Fidalgo Bay Sediment Investigation
Anacortes, WA

Sediment Sampling and Analysis Plan

FINAL

Prepared for

Washington State Department of Ecology
Toxics Cleanup Program
300 Desmond Drive
Lacey, Washington 98504

Prepared by

Science Applications International Corporation
18912 North Creek Parkway, Suite 101
Bothell, WA 98011

September 17, 2007

Publication No. 08-09-108

If you need this publication in an alternative format, please contact the Toxics Cleanup Program at (360) 407-7170. Persons with a hearing loss can call 711 for Washington Relay Service. Persons with a speech disability can call (877) 833-6341.

Download this publication from the Department of Ecology's Web Site at
http://www.ecy.wa.gov/biblio/0809108.html

For additional copies of this publication, please contact:

Department of Ecology
Toxics Cleanup Program
P.O. Box 47600
Olympia, WA 98504-7600
(360) 407-7170

Refer to Publication No. 08-09-108

Table of Contents

List of Tables

List of Figures

Appendices

List of Acronyms

CRI	Color Rendering Index
CSL	Contaminant Screening Level
DGPS	Differential Global Positioning System
DMMP	Dredged Material Management Program
DMMU	dredged material management unit
DUA	Decision Unit Area
ECOLOGY	Washington State Department of Ecology
ERM	Effects Range Median
GPC	gel permeation chromatography
HASP	Health and Safety Plan
HPAH	high molecular weight polynuclear aromatic hydrocarbon
LAET	lowest apparent effects threshold
LCS/LCSD	laboratory control sample/laboratory control sample duplicate
LPAH	low molecular weight polynuclear aromatic hydrocarbon
MDL	method detection limit
MS/MSD	matrix spike/matrix spike duplicate
OC	organic carbon
OHWM	ordinary high water mark
OSI	Organism-Sediment Index
PAH	polynuclear aromatic hydrocarbon
PARCC	precision, accuracy, representativeness, completeness, and comparability
PCB	polychlorinated biphenyl
PPE	personal protective clothing
PSEP	Puget Sound Estuary Program
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
REMOTS®	Remote Ecological Monitoring of the Seafloor
RI/FS	Remedial Investigation/Feasibility Study
RPD	redox potential discontinuity
SA	Selective Availability
SAIC	Science Applications International Corporation
SAP	Sampling and Analysis Plan
SEDQUAL	sediment quality (database)
SMARM	Sediment Management Annual Review Meeting
SMS	Sediment Management Standards
SOP	standard operating procedures
SPI	Sediment Profile Imaging
SQS	Sediment Quality Standard
SVOC	semi-volatile organic compound
TBT	tributyltin
TCP	Toxics Cleanup Program
TDL	target detection limit

TEF	toxic equivalent factors
TEQ	toxic equivalent quotation
TOC	total organic carbon
TPH	total petroleum hydrocarbons
TS	total solids
TVS	total volatile solids
USCS	Unified Soil Classification System
USEPA	U.S. Environmental Protection Agency
UV	ultraviolet
WDNR	Washington State Department of Natural Resources
WHO	World Health Organization

1.0 Introduction

Fidalgo Bay has been identified by the Washington State Department of Ecology (Ecology) under the Toxics Cleanup Program's (TCP) Puget Sound Initiative for focused sediment cleanup and source control. Previous sediment quality investigations have indicated that contaminants have exceeded the Washington State Sediment Management Standards (SMS) Chapter 173-204 WAC (Ecology 1995). The purpose of this combined Sampling and Analysis Plan (SAP) and Quality Assurance Project Plan (QAPP) is to conduct a sediment investigation to characterize the sediment quality of Fidalgo Bay, Anacortes, WA. This work plan includes the components of the SAP and QAPP requirements per WAC 173-340-820. The plan also specifies analytical procedures in accordance with WAC 173-340-830.

1.1 Site Description

Fidalgo Bay is a generally shallow embayment, bounded to the west by the City of Anacortes and to the east by March Point (Figure 1-1). Tideland filling, shoreline armoring, and over-water structures are present throughout the bay. A railroad trestle, owned by the City of Anacortes, runs across the southern part of the bay. Southern Fidalgo Bay has been proposed as an Aquatic Reserve to be managed by the Washington State Department of Natural Resources (WDNR 2007). It contains expanses of eelgrass and extensive tide flats that support spawning and rearing of forage fish (e.g., Pacific herring, surf smelt, and sand lance) and juvenile salmonid migration. Other species that use the bay include bald eagles, peregrine falcons, migratory waterfowl, wading birds (e.g., great blue heron and least sandpiper), and abundant marine life. Water quality monitoring indicates the bay is generally well mixed vertically and has levels of dissolved oxygen, fecal coliform, and nutrients within state guidelines (WDNR 2007).

Fidalgo Bay has been utilized by a number of industries including saw mills and plywood manufacturing, paper production, oil refining, and boat building. Across the bay from Anacortes are two oil refineries that produce gasoline, diesel fuel, and propane. There have been a number of accidental releases from these sites as well as a multi-year release from the Cap Sante Marina fueling station. The bay has been included in a nationwide monitoring program for the antifouling agent tributyltin (TBT) due to the presence of the marina, boat yards, and oil tankers (Ecology 1997).

1.2 Previous Investigations

The following sections summarize previous environmental investigations that have been conducted in Fidalgo Bay over the past 10 years. The studies are discussed in chronological order based on when the associated sampling activities occurred. Ecology's Environmental Information Management (EIM) online database was used for the historical data search. Sampling locations from the previous investigations are shown in Figure 1-2.

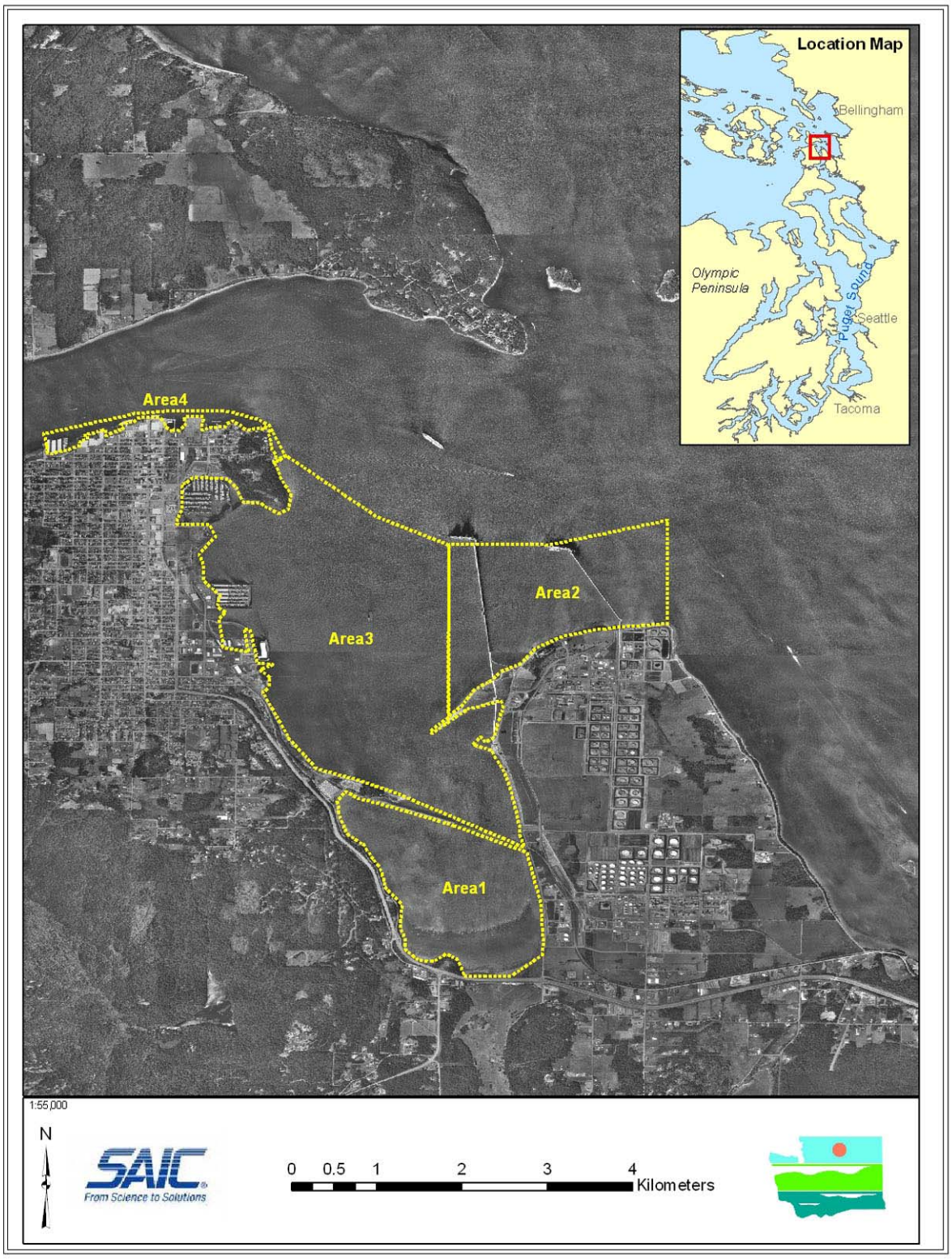

Figure 1-1. Fidalgo Bay Study Area

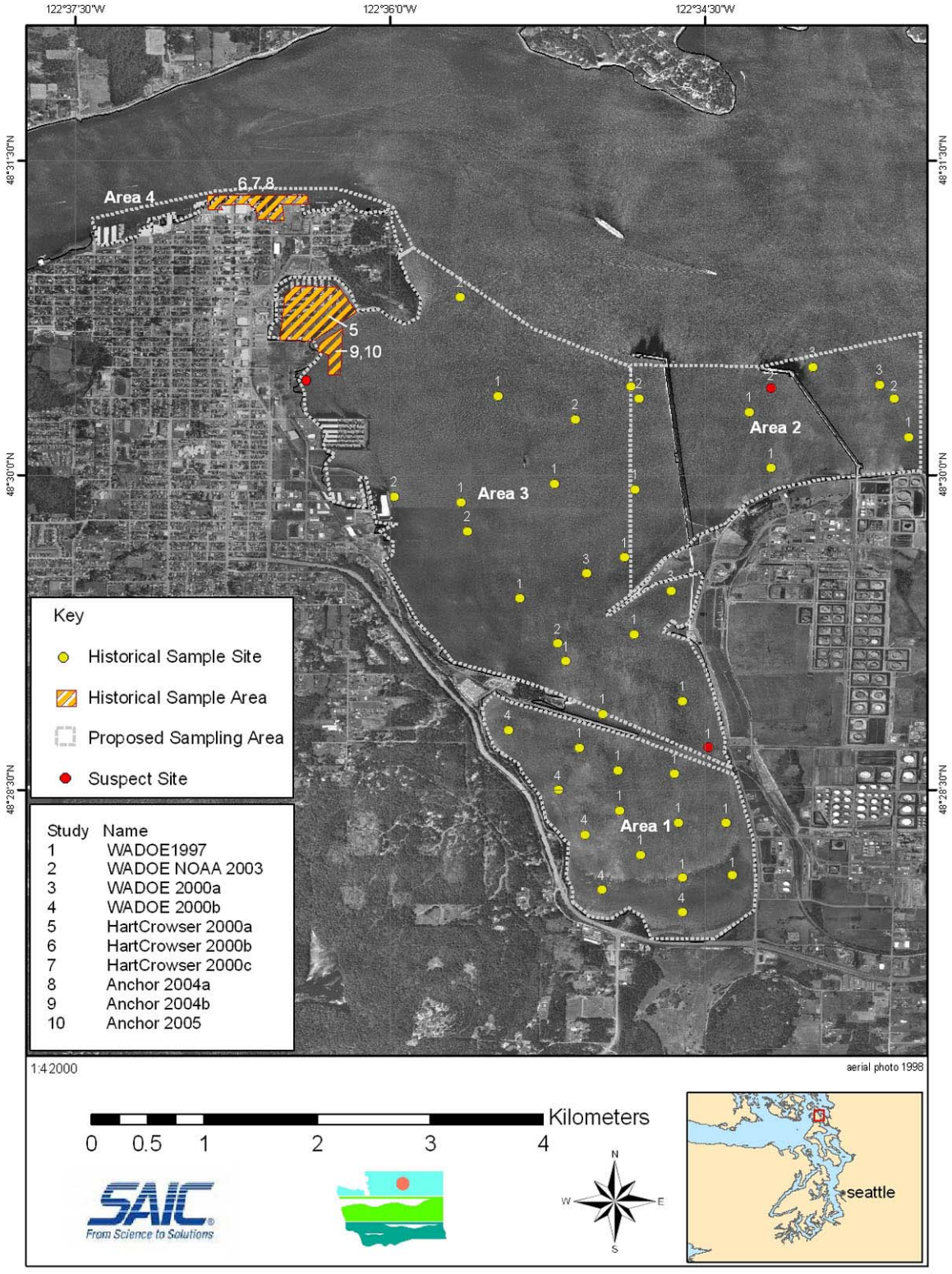

Figure 1-2. Fidalgo Bay Area Historical Sampling Sites

1.2.1 Ecology Survey for Petroleum and Other Contaminants in Fidalgo Bay Sediments (Ecology 1997)

Ecology conducted a sediment survey in April 1997, 6 years after approximately 20,000 gallons of North Slope crude spilled in Fidalgo Bay in February 1991. The survey attempted to determine how widespread the oil contamination was and if sediments met chemical criteria. A total of 27 locations were sampled from the head of Fidalgo Bay and the east side of March Point. Three background sites were sampled in Padilla Bay. Each sample collected for analysis was a composite of three individual surface sediment (0–10 cm) grabs. All samples were analyzed for total petroleum hydrocarbons (TPH). A subset of 14 samples were analyzed for metals (zinc, chromium, copper, arsenic, lead, cadmium, silver, and mercury), semivolatile organic compounds (SVOCs), polychlorinated biphenyls (PCBs), and sediment conventionals (grain size and total organic carbon). Five locations in the outer bay were analyzed for organotins.

No oil or sheens were observed on the samples during field sampling. TPH analysis did not match crude oil. Motor oil was detected from a site close to the western shore of March Point near a culvert running under March Point Road. This site (#3) exceeded sediment quality standards (SQS) for total high molecular weight polycyclic aromatic hydrocarbons (HPAHs) and for the individual compounds chrysene and fluoranthene but did not exceed cleanup screening levels (CSLs). Zinc and chromium concentrations were significantly higher in the inner bay sediments than in the outer bay. Metals and other organics were below their respective SQS criteria. Polynuclear aromatic hydrocarbon (PAH) concentrations in the bay were generally two to four times higher than concentrations measured in reference areas. PCBs were detected at only two inner bay sites at concentrations of 9 and 10 µg/kg total PCBs. Tributyltin was detected at 0.1 – 1.9 µg/kg at three of five outer bay sites tested. The report concluded that the chemical quality of Fidalgo Bay sediments was generally good. PAHs were moderately elevated (10 -100 µg/kg) through much of the bay with combustion (which produces pyrogenic PAHs) indicated as the primary source.

1.2.2 Joint Ecology/NOAA Survey for Chemical Contamination, Acute Toxicity, and Benthic Impacts in Puget Sound Sediments (Ecology and NOAA 2003)

Surficial sediments were collected from 300 randomly chosen locations throughout Puget Sound, including 12 within Fidalgo Bay or just to the north in Padilla Bay. Based on sediment quality triad, eight of the sites were rated as high quality; sites 51, 54, and 56 were rated intermediate-high quality; and site 48 was rated intermediate-degraded. Site 48 was located off the northern shore of March Point and is a site of interest for further investigation. Three of the locations demonstrated some indication of statistically significant toxicity in larval development or cytochrome P450 induction test. Benthic infaunal index for evenness was in the lower quartile for one location and total abundance was in the lower quartile for one location. Seven locations exceeded the SQS for benzoic acid, 4-methyphenol and phenol. Two sites exceeded the SQS for at least one contaminant besides benzoic acid, 4-methylphenol and phenol. No sites exceeded CSL standards.

1.2.3 Ecology Screening Analysis for Metals and Organic Compounds in Shellfish from Padilla Bay and Vicinity (Ecology 2000a)

Shellfish were sampled in May and June 1999 from two sites in Fidalgo Bay (crabs and clams) and two sites north of March Point (crabs and mussels). Analytes included metals (arsenic, lead, cadmium, selenium, mercury, tributyltin), PAHs, PCBs, bioaccumulative pesticides, and polychlorinated dioxins and furans. Mussels and crabs off of March Point were only analyzed for PAHs. Results indicated a low level of contamination relative to other parts of Puget Sound. Site-specific human health screening values, reflecting a daily intake value not likely to result in negative impacts over a lifetime of exposure, were calculated using U.S. Environmental Protection Agency (USEPA) methods (USEPA 1995). Shellfish consumption values derived for the Tulalip Tribe were used, and a diet consisting of a high shellfish consumption rate was assumed. Only arsenic exceeded human health screening criteria. Arsenic concentrations in Fidalgo Bay crab muscle were lower than those collected at the Samish Island reference site (5,230 µg/kg vs. 5700 µg/kg) while those at March Point were somewhat higher (7,350 µg/kg).

1.2.4 Sediment Quality on the West Side of Inner Fidalgo Bay (Ecology 2000b)

Five sediment samples on the western side of inner Fidalgo Bay were collected in October 1999 and analyzed for metals and organic compounds. Most chemicals detected were at concentrations similar to or only slightly higher than those in reference sediments from Samish Bay, 9 miles to the north. Combustion sources were indicated as the sources of PAHs. No petroleum was found in TPH samples. No PCBs or pesticides were detected. All chemical concentrations of detected compounds were below the SQS criteria.

1.2.5 Dredge Material Characterization of Cap Sante Marina (Hart Crowser 2000a)

Sediment samples were collected from 47 stations within Cap Sante Marina. Sediment toxicity tests were conducted for one dredged material management unit (DMMU C8) that had PAHs (phenanthrene, chrysene, fluoranthene, pyrene, and total high molecular weight PAHs) exceeding the screening levels. Bioaccumulation testing was performed on composite samples from nine DMMUs that exceeded the Dredged Material Management Program (DMMP) bioaccumulation trigger for TBT. Testing results indicated the proposed dredge materials met the chemical, toxicological, and bioaccumulation suitability criteria for open-water disposal. Toxicity testing results indicated that the CSL exceedance in DMMU C8 did not result in significant toxicity to marine test organisms. Bioaccumulation testing indicated that significant uptake and potential adverse effects were unlikely to result from exposure to tributyltin in the dredged materials.

1.2.6 April 2000 Dredge Material Characterization for Pier 1, Anacortes, WA (Hart Crowser 2000b, Report J-7152)

Sediment samples were collected from eight locations offshore of Pier 1. Ten metals were detected in two composite sediment samples. Tributyltin was detected in the pore water of two composite sediment samples. Phenanthrene was detected in one composite sample. High

molecular weight PAHs were detected in two of the composite sediment samples. None of the analyte detections exceeded their respective screening values and the proposed dredged materials met the criteria for open-water disposal. The dredging of the Pier 1 redevelopment area has not yet been completed.

1.2.7 Dredge Material Characterization for Dakota Creek Shipyard, Anacortes, WA (Hart Crowser 2000c, Report J-7152)

Sediment samples were collected from eight locations offshore of the Dakota Creek Shipyard between Piers 1 and 2. Several SVOCs exceeded their respective screening limits in a composite sample taken from DMMU D2. Sediments from DMMU 1 met the suitability criteria for open-water disposal. Tributyltin was detected in pore water of the two composite samples analyzed and was reported at the screening level due to significant figure rounding. Eight of ten high molecular weight PAHs detected exceeded their screening levels in DMMU 2. The report indicates that the DMMU 2 surface sediments would not meet the disposal criteria without additional testing.

