
2-methylnaphthalene	EPA 8270D	Alpha	µg/kg dw	33	3	30%RPD	40-140%	95%
Dibenzofuran	EPA 8270D	Alpha	µg/kg dw	33	2	30%RPD	40-140%	95%
Hexachlorobenzene	EPA 8270D	Alpha	µg/kg dw	33	3	30%RPD	40-140%	95%
n-Nitrosodiphenylamine	EPA 8270D	Alpha	µg/kg dw	33	2	30%RPD	40-140%	95%
Polychlorinated biphenyls Congeners[5]								
PCB Congeners	EPA 1668C	Frontier	ng/kg dw	16	16	50%RPD	40-140%R	95%
Dioxins/Furans Congeners[6]								
2,3,7,8-TCDD	EPA 1613	Frontier	ng/kg dw	0.5	0.0276	67-158	78-129	95%
1,2,3,7,8-PeCDD	EPA 1613	Frontier	ng/kg dw	2.5	0.0348	70-142	78-130	95%
1,2,3,4,7,8-HxCDD	EPA 1613	Frontier	ng/kg dw	2.5	0.0329	70-164	78-128	95%
1,2,3,6,7,8-HxCDD	EPA 1613	Frontier	ng/kg dw	2.5	0.0361	76-134	78-128	95%
1,2,3,7,8,9-HxCDD	EPA 1613	Frontier	ng/kg dw	2.5	0.0328	64-162	82-122	95%
1,2,3,4,6,7,8-HpCDD	EPA 1613	Frontier	ng/kg dw	2.5	0.0964	70-140	86-116	95%
OCDD	EPA 1613	Frontier	ng/kg dw	5	0.175	78-144	79-126	95%
2,3,7,8-TCDF	EPA 1613	Frontier	ng/kg dw	0.5	0.0255	75-158	84-120	95%
1,2,3,7,8-PeCDF	EPA 1613	Frontier	ng/kg dw	2.5	0.0267	80-134	82-120	95%
2,3,4,7,8-PeCDF	EPA 1613	Frontier	ng/kg dw	2.5	0.0268	68-160	82-122	95%

Table 3.6
Methods and Acceptable Quality Assurance Criteria for Chemistry in Sediment Samples

Parameter	Analytical Method	Lab	Units	Sensitivity [1]		Precision[2]	Accuracy[3]	Completeness[4]
				RL/LOQ	MDL/LOD			
Dioxins/Furans (continued)								
1,2,3,4,7,8-HxCDF	EPA 1613	Frontier	ng/kg dw	2.5	0.0237	72-134	90-112	95%
1,2,3,6,7,8-HxCDF	EPA 1613	Frontier	ng/kg dw	2.5	0.0232	84-130	88-114	95%
1,2,3,7,8,9-HxCDF	EPA 1613	Frontier	ng/kg dw	2.5	0.027	78-130	90-112	95%
2,3,4,6,7,8-HxCDF	EPA 1613	Frontier	ng/kg dw	2.5	0.0335	70-156	88-114	95%
1,2,3,4,6,7,8-HpCDF	EPA 1613	Frontier	ng/kg dw	2.5	0.0398	82-122	90-110	95%
1,2,3,4,7,8,9-HpCDF	EPA 1613	Frontier	ng/kg dw	2.5	0.0489	78-138	86-116	95%
OCDF	EPA 1613	Frontier	ng/kg dw	5	0.0876	63-170	63-159	95%

Notes:

1. Sensitivity is assessed by the use of initial and continuing calibration and laboratory control samples.
2. Precision is assessed by the use of laboratory control samples and laboratory duplicates.
3. Accuracy is assessed by calibration, laboratory control samples, and matrix spikes/matrix spike duplicates.
4. Completeness is measured as the number of results that are acceptable for use vs. the number of samples analyzed.
5. Precision and accuracy are assessed following procedures in Section 9 of the method; values shown above are within the method criteria of Table 6 of the method.
6. Precision and accuracy are assessed following procedures in Section 9 of the method; values shown above based on Table 6 of the method.

Abbreviations:

Alpha	Alpha Analytical Laboratory
EPA	U.S. Environmental Protection Agency
LOD	Limit of detection
LOQ	Limit of quantification
MDL	Method detection limit
mg/kg dw	Milligrams per kilogram dry weight
NA	Not applicable
ng/kg dw	Nanograms per kilogram dry weight
PCB	Polychlorinated biphenyl
R	Recovery
RL	Reporting limit
RPD	Relative percent difference
µg/kg dw	Micrograms per kilogram dry weight

Table 3.7
Laboratory QA/QC Requirements

Parameter	Analytical Method	Initial Calibration	Continuing Calibration	Method Blanks	Laboratory Control Samples	Sample Matrix Quality Control			Surrogate Spikes
						Matrix Spike	Matrix Spike Duplicate	Laboratory Duplicate or Triplicate	
Sediment									
PCB congeners	EPA 1668C	Prior to analysis	Every 10 to 20 analyses or 12 hours	1 per batch[1]	1 per batch[1]	Handled by use of isotope dilution in EPA 1668C		NA	Each sample
ENR Substrate (Baseline Event Only)[2]									
SMS Metals (except Hg)	EPA 6020A	Prior to analysis	Every 10 samples	1 per batch[1]	1 per batch[1]	1 per SDG[1]	NA	1 per 20 samples	NA
SMS Hg	EPA 7474	Prior to analysis	Every 10 samples	1 per batch[1]	1 per batch[1]	1 per SDG[1]	1 per SDG[1]	NA	NA
SMS SVOCs	EPA 8270D	Prior to analysis	Every 12 hours	1 per batch[1]	1 per batch[1]	1 per SDG[1]	1 per SDG[1]	NA	Each sample
PCB congeners	EPA 1668C	Prior to analysis	Every 10 to 20 analyses or 12 hours	1 per batch[1]	1 per batch[1]	Handled by use of isotope dilution in EPA 1668C		NA	Each sample
Dioxins/Furans	EPA 1613	Prior to analysis	Beginning and end of every analytical run	1 per batch[1]	1 per batch[1]	Handled by use of isotope dilution in EPA 1613		NA	Each sample
Sediment and ENR Substrate (Baseline Event Only)[2]									
Total organic carbon	EPA 9060	Daily	Every 10 samples	1 per batch[1]	1 per batch[1]	1 per SDG[1]	NA	duplicate per SDG	N/A
Black carbon	Gustafsson et al. (1997)	Daily	Every 10 samples	1 per batch[1]	1 per batch[1]	1 per SDG[1]	NA	duplicate per SDG	N/A
Grain size	ASTM D422	NA	NA	NA	NA	NA	NA	triplicate per SDG	N/A

Table 3.7
Laboratory QA/QC Requirements

Parameter	Analytical Method	Initial Calibration	Continuing Calibration	Method Blanks	Laboratory Control Samples	Sample Matrix Quality Control			Surrogate Spikes
						Matrix Spike	Matrix Spike Duplicate	Laboratory Duplicate or Triplicate	
SPME Fiber Extracts									
PCB congeners	EPA 1668C	Prior to analysis	Every 10 to 20 analyses or 12 hours	1 per batch[1]	1 per batch[1]	Handled by use of isotope dilution in EPA 1668C		NA	Each sample

Notes:

1. Project SDGs are expected to range in size from 1 sample to 20 samples. Batches are groups of 20 or fewer samples that move through sample preparation and analysis together. A batch formed at the lab may include samples from more than one SDG, and the SDGs in a batch may be from multiple projects. In the table above "per SDG" indicates that the "batch" QC must be run on a sample from the SDG from the project.
2. Granular activated carbon will be analyzed for PCB congeners only.

Abbreviations:

ASTM American Society for Testing Materials
EPA U.S. Environmental Protection Agency
ENR Enhanced natural recovery
Hg Mercury
NA Not applicable
PAHs Polycyclic Aromatic Hydrocarbons
PCB Polychlorinated biphenyl
SDG Sample Delivery Group
SMS Sediment Management Standards
SPME Solid-phase microextraction
SU Salinity Unit

Table 3.8
Average Method Detection Limits for Freely-Dissolved PCB Congeners (by Homolog) in Sediment Porewater

						Lowest Achievable MDL in Porewater (Complete Equilibrium Exposure)	MDL in Porewater (4-Week Exposure)		Expected Average Pilot Study Concentrations of PCB in Porewater (pg/L)		
Length Fiber (cm)	PCB Homolog	MDL[1] (ng)	K_{fs}[2] (L/L_{PDMS})	Volume of PDMS on Fiber (µL)	Concentration of PCB in PDMS (ng/L)	Concentration of PCB in Porewater (pg/L)	Percent to Equilibrium[3]	Concentration of PCB in Porewater (pg/L)	Baseline[4]	Post-Treatment[5]	Method Sensitivity
480	Tri	0.50	260,000	33.17	15,075	58	87%	66	970	97 - 194	Adequate
480	Tetra	0.50	700,000	33.17	15,075	22	71%	30	740	74 - 148	Adequate
480	Penta	0.50	2,000,000	33.17	15,075	7.5	52%	15	1,300	130 - 260	Adequate
480	Hexa	0.50	5,000,000	33.17	15,075	3.0	37%	8.2	400	40 - 80	Adequate
480	Hepta	0.50	13,000,000	33.17	15,075	1.2	25%	4.7	60	6 - 12	Adequate
480	Octa	0.50	36,000,000	33.17	15,075	0.4	**15%**	2.7	7.0	0.7 - 1.4	Some results may be flagged as estimated values, and most post-treatment results likely to below detection limit.

Notes:

1. 5 picograms per 1 µL injection is the MDL. The 1800-µL SPME hexane extract is concentrated to approximately 100 µL.
2. Approximate average for homolog group as referenced from Smedes et al. (2009).
3. Based on sampling results from a sampling event at Bremerton, WA activated carbon amendment site. When the percentage is less than 20% (**bold and red font**), analytical results for congeners within those homologs may be flagged as estimated (J-flag or equivalent) values.
4. Calculations are provided in Table 5.c. Average Concentration of PCB Congener Detections in Porewater, as Estimated by Two-Carbon Model.
5. Assuming 80-90% reduction in PCBs from baseline.

Abbreviations:

µL	Microliter
cm	Centimeter
K_{fs}	Fiber PDMS-Solution Water Partition Coefficient
L	Liter
MDL	Method detection limit
ng	Nanogram
PCB	Polychlorinated biphenyl
PDMS	Polydimethylsiloxane
pg	Picogram
SPME	Solid-phase microextraction

FIGURES

Legend

- Total PCBs Sample Location
- Plot Area
- 10 ft contour
- 5 ft contour
- 1 ft contour
- Navigation Channel
- 1.2 River Mile Markers

Notes:
- All results are for surface sediments (0-10 cm).
- Units for analytical results are in µg/kg DW or mg/kg-OC.
- Bathymetry units are in feet MLLW.
- Orthoimage provided by USGS, 2012.

Abbreviations:
AC = Activated Carbon
cm = centimeter
DW = Dry Weight
ENR = Enhanced Natural Recovery
J = Concentration is estimated but acceptable for most uses
µg/kg = micrograms per kilogram
mg/kg-OC = milligrams per kilogram organic carbon normalized
OC = Organic carbon normalized
PCB = Polychlorinated biphenyl
MLLW = Mean Lower Low Water

N

0 25 50 100
Scale in Feet

CH0030:
Total PCBs µg/kg DW: 83 J
Total PCBs mg/kg-OC: 4.3 J

LDW-PILOT6A-SS1:
Total PCBs µg/kg DW: 460
Total PCBs mg/kg-OC: 28

LDW-PILOT6A-SS2:
Total PCBs µg/kg DW: 202
Total PCBs mg/kg-OC: 10.4

LDW-PILOT6A-SS3:
Total PCBs µg/kg DW: 290
Total PCBs mg/kg-OC: 13

LDW-SS40:
Total PCBs µg/kg DW: 510 J
Total PCBs mg/kg-OC: 27 J

LDW-PILOT6A-SS4:
Total PCBs µg/kg DW: 1530
Total PCBs mg/kg-OC: 80.5

LDW-PILOT6B-SS2:
Total PCBs µg/kg DW: 1470
Total PCBs mg/kg-OC: 116

LDW-PILOT6B-SS1:
Total PCBs µg/kg DW: 2900
Total PCBs mg/kg-OC: 180

LDW-PILOT6B-SS4:
Total PCBs µg/kg DW: 450 J
Total PCBs mg/kg-OC: 68 J

DR075:
Total PCBs µg/kg DW: 118
Total PCBs mg/kg-OC: 5.11

ENR+AC West Lane

ENR Only East Lane

-30 -20 -10 0 1.2

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Figure 1.1
Subtidal Plot

I:\GIS\Projects\AMEC-KC-ENR\MXD\Document 2015_0422\Figure 1.1 Subtidal Plot.mxd
6/12/2015

Legend

- Total PCBs Sample Location
- Plot Area
- Berthing Area
- 10 ft contour
- 5 ft contour
- 1 ft contour

Notes:
- All results are for surface sediments (0-10 cm).
- Units for analytical results are in µg/kg DW or mg/kg-OC.
- Bathymetry units are in feet MLLW.
- Orthoimage provided by USGS, 2012.

Abbreviations:
AC = Activated Carbon
cm = centimeter
DW = Dry Weight
ENR = Enhanced Natural Recovery
J = Concentration is estimated but acceptable for most uses
µg/kg = micrograms per kilogram
mg/kg-OC = milligrams per kilogram organic carbon normalized
OC = Organic carbon normalized
PCB = Polychlorinated biphenyl
MLLW = Mean Lower Low Water

N

0 25 50 100

Scale in Feet

ENR+AC Downstream Subplot

ENR Upstream Subplot

LDW-PILOT1A-SS1:
Total PCBs µg/kg DW: 208
Total PCBs mg/kg-OC: 14.6

LDW-PILOT1A-SS2:
Total PCBs µg/kg DW: 440
Total PCBs mg/kg-OC: 26

LDW-SS6:
Total PCBs µg/kg DW: 1920
Total PCBs mg/kg-OC: 183

LDW-PILOT1A-SS3:
Total PCBs µg/kg DW: 239
Total PCBs mg/kg-OC: 6.81

LDW-PILOT1A-SS4:
Total PCBs µg/kg DW: 172
Total PCBs mg/kg-OC: 6.83

LDW-PILOT1B-SS1:
Total PCBs µg/kg DW: 225
Total PCBs mg/kg-OC: 23.3

LDW-PILOT1B-SS2:
Total PCBs µg/kg DW: 260
Total PCBs mg/kg-OC: 7.6

LDW-SS7:
Total PCBs µg/kg DW: 240
Total PCBs mg/kg-OC: 8.82

LDW-SS305:
Total PCBs µg/kg DW: 590 J
Total PCBs mg/kg-OC: 20 J

LDW-PILOT1B-SS3:
Total PCBs µg/kg DW: 260
Total PCBs mg/kg-OC: 9.2

LDW-PILOT1B-SS4:
Total PCBs µg/kg DW: 213
Total PCBs mg/kg-OC: 9.42

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Figure 1.2
Scour Plot

I:\GIS\Projects\AMEC-KC-ENR\MXD\Document 2015_0422\Figure 1.2 Scour Plot.mxd
6/12/2015

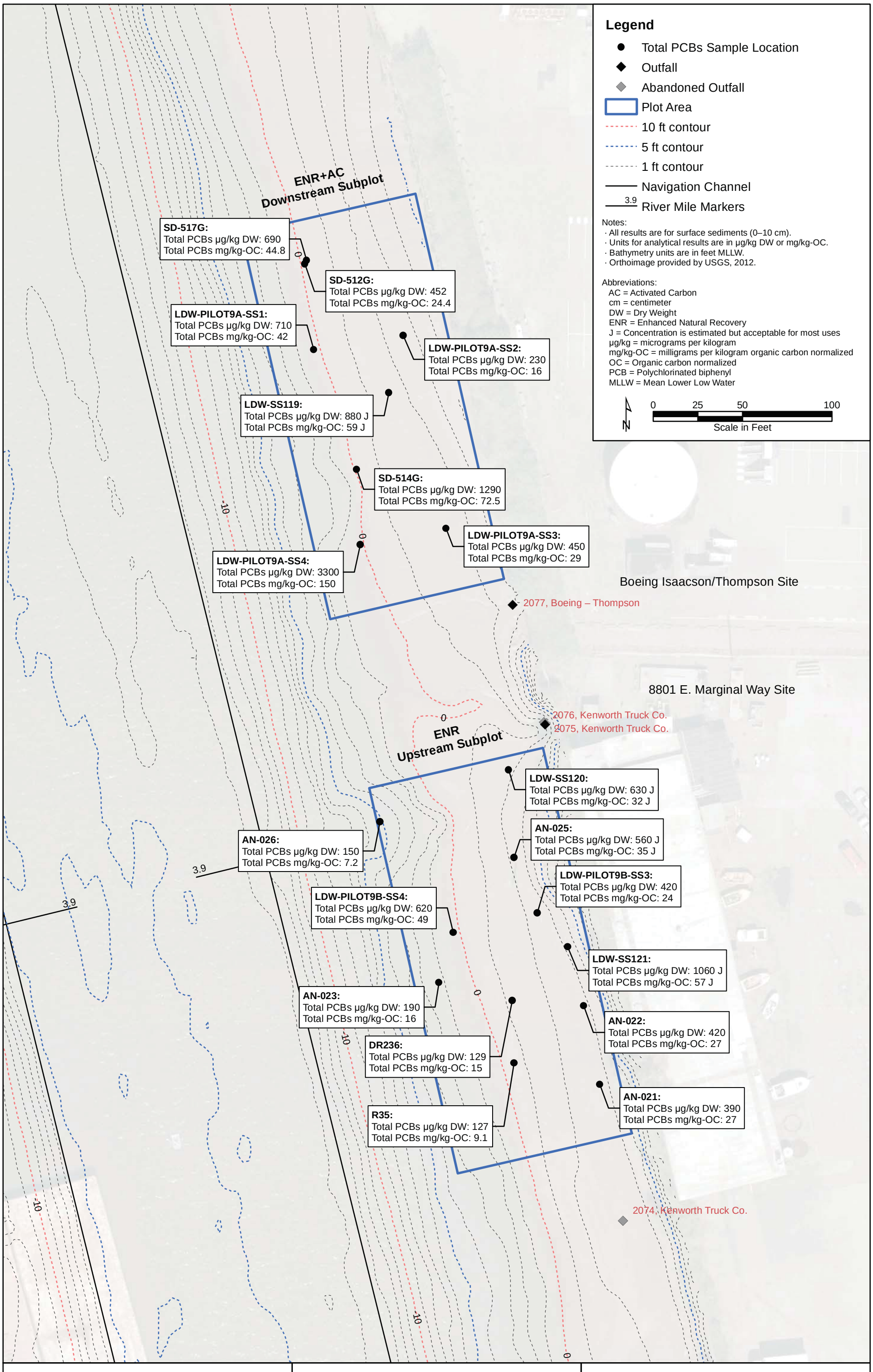

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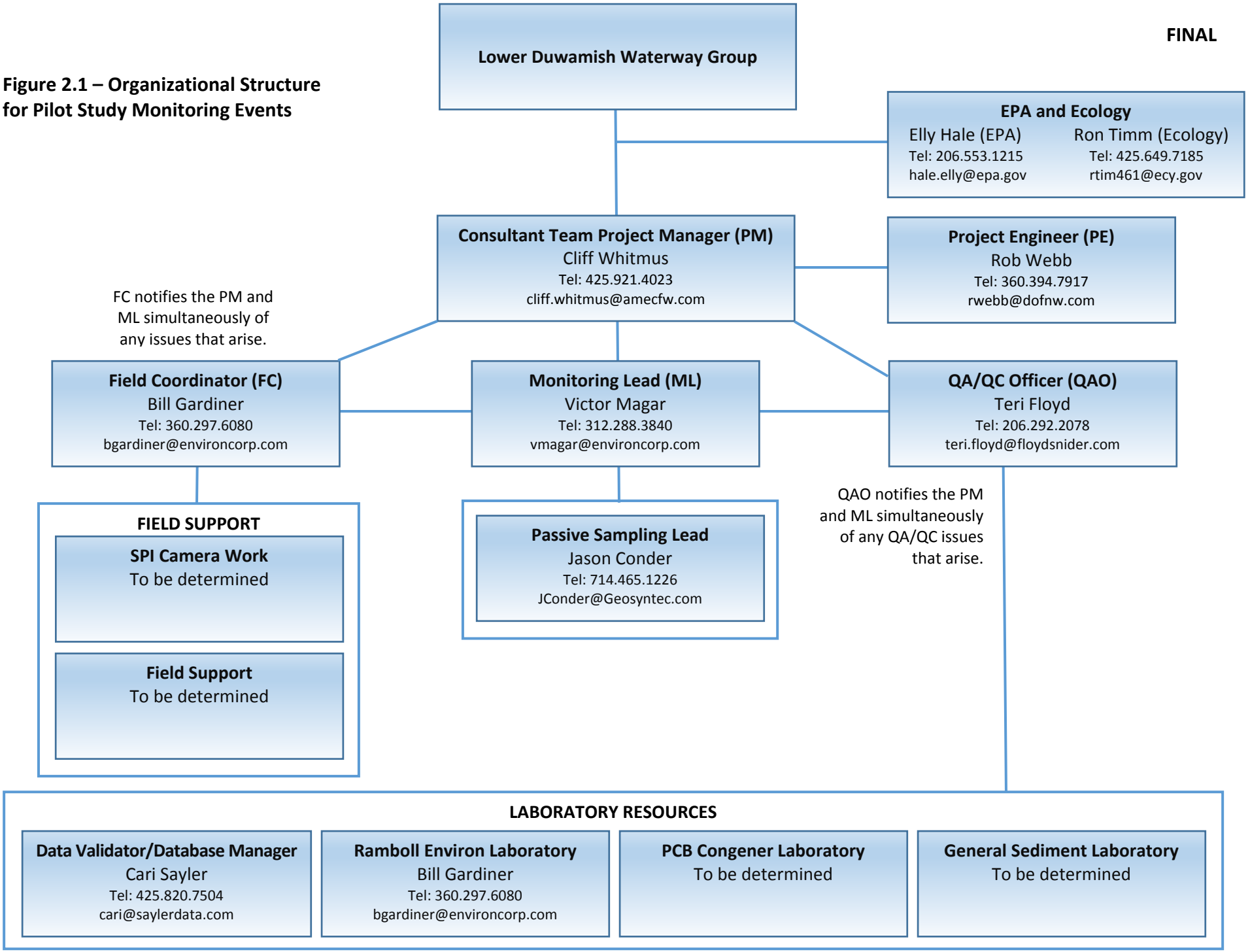
Figure 1.3
Intertidal Plot

