Quality Assurance Project Plan

Using Sediment Profile Imaging (SPI) to Evaluate Sediment Quality at Two Puget Sound Cleanup Sites: Part I - Lower Duwamish Waterway

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December 2006

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Acronyms and Abbreviations

This list contains acronyms used frequently in this document. Other acronyms are used infrequently and defined only in the text.

BNA	base neutral acid organic compounds
CSL	cleanup screening level
DQO	data quality objective
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management System (Ecology)
EPA	U.S. Environmental Protection Agency
LDW	Lower Duwamish Waterway
MEL	Manchester Environmental Laboratory (Ecology)
MQO	measurement quality objective
MTCA	Model Toxics Control Act
PAH	polycyclic aromatic hydrocarbon
PSEP	Puget Sound Estuary Program (EPA)
RPD	relative percent difference
RSD	relative standard deviation
QA	quality assurance
QC	quality control
SMS	Sediment Management Standards
SPI	Sediment Profile Imaging
SQS	Sediment Quality Standards
TOC	total organic carbon
WAC	Washington Administrative Code

Abstract

The Washington Department of Ecology (Ecology) is evaluating the use of preliminary Sediment Profile Imaging (SPI) surveys to streamline studies of contaminated sediment cleanup sites. This may be feasible if SPI data, such as the Redox Potential Discontinuity depth or Organism Sediment Index, can predict at least some of the commonly measured sediment quality triad data. These data include contaminant chemistry, laboratory toxicity, or direct evidence of benthic community impairment. If SPI data can predict at least some types of benthic habitats or sediment samples, then a preliminary SPI survey might reduce the need for, the scope, and the cost of more detailed cleanup site investigations.

The SPI Feasibility Study involves two sites. The Lower Duwamish Waterway in Seattle has surface sediments containing mixtures of chemical contaminants, including PCBs, phthalates, trace metals, and polycyclic aromatic hydrocarbons. In contrast, the former Pope and Talbot mill site on Port Gamble Bay contains few of the contaminants found elsewhere in Puget Sound but does have large areas of wood waste that can alter benthic communities.

This Quality Assurance Project Plan describes the project that will be conducted at the Lower Duwamish Waterway site. The preliminary SPI survey will be conducted from July 23-25, 2006. Ecology will conduct its follow-up sediment quality survey from August 8-11, 2006.

The focus of the final report, targeted for completion in April 2007, will be to describe any relationships that exist between the SPI data and triad indicators of benthic community impairment for this site. In addition, some sample data may serve to fill data gaps, confirm earlier results, or provide a baseline for post-cleanup monitoring.

Background

Sediment Profile Imaging (SPI) is a generic term used to describe technology developed in the 1970s (Rhoads and Young, 1970) and patented in 1983 as Remote Ecological Monitoring Of The Seafloor (REMOTS). Historically, SPI has been used for three main purposes:

- Identify open-water sites deemed suitable for disposal of dredged material.
- Map recently deposited dredged material.
- Assess the degree of benthic community recolonization/recovery after a physical disturbance or other perturbation.

Valente (2004) summarized the role that SPI has played in dredged material management in many countries around the world. In the Pacific Northwest, the Dredged Material Management Program (DMMP) has used SPI technology since the late 1980s to help establish five permitted open-water disposal sites in Puget Sound and to confirm accurate placement of dredged material at those sites (PSDDA, 1988a, 1988b). SPI technology has also been used more recently to assess benthic communities near the mouth of the Columbia River and assess their recovery after physical disturbance.

SPI technology has less frequently been used to investigate known or suspected contaminated sediment cleanup sites. Within the Northwest, these sites include the Denny Way/Lake Union combined sewer overflow outfall (Seattle), Hylebos Waterway (Commencement Bay - Tacoma), Eagle Harbor, Port Angeles Harbor, Port Gamble Bay, the Willamette River (Oregon), and sites in Alaska. There are also ongoing investigations of sediment cleanup sites located on the East Coast that are using SPI technology. SPI studies of cleanup sites have usually been intended to:

- Map the extent of areas potentially impaired by the presence of chemical contaminants or wood waste.
- Evaluate the efficacy of aquatic disposal or cap placement.
- Assess the recovery of benthic communities after remedial actions have occurred.

With perhaps one exception, SPI surveys associated with these cleanup sites were not designed with the express purpose of relating results to more typical sediment quality triad indicators of benthic community impairment, e.g., contaminant chemistry, laboratory toxicity, or benthic community diversity.

The Washington State Department of Ecology (Ecology) believes that if preliminary SPI surveys can screen for benthic community impairment, at least to some degree, then the need to collect sediment samples and measure sediment quality triad indicators of benthic community impairment at sediment cleanup sites would be reduced. This provides the impetus for the current SPI Feasibility Study that includes two project sites.

Project Description

Lower Duwamish Waterway Site

One of the two sites selected for the study is the Lower Duwamish Waterway (LDW) in Seattle (Figures 1 and 2). It is a channelized and heavily industrialized section of the Duwamish River that drains into Elliott Bay.

Ecology first identified certain areas within the LDW as being of potential concern in its 1996 Contaminated Sediment Site List. Parts of the river that showed signs of impairment have appeared on subsequent federal Clean Water Act 303(d) lists for various contaminants in both water and sediments. The U.S. Environmental Protection Agency (EPA) Superfund Program placed a substantial portion of the LDW – from approximately river mile 0.0 at the south end of Harbor Island to approximately river mile 5.0 south of the turning basin – on the National Priority List in 2000. Ecology signed an Agreement On Consent that made the LDW a Model Toxics Control Act (MTCA – Ecology, 2001 and 2005a) and Sediment Management Standards (SMS - Ecology, 1995) cleanup site that same year.

This stretch of waterway has been under remedial investigation ever since, resulting in a compilation of extensive historical sediment quality data and collection of substantial new data (www.ldwg.org/ rifs_docs.htm#t12). The final field efforts, draft baseline risk assessments, and draft remedial investigation are due within the next year, with feasibility studies commencing soon.

The baseline risk assessment will evaluate risk and harm to *in situ* benthic communities that are critical to food webs in the river and general vicinity. However, direct assessment of benthic community health throughout this site is complicated by non-anthropogenic influences such as variations in salinity with depth and river mile, differing sediment grain size characteristics, and patterns of erosion. Consequently, the risk assessment for benthic communities will be indirect, relying on comparisons of environmental data to the adopted sediment chemistry and toxicity criteria listed in Washington's SMS rule (Ecology, 1995) or DMMP sediment quality guidelines (DMMP, 2003).

The major contaminants of concern found in surface sediments throughout much of the LDW are polychlorinated biphenyls (PCBs) and phthalates. Arsenic and other trace metals, polycyclic aromatic hydrocarbon (PAHs), tributyltin, and dioxins/furans also occur in some areas. More than 60% of the surface sediment samples that exceed Washington State Sediment Quality Standards (SQS) *and* that underwent standard laboratory toxicity testing can be classified as toxic (Windward, 2004a). Most of the available information on benthic community resources in the LDW is from a survey conducted the same year (Windward, 2004b). However, that survey was not designed to evaluate the feasibility of relating SPI data to indicators of benthic community impairment (see www.ldwg.org/Assets/BI/Taxonomy/FINAL_BI_Taxon_Report.pdf).

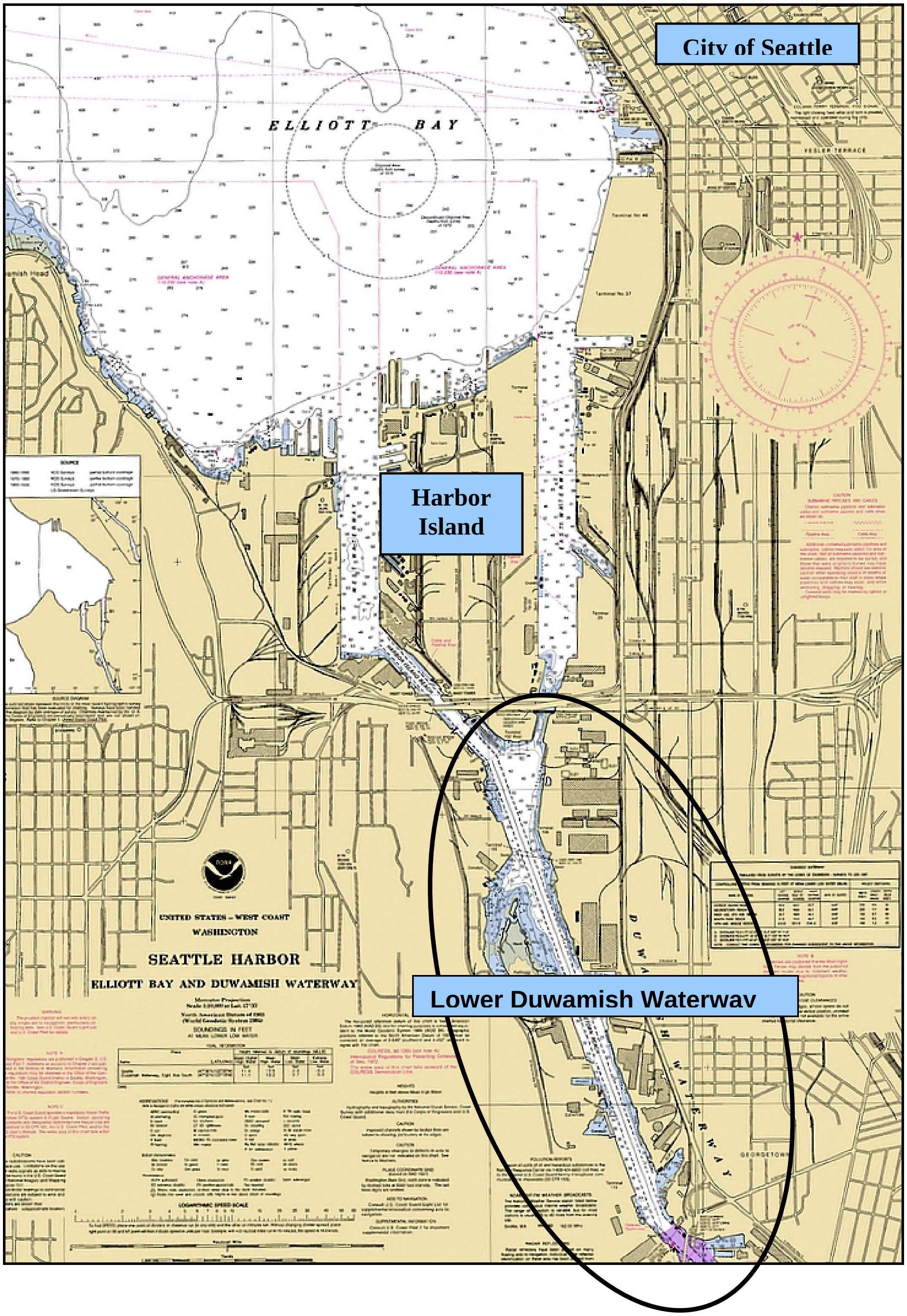

Figure 1. Lower Duwamish Waterway site for Ecology's SPI Feasibility Study.

The study site begins immediately south of Harbor Island and extends slightly off the bottom of this chart to the south.

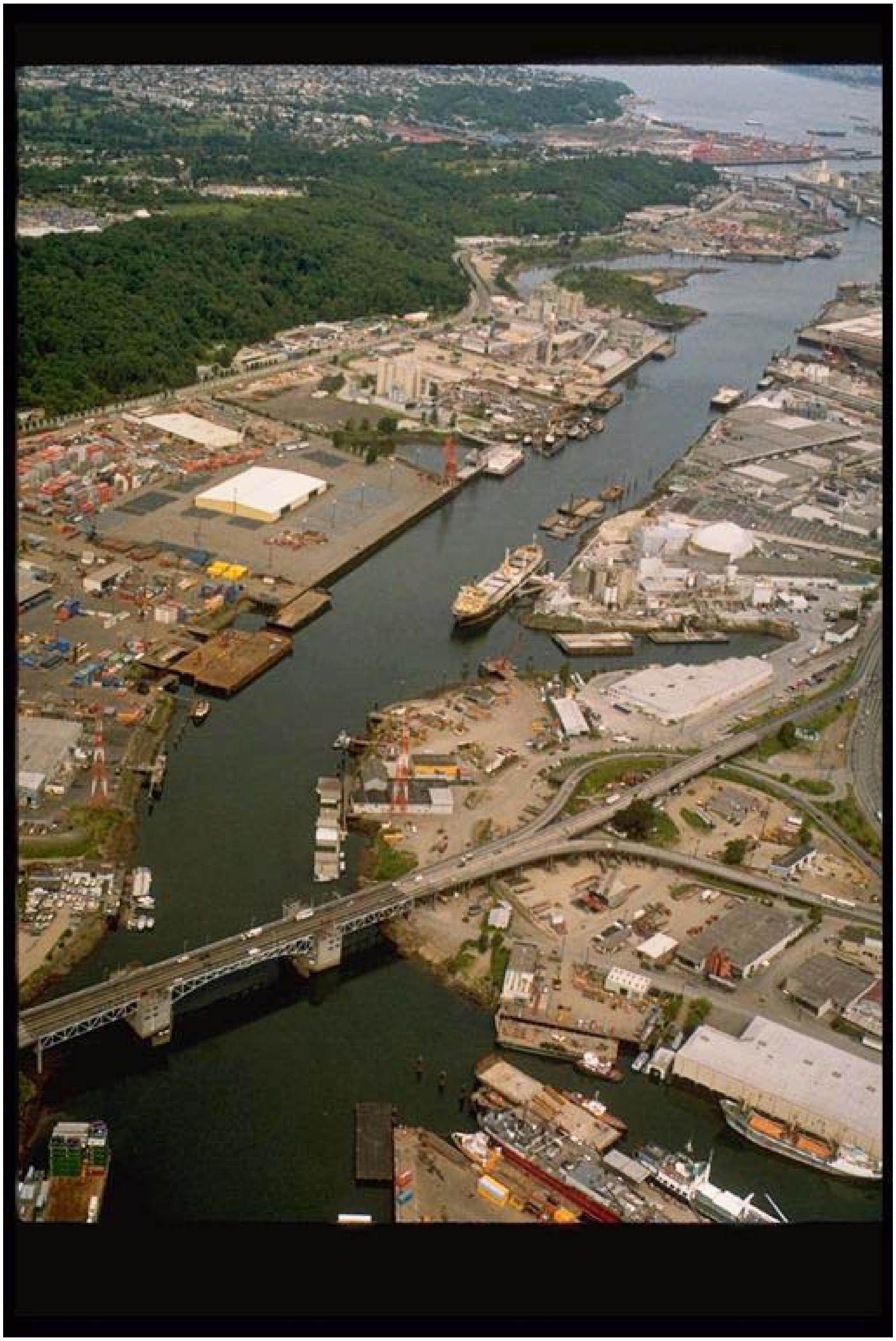

Figure 2. Aerial photograph of the northern portion of the Lower Duwamish Waterway study site.

View is looking approximately NW from river mile 2.2 (bottom of chart in Figure 1).

Two surveys will be conducted in the area shown in Figure 1. The first will use underwater video, plan-view still, and SPI cameras to collect images at a minimum of 80 surface sediment sampling locations in the waterway. This will be followed closely by a survey that will collect surface sediment samples from 30 of those SPI stations. The sediment samples will be analyzed for conventional parameters, contaminant chemistry, toxicity, and direct evidence of benthic community impairment. Ecology will explore potential relationships between the results of both surveys and the feasibility of using SPI survey results to narrow the scope of more in-depth and costly investigations at sediment cleanup sites.

This LDW portion of the overall SPI Feasibility Study has the following four goals, listed in approximate order of importance:

1. Evaluate the feasibility of using SPI survey data to predict sediment quality triad results found at sediment cleanup sites, e.g., concentrations of sediment contaminants, sediment-related toxicity (as measured in laboratory tests), and direct measures of benthic community impairment.
2. Use SPI survey results to supplement existing information characterizing the spatial distribution of various sediment characteristics, benthic habitat types, and benthic communities present.
3. Identify benthic communities that are likely to be impaired from exposures to chemical toxicants. This will be done principally by comparing chemistry and toxicity results to Washington State Sediment Quality Standards. However, benthic habitat and community information from SPI images, other photographic methods, and detailed community analysis may add to weight-of-evidence evaluations of sediment quality and may influence decisions on the need for remedial actions.
4. Characterize a 'baseline' condition for benthic habitats and communities to which future site monitoring results, obtained using a similar approach and methods, can be compared.

Specific objectives are that Ecology will:

- Collect sediment quality triad samples from approximately 30 locations that are as close as possible to the SPI stations sampled within the LDW site.
- Analyze each sediment sample for conventional parameters (e.g., grain size distribution, total organic carbon, ammonia, and sulfides), contaminant chemistry, toxicity, and evidence of benthic community impairment.
- Determine whether or not any individual or combination of SPI metrics can be related to or predict any of the sediment quality triad indicators measured within the study site. Statistical analyses may include simple linear and nonlinear regressions, Chi Square tests of station classifications, Spearman rank correlations, comparisons of ordination results, or linear discriminant analysis (see Germano and Associates, 2006).
- Prepare a report that presents results of the SPI and sediment quality triad surveys. The main focus of the report will be to (1) present results of various statistical analyses of relationships between results of the SPI survey and Ecology's sediment quality triad measures, and (2) discuss the feasibility of expanding the use of SPI technology to investigate more sediment cleanup sites.

