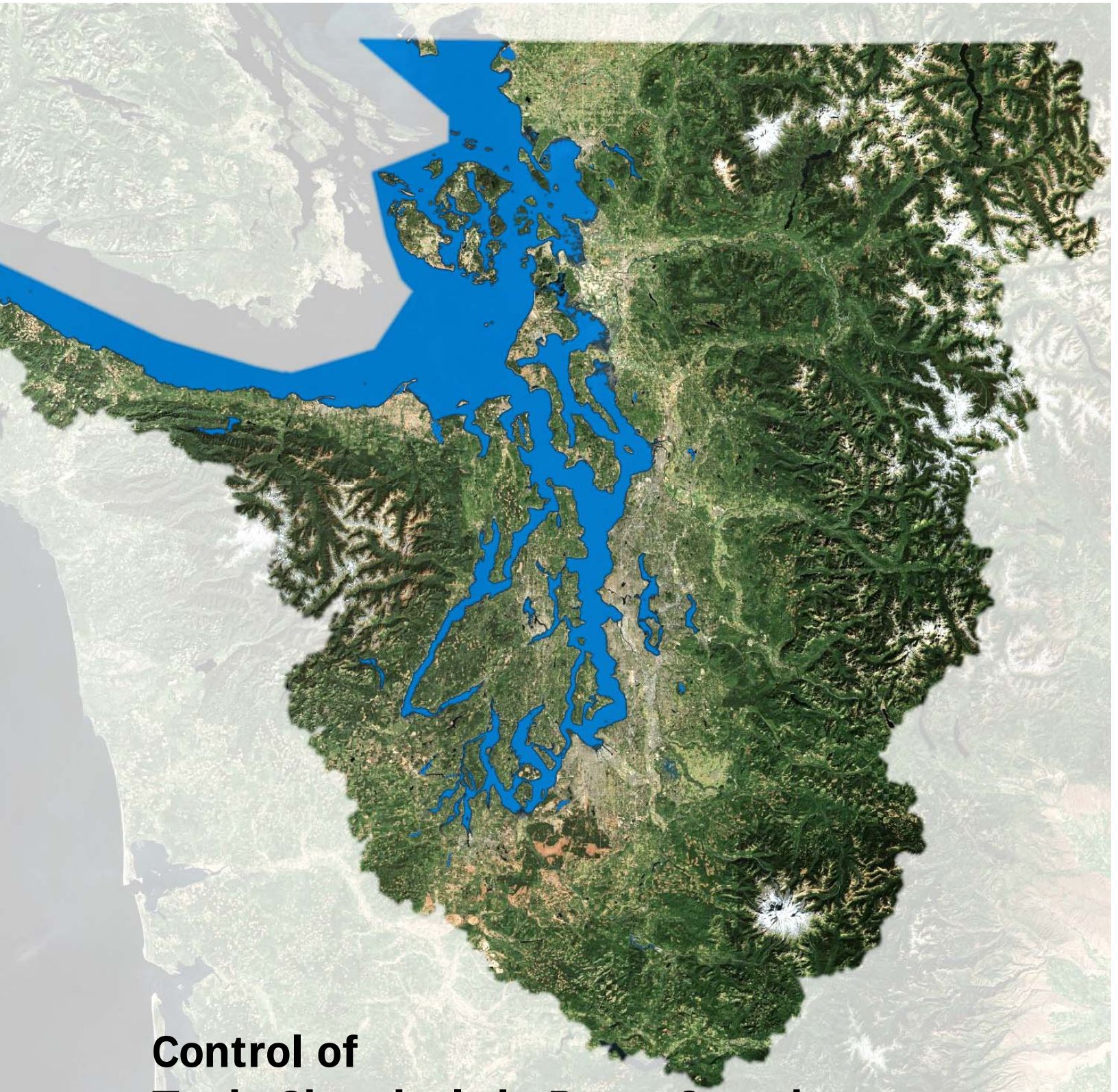

Control of Toxic Chemicals in Puget Sound

Quality Assurance Project Plan for Phase 3: Characterization of Toxic Chemicals in Puget Sound and Selected Major Tributaries

WASHINGTON STATE DEPARTMENT OF ECOLOGY

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Quality Assurance Project Plan

Control of Toxic Chemicals in Puget Sound Phase 3: Characterization of Toxic Chemicals in Puget Sound and Selected Major Tributaries

August 2009

Approved by:

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Signatures are not available on the Internet version.
TSU = Toxics Studies Unit.
EAP = Environmental Assessment Program.
EIM = Environmental Information Management system.

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Abstract

The Puget Sound Partnership identified the control and reduction of toxic chemicals entering Puget Sound as vital to the ecosystem's recovery and maintenance. In a multi-phase effort to develop source-control strategies for toxic contaminants, the Puget Sound Toxics Loading Analysis (PSTLA) will quantify concentrations within, and loadings to, Puget Sound, ultimately guiding management decisions.

Existing data were used to estimate chemical loadings during Phase 1 of the PSTLA. Phase 2 efforts included development of the Puget Sound Toxics Box Model to simulate chemical fate, transport, and bioaccumulation. This numerical model gives managers the ability to evaluate impacts on water, sediment, and biota under different control strategies. Initial modeling exercises indicated that additional data on toxic chemical concentrations in the marine water column, oceanic boundary waters, and major rivers discharging to Puget Sound were needed to reduce uncertainty in the model outputs.

For the present study, the Washington State Department of Ecology (Ecology) will collect seasonal water samples (June, September, and December of 2009) at three oceanic boundary sites, in four Puget Sound basins, and at the mouths of the five largest rivers discharging to the Sound. Water samples will be collected above and below the halocline at marine stations, and above tidal influence at river sampling sites. Suspended particulates will be collected during one event from the four Puget Sound basin stations and the five major rivers.

Target analyses will include metals, semivolatile organics, chlorinated pesticides, polynuclear aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and polybrominated diphenyl ethers (PBDEs). This information will fill identified data gaps, providing concentration and loading estimates for model input and calibration.

Each technical study conducted by Ecology must have an approved Quality Assurance Project Plan. The plan must describe the objectives of the study and the procedures to be followed to achieve those objectives. After completion of the study, a final report describing the study results will be posted to the Internet.

Background

Puget Sound Toxics Loading Analysis

The State of Washington enacted legislation in 2007 to advance efforts to restore and protect the health of the Puget Sound ecosystem by 2020. Charged with coordinating and overseeing these efforts, the Puget Sound Partnership (Partnership) identified the control and reduction of toxic chemical releases to the Sound as a priority action necessary to ensure recovery of the ecosystem.

To this end, the Washington Department of Ecology (Ecology) is working in collaboration with the Partnership, the U.S. Environmental Protection Agency (EPA), and other local, state, and federal agencies to study toxic chemical loadings to Puget Sound. This multi-year effort, the Puget Sound Toxics Loading Analysis (PSTLA), will quantify the sources of toxic contaminants that enter Puget Sound and improve understanding of how these chemicals move within the ecosystem. The collected information will guide management decisions about how to direct resources to effectively resolve toxic contamination issues.

Initial Phases

In Phase 1 of this effort, existing data were used to obtain quantitative estimates of loadings released to Puget Sound via surface runoff, atmospheric deposition, permitted wastewater discharges, combined sewer overflows, and direct spills (Hart Crowser et al., 2007).

Land use classifications were refined and roadway loadings were incorporated during Phase 2, yielding improved toxic chemical loading estimates for the entire Puget Sound Basin (EnviroVision et al., 2008).

Phase 2 also saw the expansion of numerical modeling efforts to provide insights about the relative importance of the various loading pathways. The Puget Sound Toxics Box Model is composed of three parts (Pelletier and Mohamedali, 2009):

1. Water circulation and transport box model.
2. Contaminant fate and transport mass balance model.
3. Food web transfer bioaccumulation model.

Seeded with the Phase 2 loading estimates, the Puget Sound Toxics Box Model allowed managers to investigate the response of contaminant concentrations in the water, sediment, and biota of Puget Sound under various source-control scenarios. Initial modeling exercises were performed for polychlorinated biphenyls (PCBs) due to the relative abundance of existing PCB data. Polybrominated diphenyl ethers (PBDEs) will be evaluated with the model during Phase 3.

Data Gaps and Recommended Actions

A review of readily available data collected since 1995 on selected toxic chemicals in Puget Sound and the Straits of Juan de Fuca and Georgia (Serdar, 2008) identified significant gaps and limitations in the existing data. With very few exceptions, the available data were inadequate for providing representative concentrations for model input and analyses.

Initial simulations run by the Puget Sound Toxics Box Model agreed, indicating that further data collection would improve the accuracy of model predictions. To address these data gaps, Pelletier and Mohamedali (2009) recommended the following targeted efforts:

- **Water column toxics.** Data on the concentrations of toxic chemicals in the water column throughout Puget Sound are very limited. While typical ambient concentrations are extremely low, the uptake of toxics by biota is sensitive to both the distribution and partitioning of toxics in this reservoir. Toxic chemical concentrations in the major basins of Puget Sound should be measured to facilitate improved calibration of the model.

- **Marine boundary.** Existing data from the marine waters bordering Puget Sound are scarce. The loading from the marine boundary is estimated to be comparable in magnitude to the loadings from each of the major land use types in the Puget Sound watershed, and therefore has the potential to significantly influence the concentrations of toxics in the Sound. Additional data should be collected in the Strait of Juan de Fuca and Haro Strait to improve the accuracy of the fluxes modeled through this boundary.

- **External loads.** While Phases 1 and 2 provided estimates of toxic chemical loadings to Puget Sound, surface runoff loading estimates for various land uses should be improved to reduce uncertainties in the model.

These data are needed to improve calibration of the Puget Sound Toxics Box Model and to reduce uncertainty in model predictions for the examination of toxic chemical fate and transport in Puget Sound.

Project Description

The present study is part of Phase 3 of the collaborative work on toxic chemicals in Puget Sound. The study is motivated by significant data gaps identified during the development of the Puget Sound Toxics Box Model. The study will provide an extensive set of data on toxic chemical concentrations in the water column of the major basins in Puget Sound, in the marine boundary waters of the Straits of Juan de Fuca and Haro Strait, and in the freshwater flows of five major rivers that discharge to the Sound.

Objectives

Objectives of the study are to:

- Quantify concentrations of target toxic chemicals and other water quality parameters above and below the halocline in four Puget Sound basins (Main, Whidbey, South Sound, and Hood Canal South) and in marine boundary waters (Strait of Juan de Fuca and Haro Strait).
- Measure freshwater loadings of target toxic chemicals and other water quality parameters in the five largest tributaries discharging to Puget Sound (Nooksack, Skagit, Stillaguamish, Snohomish, and Puyallup Rivers).
- Determine concentrations of toxic chemicals associated with suspended particulates in marine water and freshwater samples.
- Assess seasonal variability in concentrations and loadings of target toxic chemicals and other water quality parameters.

Parameters

Samples from the marine water column will be analyzed for an extensive suite of parameters, many of which have not historically been monitored in Puget Sound. These data will facilitate extension of the modeling framework to evaluate the fate, transport, and bioaccumulation of chemicals of concern beyond those presently used in model simulations. Target analytes will include PCB and PBDE congeners, chlorinated pesticides, polynuclear aromatic hydrocarbons (PAHs), semivolatile organics, and total and dissolved metals. Analyses will also measure total and dissolved organic carbon (TOC/DOC) and total suspended solids (TSS) to better understand partitioning and fate of the target analytes.

Freshwater (river) samples will be analyzed for the identical suite of analytes, but will incorporate additional analyses of several conventional water quality parameters. These will include water hardness and nutrients (ammonia nitrogen, nitrate and nitrite nitrogen, total persulfate nitrogen, orthophosphate phosphorus, and total phosphorus). Total petroleum hydrocarbons (TPH-gas and TPH-diesel) and hexane-extractable materials (HEM, or “oil and grease”) will also be measured to clarify and improve external loading estimates from surface runoff for oil and petroleum products.

Particulate samples from both marine waters and freshwaters will be analyzed for TOC, metals, semivolatile organics, chlorinated pesticides, and PCB and PBDE congeners.

Sampling Sites and Schedules

Marine water sampling locations will be established at the approximate centroid of each of the four Puget Sound basins of interest to represent ambient mean basin conditions. Water samples will be collected from above and below the halocline at each location. Sampling will not target or address acute localized impacts from contaminated nearshore environments. Boundary conditions for the model will be determined from the average of concentrations measured at two sites in the Strait of Juan de Fuca and one site in the Haro Strait.

Major rivers will be sampled at the first bridge crossing above marine saline influence with a companion gage station operated by the U.S. Geological Survey (USGS) or Ecology.

Water sampling at both marine and freshwater sites will be conducted on three occasions to estimate seasonal concentrations of the target parameters. Sampling will occur in June (after spring flushing), September (after first seasonal flush), and December (wet season), providing loading data for a wide range of discharge.

Suspended particulate samples will be collected from the surface and bottom waters of the four Puget Sound basins, and from the discharges of the five selected rivers. Marine particulate samples will be collected once, during the period of October to December 2009. Collection of particulate samples from the five river sites will also occur once, coinciding with the marine particulate collection.

Outcomes

The information generated by the present study will result in direct contributions to the creation and implementation of pollution-reduction strategies for toxic chemicals entering Puget Sound. Products of this study will include the following:

- **Water column toxics.** Marine water column samples from four Puget Sound basins will (1) yield baseline measurements of a large suite of toxic chemicals, and (2) provide a better understanding of present concentrations and seasonal variation. These data will be used as input and for calibration of the Puget Sound Toxics Box Model.
- **Marine boundary fluxes.** Measurements of toxic chemical concentrations in the Strait of Juan de Fuca and Haro Strait will facilitate estimation of the import and export of contaminants between Puget Sound and the ocean boundary waters. Incoming loadings from the boundary waters to Puget Sound will be estimated using bottom layer concentrations of the target contaminants and flow information generated from the circulation component of the Puget Sound Toxics Box Model. Outgoing loads will be estimated in a similar way using surface layer concentrations and flow information.

- **External loading estimates.** Water samples from the major rivers discharging to Puget Sound will support improved estimates of toxic chemical loadings to the Sound from surface runoff. Study data on contaminant concentrations and flow from the freshwater discharges will be provided electronically to Herrera Environmental Consultants for their use in the development of overall contaminant loading estimates for Puget Sound.
- **Partitioning.** Determinations of dissolved- and particulate-phase concentrations of toxic chemicals in Puget Sound waters, oceanic boundary waters, and major freshwater inputs will improve the accuracy of model predictions of chemical transport and fate.
- **Additional chemicals of concern.** Concentration measurements for an extensive suite of contaminants will allow extension of the Puget Sound Toxics Box Model beyond the initial PCB simulations to additional contaminants of concern. Preliminary exercises will be run to simulate the transport and fate of PCBs and PBDEs in Puget Sound and to estimate the net flux at the oceanic boundary.