1.2.8 Supplemental Sediment Characterization for Dakota Creek Shipyard and Pier 1 Redevelopment Area, Anacortes, WA (Anchor 2004)

Sediment samples were collected from five locations offshore of the Dakota Creek Shipyard and Pier 1 and analyzed for dioxins and furans. The report specifically addressed collection and analysis of cores from DMMUs that had been previously established in the Hart Crowser studies conducted in 2000. Bulk sediments did not exceed the DMMP criterion for 2,3,7,8-TCDD (5 ng/g) or the calculated 2,3,7,8-TCDD toxicity equivalent concentration (15 ng/g). The previously issued open-water disposal suitability determination was confirmed for all DMMUs.

1.2.9 Initial Remedial Investigation Sediment Sampling Wood Debris Evaluation Data Report for the Former Scott Paper Mill Site, Anacortes, WA (Anchor 2004)

A total of 19 sediment grab samples were collected in Fidalgo Bay offshore of the former Scott Mill Paper Site and analyzed for total organic carbon (TOC), total solids (TS), and total volatile solids (TVS). Higher amounts of wood debris were generally observed in samples collected nearest to the shoreline while those samples collected more than 300 feet off shore generally had a lower quantity of wood debris. TOC and TVS percentages were also highest nearer the shoreline, particularly in the middle of the study area and north of the pier. None of the samples exceeded 25 percent TVS, 10 percent TOC. Several samples contained wood debris densities at or above 50 percent.

1.2.10 Draft Data Report for the Remedial Investigation/Feasibility Study of the Former Scott Paper Mill Site, Anacortes, WA (Anchor 2005)

Sediment samples were collected from eight locations offshore of the former Scott Mill Paper Site and analyzed for metals, PCBs, SVOCs, dioxins, and furans. Of 24 core samples analyzed, only one exceeded SMS criteria for 4-methylphenol (680 mg/kg dry weight).

1.3 Project Scope and Work Plan Objectives

The scope of this Sediment Investigation SAP is limited geographically to the aquatic areas of Fidalgo Bay in water depths of five fathoms or less, except for the area immediately north of the March Point refinery fuel piers. The study area has been divided into four Decision Unit Areas (DUAs) as shown in Figure 1-1. Area 1 consists of the southern portion of Fidalgo Bay south of the railroad dyke and trestle. Area 2 comprises the area eastward from the northeastern tip of March Point to Buoy 2. Area 3 encompasses the remainder of the proper embayment of Fidalgo Bay. Area 4 is the nearshore areas from Cap Sante, west along the Anacortes waterfront to the westernmost extent of the cable crossing between Fidalgo and Guemes Islands.

The purpose of this workplan is to describe the manner and methods for which data collection efforts will be performed to characterize the sediment quality of Fidalgo Bay. The results of the sediment characterization will be used to determine whether potential cleanup action(s) are warranted to minimize the potential for adverse impacts to the biotic community.

The objectives of the workplan will be to conduct a multi-faceted, tiered sediment characterization of the site designed to define the nature and extent of potential sediment contamination. The specific objectives of the sediment investigation will include the following:

- Conduct a more intensive sampling and analysis effort to characterize the overall nature and extent of sediment contamination in Fidalgo Bay.
- Collect, process, and analyze representative sediment data to characterize the site in accordance with protocols, timing, and quality assurance/quality control (QA/QC) requirements outlined by Washington State SMS protocols, Puget Sound Estuary Program (PSEP) protocols, and subsequent Sediment Management Annual Review Meetings (SMARM) updates.
- Compare the sediment chemistry results to Washington State SMS, SQS, and CSL.
- Analyze for dioxins/furans in Fidalgo Bay sediments so that Ecology can evaluate the dioxin/furan concentrations relative to human health and ecological health concerns. Analysis of dioxins/furans will follow USEPA Method 1613B for 2,3,7,8-substituted chlorinated dioxins and furans. Tissue collection and analysis may also be conducted to assess the uptake of dioxins/furans in ecological receptors, if warranted.
- Conduct a suite of sediment toxicity tests on synoptic surface sediment samples that exceed the SQS chemical criteria. The suite of toxicity tests will include a larval development bioassay, an amphipod mortality bioassay, and a juvenile polychaete growth bioassay. In addition, due to the intertidal nature of portions of the site, bioassays will be conducted utilizing full-spectrum lighting if the presence of PAHs is observed in intertidal areas (Ecology 2003).
- Collect subsurface sediment cores to determine the vertical extent of potential contamination through chemical analysis and the sedimentation rate and surface mixed layer via radioisotope dating.
- Conduct a sediment profile imaging survey to determine the physical conditions of the bottom substrate and benthic habitat types.
- Collect fish and shellfish for archival and potential tissue residue analysis for bioaccumulative compounds measured in sediments.

1.4 Project Team and Responsibilities

The implementation of this workplan will be conducted by Science Applications International Corporation (SAIC) and its subcontractors at the discretion of Ecology. The following sections describe the key roles and responsibilities of the project team.

1.4.1 Project Planning and Coordination

Ted Benson, from Ecology, will serve as the Government Project Manager and will oversee the overall project coordination, supply government-furnished data and services, provide review comments on the report, and coordinate with the contractor selected to perform the Remedial Investigation/Feasibility Study (RI/FS) tasks. Tim Hammermeister will serve as the SAIC project manager and will be responsible for executing the approved SAP/QAPP, ensuring the proper collection and analysis of field samples, and reporting analytical results.

SAIC
Tim Hammermeister
18912 North Creek Parkway
Suite 101
Bothell, WA
Phone: (425) 482-3306
Fax: (425) 487-1491
mailto:tim.j.hammermeister@saic.com

1.4.2 Sample Collection

Brion Dolan of SAIC will also serve as field manager and will be responsible for the collection and processing of samples in accordance with the SAP/QAPP, and transport of samples to the analytical and biological laboratory for analysis and testing. The field manager will ensure accurate station positioning and reporting.

1.4.3 Laboratory Sample Preparation and Analysis

Will Hafner of SAIC will serve as laboratory coordinator and will be responsible for subcontracting state-certified laboratories, delivery of samples to the analytical and biological laboratories, and ensuring that established protocols for decontamination, sample preservation, holding times, chain-of-custody documentation, and laboratory reporting will be observed.

1.4.4 QA/QC Management

John Nakayama will serve as the SAIC QA/QC manager and will perform quality assurance oversight for the laboratory programs. He will ensure that the laboratory analytical and QA/QC data are considered valid and procedures meet the required analytical quality control limits.

1.4.5 Health and Safety Manager

John Nakayama will serve as the designated SAIC Health and Safety Manager. He will ensure that all personnel are properly trained, are fully aware of potential site hazards, conduct all work in a safe manner, wear appropriate personal protective clothing (PPE), and abide by the conditions set forth in the site-specific Health and Safety Plan (HASP).

1.4.6 Subcontractor Support

The SAIC project team will also consist of the following subcontractors to support the data collection activities and laboratory analytical services:

1) Data Collection and Biological Testing

   NewFields
   Jack Word
   P.O. Box 216
   4729 NE View Drive
   Port Gamble, WA 98364
   Phone: (360) 297-6060
   Fax: (360) 297-7268
   mailto:jqword@newfields.com

2) Analytical Chemistry

   Columbia Analytical Services, Inc.
   Harvey Jacky
   1317 South 13th Ave.
   Kelso, WA 98626
   Phone: (360)577-7222
   mailto:hjacky@kelso.caslab.com

3) Sampling Vessel for Sediment Collection Activities

   Marine Sampling Systems
   R/V *Nancy Anne*
   Bill Jaworski
   Phone: (253) 208-1515
   Fax: (253) 857-3336
   mailto:msampling@aol.com

4) Sampling Vessel for Sediment Profile Imaging and Bottom Trawling

Bio-Marine Enterprise
R/V *Kittiwake*
Charles Eaton
2717 3rd Ave. N
Seattle, WA 98109
Phone (206) 282-4945
cmeaton@msn.com

5) Dioxin/Furan Congener Analysis

Axys Analytical Services, Ltd.
Georgina Brooks
2045 Mills Road
Sidney BC V8L 3S8
CANADA
Phone: (250) 655-5801
Fax: (250) 655-5811
mailto:gbrooks@axys.com

6) Radioisotope Dating

Battelle Marine Sciences Laboratory
Linda S. Bingler
1529 West Sequim Bay Rd.
Sequim, WA 98382
Phone: (360) 681-3627
Fax: (360) 681-3699
mailto:l.bingler@pnl.gov

1.5 Schedule

The tentative schedule for the proposed field activities is for a 3-week period from August 20 through September 7, 2007. The draft data report will be submitted to Ecology on November 30, 2007, and the final data report will be completed by January 11, 2008.

2.0 Study Design

This section describes the study design for each data type to be collected for the Fidalgo Bay Sediment Investigation. Proposed sampling locations for each data type are presented in Figures 2-1, 2-2, 2-3, 2-4, and 2-5. The data collection methods are described in Section 3.0.

2.1 Sediment Profile Imaging

The initial component of the investigation will be to conduct an area-wide survey using a Sediment Profile Imaging (SPI) camera. Information from the SPI survey will be used to refine the sampling locations for the other data types (Sections 2.2 and 2.3). A total of 120 locations will be surveyed using the SPI camera, including 40 locations in Area 2, 50 locations in Area 3, and 30 locations in Area 4 (Figures 2-2 to 2-4). The SPI camera will not be utilized in Area 1 due to the shallow conditions that will prohibit its deployment. A Benthos digital SPI camera will be used to survey the benthic habitat conditions in Fidalgo Bay. SPI photography provides a cross-sectional photograph of the sediment/water interface (in profile) and near-surface sediment.

The SPI survey will be used to assess the condition of the benthic habitat and the physical characteristics of the surface sediment. Parameters assessed using the images include:

- Infaunal successional stage,
- Calculation of the organism-sediment index,
- Depth of apparent redox potential discontinuity,
- Presence and thickness of depositional layers,
- Grain size mode and range, and
- Evidence of erosional and depositional events to identify high- and low-energy layers.

A preliminary review of the SPI photography will be used to identify specific grab sampling locations of interest for analysis of chemistry and conventional parameters. Surface sediment samples co-located at selected SPI stations will also be used to ground truth observations made from the images.

2.2 Surface Sediment Samples

The major component of this study is to conduct an investigation utilizing the SMS interpretive criteria for chemistry and biological effects to characterize the nature and extent of potential contamination and any related adverse impacts to biota in the bay.

Surface sediment (0 to 10 cm) samples will be collected at a total of 130 sampling locations (Figures 2-1 to 2-4). Approximately sixty of the surface sediment samples (Up to 15 from each area of interest) will be submitted for chemical analysis. The remaining sediment samples will be archived. Additional sediment from the locations sampled for chemistry will be collected for potential toxicity testing, pending the outcome of the chemical analysis. A subset of the samples archived for potential toxicity testing will be submitted for confirmatory biological testing. Sampling locations were placed to provide spatial coverage throughout the study areas. Surface

sediment will be collected from reference locations (areas with similar environmental conditions that are free of any known contaminants) to aid in the interpretation of the toxicity test results. Each of these data types is discussed in further detail below.

2.2.1 Chemistry

The chemical analysis of the surface sediment samples collected in Fidalgo Bay will include the SMS analyte list, sediment conventionals, and dioxin/furan congeners.

The chemical results will be compared to the SMS SQS and CSL numeric criteria. The SMS provides a regulatory basis, management goal, and decision process for the characterization and cleanup of contaminated sediments (Ecology). The SMS chemical numeric criteria and biological effects interpretive criteria provide the means for evaluating the chemistry and toxicity test results. These criteria will be used to determine whether anthropogenic contaminants in sediments are a source of adverse effects to biological resources. In addition to the analytes on the SMS list, dioxin/furan congeners and organotins will also be analyzed in a subset of samples. Sediment chemistry is evaluated to determine whether further evaluation is needed due to elevated concentrations of contaminants.

The concentration of dioxin/furan compounds will be normalized to the toxicity of 2,3,7,8-TCDD using toxic equivalent factors (TEFs) updated by the World Health Organization (WHO) in 2005 (Van den Berg et al. 2006). The toxic equivalent quotient (TEQ) is equivalent to the sum of the concentrations of individual congeners multiplied by their TEF (potency relative to 2,3,7,8-TCDD). Non-detected values will be assessed as half of the method detection limit for data evaluation purposes. The chemical analyte list, analytical methods, target detection limits, and comparative criteria are discussed in Section 4.1.

2.2.2 Toxicity Testing

Toxicity testing involves the exposure of sensitive test organisms to contaminants found in the sediments. Chronic and acute toxicity endpoints are measured to determine the incidence and relative extent of adverse biological effects. Samples from locations with chemistry exceeding the SQS will be submitted for toxicological testing. Toxicity tests to be conducted on Fidalgo Bay sediments include amphipod mortality, juvenile polychaete growth, and larval development bioassays. Testing parameters will utilize full-spectrum ultraviolet (UV) lighting as recommended by Ecology if site conditions include elevated PAHs in shallow water sediments (Ecology 2003). Details on the toxicity testing methodology are provided in Section 4.2.

2.3 Subsurface Sediment Cores

The vertical extent of potential contamination will be evaluated by the collection of subsurface sediment cores. The core collection and evaluation will include a physical description of the stratigraphy, as well as the collection of sediment composites for potential chemical analysis. The cores will be advanced to 4 feet below the surface in Area 1 using a hand corer, and up to 8 feet, or refusal, in Areas 2, 3, and 4 (Figures 2-1 to 2-4). The subsurface sediment cores will be individually composted over 1-foot intervals (i.e., 0 to 1, 1 to 2, … 7 to 8 feet). The subsurface sediment samples will be archived pending the results of the surface chemical analysis and

toxicity testing. Subsurface samples will be submitted for chemical analysis to determine the vertical extent of impacted sediments. Visual observations indicating potential contamination, depositional material, and native substrate will be used to help determine candidate intervals for further analysis.

2.3.1 Chemistry

The chemical analysis of subsurface cores will depend on the results of the surface sediment chemistry results. Analytes in subsurface sediments will be limited to the contaminants that exceed the SQS or CSL, or elevated concentrations of dioxin/furan congeners in co-located surface sediments, unless other indications (i.e., visibly contaminated intervals) warrant further analysis.

2.3.2 Radioisotope Dating

Sediment cores will also be collected for evaluating the sedimentation rate and surface mixed layer depth. Four cores, one from each study location, will be collected for radioisotope dating through the analysis of beryllium-7 (Be-7), lead-210 (Pb-210), and cesium-137 (Cs 137). Sedimentation rate will be determined using the Pb-210 results. The Cs-137 results will be used to verify the dates determined for the sedimentation rate. Be-7 results will be used to estimate the mixed depth.

2.4 Fish, Clam, and Crab Tissue

Tissue samples will be collected and archived for fish, crab, and clams from each of the study areas. Fish and crab will be collected using bottom trawls in Areas 2, 3, and 4 (Figure 2-5). Additional sampling locations for crabs and clams will be identified while in the field. All tissue samples will be archived for potential analysis depending on the results of the surface sediment chemistry. At Ecology's discretion, tissue residues will be analyzed for bioaccumulative compounds measured at elevated concentrations in surface sediments.

2.5 Aquatic Habitat Types

The existing aquatic habitat types will also be identified, described, and delineated as part of the sediment quality investigation. The qualitative aquatic habitat survey will be based primarily on observations made during the field investigation and will include:

- Identifying the type of substrate based on the grain size distribution and observation (i.e., muddy soft bottom, sand, gravel, cobble, shell debris, organic matter, detritus, etc.);
- Bathymetry of aquatic site, including ordinary high water mark (OHWM), deep subtidal (below -14 feet), shallow subtidal (-14 to -4 feet), intertidal (-4 feet to +13 feet);
- Physical artificial impairments, such as overwater structures, pilings, or concrete rubble, impacting the natural environment;
- Vegetation types (nearshore terrestial and aquatic) and locations;
- Terrestial and aquatic receptors noted during field investigations or existing documents, as well as density in comparison to appropriate reference sites: including benthic

community types, seagrasses, types of fish, rookeries, sensitive species, or critical habitat, etc.;

- Types, concentrations, and areal extent of contamination; and
- Presence and depth of fill material.