Ecology has a vendor under contract to conduct an SPI survey of the LDW site that is designed to help meet the goals and the objectives described above. The vendor will provide Ecology with all image-derived data that are at all likely to relate to the sediment quality data that Ecology will collect.

Within three weeks of the SPI survey, and after discussing preliminary results with the contractor, Ecology will collect surface sediment samples from a subset of approximately 30 of the SPI stations. These samples will be analyzed for certain physical characteristics and chemical contaminants. Sediment toxicity of these samples will be evaluated using standardized laboratory protocols. Evidence for impairment of *in situ* benthic communities found at these locations will also be evaluated using regional guidelines (EPA, 1987) and various community metrics (see Ecology 1995, 2003, 2005b). Ecology will then present and summarize in a final report the results from the SPI survey, sediment quality triad sampling, and exploratory analyses of possible relationships between the two data sets.

Port Gamble Bay Site

The second SPI Feasibility Study site is an area within Port Gamble Bay near the historic Pope and Talbot timber mill and log rafting facility. This area is a cleanup site that differs substantially from the LDW site. Instead of being contaminated with PCBs and other anthropogenic (human-caused) toxicants, it is dominated by wood waste that can have both direct and indirect deleterious consequences for native benthic communities. Ecology suspects there are many such wood waste sites in the Puget Sound region that require investigation and may need remedial action. For this reason, the agency is interested in exploring possible relationships between SPI data, wood waste-related chemistry, and direct evidence of benthic impairment. Ecology's investigation of the Port Gamble Bay study site is described in a separate QA Project Plan (Gries, 2006). Results from Ecology's investigation of this site are not expected to relate to those of the LDW site, and vice versa.

Organization and Schedule

This SPI Feasibility Study of the LDW site will be organized as depicted in Figure 3.

Dale Norton of Ecology's Environmental Assessment Program will act as project supervisor. His role will include tracking project resources and progress, ensuring consistency with program guidance, providing technical review, and helping recruit field crew. He will also serve as pilot of Ecology's research and sampling vessel, the RV Skookum, and thus be partly responsible for positioning the vessel for the sediment triad sampling.

Tom Gries will act as project manager, chief scientist, and safety officer for the cruise. His responsibilities include:

- Managing and acting as point of contact for the overall SPI Feasibility Study.
- Managing the process by which the SPI vendor was selected.
- Overseeing SPI QA Project Plan development, SPI surveys, and reporting of SPI data.
- Preparing Ecology's QA Project Plan for collecting co-located sediment quality triad samples and data.
- Selecting and contracting with vendors to provide various purchased services, e.g., sample analyses not performed by Manchester Environmental Laboratory.
- Overseeing all aspects of the sediment quality sampling efforts (some responsibilities may be delegated to crew members).
  - Ensuring compliance with boating safety regulations and informing crew members of potential onboard hazards.
  - Ensuring adherence to the contents of this QA Project Plan, e.g., collecting sediment samples no more than three meters from target station locations.
  - Making decisions on plan deviations necessitated by field conditions.
  - Completing chain-of-custody forms.
  - Keeping necessary records (e.g., field logs).
- Coordinating with staff of Manchester Laboratory and Ecology's Quality Assurance officer, as needed.
- Developing GIS displays and conducting statistical analyses of field/lab data.
- Preparing the final project report.

The field crew will be composed of Ecology staff. Each crew member will be familiar with the Health and Safety Plan (Appendix C) and will be required to have taken a refresher course on Boating Safety and First Aid/Cardiopulmonary Resuscitation (CPR) within the previous year. They will be briefed by the project manager and pilot regarding avoidance of onboard hazards, e.g., handling field gear, and contingencies for problems that might reasonably arise. Crew members will help collect, handle, and store surface sediment samples, so each will be familiar with elements of this QA Project Plan related to those activities. Crew members will include Environmental Assessment Program and other Ecology staff.

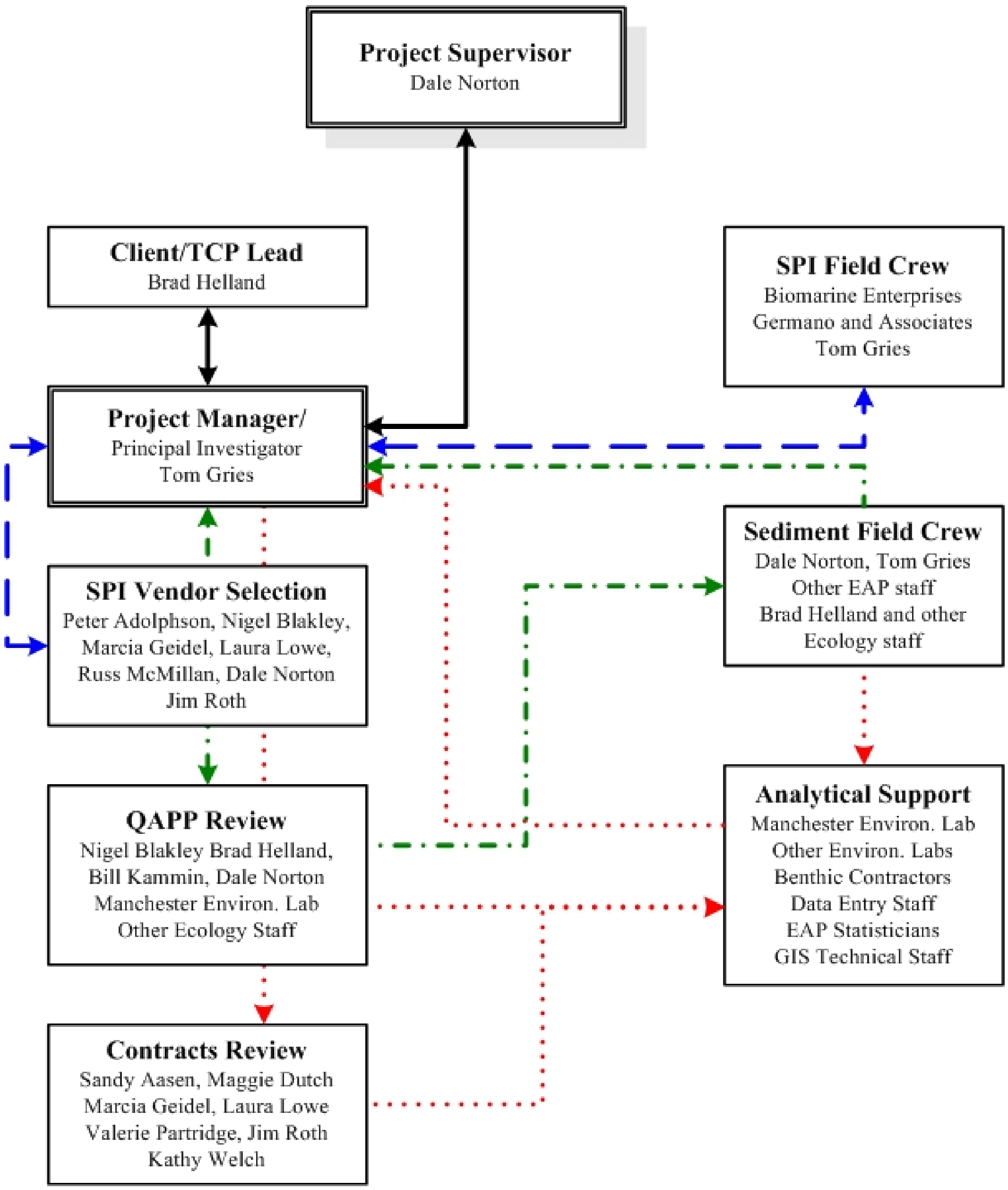

Figure 3. Organization of the SPI Feasibility Study in the Lower Duwamish Waterway.

Includes Ecology and external personnel. Solid lines connect Ecology staff involved in planning and managing the project. Dashed lines are for staff involved in selecting the SPI vendor, SPI field crew, and feedback loop whereby preliminary SPI data are provided to the project manager. Lines with dashes and dots indicate staff involved in developing and implementing Ecology's QA Project Plan, and feedback loop from the field survey crew to the project manager. Dotted lines indicate staff involved in arranging for analytical services, analytical staff, and feedback loop for lab data returning to the project manager.

TCP – Toxics Cleanup Program
EAP – Environmental Assessment Program
QAPP – Quality Assurance Project Plan
GIS – Geographic Information System

Manchester Laboratory staff will be responsible for analysis of sediment samples for total and percent solids, total organic carbon, and total volatile solids, as identified in this QA Project Plan. Lab staff will be familiar with contents of the final QA Project Plan and be responsible for informing the project manager of any failures to achieve applicable detection/reporting limits or QA/QC requirements. In such an event, they *may* be required to re-analyze a sample. Other Ecology staff will likely assist the project manager in entering data, developing GIS displays, conducting statistical analysis of results, and reviewing the draft reports.

Private vendors will also play key roles in the project. The SPI vendor, selected by means of a competitive bid process, is Germano and Associates, LLC. Their team has prepared an Ecology-approved QA Project Plan describing details of how the SPI survey will be conducted (Germano and Associates, 2006). They will be responsible for conducting the LDW SPI survey, providing Ecology with preliminary SPI results, and incorporating final results into a report describing the SPI survey. Other vendors will measure conventional sediment parameters (e.g., grain size, total solids, total volatile solids, total organic carbon, ammonia, and total sulfides), contaminant chemistry, sediment toxicity, and benthic community composition in the sediment samples, as specified in this QA Project Plan.

The project will be conducted according to the schedule listed in Table 1 and depicted in Figure 4. The approximate costs of analytical services associated with the LDW portion of the SPI Feasibility Study are summarized in Table 2.

The major risk to timely completion of Ecology's analysis and report appears to be related to the acquisition of benthic community assessment results, e.g., sorting and taxonomic identification/ enumeration, by mid-December. This will represent approximately 18 weeks between the time Ecology delivers samples to a contractor for sorting and the time final benthic community data packages are submitted back to Ecology. This is similar to the timeframe for a comparable benthic survey conducted in the Lower Duwamish Waterway (Windward, 2004b). In the unlikely event that the RV Skookum is not operable when the sampling is expected to occur (August 8-14), then the sampling will occur during the week of August 21, 2006.

Table 1. Schedule for SPI Feasibility Project in the Lower Duwamish Waterway.

Task Categories/Tasks	Date (approx.)
Contracts	
SPI Survey Contract	*May 17*
Research Vessel (RV Kittiwake)	June
Conventional Parameters	July
Contaminant Chemistry (Manchester Laboratory)	July
Sediment Toxicity	July
Benthic Community Taxonomic Services	July
Field Preparations	
SPI QA Project Plan (Draft/Final)	*June 21/July 10*
Ecology QA Project Plan (Supervisor Draft/Draft Final)	*June 20/August 7*
Gear - purchase/schedule field gear and order lab containers	May-June
Skookum - schedule, modify deck space/equipment	June-July
Gear - assemble, organize and load	July 25-Aug 7
Field Work	
SPI Survey	*July 23-25*
Sediment Quality Sampling	*August 8 - August 14*
Data Acquisition	
SPI Data (Preliminary)	*July 28*
SPI Report (Draft/Final)	*October 6/November 15*
Conventionals, Chemistry, Toxicity	*November 1*
Benthic Community Assessment	*December 20*
Environmental Information System (EIM) Data Set	
EIM Data Engineer	Carolyn Lee
EIM User Study ID	SPILDW06
EIM Study Name	SPI Feasibility Study – Lower Duwamish Waterway
EIM Completion Due	*April 2007*
Analysis and Reporting	
Data Analysis	*November 2 – January 31*
Report Lead Author	Thomas H. Gries
Report - Supervisor Draft Due	*February 1, 2007*
Report - Client/Peer Draft Due	February 22, 2007
Report - External Draft Due	March 16, 2007
Report - Final Due	*April 2007*

Milestones are in *italics*.

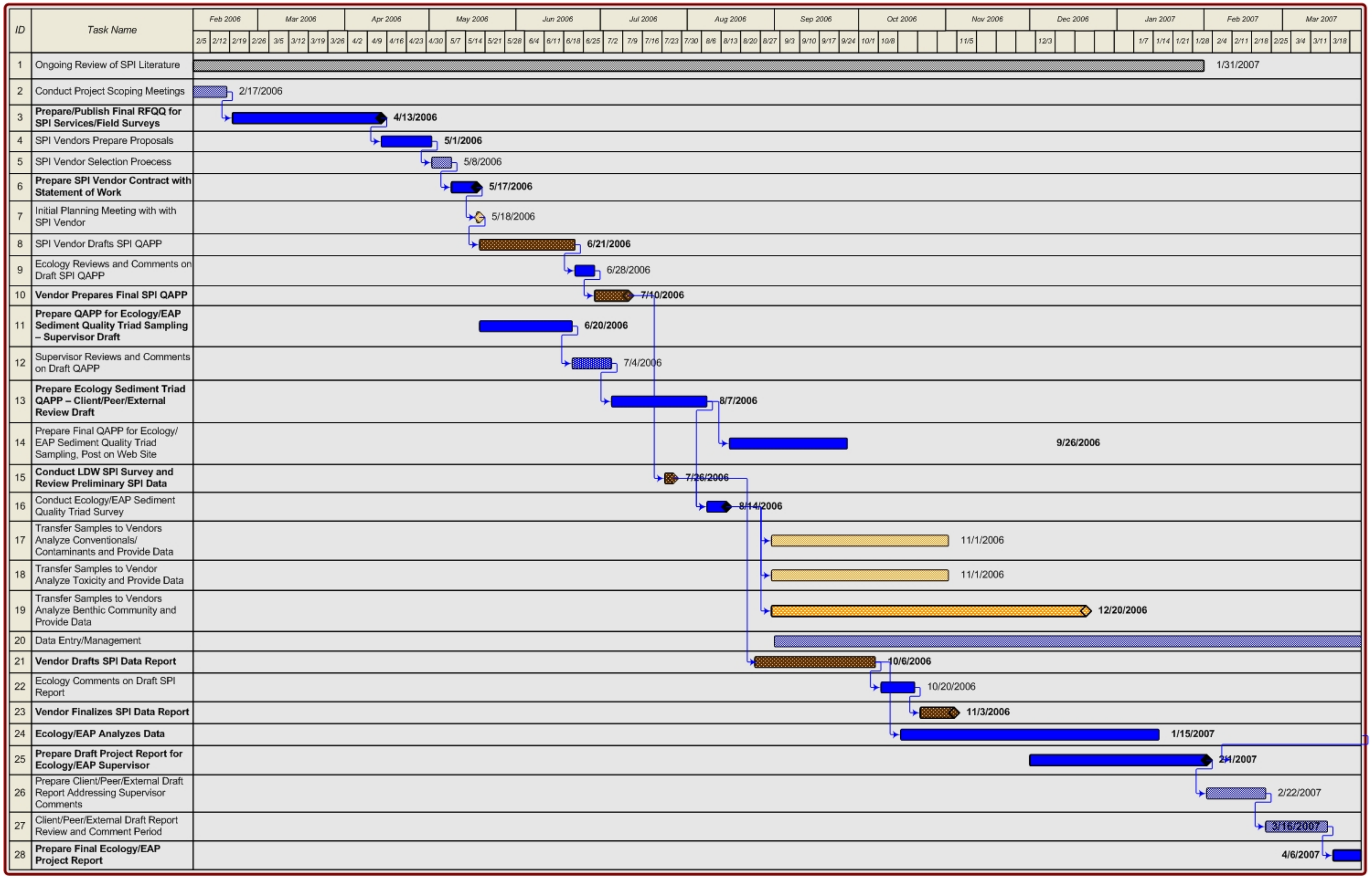

Figure 4. Schedule/Timeline for the SPI Feasibility Project in the Lower Duwamish Waterway (LDW).

Ecology tasks are shown in blue, SPI vendor tasks are shown in brown, and analytical services vendor tasks are shown in orange. Milestone tasks are denoted by bold colors.

RFQQ – Request for Quotation and Qualification; QAPP – Quality Assurance Project Plan; EAP –Environmental Assessment Program

Table 2. Summary of estimated analytical costs for Ecology's sediment quality triad survey of the Lower Duwamish Waterway.

Analysis Parameter	No. of Samples	No. QC Samples	No. Samples Total	Unit Cost ($)	Total Cost ($)
% Solids	33[a]	3[b]	36	15[e]	495
Grain Size	33[a]	3[b]	36	100	3,300
Total Ammonia	33[a]	3[b]	36	30	990
Total Organic Carbon	33[a]	3[b]	36	39[e]	1,287
Total Sulfides	33[a]	3[b]	36	27	891
Metals-SQS	33[a]	3[b]	36	185[e]	6,105
Organotins	33[a]	3[b]	36	200[e]	6,600
PCBs (Aroclors)	33[a]	3[b]	36	100[e]	3,300
PAHs-SQS + BNA-SQS	33[a]	3[b]	36	325[e]	10,725
Amphipod	30	2[c]	32	600	19,200
Larval	30	2[c]	32	500	16,000
BCA	30	2[d]	32	625	20,000
TOTAL					$88,893

a Conventional sediment parameters and contaminant chemistry will be measured in 30 test samples, one field replicate, and two biological reference samples.

b Contaminants will typically be measured in three quality control samples: a laboratory duplicate, a laboratory control sample (e.g., spike), and a matrix spike. There is no cost associated with analysis of these control samples, and there is a 50% price discount for Manchester Laboratory sample analysis.

c Each toxicity test will include one negative control sample (sediment) and two reference samples per batch.

d Benthic community assessments will include two samples collected from a reference area.

e Unit cost for Manchester Laboratory analyses includes a 50% price discount.