Organization and Schedule

The following people are involved in this project. All are employees of the Washington State Department of Ecology.

Table 1. Organization of Project Staff and Responsibilities.

Staff (all are EAP except client)	Title	Responsibilities
James M. Maroncelli Water Quality Program Phone: (360) 407-6588	Client	Clarifies scope of the project, provides internal review of the QAPP, and approves the final QAPP.
Randy Coots Toxics Study Unit, SCS Phone: (360) 407-6690	Project Manager	Writes the QAPP, conducts QA review of data, and analyzes and interprets data.
Tom Gries Toxics Study Unit, SCS Phone: (360) 407-6327	Principal Investigator	Analyzes and interprets data. Writes the draft report and final report.
David Osterberg Toxics Study Unit, SCS Phone: (360) 407-6446	Field Lead	Oversees field sampling and transportation of samples to the laboratory, records field information, and enters data into EIM.
Dale Norton Toxics Study Unit, SCS Phone: (360) 407-6765	Unit Supervisor for Project Manager	Provides internal review of the QAPP, approves the budget, and approves the final QAPP.
Will Kendra SCS Phone: (360) 407-6698	Section Manager for Project Manager	Reviews the project scope and budget, tracks progress, reviews the draft QAPP, and approves the final QAPP.
Robert F. Cusimano Western Operations Section Phone: (360) 407-6688	Section Manager for Study Area	Reviews the project scope and budget, tracks progress, reviews the draft QAPP, and approves the final QAPP.
Stuart Magoon Manchester Environmental Laboratory Phone: (360) 871-8801	Director	Approves the final QAPP.
William R. Kammin Phone: (360) 407-6964	Ecology Quality Assurance Officer	Reviews the draft QAPP and approves the final QAPP.

EAP = Environmental Assessment Program.
SCS = Statewide Coordination Section.
QAPP = Quality Assurance Project Plan.
QA = Quality Assurance.
EIM = Environmental Information Management system.

Table 2. Proposed Schedule for Completing Field and Laboratory Work, Data Entry into EIM, and Reports.

Field and laboratory work	Due date	Lead staff
Field work completed	December 2009	David Osterberg
Laboratory analyses completed	February 2010	
Environmental Information System (EIM) database		
EIM user study ID	RCOO0010	
Product	Due date	Lead staff
EIM data loaded	July 2010	David Osterberg
EIM QA	August 2010	Dale Norton
EIM complete	September 2010	David Osterberg
Final report		
Author lead and support staff	Tom Gries	David Osterberg
Schedule		
Draft due to supervisor	May 2010	
Draft due to client/peer reviewer	June 2010	
Draft due to external reviewer(s)	Not applicable	
Final (all reviews done) due to publications coordinator (Joan)	August 2010	
Final report due on web	September 2010	

Quality Objectives

Manchester Environmental Laboratory (MEL) and their contractors are expected to meet quality control requirements of methods selected for the project. Quality control (QC) procedures used during field sampling and laboratory analyses will provide data for determining the accuracy of the monitoring results. Tables 3 and 4 show the measurement quality objectives (MQO) for the methods selected for water and particulate sample analysis.

Analytical precision and bias will be evaluated and controlled by use of laboratory check standards, duplicates, spikes, and blanks analyzed along with study samples.

Precision is a measure of the ability to consistently reproduce results. Precision will be evaluated by analysis of check standards, duplicates/replicates, spikes, and blanks. Results of duplicate (split) analyses will be used to estimate laboratory precision. Overall precision of the entire sampling and analysis process is estimated by analysis of field replicates. Field precision is the difference between laboratory precision estimates and overall precision estimates.

Bias is the systematic error due to contamination, sample preparation, calibration, or the analytical process. Most sources of bias are minimized by adherence to established protocols for the collection, preservation, transportation, storage, and analysis of samples. Check standards (also known as laboratory control standards) contain a known amount of an analyte and indicate bias due to sample preparation or calibration.

Blanks are particularly important quality control samples for low level analyses where results are expected near detection limits. Method blanks will be analyzed along with all samples to measure any response in the analytical system for target analytes. Method blanks have an expected theoretical concentration of zero. Field blanks are used to detect bias from contamination. This may include contamination from containers, sample equipment, environmental surroundings, preservatives, transportation or storage, other samples, or laboratory analysis.

Surrogates will be added to all organic samples prior to extraction. Surrogates have similar characteristics to target compounds. The recovery of surrogate spikes is used to estimate the recovery of target compounds in samples.

The lowest concentrations of interest in Tables 3 and 4 are from reporting limits MEL and their contractors have reported for water and sediment analyses from previous studies.

Table 3. Measurement Quality Objectives for Water Samples.

Parameter	Lab Control Samples (% Recovery)	Duplicate Samples (RPD[5])	Matrix Spike (% Recovery)	Matrix Spike Dups (RPD)	Surrogate Recoveries (% Recovery)	Lowest Concentration of Interest
TSS	80 - 120%	≤20%	NA[6]	NA	NA	1 mg/L
TOC	80 - 120%	≤20%	NA	NA	NA	0.10%
DOC	80 - 120%	≤20%	NA	NA	NA	0.10%
Hardness	80 - 120%	≤20%	75 - 125%	20%	NA	1 mg/L
PO_4^{-3}	80 - 120%	≤20%	80 - 120%	≤20%	NA	3 *u*g/L
TP	80 - 120%	≤20%	80 - 120%	≤20%	NA	5 *u*g/L
$NO_2 + NO_3$	80 - 120%	≤20%	80 - 120%	≤20%	NA	10 *u*g/L
NH_3	80 - 120%	≤20%	80 - 120%	≤20%	NA	10 *ug*/L
TPN	80 - 120%	≤20%	80 - 120%	≤20%	NA	25 *u*g/L
Metals – Marine Water						
Arsenic	85 - 115%[1]	≤20%	80 - 120%	20%	NA	0.05 *u*g/L
Cadmium	85 - 115%[1]	≤20%	75 - 125%	20%	NA	0.01 *u*g/L
Copper	75 - 125%[1]	≤20%	70 - 130%	20%	NA	0.05 *u*g/L
Lead	80 - 120%[1]	≤20%	75 - 125%	20%	NA	0.05 *u*g/L
Zinc	75 - 125%[1]	≤20%	65 - 135%	20%	NA	0.25 *u*g/L
Metals – Freshwater						
Arsenic	75 - 125%[1]	≤20%	65 - 135%	20%	NA	0.1 *u*g/L
Cadmium	75 - 125%[1]	≤20%	65 - 135%	20%	NA	0.1 *u*g/L
Copper	75 - 125%[1]	≤20%	65 - 135%	20%	NA	0.4 *u*g/L
Lead	75 - 125%[1]	≤20%	65 - 135%	20%	NA	0.1 *u*g/L
Zinc	65 - 135%[1]	≤20%	65 - 135%	20%	NA	0.5 *u*g/L
TPH-diesel	50 - 150%	≤50%	25 - 150%	50%	50 - 150%	0.15 mg/L
TPH-gas	50 - 150%	≤50%	25 - 150%	50%	50 - 150%	0.14 mg/L
HEM (“oil and grease”)	50 - 150%	≤50%	25 - 150%	50%	50 - 150%	5 mg/L
Semivolatiles (BNA)	40 - 150%	≤50%	40 - 150%	40%	10 - 150%[2]	1 - 5 *u*g/L
PAHs	40 - 150%	≤50%	40 - 150%	40%	10 - 150%[2]	0.01 *u*g/L
Chlorinated Pesticides	50 - 150%	≤50%	50 - 150%	40%	30 - 150%[2]	0.07 ng/L
PCB Congeners	50 - 150%	≤50%	NA	NA	25 - 150%[3]	10 pg/L
PBDE Congeners	50 - 150%	≤50%	50 - 150%	40%	25 - 150%[3,4]	10 pg/L

[1] = Blank spike recovery.
[2] = Surrogate recoveries are compound specific.
[3] = Labeled congeners.
[4] = BDE 209 recovery between 20 – 200%.
[5] = Relative percent difference.
[6] = Not applicable.

Table 4. Measurement Quality Objectives for Particulate Samples

Parameter	Lab Control Samples (% Recovery)	Duplicate Samples (RPD[2])	Matrix Spike (% Recovery)	Matrix Spike Dupes (RPD)	Surrogate Recoveries (% Recovery)	Lowest Concentration of Interest
TOC	75 - 125%	≤20%	NA[3]	NA	NA	0.1 *u*g/Kg
Metals[1]	80 - 120%	≤20%	70 - 130%	30%	NA	0.1-5 mg/Kg
Semivolatiles (BNA)	40 - 150%	≤50%	40 - 150%	40%	10 - 150%	1 *u*g/Kg
PAHs	40 - 150%	≤50%	40 - 150%	40%	10 - 150%	1 *u*g/Kg
Chlorinated Pesticides	50 - 150%	≤50%	50 - 150%	40%	50 - 150%	1 *u*g/Kg
PCB Congeners	25 - 150%	≤50%	NA	NA	25 - 150%[4]	0.05 *u*g/Kg
PBDE Congeners	NA	≤50%	NA	NA	25 - 150%[4-5]	0.05 *u*g/Kg

1 = Total recoverable for particulate metals.
2 = Relative percent difference.
3 = Not applicable.
4 = Labeled compounds.
5 = BDE 209 recovery between 20 – 200%.

Sampling Design

This study will generate baseline data for a suite of organic chemicals, metals, and conventionals in the marine and freshwaters of Puget Sound. The data are needed to (1) provide representative concentrations of chemicals of concern in the major basins of Puget Sound, (2) estimate the flux of toxic chemicals at the ocean boundary of Puget Sound, and (3) improve loading estimates from surface runoff to the Sound. An overview of sample collection for the study can be found in Table 5.

Table 5. Summary of Sample Collection at Marine and Freshwater Sites.

Marine Site	Water[1]		Particulates[2]	
	Below Halocline	Above Halocline	Below Halocline	Above Halocline
Hood Canal South	3	3	1	1
Puget Sound Main Basin	3	3	1	1
Whidbey Basin	3	3	1	1
South Sound Basin	3	3	1	1
Haro Strait	3	3	NA[3]	NA
Strait of Juan de Fuca North	3	3	NA	NA
Strait of Juan de Fuca at Sill	3	3	NA	NA
Total =	42		8	

Freshwater Site	Water[1]	Particulates[2]
Nooksack River	3	1
Skagit River	3	1
Stillaguamish River	3	1
Snohomish River	3	1
Puyallup River	3	1
Total =	15	5

[1] Samples collected June, September, and December.
[2] Samples collected from October to December only.
[3] Not applicable.

Marine Sampling

Marine water samples will be collected from above and below the halocline at seven locations throughout Puget Sound and its ocean boundary waters. The latitudes and longitudes of the marine sampling sites are listed in Appendix A (Table A1) and shown on Figure 1.

Marine sampling sites were selected to correspond to basin cells in the Puget Sound Toxics Box Model. Four basins were selected based on geographic distribution across Puget Sound, with priority given to basins having greater size and depth. The sampling site in each of the selected basins represents the deepest location in the approximate centroid of the corresponding model basin cell.

For the purposes of the model, the sills at Admiralty Inlet and Deception Pass were defined as the boundary for Puget Sound. Two sampling sites in the Strait of Juan de Fuca and one in Haro Strait represent the ocean boundary waters of Puget Sound. These sites in the Straits coincide with monitoring station locations established by the Joint Effort to Monitor the Strait of Juan de Fuca (JEMS).

Contaminant movements between Puget Sound basins and fluxes between ocean boundary waters and Puget Sound will be simulated using the water circulation and transport component of the Puget Sound Toxics Box Model (Babson et al., 2006; Pelletier and Mohamedali, 2009). Incoming loads at the ocean boundary will be estimated using bottom layer concentrations of target chemicals, while contaminant exports from the Sound at the ocean boundary will be similarly estimated using surface layer concentrations.

Suspended particulates will be collected by moored sediment traps in the four selected Puget Sound basins. Traps will be moored above and below the halocline, and located as near as possible to water sampling sites where water depth does not exceed 50 meters. Bottom traps will be at least 10 meters above the sediment to avoid collection of re-suspended material, and surface traps will be roughly 10 meters below the surface. Sediment traps have been used successfully in other Ecology studies measuring contaminants associated with particulates in marine waters (Norton, 2001, 1996, and 1995).

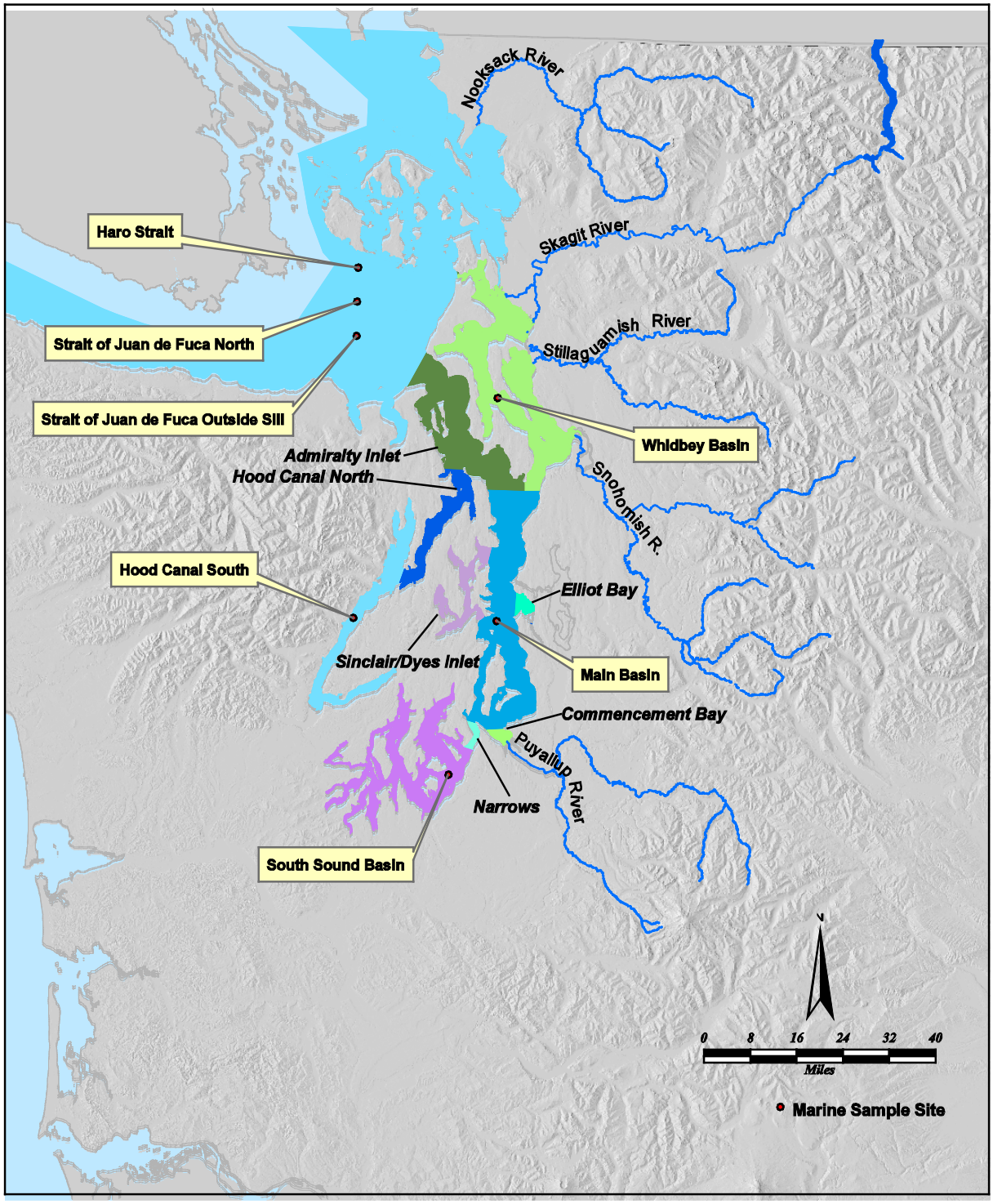

Figure 1. The Seven Marine Water Sampling Sites, Including the Four Puget Sound Toxics Box Model Basins.

