Port Angeles Harbor
Sediment Characterization Study
Port Angeles, Washington

Sediment Investigation Report

Prepared for

DEPARTMENT OF
ECOLOGY
State of Washington

Washington State Department of Ecology
Toxics Cleanup Program
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DISCLAIMER

This report documents the data results for a Port Angeles Harbor sediment investigation designed and conducted by Ecology & Environment, Inc. (E & E) for the Washington State Department of Ecology (Ecology). Analysis of the data collected for the sediment investigation was initially submitted to Ecology by E & E as a draft data report. At the direction of Ecology, E & E's data analysis was subsequently edited and reorganized by NewFields to produce this data report. All data analysis and recommendations presented in this report are based upon E & E's data results, presentation, and evaluation. A more detailed discussion of the data is presented in the Port Angeles Harbor Supplemental Data Evaluation to the Sediment Investigation Report (NewFields 2012).

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List of Acronyms

ADCP	acoustic Doppler current profiler
AOPC	area of potential concern
ARI	Analytical Resources, Inc.
AXYS	Axys Analytical Services
BCOCs	bioaccumulative contaminants of concern
BMPs	Best Management Practices
BTEX	benzene, toluene, ethylbenzene, xylenes
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	contaminant of concern
COPCs	contaminants of potential concern
CSL	cleanup screening levels
CSO	combined sewer overflow
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethylene
DO	dissolved oxygen
DDT	dichlorodiphenyltrichloroethane
DW	dry weight
Dx	diesel
E & E	Ecology and Environment, Inc.
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management
EMPC	estimated maximum possible concentration
EPA	United States Environmental Protection Agency
ERL	effects range low
ERM	effects range median
ESI	Expanded Site Inspection
FS	feasibility study
GeoSea	GeoSea Consulting Ltd.
FEDEX	Federal Express
GPS	global positioning system
HPAH	high molecular weight polycyclic aromatic hydrocarbon
IHS	indicator hazardous substances
J	Analyte was positively identified. The reported result is an estimate.
LAET	lowest apparent effects threshold
LCS	laboratory control sample
LNAPL	light non-aqueous phase liquid
LPAH	low molecular weight polycyclic aromatic hydrocarbon
LUSTs	leaking underground storage tanks
M&R	Merrill & Ring
MDL	method detection limit
MIG	mean individual growth rate
MLLW	mean lower low water
MRI	Marine Remedial Investigation
MS/MSD	Matrix Spike/Matrix Spike Duplicate
MTCA	Model Toxics Control Act
NewFields	NewFields Northwest Laboratory

NOAA	National Oceanic and Atmospheric Administration
NOEC	no observed effects concentration
NPDES	National Pollutant Discharge Elimination System
NWTPH-Dx	Northwest total petroleum hydrocarbon – semivolatile petroleum products method
NWTPH-HCID	Northwest total petroleum hydrocarbon – hydrocarbon identification
PAHs	polycyclic aromatic hydrocarbons
PCBs	polychlorinated biphenyls
ppb-dw	parts per billion-dry weight
ppt-dw	parts per trillion-dry weight
PQL	practical quantitative limit
PSEP	Puget Sound Estuary Program
QA1	level 1 quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
RPD	redox potential depth
SAP	Sampling and Analysis Plan
SAIC	Science Applications International Corporation
SIM	selected ion monitoring
SMS	Washington State Sediment Management Standards
SQS	Washington State Sediment Quality Standards
STA	Sediment Trend Analysis
SVOCs	semivolatile organic compounds
TA	Test America Laboratories
TBT	tributyltin
TCDD	tetrachlorodibenzo-p-dioxin
TEF	toxic equivalency factor
TEQ	toxic equivalency
TOC	total organic carbon
TPH	total petroleum hydrocarbons
TPH-D	diesel-range total petroleum hydrocarbons
TPH-G	gasoline-range total petroleum hydrocarbons
TPH-oil	total petroleum hydrocarbons as heavy-oil range hydrocarbons
TSS	total suspended solids
TVS	total volatile solids
U	Undetected
USEPA	United States Environmental Protection Agency
USTs	underground storage tanks
VOCs	volatile organic compounds
ww	wet weight
WHO	World Health Organization
WSDNR	Washington State Department of Natural Resources
WSDOT	Washington State Department of Transportation
WWTP	wastewater treatment plant

Executive Summary

Introduction

For the past 100 years, Port Angeles Harbor has been home to a number of industries, including saw mills, plywood manufacturing, pulp and paper production, marine shipping and transport, boat building, bulk fuel facilities, marinas, and commercial fishing. The largest and one of the oldest facilities that operated in the harbor is the former Rayonier Mill pulp and paper facility at the east end of the harbor. Numerous terrestrial and aquatic studies have been conducted in and around the harbor with the goal of identifying areas that have been affected by industrial activity and may require remedial action. These studies found contaminants of potential concern (COPCs) exceeding the Model Toxics Control Act (MTCA) levels in terrestrial environments and exceeding Washington State Sediment Quality Standards (SQS) in the aquatic environment.

This sediment investigation characterizes the nature and distribution of chemical contamination and wood debris in the harbor. The first component of this investigation was to assess conditions in the greater harbor area. A second component was to examine marine sediment conditions adjacent to the Rayonier Mill property.

To determine the fate of COPCs, three additional elements were added to the study design. The first was a study of the surface and bottom currents in the harbor and surrounding area. The second was a sediment trend analysis (STA) to identify depositional areas within the harbor where COPCs may have accumulated. The third was a marine geomorphic study that integrates the first two studies and describes the physical environment within Port Angeles Harbor and sediment transport throughout the area.

A Screening Level Human Health and Ecological Risk Assessment was also conducted in association with this study.

Sediment Transport Processes

Several studies have been undertaken in the Port Angeles Harbor area to attempt to characterize the physical processes responsible for the introduction, transportation, and distribution of sediments within Port Angeles Harbor. These processes include wind; waves; alongshore drift; and currents, including tidal and gravity flow currents. Evidence suggests the existence of a depositional area in the inner harbor, an erosional area near the former Rayonier Mill property, and both tidal eddies and currents causing sediment transport. Based on available information, it may be generally concluded that most or all of the sediment introduced to the harbor is retained within the harbor, and a significant quantity of this sediment is transported westward into the inner harbor, where it is retained indefinitely.

Sediment transport in the nearshore zone of the harbor results predominantly from wave action. Local waves are created primarily from the predominant westerly winds but also result from easterly and northeasterly winds. The northeasterly winds occur less frequently and are generally weaker than the strongest winds from the west, but the comparatively large fetch to the northeast of Port Angeles Harbor results in westward moving waves that are larger than the eastward moving waves generated by the westerly winds. The portion of the harbor bottom shallower than 55 feet may be subject to wave-derived transport, including resuspension and transport.

Sediments in all areas of the harbor, including the nearshore, may be subject to transportation by currents, including tidal currents. Due to strong and persistent wind stress from the west and an intense eastward boundary current along the southern shoreline of the Strait of Juan de Fuca, surface currents run strongly eastward east of Lees Creek. A single tidal eddy postulated in some previous studies likely does not represent the most important current events that initiate or maintain sediment transport. Rather, the most intense currents appear to be small, localized events of short duration. The strongest currents near the sediment bed have a westward component.

Extremes associated with sediment transport, both wind-induced and current-induced, are expected to result from large windstorms. The existence of sediment "parting zones" may be better understood in consideration of extreme wave events. It is speculated that such extreme events could redistribute sediments in the harbor, replenishing the "parting zones" with sediment, followed by the "everyday" transport.

Sampling and Analysis

Three sample types were collected as part of this sediment investigation: surface sediment grab samples (Figures 3–1 and 3–2), subsurface sediment core samples (Figure 3–4), and tissue samples (Figure 3–5). The surface grab samples were used for chemical analysis and/or bioassay toxicity testing. The subsurface cores sampled were used for chemical analyses and stratigraphic observations. Tissue samples were collected for chemical analysis and included horse clams, geoduck clams, lingcod, eelgrass, and bull kelp

COPCs in harbor sediments and biota were identified based on known chemical associations with the historical and current land-use practices as well as data from prior sediment investigations within the harbor. These investigations also identified chemicals commonly associated with wood debris degradation. The identified COPCs include dioxins/furans, polychlorinated biphenyls (PCBs), chlorinated pesticides, semivolative organic compounds (SVOCs), resin acids/guaiacols, organotins, ammonia, sulfides, and metals. The significance of COPC concentrations was determined by comparing the analytical results to Washington State Sediment Management Standards (SMS) and Puget Sound lowest apparent effects threshold (LAET) criteria. In this report, sediment chemistry results are only compared to LAET criteria when total organic carbon (TOC) concentrations are outside the range of 0.5 to 3.5 percent or when SMS criteria do not exist for an analyte.

Summary of Surface Sediment Chemistry and Bioassay Results

In general, the highest concentrations of COPCs and most bioassay test failures were found at nearshore sample stations located between the Inner Ediz Hook and Ferry Terminal areas; lower concentrations of COPCs were generally found in offshore areas in deeper waters of the harbor and in the eastern portion of the Eastern Intertidal/Subtidal area.

Surface sediment samples in Port Angeles Harbor exceeded SMS or LAET criteria for metals, phenols, and phthalates (Table 5.4–1; Figure 5.4–1). Exceedances of metals were restricted to western harbor study areas, with mercury being the most frequent metal of exceedance. With the exception of a single phthalate exceedance in the Lagoon study area, SMS and LAET exceedances of phenols and phthalates occurred only at locations along the southern harbor and in Rayonier Mill study areas. The highest concentrations of dioxin/furan congeners and toxic equivalencies (TEQs) were in the Lagoon and Inner Harbor areas. Detected congener concentrations and associated TEQs were relatively lower in the Rayonier Mill area.

Bioassay test results exceeded SMS criteria at sediment stations in nearly all study areas in the harbor (Table 6–2; Figure 6–1). The areas with the most bioassay test failures included the Inner Ediz Hook, Marina, Boat Launch, and K-Ply areas. Five sediment stations were found with co-occurring bioassay test failures and exceedances of chemical sediment criteria, including metals, phenols, and phthalates (Table 6–3). Bioassay test failures occurred at 25 stations with no chemical sediment criteria exceedances.

Summary of Subsurface Sediment Chemistry Results

Subsurface sediments samples in Port Angeles Harbor exceeded SMS or LAET criteria for metals, PCBs, polycyclic aromatic hydrocarbons (PAHs), phenol, phthalates, and pesticides (Table 5.4–2; Figure 5.4–2). As in surface sediments, exceedances of metals were restricted to western harbor study areas, with mercury being the most frequent metal of exceedance. PCB, PAH, and phenol exceedances occurred only in Rayonier Mill study areas. Unlike surface sediments, subsurface phthalate exceedances were found only in western harbor study areas. A single location in the Ferry Terminal study area exceeded LAET criteria for two pesticides. The highest concentrations of dioxin/furan congeners and TEQs were detected in the Inner Harbor area. In the Rayonier Mill area, detected congener concentrations and associated TEQs in subsurface sediments were relatively higher than surface sediment concentrations.

Wood Debris Distribution

Four major mills, the Port of Port Angeles, and one plywood manufacturing company have operated and discharged process effluent into Port Angeles Harbor from 1914 to the present. Each facility has at one time or another transported and stored logs, wood chips, and/or sawdust in nearshore areas or on barges in the harbor.

The quantity and distribution of wood debris in Port Angeles Harbor has been qualitatively examined during three surveys in the harbor. The largest area with current and historical log rafting and wood chip/sawdust barging activity is located along the north side of inner Port Angeles Harbor, extending along the arm of Ediz Hook (Figure 8–1). Portions of this area have been leased at one time or another to Rayonier Corporation, Nippon Industries, the Port Angeles Management Area, and Foss Maritime. Rayonier Corporation also leased areas surrounding the Mill Dock and Log Pond areas on the southeast side of the harbor.

The largest amounts of wood debris have been observed along the western shoreline of the Inner Harbor and along the base of Ediz Hook (Figures 8–2 through 8–6). Other areas with measurable amounts of wood debris were located offshore of the Boat Haven Marina and surrounding the Rayonier Mill Dock and Log Pond.

Screening-Level Human Health and Ecological Risk Assessment

Potential exposure to chemicals in sediment and fish and shellfish tissue for a subsistence fisher, recreational fisher, residential user, and recreational user were evaluated based on site-specific exposure parameters. The potential excess cancer risks exceeded the Washington State Department of Ecology (Ecology) threshold of 1 in 100,000 (1 x 10-5) for the subsistence and recreational fisher receptors (Table 10–1). Noncancerous hazards also exceeded Ecology's threshold of 1.0 for the subsistence and recreational fisher scenarios (Table 10–3). The largest contributors to hazards and risks were exposure to arsenic, total PCBs, and 2,3,7,8-TCDD TEQ through ingestion of fish and shellfish.

Marine vegetation and benthic invertebrates are the receptor groups most at risk from current environmental conditions in Port Angeles Harbor (Table 10–4). Sediment habitat degradation by wood debris and selected metals and organic contaminants appear to be the most critical stressor. Arsenic may pose a risk to fish and omnivorous mammals.

Conclusions

Major conclusions from this study are as follows:

- Regulatory sediment criteria for multiple metals and organic compounds have been exceeded in the harbor.
- Bioassay failures throughout the harbor indicate possible toxic sediment conditions; however, the bioassay failures are not strongly correlated with elevated COPC concentrations.
- COPCs were detected in marine biota that are of potential subsistence and recreational importance.
- Significant wood debris accumulations on the sediment surface and in subsurface sediments persist in nearshore areas of the southern and western portions of the harbor and immediately west of the former Rayonier Mill.
- Sediment transport conditions indicate that the western portion of the harbor is a sink for sediments and associated contaminants, including wood debris.
- Potential excess cancer risks exceed the threshold of 1 in 100,000 (1×10^{-5}) for human subsistence and recreational fisher receptors. Cancer risks and noncancerous hazards for the residential and recreational users were below regulatory thresholds. The largest contributors to human health hazards and risks were exposure to arsenic, total PCBs, and 2,3,7,8-TCDD TEQ through ingestion of fish and shellfish.
- Marine vegetation and benthos are the ecological receptor groups most at risk from current environmental conditions in the harbor. Sediment habitat degradation by wood debris and the presence of metals and organic contaminants appear to be the critical stressors. Arsenic may pose a risk to fish and omnivorous mammals in the harbor.

1.0 Introduction

Port Angeles Harbor is located on the northern coast of Washington's Olympic Peninsula and on the Strait of Juan de Fuca (Figure 1–1). For the past 100 years, Port Angeles Harbor (the harbor) has been home to a number of industries including sawmills, plywood manufacturing, pulp and paper production, marine shipping and transport, boat building, bulk fuel facilities, marinas, and commercial fishing. The largest and one of the oldest facilities that operated in the harbor is the former Rayonier Mill pulp and paper facility at the east end of the harbor. Numerous terrestrial and aquatic studies have been conducted in and around the harbor with the goal of identifying areas that have been affected by industrial activity and may require remedial action. These studies found contaminants of potential concern (COPCs) exceeding the MTCA levels in terrestrial environments and exceeding SQS in the aquatic environment. As a result of these studies, the harbor was identified by Ecology as a priority cleanup and restoration site under the Puget Sound Initiative. Ecology's Toxics Cleanup Program is responsible for overseeing source control, cleanup, and restoration of the harbor area (E & E 2008a).

Ecology tasked Ecology and Environment, Inc. (E & E) with conducting a sediment investigation to characterize the nature and distribution of chemical contamination and wood debris in the harbor. The sediment investigation integrated two components identified in the *Sediment Sampling and Analysis Plan* (SAP) (E & E 2008d). The first component was a Harbor-Wide study to assess conditions in the greater harbor area. The second was a Rayonier Mill study to examine marine sediment conditions adjacent to the Rayonier Mill property (Figure 1–2). Consultants for the Rayonier Corporation began a remedial investigation/feasibility study (RI/FS) of the upland and marine portion of the site in 2002. The current sediment investigation provides data to supplement that effort.

To determine the fate of COPCs, three additional elements were added to the study design. The first was a Current Study of the surface and bottom currents in the harbor and surrounding area. The second was a STA to identify depositional areas within the harbor where COPCs may have accumulated. The third was a marine geomorphic study that integrates the first two studies and describes the physical environment within Port Angeles Harbor and sediment transport throughout the area. *The Current Data Collection and Analysis Report* is included as Appendix D, the STA Report is included as Appendix E, and the Geomorphic Report is included as Appendix I.

A Screening Level Human Health and Ecological Risk Assessment was also conducted in association with this study. This analysis focused on the marine environment and associated terrestrial and aquatic source areas of potential concern (AOPC). This report is included in Appendix G.

1.1 Overview of Investigation Area

The City of Port Angeles contains 26 miles of marine shoreline and is considered a deepwater port with depths exceeding 90 feet near the eastern end of the harbor. A defining feature of the harbor is the 2.5-mile-long Ediz Hook that extends to the east from the harbor's west end (Figure 1–1). The Ediz Hook protects the harbor from Pacific Ocean storms and offers safety for commercial ships, fishing vessels, and pleasure boats. The marine waters of Port Angeles Harbor are listed as impaired by the State of Washington under Section 303(d) of the Clean Water Act due to low dissolved oxygen (DO) and fecal coliforms (Ecology 2009).

A number of potential sources of COPCs have been identified in and around the harbor. Treated and untreated mill process effluents were commonly discharged into the harbor. Wood product sources throughout the harbor have been identified as significant sources of COPCs in marine sediments. Petroleum storage and transport businesses have historically operated and currently conduct business along the Port Angeles waterfront. Spills and leaks from petroleum facilities and tankers, as well as from facilities with leaking underground storage tanks (LUSTs), have also introduced COPCs into the harbor. Marinas, shipping industries, docks, and piling infrastructure all have a variety of potentially associated COPCs. Historically and currently, the harbor has also received discharges from combined sewer overflows (CSOs), deepwater effluent outfalls, septic systems in various stages of maintenance outside the city limits, nonpoint source stormwater runoff, and surface water discharge from creeks flowing through varying types of residential and commercial land uses. Any of these discharges may have contributed COPCs to the harbor in the past, and some could still be contributing COPCs. Further information on COPCs and their known and potential sources can be found in the *Port Angeles Harbor Final Summary of Existing Information and Identification of Data Gaps Report* (E & E 2008b).

1.2 Previous Investigations

Previous environmental investigations have indicated that COPCs generated by industrial and urban activities have been detected in the marine sediments and biota of the harbor. These chemicals may pose a risk to human health and the environment because some have been detected at levels that exceed the SMS specified in Chapter 173-204 WAC (Ecology 1995) and other established environmental thresholds (USEPA 1998; Long and Morgan 1991; Long et al. 1995). Investigations conducted in the harbor over the past 15 years include:

- United States Environmental Protection Agency (USEPA) Dioxin and Furan Concentrations in Puget Sound Crabs (USEPA 1991)
- USEPA Expanded Site Inspection (ESI) of Rayonier Mill (E & E 1998 and 1999)
- Ecology Marine Sediment Monitoring Program (MSMP) (Ecology 1998a and b)
- Ecology Port Angeles Harbor Wood Waste Study (SAIC 1999)
- Rayonier Log Pond Survey for Remedial Investigations (RI) (Foster Wheeler 2001a)
- Washington State Department of Transportation (WSDOT) Port Angeles Graving Dock (GeoEngineers 2003)
- Remedial Investigation and Phase 2 Addendum for the Marine Environment near the Former Rayonier Mill Site (Malcolm Pirnie 2007a)
- Ecological Risk Assessment for the Marine Environment near the Former Rayonier Mill Site (Malcolm Pirnie 2007b)
- Washington Department of Health Consultation: Rayonier Mill Site Exposure Investigation (WA DOH 2005)
- Environmental Baseline Investigation, Washington State Department of Natural Resources (WSDNR) Lease 22-077766: Nippon Paper Industries USA Co., Ltd., Port Angeles, Washington (Exponent 2008)

- Sampling and Analysis Report, Sediment Grab Sampling and Log Density Survey (Anchor 2005)

These studies are discussed in detail in the *Port Angeles Harbor Final Summary of Existing Information and Identification of Data Gaps Report* (E & E 2008b).

1.3 Goals and Objectives

As mentioned above, the sediment investigation is comprised of two previously identified components — a Harbor-Wide study and a Rayonier Mill area study. The Harbor-Wide study includes the sediment and intertidal zones of the general harbor area. The Rayonier Mill study area is a subsection of the Harbor-Wide study area, and this part of the study specifically addresses sediments and intertidal zones adjacent to the former Rayonier Mill property and associated outfalls. Although the two studies have different objectives, the results from both studies have been integrated to assess the harbor area holistically.

1.3.1 Harbor-Wide Study Area

The Harbor-Wide study area encompasses the entire harbor/sediment area from the eastern intertidal zone at the mouth of Morse Creek, northwest along the Port Angeles shoreline to the base of Ediz Hook, and east to its tip (Figure 1–1). The primary goal of the Harbor-Wide study was to conduct an investigation to characterize the nature of sediment chemical contamination, identify potential sources of this contamination, map the presence of wood debris, and determine the potential uptake of chemical contaminants in marine biota. E & E used a multifaceted approach that included characterizing the distribution of chemical contamination, identifying potential sources, mapping wood debris, and determining the potential effects of COPCs on resident fish, macroalgae, and the benthic infaunal community.

The specific objectives of the Harbor-Wide study were to:

1. Characterize sediment quality and conditions at locations throughout the harbor.
2. Fill data gaps in existing knowledge, as identified in the *Port Angeles Harbor Summary of Existing Information and Data Gaps Report* (E & E 2008b).
3. Identify terrestrial and aquatic sources of chemical contaminants, wood debris, and wood-debris-related degradation products.
4. Evaluate human health and ecological risk from harbor sediments. For further information on the risk assessment approach, refer to the *Human Health and Ecological Risk Assessment Work Plan for Port Angeles Harbor Marine Environment*, which is in Appendix D of the *Port Angeles Harbor Sediment Characterization Study, Sampling and Analysis Plan* (E & E 2008d).
5. Evaluate bottom currents and sediment transport in the harbor. See Appendix D and E for detailed information on field implementation of these studies.

The Harbor-Wide study was designed to provide data to support risk-based decisions for the harbor. The study was not intended to be an RI/FS.

1.3.2 Rayonier Mill Study Area

The former Rayonier Mill Study Area is comprised of an upland and a marine portion and lies within the Harbor-Wide study area (Figure 1–2). For the purposes of this report, this area refers only to the marine portion of the Rayonier Mill Study Area as shown in Figure 1–2. It extends east from the western boundary of the former Rayonier Mill property, past the mouth of Ennis Creek, to the eastern boundary of the property. A primary goal of the current Rayonier Mill study is to supplement the existing data and information found in the Marine Remedial Investigation (MRI) reports prepared in 2007 (Malcolm Pirnie 2007a).

The specific objectives of the current Rayonier Mill study were to:

1. Collect, analyze, and validate additional data necessary to:
    a. Further delineate the horizontal and vertical distribution of mill-related contaminants in marine sediments around the former mill,
    b. Determine the depth of wood debris around the Rayonier Mill dock and log pond areas, and
    c. Ascertain the presence of mill-related contaminants at and near the mouth of Ennis Creek.
2. Provide additional information for the Harbor-Wide study.

The Rayonier Mill study was intended to fill data gaps and augment data and information from previous studies. The data were intended to be interpreted and reported as part of the Harbor-Wide study. Separate interpretation and reporting of the results within the marine portion of the Rayonier Mill study area was not an objective of this study.

1.4 Study Design

The study design for the sediment investigation included the identification of AOPCs based on the following criteria:

- Areas identified as having potential sources of COPCs based on current and historical shoreline use and operations;
- Areas where prior data indicated COPCs exist in sediment or biota, and some locations with known exceedances of SMS or other threshold criteria;
- Areas where data on potential sediment contamination associated with known COPCs sources is lacking; and
- Areas identified as having the potential for increased risk to human health from exposure to sediment and/or biota.

Based on these considerations, the harbor was subdivided into 16 AOPCs (Figure 1–3). The AOPC identified in Figure 1–3 as the Rayonier Mill area was further divided into an additional seven areas. After discussion with Ecology, Dungeness Bay was selected as the reference area for both the Harbor-Wide and Rayonier Mill study areas (E & E 2008c). A detailed discussion of each AOPC within the two study areas can be found in the *Port Angeles Sampling and Analysis Plan* (E & E 2008d).

1.4.1 Harbor-Wide Investigation Study Design

A non-random sampling design was used with a tiered laboratory analysis scheme to characterize sediment conditions in the harbor. In order to determine if sediment contamination is negatively impacting biota at the site, the first tier of the analysis included sediment toxicity tests, bioaccumulative compound analysis in marine tissue, and analysis of sediment samples for chemicals with short laboratory holding times. All other samples were archived for potential later analysis with the exception of select stations where full-suite chemical data were needed. Section 3.10 explains in further detail the selection criteria for analyzing and archiving samples.

The second tier of analysis involved further analytical testing of archived sediment samples to identify COPCs. The initial decision criterion for analyzing archived samples was the passage or failure of sediment toxicity tests. For samples that failed toxicity bioassay criteria as established by SMS, the associated archived samples were recommended for analysis. After identifying sample stations with toxicity bioassay test failures, sample locations in close proximity were examined to determine whether additional analyses should be conducted to characterize a zone of sediment contamination.

1.4.2 Rayonier Mill Investigation Study Design

The Rayonier Mill study design was based solely on filling data gaps identified by Ecology in the MRI (Malcolm Pirnie 2007a). More specifically, this sampling plan was designed to more clearly define the horizontal and vertical distribution of mill-related contaminants and further characterize wood debris in the Rayonier Mill study area of the harbor.

1.4.3 Screening Level Human Health and Ecological Risk Assessment Study Design

Environmental investigations throughout Port Angeles Harbor have indicated that chemicals in marine sediments and biota may pose a risk to human and environmental receptors. A screening level risk assessment was conducted at the site, focusing on the marine environment and associated terrestrial and aquatic source areas. The risk assessment was conducted in accordance with Washington State and USEPA guidance.

Potential constituents of concern to harbor sediments and biota were identified based on known chemical associations with historical and current land uses, as well as a significant amount of data collected during prior sediment investigations within the harbor. The following chemicals were previously identified as potential constituents of concern and reviewed for inclusion in the risk assessment:

- Dioxins and furans;
- PCBs;
- Chlorinated pesticides;
- SVOCs, including PAHs, phenols, and phthalates;
- Resin acids/guaiacols;
- Tributyltin (TBT);
- Ammonia, sulfides, and TOCs; and

- Heavy metals, including inorganic and organic forms.

Numerous studies have characterized chemical constituents in sediment and distribution of wood debris in Port Angeles Harbor. Data from reports written over the past approximately 10 years were used in the screening level human health and ecological risk assessment, and include data from this sediment investigation and historical data for the harbor including the Rayonier study area.

For the human health risk assessment, potential exposure to chemicals in sediment, fish, and shellfish were evaluated based on site-specific exposure parameters for the following four groups of receptors:

1. Current/future subsistence fisher,
2. Current/future recreational fisher,
3. Current/future residential user, and
4. Current/future recreational user.

For the ecological risk assessment, eight assessment endpoints were evaluated:

1. Marine plants and macroalgae,
2. Benthos,
3. Fish,
4. Carnivorous birds,
5. Omnivorous birds,
6. Herbivorous birds,
7. Carnivorous mammals, and
8. Omnivorous mammals.

Potential risk from exposure to all indicator hazardous substances (IHSs) was determined, including assessing potential exposure to dioxins/furans and PCB congeners as well as PCB Aroclors. Uncertainties in the assessment were addressed for both the human health and ecological evaluations.

1.4.4 Sediment Trend Analysis Study Design

E & E used the STA technique developed by GeoSea Consulting Ltd. (GeoSea) to determine relative changes in the grain-size distributions of transport-derived sediment deposits in Port Angeles Harbor. The STA determined patterns of sediment transport over the area of interest through the particle-size analysis of a large number of sediment grab samples collected on a uniformly spaced grid.

The objectives of the project were to:

1. Identify, based on sediment texture, the nature and extent of all the sedimentary environments present in the harbor.

2. Determine the transport pathways (net sediment movement) and the dynamic behavior of the bottom sediments.
3. Identify areas of erosion, stability (dynamic equilibrium), and deposition as well as identify sediment sources and sinks.
4. Explore the relationship between sediment dynamics and the wood debris visually observed in the sediments.

1.4.5 Current Analysis Study Design

E & E coordinated with a subcontractor, Evans Hamilton Inc., to implement the current study to collect lower water column current data and other parameters within Port Angeles Harbor. The study included three bottom-mounted tripods that were each equipped with an upward-looking acoustic Doppler current profiler (ADCP), a pressure transducer or wave gauge, an electro-magnetic current meter (EMCM), and an optical backscatter sensor (OBS). A profile of conductivity, temperature, and depth was obtained at the same time each tripod was deployed and retrieved at each location.

Measurements were collected for one-month deployments starting March 26 through April 25, 2008. Data were then analyzed to determine current speed versus depth and time, and current direction versus depth and time.

1.4.6 Geomorphic Report Study Design

E & E coordinated with subcontractor Herrera Environmental Consultants Inc. to perform the geomorphic analysis in Port Angeles Harbor. The geomorphic report analyzes the physical environment of the harbor, particularly with respect to bottom currents and sediment transport. The study area was defined as the shoreline between the mouth of Morse Creek and the tip of Ediz Hook on the Strait of Juan de Fuca. This includes all of Port Angeles Harbor as well as a short distance of shoreline on the Strait of Juan de Fuca east of the harbor. Sediment transport is a complicated physical process that cannot be easily measured directly, so several different techniques and analyses were used to build an integrated, qualitative model of sediment transport and fate mechanisms. A process-based approach was adopted to describe sediment transport throughout Port Angeles Harbor. Three primary physical processes are responsible for sediment transport and are treated in order from source to sink: sediment input, nearshore sediment transport (i.e., transport from waves), and sediment transport by tides and currents.

The goals of the study were as follows:

1. Characterize general circulation patterns in the harbor, both in the water column and near the bed.
2. Identify the role of waves to mobilize bed materials.
3. Determine the character and temporal change in extreme events associated with sediment transport.
4. Characterize the nature and quantity of sediments being delivered to the harbor.
5. Link these elements to arrive at a broad picture of sediment transport throughout the harbor.

1.4.7 Deviations from Study Design

There were no major deviations from the projected study design. For more specific deviations from the SAP (E & E 2008d), please see Section 3.12.

1.5 Report Organization

The remainder of this document contains a discussion of the methods and results from the sediment investigation. Chapter 2 contains a brief summary of existing information. Chapter 3 provides a description of the field and laboratory analytical methods used to complete the scope of work. Chapter 4 presents the Level 1 and 2 Quality Assurance (QA1 and QA2) data validation results for the analytical chemistry and sediment toxicity tests, Chapter 5 presents the results of the sediment chemistry analyses, Chapter 6 presents the results of the sediment toxicity tests, and Chapter 7 discusses the tissue sampling results. Chapter 8 discusses the distribution of wood debris and how it correlates with often-associated chemicals. Chapter 9 discusses the effect of currents on sediment transport. Chapter 10 summarizes the findings of the screening level human health and ecological risk assessment. Chapter 11 offers a summary and discusses conclusions followed by the cited references for this report.

2.0 Summary of Existing Information

Numerous environmental and sediment studies have been conducted in Port Angeles Harbor and around the Rayonier Mill site in the last 15 years. A more detailed review of these studies is found in the Project Work Plan (E & E 2008a) and in the *Port Angeles Harbor Final Summary of Existing Information and Identification of Data Gaps Report* (E & E 2008b). The studies reviewed include those listed in Section 1.2. The following sections provide summaries of the potential contamination sources by industrial processes and activities in Port Angeles Harbor, the COPC, existing information on the health of biological resources, and the historical water circulation and sediment transport studies in Port Angeles Harbor.

2.1 Potential Sources of Contamination

Historical and current industrial processes in Port Angeles Harbor have been listed for investigation by state and federal agencies in the last 20 years. These process areas include:

- The Rayonier Mill site,
- Wood processing facilities (current and historical processes/log rafting),
- Marine and shipping services,
- Creosote-treated marine lumber,
- Municipal wastewater,
- Petroleum storage facilities, and
- Commercial fish and shellfish harvesting.

2.1.1 Rayonier Mill Site

The Rayonier Mill operated from 1930 until 1997, at which time paper production ceased and the company began dismantling the site. For the past 30 years, the mill property has been the focus of internal and external environmental investigations in relation to compliance with National Pollutant Discharge Elimination System (NPDES) requirements for the former shallow and deepwater outfalls, spill/leak response, and site remediation (E & E 1998 and 1999; Integral 2007; and Malcolm Pirnie 2007a).

From 1988 to 2006, several interim cleanup actions were conducted on the site after routine investigations found evidence of contaminant releases. In 1989, hydraulic fluid was observed seeping through the riprap on the west bank of Ennis Creek. Remedial actions for this incident included removal of soil and riprap adjacent to the creek, ground/surface water quality testing, and habitat restoration. Some contamination was left in place around a bridge support at the mouth of the creek (Integral and Foster Wheeler 2003; Integral 2007). In 1995, as part of the NPDES permit compliance, Rayonier conducted Dungeness crab (*Cancer magister*) tissue analyses for dioxins near the deepwater outfall (Malcolm Pirnie 2007a). Elevated dioxin concentrations were detected in all tissue samples.

After mill closure in 1997, the USEPA initiated an ESI to determine whether the site should be recommended for the National Priorities List (NPL) under the Comprehensive Environmental

Response, Compensation, and Liability Act (CERCLA) (E & E 1998 and 1999). The ESI involved collection of surface and subsurface soil, freshwater and marine sediments, groundwater, and marine shellfish tissue samples from intertidal and subtidal areas.

The ESI found chemical concentrations from mill operations at levels of concern in onsite soil, with elevated concentrations of metals, SVOCs, dioxins/furans, phthalates, and PCBs. The ESI also found that mercury exceeded the SQS at five marine sediment stations, cadmium at two, and arsenic and zinc at one station in the Inner Harbor area on the waterfront near where the arm of Ediz Hook connects to the mainland. In the area surrounding the Rayonier Mill pier, three stations exceeded the SQS for 4-methyl phenol (*p*-creosol), and two stations were found with numerous exceedances of low molecular weight polycyclic aromatic hydrocarbon (LPAH) and high molecular weight polycyclic aromatic hydrocarbon (HPAH) compounds. Marine sediment samples showed gradients of dioxin/furan congener concentrations in relation to industrial/urban areas, with the highest levels located around the mill site and in the Inner Harbor area. Lower concentrations were found in the deeper waters toward Ediz Hook, but nearly all sediment samples had elevated concentrations of SVOCs, metals, PCBs, pesticides, and volatile organic compounds (VOCs). Samples from Ennis Creek had elevated levels of dioxin TEQs and elevated phthalates, chromium, and carbon disulfide. Marine tissue samples contained elevated concentrations of metals and dioxins/furans at all harbor stations. Crab samples had elevated PCBs and dioxin/furan congeners, while geoduck samples (*Panopea* spp.) showed elevated dioxins/furans and mercury levels. Neither SVOCs nor pesticides were found in tissues at any harbor stations.

In 2000, monitoring actions occurred in conjunction with the removal of over 2,500 sunken logs, 200 creosoted dolphin pilings, and 100 cubic yards of sunken jetty rock. Monitoring results were generally below established water and sediment quality criteria (Foster Wheeler 2001b), although one sample exceeded SMS criteria for methylphenol. Data were collected on chemicals without SMS criteria (resins, guaiacols, dioxins), and although there was no evaluation of those data, results prompted the inclusion of these constituents as COPCs in subsequent Rayonier marine sediment investigations.

The USEPA deferred the CERCLA listing and has allowed Washington State to take over the cleanup process under the MTCA (Ecology 2001). Following MTCA requirements, consultants for the former Rayonier Mill facility began an RI/FS at the site in 2002 in accordance with provisions of two Agreed Orders between Ecology and Rayonier, Inc. (Foster Wheeler 2002; Malcolm Pirnie 2007b). The RI was undertaken in two parts, the Uplands Environment (Integral 2007) and the Marine Environment (Malcolm Pirnie 2007a). The Marine RI focused on three areas including the mill dock, log pond, and the deepwater outfall. Chemical analysis of surface and subsurface core samples showed no exceedances of SMS chemicals above SQS at the deepwater outfall location. Stations within the Rayonier Mill dock area had an exceedance of total PCBs at one station, and two stations exceeded the SQS and cleanup screening levels (CSL) for 4-methyl phenol (*p*-cresol). Stations within the Rayonier Mill dock area had elevated levels of dichlorodiphenyltrichloroethane (DDT) and dioxins/furans above background. In the log pond area, 4-methyl phenol exceeded SQS and CSL at five stations, while 2-methyl phenol and 2,4-dimethyl phenol exceeded SQS and CSL at one station. Mercury and bis(2-ethylhexyl) phthalate exceeded the SQS at one station each. Other SVOC compounds were found at elevated concentrations at some stations but none exceeded SQS or CSL. Stations within the log pond also had elevated concentrations of DDT above national criteria and LAETs, and dioxin/furan concentrations above the Sequim Bay reference.

Numerous stations in the log pond failed bioassay criteria, and elevated levels of PCBs and dioxins/furans were found in the tissues of horse clams, coon-striped shrimp, and Dungeness crab.

In 2002, interim actions were carried out at three areas on the Rayonier site: the Ennis Creek-Finishing Room area, the Former Fuel Oil Tank No. 2, and the Former Machine Shop. The first two areas were selected for interim actions to address remaining upland soil contamination. The Machine Shop area was selected because oil contamination was noted on the ground after the building was removed. A total of 5,260 tons of soil/sediment were excavated from the three areas combined, along with the removal of over 153,000 gallons of oil and water (Integral and Foster Wheeler 2003).

In 2006, an interim action was implemented near the Former Wood Mill and Fuel Oil tank No. 1 on the west side of the former Rayonier Mill site. The purpose was to remove soil contaminated with diesel (Dx) and lube-oil-range total petroleum hydrocarbons and prevent further migration of the identified contaminants. PCBs, carcinogenic polycyclic aromatic hydrocarbons (cPAHs) and naphthalene were also identified as contaminants of concern (COCs). A total of 7,979 tons of contaminated soil were removed from the two areas combined (GeoEngineers 2006).

2.1.2 Wood-Debris-Producing Facilities

Five major wood-processing companies have operated and discharged process effluent into Port Angeles Harbor at various times from 1917 to the present (Figure 2–1). These facilities and their dates of operation are:

- Nippon Paper Industries (formerly Diashowa and Georgia Pacific) (1921 – present),
- Merrill & Ring Timber (M&R) (1958 – present),
- Fibreboard Paper Products Corporation (1918 – 1970),
- K-Ply Inc. plywood mill (1941 – 2008), and
- Rayonier Mill (1917 – 1997).

Nippon still operates a large mill on the western end of the harbor at the base of Ediz Hook (Figure 1–2). As part of current operations, log booms are stored along the nearshore areas at the west end of the harbor. Remnant logs are also present in the shallow natural lagoon where logs were stored in the past. Nippon leases four aquatic areas in the western end of the harbor along Ediz Hook. In 2001, Nippon conducted sediment sampling in one of these areas (approximately 85.7 acres). The sampling was conducted in accordance with WSDNR lease requirements to characterize the distribution of sunken log/woody debris and to augment data on surface sediment quality (Anchor 2005). The study found a high density of submerged logs in the east central and southwestern portions of the lease parcel. Sediment chemistry indicated no exceedances of SMS criteria for metals, although mercury concentrations in the southwestern sample were slightly elevated.

In February 2008, contractors for Nippon undertook an environmental baseline sediment investigation for the renewal of the WSDNR harbor lease area (WSDNR Lease 22-077766). Study results found high concentrations of cadmium, mercury, and zinc exceeding SMS at one station in the lagoon and two stations to the northeast of the facility. PAHs, PCBs, and phthalates were found at concentrations below the SMS concentrations. Polychlorinated dibenzo-*p*-

dioxins/furans were highest in the inner harbor samples, as was the highest concentration of pulp wood debris (Exponent 2008).