BCA – benthic community assessment samples
QC – quality control

Quality Objectives

The data quality objectives (DQOs) for this project are to describe and implement field and laboratory procedures that ensure (1) all data will be representative of actual environmental conditions and (2) data are of known and acceptable quality for the goals and objectives described.

How well a specific surface sediment sample represents environmental conditions at the actual point of collection depends on how it is collected, handled, and preserved or stored prior to analysis. The field DQOs for surface sediment samples to be considered representative of, or equivalent to, the SPI sampling locations are as follows. Samples will be:

- Collected within three weeks of receiving preliminary SPI survey results.
- Collected from areas having relatively homogeneous surface sediments, as indicated by preliminary SPI results.
- Collected from locations no more than three meters from a target sampling location identified in the final QA Project Plan, or that are central to the corresponding triplicate SPI sampling locations.
- Collected using sampling protocols and sample acceptance guidelines consistent with those used throughout the region and previously at the study site.
- Handled and stored properly prior to analysis.

It is vital that all data be of acceptable quality for interpretation according to the Sediment Management Standards rule. This means that appropriate chemical analytical methods are used to achieve the reporting limits listed in Ecology's sediment *Sampling and Analysis Plan Appendix* (Ecology, 2003), and quality control sample results are within designated limits. It also means that toxicity testing and the benthic community assessments follow regional protocols, control and reference samples meet performance standards, and quality control requirements are met or exceeded (EPA, 1995).

Applicable chemical and biological methods for sediment samples collected in the Puget Sound region, as well as quality assurance/control requirements, can be found in the *Sampling and Analysis Plan Appendix* (Ecology, 2003), Chapter 173-204 WAC (Ecology, 1991, 1995), EPA (1986, 1987, 1995, 1997, 2003), PSDDA (1988c), DMMP User's Manual (2003), and Sediment Management Annual Review Meeting modifications, but are summarized below and in the *Data Quality* section of this QA Project Plan.

Conventional Sediment Parameters and Contaminant Chemistry

Bias is the magnitude and direction of difference of a measurement result from the true value. The measurement quality objective (MQO) for bias is expressed as the percent deviation of a sample result from the known concentration, e.g., a certified reference material, or as the percent recovery of a known concentration of analyte in a matrix spike or laboratory control sample. Precision is the measure of the reproducibility of individual measurements of the same analyte in the same sample and usually under similar conditions. The MQO for precision is expressed as the relative percent difference (RPD) for sample or matrix spike duplicates, or as the relative standard deviation (RSD) in the case of triplicate laboratory analyses (e.g., grain size and total organic carbon). Sensitivity is a measure of the ability of the analytical method to detect an analyte and the concentration that can be reliably quantified. The MQO for sensitivity is expressed in terms of the method detection limit or the minimum concentration that can be "reliably" quantified. The latter is the practical quantitation limit or, for this project, the reporting limit. The MQOs for bias, precision, and sensitivity for this project vary by analyte (Table 3).

Table 3. Quality control samples and measurement quality objectives (MQOs) for sediment conventional and chemistry analyses.

Parameter	RL	Method Blanks	MQO	Lab Repl	MQO	Lab Controls	MQO	Matrix Spikes	MQO
Total solids (% wet wt.)	0.1	--	<0.1	1 tripl	35% RSD	Na	Na	Na	Na
Grain size (% dry wt.)	1	--	<1	1 tripl	35% RSD	Na	Na	Na	Na
Ammonia (mg/kg dw)	0.10	1	<0.10	1 tripl	35% RSD	1	80-120%	1	75-125%
Total organic carbon (% dry wt)	0.1	1	<0.1	1 tripl	20% RSD	1	80-120%	--	Na
Total sulfides (mg/kg dw)	0.10	1	<0.10	1 tripl	35% RSD	1	65-135%	1	65-135%
Mercury (mg/kg dw)	0.05	1	<1/2 RL[e]	1 dupl	20% RPD	1	80-120%	1	75-125%
Metals-SQS[a] (mg/kg dw)	0.1-5.0[d]	1	<1/2 RL[e]	1 dupl	20% RPD	1	80-120%	1	75-125%
Organotins (µg/kg dw as ions)	6.0	1	<1/2 RL[e]	1 dupl	30% RPD	1	40-130%	1	40-130%
PAHs-SQS[b] (µg/kg dw)	20	1	<1/2 RL[e]	1 dupl	50% RPD	1	50-150%	1	50-150%
PCB Aroclors (µg/kg dw)	20	1	<1/2 RL[e]	1 dupl	50% RPD	1	50-150%	1	50-150%
BNA-SQS (µg/kg dw)	20-100[d]	1	<1/2 RL[e]	1 dupl	50% RPD	1	50-150%	1	50-150%
Selected BNAs[c] (µg/kg dw)	0.0067-0.033[d]	1	<1/2 RL[e]	1 dupl	50% RPD	1	50-150%	1	50-150%

a SQS metals include antimony, arsenic, cadmium, chromium, copper, lead, nickel, silver, and zinc.
b See Appendix A.
c 1,2-dichlorobenzene, 1,2,4-trichlorobenzene, 1,4-dichlorobenzene, 2-methylphenol, 2,4-dimethylphenol, benzoic acid, benzyl alcohol, butyl benzyl phthalate, di-ethyl phthalate, dimethyl phthalate, hexachlorobenzene, hexachlorobutadiene, n-nitrosodiphenylamine, and pentachlorophenol.
d Recommended reporting limits for individual chemicals are presented in Table 8.
e Blank concentration >1/2 RL is acceptable if the sample result is >> RL and may be acceptable for BNAs with RL < 3xMDL.

BNAs = base neutral acid organic compounds, Dupl = duplicate, MDL = Method Detection Limit, MQO = Measurement Quality Objective, Na = not applicable, PAHs = polycyclic aromatic hydrocarbons, Repl = replicates, RL = reporting limit, RPD = relative % difference, RSD = relative standard deviation, SQS = Sediment Quality Standards list, tripl = triplicate

Laboratory Toxicity

The DQOs for toxicity tests are that there must be no significant deviations from regional sample collection and test protocols or laboratory standard operating procedures (EPA, 1995). All toxicity results must meet published requirements and be interpretable according to the SMS rule and regional guidance (Ecology, 1991 and 1995; Ecology, 2003; DMMP, 2003). Of particular importance are the maximum 56-day holding time, the minimum of five laboratory replicates, and water quality monitoring to assess the influence of ammonia and sulfides on test results. Some MQOs for toxicity tests are listed in Table 4. Control and reference samples must meet the performance standards for each protocol listed below, and all sample results must be calculated according to guidelines. Applicable method references for the Puget Sound region are listed earlier in this section.

Table 4. Test conditions and quality control samples for two marine/low salinity estuarine sediment toxicity tests that will be conducted for this project (from *Sampling and Analysis Plan Appendix;* Ecology, 2003).

Toxicity Test	Species	Temp °C	Salinity (ppt)	Control Sample	Reference Sample
Amphipod 10-day survival	*Eohaustorius estuarius*	14-16	Ambient 2–28	>90% survival	>75%
Sediment larval 48-60 hour normal development[a]	*Mytilus* sp.[b]	15-17	Ambient ≥ 10	>70% normal survival relative to initial count	>65% of control

[a] Normal and abnormal larvae will be counted. Normal development and combined abnormality and mortality will be reported.

[b] EPA (1995) and the SMS refer to the bivalve species *Mytilus edulis*, but it may be more accurate to refer to the test organisms as members of the *M. edulis* sibling species complex.

Benthic Community Assessments

DQOs for benthic community assessments are that samples be collected following regional guidelines (EPA, 1987) and in a manner believed to be representative of the *in situ* benthic community present in the immediate sampling vicinity (see *Data Quality Objectives* above). The single field replicate collected from each sampling location must be handled and prepared for taxonomic analysis according to regional guidance, as described in this QA Project Plan (see *Measurement Procedures* section). Data quality will be assessed in terms of the accuracy of the sorting, identification, and enumeration processes. The MQOs for these are 95% sorting accuracy, agreement among two independent taxonomists on the identity of all organisms, and verification of final species count by a partial recount by the second taxonomist.

Data Entry

DQOs for data management for this project are for sediment chemistry, toxicity, and benthic community data to be calculated, transcribed, entered, and transferred into one or more final databases without error for use in future analyses. To evaluate this, 20% of the samples will be randomly selected for a complete audit/review. Raw lab results for each will be taken through the same calculation, formatting, and data entry processes. If any of the final results do not match those found in the EIM database, the source of errors will be identified. An investigation will then be conducted to see if the error is systematic or unique.

Sampling Process Design

The study design considers study goals and existing data such as bathymetry, surface sediment chemistry and toxicity, benthic community abundance and richness, sediment stability information, and known sources of contamination.

The primary goal of this project – to relate SPI and sediment quality data – is best approached using a stratified random sampling design. According to the EPA (2002), advantages of this design include:

- Greater precision in the estimates of mean and variance for a given parameter.
- More reliable estimates for subpopulations of interest.
- Greater precision for a measured parameter if it is correlated with the parameter(s) used to identify sampling strata.
- Ability to provide reproducible results within calculated uncertainty limits.
- Greater ability to make statistical inferences.
- Ability to calculate error rates associated with decisions.

However, a limited number of sediment quality samples can be collected and analyzed for this project. Thus, the final design will involve sampling different strata but with individual sample locations chosen somewhat subjectively.

The strata identified for this project are distinguished by the expected likelihood that benthic communities will be found to be altered or impaired. Locations having surface sediment chemistry exceeding at least one cleanup screening level (CSL) are expected to have the highest probability of also exhibiting toxicity or benthic community impairment. Locations with chemistry that exceeds only the Sediment Quality Standard (SQS) represent an intermediate likelihood of toxicity or benthic impairment. Locations with chemistry that does not exceed any SQS are least likely to exhibit benthic community impairment. The stations are thus identified as *High*, *Moderate,* and *Low*, respectively (Table 5). Collecting both SPI and triad data using this design allows Ecology to determine whether or not a general relationship between the two types of sediment data may exist for areas of *High*, *Moderate,* and *Low* likelihood of benthic community impairment.

The areas associated with the strata cannot be calculated so apportionment of samples within each stratum is based on best professional judgment. The proposed sampling targets 12 each of the *High* and *Low* stations and six of the *Moderate* stations. This bias toward sampling surface sediment that represents the more extreme conditions, e.g., *High* and *Low*, is because it is most important to first determine IF potentially useful relationships between SPI and triad data exist. A future study may be needed to better define the SPI-triad relationship boundaries between *High* and *Moderate,* and *Low* and *Moderate,* benthic locations. However, it is unlikely that the surface sediment chemistry of samples will match historical results, so the final classification of samples may not show this apparent bias.

Ecology will collect sediment samples for triad analysis from among the primary and alternate target locations summarized in Table 5 and listed in Table B-1. Again, these sampling locations were chosen to represent:

- A common "benthic habitat" type found at Puget Sound sediment cleanup sites, e.g., relatively shallow subtidal areas found in urban industrial areas having relatively high salinity and substantial fine-grained substrate.
- One of three types of sampling locations or strata: ones expected to show altered/impaired benthic communities because of elevated concentrations of certain sediment contaminants (>CSL), ones of more intermediate sediment quality (>SQS) where there the expectation about benthic community impairment is less certain, and ones expected to have healthy benthic communities (<SQS).

Ecology will also collect surface sediment from two target reference locations in Carr Inlet having similar depth, salinity, and grain size, to which test sample biological results will be statistically compared for regulatory interpretation.

A judgmental sampling design is also used for SPI-only station locations intended to address secondary project goals, e.g., to fill data gaps or possibly to provide baseline habitat and biological conditions to which future monitoring may be compared. These are listed in Table B-2. The main consideration for these is that they are located in subtidal waters having relatively constant and high salinity.

Figure 5 depicts the overall LDW study site with examples of the sampling strata and the individual target sampling locations indicated.

As soon as possible after the SPI survey is completed, Ecology and the SPI contractor will review preliminary results of image analysis for both primary and secondary target sediment sampling locations. Ecology staff will then determine whether or not to modify the list of target locations to better address project goals. A final list of target locations for the sediment quality triad portion of the study will then be prepared and will accompany the RV Skookum pilot, project manager, and field crew.

Sediment sampling is scheduled to begin on August 8, 2006. Carr Inlet will be sampled on August 14, 2006. Chemistry samples will be delivered to Manchester Laboratory on or before August 16, 2006. Manchester Laboratory will measure concentrations of chemical analytes according to specifications provided in the next section of this QA Project Plan, with an expected turn-around time of 11 weeks from the date of receipt. Samples for toxicity tests and benthic community assessment will be sent to an accredited toxicity laboratory on or about the same date(s). Turn-around time for all toxicity data will be 11 weeks after test initiation. Expected turn-around time for all benthic community assessment (BCA) data will be four months from date of receipt. Separate data reports containing the results of the validated chemical analyses, toxicity tests, and BCA will be submitted to Ecology.

Table 5. Summary of sampling strata, planned sample distribution among strata, and proposed identification numbers for the SPI Feasibility Study of the Lower Duwamish Waterway.

Stratum → (Relation to SMS)	High (> CSL)	Target SPI Locations	Moderate (< CSL, > SQS)	Target SPI Locations	Low (<SQS)	Target SPI Locations	Unknown
Primary SPI+Triad Locations	H1-H12	6, 15, 35, 37, 47, 48, 49, 56, 73, 84, 88, DR157, DUD8C EIT066, SG-03 SG-04, B3b	M13-M18	2, 16, 17, 26, 40, 50, 69b, 85, B1b, B2b, B4b, B5b, B6b, B7b	L19-L30	4, 7, 8, 10, 11, 23, 27, 34, 36, 45, 51, 52, 63, 66, 79, 96	
Alternate SPI+Triad Location	H33-H35		M36-M37		L38-L40		
Reference Locations					Carr31 Carr32	CR-02 CR-24	
SPI-Only Locations							41-80

Strata are defined in relation to CSL and SQS values (Ecology, 1991 and 1995). After a quick review of SPI survey images, primary target sediment sampling locations H1-H12, M13-M18, and L19-L30 and alternate sediment sampling locations H33-H35, M36-M37, and L38-L40 will be chosen from among the final SPI sampling locations indicated. Carr Inlet target reference samples are numbered 31 and 32. Coordinates for these are provided in Appendix B.

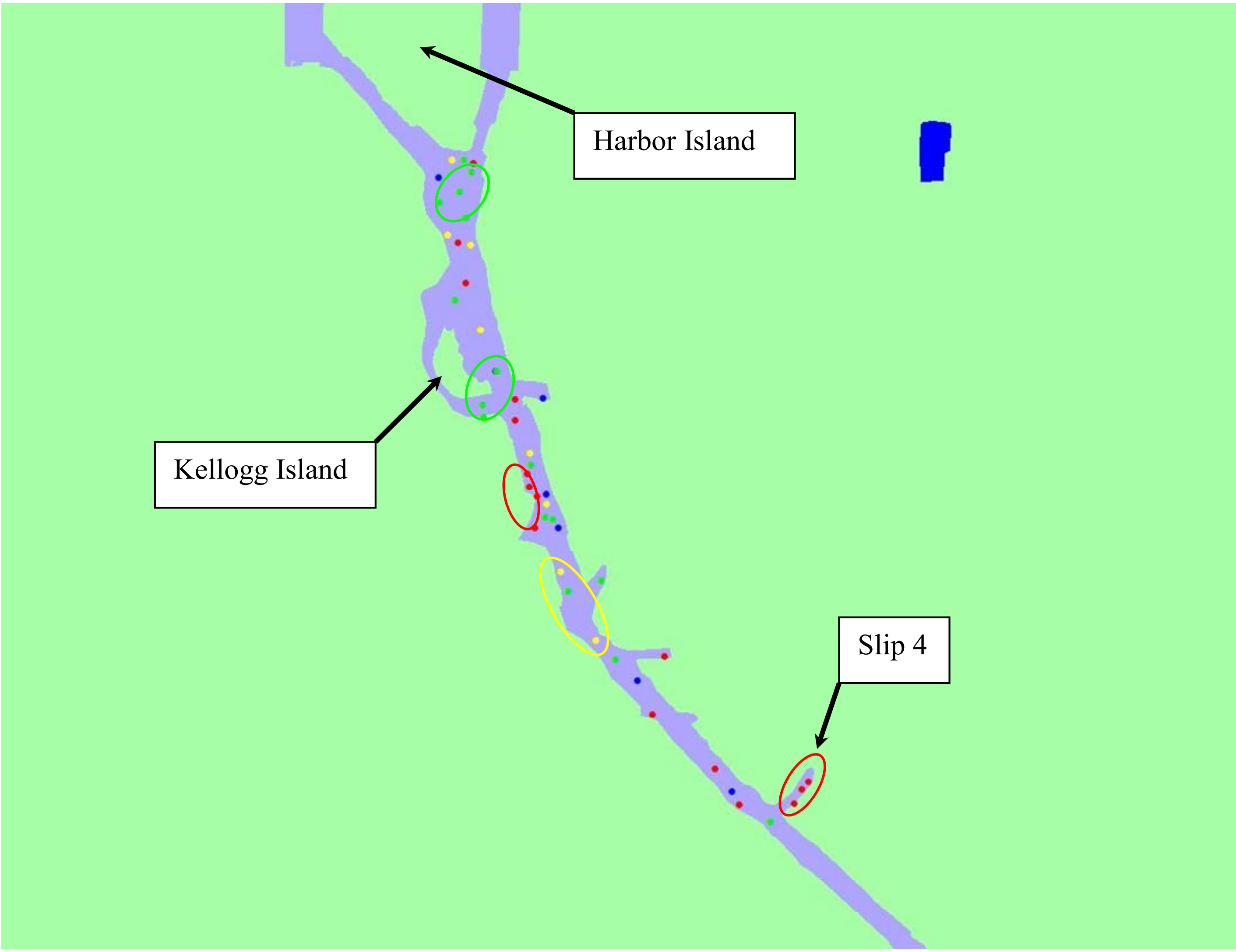

Figure 5. Map of the Lower Duwamish Waterway study site showing examples of three sampling strata and target sampling locations.