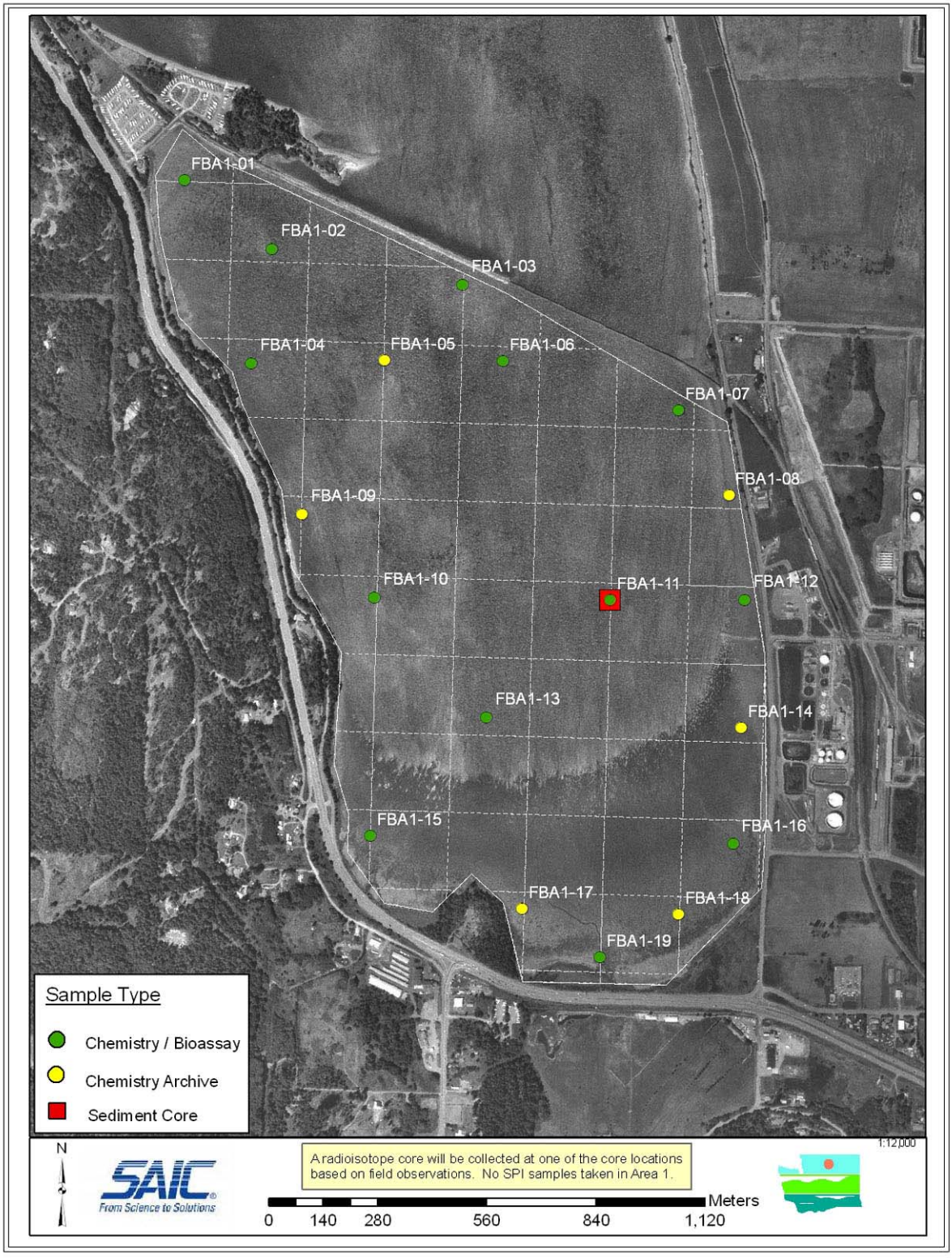

Figure 2-1. Proposed Sampling Locations in Area 1

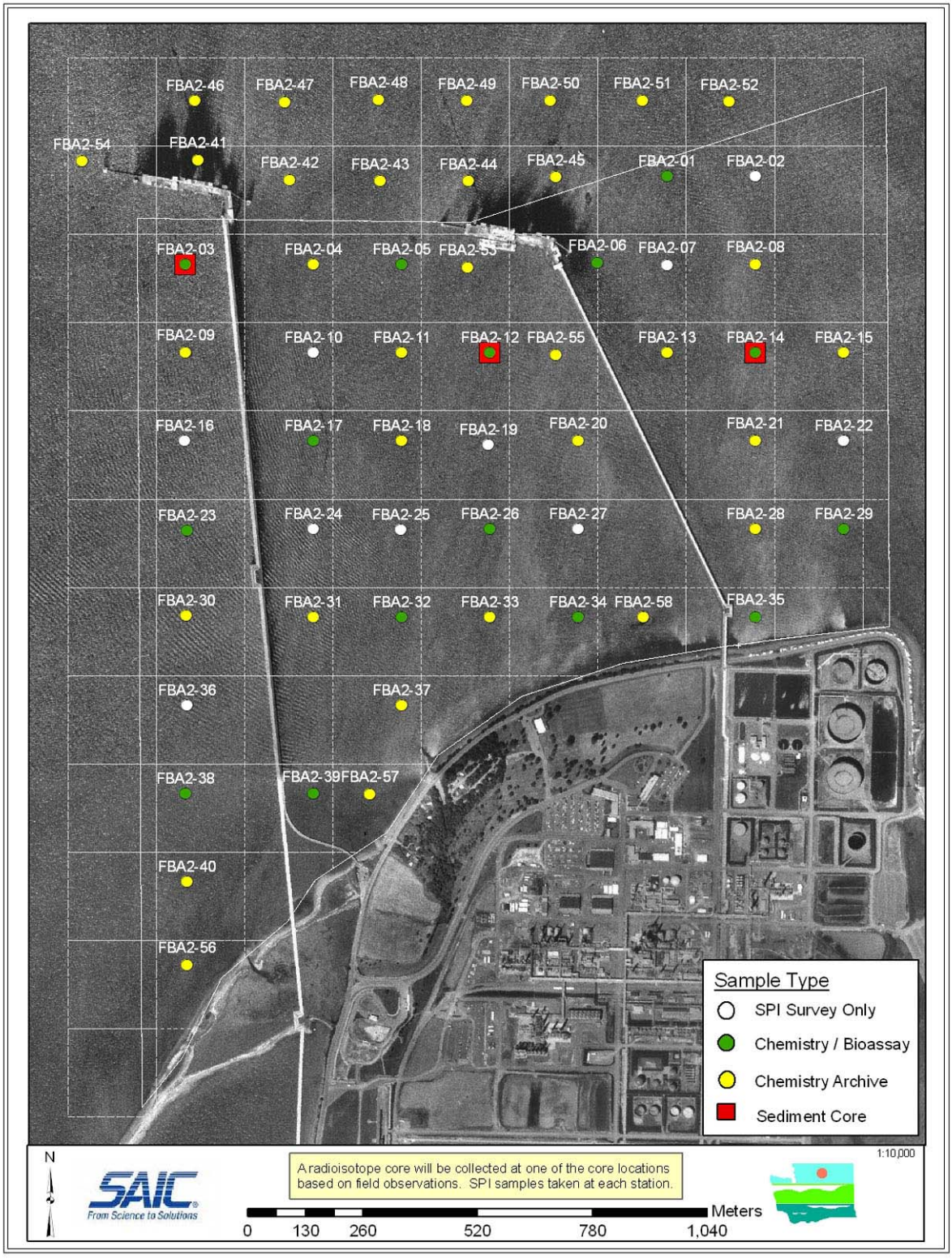

Figure 2-2. Proposed Sampling Locations in Area 2

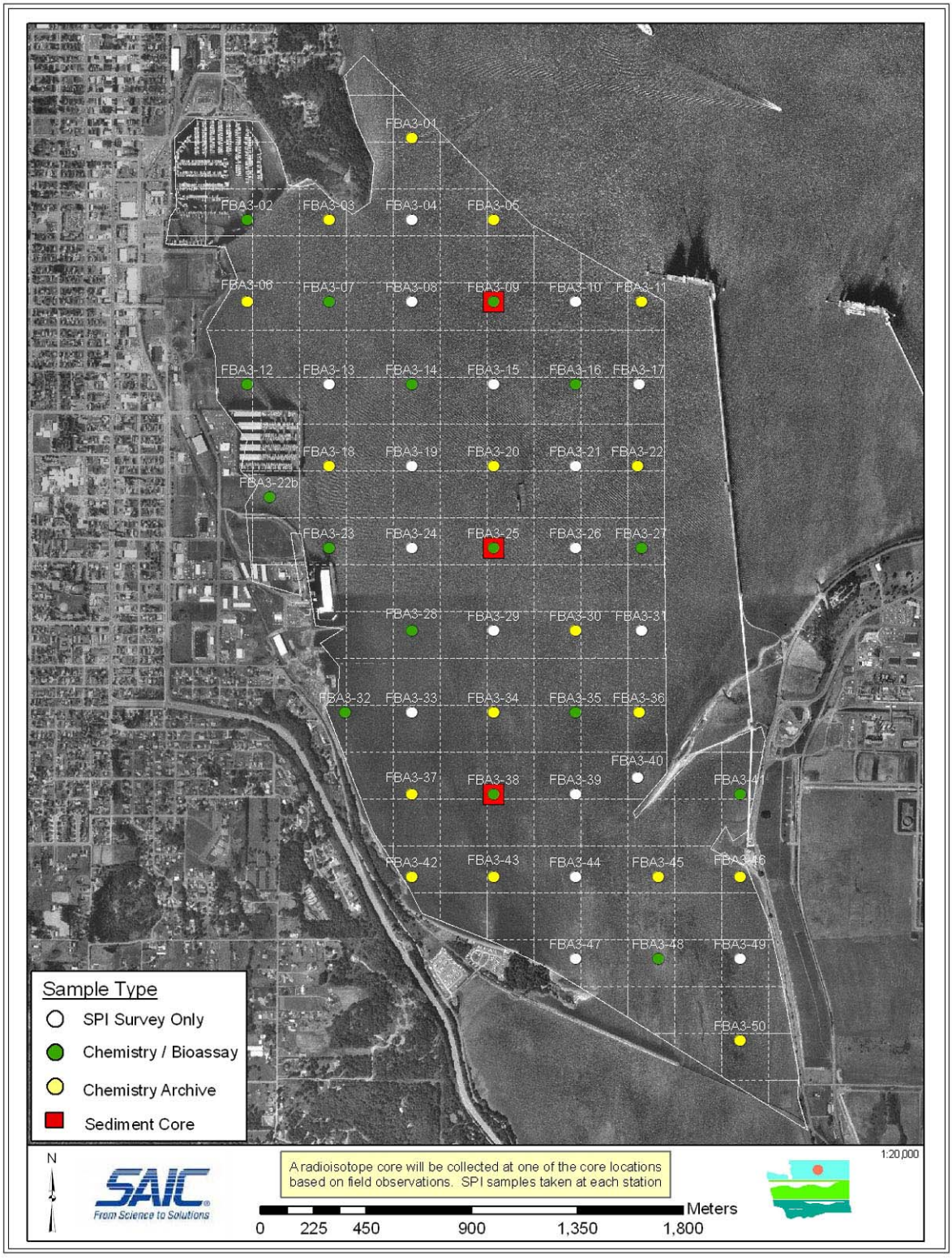

Figure 2-3. Proposed Sampling Locations in Area 3

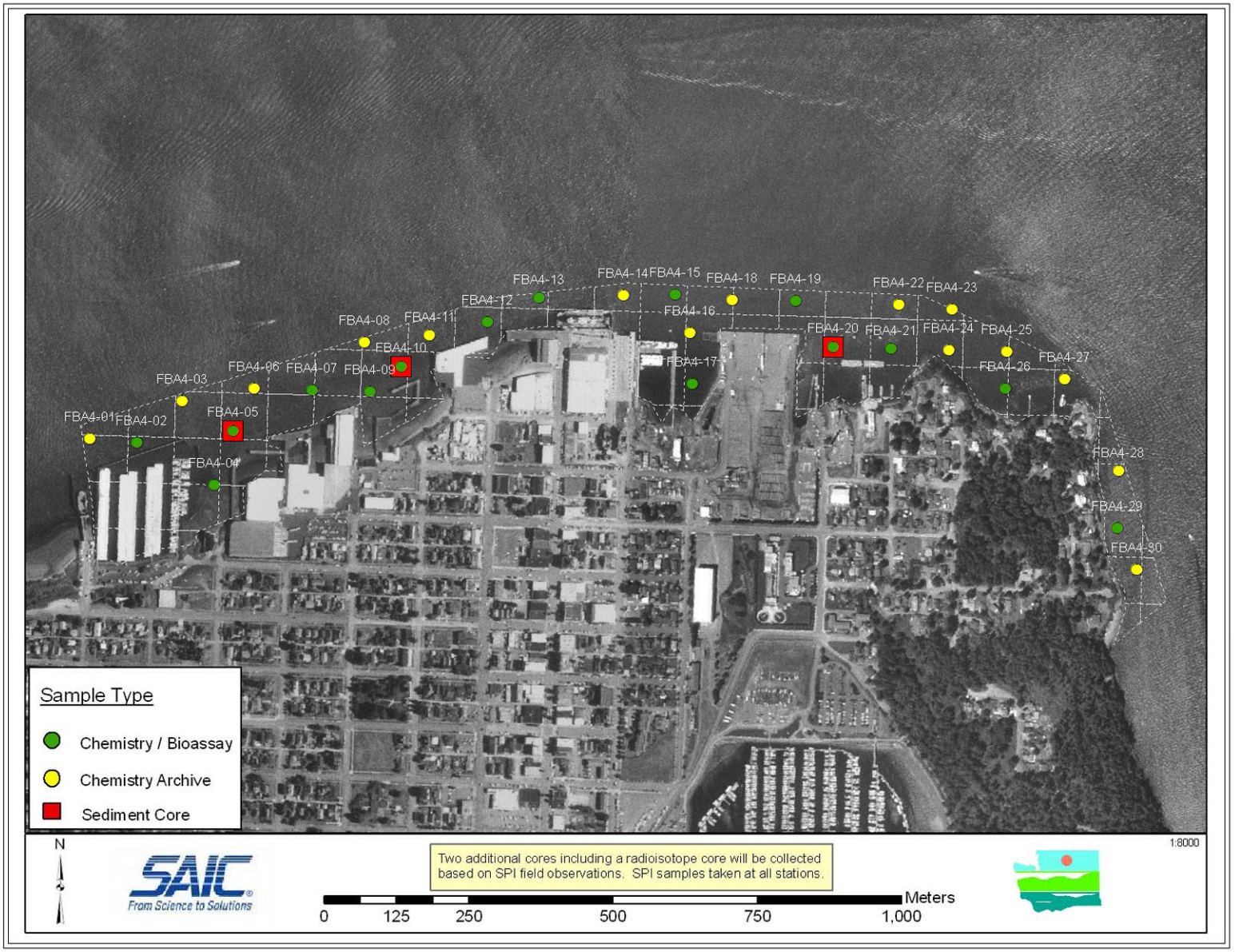

Figure 2-4. Proposed Sampling Locations in Area 4

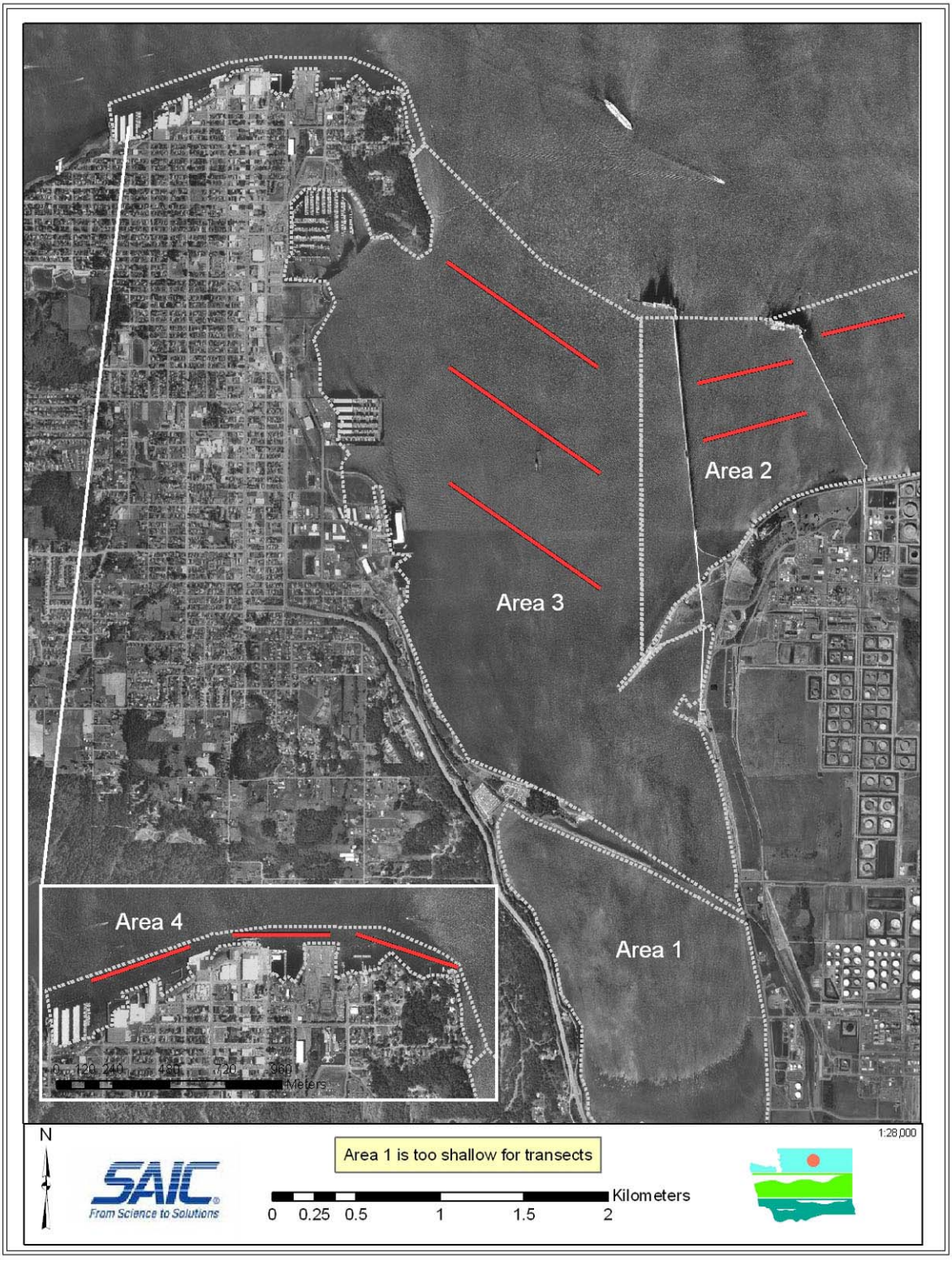

Figure 2-5. Proposed Bottom Trawling Locations

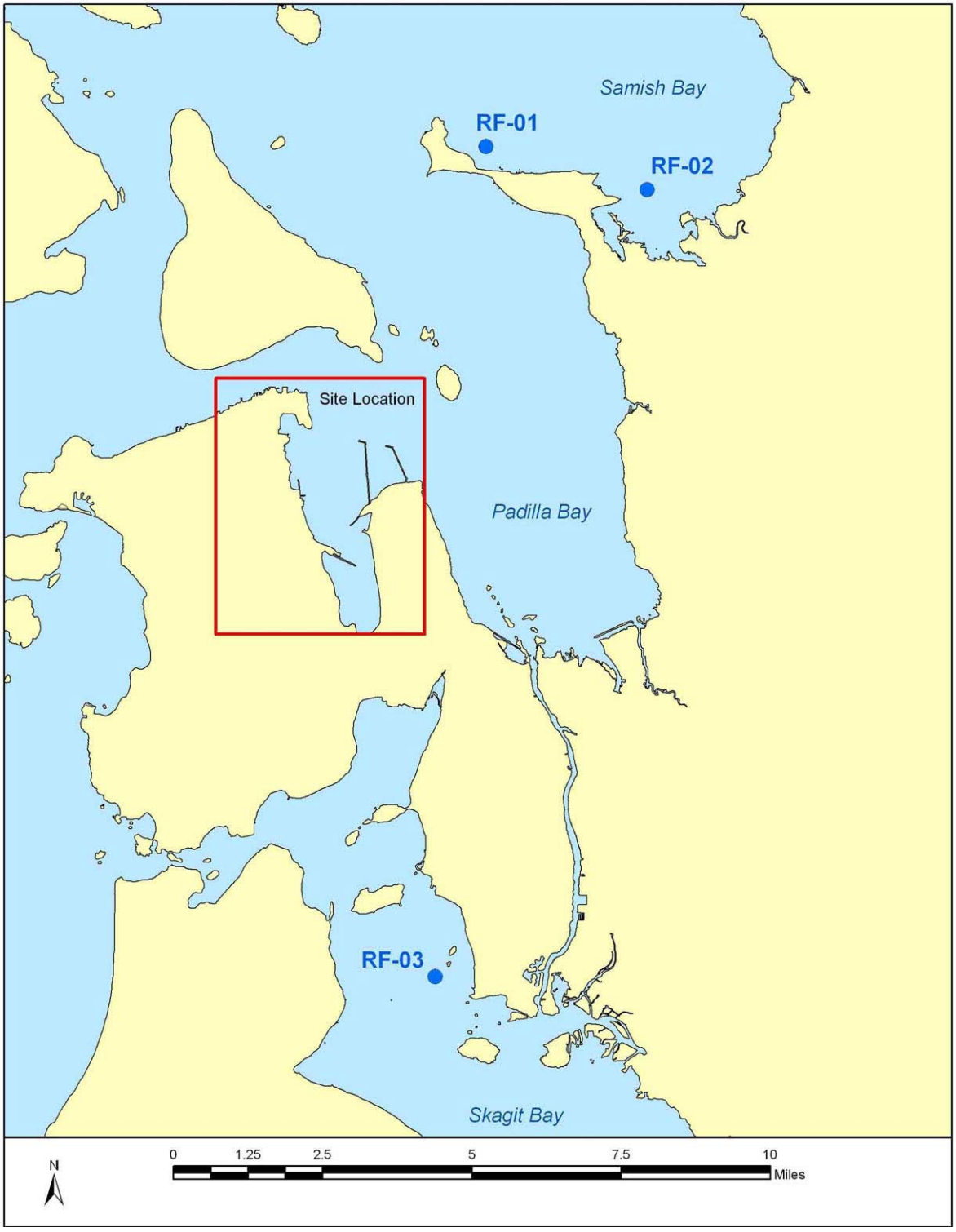

Figure 2-6. Fidalgo Bay Candidate Reference Sediment Sites

Table 2-1. Data Type to be Collected at each Target Location[1]