Just south of Nippon was the M&R Timber wood product facility. M&R was once a lumber, pulp, and plywood mill with log booming areas in the harbor in the 1930s and 1940s (E & E 2008b). Directly adjacent to M&R was the Fibreboard Paper Products Company, which operated from 1918 into the 1970s. The Port of Port Angeles also operates and/or leases land for log storage areas in the west end of the harbor (this area is called the Port log dump yard).

The K-Ply plywood mill site is located along the center shoreline of the harbor near the Port of Port Angeles log storage areas. It operated from 1941 until closure in 2008. The facility operated historical log-booming areas in the harbor, and it regularly discharged stormwater and wastewater, including boiler water treatment, boiler blowdown, and non-contact cooling water, into the harbor (SAIC 1999). In 2004, K-Ply was cited for non-compliance for the discharge of boiler ash and ash-contaminated water to the storm system. K-Ply was required to implement Best Management Practices (BMPs) to prevent exposure of ash, fiber, and petroleum products to stormwater (Ecology 2004). In 1990, the facility had a hydraulic oil leak from press machinery into soil and groundwater under the mill structure. Pentachlorophenol-contaminated soils were found beneath the building but were not excavated due to risks to the structural integrity of the building. As part of the cleanup, groundwater monitoring occurred from 1998 to 2002 and indicated high concentrations of benzene and gasoline (not associated with the hydraulic leak) in certain monitoring wells (Ecology 2005). Groundwater monitoring in January 2007 detected light non-aqueous phase liquid (LNAPL) up to 0.43 feet thick in one well (Ecology 2007a).

The K-Ply facility is part of the Marine Trades Area (MTA), an area of multiple parcels of waterfront land owned by the Port of Port Angeles and Chevron/Texaco. The MTA includes marine terminals 1 and 3 (Standard Oil Pier), the log sort yard, the K-Ply plant, and four former bulk fuel facilities (Chevron, Standard Oil, Arco, and D&D Distributors/Phillips 66). The MTA is currently undergoing remediation due to the presence of gasoline, diesel, and benzene in soil and groundwater (Floyd|Snider 2007).

In 1998, a survey was conducted to map the distribution of wood debris on the Port Angeles Harbor bottom and to assess the resulting sediment quality (DO content) and biological impact (SAIC 1999). The log pond area of the former Rayonier Mill was included in the study area. The survey found significant layers of wood pulp and debris, including logs and large wood chips, in historical and active log-booming areas. Sediments in nearshore areas by the Nippon facility, the public log dump yard, the log booming area near K-Ply, and the Rayonier Mill grounds bordered on anoxia, and stressed benthic communities were generally observed. The north and west portions of the harbor had the greatest accumulation of wood debris, and degraded benthic habitat was observed in nearshore areas of the western harbor.

A review of all available sediment chemistry data from the western harbor area identified potential trends in sediment contaminants. TOC levels were very high near dense log booming areas, specifically near the Nippon plant, the Port Angeles log dump yard, and the K-Ply log booming areas (E & E 1998, 1999; SAIC 1999; Floyd|Snider 2007). Metals, including mercury, were high in the inner harbor area from south of the Nippon mill down to the edge of the former Fibreboard property. Significant concentrations of PCBs were detected in front of the M&R Timber dock, along the Fibreboard site, and into the deeper waters in front of the Port Angeles

Boat Haven Marina. Dioxin/furan hotspots were present throughout the inner harbor and marina areas (E & E 1998; Malcolm Pirnie 2007a).

2.1.3 Marine Shipping and Services

There are numerous marine shipping facilities along the southern central waterfront of Port Angeles Harbor (Figure 2–1). The Port of Port Angeles operates a full-service port with four deepwater marine terminals (Terminals 1, 3, 4, and 7), as well as terminals for ferry service and other industrial activities. The Port has been operating in various capacities for 80 years. A WWII aircraft carrier was decommissioned over water in 1990 at Terminal 1, and during dismantling activities oil, PCBs, and metals may have been released to the marine environment from shipboard equipment (Dunn pers. comm. 2008).

A shipyard and manufacturing plant was once located near the inner harbor near M&R Timber. Shipbuilding and manufacturing activities use large quantities of metals, paints, oils/greases, and solvents, and these materials may have entered the surrounding environment (GeoEngineers 2003). In addition, shipyards and some manufacturing processes produce large amounts of sandblast grit, which can contain heavy metals. Sandblast grit mixed with paint may contain copper, lead, antimony, and zinc, all of which may migrate into sediments over time. Marine traffic areas also tend to be unusually high in zinc from anodes and in mercury from vessel instruments and anti-fouling paint.

Elevated levels of gasoline- and diesel-range petroleum hydrocarbons were detected across the western portion of the Port's marine terminal log yard. The soil contaminant concentrations were generally higher in deeper subsurface layers (7 to12 feet below ground surface) (Shannon and Wilson 1996). Diesel contamination was found at other bulk plant facilities as well, where benzene, gasoline-range total petroleum hydrocarbons (TPH-G), and diesel-range total petroleum hydrocarbons (TPH-D) were found in soil and groundwater exceeding MTCA Method A cleanup levels. In 2005, an Agreed Order was signed between the MTA (Port of Port Angeles and Chevron/Texaco) and Ecology, and an RI was initiated (Ecology 2005). The RI found that neither free product nor TPH-D in the groundwater extended across Marine Drive into the harbor. The RI concluded that contamination was apparently limited to shallow groundwater and did not appear to be transported into deeper groundwater by vertical gradients. The MTA is developing a feasibility study (FS) to identify cleanup levels and remediation actions (Floyd|Snider 2007). The MTA group is considering developing site-specific soil cleanup and remediation levels for TPH (Ecology 2008a). The MTA is currently undergoing soil and groundwater remediation and monitoring under the Agreed Order.

There are several boat moorage areas and one marina in Port Angeles Harbor. The Boat Haven Marina is a large marina owned by the Port of Port Angeles and is located northwest of Terminal 1 and the Standard Oil Pier. The marina encompasses 16.1 acres and provides permanent and temporary moorage space for over 500 boats (http://www.portofpa.com/marinas/port-angeles-boat-haven.html). The adjacent boat yard and commercial businesses provide repair, retrofit, haul-out, and charter services, as well as bait shops and restaurants, for the marina. There are three boat launch areas in Port Angeles Harbor. Two general public launch areas are located near the Boat Haven marina along the harbor waterfront just north of Terminal 1 and the Standard Oil Pier. The third boat launch area is owned and operated by the City of Port Angeles and is located along the inner Ediz Hook shoreline west of the Coast Guard facility. The Ferry Terminal, located in the Landings Pier area north of downtown, provides space for commercial ferries and other smaller commercial and recreational vessels.

Marinas and boat launch areas have been associated with high accumulations of PAHs in sediments (Edirveerasingam et al. 2006). Marinas receive PAH loading from direct release from marine engine exhaust, accidental fuel spills, and occasional oil-burdened, bilge-water discharge. As most marinas are sheltered and less subject to currents and wind turbulence, sediment particles and associated COPCs tend to settle into the sediment bed. TBT and heavy metals from boat scraping and hull painting activities are also a concern at historical and current boat yards/marinas. TBT tends to be used mostly on larger vessels, while smaller ones may still use copper or other types of anti-fouling paint.

The Port Angeles graving dock was intended to be a staging area for construction of pontoons used in the Hood Canal Bridge replacement project. However, the work was never completed due to discovery of cultural artifacts. It was located in the western harbor waterfront area near M&R Timber and the former Fibreboard property. In 2003, dredging material characterization was conducted for the WSDOT (GeoEngineers 2003). WSDOT collected one successful core (depth of 7.5 feet) for total volatile solids (TVS), TOC, and dioxins/furans. WSDOT analyzed the surface sediment portion of the core and found TVS and TOC concentrations at 3.5 percent and 2.0 percent, respectively. The dioxin congener 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) was not detected, and other dioxin/furan congeners detected were below MTCA cleanup levels. GeoEngineers recommended further delineation of the wood debris, but no further information is available.

2.1.4 Creosote-Treated Marine Lumber

Wood pilings and other wooden marine structures have been used in waters of the United States for over 100 years. These structures are often impregnated with creosote and employed as bridge or dock supports and as vessel mooring stations (dolphins). Creosote is the most commonly used chemical wood preservative (Stratus 2006). Other wood preservatives include pentachlorophenol and arsenicals containing chromium and copper.

In January 2008, Ecology toured the harbor waterfront and provided observations and photographs of wooden marine-use structures. Numerous instances of creosote-treated timber used for support pilings and mooring dolphins were noted at the Landings Pier, the boat launch area, deteriorating boat ramps near K-Ply, areas along the inner side of Ediz Hook, and at the deteriorating Rayonier Mill dock. The condition of these structures varied, with a number of pilings showing significant decay. Beached creosote timber was also documented on the shore of Ediz Hook, west of the public boat launch (Ecology 2008a). Two docks and associated creosote pilings were recently removed by the WSDNR in the western/central area of Ediz Hook (Ecology 2008d). A National Oceanic and Atmospheric Administration (NOAA) coastal survey map of Port Angeles Harbor denotes areas where erect or submerged pilings and dolphins are located. Approximately 39 areas harbor-wide are shown to have pier structures, pilings, or dolphins.

2.1.5 Municipal Facilities

The city of Port Angeles operates several facilities along the harbor (Figure 2–1). The city wastewater treatment plant (WWTP) is located near the Rayonier site and has one deepwater outfall that began discharging in 1969. Since that time, the WWTP has had occasional untreated effluent discharges to the harbor (Ecology 1976). In 2006, the WWTP inadvertently released 6 million to 8 million gallons of sewage into the harbor, prompting the Clallam County Health Department to close all beaches harbor-wide (CCHD 2006).

The city also has an extensive stormwater system operating under a NPDES permit that drains approximately 10,000 acres of the Port Angeles watershed. Major stormwater outfalls are dispersed along the waterfront in the following areas: Boat Haven Marina, the public boat launch and Standard Oil Pier/Port of Port Angeles Terminals 1 and 3, K-Ply area, Landings Pier, and the area in front of the Red Lion Inn. Historically there were 11 CSOs capable of discharging untreated sewer and stormwater into the harbor. Currently, only four CSOs are capable of discharging into the harbor during heavy storms. Between 2003 and 2007, there was an average of 65 CSO events per year with an average volume of 36.8 million gallons per year for these four CSOs (City of Port Angeles 2009).

Vandalism to two transformers at the Port Angeles Light Operations Transformer Yard resulted in an oil spill in which approximately 300 gallons of transformer oil were released (Ecology 2008b). These transformers contained a new formulation of oil and were labeled to contain less than 1 ppm PCB. Some of the oil may have reached nearby Tumwater Creek, which flows approximately 0.75 miles to the harbor. Soil from the spill site was removed and an oil/water separator was installed onsite for surface water runoff. An investigation by Ecology and Clallam County found no transformer oil in the Creek or in its vicinity (Stolz and Garcelon pers. comm. 2009).

There were also recent petroleum releases into Tumwater Creek from a Pacific Pride commercial refueling station, located off Tumwater Road, approximately one-half mile from the harbor (Stolz pers. comm. 2008; Ecology 2008b). Ecology investigations found signatures of lube oil constituents and diesel fuel originating from a stormwater pond that discharged to the creek. Several remediation actions have been conducted at the facility, and source control/cleanup activities are ongoing (Stolz pers. comm. 2009; Garcelon pers. comm. 2009).

2.1.6 Petroleum Storage Facilities

Petroleum storage and transport businesses have historically operated and are currently operating along the Port Angeles waterfront. Eight petroleum bulk plant and terminal facilities have operated at one time or another. Five major facilities closed in the early 1980s.

Chevron operated two bulk plants near the central industrial waterfront, the first of which opened in 1922 and later became Unocal. The second plant (currently Pettit Oil) is a part of the MTA, along with former bulk plants owned by Arco, Standard Oil, and Phillips 66. BP America, Inc. currently operates a bulk fuel facility on the western edge of Ediz Hook, directly neighboring Nippon. Various other types of petroleum-based facilities with above- and below-ground storage tanks exist along the waterfront and include gas stations, a propane supplier (Ferrellgas), and the U.S. Coast Guard station on Ediz Hook. Many of these facilities have had enforcement and/or cleanup actions associated with spills and leaks from above- and below-ground storage tanks or from damaged infrastructure.

The Unocal plant is undergoing interim remedial action and will conduct an RI/FS for soil and groundwater petroleum contamination (Ecology 2005). Ecology found leaks in diesel and gasoline lines during an inspection at the Unocal plant in 1984, when free product was found in monitoring wells and in groundwater. Recovery of the free product was initiated but stopped in

1998 when the monitoring well collapsed. Unocal continues to monitor groundwater at the site. In 2007, Ecology and Chevron signed an Agreed Order under MTCA for cleanup (Ecology 2007).

The U.S. Coast Guard Station decommissioned 14 underground storage tanks (USTs) on Ediz Hook in 1996 and found TPH contamination in groundwater during closure actions (U.S. Coast Guard 2005). An RI was completed at four areas on the property and analytical results indicated that no TPH or benzene, toluene, ethylbenzene, or xylene (BTEX) compounds were detected at concentrations above the MTCA Method A cleanup levels in samples collected from monitoring wells. However, reports from 2003 and 2007 indicated that TPH-contaminated soils extended into the harbor in one area and benzene was detected above cleanup levels in groundwater wells of another area (Ecology 2008d). Since 2002, oxygen release compound (ORC) has been injected into the monitoring wells to enhance the natural degradation of hydrocarbon in groundwater (U.S. Coast Guard 2005, 2006). Based on the groundwater monitoring data, Ecology is requiring further monitoring and remedial actions (Ecology 2008d).

Port Angeles Harbor has also been the site of several tanker oil spills, one of which was the largest spill in Washington State history. The Arco Anchorage oil tanker ran aground in 1985 on the inside of Ediz Hook and spilled 239,000 gallons of crude oil into the harbor, resulting in the death of 4,000 seabirds (Nalder and Cat Le 2004). The Gaz Diamond tanker spilled 1,188 gallons of fuel oil in the harbor in 2002 while refueling (Rossiter 2003). The oil was found on beaches, at the public boat launch, in eelgrass beds, and in nearby commercial fish pens along the southern shore of Ediz Hook.

2.1.7 Commercial Fishing and Shellfish Harvesting

Several seafood-oriented businesses are located along Ediz Hook. Large salmon fish pens owned by Sea Farm are located off the central inner side of Ediz Hook. Benthic community health near the Sea Farm pens has been studied in relation to potential impacts from salmon wastes on the seafloor. In 1991, the USEPA conducted dive surveys at various fish pen operations around Puget Sound, including Port Angeles Harbor (PTI 1991). The USEPA collected sediment and infauna from transects near the pens. Sediment was analyzed for TVS, nutrients, total sulfides, biological oxygen demand (BOD), chemical oxygen demand (COD), TOC, total suspended solids (TSS), and ammonia. Benthic indices of diversity and abundance were also calculated. The study found that benthic impacts, when present, were greatest under and immediately down current of the pens. The distance of the impact zone varied from zero to more than 200 feet. In 2004, Streamkeepers gave the area around the Sea Farm pens in Port Angeles Harbor a healthy listing (CCDCD 2004). The Ediz Hook Salmon Club, also located on the Hook, is a USEPA/ Ecology-regulated facility for the presence of USTs. In 1996, the Salmon Club had the tanks removed and received a “No Further Action” notice for cleanup efforts (Tank Services Northwest 1996).

2.2 Contaminants of Potential Concern

COPCs in harbor sediments and biota were identified based on known chemical associations with the historical and current land-use practices summarized above, as well as data from prior sediment investigations within the harbor (E & E 1998 and 1999; Malcolm Pirnie 2007a). Data from prior investigations formed a list of COPCs based on chemical concentrations in harbor sediments exceeding SMS. These investigations also identified chemicals commonly associated with wood debris degradation, which likely contribute to exceedances of SMS biological criteria, and COPCs from a bioaccumulation standpoint. The identified COPCs, some of which have SMS chemical criteria, include dioxins/furans, PCBs, chlorinated pesticides, SVOCs, resin acids/guaiacols, organotins, ammonia, sulfides, and metals. General trends in the distribution of the COPCs are described in the *Port Angeles Harbor Final Summary of Existing Information and Identification of Data Gaps Report* (E & E 2008b) and summarized below.

2.2.1 Polychlorinated Dibenzo-P-Dioxins and Polychlorinated Dibenzofurans

Dioxins/furans are byproducts of the combustion of organic compounds in the presence of chlorides and/or because of wood pulp bleaching practices. Other industrial processes that can lead to their formation include incineration of municipal and medical wastes, boilers, industrial furnaces, and diesel heavy-duty trucks. Dioxin source assessments conducted in Washington show incinerators, hog fuel (wood debris) boilers, bleached pulp and paper mills, cement kilns, and municipal wastewater treatment as priorities for source reduction and control (Ecology 1998c). Dioxins in the aquatic environment are highly lipophilic and are removed from the system primarily by bioaccumulation in plants, fish, and invertebrates, while furans are mostly present in the particulate-sorbed phase. Dioxins/furans have low water solubility and low chemical reactivity, making them unlikely to dissolve in the water column and resistant to biodegradation. In turbid environments, resuspension of these compounds is common and leads to increased uptake by aquatic life (ATSDR 1995b). Because they degrade very slowly by chemical or biological processes, dioxins/furans are persistent environmental contaminants (E & E 2008b).

Malcolm Pirnie sampled extensively along the south shore of Port Angeles Harbor from west of the inner harbor to east of the Rayonier Mill dock. The results indicate that TCDD TEQs in the harbor surface sediments ranged from 0.11 to 55.1 parts per trillion-dry weight (ppt-dw). Nippon undertook an environmental baseline sediment investigation for the renewal of the WSDNR harbor lease area in 2008 (WSDNR Lease 22-077766). High concentrations of polychlorinated dibenzo-*p*-dioxins/furans were observed, with the highest concentration in the inner harbor (Exponent 2008). The results indicate that TCDD TEQs in the harbor surface sediments ranged from 4.9 to 110 ppt-dw. In general, TEQs were higher in the western portion of the harbor and in the inner log pond adjacent to the Rayonier Mill dock (Malcolm Pirnie 2007a).

2.2.2 PCBs

PCBs are synthetic mixtures of chlorinated compounds that can cause a number of different harmful effects. There are no known natural sources of PCBs in the environment, and they are no longer manufactured in the United States, but are still found in many products. PCBs have been used as coolants and lubricants in electrical equipment such as transformers and capacitors, and they are found in older fluorescent lighting fixtures and electrical appliances, paints, pesticide additives, sealants, and hydraulic oils (ATSDR 2000). PCBs were extensively used in ship manufacturing as a fire retardant, and they may be introduced into waters through shipbuilding and decommissioning activities and during ship maintenance and the release of oily bilge water.

Once in the environment, PCBs do not readily break down and therefore may remain for long periods. In general, the lighter the PCBs, the farther they may be transported from the source of contamination. PCBs are present as solid particles or as a vapor in the atmosphere. They will eventually return to land and water by settling as dust or falling as rain and snow. In water, PCBs may be transported by currents, may attach to bottom sediment or particles in the water, or may evaporate into air. Heavy kinds of PCBs are more likely to settle into sediments, while lighter PCBs are more likely to evaporate. Sediments that contain PCBs can also release the PCBs into the surrounding water. PCBs adhere strongly to soil and will not usually be carried deep into the soil with rainwater. They do not readily break down in soil and may stay in the soil for months or years; generally, the more chlorine atoms that the PCBs contain, the more slowly they break down. PCBs are taken up into the bodies of small organisms and fish in water. They are also taken up by other animals that eat these aquatic animals. PCBs especially accumulate in fish and marine mammals (such as seals and whales), reaching levels that may be many thousands of times higher than in water. PCB levels are highest in animals high up in the food chain (ATSDR 2000).

PCB congeners have been measured in Port Angeles Harbor sediments for two recent studies. Malcolm Pirnie (2007a) observed the highest concentrations of total PCBs west of the Boat Haven Marina, with a maximum concentration of 2,930 parts per billion-dry weight (ppb-dw). Sediments adjacent to the former Rayonier Mill itself ranged from 2.8 to 352 ppb-dw. Nippon sampled 15 stations for total PCBs in the inner harbor area in 2008. The results ranged from 23.1 to 131 ppb-dw (Exponent 2008).

2.2.3 Chlorinated Pesticides

DDT is a chlorinated pesticide that was widely used in the United States before it was banned in 1972 because it caused thinning in seabird eggshells. Dichlorodiphenyldichloroethylene (DDE) and dichlorodiphenyldichloroethane (DDD) are derivatives and breakdown products of DDT that contaminate commercial DDT preparations, and their use has also been banned. These compounds are extremely insoluble in the aquatic environment and may be expected to adhere strongly to particulates in the water column and sediment bed. DDT, DDE, and DDD are highly lipid-soluble and readily bioavailable to aquatic organisms. These pesticides are extremely persistent and will remain in the aquatic environment for long periods of time, which contributes to significant biomagnification in higher trophic levels (ATSDR 2002b).

E & E conducted an ESI of the Rayonier Mill site in 1998 and sampled 86 stations in the harbor and areas surrounding the Rayonier Mill. DDD was detected at only three of the 86 stations, at concentrations from 2.8 to 7.8 ppb-dw. DDT and its breakdown products were undetected at the remaining stations with a detection limit of 2.8 ppb-dw. DDT and its derivatives are bioaccumulative and highly persistent in the environment. As part of the Rayonier Mill RI, Malcolm Pirnie collected sediment and tissue samples and DDT was detected in sediment and in horse clam, crab, and shrimp tissue near the deepwater outfall west of the Rayonier Mill dock (Malcolm Pirnie 2007a).

2.2.4 Semivolatile Organic Compounds: PAHS, Phenols, and Phthalates

SVOCs are a class of compounds that include LPAHs, HPAHs, phenols, methylphenols, and phthalates. Most PAHs enter the aquatic environment from atmospheric deposition, industrial effluent, municipal wastewater, and urban runoff. It is estimated that only one-third of PAHs in aquatic systems are found in dissolved form. Most PAHs are transformed in water by photo-oxidation, chemical oxidation, and microbial metabolism, or they are transported from surface waters by volatilization and sorption to settling particles. In sediments, microbial metabolism is the major process for degradation of PAHs. Additionally, PAHs are bioaccumulated in terrestrial and aquatic plants, fish, and invertebrates; however, many animals are able to metabolize and eliminate these compounds (ATSDR 1995a). Low molecular weight PAHs (LPAHs) dissolve more readily in the water column than do heavier PAH compounds (E & E 2008b). The LPAHs are composed of compounds typically found in coal tar, crude oil, creosote, and marine diesel fuel. LPAH COCs include naphthalene, acenaphthalene, acenaphthene, fluorene, phenanthrene, anthracene, and 2-methylnaphthalene. During the E & E ESI, the highest concentrations of LPAH compounds were found surrounding the Rayonier Mill dock (1,551.8 to 14,595.5 µg/kg dw) and along the city waterfront between the Ferry Terminal and offshore of the Boat Haven Marina (1,071.5 to 3,134 µg/kg dw; E & E 1998). The LPAH compound found at the highest concentration was phenanthrene, at 11,800 µg/kg dw, at Station SD-82 located at the base on the east side of the Rayonier Mill dock. Very low concentration of LPAH compounds were found during the Rayonier Mill MRI (Malcolm Pirnie 2007a). Concentrations of LPAH in the inner harbor area found in the Nippon 2008 survey ranged from 1.4 mg/kg TOC to 20.67 mg/kg TOC (Exponent 2008).

The HPAHs are primarily produced by the combustion of organic materials such as wood, coal, and fuel oils. These are also called the pyrogenic PAH compounds. HPAH COCs include benz(a)anthracene, benzo(a)pyrene, benzo(g,h,i)perylene, chrysene, dibenzo(a,h)anthracene, fluoranthene, indeno(1,2,3-cd)pyrene, pyrene, and total benzofluoracenes. The highest concentration of total HPAH was found under and immediately adjacent to the Rayonier Mill dock, the Boat Haven Marina, and the boat launch/Standard Oil terminal (E & E 1998). The concentration decreased in a northeasterly direction to the lowest levels in the outer harbor area. The HPAH compound found at the highest concentration was fluoranthene, at 15,000 µg/kg dw. As with LPAH, this location was at Station SD-82 at the base on the east side of the Rayonier Mill dock. Very low concentrations of HPAH compounds were found during the Rayonier Mill MRI (Malcolm Pirnie 2007a). Concentrations of HPAH in the inner harbor area found in the Nippon 2008 survey ranged from 5.1 mg/kg TOC to 184.84 mg/kg TOC (Exponent 2008).

Phenols are a class of chemicals that are widely distributed and are both manufactured and naturally occurring. Phenols are used primarily in the production of phenolic resins, in the manufacture of synthetic fibers and slimicides, and as ingredients in disinfectants (ATSDR 2006). Phenol was detected at eight of the 67 stations sampled during the ESI (E & E 1998). Four of the eight were located around the Rayonier Mill dock and outfall at concentrations ranging from 88.9 to 182 µg/kg dw. Three of the remaining four stations were located off and to the north of the Rayonier Mill deepwater outfall.

Cresols are methylphenols and are one of the chemicals that, along with PAHs, make up creosote, which is created from the incomplete combustion of wood or coal. Creosote is used as a preservative in marine lumber applications (e.g., dolphins and pilings). Creosoted pilings and remnants have been identified as a continuous source of marine pollution, as they leach methylphenols and PAHs to marine waters and sediments. Three phenolic compounds were analyzed for during the Rayonier Mill ESI. These were phenol, 4-methylphenol, and 2,4,6-trichlorophenol. Of the three compounds, 4-methylphenol was the most widely detected. In the inner harbor area, concentrations of 4-methylphenol ranged from 226 to 379 µg/kg dw, and the concentration surrounding the Rayonier Mill dock and outfall area ranged from 91.3 to 688 µg/kg dw (E & E 1998). 4-methylphenol exceeded SMS around the dock, outfall area, and the log pond during the ESI, and it was detected above SMS in the log pond and in the Mill Dock area during the MRI (Malcolm Pirnie 2007a).

Phthalates are widely distributed synthetic compounds, used primarily in vinyl products, plastics, and personal care products such as fragrances and nail polish. Phthalates are widely present in CSO and stormwater discharges. They tend to strongly sorb to particulates in an aquatic environment but are highly susceptible to biodegradation. Raw data were unavailable for review, but Malcolm Pirnie reported that Port Angeles Harbor background levels for bis(2-ethylhexll)phthalate (most frequently detected) had a mean concentration of 90.5 µg/kg dw.

2.2.5 Resin Acids/Guaiacols

Resin acids and guaiacols are naturally occurring in woody plants but are also present in chlorinated form in kraft pulp and paper mill waste effluents (Servos et. al.1996). Resin acids are a component of most softwood and are usually released from wood chips during the pulping process. Accumulation in sediments substantially enhances toxicity effects on benthic invertebrates and fish. This acute toxicity for fish and other aquatic life has been shown in previous studies. Resin acids may account for as much as 70 percent of the toxicity of effluents (Li et al. 1996). Guaiacols have been identified as toxic to humans as well as to aquatic organisms (PAN 2008). Retene, the most frequently analyzed resin acid, was detected at concentrations ranging from 65.3 to 2,660 µg/kg dw (E & E 1998). The highest concentrations were found around the Rayonier Mill dock and along the inner harbor shoreline. Analyses were conducted for 12 resin/fatty acids and guaiacols in 2005 (Malcolm Pirnie 2007a).

2.2.6 Butyltins

TBT is a highly toxic compound used as an anti-fouling agent in marine paints applied to the bottom of boats. It is used ubiquitously and can leach from paint into the water and when vessel hulls are scraped. Any harbor or bay with large international vessel traffic will have ongoing TBT sources. NOAA’s Mussel Watch Program, a long-term status and trends program that monitors contaminants in sediments and mussels, includes TBT as an important monitored analyte (NOAA 2007). Almost all of the TBT found in the water column of aquatic environments is bound to suspended particles. These particles may settle out to the sediment bed; TBT is strongly retained and not likely to undergo desorption from the sediments. Organotins may, to a lesser degree, undergo degradation by photochemical or biological processes, or they may partition from the environment and bioaccumulate in the fatty structures of aquatic organisms. There are no historical data on TBT available at this time for the Port Angeles Harbor area.

2.2.7 Metals

Metals such as inorganic arsenic, lead, zinc, copper, mercury, chromium, and cadmium occur naturally from geologic sources and are also used extensively in manufactured products (e.g., paints, cigarettes, fertilizers, industrial solvents, batteries, thermometers, dental fillings, light bulbs (ATSDR 2008). Common anthropogenic sources of metals include car brake dust, incineration, medical and municipal waste, boat paints, other vessel-related sources (e.g., anodes, mercury-containing instruments), and the automotive industry (manufacturing and wrecking disposal (ATSDR 2008). Metals were generally detected at low concentrations at all stations sampled during the ESI (E & E 1998). However, five stations had SMS exceedances for arsenic, cadmium, copper, mercury, and zinc. These stations were located along the shore of the inner portion of Ediz Hook and along the Inner Harbor.

2.3 Summary of Existing Biological Information

Numerous studies have been conducted characterizing and documenting the health of biological communities in Port Angeles Harbor.

Studies on harbor clam populations in the 1970s found viable populations of commercial and non-commercial clams and concluded that the harbor had all the habitat requirements necessary for sustainable clam populations (Bishop and Devitt 1970; Goodwin and Westley 1969). Those clam surveys found that beach areas near Rayonier had only pollutant-tolerant species and very low diversity, while the Ediz Hook area had higher species diversity and included the presence of other macro-organisms (annelids, crustaceans). Although no chemical analyses were conducted, black sludge was noted near the Rayonier Mill facility and on beaches adjacent to the Red Lion Hotel. A geoduck tract was also identified near the Red Lion area in the central nearshore harbor (Goodwin 1973). This tract is currently listed as a non-commercial bed (WDFW 2008). Recreational and commercial shellfish harvesting for geoduck and other clam species is closed in Port Angeles Harbor due to pollution by various sources (biotoxins and/or contaminants, (WA DOH 2008a). Shrimp and Dungeness crab are important commercial and fishery resources of the harbor, although there have been recent advisories against the consumption of crabs and recommendations limiting the consumption of rockfish (*Sebastes* spp.) due to high levels of PCBs and dioxins found during the Rayonier RI study (CCHD 2007; Shaffer 2001; WA DOH 2008b).

Common fish present in the harbor include salmonids (pink [*Oncorhynchus gorbuscha*] and chum [*Oncorhynchus keta*]), forage fish (herring [*Clupea pallassii*], sand lance [*Ammodytes hexapterus*], and smelt [*Hypomesus pretiosus*]), flatfish (sole and flounder species [family *Pleuronectidae*]), perch (family *Embiotocidae*), sculpin (family *Cottidae*), gunnels (family *Pholididae*), rockfish, and lingcod (*Ophiodon verrucosa*) (Fresh pers. comm. 2008; Shea et al. 1981). Recent preliminary data on fish characterization in the harbor has indicated healthy numbers of juvenile salmonids, forage fish, flatfish, and pelagic fish (Fresh pers. comm. 2008). Most of the nearshore areas in industrial sections of the harbor provide poor salmonid habitat, while eastern Ediz Hook and the beaches near the Red Lion Inn and east of the Rayonier Mill dock provide better habitat (Pentec Environmental 2001). Sport fishing for salmon, lingcod, Pacific halibut (*Hippoglossus stenolepis*), rockfish, and greenling (*Hexagrammos* spp.) is a viable and productive component of the Port Angeles economy (City of Port Angeles 1989). The City of Port Angeles has identified the following areas for biological habitat improvement: the Nippon lagoon, the mouths of Ennis, Peabody, and Tumwater creeks, and the establishment of eelgrass along Ediz Hook (Pentec Environmental 2001).

There are indications that sediment contamination within the harbor may be impacting biological communities. Benthic communities were found to be altered in areas where significant amounts of wood debris had accumulated (SAIC 1999). Healthy benthic fish and invertebrate communities were found where there was a minimal amount of wood debris on the sediment, although some animals were observed associated with woodpiles (crustaceans, rockfish, urchins [*Strongylocentrotus* spp.], and sea cucumbers [*Parastichopus californicus*]).

The Department of Ecology's Ambient Monitoring Program maintained a station in central Port Angeles Harbor with the intent of examining the benthic infaunal community. The results indicated the benthic community was dominated primarily by polychaetous annelids. These polychaetes were composed of two functional types. The most abundant were head-down deposit feeders in the family *Maldanidae*, and the second group was composed of species in several families that inhabit the upper 1 centimeter of the sediment surface. This group consists of surface detrital/deposit feeders, both free-living and tube-inhabiting (Ecology 1998a).

In 1968, a study was conducted on the distribution of juvenile salmonid toxicity as related to pulp and paper mill discharge in Port Angeles Harbor. Juvenile salmon were found throughout the harbor, including in the Boat Haven Marina. Defined zones of acute toxicity were found in nearshore areas at Nippon, Rayonier Mill, and Fibreboard. The toxicity was caused by sulfides originating from large sludge deposits in these areas (Ziebel et al. 1968).

2.4 Physical Oceanography: Current Modeling

Numerous studies have investigated the physical oceanographic conditions in Port Angeles Harbor. A thorough survey of relevant literature shows that circulation within the harbor varies based on tides and winds, resulting in complicated flushing patterns and conflicting reports of surface circulation direction (Tollefson et al. 1971; USEPA 1974; Ebbesmeyer et al. 1979; Shea et al. 1981; Foster Wheeler 1997).

Port Angeles physical oceanographic conditions were summarized by Shea et al. (1981). This assessment included surface and tide-induced patterns using the Puget Sound hydraulic tidal model and drift sheet and drift card surveys at the Port Angeles study area. These results indicated that the environment in the study area is extremely dynamic with currents, countercurrents, tidal eddies, turbulent mixing, and freshwater discharges all affecting the distribution of sediment particles. Oceanographic studies identified tidal eddies that form off of Freshwater Bay, Ediz Hook, and Dungeness Bay during flood and ebb tides. The model indicated the presence of two gyres varying in strength, depending on the tidal cycle. A weak clockwise gyre forms off the point of land at Morse Creek and entrains the water mass up and past the tip of Ediz Hook, while a second gyre entrains water in a counter-clockwise direction into Port Angeles Harbor. The water mass moves generally in a southwest direction into the inner harbor, then runs easterly along the shoreline past the Rayonier Mill dock.

Rayonier, Inc. conducted particulate dispersion studies that modeled the dispersion of TSS from the nearshore and deepwater outfalls (Malcolm Pirnie 2007a). In 2001, results showed that from the nearshore outfall, TSS migrated in an east-west direction hugging the shoreline. In 2004, based on modifications initially developed by Battelle (2004), the model was rerun, taking re-suspension into account; the pattern changed little except that the amount of TSS was reduced by 80 percent. In 2001, results of the deepwater outfall showed an east-west dispersion pattern. In 2004, when re-suspension was taken into account, the TSS appeared to be contained inside Port Angeles Harbor immediately to the south of the tip of Ediz Hook.

3.0 Sampling and Analytical Methods

The following section summarizes the field methods used to collect surface and subsurface sediment and tissue samples for the Port Angeles sediment investigation. This section also describes the chemical and biological analytical methods used to analyze the samples. Data validation methods used for quality assurance/quality control (QA/QC) purposes for these samples are outlined in Section 4.0. Sampling and analytical methods are outlined in the Port Angeles Harbor SAP/Quality Assurance Project Plan (QAPP) (E & E 2008d). These plans followed Ecology's recommendations for developing Sediment SAPs for Puget Sound (Ecology 2008c).

3.1 Sample Types

Three sample types were collected as part of this sediment investigation. These were surface sediment grab samples, subsurface sediment core samples with up to three subsamples taken from each core, and tissue samples. The surface grab samples were used for chemical analysis and/or bioassay toxicity testing. The subsurface cores sampled were used for chemical analyses and stratigraphic observations. Tissue samples were collected for chemical analysis and included horse clams, geoduck clams, lingcod, eelgrass, and bull kelp.

3.1.1 Surface Sediment Samples

Surface sediment samples (upper 10 centimeters) were collected from 113 stations in the Port Angeles Harbor and Rayonier Mill areas using a grab sampling device in subtidal areas, or by hand in shallow subtidal or intertidal areas (Figure 3–1 and Table B–1, Appendix B). The upper 10-centimeter depth is considered the biologically active zone and is therefore most relevant to assess ecological risk. Samples from three additional stations were collected from Dungeness Bay as reference samples for the bioassay, sediment, and tissue analyses (Figure 3–2 and Table B–1, Appendix B). The station-naming conventions are presented in Table 3–1 for the Harbor-Wide study area and the reference sample locations and in Table 3–2 for the Rayonier Mill study area.

Sediment samples for chemical analysis were placed into pre-cleaned sample jars and sent to the appropriate laboratory under Chain of Custody for analysis. The sediment samples were analyzed for the following parameters and chemical groups: TOC, grain size, SVOCs, resin acids and guaiacols, PCBs and pesticides, dioxins and furans, TPH, TBT, SMS metals (arsenic, chromium, cadmium, copper, lead, mercury, silver, and zinc), non-SMS metals (antimony, barium, and nickel), sulfides, and ammonia. Not all stations were analyzed for all chemical groups, as this determination was correlated to shoreline activity and anticipated COPCs. The rationale for sample collection and analysis is provided in the project SAP/QAPP (E & E 2008d). Section 3.10 provides further discussion of rationale for analysis of archived samples.

Bioassay tests were conducted on selected surface sediment samples from the Harbor-Wide and the Rayonier Mill study areas (Figure 3–3). Two acute and one chronic test were conducted to evaluate impairment to the test species due to contact with the sediment. The tests included the following: the acute 10-day amphipod test, the acute larval (echinoderm) test, and the chronic 20-day *Neanthes* test. Confirmation of toxicity in the tests, based on comparison to SMS biological criteria, was used to initiate the second tier of analyses, which included the chemical analysis of archived sediment samples.

3.1.2 Subsurface Sediment Cores

Subsurface sediment cores were attempted at 59 stations and successfully collected from 45 stations, which were co-located with selected surface sediment stations. These cores were collected to determine the vertical distribution of COPCs in suspected depositional areas (Figure 3–4 and Table B–2, Appendix B), the vertical distribution of wood debris in areas of known or suspected accumulation, and, in general, sedimentation rates and depths of biological mixing.

Cores were collected down to either 4 feet or 12 feet in depth from the surface, depending on the station sampling objective. Cores collected in depositional areas and those collected to determine sedimentation rates were advanced to 4 feet below the surface. If continuous wood debris was encountered, then cores were advanced as far as practicable, up to 12 feet, to reach native sediments for sample collection. Within each subsurface core, up to four intervals were identified for the collection and analysis of COPCs. Two core samples, from the Red Lion area (Station RL03) and the Marina area (Station MA06), were collected for radioisotope analysis. These cores were analyzed to obtain a general evaluation of sedimentation rates and depth of biological mixing in the sediment layers. Radioisotope samples were collected in 2-centimeter increments down to 100 centimeters, and in 10-centimeter intervals for the remainder of the core, and they were analyzed for ^{210}lead and ^{137}cesium.

3.1.3 Tissue Samples

Twenty-four stations were originally identified in the SAP for tissue sampling in the harbor and in Dungeness Bay (Figure 3–5 and Table B–3, Appendix B). The proposed sampling locations in the SAP were broad areas where target species were expected to be found to support the risk assessment. However, in many of these locations, these species were absent. Tissue samples could not be collected at eight of the stations due to species absence or presence of heavy wood debris, rocks, or excessive macroalgae. Station MD09TH was added near the Rayonier Mill dock area as a replacement for one rejected station. Tissue samples comprised of lingcod, horse clam, geoduck clams, and eelgrass or bull kelp were collected from 12 stations in the Harbor-Wide study area and six stations in the Rayonier Mill study area for analysis of COPCs (Figure 3–5 and Table B–3, Appendix B).

- Lingcod samples were collected from four stations in the Harbor-Wide study area.
- Horse clam samples were collected from three stations in the Harbor-Wide area, five stations in the Rayonier Mill study area, and two stations in the reference area.
- Geoduck clam samples were collected from one station in the Rayonier Mill study area and one station in the reference area.
- Macroalgae samples were collected from two stations in the Harbor-Wide study area.