Freshwater Sampling

Freshwater samples will be collected from the five largest freshwater discharges to Puget Sound (based on mean daily flow): the Nooksack, Skagit, Stillaguamish, Snohomish, and Puyallup Rivers. River sampling sites will be located at bridges over the lowest point in each drainage that allows sample collection above marine influence, co-located as close to permanent long-term flow stations as possible. River sampling sites, gaging stations, discharge, and drainage area information are described in Appendix A (Tables A2 and A3), and shown on Figure 2.

Freshwater samples will be depth-integrated composites collected at quarter points across the rivers. Individual grab samples will also be collected at quarter points along the river cross-section for HEM, TPH-gas, and TPH-diesel.

Discharge data for the time of sampling will be obtained from continuous long-term gaging stations operated by the USGS or Ecology. Loading rates will be calculated from instantaneous sample concentrations and flow. Annual loads will also be calculated using the mean sample concentrations and harmonic mean flows.

Collection of freshwater particulates will be from the same location as whole water samples. Representative samples of suspended particulates will be collected by pumping large volumes of water through continuous flow-through centrifuges. The time required to collect enough particulates to measure all target analytes will be based on TSS concentrations in the water column. Other toxic studies recently performed by Ecology have successfully used centrifuges to collect particulates (Serdar, 1997a, 1997b; Gries and Sloan, 2008).

Special Considerations for the Snohomish River

The Snohomish River begins at the confluence of the Skykomish and Snoqualmie Rivers. Most of the 20.5 river miles of the Snohomish River are tidally influenced. Water samples will be collected on the ebb tide from the Ecology long-term water quality monitoring station (Snohomish @ Airport Way) at river mile 12.7 in the city of Snohomish (Figure 2).

The only active gaging station on the Snohomish River is a USGS station located 0.1 miles downstream of the Skykomish-Snoqualmie confluence at river mile 20.4. Between the gaging station and the water sampling site, the Pilchuck River discharges to the Snohomish River at river mile 13.4, less than a mile upstream of the sampling location. The Pilchuck River has an active USGS gaging station. Therefore, flows for the Snohomish and Pilchuck Rivers will be combined for a total Snohomish River discharge at the sampling site.

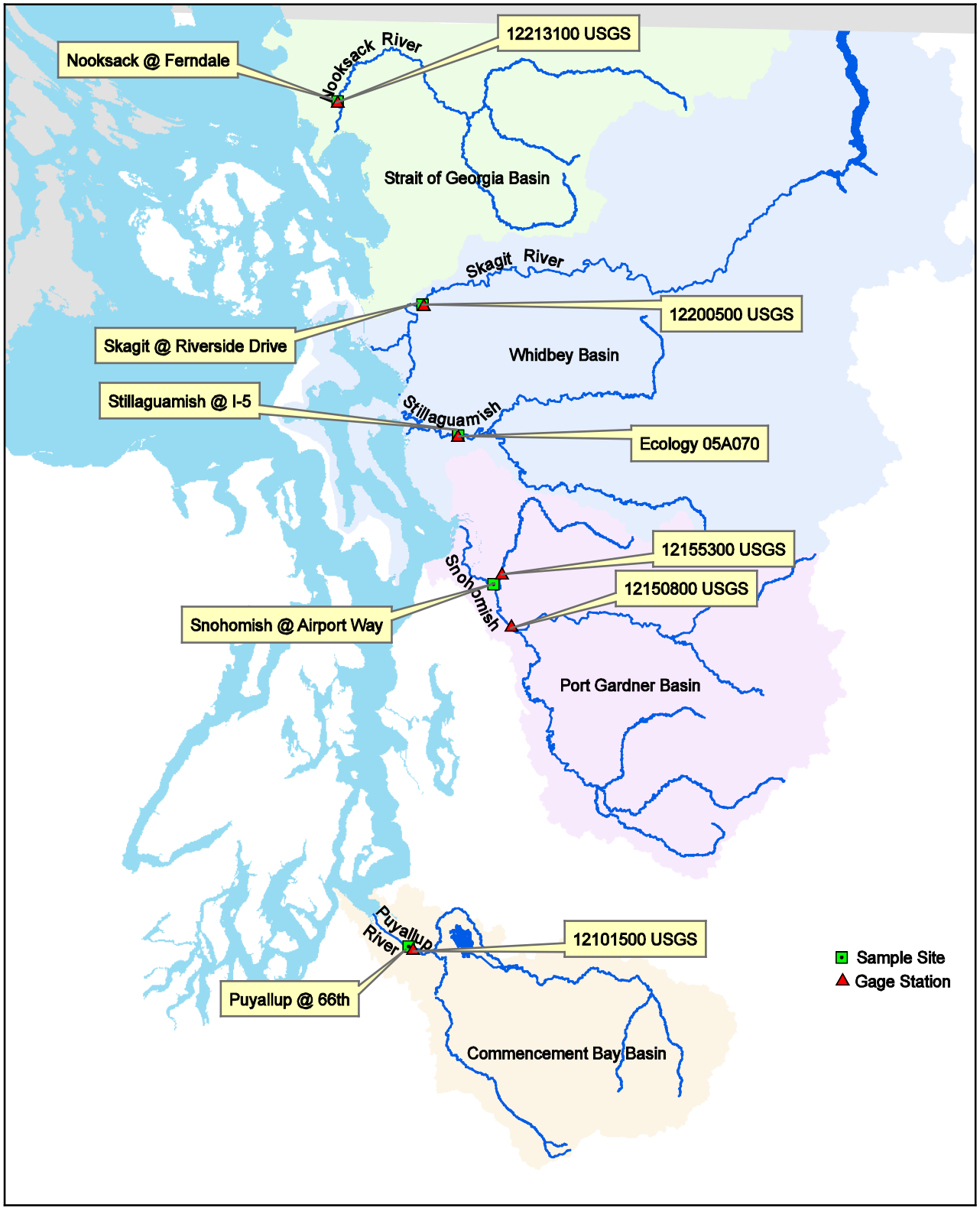

Figure 2. The Five Freshwater (River) Sampling Sites, Six Gage Locations, and Four Toxics Box Model Drainage Basins.

Sampling Schedule

Water samples will be collected at each of the seven marine and five freshwater sites on three occasions: once per month in June, September, and December of 2009. Sampling periods were selected to represent seasonal levels of contaminants over a wide range of discharge conditions. The timing of sample collection was chosen to represent contaminant concentrations following spring runoff (June), after the first flush event following the summer dry period (September), and during the wet weather of winter (December). Major river sampling will be conducted the week following the marine sampling events.

Sediment traps for collecting marine particulates will be moored in the four Puget Sound basin stations once, for a period of three months, beginning in October and ending in December 2009. Centrifugation for freshwater particulates in the major rivers will coincide with the deployment period for the sediment traps. Collection of river particulates will continue until particulate mass equals at least the minimum required for the targeted analyses. Therefore, the duration of collection will be determined by the TSS concentration in the rivers at the time of sampling.

Sampling Procedures

Marine Sampling

Water Column

The Ecology research vessel (R.V.) *Skookum* will be used as the sampling platform for the seven marine stations. The R.V. *Skookum* is a 26-foot aluminum hulled boat manufactured by Almar, equipped with hydraulic boom and winch. Boats can be a significant source of contamination when sampling for trace analytes. The hull of the R.V. *Skookum* has no antifouling coat, but has sacrificial zinc plates attached to the stern for prevention of electrolysis. Care will be taken to position the vessel down-current during sample collection. All sampling activities will be conducted on the windward side to minimize contamination from shipboard sources.

Sampling sites will be located by Global Positioning System (GPS) on board the R.V. *Skookum* and recorded in field logs. Water column samples will be collected from above and below the halocline. Historical salinity profiles will be reviewed from Ecology's Marine Ambient Monitoring Section database (www.ecy.wa.gov/apps/eap/marinewq/mwdataset.asp) at locations as close as possible to proposed sampling stations to estimate target depth requirements. A Conductivity/Temperature/Depth profiler (CTD; SBE25, Sea-Bird Electronics, Inc.) will be deployed on arrival to obtain a real-time salinity profile and confirm target depths. Collection of samples from below the halocline will precede above-halocline sampling at all locations. Sample collection depths will be recorded in field logs.

Water column samples will be collected with a pair of 10-liter, Teflon-coated GO-FLO discrete samplers (General Oceanics, Inc.). GO-FLO samplers have a *close-open-close* operation to avoid potential contamination from the microlayer at the water surface. Mounted back-to-back on a Kevlar or a like substitute rope, the samplers will be deployed in a closed position, open automatically by hydrostatic pressure release at a depth of ten meters, flush to sample depth, and close when triggered by Teflon-coated messenger. Detailed operating procedures for GO-FLO samplers are documented in Appendix D.

Immediately after retrieval of the GO-FLO samplers, they will be secured in a purpose-built storage cabinet for sample decanting. The salinity of the water in each sampler will be measured to evaluate the integrity of sampler closure. Unfiltered decanting will be conducted inside a portable glove box and will proceed in the following order: TSS, PCB and PBDE congeners, chlorinated pesticides, semivolatile organics, PAHs, and total recoverable metals. Filtration for dissolved metals will occur after all whole-water samples have been collected from the GO-FLO samplers. Filtration will employ a peristaltic pump and in-line filter following EPA Method 1669 (EPA, 1996). With the exception of a short length of MasterFlex-73 tubing in the pump head, all tubing will be Teflon. Filters will be Pall Corp., GWV high capacity capsules, 0.45-micron, or equivalent.

Table B1 in Appendix B lists the sample size, container, preservation, and holding times for each of the marine water column samples collected for the project. Approximately 16 liters of water is needed from each depth for marine samples, bottle rinses, and equipment flushes . The

simultaneous deployment of two GO-FLO samplers will collect 20 liters of sample water, allowing a single cast for each sampling depth.

Following the collection of water samples from below and above the halocline, a CTD mounted on a compact rosette frame will be deployed at each station to obtain profiles of temperature, salinity, and dissolved oxygen. Field procedures for CTD operation are detailed in Appendix E. Data are recorded at eight measurements per second as the unit is lowered through the water column. The CTD and all auxiliary sensors will undergo an initial calibration prior to the first sampling event in June, and calibration samples will be collected periodically to verify continued accuracy throughout the year.

Four 1.5-liter Niskin bottles mounted on the rosette frame will collect additional water samples during the retrieval (upcast) of CTD deployments. The unit will be pre-programmed to trigger the closure of two Niskin bottles above and two Niskin bottles below the halocline corresponding to the depths of GO-FLO sampler collections. Salinity will be measured from each bottle to confirm collection depth and bottle closure. Water samples for TOC will be decanted, and samples for DOC will be filtered (following Stutes and Bos, 2007) from these Niskin bottle collections.

Particulates

Suspended marine particulates will be collected with the use of moored sediment traps. The traps consist of a straight-sided glass collection cylinder with an area of 78.5 cm^2 and a height-to-width ratio of 5. A schematic of the construction details of the traps and their moorings is presented in Figure 3. Further discussion can be found in Norton (2001 and 1996).

The four sediment trap sites in Puget Sound will be located by GPS on-board the R.V. *Skookum* and recorded in field logs. The traps will be positioned to collect particulates from above and below the halocline. Bottom traps will be moored at least 10 meters above the bottom to avoid collection of re-suspended materials. Near-surface sediment traps will use the same mooring as bottom traps, suspended by hard shell float and positioned roughly 10 meters below the surface. To meet minimum particulate mass requirements for the proposed analyses, at least two sediment traps will be deployed both above and below the halocline at each station.

Traps will be moored for a period of three months, with deployment in October and retrieval in December. If problems arise in deployment or retrieval of sediment traps, pumping and centrifugation may be conducted as an alternative collection method, generally following procedures detailed in Appendix F.

The R.V. *Skookum* will be used as the work platform for deployment and retrieval of sediment traps. At deployment, collection cylinders will be filled with two liters of high salinity water (4% NaCl) and sodium azide (2% Na_3N) as a preservative to reduce microbial degradation of the samples. Following retrieval of sediment traps, overlying water will be removed by peristaltic pump. The remaining sample will be placed in I-Chem sample jars supplied by MEL.