Location ID	Sediment Profile Images	Surface Sediment Samples		Subsurface Cores	
		Chemistry	Toxicity	Chemistry	Radioisotope
Area 1					
A1-01		X	A		
A1-02		X	A		
A1-03		X	A		
A1-04		X	A		
A1-05		A			
A1-06		X	A		
A1-07		X	A		
A1-08		A			
A1-09		A			
A1-10		X	A		
A1-11		X	X	A	P
A1-12		X	A		
A1-13		X	A		
A1-14		A			
A1-15		X	A		
A1-16		X	A		
A1-17		A			
A1-18		A			
A1-19		X	A		
Area 2					
A2-01	X	X	A		
A2-02	X				
A2-03	X	X	X	A	P
A2-04	X	A			
A2-05	X	X	A		
A2-06	X	X	A		
A2-07	X				
A2-08	X	A			
A2-09	X	A			
A2-10	X				
A2-11	X	A			
A2-12	X	X	X	A	P
A2-13	X	A			
A2-14	X	X	X	A	P
A2-15	X	A			
A2-16	X				
A2-17	X	X	A		
A2-18	X	A			
A2-19	X				
A2-20	X	A			
A2-21	X	A			
A2-22	X				
A2-23	X	X	A		
A2-24	X				
A2-25	X				

Location ID	Sediment Profile Images	Surface Sediment Samples		Subsurface Cores	
		Chemistry	Toxicity	Chemistry	Radioisotope
A2-26	X	X	A		
A2-27	X				
A2-28	X	A			
A2-29	X	X	A		
A2-30	X	A			
A2-31	X	A			
A2-32	X	X	A		
A2-33	X	A			
A2-34	X	X	A		
A2-35	X	X	A		
A2-36	X				
A2-37	X	A			
A2-38	X	X	A		
A2-39	X	X	A		
A2-40	X	A			
A2-41	X	A			
A2-42	X	A			
A2-43	X	A			
A2-44	X	A			
A2-45	X	A			
A2-46	X	A			
A2-47	X	A			
A2-48	X	A			
A2-49	X	A			
A2-50	X	A			
A2-51	X	A			
A2-52	X	A			
A2-53	X	A			
A2-54	X	A			
A2-55	X	A			
A2-56	X	A			
A2-57	X	A			
A2-58	X	A			
Area 3					
A3-01	X	A			
A3-02	X	X	A		
A3-03	X	A			
A3-04	X				
A3-05	X	A			
A3-06	X	A			
A3-07	X	X	A		
A3-08	X				
A3-09	X	X	X	A	P
A3-10	X				
A3-11	X	A			
A3-12	X	X	A		
A3-13	X				
A3-14	X	X	A		

Location ID	Sediment Profile Images	Surface Sediment Samples		Subsurface Cores	
		Chemistry	Toxicity	Chemistry	Radioisotope
A3-15	X				
A3-16	X	X	A		
A3-17	X				
A3-18	X	A			
A3-19	X				
A3-20	X	A			
A3-21	X				
A3-22	X	A			
A3-22b	X	X	A		
A3-23	X	X	A		
A3-24	X				
A3-25	X	X	X	A	P
A3-26	X				
A3-27	X	X	A		
A3-28	X	X	A		
A3-29	X				
A3-30	X	A			
A3-31	X				
A3-32	X	X	A		
A3-33	X				
A3-34	X	A			
A3-35	X	X	A		
A3-36	X	A			
A3-37	X	A			
A3-38	X	X	X	A	P
A3-39	X				
A3-40	X				
A3-41	X	X	A		
A3-42	X	A			
A3-43	X	A			
A3-44	X				
A3-45	X	A			
A3-46	X	A			
A3-47	X				
A3-48	X	X	A		
A3-49	X				
A3-50	X	A			
Area 4					
A4-01	X	A			
A4-02	X	X	A		
A4-03	X	A			
A4-04	X	X	A		
A4-05	X	X	X	A	P
A4-06	X	A			
A4-07	X	X	A		
A4-08	X	A			
A4-09	X	X	A		
A4-10	X	X	X	A	P

Location ID	Sediment Profile Images	Surface Sediment Samples		Subsurface Cores	
		Chemistry	Toxicity	Chemistry	Radioisotope
A4-11	X	A			
A4-12	X	X	A		
A4-13	X	X	A		
A4-14	X	A			
A4-15	X	X	A		
A4-16	X	A			
A4-17	X	X	A		
A4-18	X	A			
A4-19	X	X	A		
A4-20	X	X	X	A	P
A4-21	X	X	A		
A4-22	X	A			
A4-23	X	A			
A4-24	X	A			
A4-25	X	A			
A4-26	X	X	A		
A4-27	X	A			
A4-28	X	A			
A4-29	X	X	A		
A4-30	X	A			
Candidate Reference Sites[2]					
RF-01		A	A	A	
RF-02		A	A	A	
RF-03		A	A	A	

Notes

1: Fish, clam, and crab tissue samples will be collected from each area, if available.
2: Actual reference locations will be determined in the field based on the physical characteristics of the site and the wet-sieving results. Reference locations will be used for comparison of toxicity test results and habitat types (i.e., native vegetation and organisms) for evaluating potential restoration actions.
A: Sample to be collected and archived
P: Potential sample location for data type
X: Sample to be collected and analyzed

3.0 Sampling and Handling Methods

This section describes the methodology for positioning, sample collection, processing, identification, documentation, equipment decontamination, and waste handling for the proposed field investigation. Samples will be collected for sediment profile images, sediment chemistry, toxicity, tissue residues, and radioisotope dating. The laboratory methods for chemical analysis, toxicity testing, and radioisotope analysis are presented in Section 4.0.

3.1 Sampling Platforms

Several sampling vessels will be used as needed to meet the multiple data collection objectives. The R/V *Kittiwake*, owned and operated by Mr. Charles Eaton of Bio-Marine Enterprises, will be used for the SPI survey and bottom trawling. The R/V *Nancy Anne*, owned and operated by Mr. Bill Jaworski of Marine Sampling Systems, will be used for the surface and subsurface sediment collection in Areas 2, 3, and 4. The R/V *Growler* and R/V *Schooner*, owned and operated by SAIC, will be used to sample shallow water locations including Area 1, as well as assist in the collection of crab and clam tissue.

3.2 Station Positioning and Navigation

The positioning and recording of sampling locations will be accomplished using differential Global Positioning System (DGPS). The DGPS employs a receiver that tracks and times signals emitted by satellites orbiting the earth, a Coast Guard reference beacon located in the vicinity of the survey area, and a differential receiver. The receiver deployed at the Coast Guard reference beacon (horizontal control point) is used to correct for Selective Availability (SA) (satellites emit an encrypted signal designed to degrade the accuracy for non-military users by dithering the time code embedded in the signal). This receiver calculates position based on the satellite signals and compares the calculated position to the known position at the horizontal control point. A positional offset of correction factor is calculated and transmitted to the GPS receiver, which applies the correction factor to calculate the corrected position. All station coordinates will be recorded by latitude and longitude to the decimal minute and State Plane Coordinates (NAD 83).

Vertical position (i.e., water depth) will be determined using a fathometer (when feasible) or a lead-line (weighted measuring tape) or measuring stick to measure to the nearest 0.1 foot from the water surface to the mudline.

The target sample coordinates are provided in Table 3-1, sampling locations are displayed in Figures 2-1, 2-2, 2-3, and 2-4, and candidate reference locations are displayed in Figure 2-6.

Table 3-1. Target Sample Locations

Location ID	Latitude (N)	Longitude (W)	State Plane (NAD 83)	
			Northing	Easting
Area 1				
A1-01	48 28.8924	122 35.4982	545304	1214000
A1-02	48 28.7997	122 35.3127	544723	1214737
A1-03	48 28.7563	122 34.9137	544422	1216343
A1-04	48 28.6407	122 35.3510	543760	1214560
A1-05	48 28.6493	122 35.0738	543787	1215681
A1-06	48 28.6519	122 34.8262	543780	1216682
A1-07	48 28.5891	122 34.4578	543365	1218162
A1-08	48 28.4723	122 34.3491	542645	1218586
A1-09	48 28.4332	122 35.2382	542488	1214987
A1-10	48 28.3197	122 35.0836	541785	1215596
A1-11	48 28.3236	122 34.5912	541763	1217587
A1-12	48 28.3277	122 34.3118	541762	1218717
A1-13	48 28.1571	122 34.8438	540774	1216543
A1-14	48 28.1511	122 34.3121	540689	1218691
A1-15	48 27.9892	122 35.0804	539775	1215563
A1-16	48 27.9892	122 34.3243	539706	1218620
A1-17	48 27.8922	122 34.7603	539156	1216844
A1-18	48 27.8899	122 34.4347	539112	1218160
A1-19	48 27.8280	122 34.5959	538751	1217500
Area 2				
A2-01	48 30.5751	122 33.8766	555384	1220783
A2-02	48 30.5745	122 33.7141	555365	1221439
A2-03	48 30.4704	122 34.7632	554829	1217188
A2-04	48 30.4696	122 34.5274	554802	1218140
A2-05	48 30.4690	122 34.3649	554783	1218796
A2-06	48 30.4690	122 34.0049	554751	1220250
A2-07	48 30.4656	122 33.8764	554718	1220769
A2-08	48 30.4665	122 33.7150	554709	1221421
A2-09	48 30.3625	122 34.7637	554172	1217171
A2-10	48 30.3616	122 34.5283	554146	1218122
A2-11	48 30.3610	122 34.3658	554127	1218778
A2-12	48 30.3604	122 34.2033	554109	1219434
A2-13	48 30.3592	122 33.8784	554072	1220746
A2-14	48 30.3586	122 33.7160	554053	1221402
A2-15	48 30.3580	122 33.5535	554035	1222059
A2-16	48 30.2543	122 34.7667	553514	1217143
A2-17	48 30.2537	122 34.5292	553490	1218103
A2-18	48 30.2531	122 34.3667	553471	1218759
A2-19	48 30.2472	122 34.2078	553421	1219400
A2-20	48 30.2518	122 34.0418	553434	1220072
A2-21	48 30.2506	122 33.7169	553397	1221384
A2-22	48 30.2500	122 33.5544	553379	1222040

Location ID	Latitude (N)	Longitude (W)	State Plane (NAD 83)	
			Northing	Easting
A2-23	48 30.1445	122 34.7623	552847	1217146
A2-24	48 30.1457	122 34.5301	552833	1218085
A2-25	48 30.1440	122 34.3688	552808	1218736
A2-26	48 30.1445	122 34.2052	552796	1219397
A2-27	48 30.1439	122 34.0427	552778	1220053
A2-28	48 30.1427	122 33.7178	552741	1221365
A2-29	48 30.1420	122 33.5554	552722	1222022
A2-30	48 30.0405	122 34.7649	552215	1217122
A2-31	48 30.0378	122 34.5310	552177	1218066
A2-32	48 30.0372	122 34.3685	552159	1218722
A2-33	48 30.0365	122 34.2061	552140	1219379
A2-34	48 30.0359	122 34.0436	552122	1220035
A2-35	48 30.0347	122 33.7188	552085	1221347
A2-36	48 29.9307	122 34.7641	551548	1217110
A2-37	48 29.9292	122 34.3694	551503	1218704
A2-38	48 29.8227	122 34.7681	550892	1217078
A2-39	48 29.8218	122 34.5328	550865	1218029
A2-40	48 29.7147	122 34.7659	550235	1217073
A2-41	48 30.5975	122 34.7380	555599	1217307
A2-42	48 30.5726	122 34.5701	555432	1217982
A2-43	48 30.5704	122 34.4044	555403	1218651
A2-44	48 30.5698	122 34.2412	555385	1219310
A2-45	48 30.5740	122 34.0804	555396	1219960
A2-46	48 30.6701	122 34.7434	556041	1217295
A2-47	48 30.6678	122 34.5781	556011	1217963
A2-48	48 30.6703	122 34.4062	556011	1218657
A2-49	48 30.6679	122 34.2434	555981	1219314
A2-50	48 30.6677	122 34.0901	555966	1219933
A2-51	48 30.6671	122 33.9201	555947	1220620
A2-52	48 30.6652	122 33.7610	555921	1221262
A2-53	48 30.4645	122 34.2445	554745	1219282
A2-54	48 30.5967	122 34.9524	555613	1216441
A2-55	48 30.3571	122 34.0822	554078	1219923
A2-56	48 29.6131	122 34.7670	549617	1217054
A2-57	48 29.8207	122 34.4286	550849	1218450
A2-58	48 30.0352	122 33.9249	552106	1220514
Area 3				
A3-01	48 30.8986	122 35.7225	557519	1213372
A3-02	48 30.7116	122 36.2927	556436	1211044
A3-03	48 30.7106	122 36.0084	556404	1212192
A3-04	48 30.7096	122 35.7240	556371	1213340
A3-05	48 30.7086	122 35.4397	556339	1214488
A3-06	48 30.5227	122 36.2942	555288	1211011
A3-07	48 30.5217	122 36.0099	555255	1212159

Location ID	Latitude (N)	Longitude (W)	State Plane (NAD 83)	
			Northing	Easting
A3-08	48 30.5207	122 35.7255	555223	1213308
A3-09	48 30.5197	122 35.4412	555191	1214456
A3-10	48 30.5187	122 35.1569	555158	1215604
A3-11	48 30.5179	122 34.9305	555132	1216519
A3-12	48 30.3338	122 36.2956	554139	1210979
A3-13	48 30.3328	122 36.0113	554107	1212127
A3-14	48 30.3318	122 35.7270	554075	1213275
A3-15	48 30.3308	122 35.4427	554042	1214424
A3-16	48 30.3298	122 35.1584	554010	1215572
A3-17	48 30.3290	122 34.9385	553985	1216460
A3-18	48 30.1439	122 36.0128	552959	1212095
A3-19	48 30.1429	122 35.7285	552926	1213243
A3-20	48 30.1419	122 35.4443	552894	1214391
A3-21	48 30.1409	122 35.1600	552862	1215539
A3-22	48 30.0736	122 36.2214	552551	1211243
A3-22b	48 30.1401	122 34.9464	552837	1216402
A3-23	48 29.9550	122 36.0143	551811	1212062
A3-24	48 29.9540	122 35.7300	551778	1213211
A3-25	48 29.9530	122 35.4458	551746	1214359
A3-26	48 29.9519	122 35.1615	551713	1215507
A3-27	48 29.9511	122 34.9351	551688	1216422
A3-28	48 29.7650	122 35.7315	550630	1213178
A3-29	48 29.7640	122 35.4473	550598	1214326
A3-30	48 29.7630	122 35.1631	550565	1215475
A3-31	48 29.7622	122 34.9367	550539	1216389
A3-32	48 29.5769	122 35.9639	549508	1212213
A3-33	48 29.5761	122 35.7331	549482	1213146
A3-34	48 29.5751	122 35.4488	549449	1214294
A3-35	48 29.5741	122 35.1646	549417	1215442
A3-36	48 29.5733	122 34.9447	549392	1216331
A3-37	48 29.3872	122 35.7346	548334	1213113
A3-38	48 29.3862	122 35.4503	548301	1214262
A3-39	48 29.3852	122 35.1661	548269	1215410
A3-40	48 29.4229	122 34.9523	548478	1216279
A3-41	48 29.3831	122 34.5977	548204	1217706
A3-42	48 29.1983	122 35.7361	547185	1213081
A3-43	48 29.1973	122 35.4519	547153	1214229
A3-44	48 29.1963	122 35.1677	547121	1215378
A3-45	48 29.1952	122 34.8835	547088	1216526
A3-46	48 29.1942	122 34.5993	547056	1217674
A3-47	48 29.0073	122 35.1692	545972	1215345
A3-48	48 29.0063	122 34.8850	545940	1216493
A3-49	48 29.0053	122 34.6009	545908	1217642
A3-50	48 28.8164	122 34.6024	544759	1217609

Location ID	Latitude (N)	Longitude (W)	State Plane (NAD 83)	
			Northing	Easting
Area 4				
A4-01	48 31.2142	122 37.4076	559595	1206612
A4-02	48 31.2114	122 37.3407	559572	1206882
A4-03	48 31.2512	122 37.2787	559808	1207137
A4-04	48 31.1738	122 37.2304	559333	1207322
A4-05	48 31.2249	122 37.2061	559641	1207427
A4-06	48 31.2649	122 37.1778	559882	1207547
A4-07	48 31.2646	122 37.0966	559872	1207875
A4-08	48 31.3099	122 37.0246	560141	1208172
A4-09	48 31.2643	122 37.0153	559863	1208203
A4-10	48 31.2883	122 36.9723	560005	1208380
A4-11	48 31.3180	122 36.9336	560182	1208540
A4-12	48 31.3317	122 36.8523	560257	1208871
A4-13	48 31.3555	122 36.7807	560395	1209163
A4-14	48 31.3598	122 36.6618	560410	1209644
A4-15	48 31.3615	122 36.5887	560414	1209939
A4-16	48 31.3258	122 36.5670	560195	1210022
A4-17	48 31.2785	122 36.5616	559907	1210037
A4-18	48 31.3575	122 36.5089	560382	1210261
A4-19	48 31.3580	122 36.4191	560377	1210624
A4-20	48 31.3161	122 36.3649	560117	1210837
A4-21	48 31.3158	122 36.2836	560108	1211165
A4-22	48 31.3566	122 36.2743	560355	1211208
A4-23	48 31.3535	122 36.1991	560329	1211512
A4-24	48 31.3156	122 36.2023	560099	1211493
A4-25	48 31.3153	122 36.1211	560090	1211821
A4-26	48 31.2808	122 36.1214	559880	1211815
A4-27	48 31.2907	122 36.0386	559933	1212151
A4-28	48 31.2068	122 35.9594	559415	1212459
A4-29	48 31.1528	122 35.9599	559087	1212449
A4-30	48 31.1148	122 35.9308	558853	1212562
Candidate Reference Sites[1]				
RF-01	48 34.9033	122 32.2078	581544	1228106
RF-02	48 34.3364	122 28.6571	577786	1242354
RF-03	48 22.8192	122 32.8548	508146	1223861

Note

1: Actual reference locations will be determined in the field based on the physical characteristics of the site and the wet-sieving results. Reference locations will be used for comparison of toxicity test results to SMS interpretive criteria.

3.3 SPI Survey Data Collection

SPI photography provides a cross-sectional photograph of surface and sediment near the surface. An area 20 cm high by 14 cm wide is captured in this "profile" and recorded as a digital image. Images are collected using a Benthos model 3731 sediment profile digital camera. The sediment profile camera consists of a wedge-shaped prism with a Plexiglas faceplate and a back mirror mounted at a 45° angle. Light is provided by an internal strobe. The mirror reflects the image of the profile of the sediment/water interface to a digital camera mounted horizontally on top of the prism. Three replicate images will be collected from each SPI sampling location.

3.4 Sediment Sample Collection

Surface sediment samples will be collected at a total of 123 sampling locations, including references. Surface sediment samples will be collected for chemical analysis, toxicity testing, and benthic community characterization. Table 3-2 lists the various surface sediment samples to be collected; the analytical and biological testing methods; and sample container, volume, and preservation requirements. The following sections describe the collection and processing of surface sediment samples.

3.4.1 Surface Sediment Samples

Surface sediment collected for chemical and toxicological analysis will be collected from a small boat using a stainless-steel Ekman, ponar, or similar grab sampling device in Area 1, and using a hydraulic grab sampler in Areas 2, 3, and 4. If accessible during low tide events, surface sediment samples from intertidal areas may be collected directly with stainless-steel spoons. The grab sampler will be deployed from the sampling platform using a manually triggered handle (for the Ekman in shallow water less than 3 feet deep) or using a davit/a-frame, winch, and cable (grab samplers in water greater than 3 feet deep). Multiple grab samples will be collected and composited for each sampling location to provide sufficient volume for chemical analysis and potential toxicity testing. An additional five replicates will be collected from sediment quality triad stations for benthic community analysis. The general procedure for collecting sediment using a grab sampler is as follows:

1) Make logbook and field form entries as necessary throughout the sampling process to ensure accurate and thorough record-keeping. Field documentation is described in Section 3.7.
2) Position the sampling vessel at the targeted sampling location.
3) Set the sampler jaws in the open position, place the sampler over the edge of the boat, and lower the sampler to the bottom.
4) Trip the sampler manually if using the Ekman sampler with a handle (< 3 feet deep).
5) Record the location using the DGPS; measure and record the water depth.
6) Retrieve the sampler and place it securely in the sampling vessel.
7) Examine the sample for the following sample acceptance criteria:

- The sampler is not overfilled with sample so that the sediment surface is pressing against the top of the sampler.
- The sample does not contain large foreign objects (i.e., trash or debris). A sample that is rock/gravel fill will be rejected in favor of depositional material (i.e., sand/silt/clay).
- Overlying water is present indicating minimal leakage.
- Overlying water is not excessively turbid indicating minimal sample disturbance.
- Sediment surface is relatively flat and/or intact without any indications of disturbance or winnowing.
- A penetration depth has been achieved that allows the collection of the upper 10 cm of sediment.