These samples were not composited between stations, but the clam and macroalgae samples were composites of several specimens collected at the same station (Tables 3–3 and 3–4). Chemical analysis of the clam, fish, and macroalgae samples allowed measurement of the potential uptake of COPCs from sediments, in support of the screening level human health and ecological risk assessment. Any COPCs detected in bull kelp would likely have originated from the water column, as this macroalgae does not have a root system with which to uptake nutrients.

3.2 Sample Designation

Station locations within the AOPCs were chosen to characterize nearshore source areas with suspected sediment contaminants and to determine the general distribution of contaminants from the nearshore areas out into the harbor. The station-naming conventions are presented in Table 3–1 for the Harbor-Wide study area and the reference sample locations and in Table 3–2 for the Rayonier Mill study area.

The surface grab sample stations were labeled with the initials of the area from which the station was located and a simple numeric designation for a sample number. The letter “A” indicated the sample was from the upper 10 centimeters of the grab sample sediment.

The subsurface core stations were co-located with the surface sediment stations where possible; thus, they were given the same abbreviation and numeric designation. The letter following the station name refers to the depth along the sediment core at which the sample was collected. The subsurface sediment cores were divided into discrete subsections consisting of a “B,” “C,” and “D” core interval depending on location and data objectives. All subsurface “B” intervals were selected directly below the surface sediment layer down to a depth where a visual change in the core column was identified. The “B” core samples were collected where a substantial amount of sediment was present above or mixed within a layer of wood debris. When available the subsurface “C” core sediment samples were collected from the sediment below the wood debris layer or in what appeared to be native sediment. One subsurface “D” core sample was collected near the deepwater outfall.

Samples collected of fish, bivalves, and macroalgae used the same field identification and area designations as the grab and core stations. The following tissue designators replaced the surface grab and core depth designations:

- TL tissue lingcod
- TH tissue horse clam
- TG tissue geoduck
- TM tissue macroalgae (includes eelgrass and bull kelp)

A more complete description of the naming conventions for the AOPCs is provided in the project SAP/QAPP (E & E 2008d).

3.3 Field Schedule

Field sampling in the Port Angeles region occurred in two shifts, based on the availability of sampling vessels. Sampling commenced on June 2 and concluded on July 26, 2008.

Surface sediment grab sampling in Port Angeles Harbor was conducted from June 2 to June 23, 2008. Samples were collected from the research vessel (R/V) *Caroline Dow*, owned and operated by Mr. Eric Parker of Research Support Services, Bainbridge Island, Washington.

The first round of mobilization for the subsurface core sampling also began on June 2, 2008, and continued until June 21, 2008, when it became necessary to change the sampling vessel. The first-round subsurface coring was conducted aboard the motor vessel (M/V) *Salvager*, owned and operated by Northwest Underwater Construction, Inc. The second round of mobilization commenced on July 14, 2008, and continued until completion of the coring on July 26, 2008. Second-round coring was conducted from the vessel R/V *Caroline Dow*, which had completed the grab sampling field activities. The vessel change was made due to the increased mobility and accuracy provided by the smaller and more agile R/V *Carolyn Dow* for obtaining and maintaining sampling position.

The collection of fish, shellfish, and macroalgae tissue for chemical analysis occurred on multiple days during the sampling events. Samples were collected from the coastal craft Tse-Whit-Zen by divers from the Lower Elwha Klallam Tribe and relinquished to E & E field staff personnel. During the first event, tissue samples were collected on June 14, 21, and 22, 2008. Tissue samples for the second event were collected on July 12, 2008.

3.4 Positioning

3.4.1 Surface Sediment Samples

Vessel-based station positioning was accomplished using a differential global positioning system (GPS) that provided an accuracy of 1 to 3 meters. The GPS receiver routed latitude and longitude to an integrated navigation system, which displayed the vessel's position in relation to the sample location. Navigation data, including the range and bearing to the sample location, was then provided to the vessel operator in plane view at a user-defined scale. Shore-based sample positioning was conducted either using a hand-held GPS system or by triangulation using known, permanent, shore-based fixtures. Subsequently, when the hand-held unit became available, those stations that had been sampled using the triangulation method were reoccupied and GPS coordinates were obtained (Table B–1, Appendix B).

3.4.2 Subsurface Sediment Samples

The vessel positioning method used for the sediment core sampling was similar to the method used for grab sampling. To occupy the actual station coordinates, the sampling vessel anchored up-current from the desired station coordinates and backed down onto the coordinates by letting out anchor line. When the vessel was on station, a one or two point anchor was set, holding the vessel on station for core collection (Table B–2, Appendix B).

3.4.3 Fish and Shellfish Tissue

Station positioning for collecting tissue samples was accomplished using a hand-held GPS receiver. The sampling vessel was positioned over the selected coordinates and anchored in place. The tissue samples were then collected by a diver within a 50-foot radius of the sampling vessel (Table B–3, Appendix B).

3.5 Sample Collection and Processing Methods

The procedures used for sample collection, handling, decontamination, compositing, storage, and transfer were described in detail in the project SAP/QAPP and are summarized here. Sample collection was performed in accordance with the SAP/QAPP except where noted.

3.5.1 Sample Collection and Equipment Decontamination Procedures

Surface sediment samples were collected using a pneumatic-powered grab sampling device. Subsurface core samples were collected using a Vibracore, and tissue samples were hand-collected by divers.

Sediment sampling equipment for both the grab and core samples were decontaminated between each sample location as well as between replicate samples collected at the same location. The following procedure was used to decontaminate the sampling equipment prior to use:

1. Rinse with water provided by the sampling vessel.
2. Scrub with a brush and Alconox soap.
3. Rinse with site water.
4. Rinse with ethanol.
5. Rinse with deionized water.
6. Cover with aluminum foil, faded side down.
7. Rinse with site water immediately prior to sampling.

Stainless steel bowls, spoons, and the hand-held coring device were also decontaminated in the above manner. The grab sampler was decontaminated as described but without the ethanol rinse.

Sediment Grab Sampling

Eighty-six stations from fourteen Harbor-Wide study areas were designated for sediment grab sampling (Figure 3–1 and Table B–1, Appendix B). Four of these stations were abandoned at the time of sampling because samples could not be collected due to the presence of rocks, excessive amounts of macroalgae, or large amounts of wood debris. Included in these 86 stations were the three reference sample locations in Dungeness Bay (Figure 3–2).

Thirty-five stations from seven Rayonier Mill site study areas were designated for sampling (Figure 3–1 and Table B–1, Appendix B). One station was abandoned because large rocks impeded the grab sampler.

Subtidal surface sediments were collected using a pneumatic-powered, van Veen-type grab sampler with a surface area of 0.2 meters squared (m^2). The device was lowered to within 1 meter of the sediment surface while the vessel was repositioned over the target location. When the vessel was over the sample location, the winch operator lowered the grab sampler and the sediment was collected.

Intertidal and shallow subtidal stations were sampled by hand. Shallow subtidal samples were collected using a hand-operated, saw-toothed coring device 20 centimeters in diameter by 10 centimeters deep. The sampling personnel selected an area within the 1-meter radius of the sample position and collected the sample by twisting the coring device into the sediment and extracting the core. This process was repeated until sufficient sediment volume was obtained to complete the sample collection. Intertidal samples were collected by hand using a stainless steel spoon. When GPS coordinates were available, the sampler collected the sample within a 1-meter radius of the desired position. When the GPS was unavailable, the sampler measured the distance from a permanent fixed location to the desired sampling site, then identified and photographed three permanent shore triangulation points that overlapped with others at a further distance. The sample was then collected within 1 meter of the sampler.

The grab sample was examined upon retrieval to determine whether it met the acceptance criteria described in the Port Angeles SAP (E & E 2008d). If the sample was acceptable, the following qualitative information was recorded on the grab sample log sheets (see Appendix A): penetration depth, texture, color with depth, redox potential depth (RPD), odor, amount and type of wood debris, the presence of chemical type sheens, and the presence of biological organisms. A summary of surface sediment findings can be found in Table B–4 (Appendix B). When the characterization was completed, the top 10 centimeters of the sediment were removed and placed into a stainless steel bowl. Multiple casts of the sampling device were needed at some stations to obtain enough sediment volume to satisfy the requirements for bioassay toxicity tests.

Sediment samples for sulfide analyses were collected directly from the grab sample apparatus, placed into a 2-ounce jar with no headspace, and preserved with a solution of zinc acetate. The remaining sediment in the bowl was then homogenized until it was a consistent color and texture and then placed into sample jars. Sediment samples for toxicity testing (Figure 3–3) were placed into 10 L, 4-mil thick sediment bags, which were then placed into a second identical bag and appropriately labeled. Each individual sediment bag was twisted closed and tightly sealed using a zip tie. Samples for chemical analysis and toxicity testing were stored in coolers with ice until delivery to the sample processing center. Field grain size determinations were not conducted at the direction of Ecology.

Subsurface Core Sampling

Subsurface sediment sampling was conducted using a 12-foot Vibracore and aluminum barrels varying from 4 to 12 feet in length depending on the location, substrate, and sampling objectives. Lexan polycarbonate liners were used for core collection and sediment sampling. All sediment core collection and sampling equipment was decontaminated before use according to the quality standards given in Puget Sound Estuary Program (PSEP) protocols (PSEP 1997).

Sediment cores were attempted at 59 stations located in 16 AOPCs (Figure 3–4). Cores could not be collected at 14 of those locations. Effort was employed to co-locate subsurface samples to within 1 meter of the surface sample station. Up to three attempts were made at each sampling station to achieve one successful core with the minimum sediment volume needed to perform all necessary analyses specific to each station. Subsurface cores were advanced to a maximum depth of 12 feet, to define the depth of the wood debris and characterize the underlying native sediment.

Sediments from each core were extracted by cutting open the Lexan liner with a decontaminated tile scorer. The subsurface sediment was divided into discrete intervals consisting of a “B,” “C,”and “D” core interval depending on location and data objective. Visual observations and descriptions of wood debris within the core were made in the field as cores were sectioned into samples (Table B–5, Appendix B). Descriptions included color, odor (if present), the presence and depth of distinct sediment layers, sediment type, color, odor, the presence of sand blast grit and the amount and type of wood debris, and the depth to native sediment.

Sampling intervals were based on visual and olfactory screening conducted by the E & E sampling team. For the subsurface "B" core interval, a sample was collected where a substantial amount of fine-grained sediment was present that visually contained wood debris and/or appeared to have a chemical residue. These samples were sent for chemical analysis. When available, the subsurface "C" core sample was collected from the native sediment beneath the wood-debris/chemical residue horizon. If a clear horizon between the impacted and native sediment layer could not be identified, a sample was collected from the sediment directly beneath a layer of sediment that visually contained wood debris or other anthropogenic material. Only one subsurface interval was desired at nearshore outfall locations in the study area. At the deep water outfall locations four subsurface intervals (B-E) were to be collected at one foot intervals. No subsurface "E" cores were collected and only one "D" core inverval could be collected (Station DO04D). Due to hard substrate and/or various types of debris, 14 of the sediment core locations were abandoned at the time of collection. Once sample intervals were observed and selected, the sediment was placed in a decontaminated stainless steel bowl and homogenized. Samples submitted for bulk chemistry were placed in appropriately labeled sample jars and placed in a secure cooler packed with ice.

Cores for radioisotope analysis were collected from two stations, RL03 and MA06. Station RL03 was relocated 3,200 feet from original coordinates due to the sand/gravel substrate found during the surface grab sampling event. Station MA06 was relocated 500 feet east of the original coordinates to avoid wood debris found during the grab sampling event. Sediment cores were diver-collected using a piston corer with a 15-pound hammer. The corer was attached to a float package to extract the device from the sediment and bring it to the surface. The core was visually inspected and opened using a decontaminated tile scorer. Samples were collected in 2-centimeter increments down to 100 centimeters, and in 10-centimeter intervals for the remainder of the core.

Fish and Shellfish Tissue Collection

Tissue samples were hand-collected by a self-contained underwater breathing apparatus (SCUBA) diver (Figure 3–5 and Table B–3, Appendix B). Ten pounds of eelgrass and bull kelp were collected and rinsed with site water. The diver grabbed and held onto the neck of horse clams and geoducks to prevent them from retracting into their burrows and washed away the sediment from the clams' bodies using a high-powered water hose. The lingcod samples were collected by spear fishing. Many of these samples were composed of more than one specimen collected from the same station.

All tissue samples were rinsed with site water and wrapped in aluminum foil with the dull side facing the sample. They were placed into plastic bags and stored on ice prior to completing the sample handling inventory and shipping them to the lab.

3.6 Archeological and Cultural Resources

The surface and subsurface samples collected in less than 50 feet of water throughout Port Angeles Harbor were examined by a qualified archaeologist to look for cultural and historical artifacts associated with the neighboring North American native tribes. Information relating to these observations is contained in the *Cultural Resources Report* provided as Appendix F.

3.7 Sample Handling

Sediment samples were delivered twice each day to the City of Port Angeles Boathouse, where E & E personnel inventoried the samples and completed Chain of Custody forms. Tissue samples were delivered to the boathouse at the end of the day in which they were collected. Upon reaching the boathouse, all samples were inventoried and entered into an electronic database for sample tracking.

3.7.1 Chain of Custody Procedures

At the end of each sampling day, the sediment samples were removed from the coolers and checked against the field sample log. Sample collection information was then entered into the SCRIBE database management system for tracking and creation of Chain of Custody forms. Sediment samples were placed back into coolers with fresh ice, and transportation to the appropriate analytical laboratory was arranged. Chain of Custody forms were signed by the sample crew leader and placed into the coolers, which were then sealed with Chain of Custody seals.

3.7.2 Sample Transport Procedures

On completion of final sample inventory, each glass sample container was placed into a plastic bag and sealed. Samples were immediately placed on ice. A Chain of Custody form was computer-generated and placed into the cooler. The coolers were clearly labeled with sufficient information to enable positive identification (name of project, time and date the cooler was sealed, name of person sealing the cooler).

Sediment samples for toxicity testing were delivered to the offices of NewFields Northwest Laboratory (NewFields) every three days by the sampling crew. Sediment samples for dioxin/furan congener analysis were shipped by Federal Express (FEDEX) to Axys Analytical Services (Axys) in Sidney, British Columbia, Canada. Samples that were sent to Test America Laboratories, Inc. (TA) in Tacoma, Washington, and in Austin, Texas, or Analytical Resources, Inc. (ARI) in Tukwila, Washington, for analysis of the other chemical constituents were either sent by FEDEX or picked up and delivered by a lab-designated courier service. The final set of samples for TA and ARI were delivered by sampling personnel at the close of each phase of the work.

3.8 Chemical and Physical Analyses

The master list of chemicals to be analyzed for the Harbor-Wide and Rayonier Mill study areas was based on chemicals either commonly known to be associated with nearby industrial activity or detected above SMS in previous investigations (Section 2.2). Depending on the station type, sediment from surface and subsurface samples was either sent to chemical laboratories for analysis or for archiving. Chemical analysis of sediment samples included the SMS analyte list and conventional sediment parameters (TOC, grain size, total solids, ammonia, and sulfides). In addition, chlorinated pesticides, Northwest total petroleum hydrocarbon – semivolatile petroleum products method (NWTPH-Dx), TBT, non-SMS metals, dioxin/furan congeners, and wood resin compounds were analyzed for in areas where these compounds might be found.

As discussed previously, not all chemicals on the master list were analyzed in all samples. Chemicals were selected for analysis if they were known to be associated with a nearby industrial activity. Samples not selected for analysis were archived. In some cases, samples were pulled from archive and analyzed later in one of several waves of analysis. These analysis and archive decision selections are shown in Tables 3–3 and 3–4. Field logs describing sample collection activity are included in Appendix A.

3.8.1 Surface Grab Samples

All surface grab samples were visually characterized prior to collection of sediment for chemical analysis. The qualitative characteristics recorded included sampler penetration depth, surface sediment texture, RPD, odor, presence and type of wood debris, and presence and types of infauna. This qualitative data has been outlined in Table B–5 (Appendix B), and full field forms are available in Appendix A. All surface samples were analyzed for TOC, grain size, and total solids. Selected sediment samples, depending on nearshore industrial activity, were analyzed for PCBs and pesticides, SVOCs, resin compounds, dioxins/furans, NWTPH-Dx, metals and/or mercury, organotin, sulfides, ammonia, and toxicity. In many cases, samples for one of these analytes were collected and archived for future analysis.

3.8.2 Subsurface Core Samples

Upon removal from the core tube, subsurface core samples were visually characterized for the presence and depth of distinct sediment layers, sediment type, color, odor, the presence of sand blast grit and wood debris, and the depth to native sediment. This qualitative data has been outlined in Tables 3–3 and 3–4, and full field forms are available in Appendix A. In the Harbor-Wide and Rayonier Mill study areas, all subsurface core samples were analyzed for TOCs, grain size, total solids, SVOCs, metals, and mercury. As with the surface grab sampling, selected sediment samples, depending on nearshore industrial activity, were analyzed for PCBs and pesticides, resin compounds, dioxins/furans, NWTPH-Dx, organotin, sulfides, ammonia, and toxicity. In many cases, samples for one of these analytes were collected and archived for future analysis.

3.8.3 Fish and Shellfish Tissue Collection

Lingcod, bivalve, and macroalgal samples were rinsed with site water. The lingcod were weighed, measured (total length), and examined for any abnormalities. The bivalve samples were measured (total length), and the macroalgal sample was weighed. Full field forms are available in Appendix A. All tissue samples were analyzed for SVOCs, PCBs, dioxins/furans, metals, and mercury. Selected tissues were also analyzed for pesticides. Due to high detection limits in the initial PAH analysis, tissue samples were re-analyzed using the low-detection limit PAH-selected ion monitoring (SIM) method. The methods employed followed protocols established for the PSEP (PSEP 1997) and the Port Angeles project SAP (E & E 2008d).

3.9 Analytical Methods

The chemical analytical procedures used in this program followed the most recent SMS and PSEP protocols and guidelines, and Ecology's *Sediment Sampling and Analysis Plan* Appendix (Ecology 2008). Each laboratory participated in the National Laboratory Accreditation Program (NELAP) and was accredited by Ecology's laboratory certification program.

Three analytical chemical laboratories were used to analyze sediment and tissue samples. Axys analyzed sediment samples for dioxin/furan congeners and analyzed tissue samples for dioxin/furan congeners, PCB congeners, and SIM analysis for PAH compounds. TA was responsible for analysis of PCB Aroclors and pesticides, NWTPH-Dx, metals, mercury, and radioisotopes. ARI was responsible for analysis of the TOC, grain size, butyltins, resin acids and guaiacols, SVOCs, ammonia, and sulfides.

3.9.1 Sediment Chemical Analyses

Table 5–1 in the project SAP/QAPP details the analytical methods used for the sediment analysis (E & E 2008d). All analytical laboratory analytical procedures were approved by Ecology. The laboratory analyzed the chlorinated guaiacols by EPA Method 8270, which is approved by Ecology. Each laboratory followed its own standard operating procedures, which were appended to the project SAP/QAPP (E & E 2008d). Radioisotope samples were analyzed for ^{210}lead, and ^{137}cesium by TA.

3.9.2 Sediment Toxicity Testing

NewFields was responsible for the bioassay toxicity testing. The three toxicity tests used on sediments from Port Angeles Harbor were the acute 10-day amphipod test, the acute larval development test, and the chronic 20-day juvenile polychaete growth test. Test methodologies can be found in the PSEP protocol "Recommended Guidelines for Conducting Laboratory Bioassays on Puget Sound Sediments" (PSEP 1995). A wide range of salinity and grain size were expected in the study area; therefore, the test species used in the amphipod test was *Eohaustorius estuarius*. This species was selected over *Rhepoxynius abronius* or *Ampelisca abdita* because it is tolerant of a wider range of salinity and grain-size environments. The sand dollar (*Dendraster excentricus*) was selected for the larval test over *Mytilus edulis* due to the availability of larvae. The juvenile growth test was conducted using the polychaete *Neanthes arenaceodentata*.

Reference Area Comparison

Three stations in Dungeness Bay were selected by E & E and Ecology personnel as reference stations for the Port Angeles study. These locations were selected based on data from the ESI study (E & E 1998) and the Rayonier Mill Phase 2 addendum to the remedial investigation (Malcolm Pirnie 2007a). The reference sediments were collected for use as reference samples for the sediment toxicity tests and as potential background stations for chemical analyses (E & E 2008c).

The bioassay results from the test stations were compared with the results from all three reference stations and to the test batch control sample. This approach was used because of the concern that the selected reference stations would not effectively bracket the range of grain sizes seen at Port Angeles Harbor stations. If a test station grain size matched a specific reference station within 20 percent fines, then that reference station was used for comparison with SMS bioassay criteria. If the percent fines between test and reference station was not within 20 percent, then the reference station with the closest percent fines or the control sample was used for the comparison.

Additions to the Bioassay Tests

Sediment from Station EC01A was taken from a freshwater environment, raising the question of whether the marine bioassay organisms could survive in freshwater sediment. To control for the possibility that survival would be affected by salinity, one set of samples was acclimated to seawater for bioassay testing and a second set was tested without acclimation.

Recent research compiled and summarized by Ecology has suggested that the toxicity of certain PAHs may increase with their exposure to certain wavelengths of ultraviolet radiation (Adolphson 2003). To examine this hypothesis, all bioassays from sediment samples collected in water depths less than 12 feet were conducted under full-spectrum lighting including the ultraviolet wavelengths.

3.9.3 Selected Sediment Toxicity Tests

10-Day Amphipod Test

The 10-day amphipod specimen toxicity test using *Eohaustorius estuarius* was conducted on Port Angeles sediment using the protocol found in “Recommended Guidelines for Conducting Laboratory Bioassays on Puget Sound Sediments” (PSEP 1995). The species was selected after discussions with Ecology and NewFields. At that time, it was recognized that there was a large range of sediment grain sizes in the study and that most would be less than 60 percent fines. The team chose *E. estuarius* because it has wide grain size and salinity tolerance ranges as long as clay fraction is <20 percent. A wide range of salinity ranges as well as grain sizes were expected to be found in the harbor. The reason interstitial salinity was not used in the test regime was discussed, and it was believed that the input of freshwater from the creeks entering the harbor may reduce the salinity in the nearshore area. Since many stations were located in the nearshore area at the confluence of these creeks, it was believed that *E. estuarius* was the best choice for the toxicity test. Five separate batches were run, the first with 14 samples, the second with 28 samples, the third with 13 samples, and the fourth with 13 samples. The samples in the fourth batch were treated with ultraviolet light due to sample depth (<12’) and presumed PAH presence in the harbor regime (Ecology 2008c). The fifth batch consisted of two samples that were retested due to high mortality. This batch was run concurrently with batch 4 because there was insufficient reference sediment remaining to run a fifth set of reference samples. This is a 10-day test with mortality and reburial as the measured endpoints.

Larval Development Test

The larval development test used the sand dollar (*Dendraster excentricus*) as the test organism. Test methodology can be found in the PSEP protocol “Recommended Guidelines for Conducting Laboratory Bioassays on Puget Sound Sediments” (PSEP 1995). Four separate batches were run: the first with 20 samples, the second with 20 samples, the third contained 15 samples, and the fourth contained 12 samples. Samples in this batch were also treated with ultraviolet light. This is a 4- to 5-day test with endpoints of mortality and abnormality.

Juvenile Polychaete Growth Test

The juvenile polychaete growth test is a 20-day sublethal test with endpoints of mortality and growth. The test species in this bioassay was the polychaete worm *Neanthes arenaceodentata*. Three separate batches were run: the first with 28 samples, the second with 24 samples, and the third with 13 samples. Batch 3 was treated with ultraviolet light.

3.10 Selection of Archived Samples for Analysis

Cost constraints did not allow the analysis of all COPCs at all stations. Selection of chemical groups for analysis was based on results from previous surveys and on the potential for a COPC to be present due to upland or shoreside activity. If there were no presumptive data indicating that either sediment contamination or toxicity were present, some sediment samples for some analytical groups were archived for future analysis. These samples were archived pending the results of initial analyses. The decision framework to determine which of these samples should be analyzed, and for which analytes, involved the five criteria outlined below. If none of these decision criteria were met, then an archived sample was not analyzed. Analyses selected from archived samples are shown in Tables 3–3 and 3–4.

- **Criterion 1. Bioassay Failure.** If a bioassay failed at a station and the chemistry portion of the sample was archived, the archived portion was analyzed for full-suite chemistry to evaluate what may have caused the bioassay failure.
- **Criterion 2. Chemical Exceedance for Short Holding Time Analytes**. In the archived samples discussed above, certain chemicals had been previously analyzed due to limited holding times (e.g., mercury, TOC, ammonia, sulfides). If any of these analytes exceed SMS criteria or had exceedances of reference concentrations of non-SMS chemicals, the archived samples were analyzed.
- **Criterion 3. Chemical Exceedances in Adjacent Surface Sediment Samples**. Certain surface sediment samples were selected for immediate chemical analysis in the SAP based on proximity to known sources or the lack of existing information. If these samples exhibited SMS exceedances, or showed significant elevations of other potentially toxic or bioaccumulative chemicals over background or risk-based concentrations, adjacent archived samples were evaluated to determine whether they could contribute to the delineation of boundaries, identification of sources, or other project goals. If so, they were analyzed for the contaminants that exceeded levels of concern in adjacent samples.
- **Criterion 4. Elevations of Bioaccumulative Contaminants of Concern in Tissues.** Tissue results for bioaccumulative compounds were evaluated to determine whether (1) concentrations exceeded risk-based criteria for human health or wildlife, or (2) concentrations were elevated above natural background concentrations. If both conditions were true, these compounds were considered bioaccumulative contaminants of concern (BCOCs) and were retained for further evaluation. Once BCOCs had been identified, surface chemistry results were evaluated to determine whether there was sufficient information on the BCOCs to evaluate sediment contributions to tissues. Because bioaccumulative exposure is an area-wide phenomenon, it was not necessary to delineate

concentrations in all areas. However, sufficient information was available to identify (1) source areas and hot spots, (2) general harbor-wide concentrations, and (3) area-wide and/or natural background concentrations. If the first round of chemical analyses, in conjunction with historical data, left data gaps in some of these areas, certain archived samples were selected and analyzed for BCOCs.

- **Criterion 5. Evaluation of Field Logs.** Field logs were occasionally used to identify samples of special interest; for example, those in which petroleum, paint chips, sandblast grit, odors, or other evidence of contamination was noted. If a review of the field logs identified potential evidence of contamination in an archived sample, that sample was analyzed for the contaminants suggested by the field notes and any other contaminants considered likely based on the results of nearby samples or known sources and site uses.

3.11 Data Analysis Methods

The data analysis methods described below were used to reduce, summarize, and report the chemistry, bioassay, tissue, and radioisotope laboratory results. Laboratory reports containing the reported data are not included in this document but are available from Ecology. The data can be accessed in Ecology's Environmental Information Management (EIM) database under the study ID PASED08. Data validation summary memorandums for sediment chemistry analyses can be found in Appendix H. Final laboratory data reports for the bioassay analyses can be found in Appendix K. A more detailed discussion of the data results are presented in the *Port Angeles Harbor Supplemental Data Evaluation to the Sediment Investigation Report* (NewFields 2012).

3.11.1 Sediment Chemistry

Analytical results from the sediment chemical analysis underwent a QA1 review by E & E staff to determine whether the data were acceptable for use (Section 4). A third-party QA Level 2 (QA2) review was also conducted at the request of Ecology so that sufficient documentation would exist if regulatory actions required a high level of validation.

Sediment chemistry data were tabulated by station in a west-to-east direction. Analysis of data included comparing the results to the SMS numeric criteria and, when relevant, other thresholds of concern; these thresholds were the LAET (Barrick et al. 1988) and NOAA's Effects Range Low (ERL) and Effects Range Median (ERM) (Long et al. 1995).

The concentrations of dioxin/furan compounds were evaluated as dry weight (dw) concentrations and as a 2,3,7,8-TCDD total TEQ. The TEQ is the sum of the concentrations of individual congeners multiplied by their respective toxic equivalency factor (TEF) values (potency relative to 2,3,7,8-TCDD for dioxins/furans (Van den Berg et al. 2006). If a congener was detected in one or more samples within the dataset, then any non-detect results were replaced with a value equal to one-half of the method detection limit (MDL).

3.11.2 Tissue Chemistry

The tissue chemistry data were tabulated by station and by tissue type. Tissue chemistry results were used in the screening level human health and ecological risk assessment. Tissue samples were analyzed for SVOCs, chlorinated pesticides, metals, dioxin/furan congeners, and coplanar dioxin-like PCB congeners. The concentration of dioxin/furan congeners and PCB congeners was normalized to the toxicity of 2,3,7,8-TCDD TEQ using TEFs (potency relative to 2,3,7,8-TCDD) appropriate for human, fish, and wildlife receptors as updated by the World Health Organization (WHO) in 2005. The WHO TEF values are the same as those required by MTCA. Non-detect values were assessed as half of the MDL for data evaluation purposes. Historical tissue concentration data were used as additional data points to the extent practicable.

3.11.3 Sediment Bioassays

Results from the sediment bioassay tests underwent a QA1 level of validation to ensure the data were of sufficient quality for use in the analysis and evaluation. The results were compared with the SMS biological criteria and exceedances of SQS and CSL were noted. Regression analyses were conducted to examine the relationship among the bioassay results and conventional parameters.

3.11.4 Radioisotopes

Sedimentation rate information including sediment age in years, year of deposition, sediment accumulation rate (cm/yr), and sedimentation rate ($g/cm^2/yr$) were determined and reported. The sedimentation rate is normally derived from ^{210}lead results; however, in some cases, the ^{137}cesium data were used to determine the sedimentation rate and sediment ages, as ^{137}cesium results are normally used to verify dates derived from ^{210}lead sedimentation rates.

3.12 Deviations from Sampling and Analysis Plan

There were few deviations from the project SAP (SAP; E & E 2008). Deviations include the following:

- Field decisions were implemented to change sample locations when collection from the target location was not practicable. These scenarios included insufficient recovery, gravel/hard substrate blocking sampling apparatus, or the presence of physical obstacles such as barges, piers, or boat traffic. Stations were relocated to enable collection at all possible target sampling areas.
- Radioisotope cores sampling methods deviated slightly from the study design. Sediment samples were collected and analyzed for ^{210}lead and ^{137}cesium only, and not by ^{7}beryllium as projected.
- Sampling intervals were based on visual and olfactory screening conducted by the E & E sampling team. For the subsurface “B” core interval, a sample was generally collected where a substantial amount of fine-grained sediment was present that visually contained wood debris and/or appeared to have a chemical residue. When available, the subsurface “C” core sample was generally collected from the native sediment beneath the wood-debris/chemical residue horizon. These intervals occasionally varied due to field conditions. Specific core sample information can be found in Table B–5 (Appendix B).
- Reference sediment samples collected were not representative of the grain size distribution observed in bay-wide sediment samples. Two of the three samples collected were dominantly sand.
- A tissue sample for a given location and species did not always consist of a composite of multiple individuals.

- Petroleum analysis was completed by running NWTPH-Dx instead of Northwest total petroleum hydrocarbon – hydrocarbon identification (NWTPH-HCID).
- Unplanned samples were analyzed by the laboratory or were requested by the contractor without request from Ecology.

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4.0 Data Validation

This section summarizes the data validation findings for the chemical and biological testing performed for the Port Angeles Sediment Investigation.

4.1 Overview of Analytical Chemistry Data Validation

Upon receipt of laboratory analytical sediment and tissue data, E & E conducted a quality assurance review and data validation of all data sets following the procedures outlined in Ecology QA1 review guidelines (PTI 1989a). A QA2 review (PTI 1989b) of all dioxins, furans, PCB Aroclors, and PAH data was performed by EcoChem, Inc. of Seattle, Washington.

Three analytical chemical laboratories were used to analyze sediment and tissue samples. Axys analyzed sediment samples for dioxin/furan congeners and analyzed tissue samples for dioxin/furan congeners, PCB congeners, and SIM analysis for PAH compounds. TA was responsible for analysis for PCB Aroclors and pesticides, NWTPH-Dx, metals, mercury, and radioisotopes. ARI was responsible for analysis of the TOC, grain size, butyltins, resin acids and guaiacols, SVOCs, ammonia, and sulfides.

A QA1 review was performed by an E & E chemist. The laboratory summary reports were reviewed for holding times, surrogate recovery, laboratory control sample (LCS) recovery, Matrix Spike/Matrix Spike Duplicate (MS/MSD) recovery, internal standard recovery, method blank contamination, and instrument calibration. All quality assurance (QA) data review summary memoranda and third-party validation reports are located in Appendix H. The results of the QA1 review indicated that the data were of acceptable quality and were useful for the intended purposes.

A third party QA2 data validation was performed for selected analyses by EcoChem, Inc. The results of the validation on the sediment PAH and dioxin/furan data, the initial tissue PAH and dioxin/furan data, and the secondary tissue PAH-SIM and PCB Aroclor data can be found in Appendix H. The following elements were evaluated as part of the QA2 validation effort:

Holding Times and Sample Preservation
GC/MS Tuning
Initial Calibration
Continuing Calibration
Laboratory Blanks
Field Blanks
Surrogate Compounds
MS/MSD
Laboratory Control Samples
Field Duplicates
Internal Standards
Compound Identification and Reported Results
Reference Materials
Reporting Limits
Calculation Verification

The QA2 validation of the sediment and tissue dioxin/furan data determined that the laboratory followed the specified method (Axys Method MLA-017, a modified EPA Method 1613B). Accuracy and precision were acceptable as indicated by the labeled compounds and the percent recovery of the ongoing precision and recovery samples and by the relative percent difference values for the laboratory duplicate samples. Data were qualified as undetected to indicate that "estimated maximum possible concentration" (EMPC) values indicated elevated detection limits, and because of method blank contamination. Some data were qualified as estimates because of laboratory duplicate precision outliers. Some data were labeled "do not report" to indicate a value that should not be used for any purpose because a more appropriate alternative value remains for all compounds in each sample (EcoChem 2009). For the detailed results of the QA2 evaluation, see Appendix H.

The overall assessment provided by EcoChem, Inc., of the sediment PAH data determined that the laboratory followed the specified analytical method (SW8270D). Accuracy was acceptable, as indicated by surrogate, LCS, and MS/MSD percent recovery values. Precision was acceptable, as indicated by the relative percent difference for the MS/MSD analyses. Some data were estimated based on the MS/MSD accuracy and precision results and internal standards area outliers. Details regarding these exceptions are described in the QA2 evaluation provided in Appendix H.

The assessment of tissue PAH data determined that the laboratory followed the specified analytical method (SW8270D). Accuracy was acceptable, as indicated by surrogate, LCS, and MS/MSD percent recovery values. Precision was acceptable, as indicated by the relative percent difference for the MS/MSD analyses. Some data were estimated based on the continuing calibration percent difference outliers. All reporting limits were greater than the 20 µg/kg target limits specified in the SAP ranging from 460 to 2000 µg/kg. The greater limits were caused by the need to obtain a small sample size and analyze at a dilution to lower interference from the high lipid content (EcoChem 2009). This prompted the re-analysis of these tissue samples using a low-detection level PAH-SIM method. There were exceptions to the above and details can be seen in Appendix H.

The overall assessment provided by EcoChem, Inc. for the subsequent low-detection level, PAH-SIM analysis determined that the laboratory followed the specified analytical method (Axys Method MLA-021). Accuracy and precision were acceptable as indicated by the labeled compounds and the percent recovery of the ongoing precision and recovery samples and by the relative percent difference values for the laboratory duplicate samples. Data were qualified as undetected due to method blank contamination in some samples. Data were also qualified as undetected to indicate that EMPC values indicated elevated detection limits. In consultation with a senior-level chemist at E & E, it was decided that these undetected values would be converted to "J" qualified, detected results if the concentrations exceeded both the practical quantitative limit (PQL) and the MDL for that analyte. For the detailed results of the QA2 evaluation, see Appendix H

The assessment for the PCB-Aroclor tissue data determined that the laboratory followed the specified analytical method (SW8082). Accuracy was acceptable, as indicated by surrogate, LCS, and MS/MSD percent recovery values. Precision was acceptable, as indicated by the relative percent difference for the MS/MSD analyses. No data were qualified for any reason. For the detailed results of the QA2 evaluation, see Appendix H.

4.2 Overview of Sediment Toxicity Test Data Validation

Bioassay testing of surface sediments was conducted by NewFields in accordance with protocols cited in the project SAP (E & E 2008d). Bioassay data validation was performed by NewFields in consultation with a senior-level marine biologist at E & E. Bioassay validation reports are located in Appendix K and are summarized below. The sole deviation from established protocols was the requirement by Ecology to use full-spectrum lighting for samples collected at water depths shallower than 12 feet (mean lower low water [MLLW]) and where PAH contamination was suspected (Ecology 2008). Some data suggest that solar ultraviolet radiation may cause sediments containing PAHs to become more toxic due to photoactivation of the electrons within PAH molecules.

NewFields conducted the acute 10-day amphipod bioassay (using *Eohaustorius estuarius*), the acute sediment larval echinoderm development bioassay (using *Dendraster excentricus*), and the chronic 20-day juvenile polychaete bioassay (using *Neanthes arenaceodentata*). The bioassays were evaluated according to the biological effects criteria in the SMS found in Table 6–1 (WAC 173-204-315(2)). All tests were conducted within the 8 week (56 days) holding time.

Three reference stations were selected for sampling in Dungeness Bay. The percent fines at two of the reference stations was less than 2.5 percent, while at the third reference station it was 73.7 percent. The percent fines at the Port Angeles Harbor/Rayonier Mill stations ranged from 0.2 to 82.6 percent. The standard range for matching a test station with a reference station for bioassay comparisons is ±20 percent. There were 15 stations with a percent fines range of 22.5 to 53.7 percent. Regardless of the percent fines, each test station sample was compared with each of the three reference station samples, and the results were presented in the *Biological Testing Results for the Port Angeles Harbor Sediment Characterization* (NewFields 2008; Appendix K). Since 15 stations fell outside of the recommended percent fines range, the statistics for these stations were recalculated using the batch-specific control sample and the reference station with the closest percent fines. No differences in the bioassay results were noted between the comparison of each test station sample result to the reference station samples and the comparison of each test station sample result to the respective control sample result. The control samples in the larval test were water-only samples, providing the best possible conditions for the test species. A sediment control was not used for the larval bioassay. Even with 15 test stations without an adequate percent fines match, a comparison to the reference station with the closest percent fines was completed as long as the reference/control met the WA-SMS performance standards. Table 4–1 shows the performance summary of the control and reference tests. All control and reference standard results were within recommended guidelines.

4.2.1 Acute 10-Day Amphipod Bioassay

The 10-day amphipod bioassay was run on samples from 59 stations in five batches. Batches 1 through 3 were conducted using the standard protocol described in the project SAP. All water-quality parameters were within acceptable limits throughout all of the tests except for minor deviations in salinity and pH. The deviations were within the tolerance range for this species and would not be expected to affect the test results.

Initial and final interstitial ammonia concentrations were all below the threshold concentration of 30 mg/L total ammonia that trigger ammonia reference toxicant testing. With one exception, initial and final sulfide concentrations were below 5 mg/L in both overlying and interstitial waters. Sample ED04A in the retest batch (Batch 5) had very high interstitial sulfide concentrations rising from 81 mg/L at test initiation to 227.5 mg/L at the end of the test. Batch 5 consisted of two samples that were retested because significant mortality was observed at the stations when the samples were first tested. Batch 5 testing was conducted concurrently with testing of samples from Batch 4 because insufficient sediment remained from the reference stations to conduct the test as a completely separate batch. Batch 4 was conducted using full-spectrum lighting for samples collected at water depths shallower than 12 feet MLLW and where PAH contamination was suspected (Ecology 2008). There were minor variations from established guidelines in water quality parameters during each batch. None of these variations were of sufficient magnitude or duration to invalidate the tests (NewFields 2008).

Three samples in Batch 2 had one replicate in which mortality was 100 percent whereas all other replicates had 0 to 5 percent mortality. For at least one of these there were indications that animals were not added to the test chamber. Sample IH05A had two replicates with 100 percent mortality and three replicates and the surrogate with low mortality. Because the results were so variable compared to all other samples, the sample was retested. The retest of this sample resulted in no mortality. In addition, sample ED04A, which showed 98 percent mortality in Batch 3, was retested for confirmation of the first result with 100 percent mortality. Sulfides were high in this sample, and they may have contributed to mortality.