I:\GIS\Projects\AMEC-KC-ENR\MXD\Document 2015_0422\Figure 1.3 Intertidal Plot.mxd
6/12/2015

Figure 2.1 – Organizational Structure for Pilot Study Monitoring Events



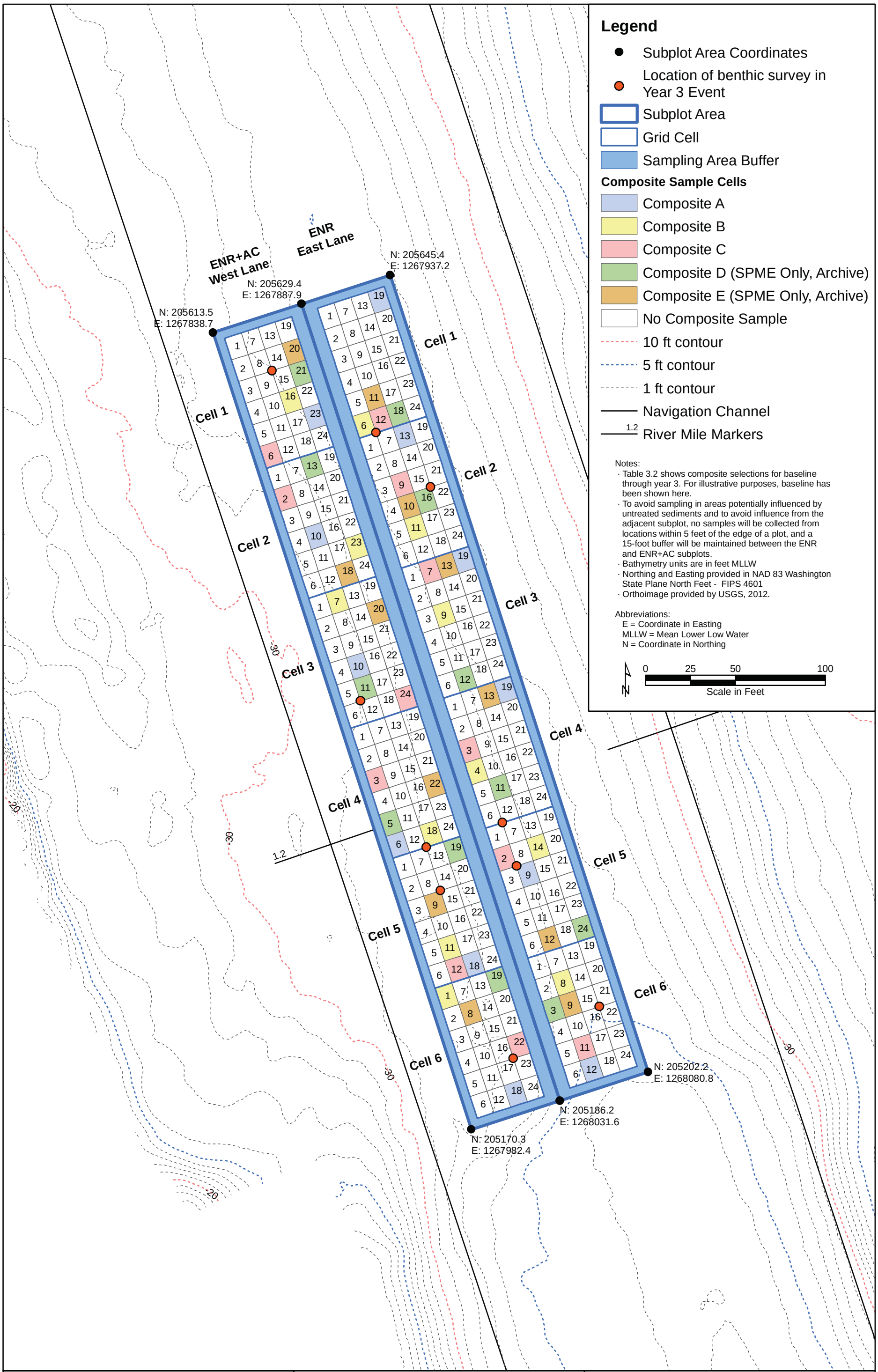


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Figure 3.1
Subtidal Plot
Sample Composite Grid

I:\GIS\Projects\AMEC-KC-ENR\MXD\Document 2015_0422\Figure 3.1 Subtidal Plot with Sample Composite Grid.mxd
10/19/2015

Legend

- Subplot Coordinates
- Location of benthic survey in Year 3 Event
- Outfall
- Berthing
- Uplands Tax Parcel
- Subplot Area
- Grid Cells
- Sampling Area Buffer

Composite Sample Cells

- Composite A
- Composite B
- Composite C
- Composite D (SPME Only, Archive)
- Composite E (SPME Only, Archive)
- No Composite Sample
- Cell Removed From Analysis
- 10 ft contour
- 5 ft contour
- 1 ft contour

Notes:

· Table 3.2 shows composite selections for baseline through year 3. For illustrative purposes, baseline has been shown here.

· To avoid sampling in areas potentially influenced by untreated sediments and to avoid influence from the adjacent subplot, no samples will be collected from locations within 5 feet of the edge of a plot, and a 15-foot buffer will be maintained between the ENR and ENR+AC subplots.

· Bathymetry units are in feet MLLW

· Northing and Easting provided in NAD 83 Washington State Plane North Feet - FIPS 4601

· Orthoimage provided by USGS, 2012.

Abbreviations:

E = Coordinate in Easting
MLLW = Mean Lower Low Water
N = Coordinate in Northing

N

0 25 50 100

Scale in Feet

2154, Port of Seattle

ENR+AC Downstream Subplot

N: 211257.9
E: 1267009.2

N: 211223.5
E: 1267122.2

N: 211168.3
E: 1267138.2

N: 211114.3
E: 1266965

N: 211070.7
E: 1267108.5

ENR Upstream Subplot

N: 210975.3
E: 1266922.8

N: 210932.1
E: 1267065

Grid 1
Grid 2
Grid 3
Grid 4
Grid 5
Grid 6

-20
-10
0
10
20
30

Lower Duwamish Waterway Group Port of Seattle / City of Seattle / King County / The Boeing Company	**ENR/AC Pilot Study** **Quality Assurance Project Plan** Lower Duwamish Waterway	**FINAL** Figure 3.2 Scour Plot Sample Composite Grid

I:\GIS\Projects\AMEC-KC-ENR\MXD\Document 2015_0422\Figure 3.2 Scour Plot with Sample Composite Grid.mxd
10/19/2015

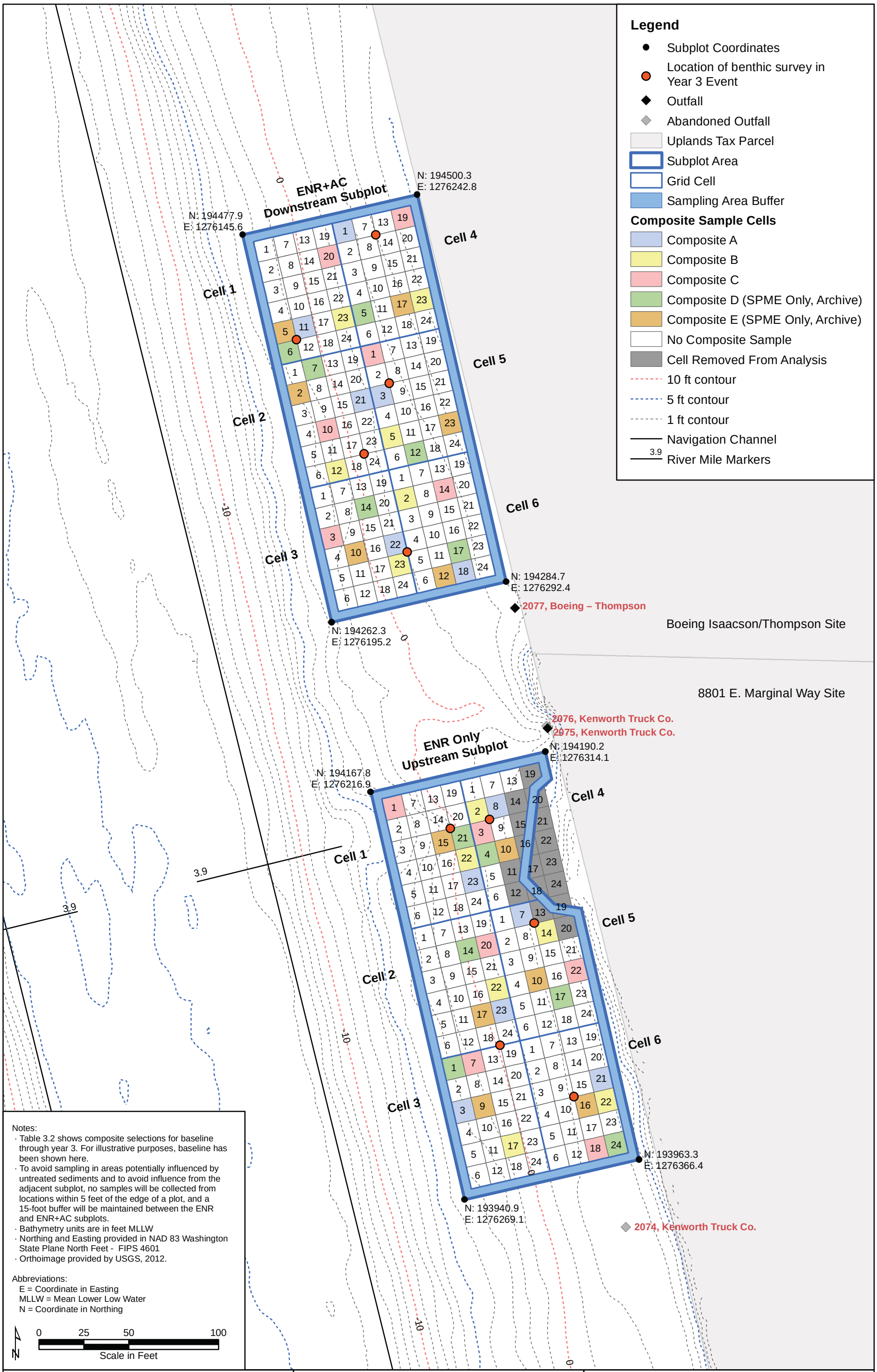

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Figure 3.3
Intertidal Plot
Sample Composite Grid

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ATTACHMENT A

Field Forms

QUALITY ASSURANCE PROJECT PLAN
Attachment A – Sample Forms for Contractor Daily Report
Lower Duwamish Waterway

1.0 INTRODUCTION

The forms contained in this Attachment are representative forms that have been used on previous projects. The actual field forms will be similar but may differ and may evolve during the course of the multi-year monitoring program. It is also expected that several of the forms will become electronic forms designed for direct input into project electronic records and database.

1.1 LOCATION INFORMATION

Location information will be recorded on a sampling station location log that may be a Microsoft Excel® table. The table will include information on the weather and waterway conditions; position checks with the fixed control checkpoint; and station-specific information (DGPS coordinates, water depth, date, and time). If the station is occupied for more than 1 hour or for the collection of more than one type of sample, the information will be measured and recorded again for the additional samples so that no more than 1 hour passes between measurements.

The log will include the DGPS coordinates for the proposed sampling location that is developed from the information in Table 3.2 of the QAPP. No example form is included.

1.2 PHOTOGRAPHIC INFORMATION

Three types of photographic information may be collected for this project:

- Paired In-water images of one or more sediment profile images and a plan view image of the location where the sediment profile image(s) are collected.
- Images of the shallow sediment cores as they are being processed to document the conditions encountered.
- Occasional photographs collected in the field to augment field notes.

All photographs will be assigned a unique number and will be entered into the photo log. A representative photo log is attached.

1.3 SEDIMENT SAMPLING INFORMATION

Sediment sampling information for this project will be collected from shallow sediment cores collected by diver (or wader in the case of the intertidal plot). The field technician will complete a surface sediment core sample collection (attached). Photographs of the core during processing will be recorded on the photograph log form and cross-referenced to the surface sediment core sample collection form.

1.4 SEDIMENT AND POREWATER COMPOSITING FORMS

Forms: Compositing information will be recorded on the Sediment Composite Log. Chain-of-custody forms will also be completed for transfer of the sample jars to the laboratories under custody (see Section 4.3.1).

Forms: The analyst will complete a SPME preparation form (QAPP Attachment A) for each batch of SPME fibers. The form will document the source of the base fibers, their purchase date, reference vendor-supplied information, reference to the analysis of the cleaned fiber, a list of the PRCs used and their concentrations in the soaking solutions, and a reference to the analysis of the PRC-loaded fiber.

Forms: SPME deployment and recovery forms (Appendix A) will be used to record the batch ID, discrete and composite sample IDs, coordinates, dates and times of deployment and retrieval, water depths, depth of ENR or ENR/AC and diver observations for each sample.

Forms: The compositing step will be documented on the SPME extraction and compositing form (QAPP Attachment A).

Forms: Information related to the collection of the grab samples for benthic macroinvertebrate analysis will be recorded on the Sediment Grab Log. Chain-of-custody forms will be completed for transfer of the sample jars to the Ramboll Environ laboratory. Benthic taxa identified during the sorting and identification will be recorded on “infaunal sample identification and sorting” sheets.

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Representative Form

The format of the final form may be different and may evolve during the multi-year monitoring project.

Photo Log

Photo File Number	Date	Time	SPI	Plan View Aquatic	Other activity (describe)	Location Description

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Diver Core Log

PROJECT/SURVEY			DATE	SAMPLER	RECORDER
STATION ID			NAV DATUM	LATITUDE	LONGITUDE
ATTEMPT of	TIME STARTED	TIME FINISHED	WATER DEPTH (FT)	TIDE (FT)	MLLW (FT) = WATER DEPTH - TIDE
DRIVE METHOD	PENETRATION DEPTH (cm)		TARGET CORE LENGTH (cm)	RECOVERY (cm)	CORE DIAMETER (cm)

Depth (cm)	SEDIMENT TYPE	ODOR	COLOR	SAMPLE ID BY DEPTH	MISC
5					
10					
15					
20					
25					
30					
35					
40					
45					
50					

NOTES

Representative Form

The format of the final form may be different and may evolve during the multi-year monitoring project.

COMPOSITE CREATION FORM

COMPOSITE ID: _____

Media:	☐ Sediment ☐ SPME Fibers	**Sampling Event:**	☐ Baseline ☐ Year 0	☐ Year 1 ☐ Year 2	☐ Year 3 ☐ EXTRA
Date of Sampling:		**Plot:**	☐ Subtidal ☐ Scour ☐ Intertidal	**Subplot:**	☐ ENR Only ☐ ENR+AC
Date of Composing:					
Sampling Personnel:		**Compositing Personnel:**			

Discrete Sample ID	**Bowl/vial weight (g)**	**Sample Notes**	**FOR SEDIMENT COMPOSITES ONLY:**	
	Tare wt		**Pre-sieve Jars to fill:**	☐ Grain size ☐ Archive ☐ Salinity (intertidal)
Sample ID 1	*With Sample 1*			
Sample ID 2	*With Sample 2*		**Total wt pre sieve (g)**	*Reweighted bowl*
Sample ID 3	*With Sample 3*		**Weight of gravel (g)**	*Wt of gravel removed*
Sample ID 4	*With Sample 4*		**Total wt post sieve (g)**	*difference*
Sample ID 5	*With Sample 5*		**Post-sieve jars to fill:**	☐ TOC + BC ☐ PCB congeners ☐ Sieved archive (optional)
Sample ID 6	*With Sample 6*			
Extra sample (optional)	*Total bowl + composite*			

Additional Compositing Notes:

Representative Form
The format of the final form may be different and may evolve during the multi-year monitoring project.

SPME PREPARATION FORM

Basic Information

Batch ID:		Number of Envelopes per Batch:
Fiber Silica Diameter (µm):	Fiber PDMS Coating Thickness (µm):	Envelope Steel Mesh Specifications (mesh size, mesh opening):
Length of Individual Fibers (cm):		Number of Fibers per Envelope:
Vendor:		Purchase Date:
Vendor Supplied Fiber Information:		

Fiber Pre-Cleaning

Date:	Personnel:
Last Blank Fiber Analysis Date (attach analytical results):	

Performance Reference Compound Loading

Date of Removal from PRC Soaking Solution:	Personnel:
PCB Congeners Used as PRCs (Concentration in Soaking Solution):	
Duration of PRC Loading:	Roller Rotations per Minute:
Expected PRC Concentration in PDMS (ng PCB/L PDMS):	

Storage Conditions

Location	Start Date	End Date	Temperature (˚C)	Notes

Representative Form

The format of the final form may be different and may evolve during the multi-year monitoring project.

SPME DEPLOYMENT FORM										
Sampling Event:				Plot:					Subplot:	
Date:				Personnel:						
Grid Cell	Batch ID	Discrete Sample ID	Latitude	Longitude	Time	Water Depth (ft)	Tide (ft)	Water Depth (ft MLLW)	Depth of ENR or ENR/AC [1]	Diver Observations
1										
2										
3										
4										
5										
6										

[1] Depth of ENR or ENR/AC must be 80% of target depth to be an acceptable SPME sample location

Deployment Notes:

Representative Form

The format of the final form may be different and may evolve during the multi-year monitoring project.

SPME RETRIEVAL FORM						
Sampling Event:		Plot:			Subplot:	
Date:		Personnel:				
SPME Envelope Deployment Position – Check one box: ☐ 0-10 cm SPMEs -or- ☐ 0-1 cm sediment-water interface SPMEs						
Grid Cell	Discrete Sample ID	Time	Length of SPME Envelope Above Sediment Surface (cm)	Length of SPME Envelope Below Sediment Surface (cm)	SPME Envelope Condition	Diver Observations
1						
2						
3						
4						
5						
6						

Retrieval Notes:

Representative Form

The format of the final form may be different and may evolve during the multi-year monitoring project.