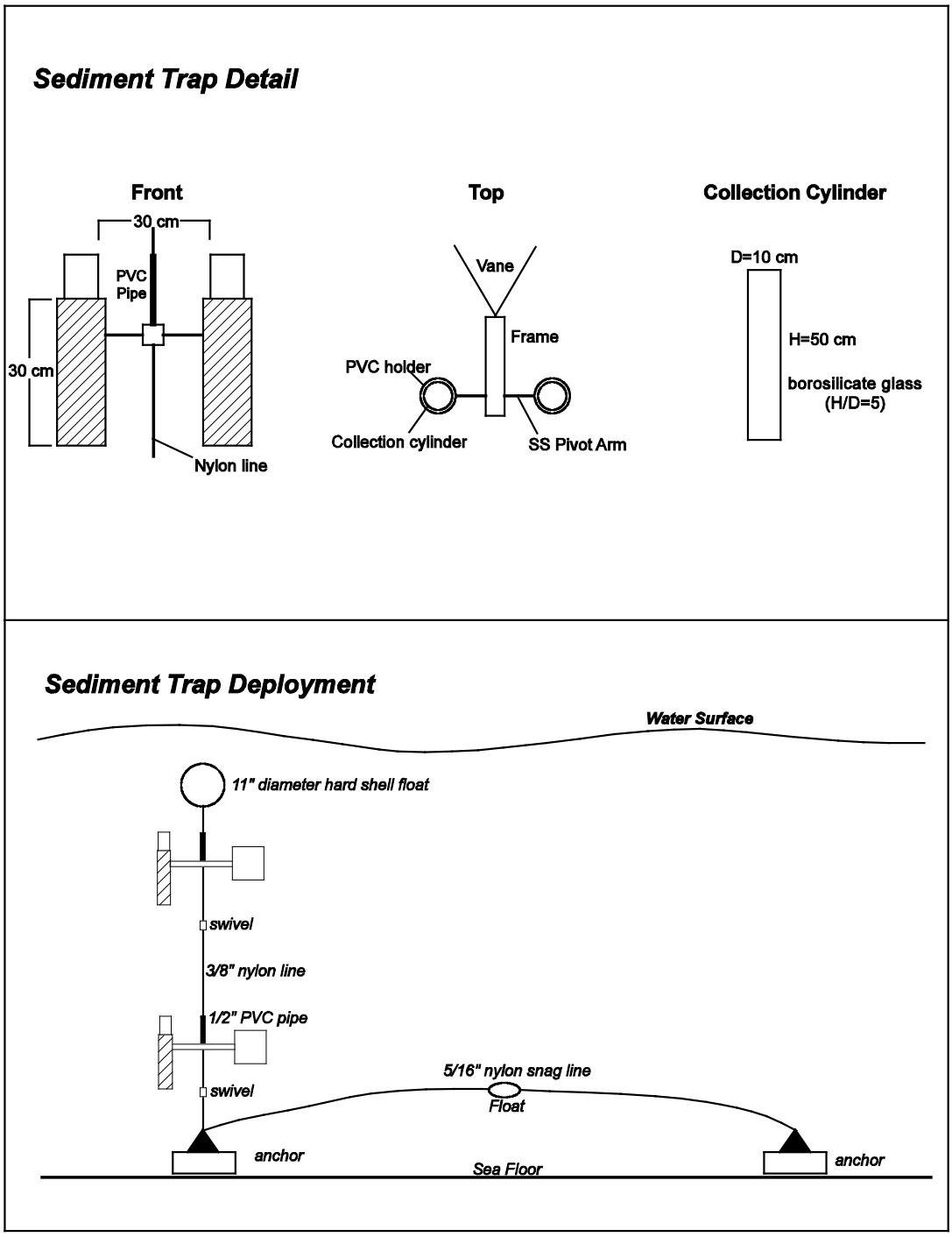

Figure 3. Schematic of Sediment Traps and Moorings.

Laboratories use dry weight sample minimums for solids to assure the lowest possible detection limits. Dry weights from wet samples are difficult to estimate, so sediment trap particulates will be centrifuged in the Ecology Headquarters laboratory before apportioning aliquots for individual analyses. If centrifuged samples are able to reach 90% solids, a minimum of 170 grams of sample from each site will be needed to complete required analyses. Following

centrifugation of the sample, the particulates will be homogenized in a clean environment before aliquots are removed for TOC, metals, semivolatile organics, PAHs, chlorinated pesticides, and PCB and PBDE congener analyses. Table B2 in Appendix B lists the sample size, container, preservation, and holding times for each marine particulate sample collected during the project.

Freshwater Sampling

Water Column

Freshwater (river) sampling for most of the target parameters will be performed manually from bridges using a US DH-95 isokinetic, depth-integrating sampler (FISP, 2000). The DH-95 sampler consists of a plastic tail section and a plastic-coated bronze body into which a rigid 1-L Teflon bottle, cap, and nozzle are fitted. The nozzle points into the flow when submerged, minimizing the potential for contamination by avoiding contact of the sampled water with the sampler components. Water and suspended particulates flow through the nozzle into the collection bottle while air exhausts out a vent in the cap.

Sampling procedures for the DH-95 will be conducted according to USGS (2005) to the extent possible. A preliminary sounding will be made by lead weight to determine depth at each sampling point. During deployment, the DH-95 sampler will be lowered through the water column at a fixed rate until located within a meter above the streambed, where the sampler will then immediately reverse in direction and be raised at an equal rate. Each deployment (called a "vertical," consisting of the complete downward and upward transit of the sampler) will be conducted at a rate that allows collection of 800 to 1000 mL of sample without overfilling the bottle. Transit rate will be dictated by the nozzle opening diameter, the river velocity, and river depth at each deployment following USGS (2005) and FISP (2000).

Verticals will be conducted at quarter points along the river cross-section. Finished samples will be manual composites of these quarter point collections (i.e., water from each quarter point will contribute one-third of the volume for analysis to the sample container). The total volume required for the target analyses is approximately 17 liters; therefore, a minimum of 6 liters will be collected at each quarter point. Table B3 in Appendix B lists the sample size, container, preservation, and holding times for each of the freshwater samples collected for the project.

Direct decanting from the sampler bottle into finished sample containers will be conducted on-site for TSS, TOC, hardness, and nutrients. Filtration of composite samples for DOC and orthophosphate will also be carried out in the field. Compositing and filtration activities for total and dissolved metals samples will be conducted within a portable glove box and will generally follow Ward (2007) and EPA (1996).

To minimize exposure to dust and particulates from the road and bridge, compositing for the most sensitive target analytes will not be conducted in the field. These analytes include semivolatile organics, PAHs, chlorinated pesticides, and PCB and PBDE congeners. Approximately 3.75 liters collected at a single quarter point will be combined in a one-gallon glass container and placed in a cooler on ice. Composite samples consisting of equal volume

contributions from the quarter points for the above-mentioned analytes will then be decanted in a clean lab environment.

The only parameters that will not involve depth-integrated collection at quarter points will be TPH (both -gas and -diesel) and HEM. Sampling for these parameters will involve collection of grab samples at quarter points along the cross-section. Grabs will be collected from a depth of approximately 0.5 meters, and sampling will follow conventional practices except sample bottles will not be pre-rinsed.

Particulates

Suspended particulates will be collected by flow-through centrifuge at the river sampling sites. A detailed description of field operating procedures is documented in Appendix F. These procedures follow Gries and Sloan (2008) to the extent possible.

A pump (Model SP4, Gundfos Inc.) will be used to draw water from the location determined to be the average suspended sediment load at the site. The intake line for the pump will initially be positioned in the thalweg of the stream at 6/10 of depth. Positioning of the intake may be adjusted based on field observations and periodic measurements of water depth, velocity, and specific conductivity throughout the sampling event.

Two flow-through centrifuges (Alfa-Laval Corporate AB, MAB 103B) will receive the pumped water and remove the sediment. Removal efficiency of suspended particulates is expected to be >90%. The amount of collected sample will be monitored and removed as needed to maintain maximum retention efficiency.

River water will be centrifuged continually until the minimum amount of particulate is collected to allow analysis of all target parameters. Assuming a centrifuged sample is 90% solids, a minimum of at least 170 grams of sample from each site will be needed to complete the required analyses. The length of time centrifuges must run to collect this amount of particulate will depend on the concentration of TSS in the water column. During high or storm flows, TSS in rivers may be 50 mg/L or greater, while in low-flow periods TSS may be less than 3 mg/L. For a centrifuge operating at 360 liters/hour and 100% efficiency of particle retention, the range of time needed for collection of at least 170 grams of particulate sample at each site would be 9.4 to 157 hours for high (50 mg/L) and low (3 mg/L) TSS conditions, respectively.

When sample collection is concluded, particulates will be placed in the appropriate sample container and immediately placed in a cooler on ice. Once back from the field the particulate sample will be homogenized in a clean environment before aliquots are removed for TOC, metals, semivolatile organics, PAHs, chlorinated pesticides, and PCB and PBDE congener analyses. Table B4 lists the sample size, container, preservation, and holding times for each freshwater particulate sample collected for the project.

Measurement Procedures

The analytical parameters, sample numbers, methods, and reporting limits to be used for the study are presented in the Appendix C, Tables C1 through C3, for marine, river, and particulate samples. Method selection was based on the lowest detection limits available for the matrices. A complete analyte list for semivolatile organics, PAHs, and chlorinated pesticides can be found in Appendix C.

All sample containers will be obtained from MEL or the contract laboratories conducting the analysis and cleaned to analyte-specific standards. Chain-of-custody procedures will be followed throughout the sampling and analysis process.

All project samples will be analyzed at MEL or a laboratory contracted by MEL. Laboratories may use other appropriate methods as needed following consultation with the project manager.

Laboratories contracted by MEL must be on the Ecology list of accredited laboratories (www.ecy.wa.gov/programs/eap/labs/lab-accreditation.html). Additionally, when available, laboratories conducting analysis for Ecology studies must be on the General Administration master contract.

Marine samples collected for metals analysis will be analyzed by Frontier GeoSciences, in Seattle, Washington. Marine and freshwater analyses of PBDE congeners will be contracted to the Pacific Rim Laboratory, in Surrey, British Columbia. Marine and freshwater analyses of PCB congeners will be contracted to Analytical Perspectives, in North Carolina.

The analytical cost for the project is estimated to be $294,208 (Table 6). The estimate includes a 50% cost discount for analysis conducted at MEL. Also included is a 25% surcharge for MEL's contracting services and data quality review for results from contract laboratories. The cost estimate assumes analysis of water samples collected on three occasions at seven marine sites (samples from two depths at each site) and at the five major rivers. Particulates will be collected once from the four Puget Sound stations (samples from two depths at each site) and from the five major rivers.

Table 6. Cost of Water and Particulate Sample Analyses (includes contract services).

Parameter	Number of Samples	Number of QA Samples	Sample Total Per Event	Cost Per Sample	Subtotal
Water					
TSS	19	3	22	11	242
TOC	19	4	23	33	759
DOC	19	4	23	35	805
Hardness	5	1	6	22	132
Nutrients (5)	5	1	6	78	468
Metals (Total and Dissolved) Marine Water:					
As, Cd, Cu, Pb, Zn	28	5	33	300	9900
Metals (Total and Dissolved) Freshwater:					
As, Cd, Cu, Pb, Zn	10	5	15	107	1605
TPH-diesel	15	1	16	104	1664
TPH-gas	15	1	16	75	1200
HEM (“oil and grease”)	15	2	17	55	935
Semivolatiles (BNA)	19	4	23	265	6095
PAHs	19	4	23	315	7245
Chlorinated Pesticides	19	4	23	250	5750
PCB Congeners	19	4	23	1250	28750
PBDE Congeners	19	4	23	750	17250
				Cost per 1 event	$82,800
				Cost per 3 events	$248,400
Particulates					
Percent Solids	13	2	15	11	165
TOC	13	2	15	42	630
Metals Total Recoverable:					
As, Cd, Cu, Pb, Zn	13	2	15	114	1710
Semivolatiles (BNA)	13	3	16	275	4400
PAHs	13	3	16	315	5040
Chlorinated Pesticides	13	3	16	250	4000
PCB Congeners	13	1	14	1250	17500
PBDE Congeners	13	1	14	750	10500
				Cost per 1 event	$43,945
Other Materials	Number of Samples	Cost Per Sample	Subtotal Per Event	Number of Events	Subtotal
Metals Filters	8	27	216	3	648
Metals Bottles and Acid	15	27	405	3	1215
				Subtotal Other Materials	$1,863
				Subtotal Water Samples (3 Events)	$248,400
				Subtotal Particulates (1 Event)	$43,945
				Grand Total	$294,208

Quality Control Procedures

Field

Table 7 shows a list of the field quality control (QC) samples and types to be analyzed for the project. Field QC samples provide an estimate of the total variability of the results, field plus laboratory. Field QC will consist of collection and analysis of replicate samples and blanks. Replicate water samples will be two samples collected one after the other as close to the same time and location as possible. Equipment blanks will consist of reagent grade water prepared by MEL or their contractor passed through the sample equipment, placed in a sample container, and returned as other samples to the laboratory for analysis.

Table 7. Field Quality Control Samples for Water[1].

Analysis	Replicates[2]	Transfer Blanks	Filter Blanks
TSS	2/event[3]	--	--
TOC	1/event	--	--
DOC	1/event	--	--
Hardness	1/event	--	--
Nutrients	1/event	--	--
Marine Metals	1/event	1/event	1/event
Freshwater Metals	1/event	1/event	1/event
TPH-diesel	1/event	--	--
TPH-gas	1/event	--	--
HEM (“oil and grease”)	1/event	--	--
Semivolatiles (BNA)	1/event	1/event	--
PAHs	1/event	1/event	--
Chlorinated Pesticides	1/event	1/event	--
PCB Congeners	1/event	1/event	--
PBDE Congeners	1/event	1/event	--

[1] Includes marine and river samples.
[2] Independent sample collected at the same location.
[3] Sample collection events in June, September, and December.

All efforts will be made to avoid cross-contamination. Field staff will wear non-talc Nitrile gloves throughout the sample collection process. Immediately following collection, samples will be stored in iced coolers, until delivered to MEL.

To minimize field variability from sample collection, field samplers will be familiar with and follow methods for the collection and processing of water and particulate samples. Operating procedures are described in Appendix D for GO-FLO discrete water samplers, Appendix E for CTD deployment, and Appendix F for centrifuge operation for collection of particulates.

Additional guidance can be found in the Ecology SOPs *Manually Obtaining Surface Water Samples* (Joy, 2006) and *Collection and Field Processing of Metals Samples* (Ward, 2007), as well as PSEP (1997a and 1997b).

Any equipment used in collection or processing samples will be decontaminated prior to going to the field by washing thoroughly with hot tap water and Liquinox detergent, followed by sequential rinses of 10% nitric acid, de-ionized water, pesticide grade acetone, and finally, pesticide-grade hexane. After decontamination, sampling equipment will be air dried under a fume hood, covered with aluminum foil, and placed in a new plastic zip-lock bag until used.

Field QC for particulates will be split samples of remaining materials. Sediment trap particulates will require centrifugation back at the laboratory to concentrate solids. Until samples are processed, the total mass of particulates will be unknown. Target analytes for the study will be a higher priority for analysis than QC samples. If the particulate mass is not collected in sufficient quantity to submit QC samples for all parameters, a determination will be made at that time through consultation with the MEL as to prioritizing analyses for remaining particulates.