Control survival for all five batches was greater than 90 percent, and reference sediment survival was greater than 75 percent as required for test validation. The reference toxicant lethal concentrations were within the laboratory control charts' warning limits. Data completeness for each batch was essentially 100 percent. Thus, all data associated with this test are considered valid.

4.2.2 Acute Larval Echinoderm Development Bioassay

The larval echinoderm bioassay was conducted in four batches, with Batch 4 conducted under full-spectrum lighting to account for the potential photoactivation of PAH compounds. Stocking densities for the four batches ranged from 25 to 31 larvae, which were all within the PSEP recommended density of 20 to 40 larvae/mL water and are therefore adequate for accurate test results.

There were minor deviations from the recommended temperature range at several stations in all batches during the test. In all cases the temperature was below the recommended range of 15 to 17 degrees Centigrade (ºC), but by no more than 0.5ºC. DO concentrations were below the recommended concentration of 6 milligrams per liter (mg/L; 100 percent saturation) in several samples in each batch. However, the DO concentrations never fell below the recommended lower limit of 3.6 mg/L oxygen (60 percent saturation) for the larval test. Ammonia and sulfide values detected in the test chambers were below the no observed effects concentration (NOEC) values for *D. excentricus* and were not confounding factors in this analysis.

Control survival in all four batches was greater than 70 percent as recommended. The mean survival rate in each of the three reference sediment samples was greater than the recommended limit of 65 percent of control values. The reference toxicant LC_{50}'s were within the laboratory control charts' warning limits. Data completeness for each batch was essentially 100 percent. Thus, all data associated with this test are considered valid.

4.2.3 Chronic 20-Day Juvenile Polychaete Bioassay

The juvenile polychaete test was conducted in three batches, with Batches 1 and 2 using the standard protocol and Batch 3 using full-spectrum lighting to account for the potential photoactivation of PAH compounds.

There were minor variations in temperature in Batches 1 and 2 and an elevation in salinity in two samples in Batch 2. Elevations in ammonia occurred at one station at concentrations above the NOEC at test initiation. The initial concentration of sulfides in several samples was also above the NOEC. Concentrations of both compounds decreased rapidly from initial high levels and were within acceptable limits by test termination (NewFields 2008). None of these variations were of sufficient magnitude or duration to invalidate the tests, and are not considered confounding factors in this analysis.

Mean control survival in all three batches was greater than 90 percent, and the mean individual growth rate (MIG) was greater than 0.38 mg/individual/day. The mean survival in the reference sediment samples was greater than 80 percent of control values, and the MIG was within limits except in Batch 1, where the growth rate for Station RF03A was 78 percent of the control values. At E & E's request, an outlier analysis was performed by NewFields to identify the reason for RF03A not meeting control limits. The analysis indicated that replicate three was an outlier. The laboratory data sheets indicated there was an unusual amount of algal growth and fungal patches in the replicate. At the conclusion of the test, this replicate had only one surviving polychaete compared with five in the other replicates. As a result, the mean individual growth for RF03A was low compared to that of the control sample. Following the outlier analysis, replicate three at the reference station was removed from the calculation. The MIG-Reference/MIG-Control was recalculated with the result that RF03A was within control limits recommended by the SMS performance standards (94 percent). Statistical comparisons of test stations within Batch 1 with a percent fines match to RF03A were completed and results are discussed below.

Results of the reference toxicant test indicated that the organisms in Batch 2 were more sensitive than those used in Batches 1 and 3. The LC_{50} for Batch 2 was slightly lower than the lower limit of the control charts for the laboratory. Data completeness for each batch was essentially 100 percent. Thus, all data associated with this test are considered valid.

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5.0 Sediment Chemistry Results and Comparison with Criteria

This section presents the analytical chemistry results of surface and subsurface sediment samples. The reported data can be accessed in Ecology's EIM database under the study ID PASED08. The significance of COPC concentrations was determined by comparing the analytical results to sediment management criteria. These criteria include:

- SMS (WAC 173-204). Sediment chemical concentrations were compared with SQS and CSL criteria. SQS criteria represent the concentration below which "no effects" to aquatic biota occur and are sediment quality goals. CSL criteria represent the concentration below which "minor adverse effects" to aquatic biota occur and are used in sediment cleanup decision making.
- Puget Sound LAET for samples containing either low (less than 0.5 percent) or high (greater than 3.5 percent) levels of TOC (Michelsen 1992). The LAET is the dw concentration of a chemical compound from which the TOC-normalized SQS and CSL criteria are derived. In this report, sediment chemistry results are only compared to LAET criteria when TOC concentrations are outside the range of 0.5 to 3.5 percent, or when SMS criteria do not exist for an analyte.
- NOAA Sediment Quality Guidelines (SQGs). The SQGs are appropriate comparison criteria for chemicals that do not have a SMS criterion. They are non-regulatory guidelines for interpreting chemical data from the analysis of sediment samples (NOAA 2007). Similar to SMS, there are two concentrations of concern associated with the SQGs. These include the ERL 10th percentile, which indicates a concentration below which adverse effects rarely occur, and the ERM: 50th percentile, which is the concentration above which adverse effects frequently occur. In this report, sediment results are only compared to SQG criteria when SMS and LAET criteria do not exist for an analyte.

Sediment sample results tables presented in Appendix C include appropriate criteria to determine the significance of the analytical results. Figures in this section illustrate sample results for conventional parameters and locations where chemical results exceeded either SMS or LAET criteria.

5.1 Surface Sediment Results and Exceedances

This section presents the analytical results for surface sediment samples and exceedances of relevant chemical criteria. For a detailed discussion of sediment chemistry results, including the spatial distribution of analytes throughout the harbor, please refer to the *Port Angeles Harbor Supplemental Data Evaluation to the Sediment Investigation Report* (NewFields 2012).

For data presented in this section, refer to Figures 3–1 and 3–2 for the harbor surface sediment locations. Tables C–1 through C–15 (Appendix C) present the results of the surface sediment chemistry samples.

5.1.1 Conventional Parameters

Figures 5.1–1 through 5.1–4 illustrate the results at each sample site. The conventional parameters analyzed include sediment grain size, total sulfides, ammonia, and TOC. A total of 116 samples were analyzed for sediment grain size and TOC. Ninety samples were analyzed for total sulfides and 88 were analyzed for ammonia. Surface sediment conventional results are summarized by sampling area in Table 5.1–1.

Grain Size

Sediment grain size results are presented in Table C–1 (Appendix C), summarized in Table 5.1–1, and illustrated in Figures 5.1–1 through 5.1–4.

Stations with higher percentages of silt and clay (percent fines) were generally found at deeper water stations in the central part of the harbor, along the base of Ediz Hook, in the Inner Harbor, and in the area surrounding the Rayonier Mill dock. Coarser sediments were found on the submerged slope south of Ediz Hook and at stations to the east of the Rayonier Mill dock. Fine-grained sediment (silt plus clay) ranged from 0.1 percent at Ennis Creek (Station EC02A) to 83 percent in the Barge area (Station BA02A).

Total Organic Carbon

TOC results are presented in Table C–2 (Appendix C), summarized in Table 5.1–1, and are illustrated in Figures 5.1–1 through 5.1–4.

The highest TOC values were found at stations located along the base of Ediz Hook (Inner Ediz Hook), in the Lagoon, and along the inner harbor shoreline (Inner Harbor).TOC ranged from 0.16 percent in the Eastern Intertidal area (Station EI06A) to 33 percent in the Inner Ediz Hook area (Station IE06A). High TOC content was generally measured in samples with observable wood debris.

Sulfides and Ammonia

Sulfides and ammonia results are presented in Table C–3 (Appendix C), summarized in Table 5.1–1, and illustrated in Figures 5.1–1 through 5.1–4.

Sulfide concentrations ranged from 1.5 mg/kg in the Eastern Intertidal area (Station EI06A) to 5,250 mg/kg in the Inner Ediz Hook area (Station IE13A). Ammonia concentrations ranged from 0.47 mg/kg in the Deep Outfall area (Station DO02A) to 400 mg/kg east of the Rayonier dock (Station ED04A). The greatest sulfides concentrations are located in the active and historic log storage and transfer areas. These areas have the highest wood debris content. High ammonia concentrations can accumulate under the same anaerobic conditions as sulfides; however, the high ammonia concentrations measured throughout the central harbor do not correspond with the sulfide concentrations.

5.1.2 Metals

Sediment in the Port Angeles study area was analyzed for eight metals with SMS criteria (arsenic, chromium, cadmium, copper, lead, mercury, silver, and zinc) and three non-SMS metals (antimony, barium, and nickel). A total of 100 samples were analyzed for all 11 metals, 2 samples were analyzed for all metals except mercury, and 13 samples were analyzed for mercury only.

SMS Metals

Table C–4 (Appendix C) presents the results of the selected SMS metals in surface sediment samples. Locations with metal concentrations in exceedance of SMS criteria are presented in Figure 5.1 –5.

In general, the highest SMS metals concentrations were found in the western-most harbor. Arsenic, cadmium, mercury, and zinc exceeded SMS criteria at one or more stations in Port Angeles Harbor. The Inner Harbor area contained the highest observed concentrations for all of these metals, including SMS exceedances of arsenic and cadmium at single locations and mercury and zinc at two locations. The Inner Ediz area contained multiple SMS exceedances of both mercury and zinc. SMS exceedances of cadmium and mercury were also found in the Lagoon area, although at lower concentrations than the adjacent Inner Harbor area.

Non-SMS Metals

Table C–4 (Appendix C) presents the results of the non-SMS metals in surface sediment samples. No non-SMS metals were found in concentrations that exceed NOAA SQG criteria.

5.1.3 Butyltins

Eighteen samples were analyzed for butyltin compounds. Table C–5 (Appendix C) summarizes the butyltin results of the surface sediment samples.

In general, detected concentrations of butyltins were found at stations along the shoreline adjacent to the Marina, Boat Launch/Standard Oil, and K-Ply/Valley Creek areas, with concentrations generally decreasing with distance from the shoreline. TBT was the most frequently detected butyltin compound, detected at nine of the 18 stations. Six of the nine stations were immediately adjacent to Terminal One, which is located in the Boat Launch area. The remaining three stations with detected concentrations of TBT were located in and offshore of the Boat Haven Marina. The highest concentration was 40 µg/kg near the K-Ply facility (Station KP01A).

5.1.4 Petroleum Hydrocarbons

A total of 70 samples were analyzed for petroleum hydrocarbons. Table C–6 (Appendix C) summarizes the results of the petroleum hydrocarbon samples.

Sediment was analyzed for petroleum hydrocarbon fractions including #2 diesel and motor oil. In addition, gasoline range petroleum hydrocarbons were estimated using the NWTPH-Dx analysis by evaluating the analytical chromatograms for peaks within the elution range of gasoline compounds (C8 –C12).

In general, the highest concentrations of petroleum hydrocarbons were found at the Inner Ediz Hook and Inner Harbor areas. Gasoline was not detected in any of the samples. For #2 diesel, the highest detected concentration was 320 mg/kg in the Inner Harbor area (Station IH01A). The detections of motor oil followed the same spatial trend as #2 diesel. The highest concentration was 1,700 mg/kg (Station IH01A).

5.1.5 Polycyclic Aromatic Hydrocarbons

The Washington State SMS lists 16 individual PAH compounds as being of concern in Puget Sound sediments in addition to total LPAHs and total HPAHs. These are divided into two groups as follows:

LPAHs: 2-methylnaphthalene, acenaphthene, acenaphthylene, anthracene, fluorene, naphthalene, and phenanthrene.
HPAHs: benz(a)anthracene, benzo(a)pyrene, benzo(g,h,i)perylene, chrysene, dibenzo(a,h)anthracene, fluoranthene, indeno(1,2,3-cd)pyrene, pyrene, total benzofluoranthenes.

Ninety-two samples were analyzed for the seven LPAH and nine HPAH compounds listed above. Table C –7 (Appendix C) presents the results of individual LPAH and HPAH compounds by station. Total PAH results are presented in Table C–8 (Appendix C). An evaluation of the potential to use these PAH data for differentiating sources is presented in Appendix J.

In general, HPAH compounds were detected more frequently than LPAH compounds. The three most frequently detected LPAH compounds in surface sediments were phenanthrene, anthracene, and naphthalene. Fluoranthene, benzofluoranthenes, and pyrene were the most frequently detected HPAHs. No locations were found that exceeded chemical criteria. Similar spatial patterns were observed for both LPAHs and HPAHs, with the highest concentrations observed in the Inner Harbor area, adjacent to the Ferry Terminal, and in the vicinity of the former Rayonier Mill facility. No locations had PAH concentrations in exceedance of SMS/LAET criteria.

5.1.6 Phenols and Phthalates

Surface sediments were analyzed for phenol and phthalate compounds at 92 stations. The concentrations of phenol and phthalate compounds can be found in Table C–9 (Appendix C). Locations with phenol and phthalate concentrations in exceedance of SMS/LAET criteria are presented in Figures 5.1–6, 5.1–7, and 5.1–8.

In general, the highest concentrations of phenols and phthalates were detected in the Marina area. The most frequently detected compound was phenol, which exceeded SMS criteria at two locations in the Marina area and one location in the Rayonier Mill dock area. The only other phenol detected at more than one location was 4-methylphenol, exceeding SMS criteria at one location east of the Rayonier Mill dock.

Bis(2 ethylhexyl) phthalate was the most frequently detected phthalate and was found to exceed SMS criteria at a single location in the Marina area. Butyl benzyl phthalate exceeded LAET criteria at single locations in both the Lagoon and Marina areas.

5.1.7 Polychlorinated Biphenyls

PCBs, analyzed as Aroclors, were analyzed at 86 stations in the Port Angeles study area. Data showing the concentrations and detection limits of all seven Aroclors at each station are provided in Table C–10 (Appendix C).

Only Aroclors 1254 and 1260 were detected. The highest total PCB concentrations were found near the former Rayonier Mill property. Total PCBs did not exceed SMS or LAET criteria at any locations.

5.1.8 Pesticides

Sediment samples from 45 stations were analyzed for 21 pesticides compounds. Data showing the concentrations of pesticide compounds at each station are provided in Table C–11 (Appendix C).

Pesticides were rarely detected, with most detections qualified as estimates. The most frequently detected pesticides were heptachlor epoxide and lindane, followed by aldrin, and cis-, and gamma chlordane. At 50 percent of the stations there were no pesticides detected (Table C–11, Appendix C). While there are no Washington SMS criteria for pesticides, LAET values were developed for DDT and its breakdown products (Table C–11, Appendix C). There were no exceedances of the LAETs for DDT or its breakdown products in surface sediments.

5.1.9 Resin Acids and Guaiacols

Sediment was analyzed for the presence of 24 resin acids and guaiacols. The concentrations of resin acid and guaiacol compounds are presented in Table C–12 (Appendix C).

Guaiacols were not detected in any of the samples analyzed. The resin acids abietic acid, dehydroabietic acid, oleic acid, and retene were detected at more than 40 percent of the stations. The highest concentrations of resin acids were found in the Inner Harbor, Marina, and Deep Outfall areas.

5.1.10 Chlorinated Benzenes, Benzoic Acid, Benzyl Alcohol

A total of 92 stations were sampled for chlorinated benzenes, benzoic acid, and benzyl alcohol. Concentrations of these compounds are presented in Table C–13 (Appendix C).

Chlorinated benzene compounds were not detected in any of the samples, except for the compound dibenzofuran. Dibenzonfuran was found at its highest concentration in the Mill Dock area. Benzoic acid and benzyl alcohol were not detected in any of the samples analyzed, with the exception of one benzyl alcohol result from Station EI01A that was rejected during data validation.

5.1.11 Dioxins and Furans

Eighty-six sediment samples were analyzed for 17 congeners and eight homolog dioxins/furans. Concentrations of these compounds are provided in Table C–14 (Appendix C). Table C–15 (Appendix C) presents a summary of TEQ values for surface sediment samples. Table C–16 (Appendix C) presents the TEFs used to calculate the sample TEQs. An evaluation of the potential to use these dioxin/furan data for differentiating sources is presented in Appendix J.

Five congeners were detected at all stations: 1,2,3,4,6,7,8-HPCDD, 1,2,3,6,7,8-HXCDD, 1,2,3,7,8,9-HXCDD, 2,3,4,7,8-PECDF, and OCDD.

Total dioxin TEQs ranged from 0.06 ng/kg in the reference area (Station RF01A) to 119.1 ng/kg in the Inner Harbor area (Station IH01A). The highest TEQs were located in the Lagoon and in the Inner Harbor area surrounding the mouth of the lagoon. The lowest TEQs were found in the Dungeness Bay reference area and at East of Ennis Creek area stations.

5.2 Subsurface "B" Core Sediments Results and Exceedances

Sediment from 43 subsurface "B" core stations was sampled and analyzed for a range of chemical compounds (Figure 3–3). The number and type of analyses conducted at each station was based on specific objectives for each station as discussed in the following sections.

Table 5.2 –1 provides a summary of subsurface "B" core sediment conventional results. Tables C–B1 through C–B14 (Appendix C) present sediment conventional and chemistry results of the subsurface "B" core sediment samples.

5.2.1 Conventional Parameters

The conventional parameters analyzed for samples collected from subsurface stations included sediment grain size, TOC, and total sulfides and ammonia (Table 5.2–1). Forty-three samples were analyzed for sediment grain size and TOC. Nineteen samples were analyzed for total sulfides, and 20 for ammonia. Figure 5.2–1 illustrates the results of the conventional parameters.

Sediment Grain Size

The results for the 43 grain size samples are presented in Table C–B1 (Appendix C). Grain size distributions for subsurface "B" core samples were similar to that of overlying sediments.

Total Organic Carbon

Forty-three samples were analyzed for TOC (Table C–B2, Appendix C). The TOC ranged from 0.207 percent in the Eastern Intertidal area (EI02B) to 78.5 percent in the Inner Ediz Hook area (IE09B). The elevated TOC at this station was most likely caused by a large amount of fine wood particles or sawdust seen in the core samples. The highest values were found at stations located along the base of the Inner Ediz area, the Lagoon area, and at stations along the shoreline in the Inner Harbor area.

Sulfides and Ammonia

Nineteen samples were analyzed for sulfides and 20 for ammonia (Table C–B3, Appendix C). Maximum sulfide and ammonia concentrations were found in the Inner Harbor and Mill Dock areas, respectively.

5.2.2 Metals

Thirty-seven subsurface "B" core samples were analyzed for the eight metals with SMS criteria and three non-SMS metals (antimony, barium, and nickel). Locations with metal concentrations in exceedance of SMS criteria are presented in Figure 5.2–2.

SMS Metals

Cadmium, mercury, and zinc exceeded SMS criteria at one or more stations (Table C–B4, Appendix C). A single location in the Inner Ediz area exceeded SMS criteria for mercury. In the Inner Harbor area, a single location exceeded SMS criteria for cadmium, mercury, and zinc, while an addition location also had a mercury exceedance.

Non-SMS Metals

No non-SMS metals were found in concentrations that exceed NOAA SQG criteria.

5.2.3 Butyltins

Butyltins were analyzed for in the subsurface “B” core sediment sample collected at Station KP02B, and none were detected above the MDLs.

5.2.4 Petroleum Hydrocarbons

Petroleum hydrocarbon analyses were conducted at 30 subsurface “B” core stations. Table C-B5 (Appendix C) summarizes the results of the petroleum hydrocarbon analysis.

In general, the highest concentrations of petroleum hydrocarbons (#2 diesel and motor oil) were found at the base of Ediz Hook and extending to the Boat Haven Marina. Higher concentrations were also found at stations surrounding the base of the Rayonier Mill dock.

Based on chromatographic analyses, gasoline was not detected in any of the samples. The spatial distribution of motor oil detections was similar to that seen for #2 diesel.

5.2.5 Polycyclic Aromatic Hydrocarbons

Forty-three samples were analyzed for LPAH and HPAH compounds. The results of individual PAH compounds by station are presented in Table C–B6 (Appendix C). The results of the total PAH analyses are presented in Table C–B7 (Appendix C). Locations with PAH concentrations in exceedance of SMS/LAET criteria are presented in Figures 5.2–3.

In a pattern similar to that seen in the surface samples, the HPAH compounds were generally detected more frequently than the LPAH compounds. The individual PAHs acenaphthene, dibenzofuran, fluorene, and phenanthrene were found to be in exceedance of SMS criteria at a single location in the Ennis Creek area.

5.2.6 Phenols and Phthalates

Phenol and phthalate compounds were analyzed at 43 “B” core stations. The results of the phenol and phthalate analyses are presented in Table C–B8 (Appendix C). Locations with phenol and phthalate concentrations in exceedance of SMS/LAET criteria are presented in Figures 5.2–4 and 5.2–5.

One location in the Ennis Creek area exceeded SMS criteria for 4-methylphenol. Single locations in the Inner Ediz and Inner Harbor areas exceeded LAET criteria for butyl benzyl phthalate and bis(2-eithylhexyl) phthalate, respectively.

5.2.7 Polychlorinated Biphenyls

PCBs, analyzed as Aroclors, were analyzed at 38 subsurface “B” core sediment stations. Data showing the concentrations of PCBs in the “B” core samples are summarized in Table C–B9 (Appendix C). Locations with PCB concentrations in exceedance of SMS/LAET criteria are presented in Figure 5.2–5.

As with the surface sediment samples, only Aroclor 1254 and Aroclor 1260 were detected in the “B” core samples. Unlike the surface sediments, total PCB Aroclors exceeded SMS criteria at a single location in the Ennis Creek area and exceeded LAET criteria at a single location in the East of Mill Dock area.

5.2.8 Pesticides

Subsurface “B” core sediment samples from 20 stations were analyzed for 21 pesticides. The results for pesticides in subsurface “B” sediment samples are presented in Table C–B10 (Appendix C).

The majority of the pesticides were undetected at low detection limits and those that were detected were mostly qualified as estimates. The most frequently detected pesticides in order of decreasing detection were 4,4’-DDD, cis-chlordane, heptachlor epoxide, and gamma chlordane. The highest concentrations of pesticides were generally found in the Ennis Creek and K-Ply areas.

There were no exceedances of the LAETs for DDT or its breakdown products in any subsurface “B” core sediment samples.

5.2.9 Resin Acids and Guaiacols

Samples from 29 stations were analyzed for resin acids, and samples from 42 stations were analyzed for guaiacols. The concentrations of resin acid and guaiacol compounds in the “B” core sediment samples are presented in Table C–B11 (Appendix C).

Guaiacols were detected in a single sample in the Inner Ediz Area. The highest concentrations of resin acids in subsurface “B” core sediments were found in the Log Pond and Inner Ediz areas.

5.2.10 Chlorinated Benzenes, Benzoic Acid, and Benzyl Alcohol

A total of 42 stations were sampled for chlorinated benzenes, benzoic acid, and benzyl alcohol. Concentrations of these compounds are summarized in Table C–B12 (Appendix C).

Dibenzofuran, benzoic acid, and benzyl alcohol were the only compounds detected, but they did not exceed SMS or LAET criteria.

5.2.11 Dioxins and Furans

Thirty-eight subsurface “B” core sediment samples were analyzed for dioxin/furan congeners. The concentrations of individual dioxin/furan congeners are presented in Table C–B13 (Appendix C). Total dioxin TEQs are presented in Table C–B14 (Appendix C).

As with surface sediment samples, the highest dioxin TEQ values of subsurface “B” core sediments occurred in the Inner Harbor area, with a maximum value of 89.7 ng/kg.

5.3 Subsurface "C" and "D" Core Sediments Results and Exceedances

Sediment from 32 subsurface "C" and one subsurface "D" (DO04D) core stations were sampled and analyzed for a range of chemical compounds (Figure 3–3). The number and type of analyses conducted at each station were dependent on specific objectives for each station and are discussed in the following sections.

Table 5.3–1 provides a summary of subsurface "C" and "D" core sediment conventional results. Tables C –C1 through C –C14 (Appendix C) present sediment conventional and chemistry results of the subsurface "C" and "D" core sediment samples.

5.3.1 Conventional Parameters

As with overlying sediment intervals, subsurface "C" and "D" core sediment samples were analyzed for sediment grain size, TOC, and total sulfides and ammonia (Table 5.3–1). Thirty-two samples were analyzed for TOC and sediment grain size (31 from the subsurface "C" core samples and one from the subsurface "D" core sample). Seventeen samples were analyzed for total sulfides and ammonia in the subsurface "C" core samples and one from the "D" core sample. Figure 5.3–1 illustrates the results of the conventional parameters.

Sediment Grain Size

The results for the 31 grain size samples from the subsurface "C" core samples are presented in Table C–C1 (Appendix C). Percent fines ranged from 2.1 percent at the Rayonier Mill East Dock area (Station ED01C) to 87.6 percent in the K-Ply area (Station KP03C), with values similar to overlying sediment.

Total Organic Carbon

Thirty-one subsurface "C" core samples were analyzed for TOC (Table C–C2, Appendix C). The TOC ranged from 0.128 percent east of Ennis Creek (Station EE02C) to 6.47 percent in the K-Ply area (Station KP03C). TOC in the one subsurface "D" core sample from the Deep Outfall area (Station DO04D) was 0.424 percent.

Sulfides and Ammonia

Seventeen subsurface "C" core samples were analyzed for sulfides and ammonia (Table C-C3, Appendix C). Sulfides ranged from 1.09 mg/kg dw in the Mill Dock area (Station MD02C) to 3,030 (JL) mg/kg dw in the Ennis Creek area (Station EC03C).

Ammonia measured as nitrogen ranged from 0.49 mg/kg dw in the Mill Dock area (Station MD01C) to 175.0 mg/kg dw at Station EC03C in the Ennis Creek area. Sulfide and ammonia in the Deep Outfall sample (Station DO04D) were 17.9 mg/kg and 3.23 mg/kg, respectively.

5.3.2 Metals

Thirty-one subsurface "C" core samples and one subsurface "D" core sample were analyzed for all 11 metals (Table C–C4, Appendix C).

SMS Metals

Arsenic, chromium, copper, lead, and zinc detected in all samples. A single location in the Marina area exceeded SMS criteria mercury (Figure 5.3–2). No other SMS metals exceeded criteria in the subsurface" "C and "D" core samples.

Non-SMS Metals

No non-SMS metals were found in concentrations that exceed NOAA SQG criteria.

5.3.3 Butyltins

An analysis for butyltins was conducted only at Station KP02C. No butyltin ions were detected.

5.3.4 Petroleum Hydrocarbons

TPH analyses were conducted for 20 subsurface "C" core sediment samples (Table C–C5, Appendix C). The subsurface "D" core sample was not analyzed for petroleum hydrocarbons. The TPH analyses conducted were for #2 diesel and motor oil.

The maximum concentration of #2 diesel and motor oil were found in the Ennis Creek area, followed closely by the Ferry Terminal area.

5.3.5 Polycyclic Aromatic Hydrocarbons

Thirty-one subsurface "C" core sediment samples were analyzed for 7 LPAH and 10 HPAH compounds. The one subsurface "D" core sample was also analyzed for these compounds. The concentrations of individual PAH compounds are shown in Table C–C6 (Appendix C). The concentrations of total LPAH and HPAH compounds at each station are presented in Table C–C7 (Appendix C). Locations with PAH concentrations in exceedance of SMS/LAET criteria are presented in Figures 5.3–3.

Both the LPAH and HPAH compounds were detected at very few subsurface "C" core stations. The most frequently detected LPAH compounds were phenanthrene and naphthalene. A single location in the Ennis Creek area exceeded SMS criteria for 2-methylnaphthalene, acenaphthene, fluorine, naphthalene, phenanthrene, and total LPAH. All of these PAHs were found in lower concentrations in the overlying "B" core sediment interval.

5.3.6 Phenols and Phthalates

Sediment samples from 31 subsurface "C" core intervals and the one "D" core interval were analyzed for both phenolic and phthalate compounds (Table C–C8, Appendix C). As with surface sediments, the most frequently detected phenolic compounds in subsurface "C" and "D" core sediments were phenol and 4-methylphenol. Neither phenols nor phthalates exceeded SMS or LAET criteria in subsurface "C" and "D" core sediments.

5.3.7 Polychlorinated Biphenyls

PCBs, analyzed as Aroclors were analyzed in 21 subsurface "C" core samples. The results of the PCB analyses are presented in Table C–C7 (Appendix C). Locations with PCB concentrations in exceedance of SMS/LAET criteria are presented in Figure 5.3–4.

Aroclor 1260 was the only Aroclor detected in subsurface "C" core sediment samples. The maximum detected concentration of Aroclor 1260 occurred in the Ennis Creek area. This sample exceeded SMS criteria for total PCBs.

5.3.8 Pesticides

Sediment samples from 11 subsurface "C" core stations were analyzed for 21 pesticides. The results for pesticides in the subsurface "C" samples are presented in Table C–C10 (Appendix C).

The most frequently detected pesticide compounds were cis-chlordane, delta-BHC, gamma-chlordane, and heptachlor.

There are no SMS criteria for these pesticides. However, LAET values were developed for DDT and its breakdown products. One station near the Ferry Terminal (Station FT04C) exceeded the LAET criteria for 4,4'-DDD and 4,4'-DDE.

5.3.9 Resin Acids and Guaiacols

Analyses for resin acids were conducted for 23 subsurface "C" core sediment samples and one subsurface "D" core sample. Analyses for guaiacols, isophorone, and retene were conducted for 31 subsurface "C" core sediment samples and the one subsurface "D" core sample. The concentrations of resin acid and guaiacol compounds are presented in Table C–C11 (Appendix C).

Guaiacols were not detected in any of the samples analyzed. The highest concentrations of resin acids in subsurface "C" and "D" core sediments were found in the Ennis Creek and K-Ply areas.

5.3.10 Chlorinated Benzenes, Benzoic Acid, and Benzyl Alcohol

The subsurface "C" and "D" core sediment sample concentrations of chlorinated benzene compounds, benzoic acid, and benzyl alcohol, are presented in Table C–C12 (Appendix C).

Thirty-two stations were examined for these compounds. Detected compounds included 1,4-dichlorobenzene at Station FT04C near the Ferry Terminal, and dibenzofuran at the K-Ply facility area (46 µg/kg dw at Station KP02C) and 2700 µg/kg dw at Ennis Creek (Station EC03C). This result exceeded the SMS CSL criteria of 58 mg/kg TOC when normalized (97.12 mg/kg TOC).

Benzoic acid and benzyl alcohol were undetected or rejected for all subsurface "C" and "D" core sediment samples.

5.3.11 Dioxins and Furans

Nineteen subsurface "C" core samples and one "D" core sample were analyzed for dioxin/furan congeners. The dw concentrations of the individual dioxin/furan congeners are presented in Table C–C13 (Appendix C). Total dioxin TEQs are provided in Table C–C14 (Appendix C).

TEQs in the subsurface "C" core samples ranged from 0.14 ng/kg east of Ennis Creek (Station EE04C) to 28.7 ng/kg in the Marina area (Station MA02C). Station DO04D had a TEQ of 0.10 ng/kg.

5.4 Sediment Chemistry Summary

5.4.1 Sediment Management Standards: Surface Samples

Surface sediment samples were collected from 116 stations for chemical analysis. Table 5.4–1 and Figure 5.4–1 present a summary of locations whose chemical concentrations exceeded SMS or LAET criteria. Analytical results for locations with TOC values between 0.5 and 3.5 weight percent were compared to SMS criteria, while locations outside this range were compared to LAET criteria. Analytes without SMS or LAET criteria were compared to NOAA SQG criteria, however no exceedances of the SQG were found.

Surface sediments at 13 locations were found to exceed SMS or LAET criteria. Exceedances were restricted to metals, phenols, and phthalates. All metal exceedances (arsenic, cadmium, mercury, and zinc) occurred in western Port Angeles Harbor, in the Lagoon, Inner Harbor, and Inner Ediz study areas. Phenol and phthalate exceedances occurred in the Marina and Rayonier study areas. The Lagoon area also contained a single butyl benzyl phthalate LAET exceedance.

5.4.2 Sediment Management Standards: Subsurface Sediment Chemistry

Subsurface sediment samples that exceeded SMS or LAET criteria are presented in Table 5.4–2 and Figure 5.4–2. A total of 8 locations were found to have subsurface exceedances. Analytes in exceedance of screening criteria include metals, PCBs, PAHs, phenols, phthalates, and pesticides. As was the case with surface sediments, metal exceedances in subsurface sediments were only observed at locations in the western harbor. Western harbor locations also had two LAET exceedances for phthalate compounds. Pesticides were the only chemical class found in exceedance of LAET criteria in subsurface sediments of the southern harbor. Locations with exceedances of total PCBs occurred only in Rayonier study areas. A single location in the east of Ennis Creek study area had exceedances of PCBs and multiple PAHs in both subsurface "B" and "C" core intervals.

Criteria Exceedances with Depth

Two locations (IH02 and EC03) had SMS or LAET exceedances for the same analyte in multiple depth intervals. At location IH02, both mercury and zinc exceeded SMS criteria in surface sediment and the subsurface "B" core interval. At location EC03, total PCBs and multiple PAHs exceeded SMS criteria in both the subsurface "B" and "C" core intervals. At this location, concentrations of all exceeding analytes were greater in the subsurface "C" interval than the "B" interval.

Comparison with NOAA Sediment Quality Guidelines

For the purposes of this report, sediment results are only compared to NOAA SQG criteria when SMS and LAET criteria do not exist for an analyte. No analytes without SMS or LAET criteria exceeded their respective SQG.

6.0 Sediment Toxicity Test Results

Three bioassay tests were conducted at 59 stations as part of the study (Figure 3–3). Bioassay evaluation criteria can be found in Table 6.1. Each test station sample was compared with each of the three reference station samples. Control and reference performance summary information can be found in Table 4–1.

The results of the bioassay test provided an indication of areas in Port Angeles Harbor where sediments have the potential to cause adverse ecological effects. These results are provided in Table 6–2 and Figure 6–1. Bioassay data validation information, as well as the testing results, can be found in Appendix K.

6.1 Sediment Toxicity Tests

6.1.1 Acute 10-Day Amphipod Test

The 10-day amphipod bioassay using *Eohaustorius estuarius* was conducted on sediment samples from 59 stations throughout Port Angeles Harbor. Percent mortality at the reference stations ranged from 2 percent at Station RF01A to 23 percent at Station RF03A in the reference area (Table 6–2). The percent mortality at test stations ranged from 0 percent at IH01A and IH05A in the Inner Harbor area to 100 percent at Station ED04A on the eastern side of the Rayonier Mill dock. This was the only station that exceeded the CSL as measured by the amphipod bioassay. Other than at Station ED04A, amphipod mortality at the Port Angeles stations was generally low. The highest mortality was seen in the reference area at Station RF03A (Batch 3) at 23 percent and in the Inner Harbor and Marina area at Stations (IH03A and MA06A at 22 percent).

Bioassays were conducted on nine stations using full-spectrum illumination to determine whether ultraviolet radiation caused certain PAH compounds to become more toxic. The percent mortality at these stations was low, ranging from 2 percent at Station RL02A in the Red Lion area to 15 percent at Station IE07A in the Inner Ediz Hook area. There was concern that the estuarine amphipod used in the bioassay may not have been of a type that could survive in freshwater sediment collected from Station EC01A in Ennis Creek. To examine this possibility, sediment from the station was allowed to acclimate in seawater without test organisms for 14 days. This was done to allow marine bacterial communities to become established. These communities help break down ammonia and sulfides in the sediment, eliminating them as potential causes of toxicity. A second test was conducted concurrently using unacclimated sediment from the same station. Results showed no statistically significant difference in toxicity between the two tests (acclimated: 5 percent mortality; unacclimated: 7 percent). Bioassays on both of the above samples were also conducted under full-spectrum illumination.

6.1.2 Acute Larval Echinoderm Development Bioassay

The test and reference sample results are presented as the mean normal survival relative to the survival in the control samples. Larval bioassays using *Dendraster excentricus* were conducted in four batches using sediment from 59 stations (Table 6–2). The mean normal survivorship at test stations ranged from 32 percent (Station ED04A east of Rayonier Mill dock) to 100 percent.

The mean normal survival at the three reference area stations ranged from 66.5 percent (RF03A Batch 3) to 99.5 percent (RF01A Batch 4). Sediment from Station RF03A consistently had the lowest survivorship among all three reference stations.

Potential adverse effects using this bioassay are measured as a statistically significant difference ($p \leq 0.10$) and a normal development less than 85 percent of reference. Table 6–2 shows the results of the analysis. Twenty nine stations did not meet the SQS criteria compared with at least one of the reference stations. Additionally, twelve stations did not meet CSL criteria.

6.1.3 Chronic Juvenile Polychaete Test

The juvenile polychaete test using *Neanthes arenaceodentata* was conducted on 68 sediment samples from 59 stations (Table 6–2). The results of the test provide two endpoints that can be used to determine sediment toxicity. The first endpoint is percent mortality, which is a measure of acute sediment toxicity, and the second is a measure of chronic sediment toxicity and is measured in mg/individual/day. The growth rate of the organisms in the test sediments is compared with the growth rate of those in reference sediments; a significantly lower growth rate may indicate a chronic effect on the test organisms.

The bioassays were run in three batches, and sediment from each of the three reference stations was run with each batch. Percent mortality at the reference stations ranged from 0 to 16 percent (Table 6–2). The mortality at the test stations was low, ranging from 0 to 12 percent. There were 33 samples with 0 percent mortality and 26 samples with mortality ranging from 4 percent (16 samples) to 12 percent (1 sample). Toxicity was 4 percent for both the seawater-acclimated and the unacclimated samples from Station EC01A in Ennis Creek.

The growth rate at the reference area stations ranged from 0.43 mg/individual/day at Station RF02A (Batch 2) to 0.78 mg/individual/day at Station RF02A (Batch 3). The range seen in test sediments was from 0.3 mg/individual/day at Station EI07A in the Eastern Intertidal area to 0.96 mg/individual/day at Station RL01A in the Red Lion area. There was also no appreciable difference between the seawater-acclimated and the unacclimated samples from Ennis Creek, Station EC01A (0.7 and 0.66 mg/individual/day, respectively).

The potential for adverse effects as measured by significantly lower weight gains compared with control/reference sediment was observed at one station in Port Angeles Harbor (Table 6–2). This station that exceeded SQS criteria was located in the Marina area (Station MA02A).

6.2 Surface Sediment Bioassays Summary

Three sediment bioassays were conducted to identify toxicity. These were the acute amphipod bioassay using *Eohaustorius estuarius*, the acute larval bioassay using *Dendraster excentricus* (sand dollar), and the chronic 20-day juvenile polychaete bioassay using *Neanthes arenaceodentata*. The criteria for establishing whether a bioassay sample exceeds SQS or CSL value are presented in Table 6–1. Twenty-nine samples exceeded the SQS criteria, 12 of which also exceeded the CSL (Table 6–2). Station ED04A failed the CSL criteria for both the *Eohaustorius estuarius* (amphipod) and the *Dendraster excentricus* (larval) bioassays. In total, seventeen stations failed the SQS criteria for the *D. excentricus* larval bioassay and 12 that failed the CSL criteria.

One station failed the SQS criteria for the *Neanthes arenaceodentata* polychaete growth bioassay (MA02A).

6.3 Relationship Between Bioassay and Surface Chemistry SMS Exceedances

Five of the 59 bioassay locations had co-occurring chemical and bioassay SMS exceedances (Table 6–3). Seven of the 13 locations that exceeded SMS chemical criteria did not have bioassays conducted. Of the locations with co-occurring chemical and bioassay SMS exceedances, metal exceedances in western Port Angeles Harbor were associated with failure of the larval development bioassay. Failures of the larval development bioassay also occurred at single locations with SMS chemical exceedances of 4-methylphenol and bis(2-ethylhexyl) phthalate. The single location with an exceedance of 4-methylphenol also failed the amphipod mortality bioassay.