SPME COMPOSITING FORM					
Sampling Event:		Plot:		Subplot:	
Date:		Personnel:			
SPME Envelope Deployment Position – Check one box: ☐ 0-10 cm SPMEs -or- ☐ 0-1 cm sediment-water interface SPMEs					
Vial ID	Composite Sample ID	Vial Weight - Without Fibers (g)	Discrete Sample ID	Fiber Notes	Vial Weight - With Fibers (g)

Notes:

Representative Form

The format of the final form may be different and may evolve during the multi-year monitoring project.

Lower Duwamish Waterway Group

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

STATION COORDINATE LOG
For Van Veen

Project:_____ **Recorder:**_____

DATE	TIME	STATION	DROP NO.	LATITUDE	LONGITUDE	DEPTH (m)	RECOVERY DEPTH (cm)	COMMENTS

Representative Form

The format of the final form may be different and may evolve during the multi-year monitoring project.

Lower Duwamish Waterway Group

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

INFAUNAL SAMPLE IDENTIFICATION AND SORTING SHEET

I. Sample Identification

Project Title _____ Survey _____

Location _____ Station _____ Replicate _____

Depth _____ Screen Size _____ Date Sample Collected _____

Sample Sed. Vol. (mL) _____ No./Type Contr. _____ Sampler _____

II. Sorting

Sort Criteria _____ % Sorted By _____ Date(s) Sorted _____

Total Sort Time _____ Total No. Animals _____

Sorter Comments _____

_____

Distribution of Sorted Material

	# of Vials	# of Jars
Annelids		
Bivalvia		
Other Mollusca		
Amphipods		
Copepods		
Other Crustaceans		
Insects		
Nematodes		
Miscellaneous		
_____		
_____		
_____		
_____		

III. Sorting QA/QC

Sort Criteria _____ %

QA/QC By _____ Pass/Re-Sort _____ Date _____

QA/QC Time _____ Re-Sort Time _____ Re-Sort Date _____

No. of Animals QA/QC _____

No. of Animals Re-Sort _____

IV. Sample Qualification Comments (Circle One)

1. Single Major Component:

Shellhash Tubes Wood Algae Seeds

Fibers Coarse Sand Fine Sand Pea Gravel Organic Material

Macrodetritus Other:_____

2. Comment: _____

_____

_____

_____

_____

_____

_____

Representative Form

The format of the final form may be different and may evolve during the multi-year monitoring project.

CHAIN OF CUSTODY

Destination:	Sample Originator (Organization):	Report Results To:	Phone:
Destination Contact:	**PERSON WHO COLLECTED SAMPLE:**	Contact Name:	Fax:
Date:	Address:	Address:	Email:
Turn-Around-Time:			
Project Name:	Phone:	**Analyses:**	**Invoicing To:**
	Fax:		**Comments or Special Instructions:**
Contract/PO:	E-mail		

No.	Sample ID	Matrix	Volume & Type of Container	Date & Time							Preservation	Sample Temp Upon Receipt	LAB ID
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
13													
14													
15													
16													
17													
18													
19													
20													

Representative Form

The format of the final form may be different and may evolve during the multi-year monitoring project.

Relinquished by:	Received by:	Relinquished by:	Received by:	Matrix Codes
Print Name:	Print Name:	Print Name:	Print Name:	SPME =
Signature:	Signature:	Signature:	Signature:	SB = Salt & Brackish Water
Affiliation:	Affiliation:	Affiliation:	Affiliation:	SS = Soil & Sediment
Date/Time:	Date/Time:	Date/Time:	Date/Time:	

DEVIATION FROM QAPP

Representative Form
The format of the final form may be different and may evolve during the multi-year monitoring project.

Nature of deviation:					
Reported by:		Date:		Documentation:	*e.g., field form, field log book, "attached"*
Potential to impact study objectives: ❑ YES ❑ NO					
How:					
Assessed by:		Date:		Additional documentation attached:	❑ YES ❑ NO
Is corrective action warranted: ❑ YES ❑ NO					
Rationale:					
Assessed by:		Date:		Additional documentation attached:	❑ YES ❑ NO
Was corrective action taken: ❑ YES ❑ NO					
Was it successful:					
Assessed by:		Date:		Additional documentation attached:	❑ YES ❑ NO

Project Team Approvals:	**QAO:**	*Signature and date*	**Additional Approvals:** (if warranted by the nature of the deviation.)	LDWG	*Signature and date*
	ML:	*Signature and date*		EPA	*Signature and date*
	PM:	*Signature and date*		Ecology	*Signature and date*

ATTACHMENT B

Passive Sampling Method Development

Lower Duwamish Waterway Group

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

Passive Sampling Method Development
Attachment B
QUALITY ASSURANCE PROJECT PLAN

Enhanced Natural Recovery/Activated Carbon Pilot Study

Lower Duwamish Waterway

FINAL

Prepared for:

The US Environmental Protection Agency
Region 10
Seattle, Washington

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

Prepared by:

Amec Foster Wheeler Environment & Infrastructure, Inc.
Dalton, Olmsted & Fuglevand, Inc.
ENVIRON International Corporation
Floyd|Snider
Geosyntec Consultants

February 22, 2016

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ATTACHMENT B TO THE
QUALITY ASSURANCE PROJECT PLAN
Enhanced Natural Recovery/Activated Carbon Pilot Study
Lower Duwamish Waterway

1.0 INTRODUCTION

Concentrations of dissolved polychlorinated biphenyl (PCB) congeners in sediment porewater will be measured at the subplots in the baseline and three monitoring events as described in the Quality Assurance Project Plan, to which this document is an attachment. The concentrations will be used to evaluate the potential additional reduction in available PCBs when activated carbon (AC) is present in the enhanced natural recovery (ENR) layer. Dissolved PCBs in sediment porewater will be measured by passive sampling with solid phase microextraction (SPME) fibers placed *in situ* within surface sediments (0 to 10 centimeters [cm]) below the sediment-water interface). This attachment supplies additional detail related to the design of the SPME monitoring, including the selection of Performance Reference Compounds and the estimated sensitivity of the SPME fibers as deployed in this study.

The SPME sampling method is principally based on equilibrium partitioning of PCB congeners between the polydimethylsiloxane (PDMS) coating on the SPME fiber and the sediment porewater. When deployed in sediment under static (unmixed) conditions, the PDMS absorbs PCBs. The concentration of PCBs in the PDMS increases with exposure time until the concentration reaches steady state equilibrium with the surrounding sediment porewater. If the concentration of a particular PCB congener in the PDMS is measured at steady state, the concentration of dissolved PCB in sediment porewater can be estimated by dividing the concentration of the PCB congener in the PDMS by a partition coefficient (obtained from literature sources).

Most PCB congeners require several weeks to several months to reach steady state concentrations in PDMS (or other passive sampling devices). The more hydrophobic PCBs require the longest sampling times, while the less hydrophobic PCBs reach steady state more rapidly. Unfortunately, it is not practical to leave samplers deployed at active river sites for more than a few weeks because shifting benthic conditions, ship traffic, or vandalism/theft would result in the loss of many samplers. To shorten sampling time, while still producing useable data, Performance Reference Compounds (PRCs) can be impregnated into the PDMS prior to deployment so that the *in situ* sampling rates can be quantified. The rates of desorption of the PRCs can be applied to the measured concentrations in PDMS to provide estimates of the concentrations of PCBs that would

have been present at steady state had the sampler been allowed to remain *in situ* for several weeks or months. For example, if a sampler loses approximately 50% of the concentration of a PRC during its deployment time, concentrations of PCBs with similar hydrophobicities that have absorbed into the sampler from the sediment porewater could be multiplied by 2 to estimate steady state concentrations. As noted above, this steady state concentration is used to determine the concentration of dissolved PCB in sediment porewater. For this approach to be most accurate, a general rule is at least 20% of the concentrations of a PRC should be lost from the SPME during the deployment time (i.e., the sampling conditions indicate at least 20% of steady state is obtained).

The most hydrophobic PCBs (nona- and decachlorinated biphenyls) are not likely to attain at least 20% of steady state during a practical for deployment time (1 month) for the Lower Duwamish Pilot Study. At the other end of the spectrum, the PCB congeners with the least number of chlorines (e.g. mono- and dichlorinated biphenyls) tend to be relatively water soluble and do not sorb to PDMS strongly. Although the concentrations of mono- and dichlorinated biphenyls are likely reach at steady state within a 1-month deployment time in the Lower Duwamish, they may not be present at concentrations in the PDMS above method detection limits.

It is not practical or necessary to design a one-size-fits all sampler to measure all PCBs. The purpose of this document is to evaluate the outcome of potentially low accuracy (for nona- and decachlorinated biphenyls) and relatively high method detection limits (for mono- and dichlorinated biphenyls) on study objectives related to measuring dissolved concentrations of PCBs in sediment porewater. Additionally, the document confirms the sampler design sensitivity for the tri-, tetra-, penta-, hexa-, hepta-, and octachlorinated biphenyls.

2.0 MEASURED CONCENTRATIONS OF PCBS CONGENERS IN LOWER DUWAMISH ENVIRONMENTAL SAMPLES

The ultimate use for the concentration of dissolved PCBs in sediment porewater is to evaluate the change in PCB availability expected as a result of adding activated carbon to an Enhanced Natural Recovery (ENR) layer. The premise is this reduction in availability relates directly to a reduction in the concentration of PCBs in organisms that will inhabit the ENR layers, resulting in an overall decrease in environmental risk to humans and wildlife. This section evaluates the PCB congener composition of PCBs detected in Lower Duwamish tissues to understand which groups of PCB congeners are most bioaccumulative and/or present at the highest levels. This section also includes a prediction of concentrations of PCBs congeners in sediment porewater. Data were obtained from samples of tissues from the Lower Duwamish Waterway and sediments in the Pilot Study plot locations, as provided in the EIM, Boeing, and LDWG databases.

2.1 MEASURED CONCENTRATIONS OF PCBS IN TISSUE

The concentrations of tri-, tetra-, penta-, hexa-, hepta-, and octachlorinated biphenyls comprise 99.7% of total PCBs in fish and invertebrate tissues measured throughout the Lower Duwamish Waterway. The concentration of PCB homologs in fish tissue (Table 1.a.), as referenced from the EIM and LDWG databases, were used to calculate the percent contribution of PCB homologs in total PCBs (Table 1.b.). The average percent contribution of each homolog to total PCBs in fish tissue is shown in Figure 1 below. The percent contribution of each homolog in total PCBs in invertebrate tissue is similar to fish tissue, as shown in Figure 2 (Tables 2.a. and 2.b.).

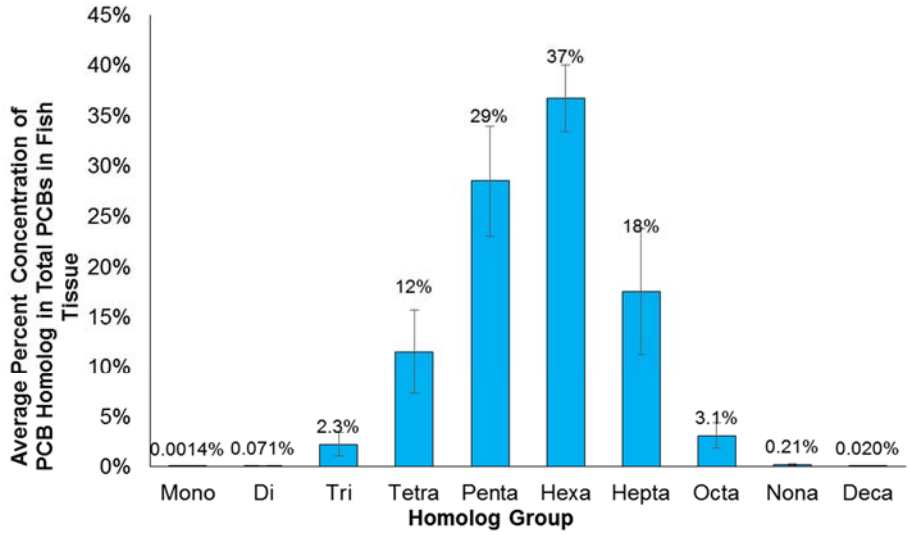

Figure 1. Average Percent Contribution of Each Homolog in Total PCBs in Fish Tissue

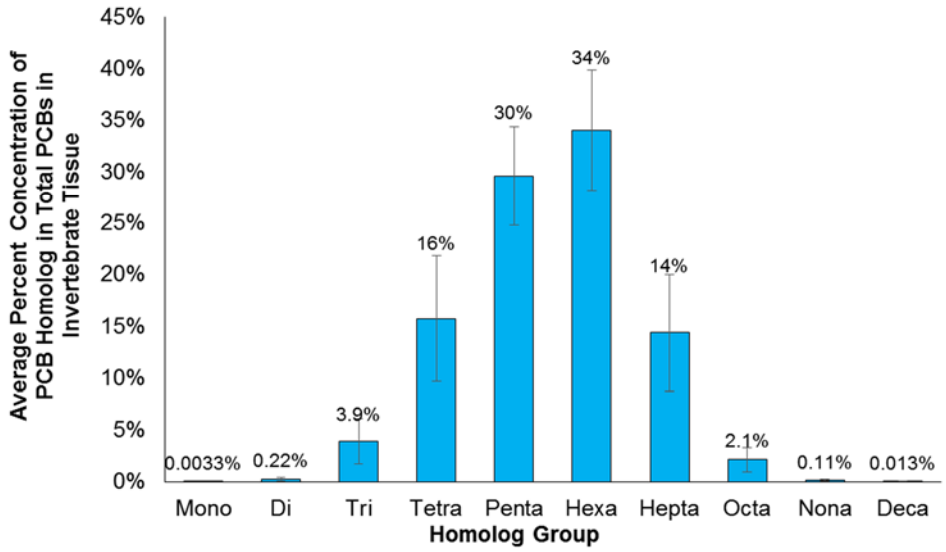

Figure 2. Average Percent Contribution of Each Homolog in Total PCBs in Invertebrate Tissue

2.2 MEASURED CONCENTRATIONS OF PCBS IN SEDIMENT

Concentrations of PCBs in surface sediment were measured at two sample locations in the scour plot, three sample locations in subtidal plot, and 4 sample locations in intertidal plot (Figure 3). The concentrations of PCB congeners measured in the surface sediment (from 0 cm to 10 cm or 60.96 cm below sediment-water interface) were referenced from the Boeing, EIM, and LDWG databases (Table 3). The concentration of PCB homologs in surface sediment (Table 4.a.) were used to calculate the percent contribution of each homolog to the concentration of total PCBs (Table 4.b.) by sample. The average percent contribution was adjusted to total 100% since the number of detected PCB congeners was not consistent among the samples (Table 4.c.). The tri- to octachlorinated biphenyls comprise 98.8% of the total quantified PCBs in surface sediments of the plots (Figure 4).

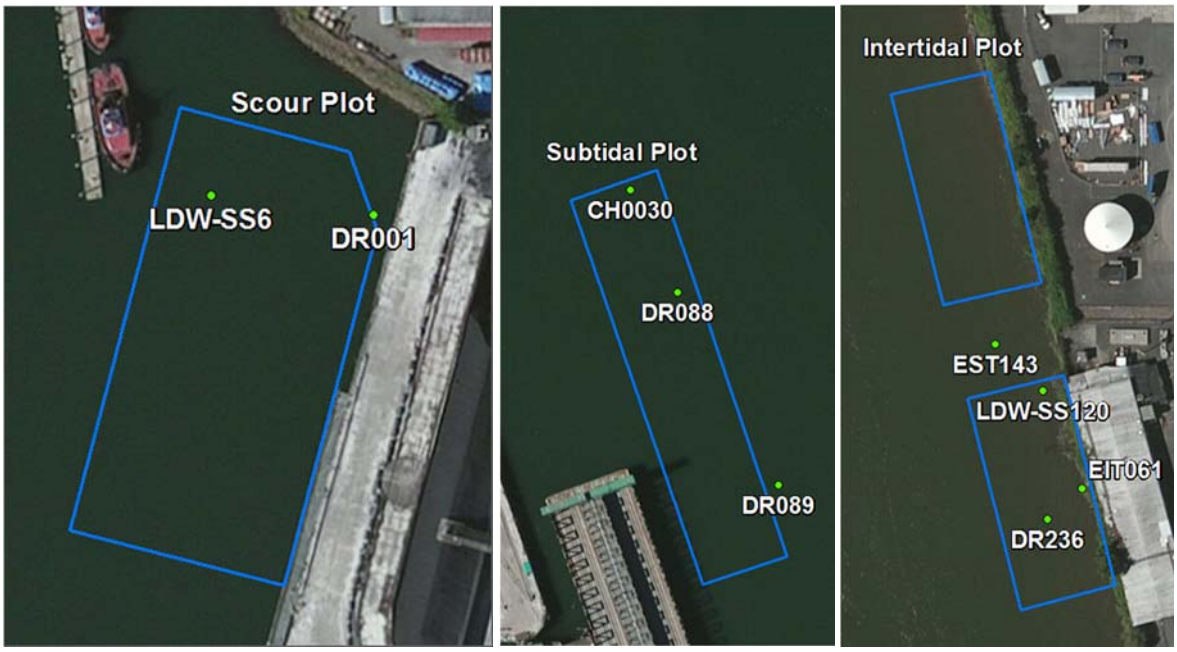

Figure 3. Sample Locations of the Sediment Samples in Plot Areas

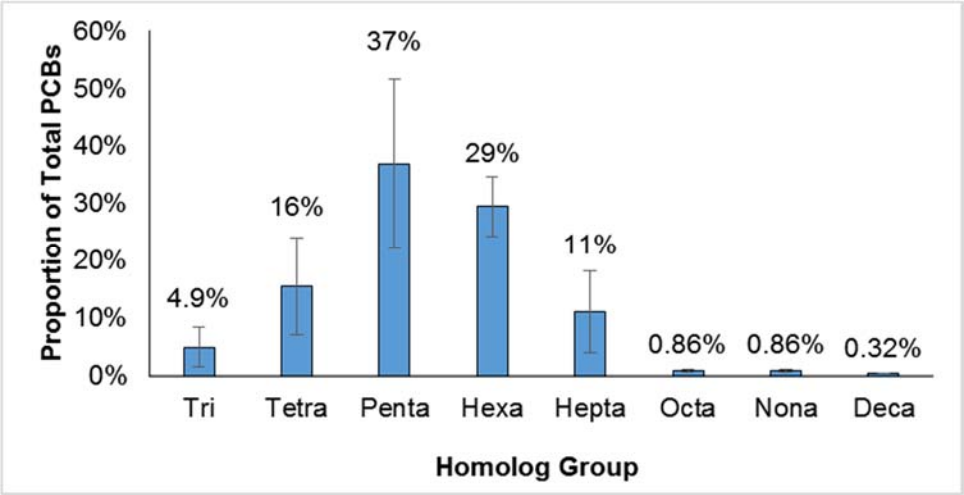

Figure 4. Average Proportion of Each Homolog Group in Total PCBs in Sediment

3.0 PREDICTED CONCENTRATIONS OF PCBS CONGENERS IN LOWER DUWAMISH SEDIMENT POREWATER

Using the sediment PCB data described above, a two-carbon model was used to estimate concentrations of dissolved tri- to octachlorinated biphenyls in sediment porewater as referenced from Perron et al. (2010). The model is principally based on the assumption that the fraction of nonpyrogenic organic carbon and black carbon are responsible for the sorption of PCBs to sediments (Hawthorne et al. 2011). The model estimates concentrations of PCBs in porewater based on the concentrations of PCBs in sediment, the fraction of nonpyrogenic organic carbon in sediment, the fraction of black carbon in sediment, and the partitioning coefficients for nonpyrogenic organic carbon and black carbon.

Total organic carbon content at the sample locations shown in Figure 3 were referenced from the Boeing and LDWG databases. The average black carbon content was referenced from *Assessing Bioavailability of Sediment Contaminants to Support Selecting Remedies* (Wakeman 2014). To calculate the concentration of dissolved PCBs in sediment porewater (C_d), the concentration of PCB congeners in the sediment (C_S) at sample locations in the plot areas (Figure 3, Table 5.a.) are divided by the sum of the product of the fraction of nonpyrogenic organic carbon (f_{NPOC}) and the partition coefficient of nonpyrogenic organic carbon (K_{NPOC}) and the product of the fraction of black carbon (f_{BC}) and the partition coefficient of black carbon (K_{BC}, Table 5.b). The equation for the two carbon model is shown in Equation 1 below.