Samples belonging to *High* stratum (see text) are indicated in red. Yellow indicates samples in the *Moderate* stratum, and green denotes samples in the *Low* stratum. Samples in various strata may or may not be clustered.

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Sampling Procedures

The field methods and specific procedures that will be used to collect surface sediment samples are described below, along with contingencies for unexpected field conditions. Modification of procedures will be at the discretion of the project manager and the boat operator. Other Ecology staff may also be consulted. All modifications will be recorded in the field logbook.

Vessel Positioning

Target sample stations will be located using a Leica MX420 differentially corrected 12 channel GPS receiver mounted on the stern corner of the RV Skookum and a Coast Guard beacon differential receiver on land. The GPS unit will receive radio broadcasts of GPS signals from satellites. The Coast Guard beacon receiver will acquire corrections to the GPS signals. The offset between GPS receiver and winch cable, vessel heading (compass bearing), and water depth will be recorded so (with water depth) final position coordinates can be corrected. Overall positioning accuracy is expected to be ± 1-2 meters and no worse than ± 3 meters.

Northing and easting coordinates of the vessel will be updated every second and displayed directly on a computer onboard the vessel. The coordinates at the time that the sampling device reaches the bottom and its doors close, thus time of sediment collection, will be processed and stored in real time using a positioning data management software package. Washington State Plane Coordinates, North (NAD 83) will be translated into degrees and decimal minutes and be used for the horizontal datum. The vertical datum will be the National Oceanic and Atmospheric Administration (NOAA) National Ocean Service mean lower low water. Vertical control will be provided by the ship's depth finder and corrected for tidal influence after sampling is completed. Tidal elevation will be determined by calling the National Ocean Service for data from their automated tide gage located in Elliott Bay.

To ensure the accuracy of the navigation system, a checkpoint will be located at a known point such as a pier face, dock, piling, or similar structure that is accessible by the sampling vessel. At the beginning and end of each day, the vessel will be stationed at the check point, a GPS position reading will be taken, and the reading will be compared with the known land-survey coordinates. The two position readings should agree, within the limits of survey vessel operational mobility, to within ± 2 m.

Field Sampling

A double 0.1m^2 van Veen grab sampler will be used to collect surface sediment from the primary target locations listed in Table B-1 (EPA, 1997). Alternate sampling locations are identified in Table 5 and B-2. If the primary location cannot be accessed because of physical obstruction, e.g., a barge occupies the location, then a suitable alternate target location will be chosen and sampled. This will also occur if the van Veen grab fails to penetrate the substrate after three attempts. Sediment will be collected from the depth interval or horizon presumed to represent that which is most biologically active, e.g., 0-10 cm. Multiple grab samples for a given location may be necessary to provide an adequate volume of sediment for chemical analysis, toxicity testing, and benthic community assessment. The detailed procedure for collecting 0-10 cm surface sediment is described below.

- Maneuver the vessel to be near the three sets of coordinates where triplicate SPI images have been collected.
- Open the grab sampler jaws into the deployment position.
- Guide the sampler overboard until it is clear of the vessel.
- Position the sampling vessel such that the GPS receiver, mounted on the stern corner of the vessel, registers being within the aforementioned three sets of coordinates or within 1-2 meters of the most central SPI replicate location.
- Lower the sampler through the water column at approximately 1 foot or 0.3 meters per second to a depth approximately 1 meter above the bottom.
- Lower the sampler to the bottom if the GPS still registers being within the aforementioned three sets of coordinates or within 1-2 meters of the most central SPI replicate location *and* if the cable is very near vertical (otherwise reposition vessel and then do so).
- Record the GPS coordinates when the sampler reaches bottom.
- Record the water depth, time, and compass reading of the vessel (to correct for horizontal offset between sampler and GPS receiver).
- Retrieve the sampler and raise it at approximately 0.3 m/s.
- Guide the sampler aboard the vessel and place it on the work stand on the deck, using care to avoid jostling that might disturb the integrity of the sample.
- Examine the sample using the following sediment acceptance criteria:
    - Penetration depth at least 11 cm.
    - Sediment not extruded out the top of the van Veen sampler.
    - Minimal loss of overlying water (sampler closed completely)
    - After siphoning off the overlying water, the sediment surface is found relatively flat or undisturbed.

The following observations will be noted in the field logbook after accepting a grab sample:

- GPS location (offset four feet from the end of A-frame boom).
- Depth as per vessel's depth sounder.
- Visual characteristics of surface sediment, e.g., cobble/debris/wood, colors, odors, oil/sheen, textures, and biological structures.
- Characteristics of sediment with depth, e.g., change in color and Redox layer.
- Maximum depth of penetration (to 0.5 cm).
- Overall quality of sample.

Sample Handling

A minimum of five liters of sediment will be collected at each location for chemical analyses and laboratory toxicity tests. Sediment from one side of the first double van Veen grab will be collected for washing through a 1.0 mm mesh screen in the field, subsequent taxonomic analysis, and overall benthic community assessment. Prior to homogenizing the sediment in the other side of the first van Veen grab, a small core of 0-10 cm surface sediment will be collected using a 60 mL syringe. This core of sediment will be placed in a 2-ounce glass sample jar, covered with a zinc acetate preservative solution, and capped such that there is zero headspace. This subsample of unhomogenized sediment will be used for total sulfide analysis.

The remaining sediment that is not in contact with the side walls of the sampler, and all such sediment from both halves a second grab taken from as near the same location as possible, will be transferred to a pre-cleaned stainless-steel bowl and homogenized using a clean stainless steel paint stirring paddle until texture and color appear to be uniform (EPA, 1997). The project manager will determine whether or not large rocks, pieces of wood, shells, or large organisms will be removed prior to homogenization. The homogenized sediment will then be split and dispensed using a stainless steel spoon into appropriate sample containers as shown in Table 6.

Aliquots of sediment for chemical analysis will be taken from the total volume of homogenized sediment and placed in certified-clean, labeled, appropriately sized, wide-mouth jars and capped with Teflon®-lined lids (see Table 6). Sediment that will undergo toxicity testing will be placed in one-gallon, glass, wide-mouth jars. All sediment sample containers will be filled leaving at least 1 cm headspace to prevent breakage during shipping and storage. Each glass container will be placed in a cooler with ice so as to minimize breakage. If samples will be transported any substantial distance, bubble wrap may be used to help prevent breakage. Benthic community samples will be gently washed through a 1.0 mm mesh wire screen. Organisms will be gently collected off the screen, placed in one-gallon zip-lock bags, and mixed with and covered by a solution of 10% formalin. Formalin-containing benthic community sample bags will also be stored inside sealed secondary containers such as coolers or plastic HDPE buckets.

A waterproof label will be affixed to all sample containers prior to start of field work. Labels will list the Environmental Assessment Program project number, triad sample identification number, parameter(s) to be analyzed, collection date and time, and initials of the person preparing the sample.

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

Table 6. Container description and laboratory conducting chemical or biological analyses.

Physical Parameter/ Chemical Analyte/ Biological Test	Sample No.	Amount Sample Needed	Container (size, material)	Laboratory
Total solids and TOC	33	100 grams ww	4 oz wide-mouth glass jar	MEL
Grain size	33	150 grams ww	8 oz wide-mouth HDPE jar	Contract Lab
Ammonia[a]	33	30 grams ww	4 oz glass wide-mouth jar	Contract Lab
Total sulfides (preserved)	33	50 grams ww	2 oz glass wide-mouth jar with no headspace and covered with 5 mL 2N zinc acetate	Contract Lab
Metals, including mercury[b]	33	100 grams ww	4 oz wide-mouth glass jar	MEL
Tributyltin[a]	33	100 grams ww	4 oz wide-mouth glass jar	MEL
BNA-SQS, incl. PAHs[b]	33	250 grams ww	8 oz wide-mouth glass jar	MEL
PCBs (as Aroclors)[b]	33	250 grams ww	8 oz wide-mouth glass jar	MEL
Chemical archive	33	250 grams ww	8 oz wide-mouth glass jar	MEL
Amphipod survival (incl. initial ammonia & sulfides)[c]	32	2.5 liters	1 gallon wide-mouth glass jar	Contract Lab
Larval development toxicity tests[c]	32	1.0 liter	Combined with sediment for amphipod test	Contract Lab
Benthic community assessment	32	--[d]	1 gallon sealable plastic bag	Contract Lab
Total		<5.0 liters		

a Homogenized sediment sample will be analyzed as soon as possible after sampling.
b Surplus sediment will be frozen and stored in case re-extraction and re-analyses of archived samples becomes necessary.
c Ammonia and total sulfides will also be measured when toxicity tests are initiated.
d Large volume benthic community samples will be reduced to a variable volume by sieving them through a 1.0 mm screen prior to placing them in plastic bags.

BNA-SQS Base neutral acid organic compounds for which there are Sediment Quality Standards
MEL Manchester Environmental Laboratory (Ecology)
N Normal (moles per liter)
PAHs Polycyclic aromatic hydrocarbons
PCBs Polychlorinated biphenyls
TOC Total organic carbon
ww wet weight

Decontamination

Sediment sampling devices and homogenizing equipment, e.g., mixing bowl, stainless-steel paddle and spoons, will be decontaminated according to established guidelines (EPA, 1997). Decontamination between grabs collected from the same target location will consist of a thorough rinse with site water (only). Between target locations, decontamination will consist of the following procedure:

- Rinse thoroughly with site water
- Wash with a scrub brush until free of sediment
- Wash with phosphate-free detergent
- Rinse thoroughly with site water again
- Rinse with acetone and distilled water if visible contamination present

Sampling devices or equipment that cannot be cleaned to the satisfaction of the project manager will be retired from use.

Waste Management

All excess sediment and non-solvent decontamination rinses will be returned to the sampling location after sampling is completed at each target location. All disposable sampling materials, such as gloves and paper towels, will be placed in a heavy-gauge, plastic garbage bag. The garbage bag will be removed from the study site at the end of each day and placed in a suitable solid waste disposal container.

Chain of Custody

Ecology will track the status and fate of all sediment samples (throughout the collection, transport, and analyses) and all resulting sample data (electronic and printed reports) using chain of custody procedures. Custody procedures will start during sample collection, and the first change in custody will occur either when samples are delivered directly or transferred for shipping to each analytical laboratory. Any person having custody of samples will sign the form only if the samples will be properly secured and not left unattended. Minimum documentation of sample handling and custody will include:

- Sample location, Environmental Assessment Program project name/number
- Unique sample number(s)
- Sample collection date and time
- Any special notations on sample characteristics or problems
- Initials of the person collecting the sample
- Date sample was sent to the laboratory
- Shipping company name and waybill number

The project manager will be responsible for all sample tracking and custody procedures for samples in the field. He will be responsible for final sample inventory and will maintain sample custody documentation. The project manager will also complete custody forms prior to removing samples from the sampling area. At the end of each day, and prior to transfer, custody entries will be made for all samples. Information on the labels will be checked against sample log entries, and sample tracking forms and samples will be recounted. Custody forms will accompany all samples. The custody forms will be signed at each point of transfer. Copies of all custody forms will be retained and included as appendices to quality assurance/quality control (QA/QC) reports and data reports. Sediment samples will be shipped in sealed coolers to the analytical laboratories. The project manager will ensure that the laboratory has accepted delivery of the shipment at the specified time.

The laboratories will ensure that custody forms are properly signed upon receipt of the samples and will note questions or observations concerning sample integrity on the custody forms. The laboratories will contact the project manager immediately if discrepancies are discovered between the custody forms and the sample shipment upon receipt.

The laboratory will ensure that a sample-tracking record follows each sample through all stages of laboratory processing. The sample-tracking record 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 being performed.

Shipping

Coolers with sediment samples for analysis of conventionals, metals and organic chemistry, and toxicity will be transported directly to Manchester Laboratory or shipped by courier to the appropriate laboratory. Temperature inside coolers will be checked upon receipt at the laboratory by measuring the temperature of a blank water sample packed inside each cooler. Laboratory staff will note any coolers that are not sufficiently cold (4° ± 2°C). Each sample will be assigned a unique laboratory number and grouped into appropriately-sized batches for analysis. Samples for toxicity testing will be stored in a refrigerator at the toxicity testing laboratory until test setup. Samples will be assigned a specific storage area within each laboratory and kept there until analyzed. Benthic community samples will be rescreened and preserved in 70% ethanol and rose bengal by the project manager or other Ecology staff prior to shipment to a contract sorter and team of contract taxonomists. Laboratories and taxonomists will not dispose of the environmental samples for this project until notified in writing by the project manager or QA/QC coordinator.

Measurement Procedures

This section describes sample handling, storage, laboratory methods, and data quality objectives for the physical, chemical, and biological analyses of the sediment samples that will be collected for this study.

Sediment Chemistry

Ecology will contract with one or more accredited commercial laboratories to measure the following conventional sediment parameters: grain size, ammonia, and total sulfides. Chemical contaminants in the sediment samples and the remaining conventional parameters (total solids and total organic carbon) will be analyzed by Manchester Laboratory. Contaminants that will be measured include most of those listed in the Sediment Management Standards (Ecology, 1991 and 1995) and reproduced in Table A-1 of Appendix A. Volatile organic compounds (VOCs) and organochlorine pesticides will not be measured in any sample. Sample handling, storage requirements, and analytical methods are all presented in this section. Surplus sediment from each sample will be archived frozen in case additional analyses are needed.

Table 7 summarizes how each sediment sample will be preserved, how long it will be stored before analysis, which analytical lab will measure each analyte, and the methods used.

Table 8 provides (1) a list of chemical analytes, e.g., individual metals, PAHs and other organic compounds, (2) additional information and guidance on methods of sample preparation, cleanup, and analysis, and (3) a list of desired maximum reporting limits that need to be attained to meet agency and program data quality objectives, e.g., requirements of Ecology's Toxics Cleanup Program.

Table 7. Conventional parameters and contaminant chemistry of sediment samples: handling requirements and analytical methods.

Physical Parameter/ Chemical Class/Analyte	'Preserved'	Holding Times[a]	Lab	Method	Method Reference
Total solids	Cool/4°C	7 days (6 months at -18°C)	tbd	oven-dried	SM 160.3 APHA, 2005
Grain size	Cool/4°C	6 months	tbd	sieve/pipette	EPA, 1986
Total organic carbon	Cool/4°C	14 days (6 months at -18°C)	MEL	combustion (70°C)	EPA, 1986
Ammonia	Cool/4°C	7 days	tbd	automated phenate	SM 350.1 (after extraction) APHA, 2005
Total sulfides	2N zinc acetate	7 days	tbd	spectrophotometric	SM 376.2 (after extraction) APHA, 2005
Mercury	Freeze -18°C	28 days	MEL	CVAA	SW 846 Method 7471A EPA, 1996
Organotins, as ions	Cool/4°C	Extract 14 days Analysis 40 days (1 year at -18°C)	MEL	GC/FPD	Krone et al. (1989)
Metals-SQS[b]	Cool/4°C	6 months (2 years at -18°C)	MEL	ICP-OES & ICP-MS	SW 846 Methods 6010 and 6020 EPA, 1996
BNA-SQS (incl. PAHs-SQS)[c]	Cool/4°C	Extract 14 days Analysis 40 days[d]	MEL	GC/MS	SW 846 Method 8270 EPA, 1996
PCBs as Aroclors	Cool/4°C	Extract 14 days Analysis 40 days[d]	MEL	GC/ECD	SW 846 Method 8082 EPA, 1996
Selected BNAs[e]	Cool/4°C	Extract 14 days Analysis 40 days[d]	MEL	GC/MS	SW 846 Methods 8270, 8270C EPA, 1996

a Holding times taken from the *Sampling and Analysis Plan Appendix* (Ecology 2003), MEL Lab User's Manual (Ecology, 2005c), and individual methods. Frozen sample extracts will be archived at the laboratory until disposal is authorized, but no later than March 2007.
b SQS metals include arsenic, antimony, cadmium, chromium, copper, lead, molybdenum, nickel, selenium, silver, and zinc.
c See Appendix A.
d Alternatively, whole sediment samples can be frozen at -18°C and held for a maximum of 1 year.
e 1,2-dichlorobenzene, 1,2,4-trichlorobenzene, 1,4-dichlorobenzene, 2-methylphenol, 2,4-dimethylphenol, benzoic acid, benzyl alcohol, butyl benzyl phthalate, di-ethyl phthalate, dimethyl phthalate, hexachlorobenzene, hexachlorobutadiene, n-nitrosodiphenylamine and pentachlorophenol.