If sample acceptance criteria are not achieved, the sample will be rejected and another sample collection attempt will be made.

8) Siphon off any overlying surface water.
9) Collect samples for total sulfides analysis directly from the grab sampler and place the sediment aliquots in appropriate, pre-cleaned, labeled sample containers (Table 3-2).
10) Measure and collect the top 10 cm with a stainless steel spoon, avoiding any sediment that is in contact with the inside surface of the grab sampler, then place the sediment into a stainless steel bowl and cover with aluminum foil.
11) Record the following observations of sediment sample characteristics on the field form (Appendix B); if more sample volume is required, repeat steps 4 through 11.
    - Texture
    - Color
    - Biological organisms or structures (i.e., shells)
    - Presence of debris (i.e., natural or anthropogenic objects)
    - Presence of oily sheen or obvious contamination
    - Odor (e.g., hydrogen sulfide, petroleum)
12) Wash excess sediment back into the water away from any areas remaining to be sampled.
13) Once sufficient sediment volume has been collected, samples should be placed in the appropriate, pre-cleaned, labeled sample containers as described in Section 3.3, placed in a cooler maintained at 4ºC, and prepared for shipment to the analytical or biological laboratory as described in Section 3.4.
14) Confirm all relevant documentation has been completed, entries are accurate, and paperwork has been signed.
15) Decontaminate all sampling equipment as described in Section 3.6 before proceeding to the next sampling location.

A single replicate for each required analysis will be collected from each target sampling location, with the exception of field duplicate and matrix spike/matrix spike duplicate (MS/MSD) samples to be collected randomly at the field supervisor's discretion. Aliquots of homogenized sediment will also be collected for toxicity testing at designated locations. The sample types collected from each location are presented in Table 3-2.

A 4 oz sample will also be retained from the homogenate of each location in a given area of interest. Once surface sediment sampling is completed in a given area, the individual aliquots will be combined and homogenized to produce an area-wide composite representative of all locations sampled. Samples from the area-wide composite will be submitted for analysis of selected conventionals (TOC and grain size), SMS analytes, and dioxin/furan congeners.

3.4.2 Wet-sieving

For locations designated for potential toxicity testing, an aliquot of sediment will be wet-sieved in the field. The purpose for wet-sieving an aliquot of homogenized sample is to separate the coarse and fine-grained material comprising a sediment sample in order to match appropriate test and reference locations for toxicological testing. The method utilizes a 63-micron sieve to separate the silt and clay (fines) from the sand and gravel portion of the sediment sample. The grain size distribution of a given sediment sample is an important physical parameter when conducting bioassays in order to determine an appropriate reference sample (Section 4.2.3) for comparison with test sediments. The wet-sieving of surface sediment samples is conducted in the field at the time of collection, so that a reference sample(s) with similar grain size distribution (as percent fines) can be targeted for the bioassays. The procedure for wet-sieving is as follows:

1) Measure and record the exact volume of a small (100 ml) flat-topped beaker. (Note: the 100 ml gradation is generally located slightly below the rim of the beaker; hence, the actual beaker volume is greater than 100 ml).
2) Completely fill the beaker to the rim with an aliquot of homogenized sediment. Lightly tap the beaker on a hard surface to remove any air bubbles, and level the surface.
3) Rinse the entire contents of the beaker through a 63-micron (#230, 4 phi) sieve. Aggregates of material should be gently broken to facilitate sieving. Continue sieving until clear rinsewater passes through the sieve.
4) Carefully transfer the coarse-grained material from the sieve into a 250 ml graduated cylinder.
5) Divide the amount of material measured in the bottom of the graduated cylinder by the capacity of the beaker to determine the decimal percentage of coarse-grained material. Subtract the decimal percentage of coarse-grained material from 1 to determine the decimal percentage of fines (silt and clay).
6) Record the percentages of coarse and fine-grained material in the logbook containing the surface sediment field collection forms (Appendix B).

3.4.3 Subsurface Sediment Collection

Subsurface sediment samples will be collected at a total of 12 locations, co-located with the benthic triad sampling stations. Core samples will be collected using a 48-inch Wildco hand-corer in Area 1, and a 10-foot vibracorer in Areas 2, 3, and 4. The cores will be advanced to a depth of 4 feet or refusal, for the hand corer, and 8 feet or refusal for the vibracorer. Each core will be sampled at 1-foot intervals: 0 to 1, 1 to 2,… 3 to 4 for hand-corer (7 to 8 feet for vibracorer), depending upon limitations of the equipment to reach targeted depth horizons.

The general procedure for collecting sediment cores is as follows:

1) Make logbook and field form entries as necessary throughout the sampling process to ensure accurate and thorough record-keeping. Field documentation is described in Section 3.8.
2) Position the sampling vessel at the targeted sampling location.
3) Record the location using the DGPS; measure and record the water depth.
4) Insert pre-cleaned Lexan or aluminum core tubes equipped with a "eggshell" core catcher to retain material in the core barrel for deployment.
5) The core-sampler is positioned vertically on the bottom and advanced to a sampling depth of approximately 4 feet for the hand corer, 8 feet for the vibracorer to include all targeted sampling intervals or until refusal.
6) Once sampling is complete, the sampler is extracted and the core liner is removed from the core barrel, or core tube is detached from the vibracorer. The core sample will be examined at each end to verify that sufficient sediment was retained. The condition and quantity of material within the core will then be inspected to determine acceptability. If sample acceptance criteria are not achieved, the sample will be rejected and another sample collection attempt will be made.
    - To verify whether an acceptable core sample has been collected, the following criteria must be met:
        a) Target penetration depth (i.e., 4 feet or 8 feet) or refusal was achieved;
        b) Sediment recovery of at least 65% of the penetration depth is targeted to deem the core acceptable;
        c) Sample appears undisturbed and intact without any evidence of obstruction or blocking within the core tube or core catcher.
    - The percent sediment recovery will be determined by dividing the length of material recovered in the core tube by the depth of core penetration below mudline. If the sample is deemed acceptable, overlying water will be siphoned from the top of the core tube, and each end of the tube will be capped and sealed with duct tape for storage until processing. The cores will be stored on ice until they are processed. The station number, station coordinates, date and time of collection, sediment description, field crew, and weather conditions will be recorded in the sediment coring log (Appendix B).
7) Record observations of sediment sample characteristics on the field form (Appendix B); if more sample volume is required, repeat steps 4 through 11.
8) Sediment cores will be labeled, capped, and stored in an upright vertical position in a container packed with ice until processed. Cores will be processed on the same day they are collected.
9) Confirm all relevant documentation has been completed, entries are accurate, and paperwork has been signed.

10) Wash excess sediment back into the water away from any areas remaining to be sampled.

11) Decontaminate all sampling equipment as described in Section 3.9 before proceeding to the next sampling location.

A single acceptable sample for each subsurface interval will be collected and archived pending the results of the surface sediment chemistry and toxicity testing results. SAIC will process all sediment cores on site at a designated processing location (extrusion, documentation, and sample collection for analysis). Disposable nitrile gloves will be worn for all handwork such as sectioning and extruding the core, sub-sampling, mixing samples, and filling sample containers. The gloves will be disposed of between sample composites in order to prevent cross contamination between samples. Sampling implements and processing equipment will be decontaminated prior to processing the sediment cores. Sediment cores will be processed in the same order as collected to minimize holding time. Each section comprising a core sample will be extruded onto a stainless steel tray using a core sample removal tool (a plunger style device that pushes the sample through the core tube). Care will be taken to preserve the integrity of the core section stratums by extruding in order from top (e.g., mudline) to bottom (native material). Once the sediment has been extruded, a visual characterization of the sample material will be immediately conducted. The core will then be visually described in the core log including the following information and characteristics:

- Station number
- Date and time of collection
- Station coordinates
- Weather conditions
- Names of persons collecting and logging the sample
- Penetration depth
- Percent sediment recovery
- Physical soil description in accordance with the Unified Soil Classification System (USCS)
- Color
- Odor (e.g., hydrogen sulfide, petroleum)
- Visual stratifications and lenses
- Vegetation and/or woody debris
- Biological Activity (e.g., detritus, shells, tubes, bioturbation, live or dead organisms)
- Presence of oil sheen or obvious contamination
- Any other distinguishing characteristics or features

Representative aliquots of sediment will be collected from the 1-foot intervals using decontaminated stainless steel spoons, to generate the composite sample that will be used to evaluate the project's technical objectives. Up to eight samples (four in Area 1) will be collected from each core representing a 1-foot vertical horizon (i.e., 0 to 1, 1 to 2,…7 to 8 feet). Sediment will be collected from the center of the core that has not been smeared by, or in contact with, the core tube. The volumes removed will be placed in a decontaminated stainless steel bowl or pan, and mixed until homogenous in texture and color. After all sediment for a composite sample is collected and homogenized, representative aliquots will be placed in the appropriate, pre-cleaned, labeled sample containers and prepared for shipment to the analytical laboratory for archiving.

3.4.4 Radioisotope Cores

Four subsurface cores will be submitted for sedimentation rate and surface mixed layer depth. Each core will be approximately 4 to 8 feet in length, and SAIC will subsample each core based on the following directions provided by Battelle:

- Section the core in 2 cm increments to 50 cm, 5 cm increments to 120 cm, and 10 cm increments for the remainder of the core.
- A full 125 ml container of wet sediment will be collected for each sample section, which should provide 100 grams of dry sediment.

3.5 Tissue Samples

Fish, crab, and clam tissue samples will be collected and archived from each of the areas of interest. Analysis of the samples will depend on the outcome of the surface sediment chemistry. The methods for collecting and processing the samples are discussed below.

3.5.1 Trawl Sampling

A 7.6-meter otter trawl will be used to collect Dungeness crab (*Cancer magister*) and English sole (*Parophrys vetulus*) in Areas 2, 3, and 4 of Fidalgo Bay. English sole will be the targeted species; however, if they are not present in abundance, alternate species may include starry flounder (*Platichthys stellatus*) or flathead sole (*Hippoglossoides elassodon*). Likewise, if Dungeness crab are not in abundance, red rock crab (*Cancer productus*) may be used as a surrogate species.

The otter trawl will be towed approximately 370 meters (1/5 nautical mile) at a ground speed of 4.2 to 5.0 kilometers/hour (2.3 to 2.7 knots), which covers an area swept by the net (opening = 6 meters) of approximately 2,220 square meters. Trawl sampling will be conducted in three areas in Fidalgo Bay, but with no particular attention to hitting specific stations (e.g., onsite, transect, perimeter). Approximately three trawls per area will be performed.

Triplicate English sole and Dungeness crab samples will be collected for each area of interest. English sole with a minimum length of 20 cm will be targeted for collection. Each English sole sample will consist of five fish. The whole bodies of each fish will be homogenized separately.

Equal volumes from each fish homogenate will be combined to make a final composite sample for analysis. The laboratory will archive the remaining tissue from each fish as separate samples.

Male Dungeness crabs with a minimum length of 9 cm will be targeted for collection. If males are not in abundance, females will be taken. Each Dungeness crab sample will consist of five crabs. The crabs in each sample will be dissected for crab meat and hepatopancreas tissue samples.

All fish will be immediately collected from the bag upon net retrieval and transferred to a holding tank where they will be identified and enumerated. Non-target species will be promptly and carefully released to the water.

Fish processing shall include identification, measurements for length and weight, and a check for obvious external abnormalities or parasites. All fish will be euthanized humanely following collection.

3.5.2 Shellfish Collection

Small shovels and trowels will be used to collect littleneck clams (*Protothaca staminea*) and Manila clams (*Ruditapes philippinarum*) at low tide from publicly accessible beaches in the vicinity of Fidalgo Bay. Clams collected during surface sediment sampling will also be retained for inclusion in the composite samples collected from the respective Area of Interest.

Crab pots may also be utilized to supplement the collection of crabs if insufficient numbers are obtained via bottom trawling.

3.5.3 Tissue Samples

Organisms collected for tissue residue analysis (English sole, littleneck and/or Manila clams, Dungeness crab) will be rinsed with site water following collection. Fish will be individually wrapped with heavy duty aluminum foil and placed in pre-labeled polyethylene bags. Crabs will be placed directly in pre-labeled polyethylene bags. All organisms collected for a composite sample will be included in the same polyethylene bag. All clams for a composite sample will be placed directly into pre-cleaned sample jars (one per species). Sample preparations (i.e., whole fish compositing, and clam shucking) will be conducted by the analytical laboratory. Tissue samples will be immediately placed on ice in coolers in the field. If not submitted immediately (within 24 hours) to the analytical laboratory, the tissue samples will be frozen at -18°C.

Bivalve, Dungeness crab, and English sole tissue samples will be immediately placed on ice in coolers in the field and archived at -18°C at the SAIC warehouse until a decision is made for analysis.

English sole samples will include five organisms per composite. The composite sample identification number and the total length of each fish included in a composite sample will be recorded on data sheets included as part of the biological sampling log. The whole body (skin on) from each individual fish will be homogenized separately, and equal volumes from each fish homogenate will be combined to create a final composite sample for analysis. The laboratory will archive the remaining tissue from each fish as separate samples.

Dungeness crab samples will include five organisms per composite. The carapace width and sex of each crab retained for analysis will be recorded on data sheets in the biological sampling log. Upon receipt by the analytical laboratory, the crabs will be dissected to collect edible meat and hepatopancreas tissue samples. The edible meat and hepatopancreas samples will be homogenized separately and archived for potential future analysis.

Triplicate tissue samples of littleneck and/or Manila clams will be collected at three beach locations in Fidalgo Bay. However, a minimum of five clams will be collected per composite. The shell length and weight for each clam retained for analysis will be recorded in the biological sampling log. Upon receipt by the analytical laboratory, the clams will be shucked to collect the edible tissues. The tissue from each sample will be homogenized and analyzed.

3.6 Sample Identification, Containers, and Labels

Samples will be identified based on the project, sampling area, location, and sample type. All samples collected during the investigation will be labeled clearly and legibly. Each sample will be labeled with a unique alphanumeric sample identification number that identifies characteristics of the sample as follows:

Project	Sampling Area	Location Number	Sample Type
FB-	A1-	01-	S

Where:

Project consists of two characters describing the project (FB = Fidalgo Bay).

Sampling Area consists of two characters describing the sampling area (A1 = Area 1; A2 = Area2; A3 = Area 3; and A4 = Area 4).

Location Number consists of two characters identifying the station location number (Figures 2-1, 2-2, 2-3, and 2-4). Tissue samples will be identified by species (ES = English sole; SF = starry flounder; DC = Dungeness crab; RC = red rock crab; LC = littleneck clam; MC = Manila clam.

Sample Type consists of one to two characters indicating the sample type. Sample type is indicated for QA/QC samples, toxicity testing, or benthic community analysis with R=rinseate, D=duplicate, T = triplicate, RB= rinseate blank, TX=toxicity, and S0-1, S1-2, S2-3, ….etc., for the subsurface sediment intervals 0 to 1, 1 to 2, 2 to 3 feet, …etc., respectively.

Sample aliquots submitted to the analytical and biological laboratories will be placed in pre-cleaned sample containers and preserved as identified in Table 3-2. The procedure for sample storage and shipping is provided in Section 3.7.

Sample labels will be self-adhering, waterproof material. An indelible pen will be used to fill out each label. Each sample label will contain the project name (Fidalgo Bay Sediment Characterization), sample identification, date and time of collection, analyses, preservative (as applicable), and the initials of the person preparing the sample. In addition, a unique, sequentially numbered jar tag will be placed on each sample container for tracking purposes. Jar

tag numbers will be recorded in a Sample Container Logbook (Appendix B). Sample labels and jar tags will be protected by packaging tape wrapped around the entire jar to prevent loss or damage of the labels during handling and storage.

3.7 Sample Storage and Delivery

All samples will be stored in insulated coolers and preserved by cooling to a temperature of 4ºC and as required by analytical method. Maximum sample holding and extraction times will be strictly adhered to by field personnel and the analytical and testing laboratories.

Preparation of bottles for shipment will be performed in the following manner:

1) Wipe or decontaminate the outside of filled, capped sample bottles to ensure there is no sample residual on the outside of the container. Secure sample lid jars with electrical tape to prevent leakage.
2) Label jars with prepared labels.
3) Each set of samples will have a unique sample ID and jar tag number.
4) Secure labels with clear packaging tape.
5) Record the samples in Sample Container Logbook (see Appendix B) and the chain-of-custody forms (Section 3.8.2).
6) Place sample containers in plastic zip-loc bubble-pack bags, or wrap in bubble pack and secure with packaging tape.
7) Prepare an empty insulated cooler by placing three to four ice packs in a garbage bag at the bottom of the cooler. Place sample containers in a garbage bag and fill with the sample bottles. Add additional bags of ice as needed to surround the bag containing the samples.
8) Seal the cooler with strapping tape and a custody seal. Samples for chemical analyses will be shipped via overnight courier to the analytical laboratory once per day or whenever a cooler is filled, and accompanied by the chain-of-custody record, which identifies the shipment contents. The chain-of-custody will be signed by the individual relinquishing samples to the onsite laboratory representative. The field personnel will be responsible for the following:
    - Packaging the samples;
    - Signing the chain-of-custody before placing inside the cooler to be sealed;
    - Ensuring sufficient ice or re-usable ice packs to maintain samples at 4º, during storage and shipping;
    - Applying a shipping label, an air bill, a custody seal, and strapping tape to the cooler; and
    - Shipping the samples in accordance with the maximum holding time allowed for the analyses to be performed.

Samples for toxicological testing and benthic analysis will be shipped to the appropriate biological laboratory at the completion of the sample collection effort for archiving. They will be properly labeled, packaged, and preserved with ice in a cooler as described above and temporarily stored under contractor custody. A separate chain-of-custody form will be filled out

for the chemistry, toxicological, and benthic community samples. The chain-of-custody will be signed by the individuals relinquishing the samples and will be placed inside the cooler before it is sealed.

All sediment samples will be retained for a minimum of 6 months from the time they were received using standard laboratory handling procedures. They may be removed from the laboratory prior to the end of the 6-month period only at the direction of the contractor project manager in consultation with Ecology.

3.8 Field Documentation

A complete record of field activities will be maintained. Documentation necessary to meet QA objectives for this project include: field notes and field forms (Appendix B), sample container labels, and chain-of-custody forms. The field documentation will provide descriptions of all sampling activities, sampling personnel, and weather conditions, and will record all modifications, decisions, and/or corrective actions to the study design and procedures identified in this workplan.

3.8.1 Field Notebooks

All handwritten documentation must be legible and completed in permanent waterproof ink. Corrections must be marked with a single line, dated, and initialed. All documentation, including voided entries, must be maintained within project files.

Field logbook(s) will be kept on site during field operations by the field manager. Daily activities will be recorded in a bound field logbook of water-resistant paper. Separate logbooks consisting of bound, paginated field forms will be kept for surface sediment grab descriptions, and an inventory of sample containers (separate from chain-of-custody documentation). Examples of the various field forms to be used are presented in Appendix B. All entries will be made legibly, in indelible ink, and will be signed and dated. Information recorded will include the following:

- Date, time, place, and location of sampling;
- Onsite personnel and visitors;
- Daily safety discussion and any safety issues;
- Quality control samples (i.e., duplicate samples, field blanks, etc.);
- Calibration of field equipment (including make and model of equipment);
- Field measurements and their units;
- Observations about site, location, and samples (weather, current, odors, appearance, etc.); and
- Equipment decontamination verification.