6.4 Regression Analysis of Bioassay Results and Conventional Parameters

The relationship between the bioassay results and the chemicals associated with wood debris were examined to determine whether correlations existed among those parameters. A regression analysis was conducted examining the relationships among TOC, percent fines, sulfides, ammonia, percent wood debris, retene, abietic acid, dehydroabietic acid, and oleic acid. The results of the analysis are presented on Table 6–4. The results comparing amphipod mortality to the concentration of these conventional and chemical parameters show a strong correlation between the concentration of ammonia ($r^2 = 0.87$) and amphipod mortality. There were no other significant relationships between amphipod mortality and the other measures. There appeared to be no relationship between the conventional/chemical parameters and *N. arenaceodentata* mortality or growth. There was a moderately strong relationship between larval survival and percent fines ($r^2 = 0.63$). This indicates that as percent fines increased so did the survival of the echinoderm larvae. There was a slight negative trend between larval survival and the concentration of sulfides; however, with an r^2 of 0.393, the relationship cannot be considered significant.

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7.0 Distribution of Chemical Compounds in Tissue Samples

Tissue samples were collected as a part of this study in support of a screening level human health and ecological risk assessment (Appendix G). These samples were collected from nine stations in the Harbor-Wide study area, six in the Rayonier Mill area (Figure 3–5) and three in the reference area of Dungeness Bay (Figure 3–2). Tissue samples were collected from five species commonly found in the area (Tables 3–5 and 3–6). These species were *Panopea abrupta* (geoduck), *Tresus capex* (horse clam), *Ophiodon elongates* (lingcod), and two genera of marine plants, which were the algae *Nereocystus leutkeana* (bull kelp) and an angiosperm *Liliopsida* (eelgrass). Lingcod tissue samples were composed of either fillets or whole-body organisms and thus varied in volume of sample. Clam tissue was collected in the area surrounding the station until a minimum weight was collected. The samples were thus composed of varying numbers of individuals. Macroalgae samples were collected as clumps of the same organism until a minimum weight was achieved (Tables 3 –3 and 3 –4). Tissue samples were analyzed for the COPCs and percent lipid concentration. Percent lipids, like TOC in sediments, is used to normalize wet weight (ww) concentrations so that COPC concentrations can be compared between different tissue samples. Resin acids, guaiacols, and butyltins were the only groups of COPCs not tested for, as these were not expected to be found in these tissues. However, some chemicals that can be classified as resin acids were tested for and reported as part of the routine SVOC analysis.

Many of the chemicals were undetected in all tissue types. Due to the high number of non-detects for specific chemicals, tissue results related to these particular compounds will not be discussed further. However, laboratory detection limits for the tissue investigation were higher than desirable for trace level PAHs, which contributed to the large number of undetected results. These primary PAH results will not be discussed further. Extra portions of these tissue samples that were previously archived were re-analyzed using a PAH-SIM method to achieve lower detection limits. Additionally, six of these tissue samples were selected to be analyzed for PCB Aroclors to assist with the screening level human health and ecological risk assessment (Tables 3–3 and 3–4). Results from these secondary analyses are included here.

7.1 Chemical Compounds in Geoduck Tissue

Geoducks (*Panopea abrupta*) were collected from two locations (Figure 3–5). One sample was collected at Station MD08TG, located roughly 1,000 feet off of the northeast corner of the Rayonier Mill dock, which was composed of three small geoducks collected from the same area. The second was at Station RF06TG, at the southern end of the Dungeness Bay reference area, and was composed of one large geoduck. Percent lipids for geoduck were 0.94 percent and 1.2 percent at MD08TG and RF06TG, respectively (Table C–T1, Appendix C).

All metals were detected at MD08TG, and all metals except antimony and mercury were detected at RF06TG (Table C–T1, Appendix C). In general, metals concentrations in this Dungeness Bay reference station were lower than those found at the Mill Dock station. Arsenic, copper, and zinc were found in the highest concentrations of all metals at both stations.

Dioxin/furan homologue detected values were consistently lower for the reference station tissue than for the Mill Dock tissue sample. Total HpCDD was the homologue with the highest concentration in both samples: 0.497 ng/kg ww at MD08TG and 0.293 ng/kg ww at RF06TG. Calculated dioxin/furan TEQs (ND=0) were 0.11 for MD08TG and 0.014 for RF06TG. TEQs of (ND=1/2 detection limit) were 0.15 for MD08TG and 0.085 for RF06TG.

Four PCB congeners, 105, 118, 156/157, and 167, were detected in both tissue samples (Table C–T1, Appendix C). The PCB congeners 105, 118, and 156/157 were detected at the highest concentrations in both samples. Detected congener values were consistently lower in tissue samples collected from the Dungeness Bay reference stations.

The PAHs benzo(b/j/k)fluoranthene, benzo(b)fluoranthene, chrysene, fluoranthene, fluorene, naphthalene, perylene, and pyrene were detected in both the Mill Dock and reference samples. All of these concentrations were higher in MD08TG than in the reference sample RF06TG. Only one compound, 2,3,5-trimethylnaphthalene, was detected in the reference sample but not in MD08TG.

7.2 Chemical Compounds in Horse Clam Tissue

Horse clams (*Tresus capex*) were collected from 10 stations; three from the Harbor-Wide study area and five from the Rayonier Mill study area (Figure 3–5), and two from the Dungeness Bay reference area (Figure 3–2 and Tables 3–3 and 3–4). EI08TH was composed of five clams from a Harbor-Wide station located in the Eastern Intertidal area of the harbor directly east of the former Rayonier Mill. IE18TH, composed of one large clam, and IE20TH, composed of five clams, were located in the western Inner Ediz Hook area, east of the Nippon log boom aquatic sites. Stations MD06TH (six clams), MD07TH (one clam), MD08TH (three clams), and MD09TH (one clam) were all located along the western and northern edge of the Rayonier Mill dock, while EC06TH (two clams) was located at the mouth of Ennis Creek directly east of the dock. Stations RF04TH (four clams) and RF05TH (five clams) were located in the southeastern portion of Dungeness Bay. Percent lipids for the horse clam samples ranged from 0.44 percent at EI08TH to 1.34 percent at MD07TH (Table C–T2, Appendix C).

Sediment samples in some areas of the harbor were found to have SMS criteria exceedances of arsenic, cadmium, mercury, and zinc. These metals were also found in detected concentrations in tissue samples. The four Mill Dock station tissues had among the highest zinc concentrations of all stations sampled, ranging from 9.9 mg/kg to 12 mg/kg. RF05TH also had one of the highest concentrations of zinc at 12 mg/kg. Arsenic was detected at the highest concentrations at the four Mill Dock stations and at EC06TH. Copper concentrations were highest at the Inner Ediz Hook stations (1.9 mg/kg to 2 mg/kg), the Eastern Intertidal station (2.5 mg/kg), and at RF05TH (3.8 mg/kg).

Dioxin/furan homologues were detected in horse clam tissue at all stations. Total HpCDD had the highest detected concentration at all stations, with a maximum of 30.8 ng/kg ww at station MD07TH. Tissue from the two reference stations generally had lower values of HpCDD and HpCDF than did the Rayonier or Harbor-Wide tissue samples. Calculated dioxin/furan TEQs (ND=0) ranged from 0.006 at IE20TH to 0.281 at MD07TH. TEQs at ND=1/2 detection limit ranged from 0.086 at EI08TH to 0.298 at MD07TH.

PCB congeners 105 and 118 consistently had the highest concentrations of all the congeners found in horse clams at all stations. PCBs 156/157 and 167 were in the second tier of highest concentrations at all stations. In general, the stations nearest the Rayonier Mill (EC06TH, MD06-09TH) had higher concentrations of PCB congeners 105, 118, 156/157 and 167 than did the Harbor-Wide samples. MD07TH had the highest concentration of all stations for these four congeners. Detected PCB values in horse clam samples were consistently lower in the reference station tissues for all congeners. Congeners 081, 126, and 169 were generally undetected at all stations.

Fluoranthene, phenanthrene, and pyrene were the four highest concentrations at all eight test stations. Naphthalene and phenanthrene were the two highest concentrations at both reference stations. The maximum concentrations of most PAH compounds were all found in MD07TH. The maximum concentrations of chrysene and fluoranthene were found in MD06TH.

7.3 Chemical Compounds in Lingcod Tissue

Lingcod tissue was collected from four stations (IE21TL, IE22TL, IE23TL, and IE24TL) in the Inner Ediz Hook area along the western inner edge of the harbor (Figure 3–4). Samples from stations IE21TL and IE24TL were analyzed as whole body (4 pounds and 20 pounds, respectively), while samples from stations IE22TL and IE23TL (3 pounds each) were analyzed as fillet only (Table 3–5). No lingcod tissue was collected from any other areas of the harbor or from the Dungeness Bay reference area.

COPCs detected in lingcod tissue were metals, dioxins/furans, and PCBs (Table C–T3, Appendix C). Station IE24TL tissue generally had the highest concentrations of detected metals.

Dioxin and furan homologues were not frequently detected in lingcod tissue. Calculated dioxin/furan TEQs (ND=0) ranged from 0.009 at IE22TL to 0.132 at IE24TL. Dioxin/furan TEQs at ND=1/2 the detection limit ranged from 0.084 at IE22TL to 0.173 at IE24TL.

Similar to results found in horse clam tissue, PCB congeners 105, 118, 156/157, and 167 were found in the highest concentrations at all stations. PCB 118 was consistently found at a higher concentration than any other congener. Station IE24TL had the highest tissue concentrations of all stations for PCBs 105, 118, 156/157, and 167. Again, similar to horse clam results, congeners 081 and 169 were undetected at all stations.

Six of the seven PCB Aroclors were undetected in all lingcod tissue samples. Aroclor 1260 was detected in all four lingcod samples. The highest Aroclor 1260 concentration was found in the whole-body sample IE24TL (0.027 mg/kg ww), while the lowest was in the fillet sample IE22TL (0.0059 J mg/kg ww).

PAH compounds were generally detected in lingcod tissue samples. The PAHs acenaphthene and dibenzothiophene were detected in all four lingcod samples.

7.4 Chemical Compounds in Macroalgal Tissue

Two types of macroalgae, bull kelp and eelgrass, were collected in the harbor. Both were collected from sites in the Inner Ediz Hook area along the innermost western edge, west of the fish pen area. Bull kelp was collected at IE25TM and eelgrass was collected at IE26TM (Figure

3–4). Macroalgae samples were not collected from any other locations in the harbor or in the Dungeness Bay reference area.

With the exception of lead, metals were detected in at least one of the two macroalgal tissue samples (Table C –T4, Appendix C). Zinc, arsenic and barium were present in higher concentrations than other metals.

Dioxin and furan homologues were undetected in bull kelp tissue; four homologues were detected in eelgrass samples. In the eelgrass tissue, total HpCDD and total HpCDF had the highest concentrations of the four detected homologues, at 2.62 ng/kg and 0.335 ng/kg ww, respectively. Calculated dioxin/furan TEQs (ND=0) were 0.001 for IE25TM and 0.07 for IE26TM. Dioxin/furan TEQs at ND=1/2 the detection limit were 0.09 for IE25TM and 0.12 for IE26TM.

Similar to results for all other tissue types, PCBs 105, 118, 156/157, and 167 had the highest concentrations found at all stations when detected. PCB 118 concentrations were consistently higher than any other congeners for both bull kelp and eelgrass and were found in both tissues at 1.84 ng/kg (JT) ww and 6.45 ng/kg ww, respectively. PCB 105 was the second-highest congener at 0.715 ng/kg (JT) ww for bull kelp and 2.27 ng/kg ww for eelgrass. No PCB Aroclors were detected in either of the two macroalgal samples.

Concentrations of PAH compounds were consistently higher in the eelgrass tissue than in bull kelp tissue. In the eelgrass tissue, fluoranthene had the maximum concentration (3.87 mg/kg ww), while pyrene had the maximum concentration (2.46 mg/kg ww) in the bull kelp tissue. Chrysene and phenanthrene were also present in high concentrations in both samples relative to other PAHs.

8.0 Wood Debris Characteristics and Distribution in Port Angeles Harbor Sediments

Historically, a large number of mills and timber-related industries have located along Port Angeles Harbor. The operations listed in this section are a subset of historic operations. Four major mills, the Port of Port Angeles, and one plywood manufacturing company have operated and discharged process effluent into Port Angeles Harbor at various times from 1914 to the present. Each facility has at one time or another transported and stored logs, wood chips, and/or sawdust in nearshore areas or on barges in the harbor. The following facilities (from west to east) are identified in Figure 1–2:

1. Nippon Industries (formerly Diashowa and Georgia Pacific)
2. Merrill & Ring (M&R) Timber
3. The Fiberboard Paper and Products Company (operated from 1918 into the 1970s)
4. The Port of Port Angeles — Terminal 1 (operates and/or leases land for log storage areas)
5. The K-Ply plywood mill
6. The Rayonier Mill

8.1 Wood Debris in Surface Sediments

The quantity and distribution of wood debris in Port Angeles Harbor has been qualitatively examined during three surveys in the harbor. The first survey was a sediment profile imaging/plane view camera survey conducted by Science Applications International Corporation (SAIC) in November 1998 (SAIC 1999). The second survey was based on the sediment grab samples from the current sediment investigation. It resulted in an estimation of the amount of wood debris in surface sediment (E & E 2009). The third survey is the STA conducted by GeoSea in May 2008 (GeoSea 2009). Results of these surveys are outlined in the following sections. Discussion of the distribution of chemicals associated with wood debris, such as resin acids and guaiacols, is presented in the *Port Angeles Harbor Supplemental Data Evaluation to the Sediment Investigation Report* (NewFields 2012).

8.1.1 SAIC 1999 Sediment Profile/Plane View Survey of Port Angeles Harbor

Areas with current and historical log rafting and wood chip/sawdust barging activity as determined by SAIC are shown in Figure 8–1 (SAIC 1999). The figure shows that the largest area of activity is located along the north side of inner Port Angeles Harbor extending along the arm of Ediz Hook. Portions of this area have been leased at one time or another to Rayonier Corporation (approximately 217 acres), Nippon Industries (92.7 acres), the Port Angeles Management Area (approximately 20 acres), and Foss Maritime (approximately 43.7 acres). While Foss Maritime was not in the wood/paper business, it did transport log rafts to and from its lease area to other locations in the harbor. Rayonier Corporation also leased an additional 43.3 acres surrounding the Mill Dock and Log Pond area on the southeast side of the harbor.

The physical distribution of wood debris in Port Angeles Harbor was mapped in detail using sediment profile imaging and a plane view camera by SAIC in 1998. SAIC qualitatively estimated that 25 percent of the harbor contained wood debris in varying amounts. As depicted in Figure 8–2, the largest amounts were located along the northern and western shorelines. Sawdust/wood chips were found distributed in an hourglass pattern beginning in the Nippon Industries (Diashowa) lease area and extending in a southeasterly direction to offshore of the Boat Haven Marina. The sawdust/wood chips in the lower portion of the hourglass were buried under 6 to 8 centimeters of silt, indicating it may have been the result of a past spill of material. Other areas with measurable amounts of wood debris were located offshore of the Boat Haven Marina and on the west side of the Rayonier Mill dock.

Table 8–1 presents the number of sediment profile image/plane view stations located within the approximate boundaries of the WSDNR lease areas within Port Angeles Harbor. SAIC sampled 93 stations divided among the six lease areas identified by DNR and reported that overall, 48.4 percent of the stations contained no identifiable wood debris of any kind. Wood/bark was found in 46.2 percent of the stations, and sunken logs were found in 4.3 percent. Sawdust and wood pulp were found in 22.6 percent, and bacterial mats were identified in 10.8 percent. These mats are typically formed in sediments with low DO and high sulfide content. The lease areas with the largest amount of wood debris were Foss Maritime (80 percent) and the Rayonier Mill dock areas (66.7 percent). Over 85 percent of the stations in the Nippon area contained sawdust and/or wood pulp, and 57.1 percent contained bacterial mats.

8.1.2 Wood Debris Collected for the 2008 Sediment Trend Analysis

Surface sediment samples collected by GeoSea in 2008 for the STA were characterized for the type and amount of wood debris. The field survey results categorized the amount of wood debris as none, low, medium, and high. The presence of wood chips and sawdust were also noted when observed. They also identified locations where samples could not be collected due to hard substrates.

Figure 8–3 shows a diagrammatic representation of the distribution of wood debris within Port Angeles Harbor. The pink areas display approximate contours of stations identified as having medium to high amounts of wood debris, while the blue area encompasses areas with low to medium amounts. Similar to the SAIC (1999) results, approximately 25 percent of the harbor contained wood debris in varying amounts. The pattern displayed shows the largest amounts of wood debris occurring in the northwest end of the harbor. Other parts of the harbor with large accumulations include the Marina area, near the Red Lion hotel, and at locations surrounding the Log Pond and the Rayonier Mill dock. Figure 8–4 shows the approximate distribution of sawdust and wood chips in the harbor. The pattern is similar to that shown in Figure 8–3. Sawdust and wood chips were primarily found in the north and west ends of the harbor, along the waterfront of the Port Management area, and in the Log Pond and the west side of the Rayonier Mill facility. For the STA, 837 stations were sampled. Sediment could not be collected at 72 stations because of hard substrate. No wood debris was found at 69.5 percent of the remaining 765 (Table 8–2). A low amount of wood debris was found at 19 percent, a medium amount at 5.5 percent, and a high amount at 6 percent of the stations.

8.1.3 Percentage Wood Debris in Surface Samples Collected in 2008 for the Sediment Investigation Study

Field logs from the 2008 field sampling conducted by E & E in Port Angeles Harbor were examined (Appendix A), and the estimated amount of wood debris in each surface sample was tabulated (Table 8–3). The estimated amount of wood debris ranged from 0 to 95 percent. The largest amounts were found in the Inner Ediz Hook (IE), Inner Harbor (IH), and Marina (MA) areas. The Lagoon area (LA) and Log Pond (LP) area were also found to have large amounts of wood debris (Figures 8–5 and 8–6). An examination of Table 8–3 shows that 21 surface samples (17.9 percent) had trace wood debris, and only 18 surface samples (15.4 percent) had a significant amount of wood debris. Samples were categorized as trace if the field reports described less than 10 percent wood debris or qualitatively indicated very little wood debris observed. Samples were categorized as significant if the field reports described more than 10 percent wood debris or qualitatively indicated a significant amount of wood debris observed. Figure 8–5 shows the distribution of wood debris in Port Angeles Harbor. The figure shows that the areas of dense accumulation were found in samples along the western shoreline of the Inner Harbor along the base of Ediz Hook. Figure 8–6 shows the distribution of wood debris around the Rayonier Mill dock. Wood debris was found in a majority of the subsurface samples collected in the immediate vicinity of the dock and in the surface samples collected in the Log Pond area. Characterization details of the wood debris can be found in Tables B–4 and B–5 (Appendix B).

8.1.4 Comparison of the Distribution of Wood Debris among Studies

A comparison among the three surveys can be conducted only as an approximation in that the amount of wood debris was inconsistently reported across the three studies. The survey conducted by SAIC contained both qualitative and quantitative data and is also more than 12 years old. The qualitative data consisted of an estimation of the amount of wood debris lying on the sediment surface from the plane view camera images, while the quantitative data consisted of the measurement of the amount of wood debris (in centimeters) from the sediment profile images. The STA qualitatively measured the amount of wood debris by estimating the amounts as none, low, medium, and high, with no more descriptive characteristics given. The STA also classified each sample as either mixed wood: bark (small, medium, or large); sawdust; wood chips; pulp fibers; or cedar. The Port Angeles sediment investigation estimated the amount as a rough percentage found in each grab sample.

8.2 Wood Debris in Subsurface Sediments

The total depth of wood debris presence was not delineated during the study; therefore, depths of wood debris are not well characterized. Sediment comprised predominantly of wood debris, including wood chips, pulp, and bark, has locally accumulated to thicknesses greater than 120 inches, as observed in sediment investigation core IE09 (see Table B–5, Appendix B). Other cores exhibiting large proportions of wood material include IE05 (to 98 inches), IE12 (to 108 inches), IE14 (to 62 inches), IH02 (to 68 inches), IH06 (to 98 inches), BL02 (to 60 inches), and KP03 (to 78 inches).

Sediment containing wood chips and other wood debris was observed in several cores in the East Dock, Ennis Creek, Mill Dock, Log Pond, and Outfall areas (Appendix A). These sediment cores were ED01 (to 54 inches), ED03 (to at least 16 inches), ED04 (to 60 inches), ED05 (to at least 36 inches), EC04 (to 32 inches), CO05 (possibly to 36 inches), CO03 (to 48 inches), MD02 (to 42 inches), MD03 (to 70 inches), MD04 (to 16 inches), and LP05 (to 21 inches).

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9.0 Summary of Sediment Transport Processes

Several studies have been undertaken in the Port Angeles Harbor area to attempt to characterize the physical processes responsible for the introduction, transportation, and distribution of sediments within Port Angeles Harbor. Those processes are wind, waves, alongshore drift, and currents, including tidal and gravity flow currents.

Summaries of previous studies and results of activities undertaken as part of the present investigation are presented in:

- *Port Angeles Harbor Current Data Collection and Analysis Report*, prepared by Evans-Hamilton, Inc., for Ecology and Environment, Inc., June 2008 (Appendix D).
- *A Sediment Trend Analysis (STA) of Port Angeles Harbor*, prepared by Patrick McLaren, GeoSea Consulting Ltd., for State of Washington Department of Ecology, February 2009 (Appendix E).
- *Draft Geomorphic Report, Port Angeles Harbor*, prepared by Herrera Environmental Consultants for Ecology and Environment, Inc., November 9, 2009 (see Appendix I)

Results of these studies and elements of the sediment investigation that pertain to transportation and distribution of sediment are summarized below.

9.1 Sediment Sources and Budget

Sediment inputs into Port Angeles Harbor have been limited by development since European settlement, including shoreline modifications that have disconnected the bluffs from the nearshore. Since the elimination of bluff material as a sediment source, sediment entering the harbor has come primarily from the creeks that empty into the harbor and solids from human activities, including wood debris, suspended sediments delivered to the harbor from land reclamation activities onshore, and application of materials associated with aquaculture operations (fish food and waste).

As part of the geomorphic evaluation of the harbor (Appendix I), the amount of sediment delivered to the harbor by Tumwater Creek was estimated. The suspended sediment flux into the harbor was thus estimated to range between 5,500 metric tons per year (0.18 kilograms per second [kg/sec]) to 27,600 metric tons per year (0.87 kg/sec).

Sediment load was estimated in Appendix I for the other creeks entering the harbor based on area, temperature, and maximum relief within the respective drainage basins using the Syvitski model (Syvitski et al. 2003, 2005). The estimate of the combined sediment input of all creeks emptying into the harbor based on the Syvitski model is 5.69 kg/sec. Using the estimated sediment input values for all creeks, the average accumulation rate of creek-supplied sediment over the 7.60 square kilometers of the harbor (roughly the area within the protection of Ediz Hook) is estimated to be between 0.22 and 1.25 centimeters per year (cm/yr), assuming the harbor acts as a no-loss repository for sediment (Appendix I). The calculated accumulation rates at the two radioisotope core locations MD06 and RL03 are between 0.14 and 0.21 cm/yr. The difference between the rates estimated from radioisotopic dating and those calculated using the Syvitski model strongly suggests that sediment accumulation within the harbor does not occur uniformly throughout the harbor. These conclusions are corroborated by the results of the STA, which identified areas of net erosion, net accretion, total erosion, and dynamic equilibrium (Appendix E).

9.2 Wave Action and Alongshore Drift

Sediment transport in the nearshore zone of the harbor results predominantly from wave action. The Geomorphic Report (Appendix I) provides a summary of existing information as well as information obtained as part of the sediment investigation to better characterize sediment transport in the nearshore that results from wave action. Results are summarized in Figure 11 of the report (Appendix I) and briefly described below.

Wave action and resulting littoral (alongshore) drift are associated with swell (large waves originating in the open ocean) and locally generated waves. Local waves result primarily from the predominant westerly winds but also result from easterly and northeasterly winds. The northeasterly winds occur less frequently and are generally weaker than the strongest winds from the west, but the comparatively large fetch to the northeast of Port Angeles Harbor results in westward moving waves that are larger than the eastward moving waves generated by the westerly winds. Both swell and local waves are subject to refraction as they shoal. An estimated wave base depth of 55 feet was calculated for Port Angeles Harbor (Appendix I). The portion of the harbor bottom shallower than this depth (nearshore zone) may be subject to wave-derived transport, including resuspension and transport.

The refraction of swell entering the harbor from the Strait of Juan de Fuca results in westward alongshore drift along the southern shore from a point located between Morse Creek and Lees Creek westward into the inner harbor. Waves originating from easterly and northeasterly winds also result in predominantly westward alongshore drift. Analysis of historical and present day geomorphic features indicates that alongshore drift in the harbor is predominantly westward (Appendix I). One notable exception is the area immediately west of the dock and jetty at the Rayonier Mill site, where there appears to be a section of nearshore that is subject to northeastward alongshore drift (Appendix I, Figure 11). This and other apparent discrepancies between conclusions of previous studies (Ecology 2008) and the present study (Appendix I) are attributed to bi-directional transport, which is noted to be common throughout Puget Sound and the Strait of Juan de Fuca (Finlayson 2006). The predominantly westward direction of alongshore drift on the southern shore of the harbor is reflected in the STA results for the nearshore area between Lees Creek and Peabody Creek (Appendix E, Figures 6 and 7). An important implication of the predominantly westward alongshore drift in the harbor is that sediments within the harbor nearshore will tend to migrate westward into the inner harbor as a result of alongshore drift.

9.3 Tidal Currents

Sediments in all areas of the harbor, including the nearshore, may be subject to transportation by currents, including tidal currents. Several previous studies have characterized tidal currents in the Strait of Juan de Fuca and/or the Port Angeles Harbor area. These previous studies are summarized in the STA Report (Appendix E) and Geomorphic Report (Appendix I). None of these previous studies adequately characterize water motions near the bed that initiate or maintain sediment transport within the harbor, particularly over periods of more than a few days. Even the targeted physical and numerical models possess inherent scale effects that limit their utility to allowing understanding of only broad, general circulation patterns. It is concluded that the models cannot reliably characterize the short-term, small-scale fluctuations and eddies in tidal flow that have been observed in the area (Appendix I).

Tides in the area are mixed semi-diurnal (i.e., tides occur every six hours with low tides of different magnitudes), with a mean tide range of 4.6 feet. Due to strong and persistent wind stress from the west and an intense eastward boundary current along the southern shoreline of the Strait of Juan de Fuca, surface currents are strongly eastward east of Lees Creek. However, strong tidal eddies are common in areas protected by Ediz Hook. These motions are not coherent across the harbor in the form of a single eddy, contrary to assumptions or conclusions of previous studies, including several dye studies performed at the University of Washington and by Battelle (Battelle 2004; Yang et al. 2004). Rather, they appear to be small, localized events of short duration.

A current study was performed as part of the present investigation. The study is summarized in *Port Angeles Harbor Current Data Collection and Analysis Report* (Evans-Hamilton, Inc. 2008), provided in Appendix D of this report. Key results of the study are also discussed in the STA Report (Appendix E) and Geomorphic Report (Appendix I) and briefly summarized below. Three current monitoring stations were deployed to measure currents, waves, and suspended sediment (turbidity) over a one-month period. The monitoring units were placed near the Nippon Paper Industries (Station #1), between the City Pier and the former Rayonier Mill site (Station #2), and immediately south of the end of Ediz Hook (Station #3). Although the direct observations of sediment transport were limited to near the seafloor, the use of ADCPs provided information on currents at a variety of depths throughout the water column, including near the water surface and the bottom.

A key finding of the current study was that, contrary to results of previous numerical and laboratory modeling, the strongest current events at each tripod occurred at different times, with no significant current being observed at the other tripods during each of these events. This is interpreted to indicate that a single tidal eddy postulated in some previous studies likely does not represent the most important current events that initiate or maintain sediment transport. The most intense currents observed during the deployment (particularly at Station #2) were consistent with highly localized tidal eddies (Appendix I).

Combined with the previous studies, the tripod observations yield a clearer picture of Port Angeles Harbor hydrography. At the water surface in the outer harbor, tidal currents are energetic and driven strongly by tidal motions in the Strait of Juan de Fuca. These currents diminish with distance into the inner harbor. Although there may be a large coherent eddy associated with the tides, the strongest tidal currents are not coherent across the entire harbor. Smaller intense eddies, such as one invoked to explain the strong, localized current events observed at Station #2 between March 30 and 31, 2008, are hypothesized to result in the strongest tidal currents in the harbor. At Station #3, currents appear most often toward the east; however, they are not as strong as those toward the west. The strongest currents near the bed have a westward component. This observation is consistent with the STA results at this location (Appendices D, E, and I).

9.4 Counterflow Currents

As is typical for estuaries, it appears that strong eastward surface currents, caused by strong west winds within the harbor, are balanced by westward counterflows near the bed (Appendix I). The westward counterflows near the sediment bed are a factor in westward sediment transport along the southern harbor shoreline as confirmed by the STA (Appendix E).

9.5 Sediment Gravity Flows

At Current Study Station #1, measurements of turbidity and near-bottom currents are interpreted to indicate localized sediment gravity flows in the inner harbor (Appendix I). Sediment gravity flows, sometimes called fluid muds or turbidity currents, drive flow downslope due to the added weight supplied to the water column from suspended sediment. They are common on steep seafloors where an excess of fresh sediment is available (Wright and Friedrichs 2006). Station #1 was the only tripod to report significant suspended sediment. The turbid conditions measured at this location were not associated with large currents or large wave events but rather appear to be related to a persistent subtidal process. The current rose indicates highly coherent unidirectional flow toward the northeast, the direction of the local slope (Appendix I, Figure 14). Such northeasterly sediment transport in this portion of the inner harbor is consistent with findings in the STA of northeasterly sediment transport in this area.

Sediment gravity flows require significant sediment supply (Wright and Friedrichs 2006). As noted in Section 9.1 and Appendix I, the historical supply sources of much of the sediment to the inner harbor area (overwash from the west side of Ediz Hook and sediment from the bluffs along the southern shore of the harbor) have been cut off. The remaining significant sources of sediment to the harbor are the creeks that flow into the southern shoreline and localized input of anthropogenic material, including wood debris. Westward transport of creek-derived sediment and some of the wood debris across the harbor is consistent with observations of predominantly westward alongshore drift (Section 9.2). It is hypothesized that, once accumulated (but remaining in suspension) in this otherwise fairly quiescent area, the suspended sediment responds to gravity and creeps downslope at approximately 10 cm/sec, ultimately flowing into the bathymetric low at the northwest end of the harbor (Appendix I).

Although such gravity flows are not presently documented or hypothesized at other areas of the harbor, it is possible that gravity flows may occur at other locations as well. Such gravity flows could potentially explain STA observations of transport direction elsewhere in the harbor. Furthermore, such gravity flows could be partly responsible for the extreme sediment transportation events hypothesized to re-distribute sediments in the harbor, replenishing the "parting zones" (see STA, Appendix E).

9.6 Extreme Weather Events

Geomorphic work conducted across Puget Sound indicates that extreme weather events play an important role in nearshore sediment transport (Finlayson 2006). Because Port Angeles Harbor is largely sheltered from swell (westward of the Rayonier property and along most of the southern shore of Ediz Hook), waves that impact the nearshore of most of the harbor are generated predominantly by wind (see Appendix I). Waves that have the greatest impact on the nearshore are generally those generated by the strongest winds. Currents are also influenced strongly by winds. Strong westerly winds, in particular, amplify estuarine exchange in the harbor by intensifying eastward flow at the surface and westward flow at depth (Dunn 2008).

Therefore, extremes associated with sediment transport, both wind-induced and current-induced, are expected to result from large windstorms. No large wind events were linked to extreme wave, current, or sediment transport occurrences during the current study instrument deployment, so this hypothesis remains untested for the harbor (see Appendix I).

The existence of “parting zones” identified in the STA Report may be better understood in consideration of extreme wave events. It is speculated that such extreme events could redistribute sediments in the harbor, replenishing the “parting zones” with sediment, followed by the “everyday” transport directions identified in the STA Report (Appendix E). For example, winds strong enough to overcome the normal estuarine currents of the strait, even resulting in current reversals as far inland as Dungeness Spit, can occur two to three times a month during winter (NOAA HAZMAT 2002).

Another type of extreme weather event that may impact sedimentation in the harbor is extreme precipitation events. Such events could result in a rapid and sudden input of new sediment into the harbor brought about by severe rains with their associated landslips and flooding (Appendix E).

9.7 Summary

The impacts of each of the sediment transport processes active in the harbor are different from each other and vary spatially and temporally. The resulting complex interaction of the waves, tidal currents, counter currents, and gravity flows in Port Angeles Harbor has not been completely defined, and the aggregate effect of the sediment transport processes acting in the harbor is not known. However, evidence presented in this section suggest the existence of a depositional area in the inner harbor, an erosional area near the former Rayonier Mill property, and both tidal eddies and currents causing sediment transport. Based on available information, it may be generally concluded that most or all of the sediment introduced to the harbor is retained within the harbor, and a significant quantity of this sediment is transported westward into the inner harbor, where it is retained indefinitely.

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10.0 Summary of Screening Level Human Health and Ecological Risk Assessment

10.1 Human Health Risk Assessment Summary

For the human health risk assessment, potential exposure to chemicals in sediment and fish and shellfish tissue for a subsistence fisher, recreational fisher, residential user, and recreational user were evaluated based on site-specific exposure parameters and are shown in Table 10–1. The potential excess cancer risks exceeded the Ecology threshold of 1 in 100,000 (1 x 10-5) for the subsistence and recreational fisher receptors. Table 10–2 is a summary of compounds that exceed 1 x 10-6 for each receptor and exposure pathway.

Noncancerous hazards also exceeded Ecology's threshold of 1.0 for the subsistence and recreational fisher scenarios. Table 10–3 is a summary of compounds that exceed a hazard quotient (HQ) of 1.0 for each receptor and exposure pathway.

Cancer risks and noncancerous hazards for the residential and recreational users were below the Ecology threshold. The largest contributors to hazards and risks were exposure to arsenic, total PCBs, and 2,3,7,8-TCDD TEQ through ingestion of fish and shellfish.

Results from lead modeling indicate that exposure to lead in fish and shellfish may result in blood lead levels for a child above the USEPA level of concern.

These risks and hazards may be considerably influenced by uncertainties associated with the IHSs and exposure pathways contributing to the greatest proportion of total risks:

- Small sample numbers used to estimate exposure point concentrations (EPCs) for tissues;
- Inclusion of IHSs likely present at concentrations consistent with reference concentrations (arsenic, pesticides);
- Quantification of seafood ingestion rates for the Lower Elwha Klallam Tribe (LEKT) and recreational users of Port Angeles Harbor; and
- Lack of sediment-specific exposure parameters, particularly for dermal exposure assessment.

Further evaluation of the impacts of the uncertainty in the assessment is warranted based on the results.

10.2 Ecological Risk Assessment Summary

The ecological risk assessment was conducted in accordance with Washington State and USEPA guidance. Eight assessment endpoints were evaluated: (1) marine plants and macroalgae, (2) benthic invertebrates, (3) fish, (4) carnivorous birds, (5) omnivorous birds, (6) herbivorous birds, (7) carnivorous mammals, and (8) omnivorous mammals. A summary of potential risks to these assessment endpoints is provided in Table 10–4. In brief, marine vegetation and benthic invertebrates are the receptor groups most at risk from current environmental conditions in Port Angeles Harbor. For these assessment endpoints, sediment habitat degradation by wood debris and selected metals and organic contaminants appear to be the most critical stressor. Arsenic may pose a risk to fish and omnivorous mammals.

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11.0 Summary, Conclusions, and Recommendations

11.1 Summary

Results from the Port Angeles Harbor sediment study are summarized below. Included are summaries of surface sediment chemistry and bioassays (Section 11.1.1), subsurface sediment chemistry (Section 11.1.2), tissue chemistry (11.1.3), the distribution of wood debris (11.1.4), sediment transport (Section 11.1.5), and the risk assessment (Section 11.1.6).

11.1.1 Surface Sediment Chemistry and Bioassays

The detailed presentation of the concentration and distribution of COPCs and bioassay test results in the surface sediment samples are presented in Sections 5.1 and Section 6.0 of this report.

In general, the highest concentrations of COPCs and most bioassay test failures were found at nearshore sample stations located between the Inner Ediz Hook and Ferry Terminal areas; lower concentrations of COPCs were generally found in offshore areas in deeper waters of the harbor and in the eastern portion of the Eastern Intertidal/Subtidal area.

SMS COPCs

Surface sediment samples in Port Angeles Harbor exceeded SMS or LAET criteria for metals, phenols, and phthalates (Table 5.4–1 and Figure 5.4–1). Exceedances of metals were restricted to western harbor study areas, with mercury being the most frequent metal of exceedance. With the exception of a single phthalate exceedance in the Lagoon study area, SMS and LAET exceedances of phenols and phthalates occurred only at locations along the southern harbor and in Rayonier Mill study areas.

Dioxins/Furans

The highest concentrations of dioxin/furan congeners and TEQs were in the Lagoon and Inner Harbor areas. Detected congener concentrations and associated TEQs were relatively lower in the Rayonier Mill area compared to other study areas in the harbor.

Bioassays

Bioassay test results exceeded SMS criteria at sediment stations in nearly all study areas in the harbor (Figure 6–1). The areas with the most bioassay test failures included the Inner Ediz Hook, Marina, Boat Launch, and K-Ply areas. Five sediment stations were found with co-occurring bioassay test failures and exceedances of chemical sediment criteria, including metals, phenols, and phthalates. Bioassay test failures occurred at 24 stations with no chemical sediment criteria exceedances.

11.1.2 Subsurface Sediment Chemistry

The detailed presentation of the concentration and distribution of COPCs in the subsurface sediment samples is presented in Sections 5.2 and 5.3 of this report.

SMS COPCs

Subsurface sediments samples in Port Angeles Harbor exceeded SMS or LAET criteria for metals, PCBs, PAHs, phenol, phthalates, and pesticides (Table 5.4–2 and Figure 5.4–2). As in surface sediments, exceedances of metals were restricted to western harbor study areas, with mercury being the most frequent metal of exceedance. PCB, PAH, and phenol exceedances occurred only in Rayonier Mill study areas. Unlike surface sediments, subsurface phthalate exceedances were found only in western harbor study areas. A single location in the Ferry Terminal study area exceeded LAET criteria for two pesticides.

Dioxins/Furans

The highest concentrations of dioxin/furan congeners and TEQs were detected in the Inner Harbor area. In the Rayonier Mill area, detected congener concentrations and associated TEQs in subsurface sediments were relatively higher than surface sediment concentrations.

11.1.3 Tissue Chemistry

Many COPCs were not detected in any of the tissue samples. The most frequently detected COPCs found in tissue samples included metals, PAHs, PCBs, and dioxins/furans. COPCs were most frequently detected in the horse clam tissue samples compared to the other tissue types. In general, the lingcod tissue samples contained the fewest detected COPCs. The Dungeness Bay reference area had generally lower COPC concentrations than the harbor stations.

11.1.4 Distribution of Wood Debris

Three studies have been conducted to determine the amount of wood debris in Port Angeles Harbor. The results of the studies are very similar. All three indicated that the majority of wood debris was located in the inner portion of the harbor. The primary areas of accumulation were located in the western portion of the harbor along the base of Ediz Hook, in the Lagoon area, along the waterfront in the Inner Harbor area, and in the Rayonier Mill area at the Log Pond and Mill Dock. The presence of wood debris generally decreases with increasing water depth in the harbor (Figures 8–1 to 8–6).

Wood debris was observed in cores accumulated up to thicknesses greater than 120 inches (Inner Ediz Hook area). The total depth of wood debris presence was not delineated during the study; therefore, depths of wood debris are likely greater than observed.

11.1.5 Sediment Transport

Sediment loading and transport was characterized through three studies as part of this investigation. These include a deployment of current meters in the harbor (see Appendix D), a STA (see Appendix E), and a geomorphic evaluation of the harbor (see Appendix I). Together, these studies indicate that multiple processes are responsible for the introduction, transportation, and distribution of sediments within the harbor. The most important physical sediment transport processes include wind, waves, alongshore drift, and currents, including tidal and gravity flow currents.

The difference between the accumulation rates estimated from radioisotopic dating and the estimated harbor-wide average rate strongly suggests that sediment accumulation within the harbor does not occur uniformly. This conclusion is corroborated by the results of the STA and by lithologic observations of subsurface cores containing wood debris at varying depths.