Laboratory

MEL routinely runs laboratory control samples for TSS, TOC, and DOC which will be satisfactory for the purposes of this project. MEL will follow standard operating procedures as described in the *Quality Assurance Manual for the Washington State Department of Ecology Manchester Environmental Laboratory* (MEL, 2006). Laboratory QC samples to be analyzed for this project are presented in Table 8.

Table 8. Laboratory Quality Control Samples for Water and Particulates.

Analysis	Method Blank	Check Standard	Duplicates	Surrogate Spikes	Labeled Compounds	MS/MSD[1]	OPR[3] Standards
Water							
TSS	1/batch	1/batch	1/batch	--	--	--	--
TOC	1/batch	1/batch	1/batch	--	--	1/batch	--
DOC	1/batch	1/batch	1/batch	--	--	1/batch	--
Hardness	1/batch	1/batch	--	--	--	--	--
Nutrients	1/batch	1/batch	--	--	--	--	--
Marine Metals	2/batch	1/batch	--	--	--	1/batch	--
Freshwater Metals	1/batch	1/batch	--	--	--	1/batch	--
TPH-diesel	1/batch	1/batch	--	--	--	--	--
TPH-gas	1/batch	1/batch	--	--	--	--	--
HEM (“oil and grease”)	1/batch	1/batch	--	--	--	--	--
Semivolatiles (BNA)	1/batch	1/batch	--	all samples	--	1/batch	--
PAHs	1/batch	1/batch	--	all samples	--	1/batch	--
Chlorinated Pesticides	2/batch	1/batch	--	all samples	--	1/batch	--
PCB Congeners	1/batch	1/batch	1/batch	--	all samples	--	each batch
PBDE Congeners	1/batch	1/batch	1/batch	--	all samples	--	each batch
Particulates							
Percent Solids	1/batch	1/batch	--	--	--	--	--
TOC	1/batch	1/batch	--	--	--	--	--
Metals[2]	1/batch	1/batch	--	--	--	1/batch	--
Semivolatiles (BNA)	1/batch	1/batch	--	all samples	--	1/batch	--
PAHs	1/batch	1/batch	--	all samples	--	1/batch	--
Chlorinated Pesticides	1/batch	1/batch	--	all samples	--	1/batch	--
PCB Congeners	1/batch	1/batch	--	--	all samples	--	each batch
PBDE Congeners	1/batch	1/batch	--	--	all samples	--	each batch

[1] = Matrix spike/matrix spike duplicate.
[2] = Total recoverable for particulate metals.
[3] = Ongoing precision and recovery.

Data Management Procedures

All field data and observations will be recorded in notebooks on waterproof paper. The information contained in field notebooks will be transferred to Excel spreadsheets after return from the field. Data entries will be independently verified for accuracy by another member of the project team.

Case narratives included in the data package from MEL will discuss any problems encountered with the analyses, corrective action taken, changes to the requested analytical method, and a glossary for data qualifiers. Laboratory QC results will also be included in the data package. This will include results for surrogate recoveries, laboratory duplicates, matrix spikes, and laboratory blanks. The information will be used to evaluate data quality, determine if the MQOs were met, and act as acceptance criteria for project data.

Field and laboratory data for the project will be entered into Ecology's EIM system. Laboratory data will be downloaded directly into EIM from MEL's data management system. Data from contract laboratories will be submitted in electronic format for inclusion into the EIM system.

Audits and Reports

MEL participates in performance and system audits of their routine procedures. Results of these audits are available upon request.

A draft report of the study findings will be completed by the principal investigator in June 2010 and a final report in September 2010. The report will include, at a minimum, the following:

- Map showing all sampling locations and any other pertinent features of the study area.
- Coordinates of each sampling site.
- Description of field and laboratory methods.
- Discussion of data quality and the significance of any problems encountered.
- Summary tables of the chemical and physical data.
- Results of the toxic contaminants related to available standards.
- Discussion of seasonal data on concentrations of toxic chemicals in marine waters and the freshwater inputs.
- Discussion of concentrations and fluxes of toxic chemicals associated with suspended particulate matter in both marine and freshwaters.
- Presentation of incoming (bottom layer) concentrations and estimated contaminant loads from ocean water to the Puget Sound, as well as outgoing (surface layer) concentrations and estimated loads for contaminant fluxes between Puget Sound and the ocean boundary.
- Discussion of toxic chemical loadings to Puget Sound from the major tributaries sampled.
- Comparison of Phase 2 loading estimates for PCBs from the Puget Sound Toxics Box Model with updated simulations generated using concentration data from the present study.
- Complete set of chemical and physical data and MEL quality assurance review in the Appendix.

Study data on contaminant concentrations and flow from the freshwater discharges will be provided electronically to Herrera Environmental Consultants for their use in development of an overall loading analysis for Puget Sound.

Upon study completion, all project data will be entered into Ecology's EIM system. Public access to electronic data and the final report for the study will be available through Ecology's Internet homepage (www.ecy.wa.gov).

Data Verification

Data verification is a process conducted by those producing data. Verification of laboratory data is normally performed by a MEL unit supervisor or an analyst experienced with the method. It involves a detailed examination of the data package using professional judgment to determine whether the measurement quality objectives (MQOs) have been met.

Final acceptance of the project data is the responsibility of the principal investigator. The complete data package, along with MEL's written report, will be assessed for completeness and reasonableness. Based on these assessments, the data will either be accepted, accepted with qualifications, or rejected and re-analysis considered.

Data verification involves examining the data for errors, omissions, and compliance with quality control (QC) acceptance criteria. MEL's SOPs for data reduction, review, and reporting will meet the needs of the project. Data packages, including QC results for analyses conducted by MEL, will be assessed by laboratory staff using the EPA Functional Guidelines for Organic Data Review.

MEL staff will provide a written report of their data review which will include a discussion of whether (1) MQOs were met, (2) proper analytical methods and protocols were followed, (3) calibrations and controls were within limits, and (4) data were consistent, correct, and complete, without errors or omissions.

Data Quality (Usability) Assessment

After the project data have been reviewed and verified, the principal investigator will determine if the data are of sufficient quality to serve as Puget Sound and major tributary baseline data for water column toxic contaminants. The data from the laboratory's QC procedures, as well as results from field replicates, laboratory duplicates, and surrogate recoveries, will provide information to determine if MQOs have been met. A review of sample results will be performed following each seasonal sampling event to assess the need for modifications to the sampling or analysis program. Laboratory and quality assurance staff familiar with assessment of data quality may be consulted. The project final report will discuss data quality and whether the project objectives were met. If limitations in the data are identified, they will be noted.

Some analytes will be reported near the detection capability of the selected methods. MQOs may be difficult to achieve for these results. MEL's SOP for data qualification and best professional judgment will be used in the final determination of whether to accept, reject, or accept the results with qualification. The assessment will be based on a review of field replicates, along with laboratory QC results. This will include assessment of laboratory precision, contamination (blanks), accuracy, matrix interferences, and the success of laboratory QC samples meeting control limits.

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Appendices

Appendix A. Station Location Information.

Appendix B. Sample Containers, Preservation, and Holding Times for Water and Particulate Samples.

Appendix C. Laboratory Parameters, Number of Samples, and Analytical Methods for Water and Particulate Sample Analyses.

Appendix D. Field Operation Procedures – GO-FLO Samplers.

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Appendix F. Field Operation Procedures – Collecting Suspended Sediment Using Flow-Through Centrifuges.

Appendix G. Glossary, Acronyms, and Abbreviations.

Appendix A. Station Location Information

Table A1. Sampling stations and coordinates for the marine water column.

Waterbody	Latitude	Longitude
Hood Canal South	47.55887	-123.00475
Puget Sound Main Basin	47.56157	-122.47593
Whidbey Basin	48.10833	-122.48999
South Sound Basin	47.18471	-122.63777
Haro Strait	48.41667	-123.02500
Strait of Juan de Fuca North	48.33333	-123.02500
Strait of Juan de Fuca at Sill	48.25000	-123.02500

Datum is NAD 83 HARN.

Table A2. Sampling stations and coordinates for the major rivers.

River	Latitude	Longitude
Nooksack	48.81898	-122.58010
Skagit	48.44500	-122.33510
Stillaguamish	48.19710	-122.21057
Snohomish	48.91074	-122.09852
Puyallup	48.20268	-122.29372

Datum is NAD 83 HARN.

Table A3. Flow station ID, river mile, discharge rate, drainage area, and latitude/longitude for the major rivers.

River	Gage ID	River Mile	Mean Daily Discharge[1]	Drainage Area (mi^2)	Latitude[2]	Longitude
Nooksack	12213100[3]	3.4	3,833	786	48.8190	-122.5800
Skagit	12200500[3]	15.9	16,580	3,093	48.4451	-122.3352
Stillaguamish	05A070[4]	11.1	4,696	557	48.1966	-122.2083
Snohomish	12150800[3]	20.4	9,514	1,714	47.8305	-122.0484
Pilchuck	12155300[3]	13.4	468	127	47.9349	-122.0737
Puyallup	12101500[3]	8.3	3,319	948	47.2026	-122.2937

[1] = Annual mean daily discharge in ft^3/second.
[2] = Datum is NAD83 HARN.
[3] = USGS gaging station.
[4] = Ecology flow and water quality site.

Appendix B. Sample Containers, Preservation, and Holding Times for Water and Particulate Samples

Table B1. Sample containers, requested volumes, preservation, and holding times for marine water column samples.

Parameter	Bottle Type and Volume	Sample Volume Requested	Preservative	Holding Time
TSS	1 L Poly	1 L	Cool to $\leq 6^{o}$ C	7 Days
TOC	60 mL Glass	60 mL	1:1 HCl to pH<2; Cool to $\leq 6^{o}$ C	28 Days
DOC	60 mL Glass	60 mL	Filter in field w/ 0.45 *u*m filter 1:1 HCl to pH<2; Cool to $\leq 6^{o}$ C	28 Days
Total Metals	500 mL HDPE	350 mL	HNO_3 to pH <2	6 Months
Dissolved Metals	500 mL HDPE	350 mL	Filter in field w/ 0.45 *u*m filter; add HNO_3 to pH ≤ 2; Cool to $\leq 6^{o}$ C	6 Months
Semivolatiles (BNA)	1 L Amber Glass	3 L	Cool to $\leq 6^{o}$ C	7 Days
PAHs	1 L Amber Glass	3 L	Cool to $\leq 6^{o}$ C	7 Days
Chlorinated Pesticides	1 Gallon Glass	3 L	Cool to $\leq 6^{o}$ C	7 Days
PCB Congeners	1 L Amber Glass	2 L	Cool to $\leq 6^{o}$ C	1 Year
PBDE Congeners	1 L Amber Glass	1 L	Cool to $\leq 6^{o}$ C	1 Year
Total 13.8 L				

Table B2. Sample containers, requested volumes, preservation, and holding times for marine particulate samples.

Parameter	Bottle Type and Volume	Sample Mass Requested (Wet Weight)	Preservative	Holding time
Percent Solids	2 oz Glass	50 Grams[1]	Cool to $\leq 6^{o}$ C	7 Days
TOC			Cool to $\leq 6^{o}$ C; may freeze at -18^{o}C	14 Days; 6 months frozen
Metals Total Recoverable			Cool to $\leq 6^{o}$ C; may freeze at -18^{o}C	6 months
Semivolatiles (BNA)	8 oz Glass	250 Grams[2]	Cool to $\leq 6^{o}$ C	14 Days; 1 year frozen
PAHs				
Chlorinated Pesticides		250 Grams	Cool to $\leq 6^{o}$ C	14 Days; 1 year frozen
PCB Congeners		50 Grams	Cool to $\leq 6^{o}$ C; may freeze at -18^{o}C	1 year
PBDE Congeners		50 Grams	Cool to $\leq 6^{o}$ C; may freeze at -18^{o}C	1 year
Total 650 Grams				

[1] = Percent solids, TOC, and metals will be collected into one sample container.
[2] = Semivolatile organics and PAHs will be collected into one sample container.

Table B3. Sample containers, requested volumes, preservation, and holding times for freshwater (river) samples.

Parameter	Bottle Type and Volume	Sample Volume Needed	Preservative	Holding time
TSS	1 L Poly	1 L	Cool to $\leq 6^{o}$ C	7 Days
TOC	60 mL Poly	50 mL	1:1 HCl to pH<2; Cool to $\leq 6^{o}$ C	28 Days
DOC	60 mL Poly	50 mL	Field Filter w/ 0.45 *u*m; 1:1 HCl to pH<2; Cool to $\leq 6^{o}$ C	28 Days
Hardness	125 mL Poly	100 mL	H_2SO_4 to pH<2; Cool to $\leq 6^{o}$ C	6 Months
Nutrients: PO_4^{-3}	125 mL Amber Poly	125 mL	Field Filter w/ 0.45 *u*m; Cool to $\leq 6^{o}$ C	48 Hours
Nutrients: TP, NO_2+NO_3, NH_3, TPN	125 mL Clear Poly	125 mL	Pre-acidify w/ H_2SO_4; Cool to $<6^{o}$ C	28 Days
Total Metals	500 mL HDPE	350 mL	HNO_3 to pH <2; Cool to $<6^{o}$ C	6 Months
Dissolved Metals	500 mL HDPE	350 mL	Field Filter w/ 0.45 *u*m; HNO_3 to pH ≤ 2; Cool to $\leq 6^{o}$ C	6 Months
TPH-diesel	1 L Amber Glass	3 L	Cool to $\leq 6^{o}$ C	14 Days
TPH-gas	40 mL VOAs	480 mL	1:1 HCl to pH<2; Cool to $\leq 6^{o}$ C	14 Days
HEM ("oil and grease")	1 L Glass	3 L	1:1 HCl, pH ≤ 2.0; Cool to $< 6^{o}$ C	28 Days
Semivolatiles (BNA)	1 Gallon Glass	3 L	Cool to $\leq 6^{o}$ C	7 Days
PAHs	1 L Amber Glass	1 L	Cool to $\leq 6^{o}$ C	7 Days
Chlorinated Pesticides	1 L Amber Glass	1 L	Cool to $\leq 6^{o}$ C	7 Days
PCB Congeners	1 L Amber Glass	2 L	Cool to $\leq 6^{o}$ C	1 Year
PBDE Congeners	1 L Amber Glass	1 L	Cool to $\leq 6^{o}$ C	1 Year
Total 16.6 Liters				

PO_4^{-3} = orthophosphate phosphorus.
TP = total phosphorus.
$NO_{2+}NO_3$ = nitrite and nitrate nitrogen.
NH_3 = ammonia nitrogen.
TPN = total persulfate nitrogen.

Table B4. Sample containers, requested volumes, preservation, and holding times for freshwater (river) particulate samples.