Acronyms in Table 7:

BNA-SQS	Base neutral acid organic compounds for which there are Sediment Quality Standards
CVAA	Cold vapor atomic absorption
EPA	U.S. Environmental Protection Agency
GC/ECD	Gas chromatography electron capture detection
GC/FPD	Gas chromatography flame photometric detection
GC/MS	Gas chromatography mass spectrometry
ICP-OES	Inductively coupled plasma atomic emission spectrometry
ICP-MS	Inductively coupled plasma mass spectrometry
MEL	Manchester Environmental Laboratory (Ecology)
Metals-SQS	Trace metals for which there are Sediment Quality Standards
N	Normal (moles per liter)
PAH-SQS	Polycyclic aromatic hydrocarbons for which there are Sediment Quality Standards
PSEP	Puget Sound Estuary Program (Protocols and Guidelines)
SM	Standard Method
SW	Solid Waste
tbd	To be determined

Table 8. Recommended sample preparation methods, cleanup methods, analytical methods, and detection limits for sediments that will be collected from the Lower Duwamish Waterway for Ecology's SPI Feasibility Study (from Ecology, 2003).

Chemical	Sample Preparation Methods[a]	Sample Cleanup Methods[b]	Analytical Methods[c]	Reporting Limits[d, e] (µg/kg dry wt)
Conventional Sediment Variables				
Total solids	--	--	SM 160.3 APHA (2005)	0.1% wet wt.
Grain size	--	--	EPA (1986)	1%
Total ammonia	--	--	SM 350.1 APHA (2005)	100
Total organic carbon	--	--	EPA, 1986	0.1%
Total sulfides	--	--	SM 376.2 APHA (2005)	100
Metals				
Antimony	SW 846 Method 3050	--	SW 846 6010/6020	50,000
Arsenic	3050	--	6010/6020	19,000
Cadmium	3050	--	6010/6020	1,700
Chromium	3050	--	6010/6020	87,000
Copper	3050	--	6010/6020	130,000
Lead	3050	--	6010/6020	150,000
Mercury	--[f]	--	7471	140
Nickel	3050		6010/6020	47,000
Silver	3050	--	6010/6020	2,000
Zinc	3050	--	6010/6020	137,000
Non-ionizable Organic Compounds				
LPAH Compounds				
Naphthalene	3541 or 3545	3630 or 3640	8270/1625	700
Acenaphthylene	3541 or 3545	3630 or 3640	8270/1625	430
Acenaphthene	3541 or 3545	3630 or 3640	8270/1625	170
Fluorene	3541 or 3545	3630 or 3640	8270/1625	180
Phenanthrene	3541 or 3545	3630 or 3640	8270/1625	500
Anthracene	3541 or 3545	3630 or 3640	8270/1625	320
2-Methylnaphthalene	3541 or 3545	3630 or 3640	8270/1625	220
HPAH Compounds				
Fluoranthene	3541 or 3545	3630 or 3640	8270/1625	570
Pyrene	3541 or 3545	3630 or 3640	8270/1625	870

Chemical	Sample Preparation Methods[a]	Sample Cleanup Methods[b]	Analytical Methods[c]	Reporting Limits[d, e] (µg/kg dry wt)
Benz[a]anthracene	3541 or 3545	3630 or 3640	8270/1625	430
Chrysene	3541 or 3545	3630 or 3640	8270/1625	470
Total benzofluoranthenes[g]	3541 or 3545	3630 or 3640	8270/1625	1070
Benzo[a]pyrene	3541 or 3545	3630 or 3640	8270/1625	530
Indeno[1,2,3-cd]pyrene	3541 or 3545	3630 or 3640	8270/1625	200
Dibenz[a,h]anthracene	3541 or 3545	3630 or 3640	8270/1625	80
Benzo[ghi]perylene	3541 or 3545	3630 or 3640	8270/1625	220
Chlorinated Benzenes				
1,2-Dichlorobenzene	3541 or 3545	3630 or 3640	8270 (or 8240)	35
1,3-Dichlorobenzene	3541 or 3545	3630 or 3640	8270 (or 8240)	55
1,4-Dichlorobenzene	3541 or 3545	3630 or 3640	8270 (or 8240)	35
1,2,4-Trichlorobenzene	3541 or 3545	3630 or 3640	8270 (or 8240)	30
Hexachlorobenzene	3541 or 3545	3630 or 3640	8270	20
Phthalate Esters				
Dimethyl phthalate	3541 or 3545	3630 or 3640	8270	25
Diethyl phthalate	3541 or 3545	3630 or 3640	8270	65
Di-n-butyl phthalate	3541 or 3545	3630 or 3640	8270	470
Butyl benzyl phthalate	3541 or 3545	3630 or 3640	8270	20
Bis[2-ethylhexyl]phthalate	3541 or 3545	3630 or 3640	8270	430
Di-n-octyl phthalate	3541 or 3545	3630 or 3640	8270	2070
Miscellaneous Extractable Compounds				
Dibenzofuran	3541 or 3545	3630 or 3640	8270	180
Hexachlorobutadiene	3541 or 3545	3630 or 3640	8270	10
Hexachloroethane	3541 or 3545	3630 or 3640	8270	45
N-nitrosodiphenylamine	3541 or 3545	3630 or 3640	8270	25
PCBs				
PCB Aroclors®	3541 or 3545	3630 or 3640	8082	5
Ionizable Organic Compounds				
Phenol	3541 or 3545	3630 or 3640	8270	140
2-Methylphenol	3541 or 3545	3630 or 3640	8270	60
4-Methylphenol	3541 or 3545	3630 or 3640	8270	220
2,4-Dimethylphenol	3541 or 3545	3630 or 3640	8270	25
Pentachlorophenol	3541 or 3545	3630 or 3640	8270	120
Benzyl alcohol	3541 or 3545	3630 or 3640	8270	55
Benzoic acid	3541 or 3545	3630 or 3640	8270	210

Notes for Table 8:

- **a** Sample preparation methods for sediment conventional analyses are described in the analytical methods. Recommended sample preparation methods include EPA (1989), Method 3500 series from SW-846 (EPA, 1996 and updates).
- **b** Preferred cleanup method for all samples is Method 3630 (Silica Gel Cleanup). Other cleanup methods that may be employed on a sample-specific basis include 3640 (Gel Preparation Chromatography), 3660 (sulfur cleanup), 3620 (florisil column cleanup for all PCB extracts), or others (EPA, 1996 and updates).
- **c** Recommended analytical methods include 1624C/1625C – isotope dilution, and the 6000, 7000, 8000, and 9000 series from publication SW-846 (EPA, 1996 and updates).
- **d** To achieve these limits for a limited number of BNA compounds, it may be necessary to reduce the water content of the sample, use an additional sample cleanup step to reduce interference, use a smaller extract volume for gas chromatography/mass spectrometry analyses (0.5 mL), or use a larger sample size. Limits shown are on a dry-weight basis unless otherwise indicated. Analysis of sediment contaminants having total organic carbon (TOC)-normalized criteria, especially in low TOC samples, may require even lower dry weight reporting limits.
- **e** These limits are based on a value equal to one-third of the 1988 dry weight, lowest apparent effects threshold (LAET) value (Barrick et al., 1988) except for 1,2-dichlorobenzene, 1,2,4-trichlorobenzene, hexachlorobenzene, hexachlorobutadiene, n-nitrosodiphenylamine, 2-methylphenol, 2,4-dimethylphenol, and benzyl alcohol. These limits equal the full value of the 1988 dry weight LAET.
- **f** The sample digestion method for mercury is described in the analytical method (Method 7471, EPA SW-846 (EPA, 1986 and updates).
- **g** Total benzofluoranthenes represent the sum of the b, j, and k isomers.

Sediment Toxicity

One line of evidence that Ecology will use to evaluate whether or not surface sediment conditions are altering/impairing *in situ* benthic communities is the observation of significant laboratory-based toxicity. Contract laboratories will conduct standardized sediment toxicity tests, as described by the EPA (1995) and below, using surface sediment samples collected from the Lower Duwamish Waterway (LDW). After collecting sediment for total sulfide analysis, the remaining volume of sediment representing a single sampling location will first be homogenized and then split. One volume of sediment will be distributed to sample containers for physical and chemical analyses (see above). Approximately four liters of homogenized sediment will then be distributed to one-gallon HDPE buckets for subsequent toxicity testing. This total volume will provide enough extra sediment for any toxicity test to be repeated.

Once toxicity samples are delivered to the contract laboratory, the headspace (if any) will be filled with nitrogen, stored in the dark at 4°C ± 2°C, and toxicity tests begun within two weeks of sample collection. An extension of this holding time may be allowed at the discretion of the project manager.

Two standardized acute tests and one chronic standardized sediment toxicity test will be conducted on each surface sediment sample:

- 10-day amphipod survival test using *Eohaustorius estuaries.*
- 48-hour bivalve larval development test using *Mytilus edulis/galloprovincialis.*

Amphipod survival toxicity tests will be conducted according to protocols, quality control, and performance standards described in *Recommended Guidelines for Conducting Laboratory Bioassays on Puget Sound Sediments* (EPA, 1995), with modifications as specified as a result of annual Sediment Management Annual Review Meetings (SMARM). Approximately 1.25 liters of homogenized surface sediment will be needed to create five laboratory replicate toxicity tests. Amphipods will be exposed to LDW sediments and reference sediments, with interstitial and overlying water pre-equilibrated to the same salinity (20-25 ppt), for a 10-day period. Survival (conversely, mortality) will be the primary interpretive endpoint.

The larval development acute toxicity test will be conducted as per regional test protocols, quality control, and performance standards (EPA, 1995) and as modified at subsequent SMARMs. Approximately 200 grams of wet surface sediment will be needed to create five laboratory replicate toxicity tests. All beakers will be aerated to maintain correct levels of oxygen saturation throughout the tests. Normal and abnormal larvae will be counted at the end of the 48-96 hour exposure, with the following endpoints calculated and reported: normal development, abnormal development, mortality, and combined mortality and abnormality.

Control sample performance standards for these toxicity tests are as follows:

- Mean amphipod mortality must be less than 10%.
- Mean combined abnormality and mortality must be less than 30% of the initial stocking density.

If control samples fail to meet these performance standards, sample results will be considered unusable or they may be interpreted relative to reference sample results.

Interpretation of laboratory-based sediment toxicity tests requires matching each test sediment with a reference sediment that is tested simultaneously. This is done to evaluate the potential influence of confounding factors such as sediment grain-size, organic carbon, ammonia, and sulfide on test results. For this study, two reference area sediment samples will be collected from the northern end of Carr Inlet. They will be wet sieved in the field to confirm two expected ranges of percent fines (silt plus clay): 40% - 65% fines and 65% - 90% fines. Additional sediment from these reference sites will be archived because chemical analyses may be needed at a later date.

Ammonia and sulfides present in surface sediments, which may not be of anthropogenic origins, can also cause toxic effects in amphipods and polychaetes that may confound the interpretation of toxicity tests (DMMP, 2001 and 2004). Therefore, a water-only, positive control test will be conducted to assess organism sensitivity to ammonia. In addition, a "blank" container will be used for measurements of ammonia and total sulfides in the overlying water and porewater at the beginning of each test, as well as in the overlying water at the end of each test.

Two reference sediment samples collected from Carr Inlet will be tested for toxicity using the same three test protocols and organisms. Reference sample performance standards are:

- Mean amphipod mortality must be less than 25%.
- Mean combined abnormality and mortality must be less than 65% of the control sample.

If reference samples fail to meet these performance standards, then sample results may be interpreted relative to control sample results.

Assuming control and reference samples meet performance standards, each LDW test sediment sample will be statistically compared to the reference sediment most similar in grain-size and total organic carbon. Final interpretation of toxicity test results will be according to the Sediment Management Standards rule (Table 9).

Table 9. Biological effects criteria for two toxicity tests to be conducted on marine study site sediments (Ecology, 1991, 1995, 2003).

Toxicity Test	Sediment Quality Standards	Cleanup Screening Levels/ Minimum Cleanup Levels/ Sediment Impact Zone$_{Max}$
Amphipod	Mean test sediment mortality > mean reference sediment mortality (t-test, P=0.05) *and* test sediment mean mortality > 25% absolute.	Mean test sediment mortality > mean reference sediment mortality (t-test, P=0.05) and mean test sediment mortality more than 30% > mean reference sediment mortality.
Larval	Mean test sediment normal survivorship of larvae < mean reference sediment normal survivorship (t-test, P=0.05) and combined abnormality *and* mortality in test sediment more than 15% > that of reference sediment.	Mean test sediment normal survivorship of larvae < mean reference sediment normal survivorship (t-test, P=0.05) and combined abnormality *and* mortality in test sediment more than 30% > that of reference sediment.

Benthic Community Assessment

Ecology will collect surface sediment samples from the LDW within 2-3 meters of the target locations identified in the final QA Project Plan (as potentially modified by SPI images and recommendations of the SPI contractor, Germano and Associates). These samples will represent similar subtidal marine habitats that are contaminated to various degrees.

Benthic samples will be collected, handled, sieved, sorted, and analyzed according to protocols and QA requirements (EPA, 1987) summarized below, except that only a single van Veen field replicate, e.g., grab, will be collected. (The number of field replicates will effectively be constrained by the study budget.) A 0.1 m^2 van Veen sampler will be used to collect surface sediment, with all samples first inspected for acceptability (see above). The top 10 cm of material from each acceptable grab will be placed on a 1.0 mm mesh screen in the field, rinsed with a gentle stream of seawater to separate organisms from sediment and organic matter, placed into a pre-labeled plastic zip-lock bag or a wide-mouthed plastic jar containing a buffered preservative (7-10% formalin), and gently mixed.

Benthic community samples will then be transported to Ecology's wet laboratory and transferred into ethanol within seven days of collection. They will subsequently be resorted by a contractor into major taxonomic groups (annelida, crustacea, mollusca, echinodermata, and miscellaneous phyla) as described below.

The following procedure will be used to sort invertebrates from relatively coarse grained sediment that contains relatively little organic matter: Each sample will be washed gently through a 0.5 mm mesh sieve into a shallow pan of water. Invertebrates attached to any larger rock, shell, or wood debris will be collected using forceps, and the debris will be disposed of appropriately. Organic matter will be separated from inorganic sediments by means of gentle agitation, with lighter organic matter being placed back onto the 0.5 mm sieve. This procedure will be repeated until visual inspection reveals no organic material remaining in the pan.

The following procedure will be used to separate benthic organisms from finer grained sediments containing relatively more organic matter: Small amounts of each sample will be placed into a Petri dish, from which the sorter will use a pair of fine forceps to remove organisms and place them into the appropriately labeled containers (annelida, crustacea, mollusca, echinodermata, and miscellaneous phyla). Each Petri dish of material will be "picked" twice, and this process will be repeated using new material until the entire samples has been sorted.

Organisms will be preserved using 95% ethanol to achieve a final concentration of approximately 70% - 80% ethanol. The volume of ethanol added to each sample will vary depending on sample characteristics, but an equal ratio of preservative volume to sample volume will usually result in the target ethanol concentration.

Ecology will contract with experienced taxonomists to photograph the sorted samples, identify all organisms at the lowest taxonomic level practical (generally species), and count them. The taxonomists will use only readily available, peer-reviewed taxonomic keys to identify organisms. Once all organisms have been identified, they will be returned to original vials. Abundance data for each sample will be reported at the major taxonomic group level (annelida, crustacea, mollusca, echinodermata, and miscellaneous phyla) and the lowest practical taxon level. A reference collection of specimens will be placed in vials and archived by Ecology. The taxonomists will complete their analyses and submit final benthic community data to Ecology by December 20, 2006, in electronic format (EIM or substantive equivalent).

Data Quality

Sediment Chemistry

Quality control limits and corrective actions applicable to the analyses of trace metals and organic chemicals in sediment samples collected for this project are listed in Tables 10 and 11, respectively. The project manager will work closely with Manchester Laboratory and contract laboratories to ensure that QA/QC requirements will be met and that appropriate and reasonable corrective actions will be taken. In lieu of corrective actions, some data will be qualified appropriately.

Of particular concern for this project is attaining some of the chemical-specific reporting limits listed in Table 8 and taken from the *Sampling and Analysis Plan Appendix* (Ecology, 2003). Manchester Laboratory will likely not have difficulty measuring most of the organic contaminants commonly found in sediment samples, e.g., PAHs and many of the BNAs, using SW 846 Method 8270. However, Manchester Laboratory will also use this method to measure certain BNAs that are often problematic because their required reporting limits are relatively low (e.g., the five chlorinated benzene compounds, dimethyl- and butyl benzyl phthalates, hexachlorobutadiene, hexachloroethane, N-nitrosodiphenylamine, 2,4-dimethylphenol, benzyl alcohol, and benzoic acid). For these analytes, Manchester Laboratory may first need to reduce the water content of samples prior to extraction, conduct a second cleanup procedure to attain the required reporting limits for these analytes, or both. Alternatives include measuring some of these compounds using either 8270C with selective ion monitoring or possibly even 8260. Manchester Laboratory and the project manager will discuss and agree to a course of action if the laboratory has difficulty attaining any required reporting limits.

Along with each sample analytical result, Manchester Laboratory will provide the sample preparation/cleanup methods used and the calculated practical quantitation or reporting limit. Each reporting limit will factor in the sample mass, extract volume, dilutions, and lowest calibration point. Detected concentrations that exceed the reporting limit will be reported without qualification. Concentrations that are detected below the reporting limit but above the detection limit will be qualified as estimated ("J"). Data that may need to be qualified for other reasons will be assigned qualifier codes according to Manchester Laboratory guidance (Ecology, 2003c).

Table 10. Quality control procedures for metal analyses.