Equation 1

$$C_d = \frac{C_S}{(f_{NPOC}K_{NPOC} + f_{BC}K_{BC})}$$

The K_{NPOC} and K_{BC} are calculated as shown in Equations 2 and 3 below, as referenced from Hawker and Connell (1988) and Hawthorne et al (2011).

Equation 2

$$Log\ K_{OC} = 0.74 \times Log\ K_{OW} + 0.15$$

Equation 3

$$Log\ K_{BC} = 0.91 \times Log\ K_{OW} + 1.37$$

K_{NPOC} is assumed to be equal to the partition coefficient for organic carbon (K_{OC}). K_{OW} is the octanol-water partition coefficient (Hawker and Connell 1988).

The predicted concentrations of PCBs in sediment porewater (Table 5.b) are difficult to interpret due to widely ranging detection limits for PCB congeners in the sediment samples. However, some information can be gleaned from examining samples with detectable levels of PCBs. For example, the average concentration of the tri- to octachlorinated congeners in sediment porewater are estimated to be approximately 970 picograms per liter (pg/L), 740 pg/L, 1,300 pg/L, 390 pg/L, 60 pg/L, and 4 pg/L for tri-, tetra-, penta-, hexa-, hepta-, and octachlorinated biphenyls, respectively. These are likely to represent approximate values for porewater that will be encountered in the baseline monitoring event.

4.0 AVERAGE METHOD DETECTION LIMITS FOR DISSOLVED PCB CONGENERS IN SEDIMENT POREWATER

This section estimates the approximate minimum concentrations of dissolved PCB congeners that will be detectable using the SPME method that has been proposed for the Pilot Study. Average method detection limits (MDLs) for dissolved PCB congeners in sediment porewater were estimated based on Frontier Analytical Laboratory method detection limit for analysis of PCB congeners by gas chromatography (United States Environmental Protection Agency [US EPA] Method 1668). The PCB congeners sorbed to PDMS during field deployment will be extracted in 1,800 microliters (µL) of hexane. The hexane extract is concentrated by Frontier Analytical Laboratories to approximately 100 µL, of which 1 µL is injected into the GC for analysis. This method has a detection limit of 5 picograms per 100 µL concentrated extract (0.5 ng).

The average concentration of tri- to octachlorinated biphenyls in porewater at equilibrium was calculated based on the volume of PDMS and the approximate average PDMS fiber partition coefficient (K_{fs}, Smedes et al. 2009) as shown in Equations 4 and 5.

Equation 4

$$C_{PDMS} = \frac{MDL}{Volume\ PDMS}$$

Equation 5

$$C_{PW} = \frac{C_{PDMS}}{K_{fs}}$$

C_{PDMS} is the concentration in PDMS and C_{PW} is the concentration in porewater. This is the lowest achievable method detection limit using 480 cm length of SPME fibers with a 10-micrometer (µm) thick PDMS coating. The field deployment will be for a duration of 4 weeks. Steady state equilibrium will not be reached after 4 weeks deployment. The percent to steady state concentration attained during the deployment period was estimated based on the sampling results from a SPME passive sampling event at an activated carbon demonstration site in Bremerton, Washington.

Approximate method detection limits for the proposed SPME deployment are shown in Table 6. The 4-week exposure is sufficient to detect approximate concentrations of dissolved concentrations of 70, 30, 15, 8, 5, and 3 pg/L for tri-, tetra-, penta-, hexa-, hepta-, and octachlorinated biphenyls, respectively. These levels are approximate and actual method detection limits will vary based on the characteristics of individual PCB congeners, site conditions that affect sampling rate, the amount of SPME fiber recovered (Table 6 assumes all 6 composite fiber subsamples will be available to comprise the 480-cm composite sample), and analytical conditions during quantification of the PCBs. Octachlorinated biphenyls absorbing into the SPME are predicted to only reach approximately 15% of steady state concentrations during the 4-week deployment. This is less than the ideal level of 20%, and thus, results of octachlorinated biphenyls may be flagged as estimated. This slight imprecision is not expected to interfere with the comparison of total dissolved PCBs in sediment porewater between the ENR and ENR+AC subplots at each location, as octachlorinated biphenyls are estimated to only comprise approximately 0.1% of the predicted concentrations of total PCBs in porewater (Table 5.c).

As shown in Table 6, approximate average MDLs for dissolved PCB congeners in sediment porewater using the SPME approach proposed for the Pilot Study are adequate to detect the average predicted concentration of dissolved PCBs present in sediment porewater predicted to be encountered during the baseline monitoring event. Additionally, assuming the baseline concentrations of dissolved PCBs in sediment porewater are reduced by approximately 80 to 90% by the ENR and/or ENR+AC treatments, the SPME approach MDLs are also adequate to detect expected concentrations of tri-, tetra-, penta-, hexa-, and heptachlorinated biphenyls following application of the amendment (Table 6). Concentrations of post-treatment octachlorinated biphenyls in sediment porewater may be below the detection limit. As noted above, octachlorinated biphenyls are estimated to comprise a contribution to total PCBs in porewater that is relatively inconsequential with regards to Pilot Study goals.

5.0 CONCLUSIONS

From a review of the best available PCB congener data in organism tissue and sediment, the proposed SPME method for measuring dissolved PCBs in sediment porewater will be adequate for providing high quality data for meeting Pilot Study objectives in comparing PCB availability between the ENR and ENR+AC treatments.

The proposed SPME method is optimized for monitoring tri-, tetra-, penta-, hexa-, hepta-, and octachlorinated biphenyls. Congeners belonging to these PCB homolog groups represent approximately 99.7% of the PCBs found in organisms in the Lower Duwamish. Thus, these compounds represent those driving PCB risk concerns associated with aquatic organism, wildlife, and human exposures, and are most important for evaluating potential sediment remedies. Although mono-, di-, nona-, and decachlorinated biphenyls will be measured with the proposed SPME method, data for these compounds may be semi-quantitative or limited by high detection limits due to the SPME passive sampling method selected for this Pilot Study. Data of higher uncertainty for mono-, di-, nona-, and decachlorinated biphenyls will not compromise Pilot Study objectives in comparing PCB availability between the ENR and ENR+AC treatments. Additionally, attempting to optimize the method to capture these relatively inconsequential compounds would jeopardize the overall study due to the extremely long *in situ* sampler deployment times needed for nona- and decachlorinated biphenyls as well as complicate sampling to incorporate multiple sampler configurations to provide additional sampler types needed to capture mono- and dichlorinated biphenyls.

6.0 REFERENCES

Hawker, D.W. and D.W. Connell. 1988. Octanol-Water Partition Coefficients of Polychlorinated Biphenyl Congeners. Environ. Sci. Technol. 1988, 22, 382-387.

Hawthorne, S.B., C.B. Grabanski, D.J. Miller, and H.P.H. Arp. 2011. Improving Predictability of Sediment-Porewater Partitioning Models using Trends Observed with PCB-Contaminated Field Sediments. Environ. Sci. Technol. 2011, 45, 7365–7371.

Perron, M.M., R.M. Burgess, K.T. Ho, M.C. Pelletier, M.G. Cantwell, and J.P. Shine. 2010. Bioavailability Assessment of a Contaminated Field Sediment from Patrick Bayou, Texas, USA: Toxicity Identification Evaluation and Equilibrium Partitioning. Environmental Toxicology and Chemistry 29(3): 742–750.

Smedes, F., R.W. Geertsma, T. Van Der Zande, and K. Booji. 2009. Polymer-Water Partition Coefficients of Hydrophobic Compounds for Passive Sampling: Application of Cosolvent Models for Validation. Environ. Sci. Technol. 2009, 43, 7047–7054.

Wakeman, J. 2014. Assessing Bioavailability of Sediment Contaminants to Support Selecting Remedies. Presentation. Seattle District. 2014 Environmental Cleanup Conference. 9 June 2014.

TABLES

Table 1a: Concentration of PCB Homolog in Fish Tissue by Sample (ng/kg, ww) [1]

Sample ID	Species	Homolog Group										
		Mono	Di	Tri	Tetra	Penta	Hexa	Hepta	Octa	Nona	Deca	Total
07DU-ESM01	Parophrys vetulus	4.52	88	2,742	26,852	92,465	121,397	57,372	13,057	1,325	236	315,539
07DU-ESM02	Parophrys vetulus	3.51	100	2,995	28,182	81,753	103,358	52,230	10,465	967	168	280,221
07DU-ESM03	Parophrys vetulus	3.46	82	2,673	24,969	87,547	125,301	60,264	13,838	1,382	225	316,285
07DU-ESM04	Parophrys vetulus	3.88	80	2,561	28,353	105,987	161,805	77,707	17,997	1,704	263	396,460
07DU-ESM05	Parophrys vetulus	3.84	93	2,292	24,031	84,109	116,773	63,381	15,350	1,491	208	307,732
07DU-ESM06	Parophrys vetulus	5.76	88	2,461	22,479	77,426	114,826	50,228	9,691	965	165	278,336
LDW-05-T1-B-SS-WB-Comp1	Shiner perch	13.56	375	13,982	68,601	190,836	283,682	104,066	20,116	1,488	161	683,320
LDW-05-T1-M-ES-WB-Comp3	English sole	20.17	921	33,787	262,471	766,738	987,564	428,793	98,298	10,809	1,050	2,590,451
LDW-05-T2-B-SS-WB-Comp1	Shiner perch	16.51	375	16,603	111,445	321,218	412,423	154,188	29,083	1,840	170	1,047,361
LDW-05-T2-M-ES-WB-Comp3	English sole	38.82	2,065	65,911	411,383	985,856	1,175,233	481,549	86,205	5,781	596	3,214,617
LDW-05-T3-D-SS-WB-Comp1	Shiner perch	26.53	682	23,737	150,153	511,759	844,607	432,996	80,186	4,108	179	2,048,433
LDW-05-T3-M-ES-WB-Comp2	English sole	24.52	1,133	30,414	191,464	461,255	531,682	180,892	34,408	1,802	273	1,433,347
LDW-07-T1-B-SS-WB-comp1	Cymatogaster aggregata	15.99	282	7,848	38,552	203,827	401,184	277,179	42,664	3,081	213	974,845
LDW-07-T1-C-SS-WB-comp1	Cymatogaster aggregata	8.81	189	7,275	42,905	127,876	208,044	98,709	18,372	1,364	143	504,885
LDW-07-T1-M-ES-WB-comp3	Parophrys vetulus	7.16	487	15,300	106,257	305,116	462,803	224,177	46,488	4,353	549	1,165,537
LDW-07-T1-M-ES-WB-comp5	Parophrys vetulus	20.31	582	12,993	58,610	170,555	318,789	173,292	35,981	3,223	378	774,423
LDW-07-T2-A-ES-WB-comp2	Parophrys vetulus	10.49	1,327	41,548	230,574	510,838	578,849	226,215	40,588	2,723	277	1,632,950
LDW-07-T2-A-ES-WB-comp4	Parophrys vetulus	17.23	1,140	27,597	116,290	464,692	632,464	304,897	52,395	3,344	405	1,603,240
LDW-07-T2-B-SS-WB-comp1	Cymatogaster aggregata	10.99	203	7,125	38,394	101,569	156,855	81,453	15,185	1,068	105	401,968
LDW-07-T2-E-SS-WB-comp1	Cymatogaster aggregata	22.63	418	9,650	40,246	141,113	267,285	161,756	26,755	1,464	126	648,836
LDW-07-T3-E-SS-WB-comp1	Cymatogaster aggregata	9.18	224	6,134	32,412	141,479	487,244	368,426	65,188	2,721	107	1,103,944
LDW-07-T3-F-SS-WB-comp1	Cymatogaster aggregata	43.78	589	10,713	79,874	378,550	905,202	896,036	182,974	8,819	164	2,462,964
LDW-07-T3-M-ES-WB-comp4	Parophrys vetulus	34.00	2,035	57,673	255,547	906,908	1,106,136	520,198	74,714	4,807	429	2,928,481
LDW-07-T3-M-ES-WB-comp6	Parophrys vetulus	8.39	650	19,084	97,878	252,272	370,003	191,139	39,759	2,716	283	973,793
LDW-M-M-0843	Rhacochilus vacca	3.05	87	6,197	28,358	62,993	64,684	24,938	4,250	484	42	192,036
LDW-M-M-9739	Embiotoca lateralis	3.24	99	7,564	45,142	128,536	169,552	78,805	12,026	614	38	442,379
LDW-M-M-PP-FL-comp-1	Pile perch	3.06	87	6,214	28,366	63,153	64,751	24,941	4,251	485	42	192,292
LDW-M-M-SP-FL-comp-1	Striped perch	3.25	99	7,564	45,142	128,536	169,552	78,805	12,026	614	38	442,379
LDW-T1-A0448	Cymatogaster aggregata	4.96	275	17,019	91,510	207,035	257,978	108,115	17,029	1,082	126	700,173
LDW-T1-A-SS-WB-comp-1	Shiner perch	4.96	275	17,019	91,510	207,035	257,978	108,115	17,029	1,082	126	700,173
LDW-T1-D7136	Leptocottus armatus	5.74	542	17,352	66,647	137,114	185,801	105,366	18,533	1,091	76	532,526
LDW-T1-D-PS-WB-comp-1	Pacific Staghorn Sculpin	5.75	542	17,352	66,647	137,114	185,801	105,366	18,533	1,091	76	532,526
LDW-T1-F2000	Cymatogaster aggregata	14.85	382	25,353	119,517	269,122	308,500	129,823	22,515	1,429	140	876,795
LDW-T1-F4288	Leptocottus armatus	5.45	416	16,620	84,578	189,409	246,845	111,202	18,366	1,105	105	668,651
LDW-T1-F-PS-WB-comp-1	Pacific Staghorn Sculpin	5.46	416	16,620	84,578	189,409	246,845	111,202	18,366	1,105	105	668,651
LDW-T1-F-SS-WB-comp-1	Shiner perch	14.85	382	25,353	119,517	269,122	308,500	129,823	22,515	1,429	140	876,795
LDW-T1-M4762	Parophrys vetulus	28.93	1,348	39,921	187,711	351,610	374,610	134,607	27,213	2,339	257	1,119,645
LDW-T1-M4763	Parophrys vetulus	18.08	966	32,112	138,726	253,208	297,922	112,334	19,916	1,513	190	856,904
LDW-T1-M5683	Parophrys vetulus	29.90	5,314	132,679	462,573	755,006	769,484	296,838	55,029	4,178	401	2,481,532
LDW-T1-M5693	Parophrys vetulus	17.96	1,939	58,186	263,503	510,404	532,658	206,079	38,561	2,970	290	1,614,608
LDW-T1-M-ES-FL-comp-1	English sole	28.93	1,348	39,921	187,711	351,610	374,610	134,607	27,213	2,339	257	1,119,645
LDW-T1-M-ES-FL-comp-2	English sole	19.56	967	32,180	138,829	253,420	298,072	112,508	19,933	1,518	190	857,636
LDW-T1-M-ES-WB-comp-2	English sole	17.96	1,939	58,186	263,503	510,404	532,658	206,079	38,561	2,970	290	1,614,608
LDW-T1-M-ES-WB-comp-4	English sole	29.90	5,314	132,679	462,573	755,006	769,484	296,838	55,029	4,178	401	2,481,532
LDW-T2-B7328	Cymatogaster aggregata	17.26	487	16,855	117,785	399,015	352,740	143,844	22,817	1,862	136	1,055,559
LDW-T2-B-SS-WB-comp-1	Shiner perch	17.26	487	16,855	117,785	399,015	352,740	143,844	22,817	1,862	136	1,055,559
LDW-T2-C1168	Leptocottus armatus	9.45	438	11,124	59,467	141,265	178,211	78,910	11,510	651	56	481,642
LDW-T2-C-PS-WB-comp-1	Pacific Staghorn Sculpin	9.45	438	11,124	59,467	141,265	178,211	78,910	11,510	651	56	481,642
LDW-T2-E6032	Cymatogaster aggregata	36.21	9,317	398,680	2,348,658	5,363,843	3,402,790	632,154	68,558	3,935	221	12,228,192
LDW-T2-E-SS-WB-comp-1	Shiner perch	36.21	9,317	398,680	2,348,658	5,363,843	3,402,790	632,154	68,558	3,935	221	12,228,192
LDW-T2-F9744	Leptocottus armatus	3.53	273	8,922	62,141	148,660	178,882	84,207	12,610	707	55	496,462
LDW-T2-F-PS-WB-comp-1	Pacific Staghorn Sculpin	3.53	273	8,922	62,141	148,660	178,882	84,207	12,610	707	55	496,462

Table 1a: Concentration of PCB Homolog in Fish Tissue by Sample (ng/kg, ww) [Continued]