Parameter	Bottle Type and Volume	Sample Mass Requested (Wet Weight)	Preservative	Holding time
Percent Solids	2 oz Glass	50 Grams[1]	Cool to $\leq 6^{o}$ C	7 Days
TOC			Cool to $\leq 6^{o}$ C; may freeze at -18^{o}C	14 Days; 6 months frozen
Metals Total Recoverable			Cool to $\leq 6^{o}$ C; may freeze at -18^{o}C	6 months; 2 years frozen
Semivolatiles (BNA)	8 oz Glass	250 Grams[2]	Cool to $\leq 6^{o}$ C; may freeze at -18^{o}C	14 Days; 1 year frozen
PAHs				
Chlorinated Pesticides		250 Grams	Cool to $\leq 6^{o}$ C; may freeze at -18^{o}C	14 Days; 1 year frozen
PCB Congeners		50 Grams	Cool to $\leq 6^{o}$ C; may freeze at -18^{o}C	1 year
PBDE Congeners		50 Grams	Cool to $\leq 6^{o}$ C; may freeze at -18^{o}C	1 year
Total 450 Grams				

[1] = Percent solids, TOC, and metals will be collected into one sample container.
[2] = Semivolatile organics and PAHs will be collected into one sample container.

Appendix C. Laboratory Parameters, Number of Samples, and Analytical Methods for Water and Particulate Sample Analyses.

Table C1. Laboratory parameters, number of samples, and analytical methods for marine water analyses per sampling event.

Parameter	Sample Number + QA	Expected Range of Results	Reporting Limits	Sample Preparation Method	Sample Cleanup Method	Analytical Method
TSS (mg/L)	16	1.0 - 50	1.0	-	-	SM 2540 D
TOC (mg/L)	16	<1.0 - 10	1.0	-	-	SM 5310 C
DOC (mg/L)	16	<1.0 - 10	1.0	Filter 0.22 *u*m	-	SM 5310 C
Metals Total Recoverable (*u*g/L):						
Arsenic	25	0.5 - 2.0	0.05	Acid digest	-	FGS 054
Cadmium	25	0.02 - 0.20	0.01	Acid digest	-	FGS 054
Copper	25	0.1 - 1.0	0.05	Acid digest	-	FGS 054
Lead	25	0.005 - 0.20	0.05	Acid digest	-	FGS 054
Zinc	25	0.2 - 5.0	0.25	Acid digest	-	FGS 054
Metals Dissolved (*u*g/L):						
Arsenic	25	0.5 - 2.0	0.05	Filter 0.45 *u*m	-	FGS 054
Cadmium	25	0.02 - 0.20	0.01	Filter 0.45 *u*m	-	FGS 054
Copper	25	0.1 - 1.0	0.05	Filter 0.45 *u*m	-	FGS 054
Lead	25	0.005 - 0.10	0.05	Filter 0.45 *u*m	-	FGS 054
Zinc	25	0.2 - 5.0	0.25	Filter 0.45 *u*m	-	FGS 054
Semivolatiles (BNA) (*u*g/L)*	16	<1-100	0.25 - 1.0	Extraction	-	EPA 8270
PAHs (*u*g/L)*	16	<1 - 10	0.01	Solid Phase Extraction	-	EPA 8270 SIM
Chlorinated Pesticides (ng/L)*	16	0.10 - 3.0	0.10 - 3.0	EPA 3510	-	EPA 8081
PCB Congeners (pg/L)*	16	5 - 500	10	Dichloromethane Extraction	Acid/base wash	EPA 1668A GC/HRMS
PBDE Congeners (pg/L)*	16	5 - 500	10 - 250	Dichloromethane Extraction	Acid/base wash	EPA 1614 GC/HRMS

* Reporting limits and expected ranges of results will vary for different organic analytes.
SM = Standard Methods.
SIM = Selective Ion Monitoring.
FGS = Frontier GeoSciences.
GC/HRMS = Gas Chromatography / High Resolution Mass Spectrometry.

Table C2. Laboratory parameters, number of samples, and analytical methods for freshwater (river) analyses per sampling event.

Parameter	Sample Number + QA	Expected Range of Results	Reporting Limits	Sample Preparation Method	Sample Cleanup Method	Analytical Method
TSS (mg/L)	6	1.0 - 100	1.0	-	-	SM 2540 D
TOC (mg/L)	7	1.0 - 10	1.0	-	-	SM 5310 C
DOC (mg/L)	7	1.0 - 10	1.0	Filter 0.45 *u*m	-	SM 5310 C
Hardness (mg/L)	6	10 - 50	1.0	-	-	EPA 200.7 ICP
Nutrients 5 (mg/L)[1]	6	0.005 - 1.0	0.005 - 0.025	-	-	SM 4500
Metals Total Recoverable (*u*g/L):						
Arsenic	8	0.2 - 5.0	0.1	Acid digest	-	EPA 200.8 ICP/MS
Cadmium	8	0.05 - 1.0	0.1	Acid digest	-	EPA 200.8 ICP/MS
Copper	8	0.5 - 5.0	0.1	Acid digest	-	EPA 200.8 ICP/MS
Lead	8	0.04 - 0.5	0.1	Acid digest	-	EPA 200.8 ICP/MS
Zinc	8	5.0 - 10.0	5.0	Acid digest	-	EPA 200.8 ICP/MS
Metals Dissolved (*u*g/L):						
Arsenic	8	0.2 - 5.0	0.2	Filter 0.45 *u*m	-	EPA 200.8 ICP/MS
Cadmium	8	0.02 - 0.50	0.02	Filter 0.45 *u*m		EPA 200.8 ICP/MS
Copper	8	0.3 - 2.0	0.1	Filter 0.45 *u*m	-	EPA 200.8 ICP/MS
Lead	8	0.02 - 0.3	0.02	Filter 0.45 *u*m	-	EPA 200.8 ICP/MS
Zinc	8	0.4 - 5.0	1.0	Filter 0.45 *u*m	-	EPA 200.8 ICP/MS
TPH-diesel (mg/L)	16	0.1 - 50	0.05	Extraction	Acid/silica	ECY 97-602
TPH-gas (mg/L)	16	0.1 - 50	0.14	Extraction	Acid/silica	ECY 97-602
HEM ("oil and grease") (mg/L)	16	2.0 - 150	1.7	-	-	EPA 1664A
Semivolatiles (BNA) (*u*g/L) *	7	<1 - 100	0.25 - 1.0	Extraction	-	EPA 8270
PAHs (*u*g/L) *	7	<1 - 10	0.01	Solid Phase Extraction	-	EPA 8270 SIM
Chlorinated Pesticides (ng/L) *	7	0.1 - 3.0	0.1 - 3.0	EPA 3510	-	EPA 8081 LVI
PCB Congeners (pg/L) *	7	5 - 500	10	Dichloromethane Extraction	Acid/base wash	EPA 1668A GC/HRMS
PBDE Congeners (pg/L) *	7	5 - 500	10 - 250	Dichloromethane Extraction	Acid/base wash	EPA 1614 GC/HRMS

*= Reporting limits and expected ranges of results will vary for different organic analytes.

SM = Standard Methods. SIM = Selective Ion Monitoring.
ICP = Inductively Coupled Plasma. LVI = Large Volume Injection.
ECY = Ecology. GC/HRMS = Gas Chromatography / High Resolution Mass. Spectrometry.
MS = Mass Spectrometry.

Table C3. Laboratory parameters, number of samples, and analytical methods for marine water and freshwater (river) particulate analyses per sampling event.

Parameter	Sample Number + QA	Expected Range of Results	Reporting Limits	Sample Preparation Method	Sample Cleanup Method	Analytical Method
Marine	-	-	-	-	-	-
Percent Solids (%)	6	40-90%	1%	-	-	EPA 160.3
TOC (%)	8	< 1.0 - 5.0	0.1	PSEP, 1986/1996	-	PSEP, 1986/1997
Metals Total Recoverable (mg/Kg):						
Arsenic	8	1.0 - 20	0.1	SW-846 3050B	-	EPA 200.8
Cadmium	8	0.1 - 5.0	0.1	SW-846 3050B	-	EPA 200.8
Copper	8	2.0 - 50	0.1	SW-846 3050B	-	EPA 200.8
Lead	8	2.0 - 20	0.1	SW-846 3050B	-	EPA 200.8
Zinc	8	10 - 100	5	SW-846 3050B	-	EPA 200.8
Semivolatiles (BNA) (*u*g/Kg)*	9	<16 - 10,000	16 - 320	SW-846	-	EPA 8270
PAHs (*u*g/Kg)*	9	<1 - 10	0.01	Soxtherm Extraction	SilicaGel	EPA 8270
Chlorinated Pesticides (*u*g/Kg)*	9	<1 - 25	2 - 10	EPA 3541	-	EPA 8081
PCB Congeners (ng/Kg)*	8	5 - 500	3 -10	Soxhlet Extraction	Acid/base wash	EPA 1668A GC/HRMS
PBDE Congeners (ng/Kg)*	8	5 - 500	2 - 50	Soxhlet Extraction	Acid/base wash	EPA 1614 GC/HRMS
River						
Percent Solids (%)	6	40-90%	1%	-	-	EPA 160.3
TOC (%)	7	0.1 - 10	0.1	-	-	EPA 415.1
Metals Total Recoverable (mg/Kg):						
Arsenic	7	1.0 - 20	0.1	SW-846 3050B	-	EPA 200.8
Cadmium	7	0.1 - 5.0	0.1	SW-846 3050B	-	EPA 200.8
Copper	7	2.0 - 50	0.1	SW-846 3050B	-	EPA 200.8
Lead	7	2.0 - 20	0.1	SW-846 3050B	-	EPA 200.8
Zinc	7	10 - 100	5	SW-846 3050B	-	EPA 200.8
Semivolatiles (BNA) (*u*g/Kg)*	7	<16 - 10,000	16 - 320	SW-846	-	EPA 8270
PAHs (*u*g/Kg)*	7	<1 - 10	0.1	Soxhtherm Extraction	SilicaGel	EPA 8270
Chlorinated Pesticides (*u*g/Kg)*	7	<1 - 25	2 - 10	EPA 3541	-	EPA 8081
PCB Congeners (ng/Kg)*	6	5 - 2000	3 -10	Soxhlet Extraction	Acid/base wash	EPA 1668A GC/HRMS
PBDE Congeners (*u*g/Kg)*	6	5 - 2000	2 - 50	Soxhlet Extraction	Acid/base wash	EPA 1614 GC/HRMS

* = Reporting limits and expected ranges of results will vary for different organic analytes.
GC/HRMS = Gas Chromatography/High Resolution Mass Spectrometry.

List of analytes for semivolatile organics (BNA) analysis by EPA Method 8270.

Benzoic Acid [1]
Benzyl Alcohol
Bisphenol A
Butylbenzylphthalate
4-Bromophenyl-Phenylether
Di-N-Butylphthalate
Caffeine
Cholesterol [1]
4-Chloro-3-Methylphenol
4-Chloroaniline [1]
Bis(2-Chloroethoxy) Methane
Bis(2-Chloroethyl) Ether
Bis(2-Chloroisopropyl) Ether
2-Chloronaphthalene
2-Chlorophenol
4-Chlorophenyl-Phenylether
3B-Coprostanol [1]
3,3'-Dichlorobenzidine [1]
1,2-Dichlorobenzene [1]
1,3-Dichlorobenzene [1]
1,4-Dichlorobenzene [1]
2,4-Dichlorophenol
2,4-Dimethylphenol [1]
2,4-Dinitrophenol [1]
2,4-Dinitrotoluene
2,6-Dinitrotoluene
1,2-Diphenylhydrazine
2-Fluorophenol
Hexachlorobenzene
Hexachlorobutadiene [1]
Hexachlorocyclopentadiene[1]
Hexachloroethane [1]
Isophorone
p-Isopropyltoluene [1]
4,6-Dinitro-2-Methylphenol[1]
2-Methylphenol [1]
4-Methylphenol [1]
2-Nitroaniline
3-Nitroaniline [1]
4-Nitroaniline [1]
Nitrobenzene
2-Nitrophenol
4-Nitrophenol [1]
N-Nitroso-Di-N-Propylamine
N-Nitrosodiphenylamine
N-Nitrosodimethylamine
4-Nonyl Phenol [1]
Pentachlorophenol [1]
Bis (2-Ethylhexyl) Phthalate
Diethylphthalate
Dimethylphthalate
Di-N-Octyl Phthalate
Phenol
Pyridine
Triclosan
1,2,4-Trichlorobenzene[1]
2,4,5-Trichlorophenol
2,4,6-Trichlorophenol

[1] These compounds have inconsistent and poor recoveries.

Surrogates

D4-2 Chlorophenol
1,2-Dichlorobenzene-D4
2-Fluorobiphenyl
D5-Nitrobenzene
D5-Phenol
D10-Pyrene
D14-Terpenyl

List of analytes for polynuclear aromatic hydrocarbons (PAHs) analysis by EPA Method 8270 SIM.

Naphthalene
2-Methylnaphthalene
1-Methylnaphthalene
2-Chloronaphthalene
Acenaphthylene
Acenaphthene
Dibenzofuran
Fluorene
Phenanthrene
Anthracene
Carbazole
Phenanthrene, 3,6-dimethyl-
Fluoranthene
Pyrene
Retene
Benzo(k)fluoranthene
Benzo(a)pyrene
Perylene
Indeno(1,2,3-cd)pyrene
Dibenzo(a,h,)anthracene
Benzo(ghi)perylene
Chrysene
Benzo(b)fluoranthene
Benzo(a)anthracene

Surrogates
Naphthalene-D8
Acenaphthene-D10
Fluorene-D10
Phenanthrene-D10
Anthracene-D10
Fluoranthene-D10
Pyrene-D10
Chrysene-D12
Perylene-D12

List of analytes for chlorinated pesticides analysis by EPA Method 8081.

Aldrin
alpha-BHC
beta-BHC
delta-BHC
gamma-BHC (Lindane)
Chlorpyriphos
cis-Chlordane (*alpha*-Chlordane)
trans-Chlordane (*gamma*)
Chlordane (Tech)
Dacthal (DCPA)[1]
2,4'-DDD
4,4'-DDD
2,4'-DDE
4,4'-DDE
4,4'-DDMU[1]
2,4'-DDT
4,4'-DDT
Dieldrin
Endosulfan I
Endosulfan II
Endosulfan Sulfate
Endrin
Endrin Aldehyde
Endrin Ketone
Heptachlor
Heptachlor Epoxide
Hexachlorobenzene
Methoxychlor
Mirex
cis-Nonachlor
trans-Nonachlor
Oxychlordane
Pentachloroanisole[1]
Toxaphene

[1] These compounds have inconsistent and poor recoveries.