Quality Assurance/ Quality Control Procedure	Frequency	Control Limit	Corrective Action
Instrument			
Initial Calibration	Daily	Correlation coefficient 0.995	Recalibrate instrument *and* reanalyze affected samples
Initial Calibration Verification	Just after initial calibration	90% - 110% recovery 80% - 120% for mercury	Resolve discrepancy prior to sample analysis
Continuing Calibration Verification	Every 10 samples or 2 hours (whichever is more frequent) and after the last sample	90% - 110% recovery 80% - 120% for mercury	Recalibrate and reanalyze affected samples
Initial and Continuing Calibration Blanks	After initial calibration, then 10% of samples or every 2 hours (whichever is more frequent) and after last sample	Analyte concentration < ½ reporting limit reported by Manchester Laboratory	Recalibrate and reanalyze affected samples
ICP Interelement Interference Check Sample	Beginning and end of each analytical batch or twice per 8-hour shift (whichever is more frequent)	80% -120% of true value	Correct problem, recalibrate, and reanalyze affected samples
Method			
Holding Times	Not applicable	Six months at 4°C Two years frozen (-18°C) Mercury 28 days at 4°C or frozen	Qualify data or collect new samples
Method Blanks	Every sample batch or 20 samples (whichever is more frequent)	Analyte concentration < ½ reporting limit	Re-digest and re-analyze samples with analyte concentrations < 10 times highest method blank
Laboratory Control Sample	Every sample batch or 20 samples (whichever is more frequent)	Control limits vary with laboratory control sample	Correct problem, re-digest and reanalyze affected samples
Internal Standards	One per each sample	30% - 120%	Correct problem by diluting sample and reanalyzing
Matrix			
Matrix Spike Sample	Every sample batch or every 20 samples (whichever is more frequent)	75% -125% recovery	Correct/minimize problem or accept but qualify data
Duplicate Sample Analysis	Every sample batch or every 20 samples (whichever is more frequent)	±35 relative percent difference	Correct/minimize problem or accept but qualify data
Detection Limits	Not applicable	(see Tables 3 and 8)	Lab contacts project manager to discuss possible corrective actions

ICP Inductively coupled plasma-atomic emission spectrometry

Table 11. Quality control procedures for analyses of organic compounds in sediment samples.

Quality Assurance/ Quality Control Procedure	Frequency	Control Limit	Corrective Action
Instrument			
Initial Calibration	As per EPA (1989 and 2003) and specified in analytical protocol	BNAs: ≤ 30% RSD and rel. response factor 0.05 PCBs: ≤ 20% RSD	Quality samples results or recalibrate and reanalyze affected samples
Continuing Calibration	BNAs: every 12 hours PCBs: every 20 samples or 6 hours *and* at end	BNAs: ≤ 25% RSD and rel. response factor 0.05 PCBs: ≤ 15% RSD	Quality samples results or recalibrate and reanalyze affected samples
Method			
Holding Times	Not applicable	BNAs and PCBs: 14 days at 4°C before extraction 1 year stored frozen (-18°C)	Qualify data or collect new samples
Method Blank	One per extraction batch	Analyte concentration < PQL/ reporting limit Warning limit = detection limit	Eliminate or greatly reduce contamination Re-analyze affected samples
Surrogate Compounds	Added to samples as specified in analytical protocol	Control limits as per MEL For BNAs: 1,2-Dichlorobenzene-D4 16-110% 2-Fluorobiphenyl 43-116% 2-Fluorophenol 21-110% D4-2-Chlorophenol 33-110% D5-Nitrobenzene 35-114% D5-Phenol 10-110% Pyrene-D10 50 -150% Terphenyl-D14 33-141% For PCBs: 50% - 150% of the reference value	As per MEL guidance Re-extract and re-analyze sample if ≥ 2 recoveries of either fraction are outside QC criteria. If re-extraction not possible or surrogates still exceed QC criteria: Results for acid analytes qualified as estimates if ≥ 2 acid surrogates exceed QC criteria. Results for base/neutral analytes qualified as estimates if ≥ 2 base/neutral surrogates exceed QC criteria.
Matrix Spike Sample and Matrix Spike Duplicate	One per sample batch *or* every 20 samples (whichever is more frequent)	50% - 150% recovery ≤ 50% RPD precision	Quality sample results
Laboratory Control Sample	One per sample batch *or* every 20 samples (whichever is more frequent)	50% - 150% recovery	Correct problem and reanalyze affected samples

Quality Assurance/ Quality Control Procedure	Frequency	Control Limit	Corrective Action
Internal Standards	Frequency per samples as specified in analytical protocol	Response 50% - 200% of calibration standard and retention time within 30 sec. of standard	Correct problem and reanalyze affected samples
Detection Limits	Not applicable	(see Table 8)	Contact project manager or QA/QC coordinator. Additional cleanup, other corrective actions possible.

BNA base neutral acid organic compounds
MEL Manchester Environmental Laboratory
PCB polychlorinated biphenyl
PQL practical quantification limit
QA quality assurance
QC quality control
RPD relative percent difference
RSD relative standard deviation

Sediment Toxicity

The main quality objective for laboratory-based sediment toxicity data will be to obtain results that can be readily interpreted, e.g., minimal concern about the influence of confounding factors and normal replicate variability. This will involve ensuring the representativeness and thorough homogenization of each field sample, collecting a total volume of sediment adequate for the needed number of lab replicates, and maintaining relatively constant environmental conditions during each exposure. The test conditions, necessary control samples, and performance standards for both control and test samples that will apply to toxicity tests conducted for this project are listed in Table 12.

The project manager will (1) provide any needed clarifications of test protocols, (2) review contract laboratory standard operating procedures for individual toxicity tests, (3) work closely with laboratory staff to anticipate issues before they arise, (4) be available to make decisions or troubleshoot problems that arise in conducting toxicity tests, and (5) review the final data package for compliance with QA Project Plan specifications.

Benthic Community Assessment

The data quality objectives (DQOs) will be to obtain benthic community data that are representative of a location (and point in time or season) and accurate. If the data are representative and accurate, they will be interpretable and usable for the purposes of this study. Specific DQOs for benthic data will be:

- Collect samples likely to be representative of *in situ* benthic communities found in the area by using appropriate field methods and by documenting any deviations.
- Sort benthic samples accurately by following appropriate sample handling, picking, and sorting protocols.
- Identify and count benthic organisms accurately.

The degree to which a benthic community sample is likely to be representative of the immediate area will be assessed in two ways:

1. Each sample will be collected from a location as close as possible to where an SPI image was taken or from within an area shown by triplicate SPI images to have homogeneous surface sediments.
2. The crew will carefully observe sample acceptance criteria (as described above).

The surface sediment of a sample will be intact within the van Veen grab sampler, e.g., overlying water will be present, and there will be evidence of no or minimal loss of surface sediment from the 0-10 cm depth interval within the entire 0.1 m^2 area.

The picking and sorting process for each sample will meet the recommended 95% accuracy for the total number of individuals, as recommended in the Puget Sound Estuary Program protocols (EPA, 1987), or the entire sample will be re-sorted.

Table 12. Marine and estuarine sediment toxicity test conditions and performance standards for control and reference samples.

Toxicity Test *(Test Species)*	WQ Monitoring Frequency		Control Limits			Control Samples Performance			Standards[a]
	Temp., Salinity, DO, and pH	Sulfides Ammonia	Temp (°C)	Salinity (ppt)	DO (% sat.)	Negative Control	Positive Control	Reference	
Amphipod *(Eohaustorius estuarius)*	Daily	Start/ End	15±1	Ambient/ porewater	NA[b]	Clean sediment	Reference toxicant in seawater	Yes	Mean control mortality <10%
									Mean reference mortality <25%
Larval Mussel (*Mytilus* sp.)	Daily	Start/ End	16±1	28±1	>60[c]	Clean seawater	Reference toxicant in seawater	Yes	Mean seawater control mortality plus abnormality <30% initial stocking density
									Mean reference mortality plus abnormality <65% control

a From WAC 173-204-315(2).
b Continuous aeration is required by the protocol.
c Aerate if the concentration of dissolved oxygen declines below 60% of saturation.

DO – dissolved oxygen
NA – not applicable
WQ – water quality

The organisms from each of the major taxonomic groups (annelida, crustacea, mollusca, echinodermata, and miscellaneous phyla) will be identified by an experienced taxonomist. The accuracy of each primary taxonomist's species identifications will be assessed in two ways:

1. Organisms in 5% of the samples will be re-identified by a second experienced taxonomist (EPA, 1987)
2. A reference collection of organisms will be created by the primary taxonomist and verified by a second taxonomist. There will be a minimum of 95% agreement on species identification between the two taxonomists

Where there is disagreement, the two taxonomists will reach consensus on the proper identification of a species and ensure that the data are edited appropriately. When sample identification and quality control have been completed, archived and reference specimen vials will be placed in jars with a small amount of 70% ethanol, tightly capped, and stored by station and date at Ecology headquarters or operations center.

Data Management

All sediment quality data generated for this project will first be evaluated for completeness and usability. This includes sediment chemistry data generated by Manchester Laboratory and stored in its LIMS database, data from analysis of some conventional parameters from contract laboratories, and all biological data generated by contract laboratories or taxonomists.

All data will be entered into Ecology's Environmental Information Management (EIM) system. If it facilitates data analysis, these data *may* also be processed into valid electronic SEDQUAL templates and transferred into Ecology's SEDQUAL database. Ecology staff will also explore the existing capabilities of its EIM System to store SPI data.

Audits and Reports

Manchester Laboratory participates in performance and system audits of routine procedures, with audit results available on request. The Laboratory Accreditation Section of Ecology's Environmental Assessment Program accredits all contract laboratories that conduct environmental analyses for the agency. The accreditation process includes performance testing and periodic laboratory assessments.

An initial draft report describing the results of this project is targeted for completion in February 2007, with the final due by April 2007. The report will include the following elements.

- Abstract.
- Background, problem statement, and study goals.
- Study design, with maps of past sediment quality data and new SPI/triad sample locations.
- SPI and triad methods, both field and laboratory.
- Sampling summary for SPI and triad samples, including date, time, location, and water depth.
- Data quality summary highlighting exceptions to SPI and Ecology QA Project Plans and any sampling difficulties encountered.
- Maps showing patterns in SPI and sediment quality.
- Analysis and mapping of toxicity and benthic community sample results, including compliance with Sediment Management Standards.
- Results of statistical analyses exploring relationships between SPI and triad data.
- Summary of findings related to other goals, e.g., confirming previous results.
- Conclusions and recommendations.
- References.
- Appendices, e.g., QA Project Plans, SPI images, SPI and triad raw data tables.

The final report and raw data will be linked to this QA Project Plan at www.ecy.wa.gov/biblio/0603116.html

Data Verification

Manchester Laboratory will review all of the chemical analyses that it conducts for this project and prepare a brief case narrative with a QC report and a summary of analytical results to accompany a complete data package. Other contract laboratories will be similarly responsible. The project manager will review all case narratives and data summaries, as well as raw laboratory data (if necessary). More specifically, the project manager will:

- Assess representativeness of results by reviewing field notes about where and how each surface sediment sample was collected
- Assess comparability of sample results to other studies by comparing the methods and protocols described in case narratives with the ones specified in this QA Project Plan (Tables 7-8).
- Verify that laboratories have complied with the quality assurance/quality control (QA/QC) requirements presented in Tables 7-12 or have appropriately qualified sample results. These QA/QC requirements include instrument calibrations, detection limits, required quality control samples within control limits or suitably qualified, toxicity test conditions, performance of toxicity control and reference samples within control limits, calculations performed correctly and the resulting data are complete, correct, and consistent).
- Briefly summarize these reviews as part of the final SPI Feasibility Study report.

Data Quality Assessment

After data have been reviewed and verified, the project manager will determine if the data are generally usable for characterizing sediment quality, and specifically usable for the primary goal of this study. This will consist of a review of representativeness, comparability, and the ability to interpret the data according to regulatory requirements and guidelines.

The need for samples to be as representative as possible of nearby environmental conditions (e.g., where SPI camera images were taken) and for field sampling methods that ensure the same are both described in this QA Project Plan (see *Sampling Procedures*). To assess representativeness, the project manager will carefully review field notes, with respect to two factors:

- The proximity of sediment triad sampling locations to SPI station coordinates.
- The extent to which sample acceptance criteria were adhered to or observed.

Chemical or biological results for any sediment sample found to have been collected too far from where SPI data were collected, or found acceptable despite not meeting all of the stated criteria, will be scrutinized for possible exclusion from analyses.

Analytical results for the sediment samples collected for this study must also be comparable to those routinely collected under the authority of contaminated sediment cleanup programs. To evaluate this, the project manager will review final analytical methods reported to have been used, laboratory standard operating procedures (SOPs), and quality control summaries or exception reports. Where possible, the project manager will also compare analytical results from this study to any previous sediment quality triad results for the same or similar locations.

Reasons that certain results may not be deemed usable include the following.

- The methods or SOPs used differ from those listed in this QA Project Plan such that they cannot be considered comparable.
- Quality control reports indicate that chemistry results may have a severe bias or are highly qualified for some other reason.
- The laboratory reports detection limits (actually reporting limits) greater than those listed in Table 8.
- Toxicity control or reference samples do not meet performance standards.
- Toxicity test protocols, SOPs, test conditions, and quality control indicate substantial deviation from those proscribed in this QA Project Plan.
- Chemical or biological results from any sample differ *substantially* from previous results for virtually the same location.

Results will, in all likelihood, be rejected if that is the recommendation made by the analytical laboratory in its quality control report.

Finally, the project manager will interpret all chemical and biological results according to regulatory requirements, written guidance, and conventions. Results that cannot be thus interpreted will be excluded from certain, if not all, future analyses.

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Appendix A.
Sediment Management Standards and Guidelines

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Table A-1. Numerical sediment quality criteria and guidelines for marine sediments in Washington State.

Chemical Analyte	Sediment Management Standards		Dredged Material Disposal Program	
	SQS	CSL, MCUL, SIZ_{Max}	SL	ML
Metals/Metalloids	**(mg/kg dry weight, ppm)**		**(mg/kg dry weight, ppm)**	
Antimony	--	--	20	200
Arsenic	57	93	57	700
Cadmium	5.1	6.7	0.96	9.6
Chromium	260	270	--	--
Copper	390	390	81	810
Lead	450	530	66	660
Mercury	0.41	0.59	0.21	2.1
Nickel	--	--	140	--
Silver	6.1	6.1	1.2	6.1
Zinc	410	960	160	1,600
Tributyltin (µg/L pore water)	--	--	0.05	--
Non-ionizable Organic Compounds	**(mg/kg organic carbon[a], ppm OC)**		**(µg/kg dry weight, ppb)**	
Aromatic Hydrocarbons				
Total LPAH[b]	370	780	610	6,100
Naphthalene	99	170	210	2,100
Acenaphthylene	66	66	64	640
Acenaphthene	16	57	63	630
Fluorene	23	79	64	640
Phenanthrene	100	480	320	3,200
Anthracene	220	1,200	130	1,300
2-Methylnaphthalene	38	64	67	670
Total HPAH[c]	960	5,300	1,800	51,000
Fluoranthene	160	1,200	630	6,300
Pyrene	1,000	1,400	430	7,300
Benz[a]anthracene	110	270	450	4,500
Aromatic Hydrocarbons				
Chrysene	110	460	670	6,700
Total benzofluoranthenes[d]	230	450	800	8,000
Benzo[a]pyrene	99	210	680	6,800
Indeno[1,2,3-cd]Pyrene	34	88	69	5,200

Chemical Analyte	Sediment Management Standards		Dredged Material Disposal Program	
	SQS	CSL, MCUL, SIZ_{Max}	SL	ML
Dibenz[a,h]anthracene	12	33	120	1,200
Benzo[ghi]perylene	31	78	540	5,400
Chlorinated Benzenes				
1,2-Dichlorobenzene	2.3	2.3	19	350
1,3-Dichlorbenzene	--	--	170	--
1,4-Dichlorobenzene	3.1	9	26	260
1,2,4-Trichlorobenzene	0.81	1.8	13	64
Hexachlorobenzene	0.38	2.3	23	230
Phthalate Esters				
Dimethyl phthalate	53	53	160	--
Diethyl phthalate	61	110	97	--
Di-n-butyl phthalate	220	1,700	1,400	--
Butyl benzyl phthalate	4.9	64	470	--
Bis[2-ethylhexyl]phthalate	47	78	3,100	--
Di-n-octyl phthalate	58	4,500	6,200	--
Miscellaneous				
Dibenzofuran	15	58	54	540
Hexachlorobutadiene	3.9	6.2	29	290
Hexachloroethane	--	--	1,400	14,000
N-nitrosodiphenylamine	11	11	28	220
Total PCBs	12	65	130	2,500
Ionizable Organic Compounds	**(µg/kg dry weight, ppb)**		**(µg/kg dry weight, ppb)**	
Phenol	420	1,200	120	1,200
2-Methylphenol	63	63	20	72
4-Methylphenol	670	670	120	1,200
2,4-Dimethylphenol	29	29	29	50
Pentachlorophenol	360	690	100	690
Benzyl alcohol	57	73	25	73
Benzoic acid	650	650	400	690

Notes on Table A-1:

--	-	no numerical criterion of this type for this chemical
AET	-	apparent effects threshold
CSL	-	cleanup screening level
HPAH	-	high molecular weight polycyclic aromatic hydrocarbon
LPAH	-	low molecular weight polycyclic aromatic hydrocarbon
MCUL	-	minimum cleanup level
ML	-	maximum level
PCB	-	polychlorinated biphenyl
SIZ_{Max}	-	Sediment Impact Zone maximum allowable contamination level (WAC 173-204-420)
SL	-	screening level
SMS	-	Sediment Management Standards (WAC 173-204)
SQS	-	Sediment Quality Standards (WAC 173-204-320)

a Values are parts per million "normalized" to the concentration of total organic carbon in the same sample.
b The LPAH criterion will be compared to the summed concentrations of naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, and anthracene. 2-methylnaphthalene is not included in the sum.
c The total HPAH criterion is compared to the sum of the concentrations of the following HPAH compounds: fluoranthene, pyrene, benz[a]-anthracene, chrysene, total benzofluoranthenes, benzo[a]pyrene, indeno[1,2,3-cd]pyrene, dibenz[a,h]anthracene, and benzo[ghi]perylene.
d The total benzofluoranthenes criterion will be compared to the sum of the concentrations of the b, j, and k isomers.