Sediment transport in the nearshore zone of the harbor results predominantly from wave action. Wave action and resulting alongshore drift are associated with swell (large waves originating in the open ocean) and locally generated waves. The refraction of swell entering the harbor from the Strait of Juan de Fuca can result in westward alongshore drift along the southern shore from a point located between Morse Creek and Lees Creek westward into the inner harbor.

Extreme weather events are also believed to play an important role in nearshore sediment transport in Port Angeles Harbor. Such extreme events could potentially explain the existence of "parting zones" identified in the STA. Extreme events could redistribute sediments in the harbor, replenishing the "parting zones" with sediment, followed by the "everyday" transport directions identified in the STA. Another type of extreme weather event that may impact sedimentation in the harbor is extreme precipitation events, which could result in a rapid and sudden input of new sediment into the harbor due to landslips and flooding.

The impacts of each of the sediment transport processes active in the harbor are different from each other, and they vary spatially and temporally. The resulting complex interactions of the processes are not well understood, and the aggregate effect of the sediment transport processes acting in the harbor is not known. However, based on available information, it may be generally concluded that most or all of the sediment introduced to the harbor is retained within the harbor, and at least some of this sediment is transported westward into the inner harbor.

11.1.6 Screening Level Human Health and Ecological Risk Assessment

Environmental investigations throughout the harbor have indicated that chemicals in marine sediments and biota may pose a risk to human and environmental receptors.

Potential COCs to harbor sediments and biota were identified based on known chemical associations with historical and current land uses, as well as a significant amount of data collected during prior sediment investigations within the harbor. The following chemicals were previously identified as potential constituents of concern:

- Dioxins/furans;
- PCBs;
- Chlorinated pesticides;
- SVOCs, including PAHs, phenols, and phthalates;
- Resin acids/guaiacols;
- TBT;
- Ammonia, sulfides, and TOCs; and
- Heavy metals, including inorganic and organic forms.

Numerous studies have characterized chemical constituents in sediment and distribution of wood debris in Port Angeles Harbor. Data from reports written over the past approximately 10 years were used in the human health and ecological risk assessments and include data from this

Sediment Investigation (E & E 2009c), as well as historical data for the harbor, including the Rayonier area.

Human Health Risk Assessment Summary

For the human health risk assessment, potential exposure to chemicals in sediment and fish and shellfish tissue for a subsistence fisher, recreational fisher, residential user, and recreational user were evaluated based on site-specific exposure parameters. The potential excess cancer risks exceeded the Ecology threshold of 1 in 100,000 (1 x 10-5) for the subsistence and recreational fisher receptors.

Cancer risks and noncancerous hazards for the residential and recreational users were below the Ecology threshold. The largest contributors to hazards and risks were exposure to arsenic, total PCBs, and 2,3,7,8-TCDD TEQ through ingestion of fish and shellfish.

Results from lead modeling indicate that exposure to lead in fish and shellfish may result in blood lead levels for a child above the USEPA level of concern.

These risks and hazards may be considerably influenced by uncertainties associated with the IHSs and exposure pathways contributing to the greatest proportion of total risks:

- Small sample numbers used to estimate EPCs for tissues;
- Inclusion of IHSs likely present at concentrations consistent with background concentrations (arsenic, pesticides);
- Quantification of seafood ingestion rates for the LEKT and recreational users of Port Angeles Harbor; and
- Lack of sediment-specific exposure parameters, particularly for dermal exposure assessment.

Further evaluation of the impacts of the uncertainty in the assessment is warranted based on the results.

Ecological Risk Assessment Summary

The ecological risk assessment addressed eight assessment endpoints: (1) marine plants and macroalgae, (2) benthos, (3) fish, (4) carnivorous birds, (5) omnivorous birds, (6) herbivorous birds, (7) carnivorous mammals, and (8) omnivorous mammals. A summary of potential risks to these assessment endpoints is provided in Table ES–3. In brief, marine vegetation and benthos are the receptor groups most at risk from current environmental conditions in Port Angeles Harbor. For these assessment endpoints, sediment habitat degradation by wood debris and the presence of selected metals and organic contaminants above SMS criteria appear to be the critical stressors. Arsenic may pose a risk to fish and omnivorous mammals.

11.2 Conclusions and Recommendations

Major conclusions from this study are as follows:

- Regulatory sediment criteria for multiple metals and organic compounds have been exceeded in the harbor.

- Bioassay failures throughout the harbor indicate possible toxic sediment conditions; however, the bioassay failures are not strongly correlated with elevated COPC concentrations.
- COPCs were detected in marine biota that are of potential subsistence and recreational importance.
- Significant wood debris accumulations on the sediment surface and in subsurface sediments persist in nearshore areas of the southern and western portions of the harbor and immediately west of the former Rayonier Mill.
- Sediment transport conditions indicate that the western portion of the harbor is a sink for sediments and associated contaminants, including wood debris.
- Potential excess cancer risks exceed the threshold of 1 in 100,000 (1×10^{-5}) for human subsistence and recreational fisher receptors. Cancer risks and noncancerous hazards for the residential and recreational users were below regulatory thresholds. The largest contributors to human health hazards and risks were exposure to arsenic, total PCBs, and 2,3,7,8-TCDD TEQ through ingestion of fish and shellfish.
- Marine vegetation and benthos are the ecological receptor groups most at risk from current environmental conditions in the harbor. Sediment habitat degradation by wood debris and the presence of metals and organic contaminants appear to be the critical stressors. Arsenic may pose a risk to fish and omnivorous mammals in the harbor.

The following is a summary of the significant findings for each AOPC and recommendations for further investigating the nature and extent of COPCs in the harbor:

Ediz Hook Area

Summary

- There were no exceedances of any chemical sediment criteria.
- There was one exceedance of the SQS criteria for the larval bioassay at station EH02A.
- No accumulations of wood debris were documented.

Recommendations

- Collect and analyze additional surface sediment samples for chemical and bioassay analyses to determine the reason for bioassay criteria failures with few or no chemical exceedances.

Fish Pen Area

Summary

- There were no exceedances of any chemical sediment criteria.
- There was one exceedance of the SQS criteria for the larval bioassay at station FP01A.
- No accumulations of wood debris were documented.

Recommendations

- Collect and analyze additional surface sediment samples for chemical and bioassay analyses to determine the reason for bioassay criteria failures with few or no chemical exceedances.

Lagoon Area

Summary

- There were exceedances of chemical sediment criteria for cadmium, mercury, and butyl benzyl phthalate in surface sediments.
- Relatively higher dioxin TEQs are present in surface sediments compared to the rest of the harbor.
- There were no exceedances of chemical sediment criteria in subsurface sediments.
- There was one exceedance of the CSL criteria for the larval bioassay at station LA02A.
- Significant accumulations of wood debris on the sediment surface are present, including wood chips and sawdust.
- Relatively high concentrations of resin acids were detected in surface sediments compared to the rest of the harbor.

Recommendations

- Collect and analyze additional subsurface sediment samples to determine the depth of contamination.
- Due to high dioxin/furan concentrations detected in surface sediment, further delineate the extent of dioxin/furan contamination.

Inner Ediz Hook Area

Summary

- There were exceedances of chemical sediment criteria for mercury and zinc in surface sediments.
- There were single exceedances of chemical sediment criteria for mercury and butyl benzyl phthalate in subsurface sediments.
- There were exceedances of the SQS criteria for larval bioassays at stations IE03A, IE04A, and IE07A.
- There were exceedances of the CSL criteria for larval bioassays at stations IE06A, IE09A, IE14A, and IE15A.
- Significant accumulations of wood debris on the sediment surface are present, including logs, wood chips and sawdust, and trace wood debris mixed with sediment.
- Relatively high concentrations of resin acids and sulfides were detected in surface sediments compared to the rest of the harbor.
- Significant accumulations of wood debris exist in subsurface sediments up to a depth of at least 120 inches.
- Relatively high concentrations of resin acids were detected in subsurface sediments.

Recommendations

- Collect and analyze additional surface and subsurface sediment samples in a grid at the mouth of the Lagoon.
- Collect and analyze additional surface and subsurface sediment samples in a grid extending along the shore of Ediz Hook from Station IE09A to IE03A.
- Conduct further tissue collection surveys to obtain geoduck samples for comparison to existing Mill Dock and reference area samples.

Inner Harbor Area

Summary

- There were exceedances of chemical sediment criteria for arsenic, cadmium, mercury, and zinc in surface sediments.
- The highest dioxin TEQs in the harbor are present in surface and subsurface sediments in this area (stations IH01A and IH02B).
- There were exceedances of chemical sediment criteria for cadmium, mercury, zinc, and bis(2-ethylhexyl) phthalate in subsurface sediment.
- There were exceedances of the SQS criteria for larval bioassays at stations IH02A, IH03A, and IH06A.
- Significant accumulations of wood debris on the sediment surface are present, including wood chips and sawdust, and trace wood debris mixed with sediment.
- Relatively high concentrations of resin acids and sulfides were detected in surface sediments compared to the rest of the harbor.
- Significant accumulations of wood debris exist in subsurface sediments up to a depth of at least 98 inches.

Recommendations

- Collect and analyze additional surface and subsurface sediment samples in a grid offshore of the Inner Harbor Stations IH01A, IH02A, and IH03A and the area surrounding the mouth of the Lagoon. The spatial extent of dioxins/furans requires further characterization.

Marina Area

Summary

- There were exceedances of chemical sediment criteria for phenol, bis(2-ethylhexyl) phthalate, and butyl benzyl phthalate in surface sediments.
- There was one exceedance of chemical sediment criteria for mercury in subsurface sediment.
- There were exceedances of SQS criteria for larval bioassays at stations MA01A and MA05A.
- There were exceedances of CSL criteria for larval bioassays at stations MA02A and MA06A.
- Significant accumulations of wood debris mixed with surface sediment are present.
- Relatively high concentrations of resin acids were detected in surface sediments.

Recommendations

- Collect and analyze additional surface sediment samples in a grid offshore of the Marina to determine the off-shore extent of existing contamination.

Barge Area

Summary

- There were no exceedances of any chemical sediment criteria.
- There was one exceedance of the CSL criteria for the larval bioassay at station BA01A.
- Trace accumulations of wood debris are present in this area.

Recommendations

- Collect and analyze additional surface sediment samples for chemical and bioassay analyses to determine the reason for bioassay criteria failures no chemical exceedances.

Boat Launch and Standard Oil

Summary

- There were no exceedances of any chemical sediment criteria.
- There were exceedances of the SQS criteria for the larval bioassay at stations BL03A and BL04A.
- There were exceedances of the CSL criteria for the larval bioassay at stations BL01A and BL06A.
- Significant accumulations of wood debris on the sediment surface are present, including wood chips and sawdust.
- Relatively high concentrations of resin acids and sulfides were detected in surface sediments.
- Significant accumulations of wood debris exist in subsurface sediments up to a depth of at least 60 inches.

Recommendations

- Collect and analyze additional surface sediment samples for chemical and bioassay analyses to determine the reason for bioassay criteria failures with few or no chemical exceedances.

K-Ply Area/Valley Creek Area

Summary

- There were no exceedances of any chemical sediment criteria.
- The highest concentration of TBT detected in the harbor was found in this area.
- There were exceedances of the SQS criteria for the larval bioassay at stations KP01A, KP02A, KP05A, and KP06A.
- Significant accumulations of wood debris on the sediment surface are present, including wood chips and sawdust.

- Significant accumulations of wood debris exist in subsurface sediments up to a depth of at least 78 inches.

Recommendations

- Collect and analyze additional surface sediment samples for chemical and bioassay analyses to determine the reason for bioassay criteria failures with no chemical exceedances.
- The spatial extent of butyltins in surface sediment requires further characterization.

Ferry Terminal Area

Summary

- There were exceedances of chemical sediment criteria for 4,4-DDD and 4,4-DDE in subsurface sediment at station FT04C.
- There were no exceedances of sediment criteria for the bioassays in this area.
- Trace accumulations of wood debris are present in surface sediment in nearshore locations in this area.

Recommendations

- Collect and analyze additional surface sediment samples in a grid offshore of the Ferry Terminal to determine the off-shore extent of existing contamination

Red Lion Area

Summary

- There were no exceedances of any chemical sediment criteria.
- There were no exceedances of sediment criteria for the bioassays.
- No accumulations of wood debris were documented in the Red Lion area.

Recommendations

- No further action is warranted in this area.

Rayonier Mill Area

Summary

- There were single exceedances of chemical sediment criteria phenol and 4-methylphenol in surface sediment.
- The highest surface sediment dioxin/furan TEQs in the vicinity of the former Rayonier Mill property were in the log pond.
- There were exceedances of chemical sediment criteria for total PCBs, 4-methylphenol, and multiple PAHs in subsurface sediment.
- There were exceedances of the SQS and CSL criteria for larval and amphipod bioassays both east and west of the former pier.
- Significant accumulations of wood debris on the sediment surface are present on the western side of the former pier (log pond area).

- Significant accumulations of wood debris in subsurface sediment are present on the eastern side of the former pier.

Recommendations

- The spatial extent of dioxins/furans requires further characterization between the Rayonier Mill area and the Red Lion area.

Outer Harbor Area

Summary

- There were no exceedances of any chemical sediment criteria.
- There were no exceedances of any bioassay sediment criteria.
- No accumulations of wood debris were documented.

Recommendations

- No further action is warranted in this area.

Eastern Intertidal/Subtidal Area

Summary

- There were no exceedances of any chemical sediment criteria.
- There were no exceedances of any bioassay sediment criteria.
- No accumulations of wood debris were documented.

Recommendations

- No further action is warranted in this area.

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Figures

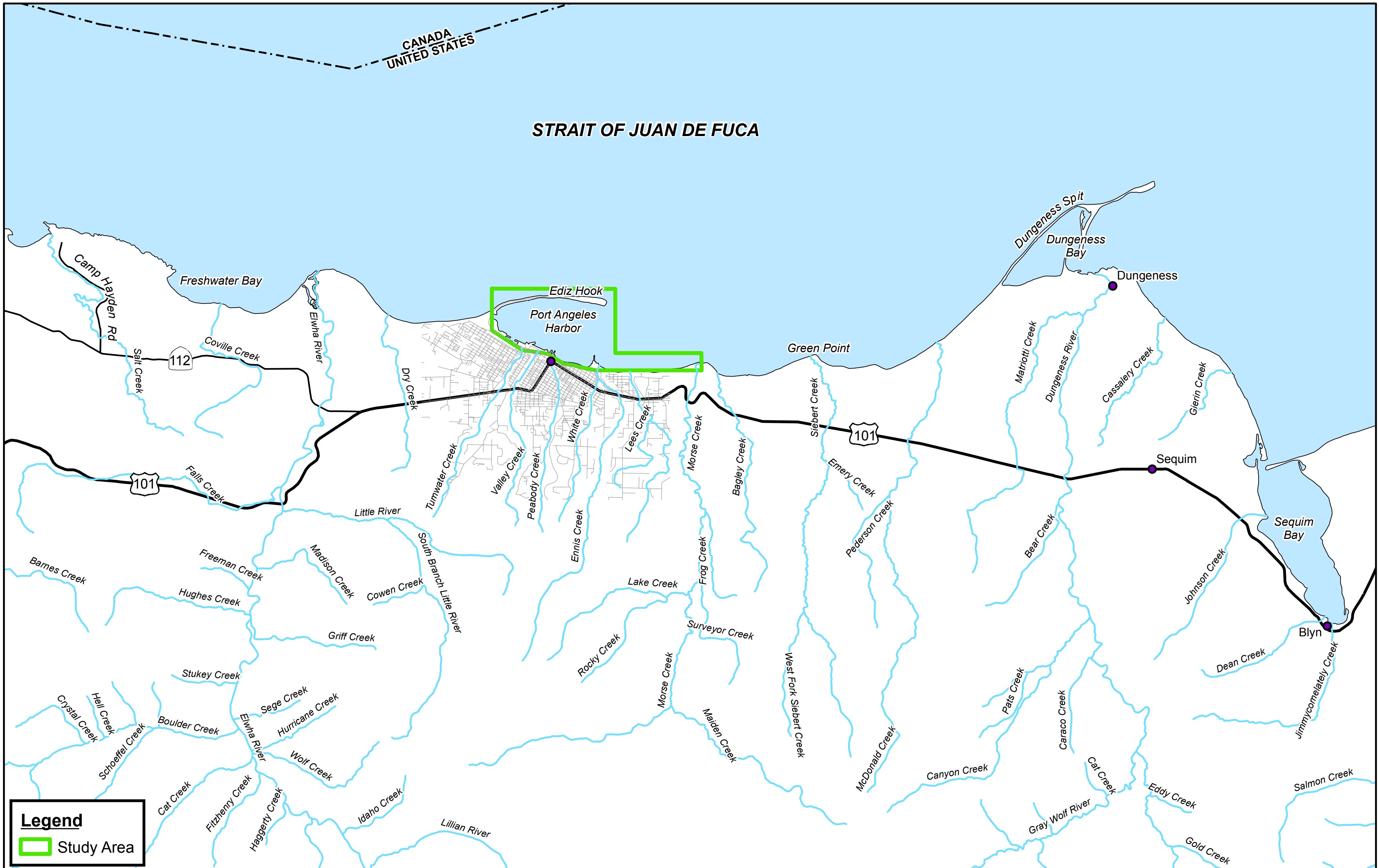

Figure 1-1

Port Angeles Harbor, Washington

Project Vicinity Map

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Figure 1-2

Port Angeles Harbor, Washington

Port Angeles Harbor and Vicinity

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N W E S

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Feet

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Figure 1-3

Port Angeles Harbor, Washington

Port Angeles Harbor Areas of Concern

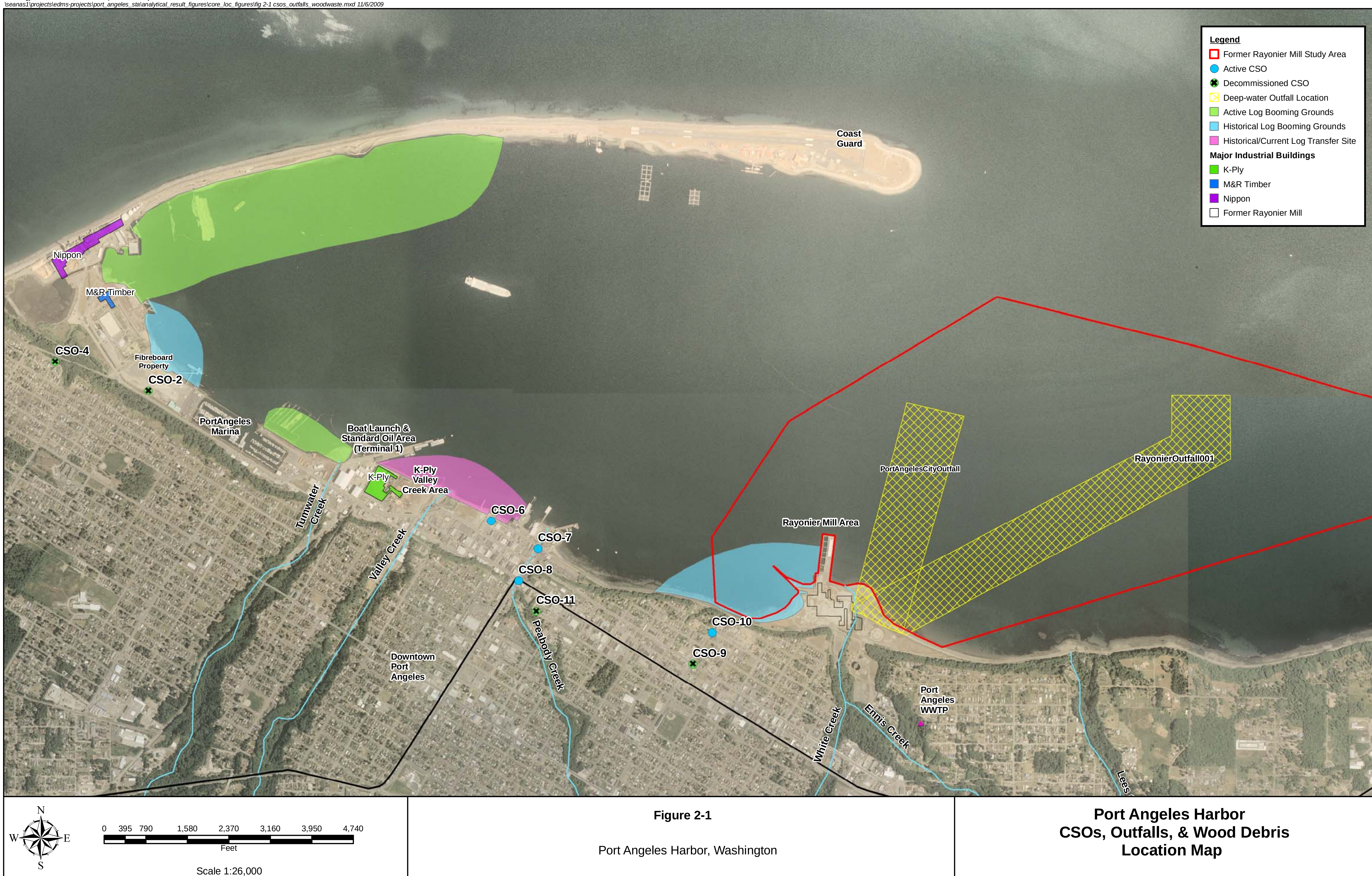

Figure 2-1

Port Angeles Harbor, Washington

Port Angeles Harbor CSOs, Outfalls, & Wood Debris Location Map

N
W E
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Miles

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Figure 3-1

Port Angeles Harbor, Washington

Port Angeles Harbor
Grab Sample Locations

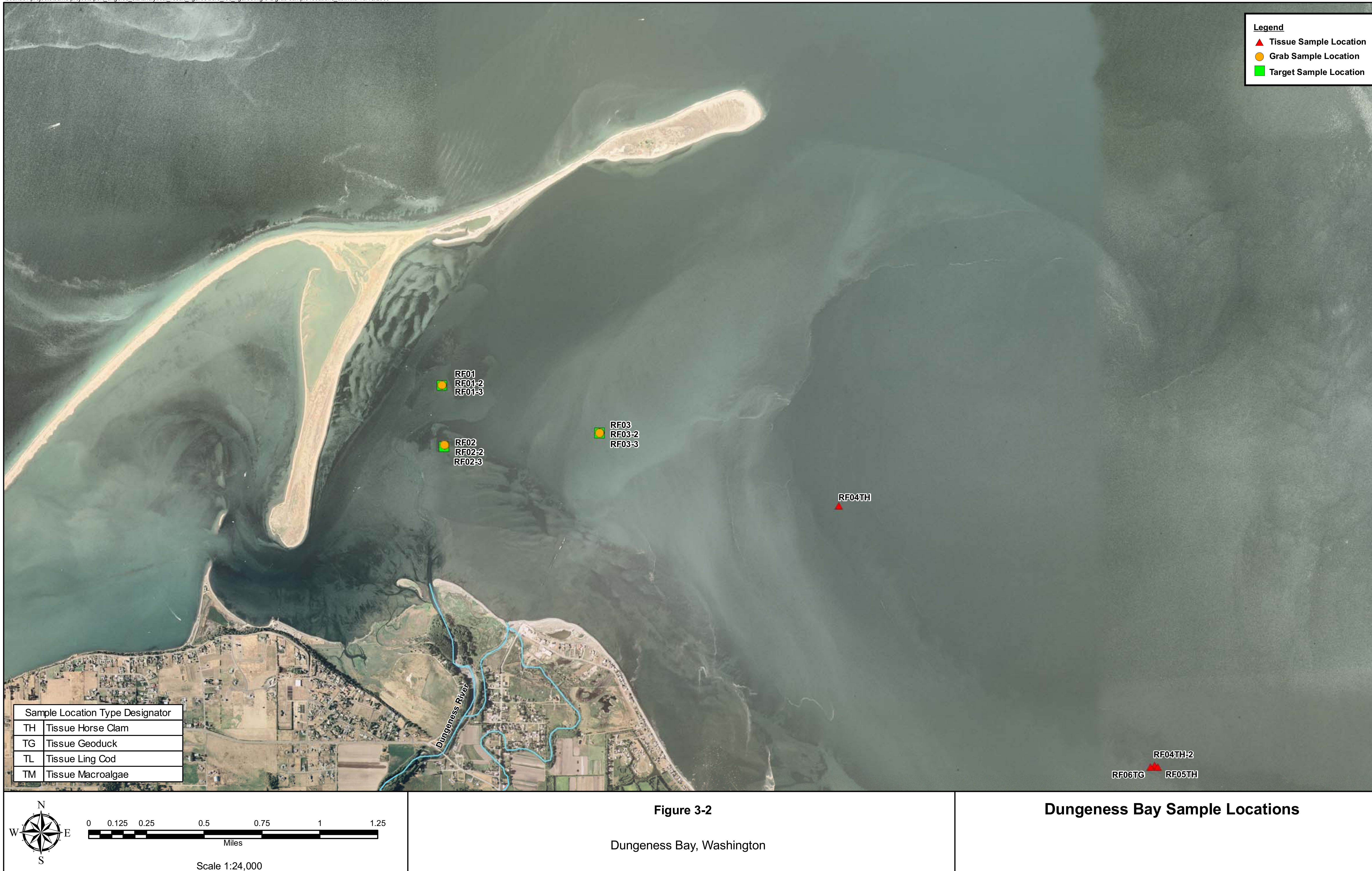

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Figure 3-2

Dungeness Bay, Washington

Dungeness Bay Sample Locations

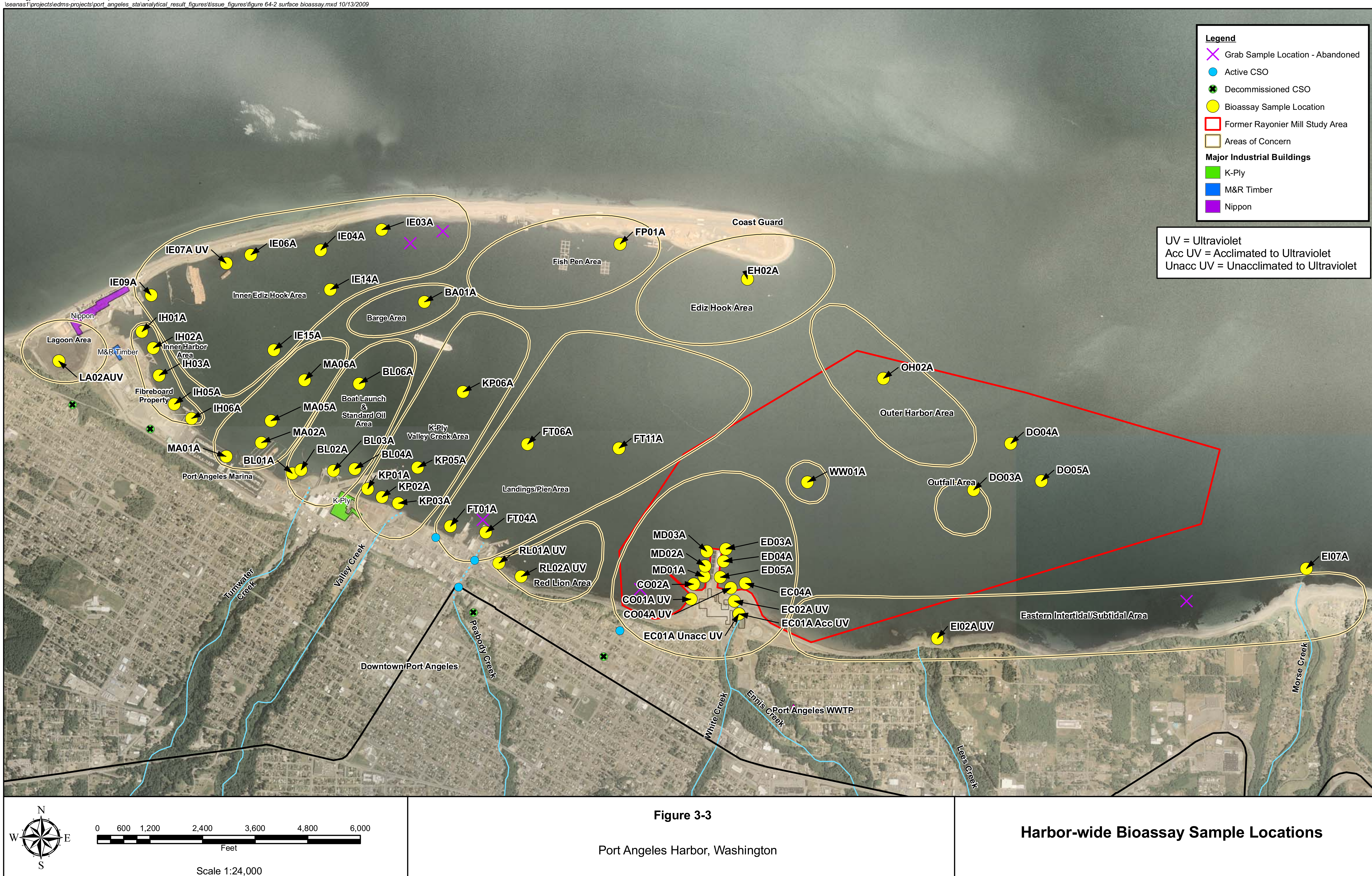

Figure 3-3

Port Angeles Harbor, Washington

Harbor-wide Bioassay Sample Locations

Figure 3-4

Port Angeles Harbor, Washington

Port Angeles Harbor Subsurface Core Sample Locations

Sample Location Type Designator	
TH	Tissue Horse Clam
TG	Tissue Geoduck
TL	Tissue Ling Cod
TM	Tissue Macroalgae

Figure 3-5

Port Angeles Harbor, Washington

Port Angeles Harbor Tissue Sample Locations

(for location of Reference Area Tissue Sample Locations see Figure 3-2)

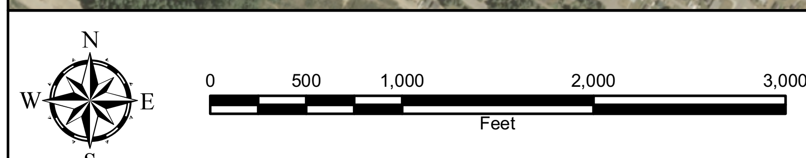

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Figure 5.1-1

Port Angeles Harbor, Washington

Port Angeles Inner-Harbor Percent Fines, Percent TOC, Ammonia, and Sulfide Grab Sample Results

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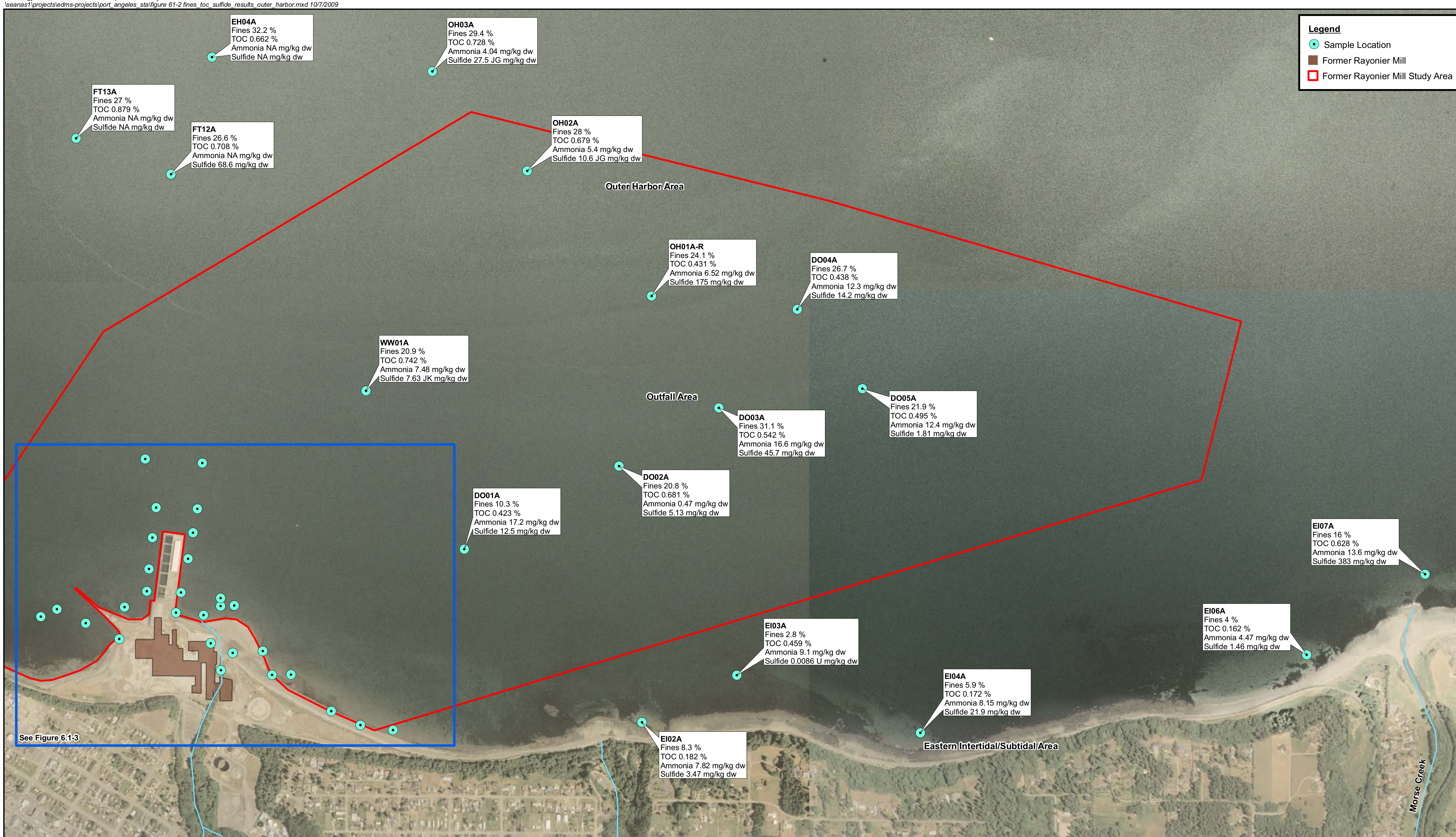

N W E S

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Feet

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Figure 5.1-2

Port Angeles Harbor, Washington

Port Angeles Outer-Harbor Percent Fines, Percent TOC, Ammonia, and Sulfide Grab Sample Results

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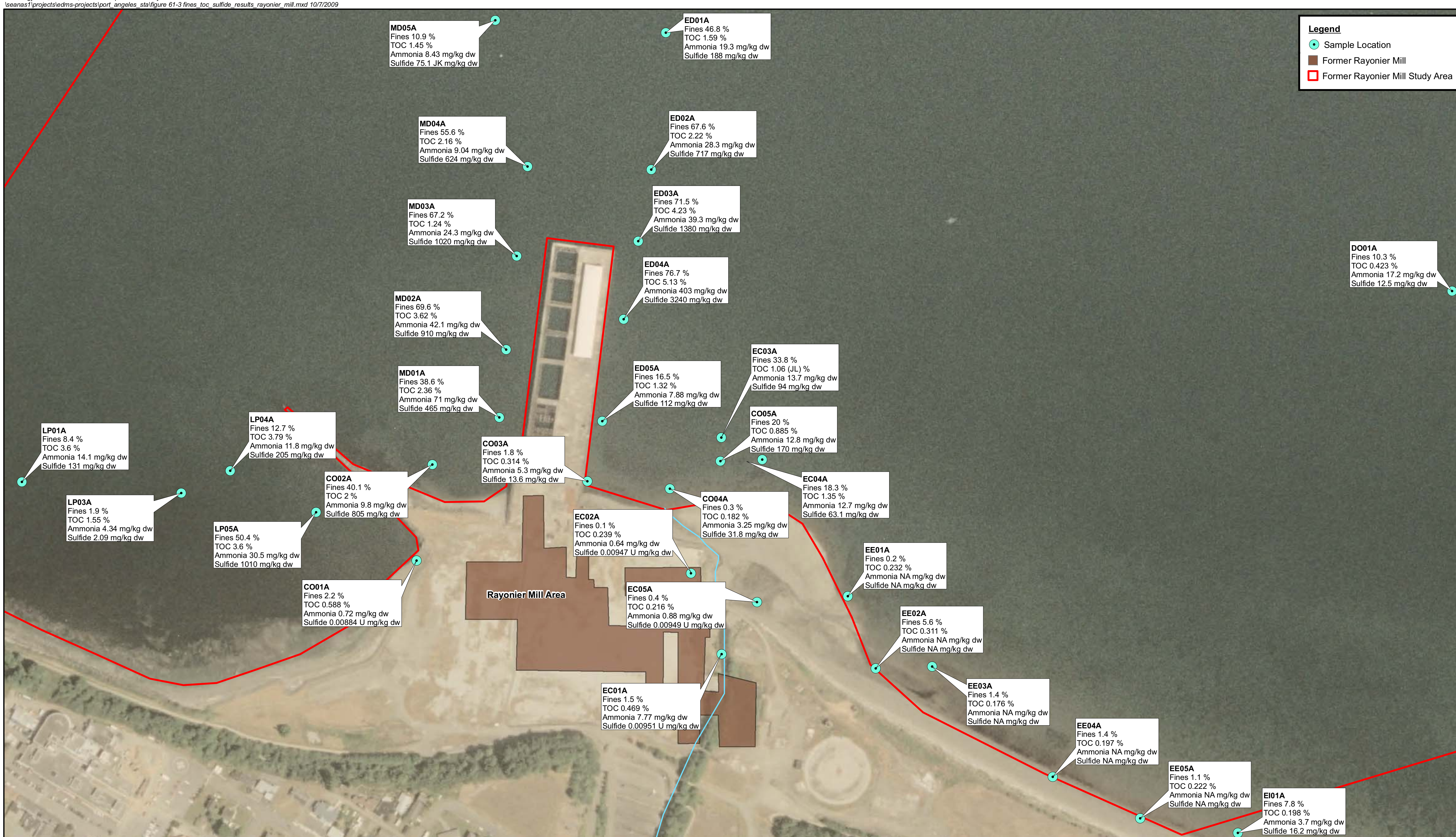

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Feet

Scale 1:4,000

Figure 5.1-3

Port Angeles Harbor, Washington

Rayonier Mill Area
Percent Fines, Percent TOC, Ammonia, and Sulfide Grab Sample Results

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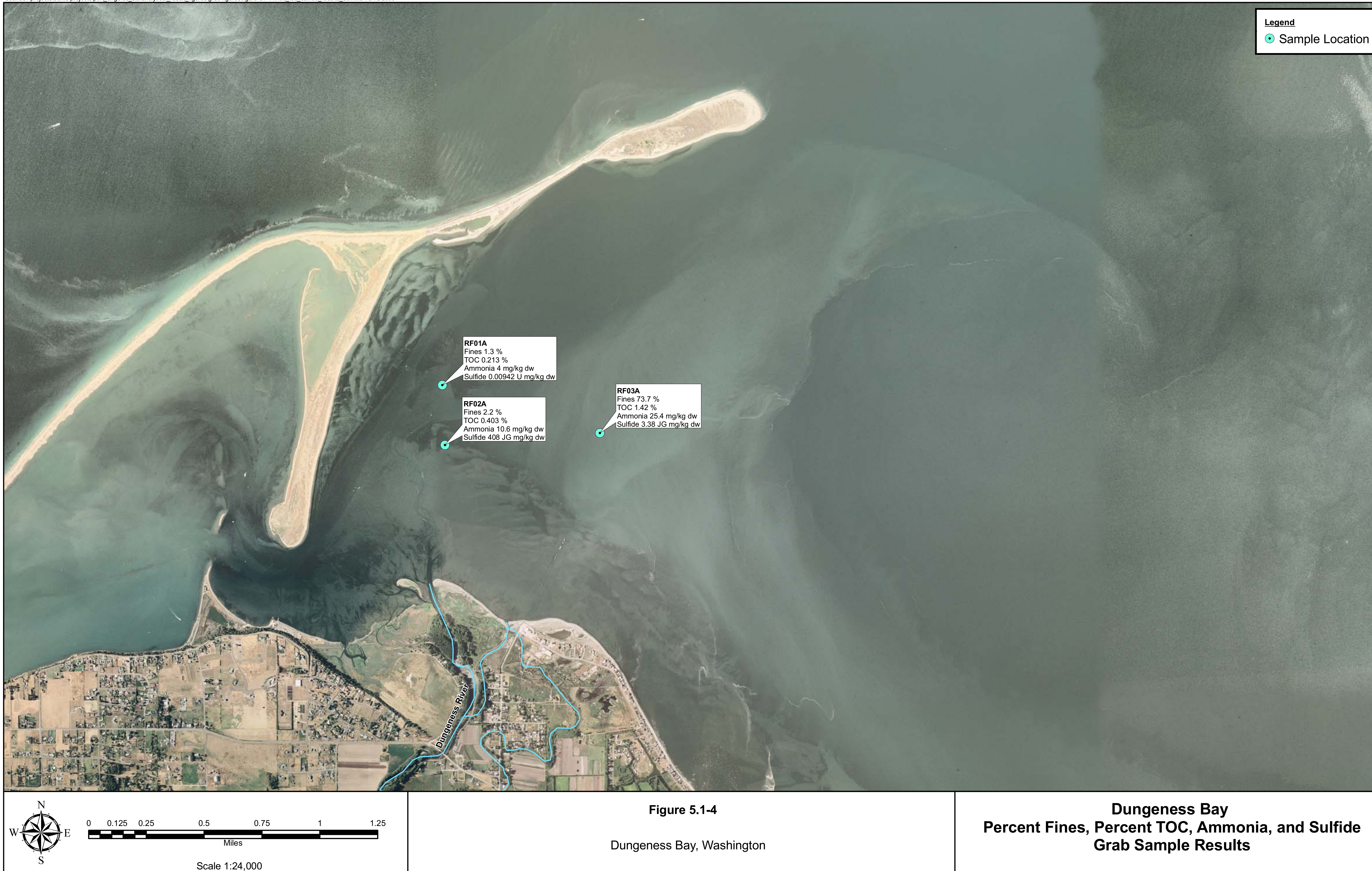