Field logbooks are intended to provide sufficient data and observations to enable participants to reconstruct events that occur during project field activities. Entries should be factual, detailed, and objective. Unless restricted by weather conditions, all original data recorded in field

logbooks and on sample identification tags, chain-of-custody records, and field forms will be written in waterproof ink. If an error is made, the individual responsible may make corrections simply by crossing out the error and entering the correct information. The erroneous information should not be obliterated. All corrections must be initialed and dated.

3.8.2 Chain-of-Custody Procedures

Samples will be retained at all times in the field crew's custody until samples are delivered to the appropriate laboratory by contractor personnel. All samples will be held and transported in coolers with ice or frozen gel-packs at approximately 4ºC.

Chain-of-custody forms will be initiated at the time of sample collection to ensure that all collected samples are properly documented and traceable through storage, transport, and analysis. When all line items on the form are completed or when the samples are relinquished, the sample collection custodian will sign and date the form, list the time, and confirm the completeness of all descriptive information contained on the form. Each individual who subsequently assumes responsibility for the sample will sign the chain-of-custody form and provide the reason for assuming custody. The field chain-of-custody terminates when the laboratory receives the samples. The field manager should retain a copy of the completed, signed, chain-of-custody form(s) for project files.

3.9 Equipment Decontamination Procedures

Sample processing equipment (i.e., spoons, bowls, and reusable containers from which samples are transferred to sample jars) will be washed with a laboratory-grade detergent (e.g., Alconox) and water solution, rinsed with deionized water, and a final distilled water rinse prior to field operations. Decontaminated equipment will be wrapped or covered with aluminum foil. Sub-sampling and processing equipment will be decontaminated before use at each station in order to prevent cross contamination of samples. Any deviations from these procedures will be documented in the field notebook.

Personal non-disposable field equipment (i.e., boots and waterproof gloves and garments) will be rinsed with water and brushed clean prior to leaving the immediate vicinity of the sample collection area. Special attention will be given to removing mud and sediments that may adhere to boot treads.

3.10 Waste Disposal

During the field investigation, field personnel will be responsible for securing appropriate waste containers, and placing wastes in labeled storage containers, performing appropriate testing, preparing wastes for disposal, and proper disposition of wastes.

Two types of waste will be generated during the activities described in this workplan:

- Excess sediment sample core not submitted to the laboratories; and
- Disposable protective clothing, sampling equipment, and packaging.

3.10.1 Sediment Sample/Sediment Core

Small quantities of excess sediment and rinseate water generated during sample processing will be returned to the site. Care will be taken to not dispose of sediment and/or rinseate at locations targeted for subsequent sampling.

3.10.2 Disposable Protective Clothing and Sampling Equipment

Used PPE, such as protective Tyvek suits or gloves, and sampling equipment, such as aluminum foil and paper towels, and any packaging material that cannot be recycled will be placed in plastic storage bags and disposed of as municipal waste.

Table 3-2. Surface Sediment Sample Types to be Collected

Sample Locations	**Surface Sediment Chemistry**							**Sediment Toxicity**
Analyses	Sediment Conventionals[1]	Total Sulfides	SVOCs, PCBs, Pesticides	Dioxin/ Furans	Metals	Mercury	Archive[10]	amphipod mortality; larval development; polychaete growth
Container(s)	16 oz glass	2 oz glass	16 oz glass	125 mL glass	8 oz glass jar		16 oz glass	Three 32 oz glass jars
Preservative	4°C/ -18°C[2]	4°C; zinc acetate	4°C/ -18°C[2]	4°C	4°C/ -18°C	-18°C	4°C/ -18°C	4°C, nitrogen purged headspace
Holding Time	14 days/ 6 months[3]	7 days	14 days/ 1 year	14 days	6 months/ 2 years	28 days	6 months	8 weeks
Area 1	15X	15X	15X	15X	15X		30A	15A
Area 2	15X	15X	15X	15X	15X		30A	15A
Area 3	15X	15X	15X	15X	15X		30A	15A
Area 4	15X	15X	15X	15X	15X		30A	15A
Reference Locations[4]								
RF-01[5]	X	X	X	X	X		-	A
RF-02[5]	X	X	X	X	X		-	A
RF-03[5]	X	X	X	X	X		-	A
QA/QC Samples								
Duplicates[6]	3X	3X	3X	3X	3X		-	-
Triplicates[6,7]	3X	3X	-	-	-			-
MS/MSD[6,8]	-	-	3X	3X	3X		-	-
Equipment Rinseate[6,8]	-	-	3X	3X	3X		-	-

Sample Locations	Surface Sediment Chemistry						Sediment Toxicity
Rinseate Blank[8]	-	-	X	X	X	-	-
Sample Totals	**69**	**69**	**73**	**32**	**73**		**63[9]**

Notes

X: sample to be collected and submitted for analysis/testing; A: sample to be collected and archived; P: potential location for sample -: no sample will be collected at this location

1: Sediment conventional parameters include grain size distribution, total solids, total volatile solids, total organic carbon, and ammonia.

2: Samples for grain size distribution and ammonia analysis should be stored at 4°C only.

3: Holding time for ammonia analysis is 7 days at 4°C; holding time for grain size distribution is 6 months at 4°C.

4: References: chemistry, toxicity testing, and potential benthic community analysis will be conducted at these locations.

5: Three candidate reference locations have been identified for the purposes of this workplan. Actual reference locations will be determined in the field based on physical attributes of the site and the results of the wet-sieving. Up to three reference locations will be sampled for chemistry and toxicity to match grain size distribution with site sediments.

6: Frequency of analysis is one per twenty samples (5%).

7: Triplicate analysis for sediment conventional parameters only.

8: MS/MSDs, equipment rinseate, and rinseate blanks conducted for organics and metals only.

9: The total number of samples to be tested is dependant on the sediment chemistry results.

10: Samples submitted for PCB congeners and bulk TBT will be taken from archived samples.

4.0 Laboratory Methods

All of the chemical analytical and biological testing procedures used in this program will be performed in accordance with the PSEP guidelines. The laboratory analysis will be consistent with PSEP guidelines (PSEP 1997a, 1997b, 1997c, 1997d), and any recent modifications proposed during the SMARM. Each laboratory participating in this program will institute internal QA/QC plans. Analyses will be required to conform to accepted standard methods and internal QA/QC checks prior to final approval.

4.1 Chemical Analyses

Chemical analysis will be conducted by laboratories subcontracted to the Ecology contractor. The specific analyses and conventional parameters to be measured, sample preparation methods, analytical methods, target detection limits (TDLs), and SMS numeric criteria (SQS and CSL) are presented in Table 4-1. The TDLs listed may be subject to modification due to elevated sample concentrations, heterogeneous samples (sediment), and potential matrix interferences that may preclude obtaining the desired quantification limit. In the event the laboratory is unable to meet the TDLs, the reasons for the deviation will also be reported. SMS guidance will be used to compare chemistry data results to determine whether further biological testing is warranted.

In addition to the analytes on the SMS list, dioxin/furan congeners and organotins will also be analyzed in a subset of samples. Analysis of dioxins/furans will follow USEPA Method 1613B for 2,3,7,8-substituted chlorinated dioxins and furans (Table 4-2). The concentration of dioxin/furan compounds will be normalized to the toxicity of 2,3,7,8-TCDD using TEFs updated by the WHO in 2005 (Van den Berg et al. 2006). The TEQ is equivalent to the sum of the concentrations of individual congeners multiplied by their TEF (potency relative to 2,3,7,8-TCDD). Non-detected values will be assessed as half of the method detection limit for data evaluation purposes.

Table 4-1. SMS Analytes (parameter, preparation method, analytical method, MDL, SMS SQS, and CSL)

Analyte	Prep Method[1]	Analytical Method[2]	Sediment MDL [3,4]	SQS	CSL
Conventional Parameters					
Total Solids (%)	---	PSEP [5]	0.1	---	---
Total Volatile Solids (%)	---	PSEP [5]	0.1	---	---
Total Organic Carbon (%)	---	PSEP [5]	0.1	---	---
Total Sulfides (mg/kg)	---	PSEP [5]	1	---	---
Ammonia (mg/kg)	---	Plumb 1981	1	---	---
Grain Size	---	Modified ASTM with Hydrometer	---	---	---
Metals			**mg/kg**	**mg/kg**	
Arsenic	PSEP/3050B	6010B/6020	19	57	93
Cadmium	PSEP/3050B	6010B/6020	1.7	5.1	6.7
Chromium	PSEP/3050B	6010B/6020	87	260	270
Copper	PSEP/3050B	6010B/6020	130	390	390
Lead	PSEP/3050B	6010B/6020	150	450	530
Mercury	---	7471A /245.5	0.14	0.41	0.59
Silver	PSEP/3050B	6010B/6020	2	6.1	6.1
Zinc	PSEP/3050B	6010B/6020	137	410	960
Low Molecular Polycyclic Aromatic Hydrocarbons (LPAH)			**µg/kg**	**mg/kg OC**	
Naphthalene	3540C/3550B	8270C/1625C	20	99	170
Acenaphthylene	3540C/3550B	8270C/1625C	20	66	66
Acenaphthene	3540C/3550B	8270C/1625C	20	16	57
Fluorene	3540C/3550B	8270C/1625C	20	23	79
Phenanthrene	3540C/3550B	8270C/1625C	20	100	480
Anthracene	3540C/3550B	8270C/1625C	20	220	1200
2-Methylnaphthalene	3540C/3550B	8270C/1625C	20	38	64
Total LPAH				370	780
High Molecular Polycyclic Aromatic Hydrocarbons (HPAH)			**µg/kg**	**mg/kg OC**	
Fluoranthene	3540C/3550B	8270C/1625C	20	160	1200
Pyrene	3540C/3550B	8270C/1625C	20	1000	1400
Benzo(a)anthracene	3540C/3550B	8270C[6]/1625C	20	110	270
Chrysene	3540C/3550B	8270C[6]/1625C	20	110	460
Benzofluoranthenes	3540C/3550B	8270C[6]/1625C	20	230	450
Benzo(a)pyrene	3540C/3550B	8270C[6]/1625C	20	99	210
Indeno(1,2,3-c,d)pyrene	3540C/3550B	8270C[6]/1625C	20	34	88
Dibenzo(a,h)anthracene	3540C/3550B	8270C[6]/1625C	20	12	33
Benzo(g,h,i)perylene	3540C/3550B	8270C/1625C	20	31	78
Total HPAH				960	5300

Analyte	Prep Method[1]	Analytical Method[2]	Sediment MDL [3,4]	SQS	CSL
Chlorinated Benzenes			**µg/kg**	**mg/kg OC**	
1,2-Dichlorobenzene	3540C/3550B	8270C[6]/1625C	3.2	2.3	2.3
1,4-Dichlorobenzene	3540C/3550B	8270C[6]/1625C	3.2	3.1	9
1,2,4-Trichlorobenzene	3540C/3550B	8270C[6]/1625C	6	0.81	1.8
Hexachlorobenzene	3540C/3550B	8270C[6]/1625C	12	0.38	2.3
Phthalate Esters			**µg/kg**	**mg/kg OC**	
Dimethyl phthalate	3540C/3550B	8270C/1625C	20	53	53
Diethyl phthalate	3540C/3550B	8270C/1625C	20	61	110
Di-n-butyl phthalate	3540C/3550B	8270C/1625C	20	220	1700
Butyl benzyl phthalate	3540C/3550B	8270C/1625C	20	4.9	64
Bis(2-ethylhexyl)phthalate	3540C/3550B	8270C/1625C	20	47	78
Di-n-octyl phthalate	3540C/3550B	8270C/1625C	20	58	4500
Ionizable Organic Compounds			**µg/kg**	**µg/kg**	
Phenol	3540C/3550B	8270C/1625C	20	420	1200
2 Methylphenol	3540C/3550B	8270C/1625C	6	63	63
4 Methylphenol	3540C/3550B	8270C/1625C	20	670	670
2,4-Dimethylphenol	3540C/3550B	8270C/1625C	6	29	29
Pentachlorophenol	3540C/3550B	8270C/1625C	61	360	690
Benzyl alcohol	3540C/3550B	8270C/1625C	6	57	73
Benzoic acid	3540C/3550B	8270C/1625C	100	650	650
Miscellaneous Compounds			**µg/kg**	**mg/kg OC**	
Dibenzofuran	3540C/3550B	8270C/1625C	20	15	58
Hexachlorobutadiene	3540C/3550B	8270C/1625C	20	3.9	6.2
N-Nitrosodiphenylamine	3540C/3550B	8270C/1625C	12	11	11
Total PCBs	3540C/3550B	8082	67	12	65
Organotins	SW3550B	Krone et al. 1989	1	-	-

Notes

MDL = method detection limit; SQS = sediment quality standards; CSL = cleanup screening levels; OC = organic carbon

1: Recommended sample preparation methods are: PSEP (1997a,b) and USEPA Method 3050B and 3500 series (sample preparation methods from SW-846 [USEPA 1986] and subject to changes by USEPA updates).

2: Recommended sample cleanup methods are: Sample extracts subjected to gel permeation chromatography (GPC) cleanup follow the procedures specified by USEPA SW-846 Method 3640A. Special care should be used during GPC to minimize loss of analytes. If sulfur is present in the samples (as is common in most marine sediments), cleanup procedures specified by USEPA SW-846 Method 3660B should be used. All PCB extracts should be subjected to sulfuric acid/permanganate cleanup as specified by USEPA SW-846 Method 3665A. Additional cleanup procedures may be necessary on a sample-by-sample basis. Alternative cleanup procedures are described in PSEP (1997a,b) and USEPA (1986).

3: MDL, SQS, and CSL are on a dry weight basis.

4: The recommended MDL is based on a value equal to one third of the 1988 dry weight lowest apparent effects threshold (LAET) value (Barrick et al. 1988) except for the following chemicals: 1,2-dichlorobenzene, 1,2,4-trichlorobenzene, hexachlorobenzene, hexachlorabutadiene, n-nitrosodiphenylamine, 2-methylphenol, 2,4-dimethylphenol, and benzyl alcohol, for which the recommended MDL is equal to the full value of the 1988 dry weight LAET.

5: Recommended Protocols for Measuring Metals in Puget Sound Water, Sediment and Tissue Samples, Puget Sound Estuary Program, April 1997.
6: Selected ion monitoring may improve the sensitivity of USEPA Method 8270C and is recommended in cases when detection limits must be lowered to human health criteria levels or when TOC levels elevate detection limits above ecological criteria levels. See PSEP Organics Chapter, Appendix B – Guidance for Selected Ion Monitoring (1997).

Table 4-2. Dioxin/Furan Analytical Method and Sediment Method Detection Limit

Parameter	Analysis Method[1]	Sediment MDL[2]
2,3,7,8-TCDD	1613B	0.2 to 0.5
1,2,3,7,8-PeCDD	1613B	0.2 to 0.5
1,2,3,4,7,8-HxCDD	1613B	1 to 5
1,2,3,6,7,8-HxCDD	1613B	1 to 5
1,2,3,7,8,9-HxCDD	1613B	1 to 5
1,2,3,4,6,7,8-HpCDD	1613B	1 to 5
OCDD	1613B	10
Total Tetra-Dioxins (TCDD)	1613B	0.2 to 0.5
Total Penta-Dioxins (PeCDD)	1613B	1 to 5
Total Hexa-Dioxins (HxCDD)	1613B	1 to 5
Total Hepta-Dioxins (HpCDD)	1613B	1 to 5
2,3,7,8-TCDF	1613B	1 to 5
1,2,3,7,8-PeCDF	1613B	1 to 5
2,3,4,7,8-PeCDF	1613B	1 to 5
1,2,3,4,7,8-HxCDF	1613B	1 to 5
1,2,3,6,7,8-HxCDF	1613B	1 to 5
1,2,3,7,8,9-HxCDF	1613B	1 to 5
2,3,4,6,7,8-HxCDF	1613B	1 to 5
1,2,3,4,6,7,8-HpCDF	1613B	1 to 5
1,2,3,4,7,8,9-HpCDF	1613B	1 to 5
OCDF	1613B	10
Total Tetra-Furans (TCDF)	1613B	0.2 to 0.5
Total Penta-Furans (PeCDF)	1613B	1 to 5
Total Hexa-Furans (HxCDF)	1613B	1 to 5
Total Hepta-Furans (HpCDF)	1613B	1 to 5

Notes
1: Method 1613 Tetra- through Octa-Chlorinated Dioxins and Furans by Isotope Dilution HRGC/HRMS. U.S. Environmental Protection Agency, Office of Water, Engineering and Analysis Division. October 1994.
2: MDL is on a dry weight basis in pg/g.

4.1.1 Analytical Laboratory Reporting

Analytical laboratory reports will be accompanied by sufficient backup data and QC results to enable independent reviewers to evaluate the quality of the data results. Analytical data will be reported in the units specified by the MDLs listed in Tables 4-1 and 4-2.

The analytical laboratory deliverables will include the following:

- Case narrative (including any problems encountered, protocol modifications, and/or corrective actions taken);
- Sample analytical and QA/QC results with units;
- All protocols used during analyses;
- Any protocol deviations from the approved sampling plan;
- Surrogate recovery results;
- Matrix spike/matrix spike duplicate results;
- Laboratory duplicate/triplicate results;
- Blank results;
- Sample custody records (including original chain-of-custody forms); and
- Analytical results in SEDQUAL (sediment quality database) electronic format.

4.2 Biological Analyses

This section describes specific procedures for the suite of bioassays used for SMS biological analysis. The decision to conduct confirmatory biological testing will be contingent on the chemistry results for a given location. To the maximum extent practicable, chemical results will be provided for bioassay decisions within 28 days of sample collection. The remaining 4-week (28-day) period of the holding time will allow time for bioassay preparation as well as time for retests if necessary.

Bioassay testing requires that test sediments be matched and run with appropriate reference sediment to factor out background conditions and sediment grain-size effects on bioassay organisms. The contractor will collect the identified reference sediments at the same time that other samples are collected. Wet-sieving in the field, however, is essential in finding an adequate match. Wet-sieving results should be recorded and submitted with the sample analysis results. The location of the reference sediment sampling location will be recorded to the nearest 0.1 second (NAD 83).

All sediment samples for potential bioassays will be stored at 4°C, with no headspace or under a nitrogen atmosphere (i.e., nitrogen-purged headspace) pending completion of chemical analyses and initiation of any required biological testing. All bioassays, including retests, will commence within 56 days from collection of the first grab sample in the sediment composite to be tested. The laboratory will maintain chain-of-custody procedures throughout biological testing.

Bioassay testing will be initiated as soon as possible after the first chemical results become available and the decision is made to conduct bioassays. This includes obtaining test organisms and control and reference sediments in a timely manner. This approach will support the opportunity for any second-round (additional) biological testing within the allowable 56-day holding period, if such need arises. As initial chemistry data become available, the project manager and the bioassay laboratory representative will maintain close coordination with Ecology to expedite biological testing decisions.

Three bioassays (Table 4-3) including amphipod mortality, larval development, and juvenile polychaete growth will be conducted on each sample identified for biological testing. All biological testing will be in strict compliance with Recommended Guidelines for Conducting Laboratory Bioassays on Puget Sound Sediments (PSEP 1995), with appropriate modifications as specified in the annual review process. General biological testing procedures and specific procedures for each sediment bioassay are summarized in the following sections.