Surrogates
Decachlorobiphenyl (DCB)
Dibutylchlorendate (DBC)
Tetrachloro-m-xylene (TCMX)

Appendix D. Field Operation Procedures - GO-FLO Samplers

Effective control of contamination during the collection and handling of Puget Sound water column samples is of paramount importance. Many of the target analytes are ubiquitous on the sampling platform and equipment, often at several orders of magnitude higher than concentrations expected in ambient waters. Introduction of contamination at this stage will negate all care taken in subsequent analytical steps.

These field protocols are intended to provide a step-by-step procedure for the collection of contamination-free water samples from depth in marine waters. Guidance was taken from the trace constituent sampling literature, and to the extent possible EPA Method 1669 "clean hands/ dirty hands" techniques are employed. The resulting protocols are understood to be performance-based, and modifications to the sampling procedure will be enacted if alternate techniques can be demonstrated to improve effectiveness. Performance will be measured through the collection and analysis of blanks and replicates.

Overview

While there is no "standard" method for obtaining at-depth samples of marine waters for trace constituent analyses, a proven and widespread technique involves the deployment of one or more Teflon-coated GO-FLO samplers (General Oceanics, Inc.) on a non-metallic hydrowire (typically Kevlar). The procedures for Puget Sound sample water collection are based on this "standard" foundation as follows:

Two Teflon-coated GO-FLO samplers are mounted back-to-back on a non-metallic Vectran rope and lowered by hand to a predetermined, above-halocline sampling depth. The samplers are remotely triggered by Teflon-coated messengers. A non-metallic windlass drum and Acetal sheave facilitate recovery of the GO-FLO samplers and ensure that the rope does not contact potentially contaminating materials. Once on-board, the samplers are kept in polyethylene bags and secured in a purpose-built storage cabinet to minimize atmospheric exposure.

Subsampling activities are conducted within a simple portable glove box. Water samples are decanted from each GO-FLO sampler via Teflon tubing that connects to the sampler drain valve inside the storage cabinet and to a Teflon petcock inside the glove box. In this way, sample bottles for the various analytes are filled in an environment isolated from major air- and ship-borne contamination sources.

The GO-FLO samplers undergo a short cleaning procedure and are re-deployed to collect water from below the halocline. After retrieval and subsampling activities, a CTD rosette cast is conducted using a hydraulic winch and stainless steel cable. CTD sensors record on the downcast, and Niskin bottles collect additional water samples from above- and below-halocline depths on the upcast. Discrete salinity measurements from each GO-FLO sampler and Niskin collection are compared to evaluate the integrity of sampler closure. At the completion of a sampling cruise, the GO-FLO samplers undergo rigorous cleaning and storage procedures.

Principal Equipment

- 10-liter GO-FLO samplers (2) – Teflon-coated with Teflon drain valves and air vent screws; spare parts kit.
- Vectran 12-strand rope (600 ft) – marked at 1- and 5-meter increments.
- Teflon-coated messengers.
- Snatch block and non-metal sheave – Ronstan single snatch block with Trunnion head and Acetal sheave.
- Non-metallic line weight – lead "fish" encased in epoxy resin.
- Cabinet for clean storage and transportation of GO-FLO samplers – constructed of UHMW polyethylene and Teflon materials.
- Large polyethylene bags capable of completely enclosing a single 10-liter GO-FLO sampler.
- Elasticized polyethylene "shower caps" (Saranwrap Quick Covers).
- Talc-free Nitrile gloves.
- Clinometer or like instrument.
- Refractometer or YSI Conductivity Meter.
- Marine flight compact rosette:
  - CTD – Model SBE25 (Sea-Bird Electronics, Inc.).
  - 1.5-liter Niskin bottles (4) – silicon springs and O-rings; AFM model SBE32 (Sea-Bird).
- Hydraulic winch with ~1200 ft of stainless steel aircraft cable.

General Rules

- Personnel must wear clean Talc-free Nitrile gloves during all sampling and subsampling operations. If glove contamination is detected or suspected, work must be halted, the contaminated gloves removed, and a new pair of clean gloves put on. Wearing multiple layers of clean gloves will allow the old pair to be quickly stripped with minimal disruption to the work activity.
- The upper ball valve of each GO-FLO sampler must be covered with an elasticized polyethylene "shower cap" at all times except during active deployment. The drain valve of each GO-FLO sampler must be covered with a Nitrile glove at all times except during active deployment and sample decanting.
- Samplers are transported around the vessel within polyethylene bags and are handled only by gloved personnel. When transferring the GO-FLO samplers to or from the storage cabinet, work rapidly and minimize the time that the inside of the cabinet is exposed to outside air. The samplers should never be placed directly on deck or any hard surface where foreign particles might be lodged in the ball valves and cause contamination of subsequent samples. Improper use and handling of GO-FLO samplers can result in permanent contamination.
- Ensure at all times that the Vectran 12-strand rope does not make contact with any part of the vessel (other than the Acetal sheave and windlass drum). When not in use, remove the rope from the snatch block and coil it inside a clean polyethylene bag. Place the bagged rope within a sealed plastic container to minimize exposure to air- and ship-borne contaminants.
- Store the snatch block and the line weights in clean polyethylene bags when not in use.

- All polyethylene storage bags are considered "one-time use." That is, once a piece of equipment is removed from its storage bag, a separate clean bag must be used for subsequent storage.

Preparation

- Upon arrival at the sampling location, turn the engine off and wait 10 minutes before placing any sampling equipment in the water. Allow the vessel to drift during all sampling operations and conduct all sampling on the windward side of the vessel to minimize contamination from shipboard sources.
- Remove the snatch block from its polyethylene storage bag and secure it to the A-frame.
- Tie off the bitter end of the Vectran rope to a plastic cleat to secure it in case of mishap. Feed the working end of the rope over the sheave, being careful not to touch any metal objects that could embed foreign particles in the braid. Keep as much standing rope inside the covered plastic container as possible.
- Remove the line weights from storage bags and attach the weights to the loop eye at the working end of the Vectran rope. Lift the weights overboard and lower them into the water so that approximately 10 meters of rope extend above the weights. Secure the rope to a plastic cleat to maintain this configuration, and replace any extra rope into the rope storage box.
- Arm the GO-FLO samplers and secure each to the Vectran rope – *This is a 2-person activity and personnel must wear clean gloves*. Layering of gloves is recommended to facilitate rapid discarding of dirty/contaminated gloves. Technicians should work carefully but quickly, striving to minimize the duration of atmospheric exposure for GO-FLO samplers secured to the Vectran rope. Follow the procedures listed below for the first GO-FLO sampler, and then repeat the procedure to arm and secure the second GO-FLO sampler.
    - Technician #1 (T1) opens the storage cabinet. Technician #2 (T2) quickly removes the sampler (keeping it inside the polyethylene bag in which it was stored). T1 closes and secures the cabinet.
    - T1 places a clean polyethylene bag flat on a stable surface away from contamination sources. T2 places the GO-FLO sampler (still inside its polyethylene storage bag) on the bag.
    - T1 puts on clean gloves and reaches inside the storage bag to arm the GO-FLO sampler; contact with the GO-FLO sampler is only made by T1. T2 assists by stabilizing the sampler and manipulating the storage bag for T1.
        - Reverse the spring over the pulley to release tension.
        - Pull the pressure release valve all the way out and position the lanyard poly-balls on either side between the valve and the stainless steel frame.
        - Attach the lanyard to the plunger mechanism by inserting the slack loop into the trip release.
        - Re-span the spring by rotating it over the pulley so that the spring and the lanyards are under tension.
        - *Optional:* Test the closing mechanism to verify that it functions properly.
            - Push the pressure release valve to cause the ball valves to move to the open position.

        - Press the plunger to release the lanyard, which results in bottle closure.
        - Re-arm the GO-FLO sampler after this check.
    - T2 carries the armed sampler (still inside the storage bag) to the Vectran rope. T1 reaches inside the storage bag and checks that the protective "shower cap" and Nitrile glove are securely covering the upper ball valve and drain valve, respectively. T1 then removes the GO-FLO sampler from the storage bag. T2 discards the storage bag and secures the GO-FLO sampler to the Vectran rope at the 10-meter marking above the line weights.
    - T2 puts on clean gloves, and the above procedure is repeated for the remaining GO-FLO sampler. Mount the second sampler just below the first, with the top of its plunger mechanism approximately one meter below the base of the upper sampler.
- To prepare the samplers for serial firing, attach a Teflon-coated messenger by its lanyard to the plunger mechanisms of the upper GO-FLO sampler, and then snap the messenger onto the Vectran rope between the two samplers.

Deployment

- GO-FLO samplers armed using the above procedures are set to be deployed in a *closed* position to avoid potential contamination from the surface microlayer. If the number of line weights needed to overcome the buoyancy of the air trapped in the GO-FLO samplers becomes prohibitive, consider deploying the samplers in the *open* position. The ball valves can be easily released to the *open* position by depressing the pressure release piston. Note that the poly-balls on the lanyards are under tension and will snap quite suddenly when the pressure release piston is pressed in. Keep hands well clear of the poly-balls, and use a pen wrapped in either a polyethylene bag or a clean glove to depress the pressure valve.
- By convention, at the water surface the GO-FLO samplers are at 0 meters depth. Record the depth marking at which the GO-FLO samplers are mounted on the Vectran rope. This length of rope between the samplers and the line weights is called the "Weight Segment". In calm conditions when the rope angle (deviation from vertical) is negligible, the length of rope from the depth of the GO-FLO samplers in the water column to the surface (called the Sampler Segment) is equal to the total length of rope payed out (Total Length) minus the Weight Segment.

$$\text{Sampler Segment} = (\text{Total Length}) - (\text{Weight Segment})$$

- Immediately before deployment, remove the protective "shower cap" from the upper ball valve and the Nitrile glove from the drain valve of each GO-FLO sampler. Wearing clean gloves, check that all drain valves and air vent screws are tightly closed.
- Slowly lower the GO-FLO samplers by hand to ~15-20 meters depth. The hydrostatic pressure release valve should cause the ball valves to open at approximately 10 meters.
- Verify that the ball valves have opened properly: the parcel of air trapped in each sampler will be visible as it bubbles to the surface. If bubbles are not seen and there is concern that a sampler did not open, raise the rope slowly until the status of the ball valves can be assessed visually. However, note that contamination risks increase as the samplers approach the surface and the vessel. If water conditions are turbid or rough, assume that the bottle is open and accept that redeployment may be necessary. The weight of a retrieved sampler will be indicative of it being empty or filled with water.

- Lower the GO-FLO samplers to the desired sampling depth.
- Pay out additional rope as needed to adjust for significant rope angles (e.g., caused by strong currents or wind).
  - Read the Total Length and subtract the Weight Segment to determine the Sampler Segment.
  - Measure the angle of the rope from vertical (called Rope Angle) using a clinometer.
  - Calculate the actual depth of the GO-FLO samplers, the "Sampler Depth":

    (Sampler Depth) = (Sampler Segment) x cosine (Rope Angle)

  - Use the vessel's depth sounder for general verification (GO-FLO samplers should be detected by the sounder).
- Remove a Teflon-coated messenger from its storage bag, attach it to the Vectran rope, and release. This messenger will trigger closure of the upper GO-FLO sampler, followed by release of the serial messenger and subsequent triggering of the lower GO-FLO sampler.
- Allow adequate time for the messenger to reach the GO-FLO samplers before retrieval.

Recovery

- Use the windlass to recover the GO-FLO samplers, and feed the rope into the storage container as it is collected to minimize the potential for contact with contamination sources. It may be necessary to have the vessel's engine running to avoid complete draw-down of the battery by the windlass. In that case, engine assistance may only be used to raise the samplers to a depth of 10 meters. Above (i.e., shallower than) 10 meters depth, the engine must be off to avoid introducing excess contamination to the water column through which the GO-FLO samplers will travel. After the engine is off, allow at least one minute for ship-influenced water to dissipate before resuming sampler recovery.
- Once the GO-FLO samplers are retrieved to deck level, quickly inspect for leakage. If leakage is detected or suspected, prepare all samplers for re-deployment as follows:
  - Empty each GO-FLO sampler.
  - Rinse the sample chamber, the drain valve, and the air vent screw with de-ionized (DI) water.
  - Wearing clean gloves, and with the GO-FLO samplers still mounted on the Vectran rope, re-arm the samplers.
  - Re-deploy the GO-FLO samplers.
- If no leakage is apparent, immediately place clean polyethylene "shower caps" on the GO-FLO samplers' top ball valves. Rinse the samplers' drain valves with DI water and cover each with a Nitrile glove.
- Disengage the GO-FLO samplers individually and transport each to the storage cabinet. *This is a 2-person activity and all personnel must wear clean gloves*. Follow the steps below for the first GO-FLO sampler, and then repeat for the second sampler.
  - T2 supports the GO-FLO sampler to be removed, and T1 releases the screws that secure the sampler to the line.
  - While T2 holds the GO-FLO sampler, T1 places a clean polyethylene bag over the unit. T2 adjusts so that the sampler is completely contained in the bag.

- T2 carries the GO-FLO sampler to the storage cabinet; T1 acts as a spotter. The sampler should not make contact with any part of the vessel.
- Working quickly but carefully, T1 opens the storage cabinet and T2 places the GO-FLO sampler inside in an upright position (it should remain in the polyethylene bag). T1 secures the GO-FLO sampler inside the cabinet using bungee cords.
- T2 puts on clean gloves, opens the GO-FLO sampler's air vent screw, and removes the glove from the drain valve. T2 removes the Teflon stopper from the port at the bottom of cabinet.
- Inside the glove box (situated under the cabinet), T1 removes a clean Teflon tubing/petcock assembly from its storage bag. The open end of the tubing remains covered in a small plastic sheath, and the petcock remains protected by a plastic glove until subsampling activities commence. T1 feeds the tubing from inside the glove box through the port on the underside of the cabinet, and checks that the petcock inside the glove box is closed.
- T2 receives the Teflon tubing inside the cabinet, removes the plastic sheath, and connects the tubing to the drain valve. T2 opens the drain valve, and T1 makes sure that the petcock isn't leaking in the glove box. T2 closes the cabinet.

- Wearing clean gloves, remove the line weights and place them in polyethylene bags for storage. Release the Vectran rope from the snatch block. Coil the rope, place it in a polyethylene bag, and store it within the sealed container to protect against air- and ship-borne contaminants. Place the snatch block in a polyethylene bag for storage.