Sample ID	Species	Homolog Group										
		Mono	Di	Tri	Tetra	Penta	Hexa	Hepta	Octa	Nona	Deca	Total
LDW-T2-M1140	Parophrys vetulus	29.09	3,360	87,085	385,616	678,093	687,883	238,749	42,468	2,791	280	2,126,354
LDW-T2-M1150	Parophrys vetulus	20.99	2,266	73,877	370,789	825,624	962,627	400,184	71,746	4,579	456	2,712,170
LDW-T2-M8394	Parophrys vetulus	16.19	989	33,501	183,493	432,624	427,022	161,859	27,402	2,037	224	1,269,166
LDW-T2-M8395	Parophrys vetulus	23.93	1,409	45,926	221,571	405,571	397,049	162,142	29,030	1,871	193	1,264,785
LDW-T2-M-ES-FL-comp-1	English sole	16.19	989	33,501	183,493	432,624	427,022	161,859	27,402	2,037	224	1,269,166
LDW-T2-M-ES-FL-comp-2	English sole	23.93	1,409	45,926	221,571	405,571	397,049	162,142	29,030	1,871	193	1,264,785
LDW-T2-M-ES-WB-comp-3	English sole	20.99	2,266	73,877	370,789	825,624	962,627	400,184	71,746	4,579	456	2,712,170
LDW-T2-M-ES-WB-comp-5	English sole	29.09	3,360	87,085	385,616	678,093	687,883	238,749	42,468	2,791	280	2,126,354
LDW-T3-C4336	Cymatogaster aggregata	69.10	1,097	13,409	82,233	278,421	371,369	221,089	39,825	2,062	118	1,009,692
LDW-T3-C-SS-WB-comp-1	Shiner perch	69.10	1,097	13,409	82,233	278,421	371,369	221,089	39,825	2,062	118	1,009,692
LDW-T3-D8048	Leptocottus armatus	10.50	322	11,333	101,787	397,417	717,509	546,213	123,724	6,646	118	1,905,079
LDW-T3-D-PS-WB-comp-1	Pacific Staghorn Sculpin	9.70	315	11,344	101,899	397,735	718,149	547,433	123,834	6,652	118	1,907,489
LDW-T3-E1488	Cymatogaster aggregata	15.66	474	16,036	101,771	747,717	3,565,751	3,129,729	438,905	13,030	188	8,013,617
LDW-T3-E3776	Leptocottus armatus	18.02	416	10,330	58,034	197,349	445,449	286,768	47,622	2,115	76	1,048,177
LDW-T3-E-PS-WB-comp-1	Pacific Staghorn Sculpin	18.02	416	10,330	58,034	197,349	445,449	286,768	47,622	2,115	76	1,048,177
LDW-T3-E-SS-WB-comp-1	Shiner perch	15.66	474	16,036	101,771	747,717	3,565,751	3,129,729	438,905	13,030	188	8,013,617
LDW-T3-F2912	Cymatogaster aggregata	15.92	458	17,091	151,741	772,501	1,279,993	1,066,913	221,802	11,370	197	3,522,082
LDW-T3-F-SS-WB-comp-1	Shiner perch	15.92	458	17,091	151,741	772,501	1,279,993	1,066,913	221,802	11,370	197	3,522,082
LDW-T3-M3850	Parophrys vetulus	3.80	364	11,624	68,472	189,859	236,235	112,359	20,249	1,281	107	640,553
LDW-T3-M3851	Parophrys vetulus	16.44	808	30,567	152,835	338,624	350,517	127,191	21,096	1,327	108	1,023,090
LDW-T3-M6605	Parophrys vetulus	19.09	1,108	34,446	176,676	431,125	521,158	216,235	36,420	2,258	236	1,419,681
LDW-T3-M6606	Parophrys vetulus	15.95	1,554	44,500	262,335	709,784	961,136	407,190	67,732	3,478	246	2,457,969
LDW-T3-M-ES-FL-comp-1	English sole	3.73	363	11,637	68,596	190,025	236,411	112,440	20,265	1,281	107	641,130
LDW-T3-M-ES-FL-comp-2	English sole	16.44	808	30,567	152,835	338,624	350,517	127,191	21,096	1,327	108	1,023,090
LDW-T3-M-ES-WB-comp-2	English sole	19.09	1,108	34,446	176,676	431,125	521,158	216,235	36,420	2,258	236	1,419,681
LDW-T3-M-ES-WB-comp-3	English sole	15.95	1,554	44,500	262,335	709,784	961,136	407,190	67,732	3,478	246	2,457,969
LDW-T4-B9056	Cymatogaster aggregata	5.40	341	13,993	80,837	227,731	299,293	125,329	20,129	1,746	299	769,704
LDW-T4-B-SS-WB-comp-1	Shiner perch	5.41	341	13,993	80,837	227,731	299,293	125,329	20,129	1,746	299	769,704
LDW-T4-C5216	Leptocottus armatus	3.20	167	5,204	32,916	103,411	140,068	58,278	8,998	526	39	349,610
LDW-T4-C-PS-WB-comp-1	Pacific Staghorn Sculpin	3.22	167	5,204	32,916	103,411	140,068	58,278	8,998	526	39	349,610
LDW-T4-D3795	Leptocottus armatus	5.23	417	12,597	62,152	148,182	185,885	82,353	12,668	718	53	505,030
LDW-T4-D6080	Cymatogaster aggregata	8.07	420	11,350	51,192	147,954	211,101	94,997	14,504	918	77	532,521
LDW-T4-D-PS-WB-comp-2	Pacific Staghorn Sculpin	5.24	417	12,597	62,152	148,182	185,885	82,353	12,668	718	53	505,030
LDW-T4-D-SS-WB-comp-1	Shiner perch	8.07	420	11,350	51,192	147,954	211,101	94,997	14,504	918	77	532,521
LDW-T4-M1382	Platichthys stellatus	5.49	481	14,555	52,738	85,018	98,437	37,375	6,082	475	53	295,221
LDW-T4-M2518	Parophrys vetulus	3.56	435	13,258	65,968	160,929	180,501	75,618	12,451	769	96	510,028
LDW-T4-M4096	Platichthys stellatus	7.84	663	17,208	65,279	129,026	163,297	68,693	12,932	885	109	458,099
LDW-T4-M5232	Parophrys vetulus	17.01	1,445	44,882	211,338	420,555	464,487	185,649	31,127	1,862	149	1,361,510
LDW-T4-M-ES-FL-comp-1	English sole	3.58	435	13,258	65,968	160,929	180,501	75,618	12,451	769	96	510,028
LDW-T4-M-ES-WB-comp-1	English sole	17.01	1,445	44,882	211,338	420,555	464,487	185,649	31,127	1,862	149	1,361,510
LDW-T4-M-SF-FL-comp-1	Starry Flounder	5.50	481	14,555	52,738	85,018	98,437	37,375	6,082	475	53	295,221
LDW-T4-M-SF-WB-comp-1	Starry Flounder	7.85	663	17,208	65,279	129,026	163,297	68,693	12,932	885	109	458,100
Average		**15.24**	**1,021**	**33,254**	**175,749**	**435,767**	**540,951**	**274,180**	**46,613**	**2,625**	**191**	**1,510,366**
Standard Deviation		**12.44**	**1,545**	**59,496**	**338,438**	**766,669**	**686,788**	**468,758**	**70,430**	**2,694**	**147**	**2,038,084**

Table 1b: Percent Concentration of PCB Homolog in Total PCBs in Fish Tissue by Sample (%) [2]

Sample ID	Species	Homolog Group									
		Mono	Di	Tri	Tetra	Penta	Hexa	Hepta	Octa	Nona	Deca
07DU-ESM01	Parophrys vetulus	0%	0%	1%	9%	29%	38%	18%	4%	0%	0%
07DU-ESM02	Parophrys vetulus	0%	0%	1%	10%	29%	37%	19%	4%	0%	0%
07DU-ESM03	Parophrys vetulus	0%	0%	1%	8%	28%	40%	19%	4%	0%	0%
07DU-ESM04	Parophrys vetulus	0%	0%	1%	7%	27%	41%	20%	5%	0%	0%
07DU-ESM05	Parophrys vetulus	0%	0%	1%	8%	27%	38%	21%	5%	0%	0%
07DU-ESM06	Parophrys vetulus	0%	0%	1%	8%	28%	41%	18%	3%	0%	0%
LDW-05-T1-B-SS-WB-Comp1	Shiner perch	0%	0%	2%	10%	28%	42%	15%	3%	0%	0%
LDW-05-T1-M-ES-WB-Comp3	English sole	0%	0%	1%	10%	30%	38%	17%	4%	0%	0%
LDW-05-T2-B-SS-WB-Comp1	Shiner perch	0%	0%	2%	11%	31%	39%	15%	3%	0%	0%
LDW-05-T2-M-ES-WB-Comp3	English sole	0%	0%	2%	13%	31%	37%	15%	3%	0%	0%
LDW-05-T3-D-SS-WB-Comp1	Shiner perch	0%	0%	1%	7%	25%	41%	21%	4%	0%	0%
LDW-05-T3-M-ES-WB-Comp2	English sole	0%	0%	2%	13%	32%	37%	13%	2%	0%	0%
LDW-07-T1-B-SS-WB-comp1	Cymatogaster aggregata	0%	0%	1%	4%	21%	41%	28%	4%	0%	0%
LDW-07-T1-C-SS-WB-comp1	Cymatogaster aggregata	0%	0%	1%	8%	25%	41%	20%	4%	0%	0%
LDW-07-T1-M-ES-WB-comp3	Parophrys vetulus	0%	0%	1%	9%	26%	40%	19%	4%	0%	0%
LDW-07-T1-M-ES-WB-comp5	Parophrys vetulus	0%	0%	2%	8%	22%	41%	22%	5%	0%	0%
LDW-07-T2-A-ES-WB-comp2	Parophrys vetulus	0%	0%	3%	14%	31%	35%	14%	2%	0%	0%
LDW-07-T2-A-ES-WB-comp4	Parophrys vetulus	0%	0%	2%	7%	29%	39%	19%	3%	0%	0%
LDW-07-T2-B-SS-WB-comp1	Cymatogaster aggregata	0%	0%	2%	10%	25%	39%	20%	4%	0%	0%
LDW-07-T2-E-SS-WB-comp1	Cymatogaster aggregata	0%	0%	1%	6%	22%	41%	25%	4%	0%	0%
LDW-07-T3-E-SS-WB-comp1	Cymatogaster aggregata	0%	0%	1%	3%	13%	44%	33%	6%	0%	0%
LDW-07-T3-F-SS-WB-comp1	Cymatogaster aggregata	0%	0%	0%	3%	15%	37%	36%	7%	0%	0%
LDW-07-T3-M-ES-WB-comp4	Parophrys vetulus	0%	0%	2%	9%	31%	38%	18%	3%	0%	0%
LDW-07-T3-M-ES-WB-comp6	Parophrys vetulus	0%	0%	2%	10%	26%	38%	20%	4%	0%	0%
LDW-M-M-0843	Rhacochilus vacca	0%	0%	3%	15%	33%	34%	13%	2%	0%	0%
LDW-M-M-9739	Embiotoca lateralis	0%	0%	2%	10%	29%	38%	18%	3%	0%	0%
LDW-M-M-PP-FL-comp-1	Pile perch	0%	0%	3%	15%	33%	34%	13%	2%	0%	0%
LDW-M-M-SP-FL-comp-1	Striped perch	0%	0%	2%	10%	29%	38%	18%	3%	0%	0%
LDW-T1-A0448	Cymatogaster aggregata	0%	0%	2%	13%	30%	37%	15%	2%	0%	0%
LDW-T1-A-SS-WB-comp-1	Shiner perch	0%	0%	2%	13%	30%	37%	15%	2%	0%	0%
LDW-T1-D7136	Leptocottus armatus	0%	0%	3%	13%	26%	35%	20%	3%	0%	0%
LDW-T1-D-PS-WB-comp-1	Pacific Staghorn Sculpin	0%	0%	3%	13%	26%	35%	20%	3%	0%	0%
LDW-T1-F2000	Cymatogaster aggregata	0%	0%	3%	14%	31%	35%	15%	3%	0%	0%
LDW-T1-F4288	Leptocottus armatus	0%	0%	2%	13%	28%	37%	17%	3%	0%	0%
LDW-T1-F-PS-WB-comp-1	Pacific Staghorn Sculpin	0%	0%	2%	13%	28%	37%	17%	3%	0%	0%
LDW-T1-F-SS-WB-comp-1	Shiner perch	0%	0%	3%	14%	31%	35%	15%	3%	0%	0%
LDW-T1-M4762	Parophrys vetulus	0%	0%	4%	17%	31%	33%	12%	2%	0%	0%
LDW-T1-M4763	Parophrys vetulus	0%	0%	4%	16%	30%	35%	13%	2%	0%	0%
LDW-T1-M5683	Parophrys vetulus	0%	0%	5%	19%	30%	31%	12%	2%	0%	0%
LDW-T1-M5693	Parophrys vetulus	0%	0%	4%	16%	32%	33%	13%	2%	0%	0%
LDW-T1-M-ES-FL-comp-1	English sole	0%	0%	4%	17%	31%	33%	12%	2%	0%	0%
LDW-T1-M-ES-FL-comp-2	English sole	0%	0%	4%	16%	30%	35%	13%	2%	0%	0%
LDW-T1-M-ES-WB-comp-2	English sole	0%	0%	4%	16%	32%	33%	13%	2%	0%	0%
LDW-T1-M-ES-WB-comp-4	English sole	0%	0%	5%	19%	30%	31%	12%	2%	0%	0%
LDW-T2-B7328	Cymatogaster aggregata	0%	0%	2%	11%	38%	33%	14%	2%	0%	0%
LDW-T2-B-SS-WB-comp-1	Shiner perch	0%	0%	2%	11%	38%	33%	14%	2%	0%	0%
LDW-T2-C1168	Leptocottus armatus	0%	0%	2%	12%	29%	37%	16%	2%	0%	0%
LDW-T2-C-PS-WB-comp-1	Pacific Staghorn Sculpin	0%	0%	2%	12%	29%	37%	16%	2%	0%	0%
LDW-T2-E6032	Cymatogaster aggregata	0%	0%	3%	19%	44%	28%	5%	1%	0%	0%
LDW-T2-E-SS-WB-comp-1	Shiner perch	0%	0%	3%	19%	44%	28%	5%	1%	0%	0%
LDW-T2-F9744	Leptocottus armatus	0%	0%	2%	13%	30%	36%	17%	3%	0%	0%
LDW-T2-F-PS-WB-comp-1	Pacific Staghorn Sculpin	0%	0%	2%	13%	30%	36%	17%	3%	0%	0%

Table 1b: Percent Concentration of PCB Homolog in Total PCBs in Fish Tissue by Sample (%) [Continued]

Sample ID	Species	Homolog Group									
		Mono	Di	Tri	Tetra	Penta	Hexa	Hepta	Octa	Nona	Deca
LDW-T2-M1140	Parophrys vetulus	0%	0%	4%	18%	32%	32%	11%	2%	0%	0%
LDW-T2-M1150	Parophrys vetulus	0%	0%	3%	14%	30%	35%	15%	3%	0%	0%
LDW-T2-M8394	Parophrys vetulus	0%	0%	3%	14%	34%	34%	13%	2%	0%	0%
LDW-T2-M8395	Parophrys vetulus	0%	0%	4%	18%	32%	31%	13%	2%	0%	0%
LDW-T2-M-ES-FL-comp-1	English sole	0%	0%	3%	14%	34%	34%	13%	2%	0%	0%
LDW-T2-M-ES-FL-comp-2	English sole	0%	0%	4%	18%	32%	31%	13%	2%	0%	0%
LDW-T2-M-ES-WB-comp-3	English sole	0%	0%	3%	14%	30%	35%	15%	3%	0%	0%
LDW-T2-M-ES-WB-comp-5	English sole	0%	0%	4%	18%	32%	32%	11%	2%	0%	0%
LDW-T3-C4336	Cymatogaster aggregata	0%	0%	1%	8%	28%	37%	22%	4%	0%	0%
LDW-T3-C-SS-WB-comp-1	Shiner perch	0%	0%	1%	8%	28%	37%	22%	4%	0%	0%
LDW-T3-D8048	Leptocottus armatus	0%	0%	1%	5%	21%	38%	29%	6%	0%	0%
LDW-T3-D-PS-WB-comp-1	Pacific Staghorn Sculpin	0%	0%	1%	5%	21%	38%	29%	6%	0%	0%
LDW-T3-E1488	Cymatogaster aggregata	0%	0%	0%	1%	9%	44%	39%	5%	0%	0%
LDW-T3-E3776	Leptocottus armatus	0%	0%	1%	6%	19%	42%	27%	5%	0%	0%
LDW-T3-E-PS-WB-comp-1	Pacific Staghorn Sculpin	0%	0%	1%	6%	19%	42%	27%	5%	0%	0%
LDW-T3-E-SS-WB-comp-1	Shiner perch	0%	0%	0%	1%	9%	44%	39%	5%	0%	0%
LDW-T3-F2912	Cymatogaster aggregata	0%	0%	0%	4%	22%	36%	30%	6%	0%	0%
LDW-T3-F-SS-WB-comp-1	Shiner perch	0%	0%	0%	4%	22%	36%	30%	6%	0%	0%
LDW-T3-M3850	Parophrys vetulus	0%	0%	2%	11%	30%	37%	18%	3%	0%	0%
LDW-T3-M3851	Parophrys vetulus	0%	0%	3%	15%	33%	34%	12%	2%	0%	0%
LDW-T3-M6605	Parophrys vetulus	0%	0%	2%	12%	30%	37%	15%	3%	0%	0%
LDW-T3-M6606	Parophrys vetulus	0%	0%	2%	11%	29%	39%	17%	3%	0%	0%
LDW-T3-M-ES-FL-comp-1	English sole	0%	0%	2%	11%	30%	37%	18%	3%	0%	0%
LDW-T3-M-ES-FL-comp-2	English sole	0%	0%	3%	15%	33%	34%	12%	2%	0%	0%
LDW-T3-M-ES-WB-comp-2	English sole	0%	0%	2%	12%	30%	37%	15%	3%	0%	0%
LDW-T3-M-ES-WB-comp-3	English sole	0%	0%	2%	11%	29%	39%	17%	3%	0%	0%
LDW-T4-B9056	Cymatogaster aggregata	0%	0%	2%	11%	30%	39%	16%	3%	0%	0%
LDW-T4-B-SS-WB-comp-1	Shiner perch	0%	0%	2%	11%	30%	39%	16%	3%	0%	0%
LDW-T4-C5216	Leptocottus armatus	0%	0%	1%	9%	30%	40%	17%	3%	0%	0%
LDW-T4-C-PS-WB-comp-1	Pacific Staghorn Sculpin	0%	0%	1%	9%	30%	40%	17%	3%	0%	0%
LDW-T4-D3795	Leptocottus armatus	0%	0%	2%	12%	29%	37%	16%	3%	0%	0%
LDW-T4-D6080	Cymatogaster aggregata	0%	0%	2%	10%	28%	40%	18%	3%	0%	0%
LDW-T4-D-PS-WB-comp-2	Pacific Staghorn Sculpin	0%	0%	2%	12%	29%	37%	16%	3%	0%	0%
LDW-T4-D-SS-WB-comp-1	Shiner perch	0%	0%	2%	10%	28%	40%	18%	3%	0%	0%
LDW-T4-M1382	Platichthys stellatus	0%	0%	5%	18%	29%	33%	13%	2%	0%	0%
LDW-T4-M2518	Parophrys vetulus	0%	0%	3%	13%	32%	35%	15%	2%	0%	0%
LDW-T4-M4096	Platichthys stellatus	0%	0%	4%	14%	28%	36%	15%	3%	0%	0%
LDW-T4-M5232	Parophrys vetulus	0%	0%	3%	16%	31%	34%	14%	2%	0%	0%
LDW-T4-M-ES-FL-comp-1	English sole	0%	0%	3%	13%	32%	35%	15%	2%	0%	0%
LDW-T4-M-ES-WB-comp-1	English sole	0%	0%	3%	16%	31%	34%	14%	2%	0%	0%
LDW-T4-M-SF-FL-comp-1	Starry Flounder	0%	0%	5%	18%	29%	33%	13%	2%	0%	0%
LDW-T4-M-SF-WB-comp-1	Starry Flounder	0%	0%	4%	14%	28%	36%	15%	3%	0%	0%
Average		**0.0014%**	**0.071%**	**2.3%**	**12%**	**29%**	**37%**	**18%**	**3.1%**	**0.21%**	**0.020%**
Standard Deviation		**0.0010%**	**0.043%**	**1.2%**	**4.2%**	**5.4%**	**3.3%**	**6.2%**	**1.3%**	**0.088%**	**0.015%**
Sum of the Average Percent Contributions for Tri-, Tetra-, Penta-, Hexa-, Hepta-, and Octa-CBs				**99.70%**							

Notes

1. The concentration of PCB homologs in tissue was calculated as the sum of the average concentration of PCB congener.
2. Percent concentration of PCB homolog in total PCBs in invertebrate tissue was calculated as the concentration of each homolog divided by the concentration of total PCBs for each sample.
3. Abbreviations: % = percent ng/kg, ww = nanograms per kilogram, wet weight

Table 2a: Concentration of PCB Homolog in Invertebrate Tissue by Sample (ng/kg, ww) [1]