If a chemical is not detected in a sediment sample, the detection limit will be reported.
If all chemicals in a chemical group are undetected, then the highest individual chemical detection limit will be reported.
If at least one chemical in a group is detected, then only detected concentrations are included in the summed value.

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Appendix B.
Target Sampling Locations for SPI Feasibility Study

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Table B-1. Target sediment triad sampling locations, ordered from north to south and with stratum (predicted likelihood of benthic community impairment) indicated.

Stations are ordered from north to south, with each stratum (predicted likelihood of benthic community impairment) indicated. Locations considered good candidates for sediment quality triad sampling and analysis, based on preliminary SPI camera images, are indicated with a "Y" (Yes).

SPI ID Number	Stratum	Replicate	Meter wheel depth (meter)	Sample Location DGPS Trimble NT300D NAD 1983, SPCS, WA North		Sample Location DGPS Trimble NT300D NAD 1983, SPCS, WA North		Triad?
				X	Y	Latitude	Longitude	
002T	M	1	7.2	1266231.4	211286.9	47 34.1478	122 20.9519	Y
002T	M	2	7.4	1266234.3	211288.0	47 34.1480	122 20.9512	Y
002T	M	3	7.1	1266237.9	211283.1	47 34.1472	122 20.9503	Y
004	L	1	10.2	1266880.4	211226.1	47 34.1399	122 20.7939	Y
004	L	2	10.2	1266879.5	211223.0	47 34.1394	122 20.7941	Y
004	L	3	10.2	1266875.5	211227.4	47 34.1401	122 20.7951	Y
006T	H	1	8.6	1267022.7	211223.3	47 34.1399	122 20.7593	?
006T	H	2	8.6	1267022.6	211220.2	47 34.1394	122 20.7593	?
006T	H	3	8.4	1267023.5	211220.2	47 34.1394	122 20.7591	?
007	L	1	11.2	1266987.2	211050.7	47 34.1114	122 20.7671	?
007	L	2	11.2	1266985.3	211059.8	47 34.1129	122 20.7676	?
007	L	3	11.2	1266987.8	211058.0	47 34.1126	122 20.7670	?
008	L	1	14.8	1266544.2	210832.0	47 34.0740	122 20.8737	Y
008	L	2	14.8	1266542.2	210832.6	47 34.0741	122 20.8742	Y
008	L	3	14.8	1266548.4	210833.1	47 34.0742	122 20.8727	Y
010	L	1	11.8	1266263.3	210295.7	47 33.9849	122 20.9394	Y
010	L	2	11.8	1266258.5	210283.7	47 33.9829	122 20.9405	Y
010	L	3	11.8	1266261.5	210288.5	47 33.9837	122 20.9398	Y
011	L	1	17.6	1266642.4	210214.7	47 33.9728	122 20.8469	
011	L	2	17.6	1266639.8	210211.1	47 33.9722	122 20.8475	

SPI ID Number	Stratum	Replicate	Meter wheel depth (meter)	Sample Location DGPS Trimble NT300D NAD 1983, SPCS, WA North		Sample Location DGPS Trimble NT300D NAD 1983, SPCS, WA North		Triad?
				X	Y	Latitude	Longitude	
011	L	3	17.6	1266644.0	210215.3	47 33.9729	122 20.8465	
015T	H	1	15.6	1266498.1	209806.5	47 33.9052	122 20.8800	Y
015T	H	2	15.6	1266499.1	209816.2	47 33.9068	122 20.8798	Y
015T	H	3	15.6	1266500.7	209814.3	47 33.9065	122 20.8794	Y
016	M	1	14.0	1266291.2	209834.3	47 33.9091	122 20.9304	Y
016	M	2	14.2	1266294.1	209833.0	47 33.9089	122 20.9297	Y
016	M	3	14.2	1266297.4	209833.5	47 33.9090	122 20.9289	Y
017	M	1	10.6	1266877.1	209783.8	47 33.9027	122 20.7878	?
017	M	2	10.8	1266879.5	209778.3	47 33.9018	122 20.7872	?
017	M	3	10.8	1266880.5	209786.8	47 33.9032	122 20.7870	?
023	L	1	7.0	1266584.3	208454.3	47 33.6831	122 20.8526	
023	L	2	7.0	1266581.8	208456.2	47 33.6834	122 20.8532	
023	L	3	7.0	1266581.0	208455.0	47 33.6832	122 20.8534	
026	M	1	9.4	1267284.4	207660.4	47 33.5548	122 20.6787	Y
026	M	2	9.2	1267284.8	207660.4	47 33.5548	122 20.6786	Y
026	M	3	9.4	1267282.0	207661.6	47 33.5550	122 20.6793	Y
027	L	1	4.4	1267544.3	207312.9	47 33.4985	122 20.6139	
027	L	2	4.4	1267546.4	207315.3	47 33.4989	122 20.6134	
027	L	3	4.4	1267546.8	207316.5	47 33.4991	122 20.6133	
034	L	1	4.2	1266979.6	206478.8	47 33.3595	122 20.7471	
034	L	2	4.2	1266978.8	206478.2	47 33.3594	122 20.7473	
034	L	3	4.2	1266978.0	206480.1	47 33.3597	122 20.7475	
035T	H	1	6.0	1267913.6	206349.8	47 33.3413	122 20.5196	
035T	H	2	6.0	1267913.6	206352.3	47 33.3417	122 20.5196	

SPI ID Number	Stratum	Replicate	Meter wheel depth (meter)	Sample Location DGPS Trimble NT300D NAD 1983, SPCS, WA North		Sample Location DGPS Trimble NT300D NAD 1983, SPCS, WA North		Triad?
				X	Y	Latitude	Longitude	
035T	H	3	6.0	1267914.1	206354.7	47 33.3421	122 20.5195	
036	L	1	12.2	1267009.4	206235.6	47 33.3196	122 20.7387	Y
036	L	2	12.2	1267012.7	206233.7	47 33.3193	122 20.7379	Y
036	L	3	12.2	1267009.1	206236.8	47 33.3198	122 20.7388	Y
036	L	4	12.2	1267012.4	206241.0	47 33.3205	122 20.7380	Y
037T	H	1	12.2	1267658.1	206128.6	47 33.3041	122 20.5806	Y
037T	H	2	12.2	1267659.3	206126.8	47 33.3038	122 20.5803	Y
037T	H	3	12.2	1267646.3	206136.2	47 33.3053	122 20.5835	Y
037T	H	4	12.2	1267655.4	206139.0	47 33.3058	122 20.5813	Y
040T	M	1	12.4	1267894.4	205478.9	47 33.1980	122 20.5201	?
040T	M	2	12.4	1267896.5	205479.4	47 33.1981	122 20.5196	?
040T	M	3	12.4	1267898.1	205480.0	47 33.1982	122 20.5192	?
045	L	1	12.2	1268064.8	204847.4	47 33.0947	122 20.4757	Y
045	L	2	12.2	1268067.2	204844.3	47 33.0942	122 20.4751	Y
045	L	3	12.2	1268069.7	204844.3	47 33.0942	122 20.4745	Y
047T	H	1	8.0	1267977.4	204779.2	47 33.0832	122 20.4966	Y
047T	H	2	8.0	1267979.4	204776.1	47 33.0827	122 20.4961	Y
047T	H	3	8.0	1267978.7	204778.5	47 33.0831	122 20.4963	Y
048T	H	1	11.8	1268099.6	204670.4	47 33.0657	122 20.4664	Y
048T	H	2	11.6	1268097.2	204670.4	47 33.0657	122 20.4670	Y
048T	H	3	11.4	1268100.5	204671.6	47 33.0659	122 20.4662	Y
049T	H	1	9.4	1268125.0	204452.2	47 33.0299	122 20.4592	?
049T	H	2	9.6	1268122.6	204454.7	47 33.0303	122 20.4598	?
049T	H	3	9.6	1268121.4	204457.7	47 33.0308	122 20.4601	?

SPI ID Number	Stratum	Replicate	Meter wheel depth (meter)	Sample Location DGPS Trimble NT300D NAD 1983, SPCS, WA North		Sample Location DGPS Trimble NT300D NAD 1983, SPCS, WA North		Triad?
				X	Y	Latitude	Longitude	
050T	M	1	13.8	1268363.1	204482.8	47 33.0357	122 20.4015	Y
050T	M	2	13.8	1268365.2	204482.8	47 33.0357	122 20.4010	Y
050T	M	3	14.0	1268365.6	204484.0	47 33.0359	122 20.4009	Y
051	L	1	12.8	1268233.7	204367.4	47 33.0163	122 20.4324	Y
051	L	2	12.8	1268233.6	204366.1	47 33.0161	122 20.4324	Y
051	L	3	12.8	1268235.2	204363.7	47 33.0157	122 20.4320	Y
052	L	1	12.8	1268447.5	204313.9	47 33.0082	122 20.3802	Y
052	L	2	12.6	1268445.5	204316.4	47 33.0086	122 20.3807	Y
052	L	3	12.6	1268448.4	204316.9	47 33.0087	122 20.3800	Y
056T	H	1	14.6	1268215.7	204145.8	47 32.9798	122 20.4357	Y
056T	H	2	14.8	1268218.9	204140.2	47 32.9789	122 20.4349	Y
056T	H	3	14.8	1268223.0	204138.9	47 32.9787	122 20.4339	Y
063	L	1	7.0	1269530.9	203294.9	47 32.8441	122 20.1122	?
063	L	2	7.0	1269532.0	203291.3	47 32.8435	122 20.1119	?
063	L	3	7.0	1269532.9	203293.7	47 32.8439	122 20.1117	?
066	L	1	9.4	1268667.6	202916.6	47 32.7791	122 20.3201	Y
066	L	2	9.4	1268671.3	202918.3	47 32.7794	122 20.3192	Y
066	L	3	9.4	1268669.2	202915.3	47 32.7789	122 20.3197	Y
068	H	1	9.4	1268716.4	202359.8	47 32.6877	122 20.3056	?
068	H	2	9.4	1268716.7	202355.6	47 32.6870	122 20.3055	?
068	H	3	9.2	1268716.3	202355.0	47 32.6869	122 20.3056	?
069T	M	1	3.8	1269286.9	202038.6	47 32.6367	122 20.1655	Y
069T	M	2	3.8	1269290.6	202035.5	47 32.6362	122 20.1646	Y
069T	M	3	4.0	1269290.6	202039.1	47 32.6368	122 20.1646	Y

SPI ID Number	Stratum	Replicate	Meter wheel depth (meter)	Sample Location DGPS Trimble NT300D NAD 1983, SPCS, WA North		Sample Location DGPS Trimble NT300D NAD 1983, SPCS, WA North		Triad?
				X	Y	Latitude	Longitude	
073	H	1	3.0	1270706.4	201650.9	47 32.5775	122 19.8189	
073	H	2	3.0	1270711.7	201650.2	47 32.5774	122 19.8176	
073	H	3	3.0	1270708.9	201653.3	47 32.5779	122 19.8183	
079	L	1	7.8	1269907.0	201238.4	47 32.5071	122 20.0111	
079	L	2	7.8	1269904.6	201244.6	47 32.5081	122 20.0117	
079	L	3	7.8	1269905.4	201243.3	47 32.5079	122 20.0115	
085	M	1	3.6	1270594.2	200138.5	47 32.3284	122 19.8390	
085	M	2	3.6	1270593.0	200140.9	47 32.3288	122 19.8393	
085	M	3	3.6	1270595.9	200142.1	47 32.3290	122 19.8386	
088T	H	1	5.4	1271727.2	199347.9	47 32.2020	122 19.5601	
088T	H	2	5.2	1271727.3	199352.1	47 32.2027	122 19.5601	
088T	H	3	5.2	1271728.8	199345.4	47 32.2016	122 19.5597	
095T	H	1	5.0	1272054.8	198659.9	47 32.0899	122 19.4773	?
095T	H	2	5.2	1272054.8	198659.3	47 32.0898	122 19.4773	?
095T	H	3	5.2	1272054.8	198659.9	47 32.0899	122 19.4773	?
096	L	1	6.6	1272753.3	198343.5	47 32.0401	122 19.3062	Y
096	L	2	6.8	1272760.0	198351.3	47 32.0414	122 19.3046	Y
096	L	3	6.6	1272758.9	198337.3	47 32.0391	122 19.3048	Y
B1b	M	1	18.8	1266305.1	210810.5	47 34.0697	122 20.9317	
B1b	M	2	18.8	1266304.0	210814.2	47 34.0703	122 20.9320	
B1b	M	3	18.8	1266306.4	210812.3	47 34.0700	122 20.9314	
B2b	M	1	13.0	1267397.9	207048.3	47 33.4545	122 20.6482	
B2b	M	2	13.0	1267396.7	207050.7	47 33.4549	122 20.6485	
B2b	M	3	13.0	1267395.6	207053.8	47 33.4554	122 20.6488	

SPI ID Number	Stratum	Replicate	Meter wheel depth (meter)	Sample Location DGPS Trimble NT300D NAD 1983, SPCS, WA North		Sample Location DGPS Trimble NT300D NAD 1983, SPCS, WA North		Triad?
				X	Y	Latitude	Longitude	
B3b	H	1	3.8	1268426.8	206621.3	47 33.3876	122 20.3962	
B3b	H	2	3.8	1268425.5	206617.7	47 33.3870	122 20.3965	
B3b	H	3	3.8	1268426.3	206615.8	47 33.3867	122 20.3963	
B4b	M	1	7.4	1268472.2	204607.1	47 33.0565	122 20.3756	?
B4b	M	2	7.2	1268473.9	204610.7	47 33.0571	122 20.3752	?
B4b	M	3	7.2	1268473.0	204607.7	47 33.0566	122 20.3754	?
B5b	M	1	4.8	1268659.3	204116.4	47 32.9764	122 20.3278	
B5b	M	2	4.8	1268659.3	204112.8	47 32.9758	122 20.3278	
B5b	M	3	4.8	1268659.3	204112.8	47 32.9758	122 20.3278	
B7b	M	1	6.6	1272092.4	198899.9	47 32.1295	122 19.4693	
B7b	M	2	6.6	1272091.1	198896.9	47 32.1290	122 19.4696	
B7b	M	3	6.6	1272094.9	198897.5	47 32.1291	122 19.4687	
DR111	H	1	7.6	1269983.4	201459.5	47 32.5437	122 19.9936	?
DR111	H	2	7.6	1269983.8	201460.1	47 32.5438	122 19.9935	?
DR111	H	3	7.6	1269985.5	201463.1	47 32.5443	122 19.9931	?
DR157T	H	1	4.4	1270328.2	200392.9	47 32.3694	122 19.9048	?
DR157T	H	2	4.2	1270326.9	200389.9	47 32.3689	122 19.9051	?
DR157T	H	3	4.4	1270326.1	200393.0	47 32.3694	122 19.9053	?
DR181	H	1	6.6	1273271.2	198870.4	47 32.1284	122 19.1829	Y
DR181	H	2	6.8	1273272.5	198872.2	47 32.1287	122 19.1826	Y
DR181	H	3	6.8	1273272.4	198869.2	47 32.1282	122 19.1826	Y
DUD8CT	H	1	11.4	1266732.8	208931.1	47 33.7620	122 20.8188	
DUD8CT	H	2	11.4	1266737.7	208929.8	47 33.7618	122 20.8176	
DUD8CT	H	3	11.4	1266736.8	208928.0	47 33.7615	122 20.8178	

SPI ID Number	Stratum	Replicate	Meter wheel depth (meter)	Sample Location DGPS Trimble NT300D NAD 1983, SPCS, WA North		Sample Location DGPS Trimble NT300D NAD 1983, SPCS, WA North		Triad?
				X	Y	Latitude	Longitude	
DUD8CTb	H	1	10.6	1266868.3	208918.1	47 33.7603	122 20.7858	
DUD8CTb	H	2	10.6	1266869.2	208919.9	47 33.7606	122 20.7856	
DUD8CTb	H	3	10.6	1266868.3	208918.1	47 33.7603	122 20.7858	
EIT-066	H	1	5.4	1273245.0	198753.0	47 32.1090	122 19.1887	Y
EIT-066	H	2	5.4	1273245.0	198751.8	47 32.1088	122 19.1887	Y
EIT-066	H	3	5.4	1273244.2	198750.0	47 32.1085	122 19.1889	Y
S4-1T	H	1	4.2	1273423.8	199098.6	47 32.1664	122 19.1469	Y
S4-1T	H	2	4.2	1273424.6	199096.7	47 32.1661	122 19.1467	Y
S4-1T	H	3	4.4	1273426.3	199097.3	47 32.1662	122 19.1463	Y
S4-2T	H	1	5.8	1273301.3	198934.3	47 32.1390	122 19.1759	Y
S4-2T	H	2	5.8	1273301.2	198933.7	47 32.1389	122 19.1759	Y
S4-2T	H	3	5.8	1273284.4	198933.4	47 32.1388	122 19.1800	Y

Table B-2. SPI-only sampling coordinates and associated data.