Figure 5.1-4

Dungeness Bay, Washington

Dungeness Bay
Percent Fines, Percent TOC, Ammonia, and Sulfide
Grab Sample Results

N W E S

0 375 750 1,500 2,250 Feet

Scale 1:12,000

Figure 5.1-5

Port Angeles Harbor, Washington

Port Angeles Inner-Harbor Arsenic, Cadmium, Mercury, and Zinc Grab Sample Results

N W E S

0 500 1,000 2,000 3,000
Feet

Scale 1:12,000

Figure 5.1-6

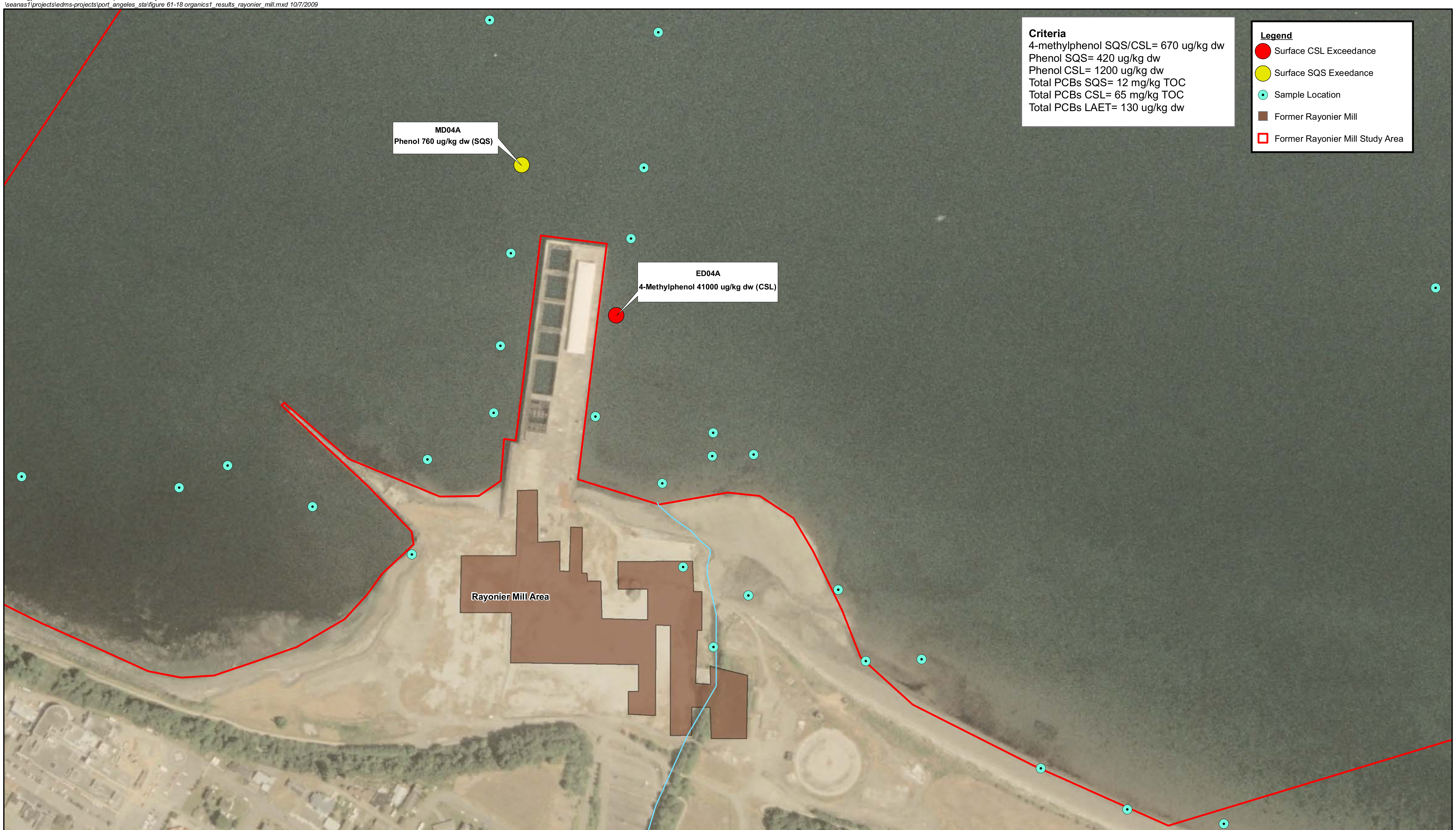
Port Angeles Harbor, Washington

Port Angeles Inner-Harbor Phthalates Grab Sample Results

Figure 5.1-7

Port Angeles Harbor, Washington

Port Angeles Inner-Harbor 4-Methylphenol, Phenol, and Total PCBs Grab Sample Results



N W E S
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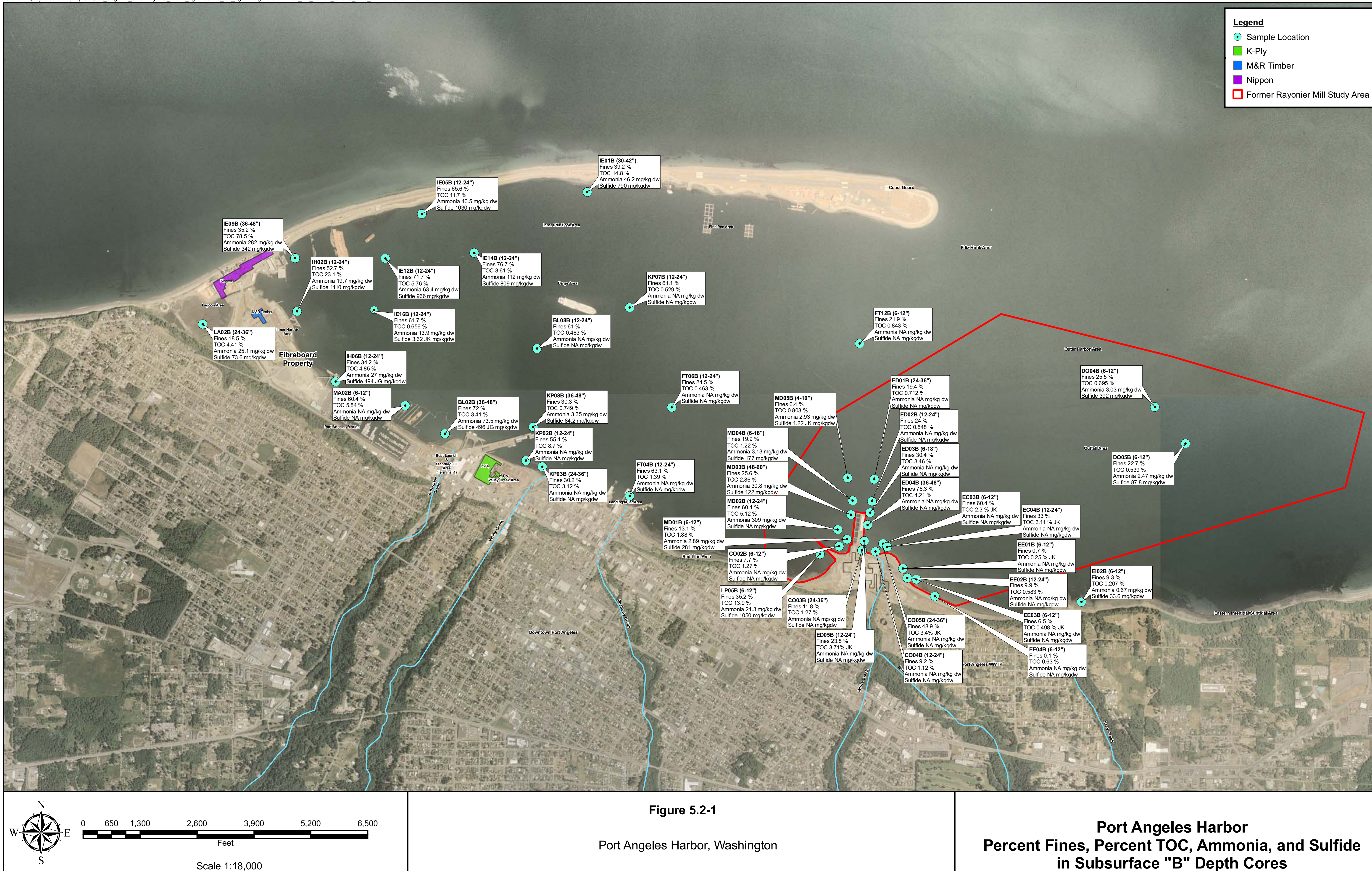
Feet
Scale 1:4,000

Figure 5.1-8

Port Angeles Harbor, Washington

Rayonier Mill Area
4-Methylphenol, Phenol, and Total PCBs
Grab Sample Results



Scale 1:18,000

Figure 5.2-1

Port Angeles Harbor, Washington

Port Angeles Harbor
Percent Fines, Percent TOC, Ammonia, and Sulfide in Subsurface "B" Depth Cores

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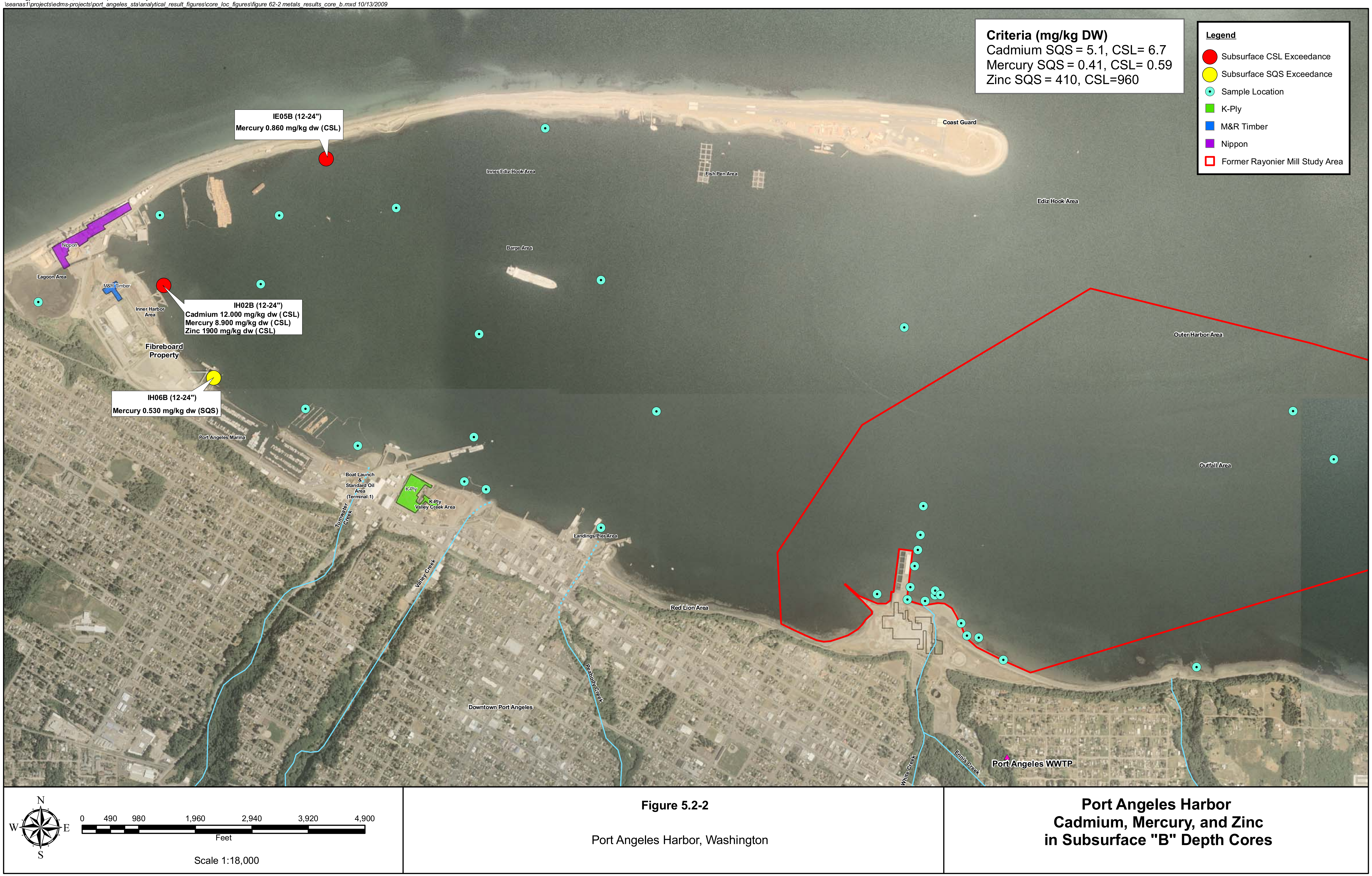
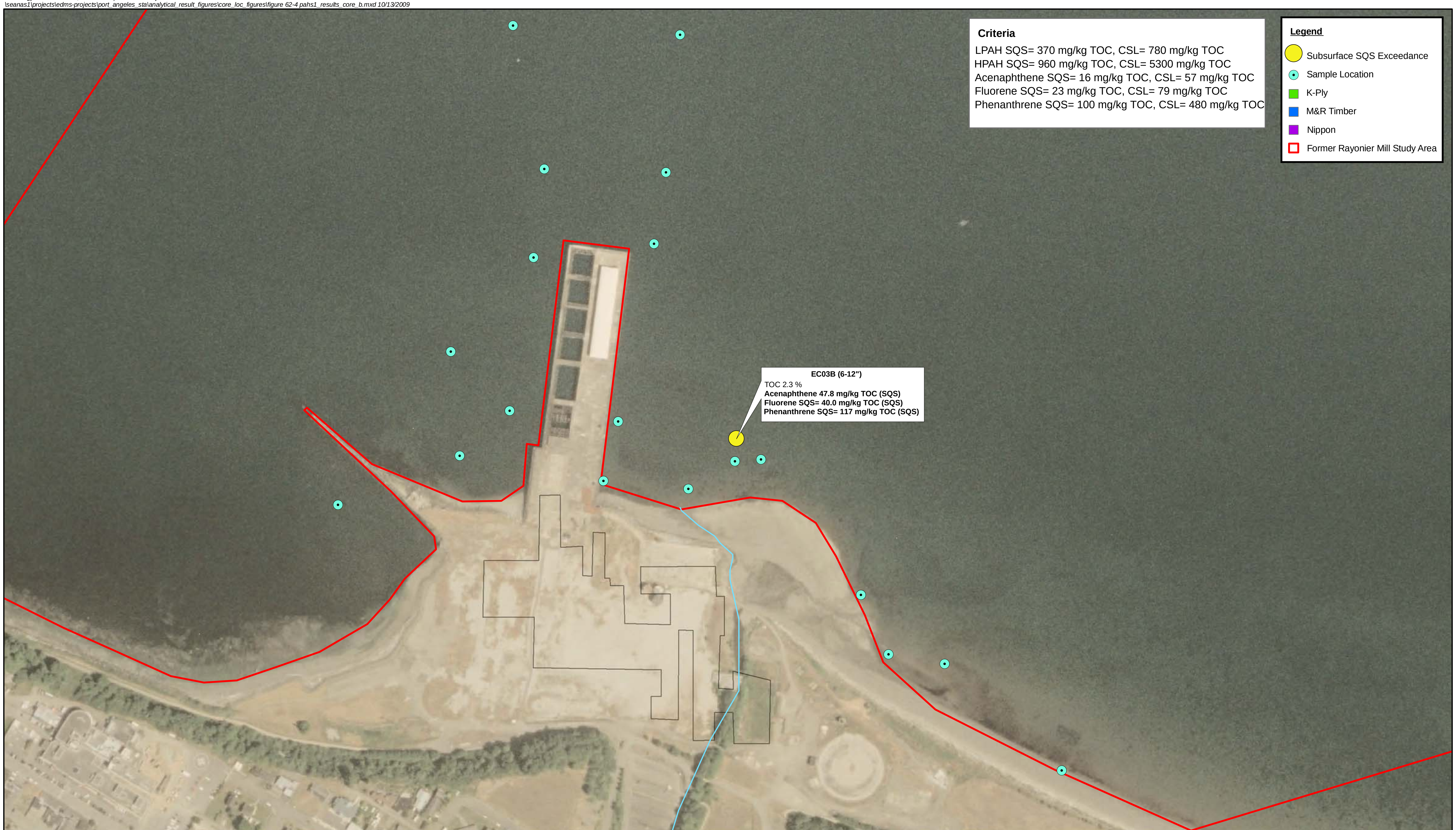


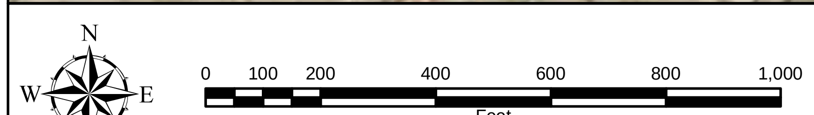
Scale 1:18,000

Figure 5.2-2

Port Angeles Harbor, Washington

Port Angeles Harbor Cadmium, Mercury, and Zinc in Subsurface "B" Depth Cores



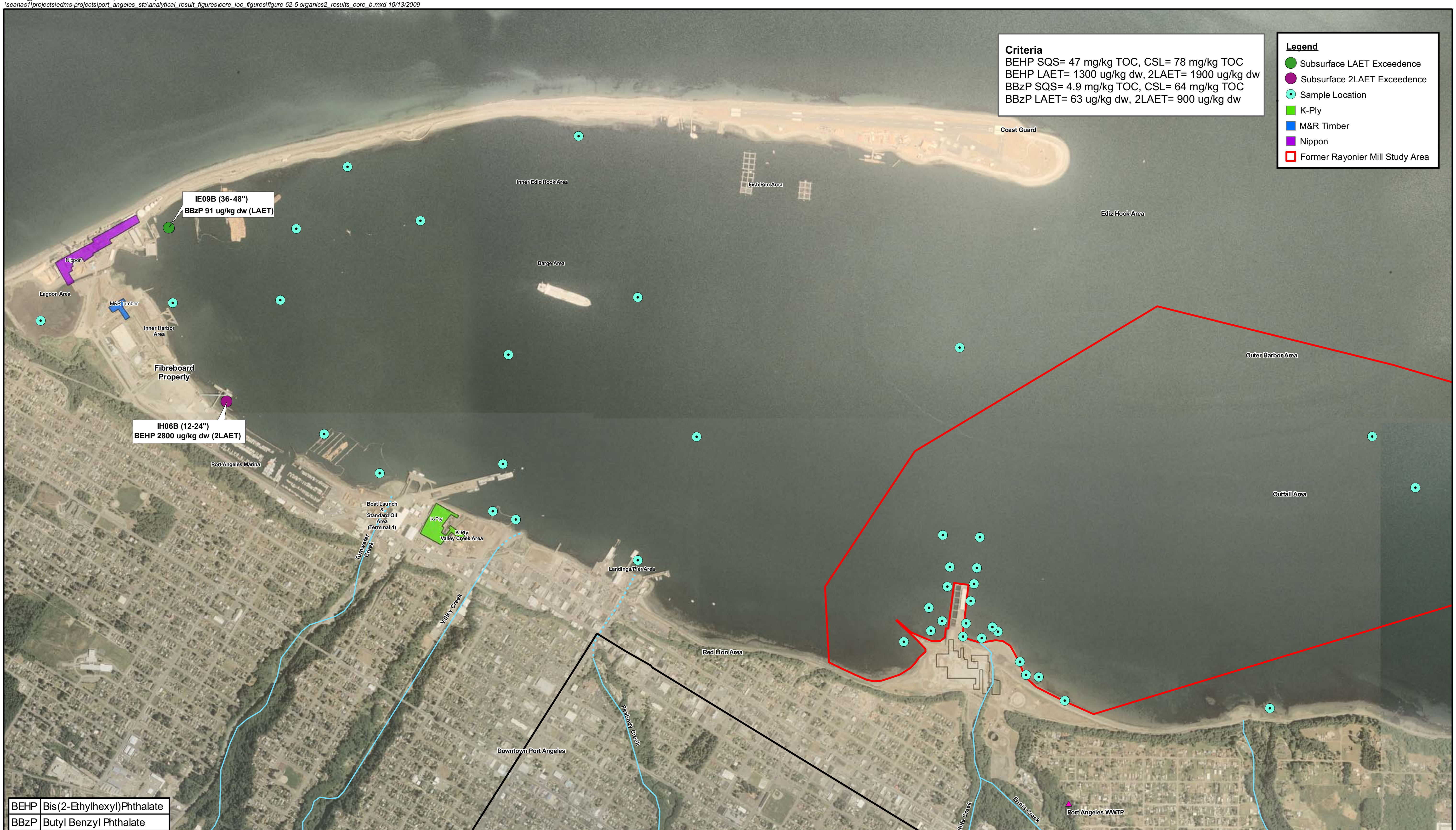


Scale 1:4,000

Figure 5.2-3

Port Angeles Harbor, Washington

Rayonier Mill Area PAHs in Subsurface "B" Depth Cores



N
W E
S

0 495 990 1,980 2,970 3,960 4,950

Feet

Scale 1:18,000

Figure 5.2-4

Port Angeles Harbor, Washington

Port Angeles Harbor
Bis(2-Ethylhexyl)Phthalate and Butyl Benzyl Phthalate in Subsurface "B" Depth Cores

N W E S

0 495 990 1,980 2,970 3,960 4,950
Feet
Scale 1:18,000

Figure 5.2-5

Port Angeles Harbor, Washington

Port Angeles Harbor 4-Methylphenol and Total PCBs in Subsurface "B" Depth Cores

N
W E
S

0 485 970 1,940 2,910 3,880 4,850
Feet

Scale 1:18,000

Figure 5.3-1

Port Angeles Harbor, Washington

Port Angeles Harbor
Percent Fines, Percent TOC, Ammonia, and Sulfide in Subsurface "C" and "D" Cores

N
W E
S

0 490 980 1,960 2,940 3,920 4,900
Feet

Scale 1:18,000

Figure 5.3-2

Port Angeles Harbor, Washington

Port Angeles Harbor
Mercury
in Subsurface "C" and "D" Cores

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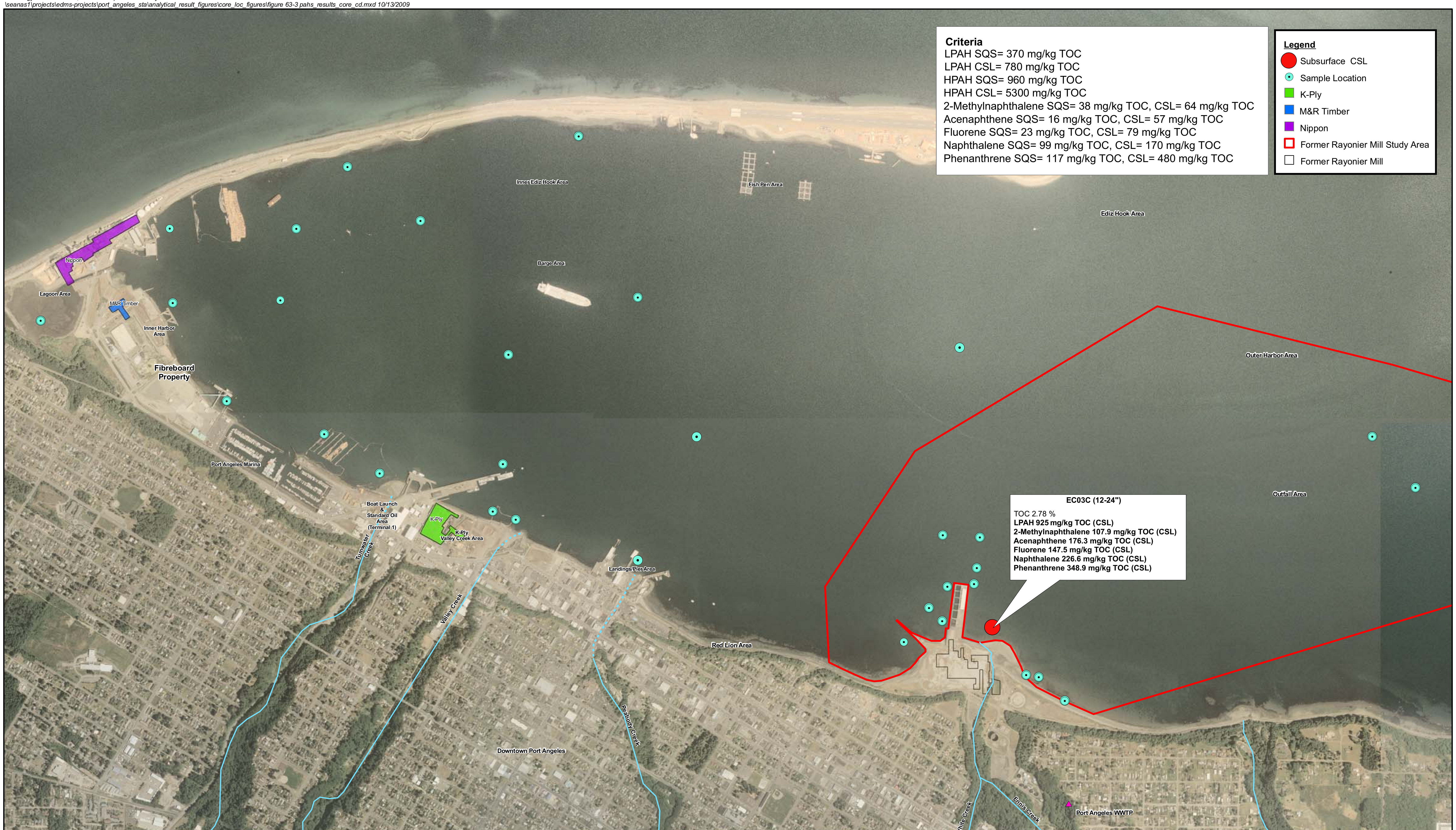

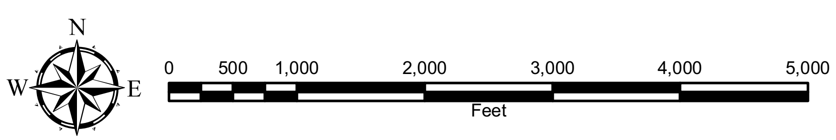

Scale 1:18,000

Figure 5.3-3

Port Angeles Harbor, Washington

Port Angeles Harbor PAHs in Subsurface "C" and "D" Cores

N
W E
S

0 425 850 1,700 2,550 3,400 4,250
Feet

Scale 1:18,000

Figure 5.3-4

Port Angeles Harbor, Washington

Port Angeles Harbor Total PCBs and Pesticides in Subsurface "C" Cores

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LA01A TOC= 11.7%

Analyte	Result	Criterion	Unit
Cadmium	5.9	5.1 (SQS)	mg/kg DW
Mercury	0.45	0.41 (SQS)	mg/kg DW

LA03A TOC= 9.2%

Analyte	Result	Criterion	Unit
Mercury	0.59	0.41 (SQS)	mg/kg DW
Butyl benzyl phthalate	73	63 (LAET)	ug/kg DW

IE09A TOC= 3.3%

Analyte	Result	Criterion	Unit
Mercury	1.2	0.59 (CSL)	mg/kg DW
Zinc	860	410 (SQS)	mg/kg DW

IE13A TOC= 8.3%

Analyte	Result	Criterion	Unit
Mercury	1.9	0.59 (CSL)	mg/kg DW
Zinc	610	410 (SQS)	mg/kg DW

IH01A TOC=17.2%

Analyte	Result	Criterion	Unit
Cadmium	7.4	5.1 (SQS)	mg/kg DW
Mercury	3.5	0.59 (CSL)	mg/kg DW
Zinc	1600	960 (CSL)	mg/kg DW

LA02A TOC= 10.3%

Analyte	Result	Criterion	Unit
Mercury	0.59	0.41 (SQS)	mg/kg DW

IE16A TOC= 4.9%

Analyte	Result	Criterion	Unit
Mercury	1.3	0.59 (CSL)	mg/kg DW

MA03A TOC= 4.0%

Analyte	Result	Criterion	Unit
Phenol	610	420 (SQS)	ug/kg DW

MD04A TOC= 2.2%

Analyte	Result	Criterion	Unit
Phenol	760	420 (SQS)	ug/kg DW

IH02A TOC= 25.4%

Analyte	Result	Criterion	Unit
Arsenic	69	0.41 (SQS)	mg/kg DW
Mercury	1.3	0.59 (CSL)	mg/kg DW
Zinc	460	410 (SQS)	mg/kg DW

MA04A TOC= 8.5%

Analyte	Result	Criterion	Unit
Phenol	740	420 (SQS)	ug/kg DW
Butyl benzyl phthalate	670	63 (LAET)	ug/kg DW

ED04A TOC= 5.1%

Analyte	Result	Criterion	Unit
4-Methylphenol	41000	670 (CSL)	ug/kg DW

MA01A TOC= 1.13%

Analyte	Result	Criterion	Unit
bis(2-Ethylhexyl)phthalate	49.6	47 (SQS)	mg/kg TOC

Figure 5.4-1

Port Angeles Harbor, Washington

Harbor-wide Surface Samples in Exceedence of SQS, CSL or LAET

IE05B (12-24") TOC= 11.7%			
Analyte	Result	Criterion	Unit
Mercury	0.86	0.59 (CSL)	mg/kg DW

IE09B (36 - 48") TOC= 78.5%			
Analyte	Result	Criterion	Unit
Butylbenzylphthalate	91	63 (LAET)	ug/kg DW

IH02B (12-24") TOC=23.1%			
Analyte	Result	Criterion	Unit
Cadmium	12	6.7 (CSL)	mg/kg DW
Mercury	8.9	0.59 (CSL)	mg/kg DW
Zinc	1900	960 (CSL)	mg/kg DW

MA02C (12-24") TOC= 3.5%			
Analyte	Result	Criterion	Unit
Mercury	0.5	0.41 (SQS)	mg/kg DW

IH06B (12-24") TOC= 4.9%			
Analyte	Result	Criterion	Unit
Mercury	0.53	0.41 (SQS)	mg/kg DW
Bis(2-ethylhexyl) phthalate	2800	1900 (2LAET)	ug/kg DW

FT04C (36 - 48") TOC= 2.43%			
Analyte	Result	Criterion	Unit
4,4'-DDD	65	43(2LAET)	µg/kg DW
4,4'-DDE	14	9 (LAET)	µg/kg DW

ED05B (12 - 24") TOC = 3.71%			
Analyte	Result	Criterion	Unit
Total PCB	250	130 (LAET)	ug/kg DW

EC03C (6-12") TOC= 2.3%			
Analyte	Result	Criterion	Unit
Total PCBs	13.5	12 (SQS)	mg/kg TOC
Acenaphthene	47.8	16 (SQS)	mg/kg TOC
Fluorene	40	23 (SQS)	mg/kg TOC
Phenanthrene	117	100 (SQS)	mg/kg TOC
4-Methyl phenol	690	670 (CSL)	ug/kg DW

EC03C (12-24") TOC= 2.8%			
Analyte	Result	Criterion	Unit
Total PCBs	14.7	12 (SQS)	mg/kg TOC
2-Methylnaphthalene	107.9	64 (CSL)	mg/kg TOC
Acenaphthene	176.3	57 (CSL)	mg/kg TOC
Fluorene	147.5	79 (CSL)	mg/kg TOC
Naphthalene	226.6	170 (CSL)	mg/kg TOC
Phenanthrene	348.9	100 (SQS)	mg/kg TOC
Total LPAH	925	780 (CSL)	mg/kg TOC

Figure 5.4-2

Port Angeles Harbor, Washington

Harbor-wide Subsurface Samples in Exceedence of SQS, CSL or LAET

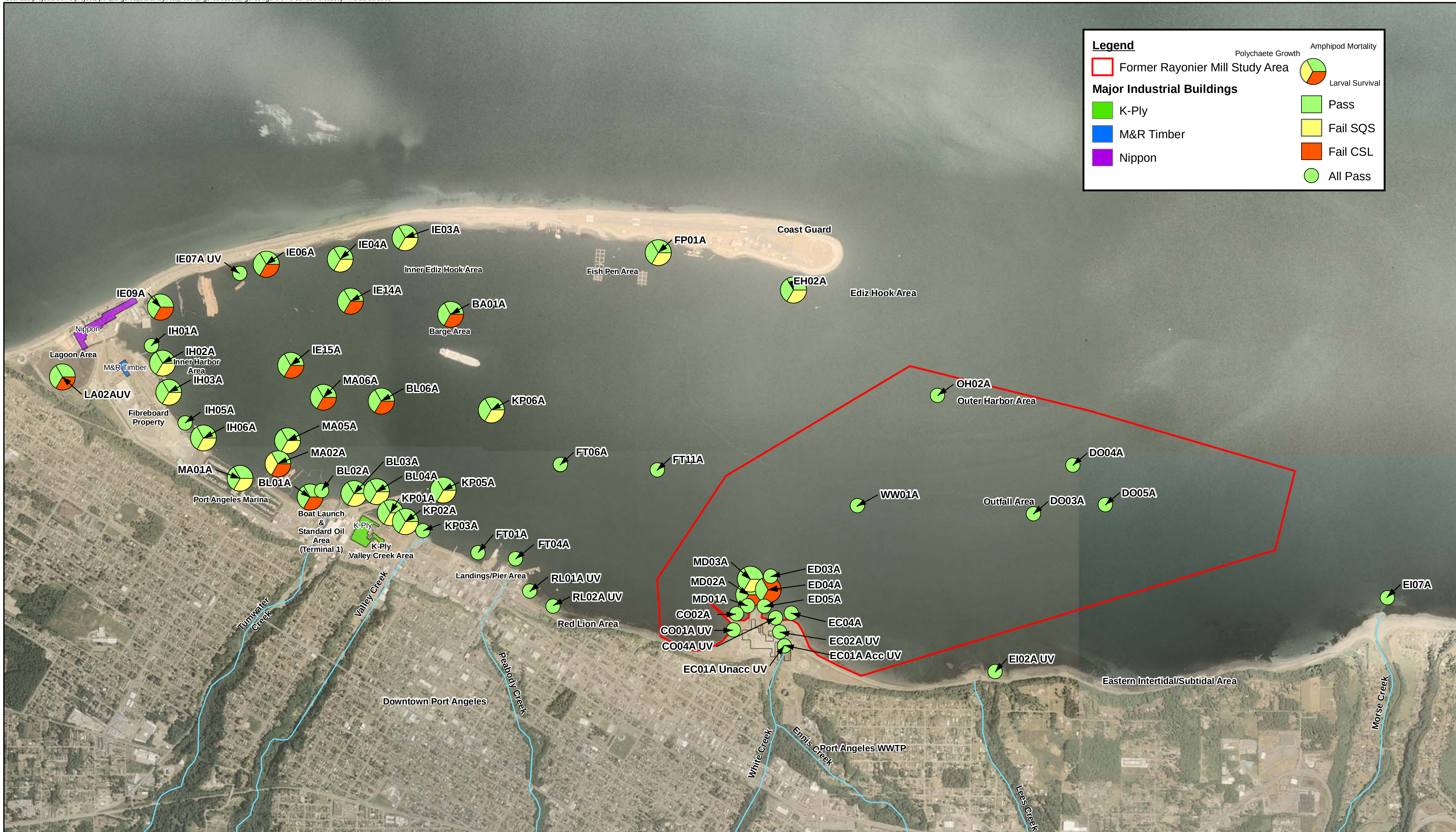

Figure 6-1

Port Angeles Harbor, Washington

Harbor-wide Bioassay Samples with CSL and SQS Failures

N
W E
S

0 500 1,000 2,000 3,000 4,000 5,000
Feet
Scale 1:18,000

Figure 8-1

Port Angeles Harbor, Washington

Port Angeles Harbor
Active and Historical Areas where Log Rafting and Barging of Wood Chips/Sawdust were Located

(SAIC 1999)

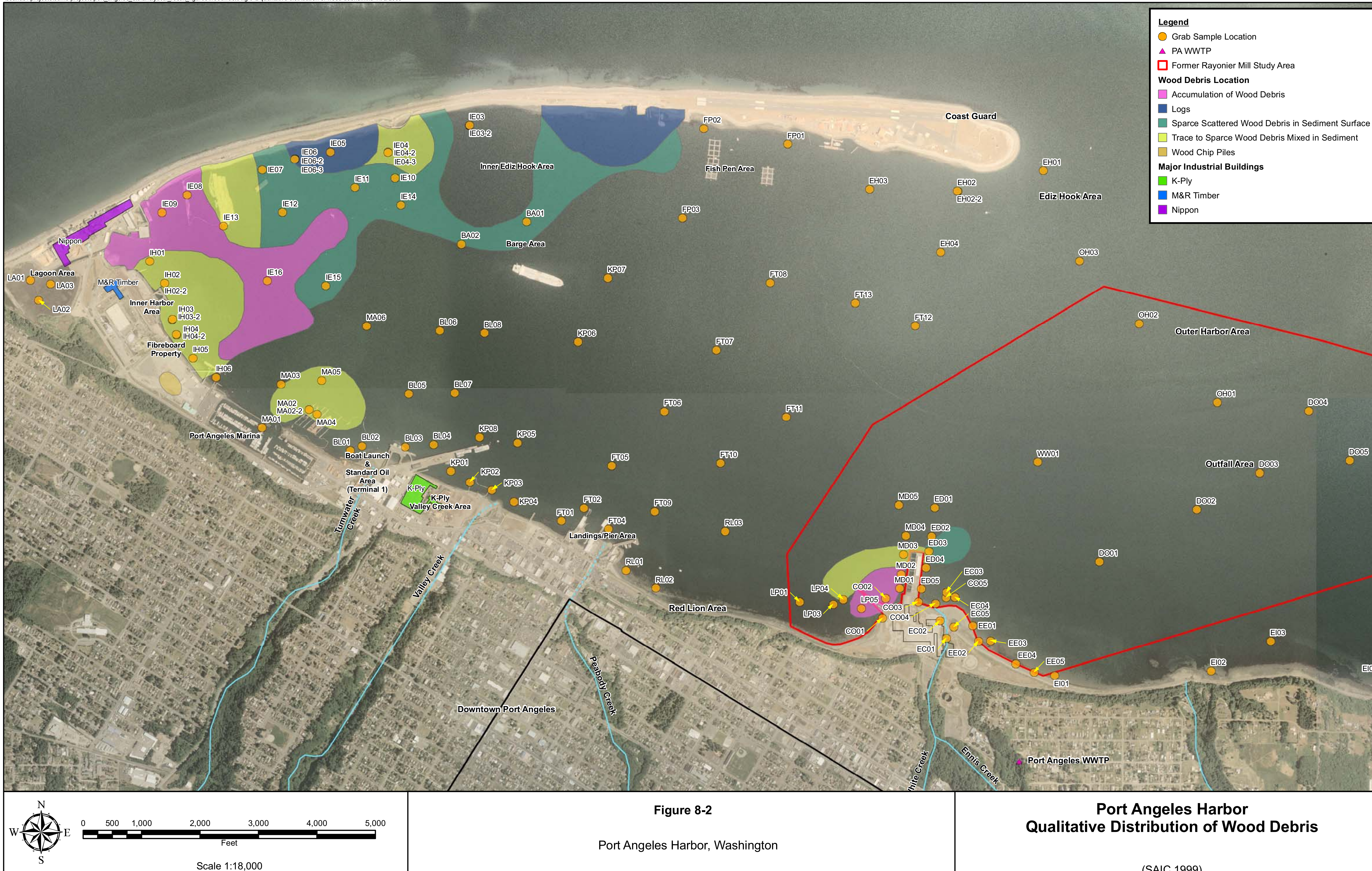

Figure 8-2

Port Angeles Harbor, Washington

Port Angeles Harbor Qualitative Distribution of Wood Debris

(SAIC 1999)