Sample ID	Species	Homolog Group										
		Mono	Di	Tri	Tetra	Penta	Hexa	Hepta	Octa	Nona	Deca	Total
LDW-07-T1-M-DC-EM-comp1	Metacarcinus magister	1.54	136.05	1,998.02	6,877.29	14,140.05	18,507.05	6,977.14	808.12	57.86	7.77	49,510.88
LDW-07-T1-M-DC-HP-comp1	Metacarcinus magister	12.71	495.10	10,976.99	46,610.37	168,239.43	267,449.73	103,057.66	14,448.87	876.60	107.00	612,274.46
LDW-07-T1-M-DC-WB-comp1 Calculated	Dungeness crab	5.01	239.42	4,775.30	19,181.25	61,871.16	95,806.83	36,786.91	5,036.49	311.20	38.50	224,052.06
LDW-07-T1-M-SC-EM-comp2	Cancer gracilis	0.69	85.94	2,756.58	15,825.03	30,736.05	44,239.57	16,266.97	1,991.82	99.91	12.70	112,015.27
LDW-07-T2-M-SC-EM-comp1	Cancer gracilis	1.01	141.50	2,826.03	13,030.53	26,243.27	32,304.35	10,344.24	1,266.09	63.03	8.07	86,228.13
LDW-07-T3-M-DC-EM-comp3	Metacarcinus magister	1.81	192.30	2,932.76	11,433.37	23,752.01	32,293.21	13,670.49	1,887.84	93.96	5.51	86,263.25
LDW-B10a1370	Melitidae	1.34	75.19	1,390.88	5,328.81	9,585.57	10,438.16	4,523.58	722.07	60.59	13.30	32,139.49
LDW-B10a-T	Benthic Invertebrates	1.35	75.20	1,390.89	5,328.82	9,585.59	10,438.19	4,523.59	722.07	60.59	13.30	32,139.59
LDW-B1b-5551	Melitidae	8.44	348.18	5,933.95	25,559.91	56,893.32	79,928.72	36,590.38	6,814.32	677.00	139.00	212,893.22
LDW-B1b-T	Benthic Invertebrates	8.44	348.18	5,933.96	25,559.93	56,893.32	79,928.74	36,590.38	6,814.32	677.00	139.00	212,893.27
LDW-B2a-1711	Melitidae	4.02	359.35	5,472.77	23,143.66	50,502.21	51,539.37	19,487.33	3,448.95	250.90	44.40	154,252.96
LDW-B2a-T	Benthic Invertebrates	4.02	359.36	5,472.79	23,143.67	50,502.22	51,539.39	19,487.35	3,448.96	250.90	44.40	154,253.05
LDW-B3b-7359	Melitidae	13.09	1,086.42	15,238.43	62,301.08	127,342.71	106,086.09	29,548.35	5,154.18	483.40	120.00	347,373.75
LDW-B3b-T	Benthic Invertebrates	13.09	1,086.43	15,238.43	62,301.09	127,342.71	106,086.11	29,548.36	5,154.18	483.40	120.00	347,373.80
LDW-B4b-8799	Melitidae	18.11	1,048.79	11,997.57	43,516.95	77,800.54	83,035.71	35,101.61	6,688.17	493.80	81.10	259,782.35
LDW-B4b-T	Benthic Invertebrates	18.11	1,048.80	11,997.58	43,516.97	77,800.55	83,035.72	35,101.62	6,688.18	493.80	81.10	259,782.43
LDW-B5a-4959	Melitidae	62.61	2,604.36	50,656.36	195,029.76	200,097.28	178,578.08	89,188.44	15,309.83	724.90	63.80	732,315.42
LDW-B5a-T	Benthic Invertebrates	62.61	2,604.36	50,656.36	195,029.77	200,097.30	178,578.10	89,188.45	15,309.84	724.90	63.80	732,315.49
LDW-B8a-2671	Melitidae	5.31	333.73	7,357.96	47,092.81	202,194.58	574,865.66	421,026.74	88,926.70	4,479.00	75.00	1,346,357.49
LDW-B8a-T	Benthic Invertebrates	5.32	333.74	7,357.97	47,092.83	202,194.60	574,865.67	421,026.74	88,926.70	4,479.00	75.00	1,346,357.57
LDW-B9b-8319	Melitidae	2.30	91.70	1,898.87	9,367.07	23,017.15	21,908.16	6,463.60	1,024.62	74.55	9.08	63,857.10
LDW-B9b-T	Benthic Invertebrates	2.32	91.72	1,898.89	9,367.08	23,017.17	21,908.17	6,463.61	1,024.62	74.55	9.08	63,857.21
LDW-C10-0494	Mya arenaria	8.69	332.38	3,924.73	14,008.36	37,526.43	113,231.81	82,334.32	12,916.30	335.95	6.53	264,625.48
LDW-C10-T1	Softshell clam	8.80	332.62	3,927.84	14,031.65	37,563.10	113,287.54	82,360.30	12,927.30	336.50	6.53	264,782.19
LDW-C1-T	Softshell clam	2.36	168.08	2,543.45	8,481.93	12,389.11	11,949.53	4,846.71	655.13	14.33	2.23	41,052.86
LDW-C1-T7656	Mya arenaria	2.35	168.07	2,543.44	8,481.91	12,389.09	11,949.51	4,846.70	655.13	14.33	2.23	41,052.76
LDW-C2-T2	Softshell clam	2.01	165.16	3,130.45	10,153.70	14,956.41	15,577.11	6,540.30	907.70	23.14	2.25	51,458.23
LDW-C2-T7210	Mya arenaria	2.00	165.15	3,130.45	10,153.68	14,956.39	15,577.08	6,540.28	907.70	23.14	2.25	51,458.12
LDW-C4-T	Softshell clam	2.00	177.06	3,290.85	10,193.21	14,281.75	12,820.79	4,988.05	719.81	19.12	4.80	46,497.44
LDW-C4-T8424	Mya arenaria	1.99	177.05	3,290.84	10,193.20	14,281.73	12,820.76	4,988.03	719.80	19.12	4.80	46,497.32
LDW-C6-T	Softshell clam	4.55	210.75	3,636.72	11,614.51	15,187.07	14,279.88	6,165.95	957.53	27.33	3.17	52,087.45
LDW-C6-T7912	Mya arenaria	4.54	210.74	3,636.70	11,614.49	15,187.06	14,279.85	6,165.94	957.52	27.33	3.17	52,087.34
LDW-C7-T1	Softshell clam	4.67	571.49	19,767.49	83,583.74	118,738.42	67,972.48	15,891.73	1,964.39	61.09	4.22	308,559.72
LDW-C7-T6731	Mya arenaria	4.66	571.49	19,767.48	83,583.73	118,738.41	67,972.47	15,891.71	1,964.39	61.09	4.22	308,559.65
LDW-C8-T	Softshell clam	117.10	7,182.45	103,814.73	307,198.75	322,309.40	158,003.68	27,404.30	3,670.36	234.10	18.30	929,953.17
LDW-C8-T9448	Mya arenaria	117.10	7,182.45	103,814.73	307,198.74	322,309.39	158,003.67	27,404.29	3,670.36	234.10	18.30	929,953.13
LDW-C9-T	Softshell clam	2.52	237.97	4,633.43	16,122.43	25,262.81	21,908.12	9,531.64	1,287.45	31.28	3.29	79,020.94
LDW-C9-T9704	Mya arenaria	2.52	237.96	4,633.42	16,122.42	25,262.80	21,908.10	9,531.62	1,287.44	31.28	3.29	79,020.85
LDW-T1-M6960	Cancer gracilis	15.18	1,018.10	19,145.94	101,252.77	234,356.50	298,346.27	120,201.39	15,176.85	891.20	118.00	790,522.20
LDW-T1-M8396	Metacarcinus magister	2.76	308.11	5,846.80	19,311.84	31,152.30	37,054.66	14,562.54	2,529.70	216.80	28.50	111,014.01
LDW-T1-M8761	Cancer gracilis	11.25	209.02	3,726.96	24,111.12	53,121.77	73,927.04	27,795.35	3,168.31	140.80	17.30	186,228.90
LDW-T1-M8764	Cancer gracilis	1.47	333.92	6,638.00	28,668.30	53,583.13	60,901.15	21,824.48	2,678.99	142.70	17.50	174,789.64
LDW-T1-M-DC-EM-comp-2	Dungeness crab	2.76	308.12	5,846.80	19,311.85	31,152.31	37,054.67	14,562.56	2,529.71	216.80	28.50	111,014.07
LDW-T1-M-SC-EM-comp-1	Slender Crab	21.75	244.16	3,729.14	24,128.20	53,144.39	74,078.05	27,813.94	3,170.31	140.90	17.30	186,488.14
LDW-T1-M-SC-EM-comp-2	Slender Crab	1.49	333.95	6,638.03	28,668.32	53,583.13	60,901.16	21,824.49	2,678.99	142.70	17.50	174,789.76
LDW-T1-M-SC-HP-comp-1	Slender Crab	15.18	1,018.10	19,145.95	101,252.77	234,356.50	298,346.27	120,201.39	15,176.86	891.20	118.00	790,522.21
LDW-T1-M-SC-WB-comp-1 Calculated	Slender Crab	19.71	479.95	8,508.39	48,012.77	109,231.33	143,537.65	56,422.63	6,898.68	373.10	48.50	373,532.71
LDW-T1-M-SC-WB-comp-2 Calculated	Slender Crab	4.79	545.10	10,511.42	51,150.66	109,620.72	134,521.90	52,290.82	6,556.97	374.50	48.70	365,625.58
LDW-T2-M0589	Cancer gracilis	17.43	1,018.19	28,967.45	150,856.87	332,926.38	380,528.50	137,634.17	14,863.89	576.90	48.90	1,047,438.68
LDW-T2-M5125	Cancer gracilis	1.58	174.78	4,651.18	28,020.03	59,816.20	63,771.54	22,006.97	2,087.82	73.59	6.59	180,610.28
LDW-T2-M5128	Cancer gracilis	2.01	218.54	4,091.48	19,532.02	41,439.93	45,965.30	16,554.69	1,814.87	67.29	5.62	129,691.75
LDW-T2-M-SC-EM-comp-5	Slender Crab	1.60	174.80	4,651.21	28,020.04	59,816.21	63,771.55	22,006.98	2,087.83	73.59	6.59	180,610.39

Table 2a: Concentration of PCB Homolog in Invertebrate Tissue by Sample (ng/kg, ww) [Continued]

Sample ID	Species	Homolog Group										
		Mono	Di	Tri	Tetra	Penta	Hexa	Hepta	Octa	Nona	Deca	Total
LDW-T2-M-SC-EM-comp-6	Slender Crab	2.02	218.56	4,091.49	19,532.03	41,439.93	45,965.32	16,554.70	1,814.88	67.29	5.62	129,691.85
LDW-T2-M-SC-HP-comp-2	Slender Crab	17.43	1,018.19	28,967.46	150,856.87	332,926.38	380,528.50	137,634.17	14,863.89	576.90	48.90	1,047,438.69
LDW-T2-M-SC-WB-comp-5 Calculated	Slender Crab	5.34	433.41	12,180.16	66,052.55	144,388.69	161,950.85	57,889.43	6,046.84	229.60	19.70	449,196.57
LDW-T2-M-SC-WB-comp-6 Calculated	Slender Crab	6.80	463.15	11,793.92	60,235.66	131,816.65	149,748.60	54,121.75	5,859.51	225.60	19.00	414,290.64
LDW-T3-M5680	Metacarcinus magister	17.72	2,226.00	68,265.21	440,684.46	1,016,562.15	1,406,545.20	645,690.83	97,939.07	4,813.00	318.00	3,683,061.64
LDW-T3-M9305	Metacarcinus magister	4.20	470.90	8,078.22	25,343.56	44,171.16	48,706.44	19,484.20	2,954.03	168.30	11.80	149,392.81
LDW-T3-M9676	Cancer gracilis	1.44	148.03	3,807.57	20,739.08	46,477.32	45,887.15	15,493.03	1,689.78	62.44	4.40	134,310.24
LDW-T3-M-DC-EM-comp-1	Dungeness crab	4.20	470.91	8,078.22	25,343.57	44,171.16	48,706.45	19,484.21	2,954.04	168.30	11.80	149,392.86
LDW-T3-M-DC-HP-comp-1	Dungeness crab	17.72	2,226.00	68,265.21	440,684.46	1,016,562.15	1,406,545.21	645,690.83	97,939.07	4,813.00	318.00	3,683,061.65
LDW-T3-M-DC-WB-comp-1 Calculated	Dungeness crab	8.40	1,012.45	26,730.77	151,077.57	345,727.05	469,780.89	213,597.71	32,379.97	1,606.00	107.00	1,242,027.81
LDW-T3-M-SC-EM-comp-2	Slender Crab	1.45	148.05	3,807.59	20,739.09	46,477.33	45,887.16	15,493.05	1,689.79	62.44	4.40	134,310.34
LDW-T4-M4336	Metacarcinus magister	23.08	1,480.60	39,921.85	264,948.77	966,626.08	1,389,547.68	812,951.80	136,479.64	6,266.00	368.00	3,618,613.50
LDW-T4-M7975	Metacarcinus magister	2.99	265.01	3,986.35	15,304.60	38,537.76	57,439.86	28,366.47	4,536.67	249.90	21.80	148,711.41
LDW-T4-M-DC-EM-comp-1	Dungeness crab	2.99	265.03	3,986.37	15,304.61	38,537.77	57,439.88	28,366.48	4,536.67	249.90	21.80	148,711.49
LDW-T4-M-DC-HP-comp-1	Dungeness crab	23.08	1,480.60	39,921.85	264,948.77	966,626.08	1,389,547.68	812,951.80	136,479.64	6,266.00	368.00	3,618,613.50
LDW-T4-M-DC-WB-comp1 Calculated	Dungeness crab	9.22	639.44	15,127.55	92,604.13	326,163.35	470,912.09	271,540.06	45,430.25	2,111.00	129.00	1,224,666.10
Average		**11.88**	**744.53**	**14,628.74**	**67,721.64**	**146,260.29**	**189,452.17**	**92,020.71**	**14,747.04**	**731.50**	**53.90**	**526,372.42**
Standard Deviation		**21.67**	**1,270.21**	**21,520.45**	**97,585.30**	**232,796.16**	**331,817.58**	**180,886.29**	**30,693.67**	**1,460.71**	**83.27**	**861,783.44**

Table 2b: Percent Concentration of PCB Homolog in Total PCBs in Invertebrate Tissue by Sample (%) [2]

Sample ID	Species	Homolog Group									
		Mono	Di	Tri	Tetra	Penta	Hexa	Hepta	Octa	Nona	Deca
LDW-07-T1-M-DC-EM-comp1	Metacarcinus magister	0%	0%	4%	14%	29%	37%	14%	2%	0%	0%
LDW-07-T1-M-DC-HP-comp1	Metacarcinus magister	0%	0%	2%	8%	27%	44%	17%	2%	0%	0%
LDW-07-T1-M-DC-WB-comp1 Calculated	Dungeness crab	0%	0%	2%	9%	28%	43%	16%	2%	0%	0%
LDW-07-T1-M-SC-EM-comp2	Cancer gracilis	0%	0%	2%	14%	27%	39%	15%	2%	0%	0%
LDW-07-T2-M-SC-EM-comp1	Cancer gracilis	0%	0%	3%	15%	30%	37%	12%	1%	0%	0%
LDW-07-T3-M-DC-EM-comp3	Metacarcinus magister	0%	0%	3%	13%	28%	37%	16%	2%	0%	0%
LDW-B10a1370	Melitidae	0%	0%	4%	17%	30%	32%	14%	2%	0%	0%
LDW-B10a-T	Benthic Invertebrates	0%	0%	4%	17%	30%	32%	14%	2%	0%	0%
LDW-B1b-5551	Melitidae	0%	0%	3%	12%	27%	38%	17%	3%	0%	0%
LDW-B1b-T	Benthic Invertebrates	0%	0%	3%	12%	27%	38%	17%	3%	0%	0%
LDW-B2a-1711	Melitidae	0%	0%	4%	15%	33%	33%	13%	2%	0%	0%
LDW-B2a-T	Benthic Invertebrates	0%	0%	4%	15%	33%	33%	13%	2%	0%	0%
LDW-B3b-7359	Melitidae	0%	0%	4%	18%	37%	31%	9%	1%	0%	0%
LDW-B3b-T	Benthic Invertebrates	0%	0%	4%	18%	37%	31%	9%	1%	0%	0%
LDW-B4b-8799	Melitidae	0%	0%	5%	17%	30%	32%	14%	3%	0%	0%
LDW-B4b-T	Benthic Invertebrates	0%	0%	5%	17%	30%	32%	14%	3%	0%	0%
LDW-B5a-4959	Melitidae	0%	0%	7%	27%	27%	24%	12%	2%	0%	0%
LDW-B5a-T	Benthic Invertebrates	0%	0%	7%	27%	27%	24%	12%	2%	0%	0%
LDW-B8a-2671	Melitidae	0%	0%	1%	3%	15%	43%	31%	7%	0%	0%
LDW-B8a-T	Benthic Invertebrates	0%	0%	1%	3%	15%	43%	31%	7%	0%	0%
LDW-B9b-8319	Melitidae	0%	0%	3%	15%	36%	34%	10%	2%	0%	0%
LDW-B9b-T	Benthic Invertebrates	0%	0%	3%	15%	36%	34%	10%	2%	0%	0%
LDW-C10-0494	Mya arenaria	0%	0%	1%	5%	14%	43%	31%	5%	0%	0%
LDW-C10-T1	Softshell clam	0%	0%	1%	5%	14%	43%	31%	5%	0%	0%
LDW-C1-T	Softshell clam	0%	0%	6%	21%	30%	29%	12%	2%	0%	0%
LDW-C1-T7656	Mya arenaria	0%	0%	6%	21%	30%	29%	12%	2%	0%	0%
LDW-C2-T2	Softshell clam	0%	0%	6%	20%	29%	30%	13%	2%	0%	0%
LDW-C2-T7210	Mya arenaria	0%	0%	6%	20%	29%	30%	13%	2%	0%	0%
LDW-C4-T	Softshell clam	0%	0%	7%	22%	31%	28%	11%	2%	0%	0%
LDW-C4-T8424	Mya arenaria	0%	0%	7%	22%	31%	28%	11%	2%	0%	0%
LDW-C6-T	Softshell clam	0%	0%	7%	22%	29%	27%	12%	2%	0%	0%
LDW-C6-T7912	Mya arenaria	0%	0%	7%	22%	29%	27%	12%	2%	0%	0%
LDW-C7-T1	Softshell clam	0%	0%	6%	27%	38%	22%	5%	1%	0%	0%
LDW-C7-T6731	Mya arenaria	0%	0%	6%	27%	38%	22%	5%	1%	0%	0%
LDW-C8-T	Softshell clam	0%	1%	11%	33%	35%	17%	3%	0%	0%	0%
LDW-C8-T9448	Mya arenaria	0%	1%	11%	33%	35%	17%	3%	0%	0%	0%
LDW-C9-T	Softshell clam	0%	0%	6%	20%	32%	28%	12%	2%	0%	0%
LDW-C9-T9704	Mya arenaria	0%	0%	6%	20%	32%	28%	12%	2%	0%	0%
LDW-T1-M6960	Cancer gracilis	0%	0%	2%	13%	30%	38%	15%	2%	0%	0%
LDW-T1-M8396	Metacarcinus magister	0%	0%	5%	17%	28%	33%	13%	2%	0%	0%
LDW-T1-M8761	Cancer gracilis	0%	0%	2%	13%	29%	40%	15%	2%	0%	0%
LDW-T1-M8764	Cancer gracilis	0%	0%	4%	16%	31%	35%	12%	2%	0%	0%
LDW-T1-M-DC-EM-comp-2	Dungeness crab	0%	0%	5%	17%	28%	33%	13%	2%	0%	0%
LDW-T1-M-SC-EM-comp-1	Slender Crab	0%	0%	2%	13%	28%	40%	15%	2%	0%	0%
LDW-T1-M-SC-EM-comp-2	Slender Crab	0%	0%	4%	16%	31%	35%	12%	2%	0%	0%
LDW-T1-M-SC-HP-comp-1	Slender Crab	0%	0%	2%	13%	30%	38%	15%	2%	0%	0%
LDW-T1-M-SC-WB-comp-1 Calculated	Slender Crab	0%	0%	2%	13%	29%	38%	15%	2%	0%	0%
LDW-T1-M-SC-WB-comp-2 Calculated	Slender Crab	0%	0%	3%	14%	30%	37%	14%	2%	0%	0%
LDW-T2-M0589	Cancer gracilis	0%	0%	3%	14%	32%	36%	13%	1%	0%	0%
LDW-T2-M5125	Cancer gracilis	0%	0%	3%	16%	33%	35%	12%	1%	0%	0%
LDW-T2-M5128	Cancer gracilis	0%	0%	3%	15%	32%	35%	13%	1%	0%	0%
LDW-T2-M-SC-EM-comp-5	Slender Crab	0%	0%	3%	16%	33%	35%	12%	1%	0%	0%

Table 2b: Percent Concentration of PCB Homolog in Total PCBs in Invertebrate Tissue by Sample (%) [Continued]