SPI ID Number	Replicate	Meter Wheel Depth (meter)	Sample Location DGPS Trimble NT300D NAD 1983, SPCS, WA North		Sample Location DGPS Trimble NT300D NAD 1983, SPCS, WA North	
			X	Y	X	Y
SP101	1	12.8	1265802.5	211431.5	47 34.1702	122 21.0568
SP101	2	12.8	1265796.9	211438.3	47 34.1713	122 21.0582
SP101	3	12.8	1265803.4	211433.3	47 34.1705	122 21.0566
SP102	1	10.2	1265805.9	211207.7	47 34.1334	122 21.0549
SP102	2	10.2	1265791.3	211216.5	47 34.1348	122 21.0585
SP102	3	10.2	1265789.2	211215.9	47 34.1347	122 21.0590
SP102	4	10.2	1265790.4	211214.7	47 34.1345	122 21.0587
SP103	1	14.0	1266524.0	210976.5	47 34.0977	122 20.8793
SP103	2	14.0	1266517.1	210979.1	47 34.0981	122 20.8810
SP103	3	14.0	1266519.4	210973.5	47 34.0972	122 20.8804
SP104	1	13.4	1266765.6	210787.5	47 34.0674	122 20.8197
SP104	2	13.4	1266764.5	210797.2	47 34.0690	122 20.8200
SP104	3	13.4	1266767.4	210794.7	47 34.0686	122 20.8193
SP105	1	18.2	1266511.6	210429.5	47 34.0077	122 20.8797
SP105	2	18.0	1266517.8	210429.4	47 34.0077	122 20.8782
SP105	3	18.0	1266511.2	210431.9	47 34.0081	122 20.8798
SP106	1	16.4	1266743.0	209951.9	47 33.9299	122 20.8212
SP106	2	16.4	1266749.5	209949.9	47 33.9296	122 20.8196
SP106	3	16.4	1266745.3	209947.5	47 33.9292	122 20.8206
SP107	1	15.6	1266494.4	209407.7	47 33.8396	122 20.8790
SP107	2	15.6	1266495.2	209407.0	47 33.8395	122 20.8788
SP107	3	15.6	1266490.7	209410.2	47 33.8400	122 20.8799
SP108	1	11.2	1266732.3	208888.6	47 33.7550	122 20.8187
SP108	2	11.2	1266728.7	208891.1	47 33.7554	122 20.8196
SP108	3	11.4	1266739.8	208890.2	47 33.7553	122 20.8169
SP109	1	11.6	1266734.0	209223.6	47 33.8101	122 20.8199
SP109	2	11.6	1266730.3	209223.6	47 33.8101	122 20.8208
SP109	3	11.6	1266732.3	209220.6	47 33.8096	122 20.8203
SP110	1	10.0	1266472.1	208569.6	47 33.7017	122 20.8804
SP110	2	10.0	1266471.0	208573.9	47 33.7024	122 20.8807
SP110	3	10.0	1266469.7	208572.1	47 33.7021	122 20.8810
SP111	1	9.8	1266967.3	208595.7	47 33.7076	122 20.7602
SP111	2	9.8	1266968.6	208595.7	47 33.7076	122 20.7599

SPI ID Number	Replicate	Meter Wheel Depth (meter)	Sample Location DGPS Trimble NT300D NAD 1983, SPCS, WA North		Sample Location DGPS Trimble NT300D NAD 1983, SPCS, WA North	
			X	Y	X	Y
SP111	3	9.8	1266971.5	208598.1	47 33.7080	122 20.7592
SP112	1	8.4	1266960.7	208046.8	47 33.6173	122 20.7592
SP112	2	8.6	1266962.1	208054.7	47 33.6186	122 20.7589
SP112	3	8.6	1266959.5	208051.7	47 33.6181	122 20.7595
SP113	1	6.4	1266955.3	207795.8	47 33.5760	122 20.7593
SP113	2	6.6	1266952.3	207790.9	47 33.5752	122 20.7600
SP113	3	6.6	1266952.9	207795.8	47 33.5760	122 20.7599
SP114	1	8.2	1267920.7	206756.5	47 33.4082	122 20.5198
SP114	2	8.0	1267912.8	206752.4	47 33.4075	122 20.5217
SP114	3	8.0	1267914.4	206751.1	47 33.4073	122 20.5213
SP115	1	8.0	1267928.9	206606.7	47 33.3836	122 20.5171
SP115	2	8.0	1267928.9	206608.0	47 33.3838	122 20.5171
SP115	3	8.0	1267929.6	206602.5	47 33.3829	122 20.5169
SP116	1	10.0	1267671.8	206613.6	47 33.3839	122 20.5796
SP116	2	10.0	1267675.1	206614.8	47 33.3841	122 20.5788
SP116	3	9.8	1267671.4	206616.6	47 33.3844	122 20.5797
SP117	1	12.0	1267690.8	205841.0	47 33.2569	122 20.5713
SP117	2	12.0	1267693.7	205841.5	47 33.2570	122 20.5706
SP117	3	12.0	1267693.2	205839.7	47 33.2567	122 20.5707
SP118	1	11.0	1267701.2	205640.1	47 33.2239	122 20.5678
SP118	2	11.0	1267702.4	205638.9	47 33.2237	122 20.5675
SP118	3	11.0	1267700.4	205638.3	47 33.2236	122 20.5680
SP119	1	11.8	1268136.5	205292.9	47 33.1682	122 20.4604
SP119	2	11.6	1268137.8	205295.3	47 33.1686	122 20.4601
SP119	3	11.6	1268136.5	205292.3	47 33.1681	122 20.4604
SP120	1	9.0	1268375.6	204740.4	47 33.0781	122 20.3997
SP120	2	9.0	1268377.2	204740.3	47 33.0781	122 20.3993
SP120	3	9.0	1268376.3	204736.7	47 33.0775	122 20.3995
SP121	1	15.0	1268358.6	203937.5	47 32.9460	122 20.4000
SP121	2	15.0	1268357.7	203934.4	47 32.9455	122 20.4002
SP121	3	15.0	1268356.5	203936.3	47 32.9458	122 20.4005
SP122	1	15.0	1268431.3	203656.9	47 32.9001	122 20.3810
SP122	2	15.0	1268430.1	203658.2	47 32.9003	122 20.3813
SP122	3	15.0	1268432.1	203655.1	47 32.8998	122 20.3808
SP123	1	14.4	1268597.1	203273.0	47 32.8375	122 20.3389

SPI ID Number	Replicate	Meter Wheel Depth (meter)	Sample Location DGPS Trimble NT300D NAD 1983, SPCS, WA North		Sample Location DGPS Trimble NT300D NAD 1983, SPCS, WA North	
			X	Y	X	Y
SP123	1	13.8	1268591.5	203277.4	47 32.8382	122 20.3403
SP123	2	14.4	1268603.3	203274.1	47 32.8377	122 20.3374
SP123	2	13.8	1268591.9	203276.2	47 32.8380	122 20.3402
SP123	3	14.4	1268594.3	203273.7	47 32.8376	122 20.3396
SP123	3	13.8	1268591.1	203277.4	47 32.8382	122 20.3404
SP123	4	14.4	1268593.8	203272.5	47 32.8374	122 20.3397
SP124	1	13.0	1268827.7	202619.1	47 32.7307	122 20.2798
SP124	2	13.0	1268825.9	202614.3	47 32.7299	122 20.2802
SP124	3	13.0	1268826.7	202612.5	47 32.7296	122 20.2800
SP125	1	9.0	1268788.5	202236.8	47 32.6677	122 20.2875
SP125	2	9.0	1268788.9	202236.8	47 32.6677	122 20.2874
SP125	3	9.0	1268787.7	202238.7	47 32.6680	122 20.2877
SP126	1	4.0	1269549.8	201691.1	47 32.5804	122 20.1000
SP126	2	4.0	1269551.0	201691.1	47 32.5804	122 20.0997
SP126	3	4.0	1269550.7	201694.1	47 32.5809	122 20.0998
SP127	1	4.2	1269887.4	201438.3	47 32.5399	122 20.0168
SP127	2	4.2	1269887.4	201437.7	47 32.5398	122 20.0168
SP127	3	4.2	1269890.7	201439.4	47 32.5401	122 20.0160
SP128	1	6.2	1270031.9	200950.8	47 32.4602	122 19.9794
SP128	2	6.2	1270030.7	200952.1	47 32.4604	122 19.9797
SP128	3	6.0	1270031.4	200948.4	47 32.4598	122 19.9795
SP129	1	6.8	1271000.8	199981.6	47 32.3039	122 19.7395
SP129	2	6.8	1271001.2	199982.2	47 32.3040	122 19.7394
SP129	3	6.8	1271000.0	199984.0	47 32.3043	122 19.7397
SP130	1	6.6	1271243.2	199678.9	47 32.2549	122 19.6792
SP130	2	6.6	1271241.7	199685.0	47 32.2559	122 19.6796
SP130	3	6.6	1271240.0	199682.6	47 32.2555	122 19.6800
SP131	1	7.0	1272210.5	198682.4	47 32.0941	122 19.4396
SP131	2	7.0	1272213.4	198684.2	47 32.0944	122 19.4389
SP131	3	7.0	1272209.3	198683.6	47 32.0943	122 19.4399
SP132	1	3.6	1272449.8	198345.8	47 32.0395	122 19.3799
SP132	2	4.0	1272455.2	198347.5	47 32.0398	122 19.3786
SP132	3	4.0	1272454.6	198356.6	47 32.0413	122 19.3788
SP133	1	6.8	1272959.3	198649.7	47 32.0911	122 19.2576
SP133	2	6.8	1272965.6	198653.8	47 32.0918	122 19.2561

SPI ID Number	Replicate	Meter Wheel Depth (meter)	Sample Location DGPS Trimble NT300D NAD 1983, SPCS, WA North		Sample Location DGPS Trimble NT300D NAD 1983, SPCS, WA North	
			X	Y	X	Y
SP133	3	6.8	1272966.0	198652.6	47 32.0916	122 19.2560
SP134	1	4.6	1273425.3	197747.4	47 31.9442	122 19.1402
SP134	2	4.6	1273432.3	197744.3	47 31.9437	122 19.1385
SP134	3	5.0	1273429.3	197737.6	47 31.9426	122 19.1392
SP135	1	7.6	1274755.0	196525.8	47 31.7475	122 18.8116
SP135	2	7.6	1274758.4	196531.8	47 31.7485	122 18.8108
SP135	3	7.6	1274757.1	196526.3	47 31.7476	122 18.8111
SP137	1	13.2	1266256.8	211072.3	47 34.1126	122 20.9447
SP137	2	13.2	1266263.3	211071.6	47 34.1125	122 20.9431
SP137	3	13.2	1266263.7	211066.7	47 34.1117	122 20.9430
SP137B	1	9.6	1267189.8	207351.5	47 33.5037	122 20.7002
SP137B	2	9.6	1267193.1	207349.0	47 33.5033	122 20.6994
SP137B	3	9.8	1267195.6	207350.8	47 33.5036	122 20.6988

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Appendix C.
Field Collection Forms

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FIELD LOG – AUGUST 2006
WASHINGTON STATE DEPT. OF ECOLOGY
SPI FEASIBILITY STUDY – LOWER DUWAMISH WATERWAY SITE

SAMPLE No.: ________________ MEL Lab ID: ________________

CREW:

☐Tom Gries ☐Dale Norton ☐Kathy Welch ☐ ☐ ☐

WEATHER:

☐Clear ☐Cloudy ☐Fog ☐Overcast ☐Continuous layer of clouds

☐Rain ☐Windy ☐Thunderstorm

SEA STATE:

☐Calm ☐Choppy ☐Rough ☐Strong Current

GRAB USED:

☐Weighted ☐Unweighted

LOCATION:____

TARGET DGPS LAT: ________________ **LONG:** ________________________

☐TARGET MOVED 100m

SAMPLING DATE: ______/______/2006

TIME OF 1ST GRAB: _______AM/PM **LAST GRAB:** ______ AM/PM

STRATUM: ☐Basin ☐Harbor ☐Passage ☐Rural ☐Urban

STATION DESCRIPTION:

____

STATION STATUS:

☐Target and Sampled ☐NN-Not Needed ☐NS-Not Sampled ☐NT-Not Targeted

☐OS-Other Sample ☐PB-Physically Inaccessible ☐ALT. for Sample No.: ______________

STATION FAIL REASON:

☐Abandoned ☐Washed ☐Poor Closure ☐Disturbed Surface

☐Shallow penetration ☐Rocky bottom ☐Algal Mats

GRAB NUMBER 1

GRAB ACCEPTABILITY: No. Taken: _______ No. Rejected: _______

Meter Wheel Depth: __________ m Surface Salinity: __________ ppt Temp: _________ ºC

Penetration Depth: ________cm RPD: ________cm ☐Sheen Observed

SEDIMENT TYPE: ☐Cobble ☐Gravel ☐Sand ☐Silt-Clay

MATERIAL IN/ON SEDIMENT:

☐Wood Fragments ☐Shell Fragments ☐Plant Fragments ☐Macroalgae

SEDIMENT COLOR: ☐Olive ☐Gray ☐Brown ☐Black **OVER**

☐Olive ☐Gray ☐Brown ☐Black

SEDIMENT ODOR: ☐H_2S ☐Petroleum ☐Other __________

☐Slight ☐Moderate ☐Strong ☐None

PARAMETERS SAMPLED: ☐ Grain Size ☐ TOC ☐ Other conventionals

☐ Chemistry ☐ Bioassay ☐ Infauna ☐ Other Tests: ______________________________

COMMENTS:____

____

REASON FOR REJECT: ☐Abandoned ☐Washed ☐Poor Closure ☐Disturbed Surface

☐Shallow penetration ☐Rocky bottom ☐Algal Mats

SUBSEQUENT GRAB INFORMATION (if different from first) (GRAB NO. ____)

GRAB ACCEPTABILITY: No. Taken: _______ No. Rejected: _______

Meter Wheel Depth: __________ m Surface Salinity: __________ ppt Temp: _________ºC

Penetration Depth: ________cm RPD: ________cm ☐Sheen Observed

SEDIMENT TYPE: ☐Cobble ☐Gravel ☐Sand ☐Silt-Clay

MATERIAL IN/ON SEDIMENT:

☐Wood Fragments ☐Shell Fragments ☐Plant Fragments ☐Macroalgae

SEDIMENT COLOR: ☐Olive ☐Gray ☐Brown ☐Black **OVER**

☐Olive ☐Gray ☐Brown ☐Black

SEDIMENT ODOR: ☐H_2S ☐Petroleum ☐Other __________

☐Slight ☐Moderate ☐Strong ☐None

PARAMETERS SAMPLED: ☐ Grain Size ☐ TOC ☐ Other conventionals

☐ Chemistry ☐ Bioassay ☐ Infauna ☐ Other Tests: ______________________________

COMMENTS:____

____

REASON FOR REJECT: ☐Abandoned ☐Washed ☐Poor Closure ☐Disturbed Surface

☐Shallow penetration ☐Rocky bottom ☐Algal Mats

FAUNA OBSERVED :

____

____

____

COMMENTS:

____

____

____

____

RECORDED BY: ____

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Appendix D.
Health and Safety Plan

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Health and Safety Plan

The following is an abbreviated Health and Safety Plan for Ecology's SPI Feasibility Study. It is a slightly modified version of the one found in the Environmental Assessment Program Safety Manual, with which all participants in this study must be familiar.

Name of Ecology staff ___*Various*___

Training requirements: *First Aid and CPR, familiarity with the EAP Safety Plan, (Boating Safety recommended)* ___

Medical monitoring requirements _*None*___

Date __August 8-11___ Arrival time __*9:00 - 11:00 a.m.*___

Site name and location: The Lower Duwamish Waterway (sediment cleanup site), located south of Seattle, starting immediately south of Harbor Island and ending approximately 3.5 river miles to the south.

Nearest city ___SEATTLE___ Nearest hospital __*Harborview*___

Emergency numbers Statewide 911 Hospital ___ Ambulance ___

Is site currently active? Yes __*X*__ No ____ Will the buddy system be used? Yes __*X*__ No ___

Site description: *Superfund and MTCA cleanup site, but underwater, risk of exposure to contaminants from handling sediment samples is low. Physical hazards associated with handling sampling gear low to moderate.*___

Scope/objective of work: _*To collect 30 surface sediment samples from the LDW, from approximately River Mile 0.0 to 2.2*___

Known contaminants on site: *PCBs, phthalates, trace metals and others (formalin preservative)*

Routes of chemical exposure: Inhalation ___*X*___ Dermal ___*X*___ No exposure ___

Overall risk of chemical exposure: Serious _____ Moderate _____ Low __*X*__ Unknown _____

Physical hazards: Confined space ___ Noise ___ Heat/cold stress __*Yes*___

Describe any area on site that could function as a confined space: *Only vessel engine room.*

Was air monitoring conducted? Yes ______ No ___*X*___

Personal protection level required: A _____ B _____ C _____ D __*X*__

Personal protective equipment required: Boots, hard hat, foul weather gear, gloves, PFD______

Other (specify): ____

Overall risk of physical hazards: Serious ______ Moderate ______ Low ___*X*___ Unknown _____

Expected parameters/contaminants to be sampled: *Sediment conventionals, trace metals and various organic contaminants, e.g., lower level PCBs, as well as benthic organisms.*

Sampling matrix: Air ______ Surface water ______ Groundwater ______ Soil ______
Sediment ___*X*___ Containers ______ Other ______