Subsampling

- Begin decanting samples from the GO-FLO samplers as soon as possible to prevent settling, biological activity, or adsorptive losses.
- Prior to the cruise, pre-labeled bottles for a specific sampling location and depth (henceforth called a "set") will have been assembled in two large, layered polyethylene bags. Wearing clean gloves, remove the outer polyethylene bag and transfer the set (still contained in the inner polyethylene bag) to the inside of the glove box.
- Place a wide-mouthed waste container inside the glove box.
- The flow of water from a GO-FLO sampler is controlled from inside the glove box using the Teflon petcock. Remove the protective Nitrile glove to access a petcock. Be extremely careful, and ensure that nothing in the glove box makes contact with the exposed petcock at any time.
- Drain the first 0.5 liters of water from each GO-FLO sampler into the waste container before decanting for analyte samples.
- Decant a small (<50 mL) sample from each GO-FLO sampler, and use a refractometer or YSI Conductivity Meter to determine the salinity of the water in each sampler. Compare the salinities of same-depth GO-FLO sampler collections to evaluate the integrity of sampler closure; salinities that do not agree indicate a problem with the deployment. If salinities do not match, the GO-FLO samplers should be emptied, rinsed, and re-deployed.
- Decant water whole-water samples.

- Remove the analyte sample bottle(s) from the set bag as they are needed, and follow analyte-specific handling procedures (e.g. bottle rinses).
- The recommended sequence for decanting analyte samples is as follows:
  - GO-FLO sampler #1:
    1. Total Suspended Solids – 1 L
    2. PCB Congeners – 2 L
    3. PBDE Congeners – 1 L
    4. Chlorinated Pesticides – 3 L
  - GO-FLO sampler #2:
    5. Semivolatile Organics – 3 L
    6. PAHs – 3 L
    7. Total Metals – 1 L
- After each analyte sample bottle is filled, attach a sample tag with the required identification information (e.g., date/time, location, analyte, etc.). Seal the individual bottle inside a polyethylene bag and then inside another polyethylene bag. Place the double-bagged sample bottles in the set bag.
- *Do not* allow the mouth of an analyte bottle to contact the petcock at any time.
- *Do not* swirl or shake the GO-FLO samplers to re-suspend settled material, as this can alter partitioning between dissolved and particulate size fractions.

- Observing "clean hands/dirty hands" guidelines, set up the in-line filtration apparatus for collecting a dissolved metals sample from GO-FLO sampler #2. Flush the metals filter and tubing with 500 mL of sample water, and then rinse the dissolved metals bottle and cap with filtrate. Collect 1 liter of filtered sample for dissolved metals determination.
- When all analyte samples have been decanted, carefully remove the set bag (filled with all of the sample bottles) from the glove box and place it in a clean, large polyethylene bag. Place completed sample set in a cooler on ice.

Between Stations or Sampling Events

- To minimize the risk of contamination to the GO-FLO samplers during short-term storage, adhere to the following precautions:
  - Store the samplers in polyethylene bag(s) inside the storage cabinet, and only remove a sampler just prior to deployment.
  - All valves (i.e., ball valves, air vent screws, drain valves) should be stored in their final closed position.
  - Cover the upper ball valve with an elasticized "shower cap," even when the sampler is inside a polyethylene storage bag.
  - Protect the drain valve by storing it covered by a Nitrile glove.
- If contamination of any GO-FLO sampler is suspected, stop using the sampler and return it to the lab for a thorough cleaning.

Extended Storage

- Prior to long-term storage, rinse the GO-FLO samplers with DI water.
- Ensure that all valves are in their final closed position.
- Cover the upper ball valve with a clean elasticized "shower cap," and place a clean Nitrile glove over the drain valve.
- Store the GO-FLO samplers in one or more clean polyethylene bag(s) within the storage cabinet, and pack the entire storage cabinet in another polyethylene bag if possible.
- If GO-FLO samplers are not to be used within 30-60 days, return the samplers to the lab and schedule a thorough cleaning and maintenance. Procedures will be guided by existing standard techniques for the cleaning of Teflon-coated sampling equipment for priority pollutant sampling.

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Appendix E. Field Operation Procedures - CTD Deployment

The Conductivity/Temperature/Depth profiler (CTD) mounted on a rosette unit is deployed as soon as possible after all subsamples have been drawn from GO-FLO samplers. Project-specific considerations for CTD deployment and Niskin bottle water collections are addressed below. Existing standard operating procedures for the compact marine flight rosette will be employed (Ecology's Marine Ambient Monitoring Section, pers. comm.), and as such are not comprehensively detailed here.

- Deployment of the CTD rosette will require use of the hydraulic winch with the vessel's engine running, creating a contamination-prone environment on-deck. Ensure that the GO-FLO samplers and all associated equipment are stored and secure prior to the CTD cast.
- Program the firing depth of the Niskin bottles to match the depth at which water samples were collected by GO-FLO samplers. Trigger two Niskin bottles at each sampling depth for redundancy.
- Secure the CTD rosette and weights (if necessary) to the stainless steel cable. Do not use the coated weights at this time, for there is a high risk of contamination from the equipment and steel cable.
- Lower the CTD rosette unit at a slow and constant rate, typically 0.5 m/s. Data recorded during the downcast will be used in later analyses; CTD and auxiliary sensor data from the upcast are discarded.
- Raise the CTD rosette unit at a velocity of approximately 0.5 m/s. Niskin bottles close at pre-programmed depths. The slow upward velocity ensures that water is obtained from a discrete depth, minimizing the vertical "smearing" of the collection through a depth interval.
- After the CTD rosette is recovered to deck level, immediately inspect the Niskin bottles for leakage. If leakage is detected or suspected, empty the Niskin bottles and prepare for re-deployment. Wait at least 5 minutes to allow quiescent conditions to re-establish before re-deploying.
- Turn off the engine off before commencing sample decanting and processing activities. Personnel must wear clean gloves during all subsampling procedures.
    - Measure sample water salinity from each Niskin bottle using a refractometer or YSI Conductivity Meter. Compare salinities of water samples collected at the same depth by Niskin bottles and GO-FLO samplers. Anomalous same-depth salinities may indicate incomplete bottle closure (and thus potential sample contamination by water from other depths), collection from the wrong sampling depth, or the influence of a dynamic water body. Discrete salinities should later be compared with the CTD salinity profile for further evaluation.
        - If Niskin sample salinities are comparable and agree with GO-FLO sampler salinities, then either Niskin bottle's contents can be used for TOC/DOC subsampling.
        - If Niskin sample salinities are comparable but disagree with GO-FLO sampler salinities:

- ☐ The Niskin bottles or the GO-FLO samplers may have closed at the wrong depth. Consider re-deployment of the CTD rosette to evaluate further.
- ☐ In areas affected by strong currents or wind-driven mixing, water at the sampling depth may have changed significantly between collection by the GO-FLO samplers and by the Niskin bottles. Make note of such physical factors and draw TOC/DOC subsamples from the Niskin collections, despite the discrepancy.

    - If Niskin sample salinities are *not* comparable but one agrees with GO-FLO sampler salinities, decant TOC/DOC subsamples from the Niskin bottle that has the same salinity as the GO-FLO sampler salinities.
    - If Niskin sample salinities are *not* comparable and both disagree with GO-FLO sampler salinities, new Niskin bottle samples must be collected before TOC/DOC subsamples can be drawn. The Niskin bottles may have closed at different depths, or sample integrity may have been compromised by incomplete bottle closure.

  - Acquire water for CTD and sensor calibration by decanting from one of the Niskin bottles.
  - Decant water from one of the Niskin bottles into TOC and DOC sample bottles. Conduct the necessary processing and filtration.

- Upload CTD data as needed (i.e., on-station, between stations, or post-cruise).
- Clear the CTD memory before the next cruise.

Appendix F. Field Operation Procedures - Collecting Suspended Sediment Using Flow-Through Centrifuges

(from Gries and Sloan, 2008)

Preparing for field work

- All equipment surfaces that will contact river water or centrifuged sediment will be cleaned appropriately (Ecology, 2006, 2008) to remove metals and organic residue:
  - Wash with phosphorus free soap (e.g., Luminox).
  - Rinse with a large volume of tap water.
  - Rinse with 10% nitric acid.
  - Rinse with deionized/distilled water and let dry.
  - Rinse with acetone and let air dry.
  - Rinse with hexane and let air dry.
  - Cover with foil.
- Replace consumables that have been used.
- Complete any maintenance or repairs.
- Assemble checklists and field logs.
- Label containers.
- Assemble field gear needed (from checklists).
- Complete field itinerary.

Set-up and pre-sampling

- Arrive at the sampling site and position centrifuge trailer so that:
  - It does not obstruct the road or bridge traffic.
  - Personnel have adequate access to the interior as well as exterior storage compartments.
  - It is easy to set up for pump sampling.
  - It is reasonably level.
- Set up centrifuge according to procedures described in operations manual (Seiders, 1990).
- Prepare tubing, attach pumps, prepare fish for deployment, and calibrate equipment.
- Start centrifuges and recycle approximately 10L of organic-free water through the entire system, including all sample tubing, for 30 minutes.
- Fill a 1L glass jar with water from the effluent (field blank).
- Profile the stream with the conductivity meter, especially near the streambed, to determine presence and extent of salt wedge.
- Profile the stream with the StreamPro according to the SOP to obtain flow and depth characteristics (minimum 4 passes).

- Use in-line sediment sensor (LISST-Streamside, Sequoia Scientific, Inc.) or turbidity meter (as surrogate) to map horizontal and vertical variability in profile of particle size distribution (PSD) in suspended sediments. Use the depth, flow, and particle size distribution/turbidity information to estimate most representative location(s) to place centrifuge intake tube. The default location will be center channel and 0.6 times the maximum depth of the freshwater layer.
- Set up tubing and pumps for sampling.
- Turn on pumps and recycle water back to the river for 10 minutes to flush the tubing, establish a constant flow, remove any bubbles in the tubing, and monitor for leaks.

Sampling

- After pumps are ready, attach tubing to the centrifuge apparatus and record in field logs: start time, tide phase (if tidal effects), stage height, centrifuge status, intake tube location, hertz, pump speed, and water flow.
- Start pumping to collect sandy suspended sediment on sieve by connecting the tubing and recording start time, tide phase, stage height, fish location, pump speed, and water flow.
- Monitor centrifuges for at least 20 minutes: influent, effluent, check for leaks, adjust flows, intake tube position, and overall operation.
- Collect samples of TSS in river water, centrifuge influent, and centrifuge effluent at designated times. Samples will be a combination of discrete and composite samples. Replicate and blank samples will also be taken.
    - Effluent water samples will be taken from a compositor located in the collection basin, while centrifuges are running.
    - Influent water samples will be taken by disconnecting the tubing just before the water enters each centrifuge. These 2 water samples will be combined into 1 influent sample.
    - Reconnect tubing to centrifuges.
- Measure flow and conductivity at designated time intervals.
- Record site conditions, weather, boat traffic, equipment performance, and any other important information in the log.
- Record changes in position of intake tube on centrifuge sample sheet including: tide phase, stage height, fish location, pump speed, water flow, and reason for relocation in the comments/notes column.
- Stop centrifuges and remove accumulation of suspended sediments using a Teflon spatula when substantial accumulation is predicted based on pumping rates and TSS. (Accumulated pellet will be removed to prevent it from contacting the discs in the bowl and decreasing retention efficiency). Place material in a pre-cleaned glass jar and seal. Put jar in cooler with ice. Record centrifuge data: stop time, elapsed time, tide phase, stage height, and total gallons pumped. Record sample data: collection time, MEL ID, sample ID, estimated amount of sample, and sample information.
- Restart centrifuges to continue collecting suspended sediment, recording the appropriate data.

- Remove sand-sized sediments from sieves when accumulation starts to restrict flow. Place sample in a pre-cleaned glass jar and put in cooler with ice. Record sieve data: stop time, elapsed time, tide phase, stage height, and estimated total gallons pumped. Record sample data: collection time, MEL ID, sample ID, estimated amount of sample, and sample information.
- Restart sieve apparatus to continue collecting sand-sized suspended sediments, recording the appropriate data.

Post-sampling

- When sampling is complete, stop centrifuges and pumps. Remove all accumulated sediments from the centrifuge and sieves, following the same procedures as removing accumulated sediments above.
- Take post-sampling flow measurements.
- Disassemble all equipment.
- Return to Ecology Operations Center and Headquarters in Lacey.

Sample processing

- Homogenize the centrifuge pellet using a stainless steel spatula.
- Split sample for analysis of study parameters.
- If needed, prioritize, with laboratory staff input, which contaminants to measure with sample mass.
- Send samples to appropriate laboratories, using chain-of-custody procedures.

Appendix G. Glossary, Acronyms, and Abbreviations

Ambient: Background (environmental).

Analyte: Water quality constituent being measured (parameter).

Bioaccumulate: Build up in the food chain.

Biota: Flora (plants) and fauna (animals).

Box model: A computer prediction tool to simulate the movement of water and pollutants within a waterbody.

Congener: In chemistry, congeners are related chemicals. For example, polychlorinated biphenyls (PCB) are a group of 209 related chemicals that are called congeners.

Flux: Amount that flows through a unit area per unit time.

Halocline: A strong vertical salinity gradient.

Loading: The input of pollutants into a waterbody.

Marine water: Salt water.

Parameter: Water quality constituent being measured (analyte).

Sediment: Solid fragmented material, that is transported and deposited by water, ice, or wind, that forms layers on the earth's surface.

Specific conductivity: A measure of water's ability to conduct an electrical current.

Thalweg: The deepest and fastest moving portion of a stream.

Acronyms and Abbreviations

BNA	Base/Neutral/Acids (semivolatile organics)
CTD	Conductivity/Temperature/Depth profiler
DOC	Dissolved organic carbon
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management system
EPA	U.S. Environmental Protection Agency
FISP	Federal Interagency Sedimentation Project
GPS	Global Positioning System
HEM	Hexane-extractable materials ("oil and grease")
JEMS	Joint Effort to Monitor the Strait of Juan de Fuca
MEL	Manchester Environmental Laboratory
MQO	Measurement quality objective

PAH	Polynuclear aromatic hydrocarbon
PBDE	Polybrominated diphenyl ether
PCB	Polychlorinated biphenyl
PSTLA	Puget Sound Toxics Loading Analysis
QAPP	Quality Assurance Project Plan
QC	Quality control
RPD	Relative percent difference
SOP	Standard Operating Procedure
SPM	Suspended particulate matter
TOC	Total organic carbon
TP	Total phosphorus
TPH	Total petroleum hydrocarbons (-gas and –diesel)
TPN	Total persulfate nitrogen
TSS	Total suspended solids
USGS	U.S. Geological Survey

NO_2 - NO_3	Nitrite and nitrate nitrogen
NH_3	Ammonia nitrogen
PO_4^{-3}	Orthophosphate phosphorus

As	Arsenic
Cd	Cadmium
Cu	Copper
Pb	Lead
Zn	Zinc

mg/L = milligram/liter (parts per million)
*u*g/L= microgram/liter (parts per billion)
ng/L = nanogram/liter (parts per trillion)
pg/L = picogram/liter (parts per quadrillion)