Sample ID	Species	Homolog Group									
		Mono	Di	Tri	Tetra	Penta	Hexa	Hepta	Octa	Nona	Deca
LDW-T2-M-SC-EM-comp-6	Slender Crab	0%	0%	3%	15%	32%	35%	13%	1%	0%	0%
LDW-T2-M-SC-HP-comp-2	Slender Crab	0%	0%	3%	14%	32%	36%	13%	1%	0%	0%
LDW-T2-M-SC-WB-comp-5 Calculated	Slender Crab	0%	0%	3%	15%	32%	36%	13%	1%	0%	0%
LDW-T2-M-SC-WB-comp-6 Calculated	Slender Crab	0%	0%	3%	15%	32%	36%	13%	1%	0%	0%
LDW-T3-M5680	Metacarcinus magister	0%	0%	2%	12%	28%	38%	18%	3%	0%	0%
LDW-T3-M9305	Metacarcinus magister	0%	0%	5%	17%	30%	33%	13%	2%	0%	0%
LDW-T3-M9676	Cancer gracilis	0%	0%	3%	15%	35%	34%	12%	1%	0%	0%
LDW-T3-M-DC-EM-comp-1	Dungeness crab	0%	0%	5%	17%	30%	33%	13%	2%	0%	0%
LDW-T3-M-DC-HP-comp-1	Dungeness crab	0%	0%	2%	12%	28%	38%	18%	3%	0%	0%
LDW-T3-M-DC-WB-comp-1 Calculated	Dungeness crab	0%	0%	2%	12%	28%	38%	17%	3%	0%	0%
LDW-T3-M-SC-EM-comp-2	Slender Crab	0%	0%	3%	15%	35%	34%	12%	1%	0%	0%
LDW-T4-M4336	Metacarcinus magister	0%	0%	1%	7%	27%	38%	22%	4%	0%	0%
LDW-T4-M7975	Metacarcinus magister	0%	0%	3%	10%	26%	39%	19%	3%	0%	0%
LDW-T4-M-DC-EM-comp-1	Dungeness crab	0%	0%	3%	10%	26%	39%	19%	3%	0%	0%
LDW-T4-M-DC-HP-comp-1	Dungeness crab	0%	0%	1%	7%	27%	38%	22%	4%	0%	0%
LDW-T4-M-DC-WB-comp1 Calculated	Dungeness crab	0%	0%	1%	8%	27%	38%	22%	4%	0%	0%
Average		**0.0033%**	**0.22%**	**3.9%**	**16%**	**30%**	**34%**	**14%**	**2.1%**	**0.11%**	**0.013%**
Standard Deviation		**0.0029%**	**0.15%**	**2.2%**	**6.0%**	**4.8%**	**5.8%**	**5.6%**	**1.2%**	**0.075%**	**0.013%**
Sum of the Average Percent Contributions for Tri-, Tetra-, Penta-, Hexa-, Hepta-, and Octa-CBs				**99.66%**							

Notes

1. The concentration of PCB homologs in tissue was calculated as the sum of the average concentration of PCB congener.
2. Percent concentration of PCB homolog in total PCBs in invertebrate tissue was calculated as the concentration of each homolog divided by the concentration of total PCBs for each sample.
3. Abbreviations: % = percent ng/kg, ww = nanograms per kilogram, wet weight

Table 3 Concentration of PCB Congeners in Sediment (ng/kg, dw)

Location ID	Sample ID	Tri PCB-018	Tri PCB-028	Tetra PCB-044	Tetra PCB-052	Tetra PCB-066	Tetra PCB-077	Tetra PCB-081	Penta PCB-090	Penta PCB-101	Penta PCB-105	Penta PCB-110	Penta PCB-114	Penta PCB-118	Penta PCB-123	Penta PCB-126	Hexa PCB-128	Hexa PCB-129	Hexa PCB-138
CH0030	CH09-01						< 310			23000	2900	5500		5100		< 280	4000		5100
EIT061	EIT06-02						< 640			570000	110000	340000		270000		< 580	140000		240000
EST143	EST09-03						< 590			100000	14000	45000		31000		< 530	11000		28000
LDW-SS120	LDW-SS120-010					8040	1060	34	32200		11800	40100	610	28400	551	163		48400	
LDW-SS6	LDW-SS6-010					87300	7630	450	136000		55800	142000	3650	118000	2250	169		120000	
DR001	SD-DR001-0000	< 1000	1000	1000	2000	4000	< 1000	< 1000		3000	1000		< 1000	3000	< 1000	< 1000	1000		7000
DR088	SD-DR088-0000	< 17000	28000	19000	25000	39000	< 1000	< 1000		28000	10000		< 2000	22000	< 1000	< 1000	6000		36000
DR089	SD-DR089-0000	2000	4000	5000	7000	< 15000	< 1000	< 1000		10000	5000		< 1000	10000	< 2000	< 1000	3000		< 19000
DR236	SD-DR236-0000	< 1000	1000	2000	4000	7000	< 1000	< 1000		7000	2000		< 1000	6000	< 1000	< 1000	2000		10000

Table 3 Concentration of PCB Congeners in Sediment (ng/kg, dw) [Continued]

Hexa PCB-153	Hexa PCB-156	Hexa PCB-157	Hexa PCB-167	Hexa PCB-169	Hepta PCB-170	Hepta PCB-180	Hepta PCB-187	Hepta PCB-189	Octa PCB-195	Nona PCB-206	Deca PCB-209	Total PCBs [1]
18000	690	< 220		< 710	5300	8300		< 320				77890
340000	28000	18000		< 1400	88000	93000		< 650				2237000
75000	3300	< 410		< 1300	8000	9400		< 600				324700
33100	5200		1790	< 17.4		11600		239				223287
87600	16400		4400	< 91.3		38300		840				820789
6000	< 1000	< 1000	< 1000	< 1000	2000	4000	3000	< 1000	< 1000	< 1000	< 1000	38000
24000	4000	1000	2000	< 1000	8000	14000	9000	< 1000	2000	2000	1000	280000
12000	2000	< 1000	2000	< 1000	6000	9000	6000	< 1000	1000	1000	< 1000	85000
6000	< 1000	< 1000	< 1000	< 1000	< 1000	3000	2000	< 1000	< 1000	< 1000	< 1000	52000

Notes:

1.) Calculated as the sum of the detected congeners.

2.) Abbrevi ng/kg, dw = nanograms per kilogram, dry weight

PCB = polychlorinated biphenyls

Table 4.a. Concentration of Homolog Groups in Sediment (ng/kg, dw) [1]

Station	Sample ID	Tri	Tetra	Penta	Hexa	Hepta	Octa	Nona	Deca	Total PCBs
CH0030	CH09-01			36,500	27,790	13,600				77,890
EIT061	EIT06-02			1,290,000	766,000	181,000				2,237,000
EST143	EST09-03			190,000	117,300	17,400				324,700
LDW-SS120	LDW-SS120-010		9,134	113,824	88,490	11,839				223,287
LDW-SS6	LDW-SS6-010		95,380	457,869	228,400	39,140				820,789
DR001	SD-DR001-0000	1,000	7,000	7,000	14,000	9,000				38,000
DR088	SD-DR088-0000	28,000	83,000	60,000	73,000	31,000	2,000	2,000	1,000	280,000
DR089	SD-DR089-0000	6,000	12,000	25,000	19,000	21,000	1,000	1,000		85,000
DR236	SD-DR236-0000	1,000	13,000	15,000	18,000	5,000				52,000

Table 4.b. Percent of the Concentration of Each Homolog Group in Total PCB Concentrations in Sediment for Each Sample (%)

Station	Sample ID	Tri	Tetra	Penta	Hexa	Hepta	Octa	Nona	Deca	Total
CH0030	CH09-01			47%	36%	17%				
EIT061	EIT06-02			58%	34%	8.1%				
EST143	EST09-03			59%	36%	5.4%				
LDW-SS120	LDW-SS120-010		4.1%	51%	40%	5.3%				
LDW-SS6	LDW-SS6-010		12%	56%	28%	4.8%				
DR001	SD-DR001-0000	2.6%	18%	18%	37%	24%				
DR088	SD-DR088-0000	10%	30%	21%	26%	11%	0.71%	0.71%	0.36%	
DR089	SD-DR089-0000	7.1%	14%	29%	22%	25%	1.2%	1.2%		
DR236	SD-DR236-0000	1.9%	25%	29%	35%	10%				
Average of Percentages		5.4%	17%	41%	33%	12%	0.95%	0.95%	0.36%	110.5%
Standard Deviation of Percentages		3.8%	9.3%	16.2%	5.8%	7.8%	0.33%	0.33%	-	
Average of Percentages (100% by ratio) [2]		4.9%	16%	37%	29%	11%	0.86%	0.86%	0.32%	100%
Standard Deviation (100% by ratio)		3.5%	8.4%	15%	5.2%	7.1%	0.30%	0.30%	-	

Table 4.c. Count of PCB Congeners Measured in Each Homolog Group

Station	Sample ID	Tri	Tetra	Penta	Hexa	Hepta	Octa	Nona	Deca
CH0030	CH09-01	0	1 ND	5 (1 ND)	6 (2 ND)	3 (1 ND)	0	0	0
EIT061	EIT06-02	0	1 ND	5 (1 ND)	6 (1 ND)	3 (1 ND)	0	0	0
EST143	EST09-03	0	1 ND	5 (1 ND)	6 (2 ND)	3 (1 ND)	0	0	0
LDW-SS120	LDW-SS120-010	0	3	7	5 (1 ND)	2	0	0	0
LDW-SS6	LDW-SS6-010	0	3	7	5 (1 ND)	2	0	0	0
DR001	SD-DR001-0000	2 (1 ND)	5 (2 ND)	6 (3 ND)	7 (4 ND)	4 (1 ND)	1 ND	1 ND	1 ND
DR088	SD-DR088-0000	2 (1 ND)	5 (2 ND)	6 (3 ND)	7 (1 ND)	4 (1 ND)	1	1	1
DR089	SD-DR089-0000	2	5 (3 ND)	6 (3 ND)	7 (3 ND)	4 (1 ND)	1	1	1 ND
DR236	SD-DR236-0000	2 (1 ND)	5 (2 ND)	6 (3 ND)	7 (4 ND)	4 (2 ND)	1 ND	1 ND	1 ND

Notes:

1.) Calculated as the sum of the detected congeners.

2.) The average of percentages totals 110.5% since each sample did not contain the same number of congeners and some were non-detect. To adjust for this, the average of the percentages were multiplied by the ratio of 100% over 110.5%

3.) Abbreviations: % = percent; ng/kg, dw = nanograms per kilogram, dry weight; ND = not detected; PCB = polychlorinated biphenyls

Table 5.a. Concentrations of PCB Congeners in Sediment (ng/kg, dw)

Station ID	Sample ID	Tri PCB-018	Tri PCB-028	Tetra PCB-044	Tetra PCB-052	Tetra PCB-066	Tetra PCB-077	Tetra PCB-081	Penta PCB-090	Penta PCB-101	Penta PCB-105	Penta PCB-110	Penta PCB-114	Penta PCB-118
CH0030	CH09-01						< 310			23000	2900	5500		5100
EIT061	EIT06-02						< 640			570000	110000	340000		270000
EST143	EST09-03						< 590			100000	14000	45000		31000
LDW-SS120	LDW-SS120-010					8040	1060	34	32200		11800	40100	610	28400
LDW-SS6	LDW-SS6-010					87300	7630	450	136000		55800	142000	3650	118000
DR001	SD-DR001-0000	< 1000	1000	1000	2000	4000	< 1000	< 1000		3000	1000		< 1000	3000
DR088	SD-DR088-0000	< 17000	28000	19000	25000	39000	< 1000	< 1000		28000	10000		< 2000	22000
DR089	SD-DR089-0000	2000	4000	5000	7000	< 15000	< 1000	< 1000		10000	5000		< 1000	10000
DR236	SD-DR236-0000	< 1000	1000	2000	4000	7000	< 1000	< 1000		7000	2000		< 1000	6000

Table 5.b. Concentrations of PCB Congeners in Porewater Estimated by Two-Carbon Model (ng/L) [3]

Station ID	Sample ID	TOC [1] (%)	BC [2] (%)	Tri PCB-018	Tri PCB-028	Tetra PCB-044	Tetra PCB-052	Tetra PCB-066	Tetra PCB-077	Tetra PCB-081	Penta PCB-090	Penta PCB-101	Penta PCB-105	Penta PCB-110	Penta PCB-114	Penta PCB-118
Log K_{OC} (L/kg OC) [4]				4.0	4.3	4.4	4.5	4.7	4.9	4.9	4.9	4.9	5.1	4.9	5.1	5.1
Log K_{BC} (L/kg BC) [5]				6.1	6.5	6.6	6.7	7.0	7.2	7.2	7.2	7.2	7.4	7.3	7.4	7.5
CH0030	CH09-01	1.94%	0.23%						< 0.009			0.654	0.047	0.127		0.069
EIT061	EIT06-02	1.67%	0.23%						< 0.019			16.309	1.793	7.898		3.648
EST143	EST09-03	1.38%	0.23%						< 0.018			2.879	0.229	1.052		0.421
LDW-SS120	LDW-SS120-010	1.94%	0.23%					0.333	0.031	0.001	0.955		0.191	0.926	0.010	0.382
LDW-SS6	LDW-SS6-010	1.05%	0.23%					3.686	0.231	0.014	4.111		0.920	3.341	0.060	1.613
DR001	SD-DR001-0000	3.01%	0.23%	< 0.294	0.121	0.102	0.170	0.162	< 0.029	< 0.029		0.083	0.016		< 0.016	0.040
DR088	SD-DR088-0000	1.68%	0.23%	< 5.21	3.511	2.017	2.201	1.623	< 0.03	< 0.03		0.801	0.163		< 0.033	0.297
DR089	SD-DR089-0000	1.92%	0.23%	0.608	0.498	0.527	0.612	< 0.621	< 0.03	< 0.03		0.285	0.081		< 0.016	0.134
DR236	SD-DR236-0000	0.85%	0.23%	< 0.315	0.128	0.217	0.360	0.297	< 0.03	< 0.03		0.204	0.033		< 0.017	0.082

Table 5.c. Average Concentration of PCB Congener Detections in Porewater, as Estimated by Two-Carbon Model (pg/L)

	Tri	Tetra	Penta	Hexa	Hepta	Octa	Total PCBs
Average	973	740	1,313	387	57	4	3,475
Percentage of Total	28%	21%	38%	11%	2%	0.11%	

Table 5.a. Concentrations of PCB Congeners in Sediment (ng/kg, dw) [Continued]

Penta PCB-123	Penta PCB-126	Hexa PCB-128	Hexa PCB-129	Hexa PCB-138	Hexa PCB-153	Hexa PCB-156	Hexa PCB-157	Hexa PCB-167	Hexa PCB-169	Hepta PCB-170	Hepta PCB-180	Hepta PCB-187	Hepta PCB-189	Octa PCB-195
	< 280	4000		5100	18000	690	< 220		< 710	5300	8300		< 320	
	< 580	140000		240000	340000	28000	18000		< 1400	88000	93000		< 650	
	< 530	11000		28000	75000	3300	< 410		< 1300	8000	9400		< 600	
551	163		48400		33100	5200		1790	< 17.4		11600		239	
2250	169		120000		87600	16400		4400	< 91.3		38300		840	
< 1000	< 1000	1000		7000	6000	< 1000	< 1000	< 1000	< 1000	2000	4000	3000	< 1000	< 1000
< 1000	< 1000	6000		36000	24000	4000	1000	2000	< 1000	8000	14000	9000	< 1000	2000
< 2000	< 1000	3000		< 19000	12000	2000	< 1000	2000	< 1000	6000	9000	6000	< 1000	1000
< 1000	< 1000	2000		10000	6000	< 1000	< 1000	< 1000	< 1000	< 1000	3000	2000	< 1000	< 1000

Table 5.b. Concentrations of PCB Congeners in Porewater Estimated by Two-Carbon Model (ng/L) [3] [Continued]

Penta PCB-123	Penta PCB-126	Hexa PCB-128	Hexa PCB-129	Hexa PCB-138	Hexa PCB-153	Hexa PCB-156	Hexa PCB-157	Hexa PCB-167	Hexa PCB-169	Hepta PCB-170	Hepta PCB-180	Hepta PCB-187	Hepta PCB-189	Octa PCB-195	Total PCBs
5.1	5.2	5.1	5.1	5.2	5.3	5.5	5.5	5.5	5.6	5.6	5.6	5.5	5.9	5.7	
7.5	7.6	7.5	7.5	7.6	7.7	7.9	7.9	8.0	8.1	8.1	8.1	7.9	8.4	8.2	
	< 0.003	0.054		0.057	0.166	0.004	< 0.001		< 0.002	0.017	0.031		< 0.001		1.2
	< 0.006	1.892		2.688	3.156	0.151	0.097		< 0.005	0.288	0.345		< 0.001		38
	< 0.005	0.149		0.315	0.700	0.018	< 0.002		< 0.004	0.026	0.035		< 0.001		5.8
0.007	0.002		0.664		0.306	0.028		0.008	< 0.0001		0.043		0.000		3.9
0.031	0.002		1.675		0.822	0.089		0.020	< 0.0003		0.143		0.002		17
< 0.013	< 0.01	0.013		0.077	0.054	< 0.005	< 0.005	< 0.004	< 0.003	0.006	0.015	0.016	< 0.002	< 0.002	0.88
< 0.014	< 0.01	0.081		0.403	0.223	0.022	0.005	0.009	< 0.003	0.026	0.052	0.050	< 0.002	0.005	11
< 0.027	< 0.01	0.040		< 0.212	0.111	0.011	< 0.005	0.009	< 0.003	0.020	0.033	0.033	< 0.002	0.002	3.0
< 0.014	< 0.01	0.027		0.114	0.057	< 0.005	< 0.005	< 0.005	< 0.003	< 0.003	0.011	0.011	< 0.002	< 0.002	1.5

Notes:

1.) TOC is referenced from Boeing and LDWG databases

2.) Black carbon was calculated as the average of 5 stations as referenced from *Assessing Bioavailability of Sediment Contaminants to Support Selecting Remedies* (Wakeman 2014)

3.) Porewater is calculated as $C_d = C_s \div [(f_{NPOC} \times K_{NPOC}) + (f_{BC} \times K_{BC})]$; where f_{NPOC} = fraction of nonpyrogenic organic carbon in sediment, f_{BC} = fraction of black carbon, K_{NPOC} = chemical- nonpyrogenic organic carbon partition coefficient, K_{BC} = chemical- black carbon partition coefficient, C_d = concentration of PCBs in porewater, C_s = concentration of PCBs in sediment, as referenced from Perron et al (2010).

4.) Log K_{OW} referenced from Hawker and Connell (1988). Log $K_{OC} = 0.74 \times \log K_{OW} + 0.15$ (Hawker and Connell 1988, Hawthorne et al. 2011).

5.) Log K_{OW} referenced from Hawker and Connell (1988). Log $K_{BC} = 0.91 \times \text{Log } K_{OW} + 1.37$ (Hawker and Connell 1988, Hawthorne et al. 2011).

6.) Abbreviations:

% = percent
BC = black carbon
L/kg = liters per kilogram
ng/kg, dw = nanograms per kilogram, dry weight
ng/L = nanograms per liter
OC = organic carbon
PCB = polychlorinated biphenyls
TOC = total organic carbon

Table 6. Average Method Detection Limits for Freely-Dissolved PCB Congeners (by Homolog) in Sediment Porewater

						Lowest Achievable MDL in Porewater (Complete Equilibrium Exposure)	MDL in Porewater (4-Week Exposure)		Expected Average Pilot Study Concentrations of PCB in Porewater (pg/L)		
Length Fiber (cm)	PCB Homolog	MDL [1] (ng)	K_{fs} [2] (L/L_{PDMS})	Volume of PDMS on Fiber (µL)	Concentration of PCB in PDMS (ng/L)	Concentration of PCB in Porewater (pg/L)	Percent to Equilibrium [3]	Concentration of PCB in Porewater (pg/L)	Baseline [4]	Post-Treatment [5]	Method Sensitivity
480	Tri	0.50	260,000	33.17	15,075	58	87%	66	970	97 - 194	Adequate
480	Tetra	0.50	700,000	33.17	15,075	22	71%	30	740	74 - 148	Adequate
480	Penta	0.50	2,000,000	33.17	15,075	7.5	52%	15	1,300	130 - 260	Adequate
480	Hexa	0.50	5,000,000	33.17	15,075	3.0	37%	8.2	400	40 - 80	Adequate
480	Hepta	0.50	13,000,000	33.17	15,075	1.2	25%	4.7	60	6 - 12	Adequate
480	Octa	0.50	36,000,000	33.17	15,075	0.4	**15%**	2.7	7.0	0.7 - 1.4	Some results may be flagged as estimated values, and most post-treatment results likely to below detection limit.

Notes

1.) 5 picograms per 1 µL injection is the MDL. The 1800-µL SPME hexane extract is concentrated to approximately 100 µL.

2.) Approximate average for homolog group as referenced from Smedes et al. (2009).

3.) Based on sampling results from a sampling event at Bremerton, WA activated carbon amendment site. When the percentage is less than 20% (**bold and red font**), analytical results for congeners within those homologs may be flagged as estimated (J-flag or equivalent) values.

4.) Calculations are provided in Table 5.c. Average Concentration of PCB Congener Detections in Porewater, as Estimated by Two-Carbon Model.