Table 4-3. Bioassay Suite for the March Point RI/FS Sediment Investigation

Bioassay Test	Test Organism
10-day Amphipod Mortality Test	*Eohaustorius estuarius;* *Rhepoxynius abronius*
48-hour Larval Development Test[1] (echinoderm or bivalve)	*Mytilus galloprovincialis;* *Dendraster excentricus*
20-day Juvenile Polychaete Growth Test	*Neanthes arenaceodentata*

Note
1: Actual test length may vary based on larval development stage.

The specific QA/QC measures employed as part of the biological analyses are discussed in detail in Section 5.0.

4.2.1 Amphipod Mortality Bioassay

This test involves exposing *Rhepoxynius abronius*, *Ampelisca abdita*, or *Eohaustorius estuarius* to test sediment for 10 days and counting the surviving animals at the end of the exposure period. Daily emergence data and the number of amphipods failing to rebury at the end of the test will be recorded as well. The control sediment has a performance standard of 10% mortality. The reference sediment has a performance standard of 25% mean mortality.

E. estuarius is the preferred test organism for sediments with percent fines >60%. *R. abronius* is the preferred amphipod species for coarser-grained sediments (<60% fines), and if sediment clay content exceeds 20%, testing with *A. abdita* is recommended.

Ammonia and sulfides toxicity may interfere with test results for this bioassay. If elevated levels of these analytes are suspected, aeration may need to be conducted throughout the test. This action will be coordinated with Ecology. Ammonia reference toxicant tests may be conducted if elevated ammonia concentration is suspected in test sediments.

4.2.2 Larval Development Bioassay

This test monitors larval development of a suitable echinoderm or molluscan species (e.g., *Dendraster excentricus* or *Mytilus galloprovincialus*) in the presence of test sediment. *D. excentricus* is the preferred species, followed by *M. galloprovincialis*. The sediment larval bioassay has a variable endpoint (not necessarily 48 hours) that is determined by the developmental stage of organisms in a sacrificial seawater control (PSEP 1995). At the end of the test, larvae from each test sediment exposure are examined to quantify abnormality and mortality. The seawater control has a performance standard of 70% mean normal survivorship. Initial counts will be made for a minimum of five 10 mL aliquots. Final counts for seawater control, reference sediment, and test sediment will be made on 10 mL aliquots.

Ammonia and sulfides toxicity may interfere with test results for this bioassay. If elevated levels of these analytes are suspected, aeration may need to be conducted throughout the test. This action will be coordinated with Ecology. Ammonia reference toxicant tests may be conducted if elevated ammonia concentration is suspected in test sediments.

4.2.3 Juvenile Polychaete Growth Bioassay

This sublethal, static-renewal toxicity test can be used to determine the relative toxicity of marine sediments using the juvenile polychaete, *Neanthes arenaceodentata*. The test is conducted in accordance with the methods described by PSEP (1995) and modifications to the test approved by the DMMP agencies.

The toxicity test involves a 20-day exposure to sediments and the response of the organisms to test sediments as compared to their response in control (clean) and reference sediment. The test endpoint is mean individual growth (expressed as mg/individual/day).

The control sediment has a performance standard of 10% mortality. The reference sediment has a performance standard of 80% of the control growth. The DMMP agencies have established a target control growth performance guideline of ≥0.72 mg/individual/day. The *N. arenaceodentata* negative control performance guideline is a target growth rate of ≥0.72 mg/individual/day; the negative control performance standard is >0.38 mg/individual/day (below which the test is considered a QA/QC failure). Use of worms smaller than 0.25 mg (dry weight) at the beginning of the test will also be considered a QA/QC failure.

4.2.4 Full-Spectrum Lighting

Under certain conditions, when PAHs are exposed to UV radiation of sufficient quality and quantity, photo-activation may occur (Kosian 1998). Photo-activation has been demonstrated to result in increased acute and chronic toxicity (Arfsten 1996). Benthic and aquatic organisms exposed to selected PAHs and simultaneously to specific wavelengths and intensities of UV radiation may be at significantly greater risk to toxic effects than organisms exposed to the same PAHs absent the UV radiation (Ahrens 2002). When the following site conditions are encountered, bioassays should be performed in the presence of full-spectrum lighting that includes UV wavelengths of sufficient intensity to mimic conditions at the site (Ecology 2003):

1) Sediment Depth: For marine or estuarine sites, if either >25% of the surface sediments, or 1/2 acre of the surface sediments, are 4 meters (12 feet) or less, including intertidal and subtidal zones.
2) Presence or presumed presence of any of the photo-activated PAHs listed in Table 4-4 (Nagpal 1993).

Table 4-4. Photo-activated Polycyclic Aromatic Hydrocarbons

Anthracene	Benz[c]acridine
Acridine	Benzathrone
Phenazine	Benzo[a]pyrene
Fluoranthene	Benzo[e]pyrene
1H-benzo[a]fluorine	Perylene
1H-benzo[b]fluorine	Dibenz[a,h]acridine
Pyrene	Dibenz[a,h]anthracene
Benz[a]anthracene	Dibenz[a,j]anthracene
Benz[b]anthracene	Benzo[b]chrysene
Chrysene	Dibenz[a,c]phenazine
Benzo[k]fluoranthene	Benzo[b]triphenyline
Benz[a]acridine	Benzo[g,h,i]perylene

Since these conditions may be encountered in Fidalgo Bay, bioassays should be conducted using full-spectrum lighting, if warranted.

Standard fluorescent laboratory lighting fixtures are not full spectrum and do not produce "natural" wavelengths and intensity of light. Therefore, the laboratory must use two light sources with different radiation characteristics. The full-spectrum fluorescent lamp needed must include the following (Ecology 2003):

1) UV-B output (280 nm < λ < 315 nm) photo-activating wavelengths.
2) UV-A output (315 nm < λ < 400 nm); this may have an effect upon burial and feeding behavior.
3) Correct Color temperature: "warm" red to "cold" blue expressed in degrees Kelvin. Daylight at noon is typically estimated at 5,500°K.
4) High Color Rendering Index (CRI): Color rendering is the degree to which a light source shows the true color of objects it illuminates. This is measured on a color rendering index rated from 0–100. A normal fluorescent lamp rates 54 on the CRI scale. High quality fluorescent lamps will rate 90–98 on the same scale.

In addition to the quality of the lamp, its proximity to the animal, its output intensity, and duration of use are also critical. It is absolutely critical that nothing is placed between the envelope of the lamp tube and the recipient test organism or vessel. UV-B is greatly attenuated by glass, plastic, and ultra-fine mesh. The amount of UV-B received is also diminished with

distance. It is recommended that any UV-B tubes be no further that 12 inches (30 cm) away from the organism or vessel (Ecology 2003).

The recommended lab conditions for full-spectrum testing include:

- Light intensity: 50–100 foot candles;
- Light duration: 16:8 (light/dark);
- Overlying water depth: not greater than 15 cm (6 inches);
- Lamp to water surface distance: not greater than 30 cm (12 inches); and
- UV wavelength range: 3–8% UV-B (280nm < λ < 315nm), (3–5% preferred)
  20–35% UV-A (315nm < λ < 400nm).

4.2.5 Bioassay Interpretation

Test interpretations consist of endpoint comparisons to controls and reference on an absolute percentage basis as well as statistical comparison to reference. The SMS biological effects criteria are presented in Table 4-5.

Table 4-5. SMS Biological Effect Criteria (Ecology 2003)

Biological Test[1]	Sediment Quality Standards	Cleanup Screening Levels
Amphipod Mortality	The test sediment has a significantly higher (t-test, P≤0.05) mean mortality than the reference sediment, and the test sediment mean mortality is more than 25% greater, on an absolute basis, than the reference sediment mean mortality.	The test sediment has a significantly higher (t-test, P≤0.05) mean mortality than the reference sediment, and the test sediment mean mortality is more than 30% greater, on an absolute basis, than the reference sediment mean mortality.
Larval Development	The test sediment has a mean survivorship of normal larvae that is significantly less (t-test, P≤0.1) than the mean normal survivorship in the reference sediment, and the mean normal survivorship in the test sediment is less than 85% of the mean normal survivorship in the reference sediment.	The test sediment has a mean survivorship of normal larvae that is significantly less (t-test, P≤0.1) than the mean normal survivorship in the reference sediment, and the mean normal survivorship in the test sediment is less than 70% of the mean normal survivorship in the reference sediment.
Juvenile Polychaete Growth	The mean individual growth rate of polychaetes in the test sediment is less than 70% of the mean individual growth rate of the polychaetes in the reference sediment, and the test sediment mean individual growth rate is statistically different (t-test, P P≤0.05) from the reference sediment mean individual growth rate.	The mean individual growth rate of polychaetes in the test sediment is less than 50% of the mean individual growth rate of the polychaetes in the reference sediment, and the test sediment mean individual growth rate is statistically different (t-test, P P≤0.05) from the reference sediment mean individual growth rate.

Note

1: Sufficient sediment will be collected at all locations to conduct the suite of three laboratory bioassays: amphipod mortality, larval development, and juvenile polychaete growth. The benthic infauna samples will only be collected at the sediment quality triad stations. The SMS biological effects criteria will be used to assist in the interpretation of the benthic infauna data results as part of the sediment quality triad evaluation.

4.2.6 Biological Laboratory Reporting

The biological laboratory responsible for conducting laboratory bioassays will prepare a written report documenting all the activities associated with toxicity testing. At a minimum, the following will be included in the report:

- Results of the laboratory bioassay analyses and QA/QC results for test and reference sediments; raw data will be legible or typed; illegible data may result in the need for a retest if the agencies cannot interpret the data as a result;
- Results of positive and negative control, including reference toxicant specific laboratory control limits;
- Water quality monitoring results;
- All protocols used during analyses, including explanation of any deviation from the PSEP protocols and the approved sampling plan;
- Chain-of-custody procedures, including explanation of any deviation from the identified protocols;
- Location and availability of data, laboratory notebooks, and chain-of-custody forms;
- Source of test organisms; and
- Source of control sediment and control seawater.

4.3 Radioisotope Analyses

Laboratory analysis will consist of beryllium-7 (Be-7), lead-210 (Pb-210), and cesium-137 (Cs-137) radioisotope activity measurements. Percent dry weight and Pb-210 in disintegrations per minute per gram (dpm/g), Be-7 in cpm/g and Cs-137 in dpm/g, will be determined for each sample. QA/QC for each core sample will include one duplicate for Be-7, one check sample and one duplicate for Pb-210 and sedimentation rate determination, and one reference material and one duplicate for CS-137.

Analysis strategy should follow the procedures recommended by Battelle:

1. Initially analyze the top five sections (top 10 cm) for Be-7. If Be-7 activity is detected at 10 cm, then analyze more sections until activity is not detected.
2. Analyze the core for Pb-210 and Cs-137. Cs-137 can be analyzed along with Be-7 in the upper portion of the core.
3. Follow a typical strategy for initial analysis of Pb-210:
    - 0–50 cm Interval: Analyzing every other or every third 2 cm section
    - 50–120 cm Interval: Analyze every other 5 cm section
    - 120–360 cm Interval: Analyze every other 10 cm section

A sedimentation rate is calculated from the Pb-210 profile of the core. If there are gaps in the profile, additional samples can be analyzed to fill in the needed information. Once the sedimentation rate has been calculated, analyze sections that correspond to ~1950–1975 for Cs-137 to verify the sedimentation rate.

5.0 Quality Assurance Project Plan

The purpose of the project QA/QC is to provide confidence in the project data results through a system of quality control performance checks with respect to data collection methods, laboratory analysis, data reporting, and appropriate corrective actions to achieve compliance with established performance and data quality criteria. This section presents the QA/QC procedures to ensure that the investigation data results are defensible and usable for their intended purpose.

5.1 Measurements of Data Quality

The tolerable limits for the data reported by the laboratory will be measured through precision, accuracy, representativeness, completeness, and comparability (PARCC).

Precision is a measure of mutual agreement among individual measurements of the same property under prescribed conditions. Precision will be assessed by the analysis of MS/MSDs, field duplicate and triplicates, and laboratory control sample/laboratory control sample duplicates (LCS/LCSD). The calculated relative percent differences for field duplicates and triplicates and MS/MSD pairs will provide information on the precision of sampling and analytical procedures, and the relative percent differences for LCS/LCSD pairs will provide information on precision of the analytical procedures.

Accuracy is the degree to which an observed measurement agrees with an accepted reference or true value. Accuracy is a measure of the bias in the system and is expressed as the percent recoveries (%Rs) of spiked analytes in MS/MSD and LCS/LCSD samples. Accuracy will also be evaluated through the surrogate spikes in each sample. The laboratory control limits for surrogates will be used for the project.

Representativeness expresses the degree to which data accurately and precisely represent an actual condition or characteristic at a particular sampling point. Representativeness is achieved by collecting samples representative of the matrix at the time of collection. Representativeness can be evaluated using replicate samples, additional sampling locations, and blanks.

Completeness refers to the amount of measurement data collected relative to that needed to assess the project's technical objectives. It is calculated as the number of valid data points achieved divided by the total number of data points requested by virtue of the study design. For this project, completeness objectives have been established at 95 percent.

Comparability is based on the use of established USEPA-approved methods for the analysis of the selected parameters. The quantification of the analytical parameters is based on published methods, supplemented with well-documented procedures used in the laboratory to ensure reproducibility of the data.

5.2 Quality Assurance and Quality Control for Chemistry Sediment Samples

Field and laboratory QA/QC samples will be used to evaluate the data precision, accuracy, representativeness, and comparability of the analytical results. The field QA samples to be collected are described in Section 5.2.1. The laboratory QA samples are discussed in Section 5.2.2.

5.2.1 Field QA/QC for Chemistry Sediment Samples

Field QC samples will be collected during sampling to quantitatively measure and ensure the quality of the sampling effort and the analytical data. Field QC samples include field duplicates, equipment rinseate, and rinseate blanks. QC samples are to be handled in the same manner as the environmental samples collected. Brief descriptions of the field QC samples are provided below.

5.2.1.1 Field Replicates

Field duplicates are collected at the same time as the original sample using identical sampling techniques. Field duplicate sample results (triplicates for sediment conventional parameters) are used to assess the precision of the sample collection process and to help determine the representativeness of the sample. Field replicates will be collected at a 5% frequency. The replicates will be designated for the same analysis as the original samples and submitted to the laboratory blind (no indication of the contents or the associated sample). The field replicates will be collected from the same homogenate as the original sample.

5.2.1.2 Equipment Rinseate and Rinseate Blanks

The equipment rinseate blank and decontamination water (rinseate) blank provide a quality control check on the potential for cross contamination by measuring the effectiveness of the sampling and processing decontamination procedures. The equipment rinseate sample consists of de-ionized water rinsed across sample collection and processing equipment after they have been used to collect a sample and have been decontaminated for use at the next sampling location. The decontamination water blank is an unadulterated sample of the de-ionized water used to create the rinseate blank, analyzed to ensure no contaminants were present in the rinse water. Equipment blank samples will not be required when using disposable sample equipment.

5.2.2 Laboratory QA/QC for Chemical Sediment Sample

One laboratory matrix spike and matrix spike duplicate will be analyzed for every 20 samples submitted or for each analytical batch of samples (if less than 20 submitted) for the analysis of SVOCs, PCBs, metals, and TOC. The combination of these spiked samples will provide information on the accuracy and precision of the chemical analysis, and to verify that the extraction and measured concentrations are acceptable. The matrix spike and matrix spike duplicates will be analyzed in accordance with USEPA methods for each respective analyte.

One laboratory replicate will be analyzed for all constituents (except grain size, TOC, and total solids) for every 20 samples submitted or for each analytical batch of samples (if less than 20 submitted). Laboratory triplicates will be analyzed for grain size, TOC, and total solids. These QA/QC samples will be analyzed in accordance with the respective USEPA method and will be used to evaluate the precision of the analytical method.

One laboratory method blank and LCS will be analyzed for all constituents (except grain size and total solids) for each analytical batch of twenty samples to assess potential laboratory contamination and accuracy. An LCSD will be analyzed if required by the method, or if the laboratory does not have enough sample volume to prepare an MS/MSD.

Laboratory control samples, certified reference material, and surrogate spikes will be used as defined by the analytical methods and equipment calibration requirements.

5.3 Biological Testing QA/QC for Sediment Samples

The detailed standard operating procedures (SOPs) for the bioassay tests proposed for this investigation will be provided by the selected biological laboratory upon request. This section summarizes the toxicity test QA/QC procedures to be implemented to ensure the test results are valid. Standard QA/QC procedures include the use of negative controls, positive controls, reference sediment samples, laboratory replicates, and daily water quality measurements. In addition, close contact with the biological laboratory will be maintained prior to and during the testing period to resolve any QA/QC problems or testing methodology issues in a timely manner.

5.3.1 Negative Control

The negative control consists of clean, inert material tested in parallel with the test sediments under identical test conditions. The biological testing laboratory provides this clean material, which usually consists of sediment collected from the original location from which the test organisms were harvested. The test acceptability criteria are based on the results of the negative control. A test with at least 90% survival (70% mean normal survivorship for larval development) in negative control test chambers is considered acceptable.

5.3.2 Positive Control

A positive control will be run for each bioassay. Positive controls are chemicals known to be toxic to the test organism and which provide an indication of the sensitivity of the particular organisms used in a bioassay. Cadmium chloride or other appropriate reference toxicant will be used for the amphipod mortality, larval development, and juvenile polychaete growth bioassays.

5.3.3 Reference Sediment

Reference sediments, which closely match the grain size characteristics of the test sediments, will be run with each test batch for all three bioassays. The reference sediment is used for test comparisons and interpretations. The collection area will be determined based on sample physical characteristics. Candidate reference sites for this investigation are presented in

Figure 3. All reference sediments will be analyzed for total solids, total and acid volatile solids, total organic carbon, bulk ammonia, bulk sulfides, and grain-size.

All bioassays have performance standards for reference sediments (see Section 4.2). Failure to meet these standards may result in the requirement to retest.

5.3.4 Laboratory Replication

Five laboratory replicates of each test sediment, reference sediment, negative control, and elutriate concentration will be run for each respective bioassay. The replication of tests provides multiple observations of effects to test organisms so that statistical comparisons can be made between test and reference sediments.

5.3.5 Bioassay Water Quality

Water quality monitoring will be conducted for the amphipod, larval development, and juvenile polychaete growth bioassays. This consists of daily measurements of salinity, temperature, pH, and dissolved oxygen (every third day for juvenile polychaete growth bioassay). Ammonia and sulfides will be determined at test initiation and termination and interstitial salinity will be determined prior to the test setup. Monitoring will be conducted for all test and reference sediments and negative controls (including seawater controls). Parameter measurements must be within the limits specified for each bioassay as listed in Table 5-1. Measurements for each treatment will be made on a separate chemistry beaker set up to be identical to the other replicates within the treatment group. In addition, interstitial ammonia measurements at test initiation and test termination will be conducted for the amphipod test.

Table 5-1. Water Quality Control Limits (Ecology 2003)

Test (*Test Species*)	Temperature	Salinity	Dissolved Oxygen	pH[3]
Amphipod Mortality (*E. estuarius; R. abronius*)	15 ± 1 °C	Ambient[1]	NA[2]	---
Larval Development (*Mytilus* sp.)	16 ± 1 °C	28 ± 1 ppt	> 60% saturation	---
Larval Development (*D. excentricus*)	15 ± 1 °C	28 ± 1 ppt	> 60% saturation	---
Juvenile Polychaete Growth (*N. arenaceodentata*)	20 ± 1 °C	28 ± 2 ppt	NA[2]	---

Notes
1. Same as interstitial salinity of test sediment
2. Continuous aeration is required by the protocol, so the dissolved oxygen should not be a cause of concern.
3. Ph is monitored as a water quality parameter. There are generally no control limits for pH; however, measurements of pH may be useful in interpreting results (Ecology 2003).