5.) Assuming 80-90% reduction in PCBs from baseline.

6.) Abbreviations:

µL = microliter
cm = centimeter
K_{fs} = Fiber PDMS-Solution Water Partition Coefficient
L = liter
MDL = method detection limit
ng = nanogram
PCB = polychlorinated biphenyl
PDMS = polydimethylsiloxane
pg =picogram
SPME = solid phase microextraction

ATTACHMENT C

Electronic Deliverable Requirements for Laboratory Reporting

QUALITY ASSURANCE PROJECT PLAN
Attachment C – Electronic Data Deliverables Requirements
Lower Duwamish Waterway

1.0 INTRODUCTION

The purpose of electronic data deliverables (EDD) is to eliminate the potential for transcription errors between the entry of samples at the analytical laboratory and the entry of sample results into the client's project-specific data base. This assumes that the laboratory has a Laboratory Information Management System (LIMS) that is tracking this information electronically from sample receipt to final reporting. It also assumes that the project-specific data base tracks information from the field collection step to final reporting.

All laboratories being used in this project have LIMS and are certified by Washington Department of Ecology for those methods that are used in this project and that Ecology certifies. The project-specific data base for the Lower Duwamish Waterway Superfund Site was developed as part of the Remedial Investigation and Feasibility Study and has been in use for almost a decade.

The final EDDs for the PCB congener laboratory and for the general sediment laboratory are being developed as part of contracting with the laboratories. Floyd|Snider (the Lead for analytical) and Sayler Data Solutions (the Lead for data validation and data base management) have both worked with the laboratories that are being used for this project on past projects, and are comfortable that final EDD requirements can be met by both the laboratories and by the Sayler Data Solutions. Draft final versions are attached.

1.1 EDD REQUIREMENTS

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 chain-of-custody (COC) forms will be provided as part of the data package. This documentation will include the time of receipt and the condition of

each sample received by the laboratory. Additional internal tracking of sample custody by the laboratory will also be documented.

- Sample results – The data package will summarize the results for each sample analyzed. The summary will include the following information, 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
    - Total solids in the samples
    - Identification of the instruments used for analysis
    - Identification of cleanup procedures used on sample extracts
    - 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, 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 duplicate summary will report the RPD for all matrix duplicate analyses. The QC limits for each compound or analyte will be listed.
- 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.

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 result for a given sample. Therefore, one complete sample will require multiple rows.
- Each row should contain the following information at a minimum: LDWG 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 an analyte is not detected then the laboratory qualifier will be U, and the value in the result column will be the sample-specific reporting limit (RL). Quantified results between the detection limit and the RL will be laboratory J-qualified.

- 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 PCB congener chemical data is provided in Table 1. An example of the acceptable organization of the electronic deliverable for SMS constituents, TOC, black carbon, grain size, and salinity chemical data is provided in Table 2.

TABLES

Table 1
Required and Optional Fields of the Electronic Data Deliverable for PCB Congeners

File	Pos#	Field Name	DataType	Primary Key	Required	Field Definition
Smp	1	sys_sample_code	Text(40)	PK	Y/K	Unique sample identifier. Each sample must have a unique value, including spikes and duplicates. Laboratory QC samples must also have unique identifiers. The laboratory and the EQuIS Chemistry user have considerable flexibility in the methods they use to derive and assign unique sample identifiers, but uniqueness throughout the database is the only restriction enforced by EQuIS Chemistry.
Smp	2	sample_type_code	Text(20)		Y	Code which distinguishes between different types of sample. For example, normal field samples must be distinguished from laboratory method blank samples, etc. IRPIMS-style sample type codes (see table X01) are understood by EQuIS Chemistry, and other valid sample types can be added by the EQuIS Chemistry user. Field sample types (e.g., field duplicates, field blanks, etc.) might be submitted blind to the laboratory; in such cases the laboratory may report all field samples as if they were all normal field samples. The laboratory is not required to export data for a spike if a spike duplicate is exported (unless the EQuIS Chemistry project manager requests all spikes).
Smp	3	sample_matrix_ code	Text(10)		Y	Code which distinguishes between different types of sample matrix. For example, soil samples must be distinguished from ground water samples, etc. IRPIMS-style sample matrix codes (see table X02) are understood by EQuIS Chemistry, and other valid sample types can be added by the EQuIS Chemistry user. The matrix of the sample as analyzed may be different from the matrix of the sample as retrieved (e.g. leachates), so this field is required at the sample level.
Smp	4	sample_source	Text(10)		Y	Must be either "Field" for field samples or "Lab" for internally generated laboratory QC samples. No other values are allowed. For example, a matrix spike duplicate sample would be a "Lab" sample, while its parent (i.e., the field sample it was derived from) would be a "Field" sample.
Tst	1	sys_sample_code	Text(40)	PK	Y/K	Unique sample identifier. Each sample must have a unique value, including spikes and duplicates. Laboratory QC samples must also have unique identifiers. The laboratory and the EQuIS Chemistry user have considerable flexibility in the methods they use to derive and assign unique sample identifiers, but uniqueness throughout the database is the only restriction enforced by EQuIS Chemistry.

Table 1
Required and Optional Fields of the Electronic Data Deliverable for PCB Congeners

File	Pos#	Field Name	DataType	Primary Key	Required	Field Definition
Tst	2	lab_anl_method_ name	Text(35)	PK	Y/K	Laboratory analytic method name or description. A controlled vocabulary (i.e., list of valid method names) is not required for the laboratory EDD unless otherwise specified by the EQuIS Chemistry project manager. The method name should be sufficient to reflect operation of the laboratory. For example both "SW8080-pest" and "SW8080-PCB" may be necessary to distinguish between laboratory methods, while "SW8080" may not provide sufficient detail.
Tst	3	analysis_date	Date	PK?	Y/K?	Date of sample analysis in MM/DD/YY format. May refer to either beginning or end of the analysis as required by EQuIS Chemistry project manager. This field is not always required, but most users will want it.
Tst	4	analysis_time	Text(5)	PK?	Y/K?	Time of sample analysis in 24-hr (military) HH:MM format. May refer to either beginning or end as required by EQuIS Chemistry project manager. This field might be required, depending on the test primary key used by the EQuIS Chemistry user. Note that this field, combined with the "analysis_date" field is used to distinguish between retests and reruns (if reported). Please ensure that retests have "analysis_date" and/or "analysis_time" different from the original test event (and fill out the test_type field as needed).
Tst	5	total_or_dissolved	Text(1)	PK?	Y/K?	If required, then it must be either "T" for total [metal] concentration, "D" for dissolved or filtered [metal] concentration, or "N" for organic (or other) constituents for which neither "total" nor "dissolved" is applicable. This field might be required, depending on the test primary key used by the EQuIS Chemistry user.
Tst	6	column_number	Text(2)	PK?	Y/K?	If required, then it must be either "1C" for first column analyses, "2C" for second column analyses, or "NA" for analyses for which neither "1C" nor "2C" is applicable. Second column data may not be required, depending on the needs identified by the EQuIS Chemistry project manager, in which case all results may be reported as "NA". However, if any "2C" tests are reported, then there must be corresponding "1C" tests present also. Also, laboratories typically can report which of the two columns is to be considered "primary". This distinction is handled by the "reportable_result" field in the result table. This field might be required, depending on the test primary key used by the EQuIS Chemistry user.
Tst	7	test_type	Text(10)	PK?	Y/K?	Type of test. Valid values include "initial", "reextract", and "reanalysis".

Table 1
Required and Optional Fields of the Electronic Data Deliverable for PCB Congeners

File	Pos#	Field Name	DataType	Primary Key	Required	Field Definition
Res	1	sys_sample_code	Text(40)	PK	Y/K	Unique sample identifier. Each sample must have a unique value, including spikes and duplicates. Laboratory QC samples must also have unique identifiers. The laboratory and the EQuIS Chemistry user have considerable flexibility in the methods they use to derive and assign unique sample identifiers, but uniqueness throughout the database is the only restriction enforced by EQuIS Chemistry.
Res	2	lab_anl_method_ name	Text(35)	PK	Y/K	Laboratory analytic method name or description. A controlled vocabulary (i.e., list of valid method names) is not required for the laboratory EDD unless otherwise specified by the EQuIS Chemistry project manager. The method name should be sufficient to reflect operation of the laboratory. For example both "SW8080-pest" and "SW8080-PCB" may be necessary to distinguish between laboratory methods, while "SW8080" may not provide sufficient detail.
Res	3	analysis_date	Date	PK?	Y/K?	Date of sample analysis in MM/DD/YY format. May refer to either beginning or end of the analysis as required by EQuIS Chemistry project manager. This field is not always required, but most users will want it.
Res	4	analysis_time	Text(5)	PK?	Y/K?	Time of sample analysis in 24-hr (military) HH:MM format. May refer to either beginning or end as required by EQuIS Chemistry project manager. This field might be required, depending on the test primary key used by the EQuIS Chemistry user. Note that this field, combined with the "analysis_date" field is used to distinguish between retests and reruns (if reported). Please ensure that retests have "analysis_date" and/or "analysis_time" different from the original test event (and fill out the test_type field as needed).
Res	5	total_or_dissolved	Text(1)	PK?	Y/K?	If required, then it must be either "T" for total [metal] concentration, "D" for dissolved or filtered [metal] concentration, or "N" for organic (or other) constituents for which neither "total" nor "dissolved" is applicable. This field might be required, depending on the test primary key used by the EQuIS Chemistry user.

Table 1
Required and Optional Fields of the Electronic Data Deliverable for PCB Congeners

File	Pos#	Field Name	DataType	Primary Key	Required	Field Definition
Res	6	column_number	Text(2)	PK?	Y/K?	If required, then it must be either "1C" for first column analyses, "2C" for second column analyses, or "NA" for analyses for which neither "1C" nor "2C" is applicable. Second column data may not be required, depending on the needs identified by the EQuIS Chemistry project manager, in which case all results may be reported as "NA". However, if any "2C" tests are reported, then there must be corresponding "1C" tests present also. Also, laboratories typically can report which of the two columns is to be considered "primary". This distinction is handled by the "reportable_result" field in the result table. This field might be required, depending on the test primary key used by the EQuIS Chemistry user.
Res	7	test_type	Text(10)	PK?	Y/K?	Type of test. Valid values include "initial", "reextract", and "reanalysis".
Res	8	cas_rn	Text(15)	PK	Y	Chemical Abstracts Registry Number for the parameter if available. Otherwise use the IRPIMS PARLABEL. Other chemical identifier codes may be allowed by the EQuIS Chemistry project manager.
Res	9	chemical_name	Text(60)		Y	Chemical name is used only in review of EDD. The cas-rn field is the only chemical identity information actually imported in EQuIS Chemistry.
Res	12	result_type_code	Text(10)		Y	Must be either "TRG" for a target or regular result, "TIC" for tentatively identified compounds, "SUR" for surrogates, "IS" for internal standards, or "SC" for spiked compounds. Not all of these result types may be required, depending on the needs of the EQuIS Chemistry project manager.
Res	13	reportable_result	Text(10)		Y	Must be either "Yes" for results which are considered to be reportable, or "No" for other results. This field has many purposes. For example, it can be used to distinguish between multiple results where a sample is retested after dilution. It can also be used to indicate which of the first or second column result should be considered primary. The proper value of this field in both of these two examples should be provided by the laboratory (only one result should be flagged as reportable). Also, the EQuIS Chemistry project manager can also use this field as needed. For example, benzene may be detected by several test methods requested for a sample, all but one can be flagged as not reportable if desired.

Table 1
Required and Optional Fields of the Electronic Data Deliverable for PCB Congeners

File	Pos#	Field Name	DataType	Primary Key	Required	Field Definition
Res	14	detect_flag	Text(2)		Y	Maybe either "Y" for detected analytes or "N" for non-detects. At the request of the EQuIS Chemistry project manager, other valid values may be used as necessary. These include "TR" for trace (above detection limit but below the quantitation limit) or ">" and "<" for tests such as flash point. Note that "<" must not be used to indicate non-detects (use "N" for non-detects instead).
Res	20	result_unit	Text(15)		Y	units of measurement for the result. IRPIMS-style unit of measurement codes (see table X02) are recognized by EQuIS Chemistry; other codes may be allowed by the EQuIS Chemistry project manager.
Bch	1	sys_sample_code	Text(40)	PK	Y/K	Unique sample identifier. Each sample must have a unique value, including spikes and duplicates. Laboratory QC samples must also have unique identifiers. The laboratory and the EQuIS Chemistry user have considerable flexibility in the methods they use to derive and assign unique sample identifiers, but uniqueness throughout the database is the only restriction enforced by EQuIS Chemistry.
Bch	2	lab_anl_method_ name	Text(35)	PK	Y/K	Laboratory analytic method name or description. A controlled vocabulary (i.e., list of valid method names) is not required for the laboratory EDD unless otherwise specified by the EQuIS Chemistry project manager. The method name should be sufficient to reflect operation of the laboratory. For example both "SW8080-pest" and "SW8080-PCB" may be necessary to distinguish between laboratory methods, while "SW8080" may not provide sufficient detail.
Bch	3	analysis_date	Date	PK?	Y/K?	Date of sample analysis in MM/DD/YY format. May refer to either beginning or end of the analysis as required by EQuIS Chemistry project manager. This field is not always required, but most users will want it.
Bch	4	analysis_time	Text(5)	PK?	Y/K?	Time of sample analysis in 24-hr (military) HH:MM format. May refer to either beginning or end as required by EQuIS Chemistry project manager. This field might be required, depending on the test primary key used by the EQuIS Chemistry user. Note that this field, combined with the "analysis_date" field is used to distinguish between retests and reruns (if reported). Please ensure that retests have "analysis_date" and/or "analysis_time" different from the original test event (and fill out the test_type field as needed).

Table 1
Required and Optional Fields of the Electronic Data Deliverable for PCB Congeners

File	Pos#	Field Name	DataType	Primary Key	Required	Field Definition
Bch	5	total_or_dissolved	Text(1)	PK?	Y/K?	If required, then it must be either "T" for total [metal] concentration, "D" for dissolved or filtered [metal] concentration, or "N" for organic (or other) constituents for which neither "total" nor "dissolved" is applicable. This field might be required, depending on the test primary key used by the EQuIS Chemistry user.
Bch	6	column_number	Text(2)	PK?	Y/K?	If required, then it must be either "1C" for first column analyses, "2C" for second column analyses, or "NA" for analyses for which neither "1C" nor "2C" is applicable. Second column data may not be required, depending on the needs identified by the EQuIS Chemistry project manager, in which case all results may be reported as "NA". However, if any "2C" tests are reported, then there must be corresponding "1C" tests present also. Also, laboratories typically can report which of the two columns is to be considered "primary". This distinction is handled by the "reportable_result" field in the result table. This field might be required, depending on the test primary key used by the EQuIS Chemistry user.
Bch	7	test_type	Text(10)	PK?	Y/K?	Type of test. Valid values include "initial", "reextract", and "reanalysis".
Bch	8	test_batch_type	Text(10)	PK	Y	Lab batch type. Valid values include "Prep", "Analysis", and "Leach". Additional valid values may optionally be provided by the EQuIS Chemistry project manager. This is a required field for all batches.
Bch	9	test_batch_id	Text(20)		Y	Unique identifier for all lab batches. Must be unique within EQuIS Chemistry database. For example, the same identifier can not be used for a prep batch and an analysis batch. The EQuIS Chemistry project manager and the laboratory have the flexibility to devise a scheme to ensure unique values of this field. The EQuIS Chemistry project manager will determine which, if any, batch types are to be required in the EDD.

Abbreviations:

PK Field is a primary key of the table
PK? Field may be included as part of a unique key on *dt_test*
Y/K Field is required and is a key of the table
Y/K? Field is required and may be included as part of a unique key on *dt_test*

Table 2
Required and Option Fields of the Electronic Data Deliverable for Analytes Other Than PCB Congeners
Template Data Dictionary

Field Name	Data Type	Requirement	Comments
CLIENT	Text	Required	The name of the client as listed in the chain of custody (COC) form.
PROJECT NAME	Text	Required	The project name as listed in the COC.
EVENT NAME	Text	Required	The event or task name as listed in the COC.
SAMPLE ID	Text	Required	The sample identifier.
LAB NUMBER	Text	Required	The tracking number that appears on various reports and bench sheets produced by the lab.
MATRIX	Text	Required	The sample matrix.
COLLECTION DATE/TIME	Date/Time	Required	Date and time of sample collection.
RECEIPT DATE/TIME	Date/Time	Required	Date and time that the sample was received by laboratory.
FIELD QC TYPE	Text	Conditional	Required only if sample is a field quality control sample. Typical codes can include 'Trip Blank', 'Rinsate', etc.
EXTRACTION METHOD	Text	Required	Extraction method. If an extraction method is not applicable for this analysis then 'NA' is acceptable.
EXTRACTION BATCH	Text	Conditional	Extraction batch identifier. Required if extraction method is not labeled 'NA'.
EXTRACTION DATE/TIME	Date/Time	Conditional	Date and time of extraction. Required if extraction method is not labeled 'NA'.
ANALYSIS METHOD	Text	Required	The analysis performed by the laboratory.
METHOD COMMENT	Text	Optional	Comments that further clarify the method used. For example, in cases were a EPA method is modified.
ANALYSIS BATCH	Text	Required	Analysis batch identifier.
DATE/TIME ANALYZED	Date/Time	Required	Date and time that the sample was analyzed.
ANALYTE	Text	Required	The analyte name as the lab reports it.
CAS NUMBER	Text	Required	The CAS registry number. If no CAS number exists, then 'NA' is acceptable.
DETECTION LIMIT	Number	Required	The instrument detection limit.
REPORTING LIMIT	Number	Required	This is the 'non-detected' limit used by the lab for this analyte.
REPORTING LIMIT TYPE	Text	Required	Source of the reporting limit. For example, 'IDL' (Instrument Detection Limit, 'MDL' (Method Detection Limit), or 'PQL' (Practical Quantitation Limit).
SAMPLE RESULT	Number	Required	Sample Result may only contain the detected concentration or the reporting limit (for non-detected samples).
LAB QUALIFIER	Text	Required	Lab qualifiers as assigned by the laboratory during analysis. (A list of definitions is required separately.)

Table 2
Required and Option Fields of the Electronic Data Deliverable for Analytes Other Than PCB Congeners
Template Data Dictionary

Field Name	Data Type	Requirement	Comments
UNITS	Text	Required	The units in which the sample is reported.
RESULT BASIS	Text	Required	The basis upon which the results were calculated. For example 'Dry', 'Wet', 'OC' (Organic Carbon Normalized).
FRACTION	Text	Required	The fraction of the result. 'Total', 'Dissolved', 'NA'.
DILUTION	Number	Required	Sample dilution.
RESULT SIGFIG	Number	Required	Number of significant figures.
INSTANCE	Number	Optional	An incremental number that helps distinguish samples that have been reanalyzed.
PERCENT MOISTURE	Number	Optional	Percent moisture.
LABORATORY	Text	Required	Laboratory where analysis was conducted.
ANALYST	Text	Required	Laboratory analyst conducting analysis.
LAB NOTES	Text	Optional	Any pertinent information related to that result.
Quality Control Specific			
PARENT SAMPLE ID	Text	Optional	For laboratory duplicates this is the Sample ID of the parent sample.
PREPARED DATE/TIME	Date/Time	Required	Date/Time QC sample was prepared.
LAB QC TYPE	Text	Required	Quality control type. Typical codes can include 'Surrogate', 'Lab Duplicate', 'Matrix Spike', etc.
TRUE VALUE	Number	Conditional	The true amount of analyte added. Required for samples where the true value is known, for example spiked samples.
PERCENT RECOVERY	Number	Conditional	The recovery of an analyte expressed as a percentage of the amount added. Required for surrogates and internal standards.
PR LOWER LIMIT	Number	Conditional	The acceptable lower limit of recovery. Required if result is reported for percent recovery.
PR UPPER LIMIT	Number	Conditional	The acceptable upper limit of recovery. Required if result is reported for percent recovery.
RPD	Number	Conditional	The relative percent difference. Required for samples were a duplicate was measured. For example Matrix Spike/Matrix Spike Duplicate.
RPD LIMIT	Number	Conditional	The acceptable limit of percent different. Required if result is reported for RPD.