5.4 Data Validation

The data generated as part of this investigation will undergo an independent quality assurance review and data validation. A QA2 chemistry data review will be conducted that examines the complete analytical process from calculation of instrument and method detection limits, practical quantitation limits, final dilution volumes, sample size, and wet-to-dry ratios to quantification of calibration compounds and all analytes detected in blanks and environmental samples (PTI 1989a). A QA1 review of bioassay data will be conducted that evaluates the acceptability of test results for positive controls, negative controls, reference sediments, replicates, and experimental water quality conditions such as temperature, salinity, pH, and dissolved oxygen (PTI 1989b).

6.0 Data Analysis and Reporting

This section describes the data analysis and reporting requirements for the data collection activities described in this workplan.

6.1 Analysis of Sediment Profile Imaging Data

SAIC has developed a standardized and formalized technique known as Remote Ecological Monitoring of the Seafloor (REMOTS®) for SPI image collection, analysis, and interpretation. Physical and biological parameters are measured directly from the SPI transparencies using a video digitizer and computer image analysis system. The image analysis system can measure up to 256 different tonal color scales so subtle features can be accurately digitized and measured. The image analysis software allows the measurement and storage of data with 21 different variables for each image. A representative image from each station will undergo full computer image analysis. In addition, a second image from 20% of the stations will be analyzed for quality assurance.

6.1.1 Benthic Macroinvertebrate Community

SPI imagery, in conjunction with benthic community grab samples, will be used to evaluate the health of the benthic macroinvertebrate community at the deep water disposal site. Depth of the apparent redox potential discontinuity (RPD), infaunal successional stage, and calculation of the Organism-Sediment Index (OSI) are three key REMOTS® image analysis parameters used to assess the health of the benthic infaunal community.

The mapping of infaunal successional stages from SPI images is based on the theory that organism/sediment interactions follow a predictable sequence after a major seafloor disturbance. Infaunal succession following a major seafloor disturbance initially involves pioneering populations (Primary or Stage I succession) of very small organisms that live at or near the sediment/water interface (Pearson and Rosenberg 1978; Rhoads and Germano 1986). In the absence of further disturbance, infaunal deposit feeders eventually replace these early successional assemblages. The start of this "infaunalization" process is designated as Stage II. Large, deep-burrowing infauna (Stage III taxa) represents a high order successional stage typically found in areas of low disturbance. The presence of Stage III feeding voids indicate the presence of Stage III organisms.

The OSI provides a measure of benthic habitat quality based on dissolved oxygen conditions, depth of the apparent RPD, infaunal successional stage, and presence or absence of sedimentary methane measured during REMOTS® image analysis (Rhoads and Germano 1986). The OSI is a numerical index ranging from -10 to +11. The lowest value is given to bottom sediments with low or no dissolved oxygen in the overlying bottom water, no apparent macrofaunal life, and methane gas present in the sediment. High OSI values are given to aerobic bottom sediments with a deep apparent RPD, mature macrofaunal community, and no methane gas. The numerical values and ranges used in calculating the OSI are provided in Table 6-1. Previous SPI surveys conducted in various coastal regions by SAIC (e.g., Puget Sound, Long Island Sound,

Chesapeake Bay, and the Florida and Louisiana coasts) have shown that OSI values less than 7 indicate a stressed or disturbed benthic environment.

6.1.2 Apparent Redox Potential Discontinuity

The depth of the apparent RPD, which is the change from oxidized to reduced sediment, will be measured using SPI photography and REMOTS® image analysis. The apparent RPD is a sensitive indicator of infaunal succession, sediment bioturbation activity, and sediment oxygen demand. In fine grain coastal areas where there is oxygen in the overlying water column, sediment near the surface will have a higher reflectance value relative to underlying hypoxic or anoxic sediment. This is because the oxidized surface sediment contains ferric hydroxide (an olive color when associated with organic particles) while the hydrogen sulfide sediments below this oxygenated layer are gray to black. The boundary between the colored ferric hydroxide surface sediment and underlying gray to black sediment is called the apparent RPD. In general, the depth of the actual RPD is shallower than the depth of the apparent RPD because bioturbating organisms mix ferric hydroxide-coated particles downward in the sediment column. As a result, the apparent RPD depth provides an estimate of the degree of biogenic sediment mixing. The area of the aerobic sediment is determined from SPI images by density slicing its unique reflectance value. This oxidized area can then be digitized, measured to scale, and divided by the prism window width to obtain a mean depth for the apparent RPD.

6.1.3 Physical Parameters

Physical parameters that will be measured include grain size, TOC, and total sulfides. In addition, we will also be using SPI photography to evaluate the grain size mode and range, sediment-bearing capacity, the presence and thickness of depositional layers, and any evidence of erosional or depositional events. The distribution of grain size major mode in phi (Φ) sizes will be determined from SPI photography using REMOTS® image analysis. The grain size mode and distribution will provide a direct measurement of the granular characteristics of dredged material disposed at the site. The camera prism penetration depth will provide a measure of sediment-bearing capacity. The presence and thickness of depositional layers will provide an important baseline for future determinations regarding the actual placement of dredged material. Evidence of erosional and depositional events will be useful for determining the relative energy at a given location, thus providing evidence whether dredged material will stay on site or eventually migrate elsewhere.

Table 6-1 Calculation of the Organism-Sediment Index

Choose One Value:	**Mean RPD Depth Classes**	**Index Value**
	0.00 cm	0
	> 0 - 0.75 cm	1
	0.76 - 1.50 cm	2
	1.51 - 2.25 cm	3
	2.26 - 3.00 cm	4
	3.01 - 3.75 cm	5
	> 3.75 cm	6
Choose One Value:	**Successional Stage**	**Index Value**
	Azoic	- 4
	Stage I	1
	Stage I – II	2
	Stage II	3
	Stage II – III	4
	Stage III	5
	Stage I on III	5
	Stage II on III	5
Choose One or Both if Appropriate:	**Chemical Parameters**	**Index Value**
	Methane Present	- 2
	No/Low Dissolved Oxygen	- 4
Organism-Sediment Index =		Range: - 10 + 11

6.2 Analysis of Sediment Chemistry Data

The analysis of chemistry data will include the comparison of the results to the SMS numeric criteria and as a line of evidence using the sediment quality triad index. The sediment chemistry data will be summarized and presented in tables indicating sediment locations and detected contaminants and any detection limits that exceed SQS and/or CSL numeric criteria, along with any data qualifiers assigned by the laboratory or during the data validation efforts. The locations with chemistry exceeding numeric criteria will be mapped to delineate any areas that may require cleanup or other remedial action.

6.3 Analysis of Biological Data

The analysis of biological data will include comparison to SMS biological effects criteria, providing two lines of evidence in the sediment quality triad approach, and as described in the sections below.

6.3.1 Toxicity Testing

The toxicity test data results will be summarized and presented in tables indicating sediment locations and test results that exceed SQS and/or CSL biological effects interpretive criteria, along with the results of statistical comparisons to reference sediment test results. The sampling locations with sediment toxicity exceeding the SMS criteria will be mapped to delineate any areas that may require cleanup or other remedial action.

6.4 Radioisotope Dating

Sedimentation rate information including sediment age in years, year of deposition, sediment accumulation rate (cm/yr), and sedimentation rate ($g/cm^2/yr$) will be determined and reported. The sedimentation rate is normally derived from Pb-210 results; however, in some cases the Cs-137 data may be used to determine the sedimentation rate and sediment ages. Cs-137 results are normally used to verify dates determined with sedimentation rates. Be-7 results will be used to estimate the mixed depth.

6.5 Subsurface Sediment Chemistry

The potential analysis of subsurface sediment intervals is dependant on the results of the surface sediment chemistry analysis, toxicity testing, and at the discretion of Ecology. If subsurface sediment samples are submitted for chemical analysis, the data results will be reported as an addendum to the sediment quality investigation.

6.6 Tissue Residue Chemistry

The potential analysis of tissue residue is dependant on the results of the surface sediment chemistry analysis and at the discretion of Ecology. If tissue samples are submitted for residue analysis, the data results will be reported as an addendum to the sediment quality investigation.

6.7 Data Report

A written data report documenting all activities associated with collection, transportation, chemical analyses, and biological testing of sediment samples will be prepared. The report will include recommendations for further action or investigation based on the data results of this investigation. The chemical, biological, and QA/QC reports will be included as appendices. At a minimum, the following will be included in the Final Report:

- Description of sampling and analysis activities;
- Protocols used during sampling and testing and an explanation of any deviations from the sampling plan protocols or the approved workplan;
- Physical descriptions of samples and site habitat;
- Methods used for station positioning, sample collection locations reported in latitude and longitude to the nearest tenth of a second (NAD 83);

- Map showing actual locations of sampling stations and results of data comparisons to SMS criteria and Sediment Quality Triad Index;
- Chain-of-custody records;
- Chemistry and biological testing results and laboratory reports;
- Comparison of data results to interpretive criteria;
- Radioisotope results and interpretation; and
- QA/QC summary and data validation reports.

7.0 References

Ahrens, M.J. and C. Hickey. 2002. UV-photoactivation of polycyclic aromatic hydrocarbons and the sensitivity of sediment-dwelling estuarine organisms. National Institute of Water & Atmospheric Research Conference: UV Radiation and its Effects: an update. 26-28 March 2002. Antarctic Centre, Christchurch, New Zealand.

Aller, R.C. 1982. The effects of macrobenthos on chemical properties of marine sediments and overlying waters. In: P.L. McCall & M.J.S. Tevesz (eds.), Animal-Sediment Relations. Plenum Publishing, NY. Pp: 53-102.

Anchor Environmental. 2004. Sampling and Analysis Data Report. Supplemental Sediment Characterization Dakota Creek Industries Shipyard Facility/Pier1 Redevelopment Area, Anacortes, WA. Prepared for Seattle District U.S. Army Corps of Engineers on behalf of Kimberly Clark Corporation and Port of Anacortes by Anchor Environmental, L.L.C. October 2004.

Anchor Environmental. 2005. Draft Data Report. Remedial Investigation/Feasibility Study of the Former Scott Paper Mill Site, Anacortes, WA. Prepared for Kimberly-Clark Corporation and Port of Anacortes by Anchor Environmental, L.L.C. November 2005.

Arfsten, D.P., Schaeffer, D.J., and Mulveny, D.C. 1996. The effects of near ultraviolet radiation on the toxic effects of polycyclic aromatic hydrocarbons in animals and plants: A review. *Ecotoxicol. Environ. Saf. 33,* 1-24.

Barrick, R.C., D.S. Becker, L.B. Brown, H. Beller, and R. Pastorak. 1988. Sediment Quality Values Refinement: 1988 Update and Evaluation of Puget Sound AET. Volume I. Final Report. Prepared for tetra tech, Inc., Bellevue, WA, and the U.S. Environmental Protection Agency, Region 10, Seattle, WA. Prepared by PTI Environmental Services, Bellevue, WA.

Ecology. 1995. Sediment Management Standards, Chapter 173-204 WAC. Prepared by the Washington State Department of Ecology, Olympia, WA. Ecology Publication No. 96-252. Revised December 1995.

Ecology. 1997. Survey for Petroleum and other Chemical Contaminants in the Sediments of Fidalgo Bay. Washington State Department of Ecology. Publication No. 97-338. November 1997.

Ecology. 2000a. Results of Screening Analysis for Metals and Organic Compounds in Shellfish from Padilla Bay and Vicinity. Washington State Department of Ecology. Publication No. 00-03-008. May 2000.

Ecology. 2000b. Sediment Quality on the West Side of Fidalgo Bay. Washington State Department of Ecology. Publication No. 00-03-007. January 2000.

Ecology and NOAA. 2003. Chemical Contamination, Acute Toxicity in Laboratory Tests, and Benthic Impacts in Sediments of Puget Sound. A Summary of Results of the Joint 1997-1999 Ecology/NOAA Survey. Washington State Department of Ecology and National Oceanic and Atmospheric Administration National Ocean Service. Ecology Publication No. 03-03-049. NOAA Technical Memorandum NOS NCCOS CCMA 163. October 2003.

Ecology. 2003. Sediment Sampling and Analysis Plan Appendix; Guidance on the Development of Sediment Sampling and Analysis Plans Meeting the Requirements of the Sediment Management Standards (Chapter 173-204 WAC). Prepared for the Washington State Department of Ecology, Sediment Management Unit, Lacey, WA. Prepared by PTI Environmental Service, Bellevue, WA. Ecology Publication No. 03-09-043. Revised April 2003.

Ecology. 2004. Sediment Quality Triad Index in Puget Sound. Prepared by the Washington State Department of Ecology, Lacey, WA. Ecology Publication No. 04-03-008. March 2004.

Hart Crowser. 2000a. Dredge Material Characterization - Cape Sante Marina, Anacortes, WA. Prepared for Cap Sante Marina by Hart Crowser. June 2000.

Hart Crowser. 2000b. Dredge Material Characterization - Pier 1, Anacortes, WA. Prepared for Port of Anacortes by Hart Crowser. July 2000.

Hart Crowser. 2000c. Dredge Material Characterization - Dakota Creek Shipyards, Anacortes, WA. Prepared for Port of Anacortes by Hart Crowser. August 2000.

Kosian, P.A., E.A. Makynen, P.D. Monson, D.R. Mount, A. Spacie, O.G. Mekenyan, and G.T. Ankley. 1998. Application of toxicity-based fractionation techniques and structure-activity relationship models for the identification of phototoxic polycyclic aromatic hydrocarbons in sediment pore water. *Environ. Tox. Chem.* 17:1021-1033.

Nagpal, N.K. 1993. Ambient Water Quality Criteria for Polycyclic Aromatic hydrocarbons (PAHs), Ministry of Environment, Lands and Parks Province of British Columbia, Water Quality Branch, Water Management Division, Vancouver, B.C.

Pearson, T.H. and R. Rosenberg. 1978. Macrobenthic Succession in Relation to Organic Enrichment and Pollution of the Marine Environment. Oceanogr. Mar. Biol. Ann. Rev. 16: 229-311.

Puget Sound Estuary Program (PSEP). 1986. Recommended Guidelines for Measuring Conventional Sediment Variables in Puget Sound. Prepared for U.S. Environmental Protection Agency, Region 10, and Seattle, WA. Tetra Tech, Inc., Bellevue, WA.

PSEP. 1986. Recommended protocols for measuring conventional sediment variables in Puget Sound. Puget Sound Estuary Program. Prepared for the U.S. Environmental Protection Agency, Region 10 and Puget Sound Water Quality Action Team, Olympia, WA. http://www.wa.gov/puget_sound/Publications/protocols/protocol.html

PSEP. 1987. Recommended protocols for sampling and analyzing subtidal macroinvertebrate assemblages in Puget Sound. Prepared for U.S. Environmental Protection Agency Region 10, Office of Puget Sound, Seattle, WA and Puget Sound Water Quality Authority, Olympia, WA. Prepared by TetraTech, Inc., Bellevue, WA.

PSEP. 1995. Recommended Guidelines for Conducting Laboratory Bioassays on Puget Sound Sediments. Final Report. Prepared for U.S. Environmental Protection Agency, Region 10, Office of Puget Sound, Seattle, WA. Washington State Department of Ecology, Olympia, WA.

PSEP. 1997a. Recommended Guidelines for Sampling Marine Sediment, Water Column, and Tissue in Puget Sound. U.S. Environmental Protection Agency, Region 10, Seattle, WA, for Puget Sound Estuary Program. April 1997.

PSEP. 1997b. Recommended Guidelines for Measuring Metals in Puget Sound Water, Sediment, and Tissue Samples. U.S. Environmental Protection Agency, Region 10, Seattle, WA, for Puget Sound Estuary Program. April 1997.

PSEP. 1997c. Recommended Guidelines for Measuring Organic Compounds in Puget Sound Sediment and Tissue Samples. U.S. Environmental Protection Agency, Region 10, Seattle, WA, for Puget Sound Estuary Program. April 1997.

PSEP. 1997d. Recommended Quality Assurance and Quality Control Guidelines for the Collection of Environmental Data in Puget Sound. U.S. Environmental Protection Agency, Region 10, Seattle, WA, for Puget Sound Estuary Program. April 1997.

PTI. 1989a. Data validation guidance manual for selected sediment variable. Prepared for the Washington State Department of Ecology, Olympia, WA. PTI Environmental Services, Bellevue, WA.

PTI. 1989b. Puget Sound Dredged Disposal Analysis guidance manual: data quality evaluation for proposed dredged material disposal projects. Prepared for the Washington State Department of Ecology, Olympia, WA. PTI Environmental Services, Bellevue, WA.

Rhoads, D.C., McCall, P.L., Yingst, J.Y. 1978. Production and disturbance on the estuarine seafloor. American Scientist 66: 577-586.

Swartz, R.C. 1978. Techniques for sampling and analyzing the marine macrobenthos. EPA 600/3-78-030. U.S. Environmental Protection Agency, Corvallis, OR. 27pp.

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

USEPA. 1995. Guidance for assessing chemical contaminant data for use in fish advisories. Volume 1. Fish sampling and analysis. Prepared by U.S. Environmental Protection Agency. Second Edition. EPA--823/R-95/007.

USEPA. 1986. Test Procedures for Solid Waste. 3rd Edition. SW-846. U.S. Environmental protection Agency, Office of Solid Waste and Emergency Response, Washington, D.C.

Van den Berg, M., L.S. Bimbaum, M. Denison, M. De Vito, W. Farland, M. Feeley, H. Fiedler, H. Hakansson, A. Hanberg, L. Haws, M. Rose, S. Safe, D. Schrenk, C. Tohyama, A. Tritscher, J. Tuomisto, M. Tysklind, N. Walker, and R. Peterson. The 2005 World Health Organization Re-Evaluation of Human and Mammalian Toxic Equivalency Factors for Dioxins and Dioxin-like Compounds. Prepared for the World Health Organization (WHO). ToxSci Advance Access published July 7, 2006. Published by Oxford University Press on behalf of the Society of Toxicology.

Warwick, R.M. 1986. A new way for detecting pollution effects on marine macrobenthic communities. Marine Biology 92:557-562.

Appendix A

Health and Safety Plan

Appendix B

Sample Forms

2007 Fidalgo Bay Sediment Investigation	
Project Number:	**Time Collected:**
Crew:	**Date:**
Comments:	

Sample Container Tag Number	Sample ID	Analysis	Laboratory

Notes

Project: Fidalgo Bay Sediment Quality Investigation

Sampling Event:____________________ **Station:**____________________________ **Date:**________________________________

Crew:____

Grab #:	Bottom depth:	Penetration Depth:	Time:
Sediment type:	***Sediment color:***	***Sediment Odor:***	***Comments:***
Cobble Gravel Sand C M F Silt/clay Organic matter Woody debris Shell debris	Drab olive Brown Brown surface Gray Black Other:	None Slight Moderate Strong Overwhelming H2S Petroleum	
Grab #:	Bottom depth:	Penetration Depth:	Time:
Sediment type:	***Sediment color:***	***Sediment Odor:***	***Comments:***
Cobble Gravel Sand C M F Silt/clay Organic matter Woody debris Shell debris	Drab olive Brown Brown surface Gray Black Other:	None Slight Moderate Strong Overwhelming H2S Petroleum	
Grab #:	Bottom depth:	Penetration Depth:	Time:
Sediment type:	***Sediment color:***	***Sediment Odor:***	***Comments:***
Cobble Gravel Sand C M F Silt/clay Organic matter Woody debris Shell debris	Drab olive Brown Brown surface Gray Black Other:	None Slight Moderate Strong Overwhelming H2S Petroleum	
Grab #:	Bottom depth:	Penetration Depth:	Time:
Sediment type:	***Sediment color:***	***Sediment Odor:***	***Comments:***
Cobble Gravel Sand C M F Silt/clay Organic matter Woody debris Shell debris	Drab olive Brown Brown surface Gray Black Other:	None Slight Moderate Strong Overwhelming H2S Petroleum	