N
W E
S

0 500 1,000 2,000 3,000 4,000 5,000
Feet
Scale 1:18,000

Figure 8-3

Port Angeles Harbor, Washington

Port Angeles Harbor
Approximate Distribution of Wood Debris

Samples were collected as part of the sediment trend analysis (GeoSea 2009)

Figure 8-4

Port Angeles Harbor, Washington

Port Angeles Harbor
Approximate Distribution of Wood Chips and Sawdust

Samples were collected as part of the sediment trend analysis (GeoSea 2009)

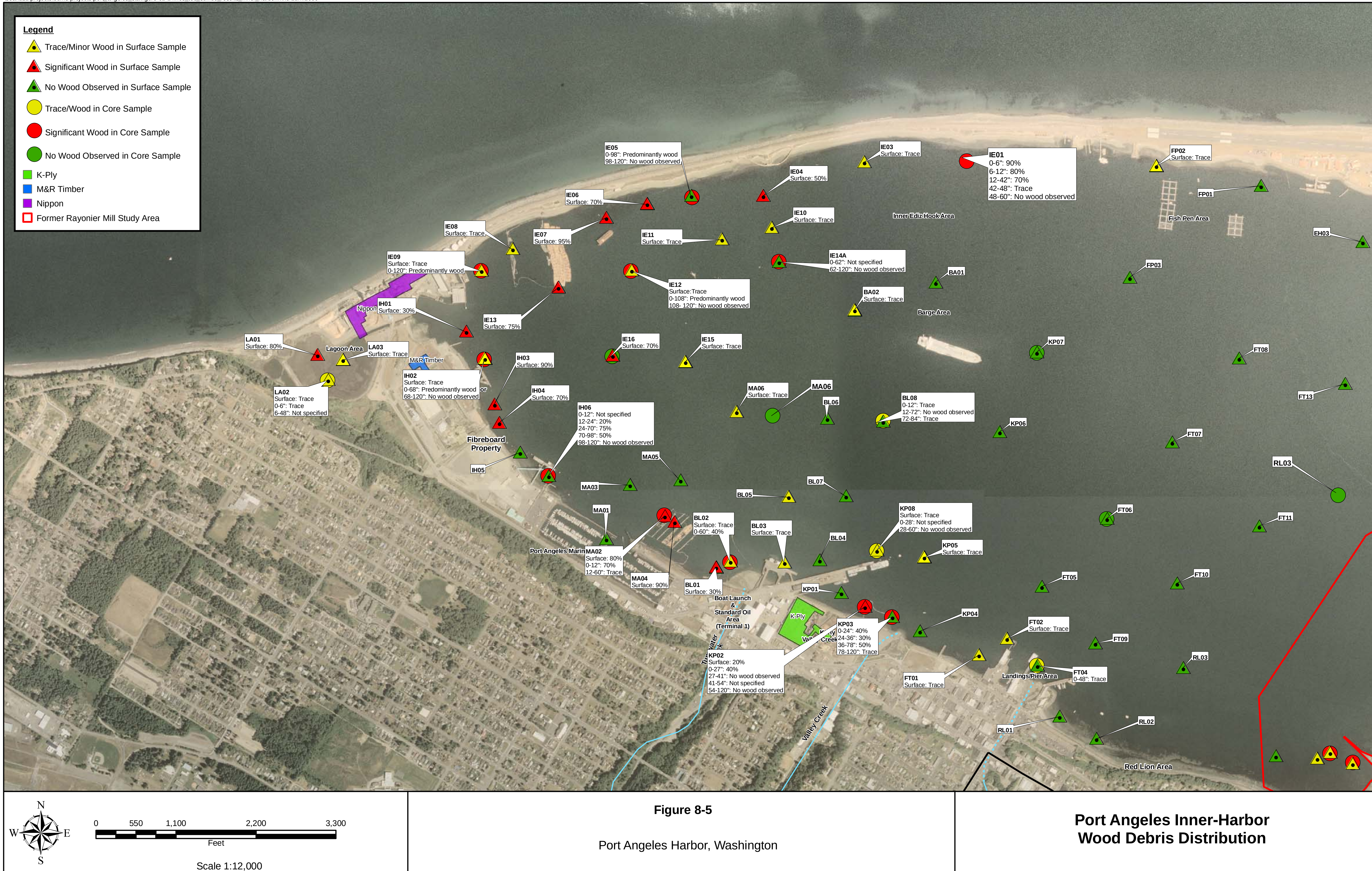

Figure 8-5

Port Angeles Harbor, Washington

Port Angeles Inner-Harbor Wood Debris Distribution

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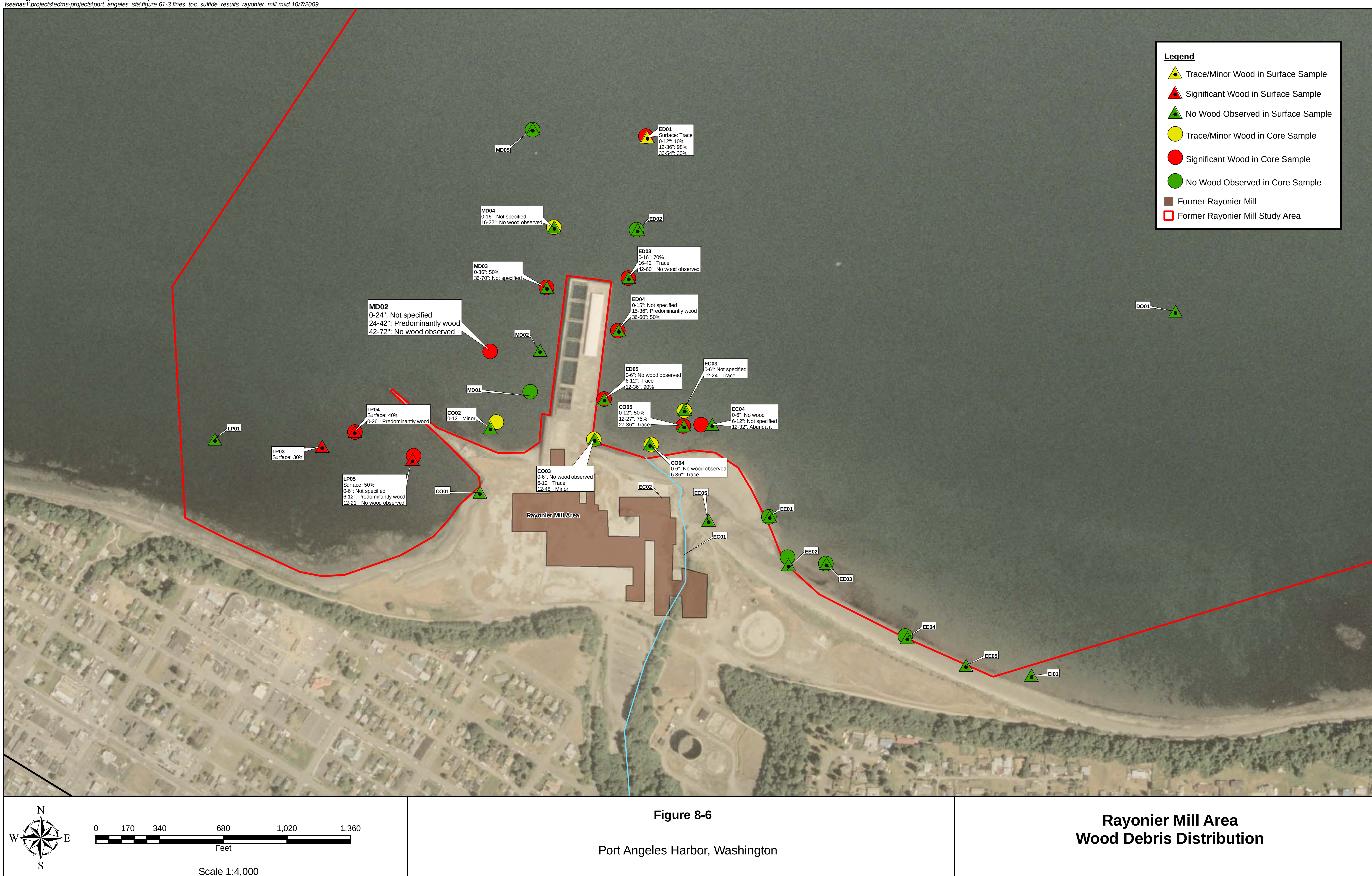

Scale 1:4,000

Figure 8-6

Port Angeles Harbor, Washington

Rayonier Mill Area
Wood Debris Distribution

Tables

Table 3–1. Station Designations for Samples Collected in the Harbor-Wide Study Area and the Dungeness Bay Reference Area

Field Identification	Harbor-Wide Study Area Locations	No. of Stations
EH	Ediz Hook Point	4
FP	Fish Pen Area	3
BA	Barge Area	2
IE	Inner Ediz Hook Area	16
LA	Lagoon Area	3
IH	Inner Harbor Area	6
MA	Boat Haven Marina	6
BL	Boat Launch	8
KP	K-Ply	8
FT	Landing Pier (Ferry Terminal)	13
RL	Red Lion Inn	3
WW	WWTP Outfall	1
OH	Outer Harbor	3
EI	Eastern Intertidal/Subtidal Shore	7
RF	Reference Samples	3

Table 3–2. Station Designations for Samples Collected in the Rayonier Mill Study Area

Field Identification	Rayonier Mill Study Area Locations	No. of Stations
LP	Log Pond	5
MD	Mill Dock	5
ED	East of Mill Dock	5
CO	Nearshore Outfall	5
DO	Deep Outfall	5
EC	Ennis Creek	5
EE	East of Ennis Creek	5

Table 3–3. Harbor-Wide Sample Analysis and Archive Summary

Sample ID	Station Name	Location Name	Sample Date	Sample Time	Collection Method	Sample Interval (inches)	Substrate/Other Remarks	TOC/Grain Size	SVOC	Resin Acids	Pesticides	PCBs	Dioxin/ Furan	NWTPH-Dx	Organotin	SMS Metals	Mercury	Sulfides	Ammonia	Bioassay
BA01A	Barge Area	Harbor-wide	6/7/2008	10:57	Grab	Surface	Surface of sediment is olive drab to 4 centimeters.	X	A	X				X		X	X	X	X	X
BA02A	Barge Area	Harbor-wide	6/7/2008	11:50	Grab	Surface	Upper sediment to 1 cm is light brown with olive drab.	X	A					X		X	X			
BL01A	Boat Launch	Harbor-wide	6/19/2008	9:44	Grab	Surface	Brown at surface. Strong hydrogen sulfide odor. Approximately 30% wood debris.	X	X	X	X	X	X	X	X	X	X	X	X	X
BL01A MS/MSD	Boat Launch	Harbor-wide	6/19/2008	9:44	Grab	Surface	MS/MSD		X	X				X	X		X	X	X	
BL02A	Boat Launch	Harbor-wide	6/13/2008	15:09	Grab	Surface	Olive color at surface. Wood debris toward bottom. No biota.	X	X	X	X	X	X	X	X	X	X	X	X	X
BL02B	Boat Launch	Harbor-wide	6/8/2008	16:11	Vibracore	36–48	Mixed sand/silt/woody debris and pockets of clay. Moderate sulfur odor.	X	X	X	X	X	X			X	X	X	X	
BL02C	Boat Launch	Harbor-wide	6/8/2008	16:11	Vibracore	60–78	Mixed sand/silt/woody debris and pockets of clay. Moderate sulfur odor.	X	X	X	X	X	X			X	X	X	X	
BL03A	Boat Launch	Harbor-wide	6/13/2008	14:19	Grab	Surface	Olive color at surface. Small amount of woody debris. Shell fragments. No apparent biota. Strong hydrogen sulfide odor.	X	X	X		X	X	X	X	X	X	X	X	X
BL04A	Boat Launch	Harbor-wide	6/13/2008	13:13	Grab	Surface	Some sheen noted. Slight odor -unknown, described as "strange". Sediment is cobble, gravel, sand (VC to VF) with little clay and silt. Shell debris present.	X	X			X	X	X	X	X	X	X	X	X
BL05A	Boat Launch	Harbor-wide	6/9/2008	15:00	Grab	Surface	Fine sand/silt/clay with drab olive surface and gray/black below. No odor. Many polychaetes, some wood debris.	X	A	A		X	A			X	X			
BL06A	Boat Launch	Harbor-wide	6/11/2008	15:11	Grab	Surface	Brown surface. Sandy silt with trace clay. No odor.	X	X			X	X			X	X	X	X	X
BL07A	Boat Launch	Harbor-wide	6/9/2008	15:34	Grab	Surface	Brown surface. No wood debris. No odor.	X	A			X	A			A	X			
BL08A	Boat Launch	Harbor-wide	6/9/2008	16:08	Grab	Surface	Brown surface. Silt grades into clay. No wood. No odor.	X	X	A		X	X			X	X	X	X	
BL08B	Boat Launch	Harbor-wide	6/11/2008	10:39	Vibracore	12–24	Olive gray silt and clay. Shell fragments and whole shells.	X	X	X			X			X	X			
BL08C	Boat Launch	Harbor-wide	6/11/2008	10:39	Vibracore	36–48	Olive gray silt and clay. Shell fragments and whole shells.	X	X	X			X			X	X			
EH01A	Ediz Hook	Harbor-wide	6/8/2008	14:58	Grab	Surface	Brown sand with cobble. No odor.	X	A					X		X	X			
EH02A	Ediz Hook	Harbor-wide	6/7/2008	7:48	Grab	Surface	Silty fine grained sand. Required 2 grabs to complete (at 07:48 and at 08:39).	X	A					X		X	X	X	X	X
EH03A	Ediz Hook	Harbor-wide	6/8/2008	15:32	Grab	Surface	Drab olive sandy silt. No odor.	X	A					X		X	X			
EH04A	Ediz Hook	Harbor-wide	6/6/2008	16:47	Grab	Surface	Silt with trace sand. Olive drab and brown to 3 centimeters. No wood debris.	X	A							X	X			
EI01A	Eastern Intertidal	Harbor-wide	6/19/2008	11:19	Grab	Surface	Drab olive/brown surface. Gray below. Sand. No odor.	X	X		X	X				X	X	X	X	
EI01A MS/MSD	Eastern Intertidal	Harbor-wide	6/19/2008	11:19	Grab	Surface	MS/MSD		X		X	X				X	X	X	X	
EI02A	Eastern Intertidal	Harbor-wide	6/18/2008	14:10	Grab	Surface	Gray sand. No odor.	X	X		X	X	X			X	X	X	X	X
EI02B	Eastern Intertidal	Harbor-wide	7/18/2008	14:40	Vibracore	6–12	Dark gray fine sand with some shell fragments and polychaete tubes. Trace small and large gravel/small and large cobble. No organic material, no wood material, no odor.	X	X		X	X	A			X	X	X	X	
EI02C	Eastern Intertidal	Harbor-wide			Vibracore		ABANDONED													

Table 3–3. Harbor-Wide Sample Analysis and Archive Summary

Sample ID	Station Name	Location Name	Sample Date	Sample Time	Collection Method	Sample Interval (inches)	Substrate/Other Remarks	TOC/Grain Size	SVOC	Resin Acids	Pesticides	PCBs	Dioxin/ Furan	NWTPH-Dx	Organotin	SMS Metals	Mercury	Sulfides	Ammonia	Bioassay
EI03A	Eastern Intertidal	Harbor-wide	6/18/2008	13:38	Grab	Surface	Gray cobble/sand. No odor.	X	X		X	X				X	X	X	X	
EI04A	Eastern Intertidal	Harbor-wide	6/18/2008	12:57	Grab	Surface	Gray sand . No odor.	X	X		X	X	X			X	X	X	X	
EI04B	Eastern Intertidal	Harbor-wide			Vibracore		ABANDONED													
EI04C	Eastern Intertidal	Harbor-wide			Vibracore		ABANDONED													
EI05A	Eastern Intertidal	Harbor-wide			Grab		ABANDONED													
EI06A	Eastern Intertidal	Harbor-wide	6/18/2008	10:10	Grab	Surface	Gray sand. No odor.	X	X		X	X				X	X	X	X	
EI07A	Eastern Intertidal	Harbor-wide	6/18/2008	8:50	Grab	Surface	Gray/black sand with cobble/gravel. Drab olive/brown surface. No odor.	X	X		X	X	X			X	X	X	X	X
EI07B	Eastern Intertidal	Harbor-wide			Vibracore		ABANDONED													
EI07C	Eastern Intertidal	Harbor-wide			Vibracore		ABANDONED													
FP01A	Fish Ponds	Harbor-wide	6/7/2008	9:26	Grab	Surface	Silty fine grained sand. Approximately 1% wood debris.	X	A		X	X	A	X		X	X	X	X	X
FP02A	Fish Ponds	Harbor-wide	6/7/2008	12:36	Grab	Surface	Small oblong gravel. No odor.	X	A		X	X	A	X		X	X			
FP03A	Fish Ponds	Harbor-wide	6/8/2008	12:52	Grab	Surface	Brown surface layer. Clay from 8 to 10 centimeters. Slight hydrogen sulfide odor.	X	A		X	X	A	X		X	X			
FP03A MS/MSD	Fish Ponds	Harbor-wide	6/8/2008	12:52	Grab	Surface	MS/MSD							X			X			
FT01A	Ferry Terminal	Harbor-wide	6/17/2008	11:54	Grab	Surface	Light brown at surface. 5% or less wood debris and some shell debris. Very slight hydrogen sulfide odor.	X	X	A	X	X	X	X		X	X	X	X	X
FT02A	Ferry Terminal	Harbor-wide	6/17/2008	12:42	Grab	Surface	Light brown at surface. Moderate hydrogen sulfide odor. Wood and shell debris.	X	X	X	X	X		X		X	X			
FT02A MS/MSD	Ferry Terminal	Harbor-wide	6/17/2008	12:42	Grab	Surface	MS/MSD		X		X	X		X		X	X			
FT03A	Ferry Terminal	Harbor-wide			Grab		ABANDONED													
FT04A	Ferry Terminal	Harbor-wide	6/17/2008	14:27	Grab	Surface	Drab olive surface, gray below. Sand/silt. No odor.	X	X	X	X	X	X	X		X	X	X	X	X
FT04B	Ferry Terminal	Harbor-wide	6/7/2008	13:12	Vibracore	12–24	Sandy silt with some clay. Shell debris, slight sulfur odor.	X	X	X	X	X		X		X	X			
FT04C	Ferry Terminal	Harbor-wide	6/7/2008	13:12	Vibracore	36–48	Sandy silt with some clay. Shell debris, slight sulfur odor.	X	X	X	X	X		X		X	X			
FT05A	Ferry Terminal	Harbor-wide	6/12/2008	13:29	Grab	Surface	Drab olive/brown surface. Silt/clay. No odor.	X	X	X	X	A				X				
FT06A	Ferry Terminal	Harbor-wide	6/12/2008	12:31	Grab	Surface	No odor. Brown surface layer. Sand is fine grained.	X	X	X	X	X	X			X	X	X	X	X
FT06B	Ferry Terminal	Harbor-wide	6/9/2008	14:48	Vibracore	12–24	Sandy silt with some clay. Gray/brown. No odor.	X	X	A		X				X	X			
FT06C	Ferry Terminal	Harbor-wide	6/9/2008	14:48	Vibracore	36–48	Mixed sand/gravel and fines. Very fine to medium sand. Shell debris.	X	X	A		X				X	X			
FT07A	Ferry Terminal	Harbor-wide	6/12/2008	9:54	Grab	Surface	Drab olive/brown surface. Silt. No odor.	X	A	A	A	A				A				
FT08A	Ferry Terminal	Harbor-wide	6/11/2008	12:16	Grab	Surface	No odor. Brown at surface. Silt grades silty clay.	X	A	A	A	A				A				
FT09A	Ferry Terminal	Harbor-wide	6/12/2008	11:11	Grab	Surface	Olive to 10 cm, then very dark gray to black. Slight hydrogen sulfide odor.	X	A	X	A	A				A				
FT10A	Ferry Terminal	Harbor-wide	6/12/2008	10:29	Grab	Surface	Brown surface. Trace fine to very fine sand. No odor.	X	X	X	X	X	X			X				
FT11A	Ferry Terminal	Harbor-wide	6/12/2008	8:49	Grab	Surface	Brown surface. Color is olive and brown with slight gray. No odor. Trace sand.	X	X	X	X	X				X	X	X	X	X
FT12A	Ferry Terminal	Harbor-wide	6/11/2008	11:13	Grab	Surface	Silt grading silt with clay with trace sand.	X	A	A	A	A	X			A	X	X		

Table 3–3. Harbor-Wide Sample Analysis and Archive Summary

Sample ID	Station Name	Location Name	Sample Date	Sample Time	Collection Method	Sample Interval (inches)	Substrate/Other Remarks	TOC/Grain Size	SVOC	Resin Acids	Pesticides	PCBs	Dioxin/ Furan	NWTPH-Dx	Organotin	SMS Metals	Mercury	Sulfides	Ammonia	Bioassay
FT12B	Ferry Terminal	Harbor-wide	7/18/2008	12:20	Vibracore	6–12	Dark brown silty fine sand, some shell fragments. No wood material, no organic material. Slight hydrocarbon odor. One snail.	X	X	A	X					X	X			
FT12C	Ferry Terminal	Harbor-wide	7/18/2008	12:20	Vibracore	36–48	Dark brown silty fine sand, some shell fragments. No wood material, no organic material. Slight hydrocarbon odor. One snail.	X	X	A	X					X	X			
FT13A	Ferry Terminal	Harbor-wide	6/11/2008	11:43	Grab	Surface	Sand/silt/clay. Drab olive/gray. Some polychaetes, shell frags.	X	X	X	X	X	X	X		X	X			
IE01A	Inner Harbor	Harbor-wide			Grab		ABANDONED													
IE01B	Inner Ediz	Harbor-wide	6/17/2008	8:01	Vibracore	30–42	Dark brown silt with large amount of wood pulp and chips. Teredos infestation.	X	X	X		X	X	X		X	X	X	X	
IE01C	Inner Ediz	Harbor-wide	6/17/2008	8:10	Vibracore	48–60	Dark brown silt with large amount of wood pulp and chips. Teredos infestation.	X	X	X		A	A	X		X	X	X	X	
IE02A	Inner Harbor	Harbor-wide			Grab		ABANDONED													
IE03A	Inner Ediz	Harbor-wide	6/7/2008	14:50	Grab	Surface	Mottled brown at sediment surface. Wood debris (bark) on sediment surface.	X	X	X		X	X	X		X	X	X	X	X
IE04A	Inner Ediz	Harbor-wide	6/8/2008	10:11	Grab	Surface	Brown surface layer. Significant (up to 50%) wood. Moderate hydrogen sulfide odor.	X	X	X		X	X	X		X	X	X	X	X
IE05A	Inner Ediz	Harbor-wide	6/7/2008	16:12	Grab	Surface	Sediment surface is brown to 1 centimeter, then black with mottled gray that fades to black downward.	X	X	X		X	X	X		X	X	X	X	
IE05B	Inner Ediz	Harbor-wide	6/13/2008	13:15	Vibracore	12–24	Mixed wood waste and organic muck. Dark gray/brown with very strong sulfur odor.	X	X	X		X	X	X		X	X	X	X	
IE05C	Inner Ediz	Harbor-wide	6/13/2008	13:15	Vibracore	98–110	Clay/silt with some fine/veryfine sand. Shell frags. Dark gray/brown with mild sulfur odor.	X	X	X		A	A	X		X	X	X	X	
IE06A	Inner Ediz	Harbor-wide	6/8/2008	16:29	Grab	Surface	Strong hydrogen sulfide odor, silt. Approximately 75% wood.	X	X	X		X	X	X		X	X	X	X	X
IE07A	Inner Ediz	Harbor-wide	6/16/2008	9:28	Grab	Surface	95% wood debris. Moderate hydrogen sulfide odor.	X	X	X		X	X	X		X	X	X	X	X
IE08A	Inner Ediz	Harbor-wide	6/13/2008	12:15	Grab	Surface	Moderate hydrogen sulfide odor. Large piece of bark (1 ft by 1 ft).	X	A	X		A	A	X		A	X	X	X	
IE09A	Inner Ediz	Harbor-wide	6/16/2008	10:21	Grab	Surface	Brown at surface. Some wood debris.	X	X	X		X	X	X		X	X	X	X	X
IE09B	Inner Ediz	Harbor-wide	6/13/2008	9:25	Vibracore	36-48	Light brown/gray wood waste. No mineral sediment observed.	X	X	X		X	X	X		X	X	X	X	
IE09C	Inner Harbor	Harbor-wide			Vibracore		ABANDONED													
IE10A	Inner Ediz	Harbor-wide	6/8/2008	18:04	Grab	Surface	Light brown surface, then olive to 9cm. At 9cm, turns to black silt with some clay. Slight hydrogen sulfide odor. Less than 5% wood debris, with bark on surface.	X	A	X		A	A			A	X	X	X	
IE11A	Inner Ediz	Harbor-wide	6/9/2008	9:37	Grab	Surface	Slight hydrogen sulfide odor. Greater than 5% wood chips, heavily degraded, not bark.	X	A	X		X	A			X	X	X	X	
IE12A	Inner Ediz	Harbor-wide	6/9/2008	12:52	Grab	Surface	Wood chips and bark present. Slight sulfur odor.	X	A	X		X	X			X	X	X	X	
IE12B	Inner Ediz	Harbor-wide	6/20/2008	10:31	Vibracore	12–24	Dark gray/brown wood debris. No mineral sediment observed. Strong sulfur odor.	X	X	X		X	X			X	X	X	X	
IE12C	Inner Ediz	Harbor-wide	6/20/2008	10:31	Vibracore	107–119	Silty sand and shell debris. Dark gray/brown. Moderate sulfur odor.	X	X	X		A	A			X	X	X	X	

Table 3–3. Harbor-Wide Sample Analysis and Archive Summary

Sample ID	Station Name	Location Name	Sample Date	Sample Time	Collection Method	Sample Interval (inches)	Substrate/Other Remarks	TOC/Grain Size	SVOC	Resin Acids	Pesticides	PCBs	Dioxin/ Furan	NWTPH-Dx	Organotin	SMS Metals	Mercury	Sulfides	Ammonia	Bioassay
IE13A	Inner Ediz	Harbor-wide	6/9/2008	14:05	Grab	Surface	Red rock and sawdust. Moderate sulfur odor. Approximately 75% wood debris.	X	X	X		X	A			X	X	X	X	
IE14A	Inner Ediz	Harbor-wide	6/9/2008	8:39	Grab	Surface	Brown at surface. No wood. No biological activity.	X	X	X		X	X			X	X	X	X	X
IE14B	Inner Ediz	Harbor-wide	6/20/2008	14:11	Vibracore	12–24	Dark gray/brown organic muck and wood debris. No mineral sediment observed. Strong sulfur odor.	X	X	X		X	X			X	X	X	X	
IE14C	Inner Ediz	Harbor-wide	6/20/2008	14:11	Vibracore	62–74	Silty sand and shell debris. Dark gray/brown. Mild sulfur odor.	X	X	X		A	A			X	X	X	X	
IE15A	Inner Ediz	Harbor-wide	6/9/2008	10:43	Grab	Surface	Drab olive/brown surface, gray below. Silt. No odor. Approximately 5% wood debris.	X	X	X		X	X			X				X
IE16A	Inner Ediz	Harbor-wide	6/9/2008	11:45	Grab	Surface	Moderate sulfur odor, silt. Sawdust present.	X	X	X		X	A			X	X	X	X	
IE16B	Inner Ediz	Harbor-wide	6/12/2008	9:25	Vibracore	12–24	Clay/silt with some fine/veryfine sand. Shell frags. Dark gray/brown with mild sulfur odor.	X	X	X		X	X			X	X	X	X	
IE16C	Inner Ediz	Harbor-wide	6/12/2008	9:25	Vibracore	36–48	Clay/silt with some fine/veryfine sand. Shell frags. Dark gray/brown with mild sulfur odor.	X	X	X		A	A			X	X	X	X	
IH01A	Inner Harbor	Harbor-wide	6/16/2008	11:07	Grab	Surface	Gravel and VC to VF sand with a thin layer of silt at 3 cm. 30% wood debris and sawdust. Color unclear - Olive, brown, yellow.	X	X	X		X	X	X		X	X	X	X	X
IH02A	Inner Harbor	Harbor-wide	6/16/2008	12:23	Grab	Surface	Brown at surface. Slight hydrogen sulfide odor. 10% wood debris.	X	X	X		X	X	X		X	X	X	X	X
IH02B	Inner Harbor	Harbor-wide	6/12/2008	12:59	Vibracore	12–24	Mixed wood debris and gelatinous material. Strong sulfur odor. Green/gray/brown.	X	X	X		X	X	X		X	X	X	X	
IH02C	Inner Harbor	Harbor-wide	6/12/2008	12:59	Vibracore	70–82	Clay/silt. Dark gray brown with mica flakes and mild sulfur odor.	X	X	X		X	X	X		X	X	X	X	
IH03A	Inner Harbor	Harbor-wide	6/16/2008	13:23	Grab	Surface	Wood chips and wood debris up to 90%.	X	X	X		X	X	X		X	X	X	X	X
IH04A	Inner Harbor	Harbor-wide	6/16/2008	14:21	Grab	Surface	Slight hydrogen sulfide odor. Wood chips, bark, and debris up to 70%.	X	X	X		X	X	X		X	X	X	X	
IH05A	Inner Harbor	Harbor-wide	6/16/2008	15:50	Grab	Surface	Brown surface. Slight hydrogen sulfide odor.	X	X	X		X	X	X		X	X	X	X	X
IH06A	Inner Harbor	Harbor-wide	6/16/2008	16:27	Grab	Surface	Brown surface. Strong odor (type not noted).	X	X	X		X	X	X		X	X	X	X	X
IH06B	Inner Harbor	Harbor-wide	6/10/2008	17:15	Vibracore	12–24	Silt, organic muck and wood debris with fine sand. Dark gray brown. Strong sulfur odor.	X	X	X		X	X	X		X	X	X	X	
IH06C	Inner Harbor	Harbor-wide	6/10/2008	17:15	Vibracore	98–100	Silty sand (very fine/fine) with some clay. Gray/brown with moderate sulfur odor. Shell fragments.	X	X	X		X	X	X		X	X	X	X	
KP01A	K-Ply	Harbor-wide	6/17/2008	9:05	Grab	Surface	Olive and brown at surface. Slight hydrogen sulfide odor.	X	X	X	X	X	X	X	X	X	X	X	X	X
KP02A	K-Ply	Harbor-wide	6/17/2008	9:47	Grab	Surface	Olive and light brown at surface. 20% wood debris. Very slight hydrogen sulfide odor.	X	X	X	X	X	X	X	X	X	X	X	X	X
KP02B	K-Ply	Harbor-wide	6/10/2008	12:47	Vibracore	12–24	Mixed wood debris and fines. Organic muck. Dark gray/brown. Strong sulfur odor.	X	X	X	X	X	X	X	X	X	X			
KP02C	K-Ply	Harbor-wide	6/10/2008	12:47	Vibracore	54–66	Sandy silt with some clay. Some roots. Green/gray bworn. No odor.	X	X	X	X	X	A	X	X	X	X			

Table 3–3. Harbor-Wide Sample Analysis and Archive Summary

Sample ID	Station Name	Location Name	Sample Date	Sample Time	Collection Method	Sample Interval (inches)	Substrate/Other Remarks	TOC/Grain Size	SVOC	Resin Acids	Pesticides	PCBs	Dioxin/ Furan	NWTPH-Dx	Organotin	SMS Metals	Mercury	Sulfides	Ammonia	Bioassay
KP03A	K-Ply	Harbor-wide	6/17/2008	10:19	Grab	Surface	Some silt. Brown surface. No odor.	X	X	X	X	X	X	X		X	X	X	X	X
KP03B	K-Ply	Harbor-wide	6/10/2008	9:03	Vibracore	24–36	Mixed sand, fines, wood debris. Dark gray/brown. Mild sulfur odor.	X	X	X	X	X	X	X		X	X			
KP03C	K-Ply	Harbor-wide	6/10/2008	9:03	Vibracore	78–90	Silt and clay with fine sand. Mild sulfur odor. Gray/brown.	X	X	X	X	X	A	X		X	X			
KP04A	K-Ply	Harbor-wide	6/17/2008	10:58	Grab	Surface	Drab olive/gray below. Sand/silt/clay. No odor.	X	X	X	X	A	X		X	X	X			
KP05A	K-Ply	Harbor-wide	6/12/2008	14:59	Grab	Surface	Brown surface layer. Little clay in sand.	X	X	X	X	X	X		X	X	X	X	X	X
KP06A	K-Ply	Harbor-wide	6/11/2008	16:15	Grab	Surface	Brown surface. Silt grades to silt with trace clay. No odor.	X	A	A	A	A	A			A	X	X	X	X
KP07A	K-Ply	Harbor-wide	6/11/2008	12:50	Grab	Surface	Brown surface. Fecal materials. Silt grading into silty clay.	X	X	X	X	X	X		X	X	X			
KP07B	K-Ply	Harbor-wide	6/21/2008	10:15	Vibracore	12–24	Clay/silt. Dark gray brown with shell fragments. No odor.	X	X	X	X	X	X			X	X			
KP07C	K-Ply	Harbor-wide	6/21/2008	10:15	Vibracore	36–48	Clay/sandy silt. Dark gray/brown. Many shell fragments and whole shells. No odor.	X	X	X	A	A	A			X	X			
KP08A	K-Ply	Harbor-wide	6/12/2008	15:58	Grab	Surface	Sediment type is cobble, gravel, sand (VC to VF), and silt. Contains wood, bark, and significant shell debris. No odor.	X	X	A	A	X	A		X	X	X			
KP08B	K-Ply	Harbor-wide	6/8/2008	9:48	Vibracore	36–48	Sand/silt/clay. Gray/brown.	X	X	X	X	X	X			X	X	X	X	
KP08C	K-Ply	Harbor-wide	6/8/2008	9:48	Vibracore	48–60	Sand/silt/gravel with shell debris and no odor.	X	X	X	X	X	A			X	X	X	X	
LA01A	Lagoon	Harbor-wide	7/23/2008	9:32	Vibracore	Surface	Brown with black mottled throughout. Silt with very trace fine sand. Woody debris 80% of the substance. Woody debris is small, mushy chips. Slight sulfur odor. Sheen.	X	X	X	X	X	X	X		X	X	X	X	
LA02A	Lagoon	Harbor-wide	7/23/2008	10:46	Vibracore	Surface	Drab olive surface with grayish-brown below. No visible RPD. Silt with some very trace fine sand. A lot of green kelp. Slight woody debris. Slight sulfur odor.	X	X	X	A	A	X	X		A	X	X	X	X
LA02B	Lagoon	Harbor-wide	7/23/2008	14:02	Vibracore	24–36	Dark brown silty sand with some subrounded gravel. Wood material present, moderate sulfur odor. No natural or organic detritus.	X	X	X	X	X	X	X		X	X	X	X	
LA02X	Lagoon	Harbor-wide	7/23/2008	14:02	Vibracore	NA	LA02C = LA02X. Not a proper sample due to continuous woodwaste, but wanted to analyze throughout.	X	X	X	X	X	X	X		X	X	X	X	
LA03A	Lagoon	Harbor-wide	7/23/2008	10:10	Vibracore	Surface	Drab olive surface, grayish-brown below. Mottled black throughout surface and below surface. Moderate sulfur odor.	X	X	X	A	A	X	X		A	X	X	X	
MA01A	Marina Area	Harbor-wide	6/17/2008	15:27	Grab	Surface	Gray surface. Moderate odor (type not noted).	X	X	X		X	X		X	X	X	X	X	X
MA02A	Marina Area	Harbor-wide	6/13/2008	10:50	Grab	Surface	Light brown color at surface. Black below with green tint. Apx 80% woody debris. Sheen noted. Strong hydrogen sulfide odor.	X	X	X		X	X	X	X	X	X	X	X	X
MA02B	Marina Area	Harbor-wide	6/11/2008	13:59	Vibracore	6–12	Strong sulfur odor. Gray/brown silt.	X	X	X		X	X	X		X	X			
MA02C	Marina Area	Harbor-wide	6/11/2008	13:59	Vibracore	12–24	Clay/silt. Gray/brown.	X	X	X		X	X	X		X	X			

Table 3–3. Harbor-Wide Sample Analysis and Archive Summary

Sample ID	Station Name	Location Name	Sample Date	Sample Time	Collection Method	Sample Interval (inches)	Substrate/Other Remarks	TOC/Grain Size	SVOC	Resin Acids	Pesticides	PCBs	Dioxin/ Furan	NWTPH-Dx	Organotin	SMS Metals	Mercury	Sulfides	Ammonia	Bioassay
MA03A	Marina Area	Harbor-wide	6/13/2008	10:01	Grab	Surface	Olive color at surface. No odor recorded.	X	X	X		X	X		X	X	X			
MA04A	Marina Area	Harbor-wide	6/12/2008	16:47	Grab	Surface	Significant wood debris (~90%).	X	X	X		X	X		X	X	X			
MA05A	Marina Area	Harbor-wide	6/13/2008	9:08	Grab	Surface	Olive color at surface. Slight odor noted, type not described.	X	X	X		X	X		X	X	X	X	X	X
MA06-002-050	Marina Area	Harbor-wide	7/25/2008	15:05	Radioisotope	2–50	Brown silt, shell fragments, no odor, no wood material.													
MA06A	Marina Area	Harbor-wide	6/11/2008	13:56	Grab	Surface	Brown surface. Approximately 5% wood.	X	A	X		A	A			A	X	X	X	X
OH01A-R	Outer Harbor	Harbor-wide	6/18/2008	16:22	Grab	Surface	Light brown at surface. Slight hydrogen sulfide odor.	X	X	X		X	X	X		X	X	X	X	
OH02A	Outer Harbor	Harbor-wide	6/11/2008	8:37	Grab	Surface	No odor. Thin brown clay and silt surface layer.	X	X	X		X	X	X		X	X	X	X	X
OH03A	Outer Harbor	Harbor-wide	6/11/2008	9:44	Grab	Surface	Brown surface. No odor.	X	X	X		X	X	X		X	X	X	X	
RL01A	Red Lion	Harbor-wide	6/18/2008	14:50	Grab	Surface	Drab olive/gray below. Sand. No odor. Organic matter present.	X	X		X	X	X	X		X	X	X	X	X
RL02A	Red Lion	Harbor-wide	6/18/2008	15:31	Grab	Surface	Organic matter in sediment. No odor.	X	A		A	A	A	X		A	X	X	X	X
RL03-010-052	Red Lion	Harbor-wide	7/25/2008	19:02	Radioisotope	10–52	Brown silt, shell fragments, no odor, no wood material.													
RL03A	Red Lion	Harbor-wide	6/12/2008	14:09	Grab	Surface	Sediment type is cobble, gravel, sand (M-F), and silt. Significant shell debris and rocks. Slight anaerobic odor around algae.	X	A		A	A	A			A	X			
WW01A	Waste Water	Harbor-wide	6/19/2008	11:59	Grab	Surface	Drab olive/light brown surface. Sand/silt. No odor.	X	A		A		X	X		A	X	X	X	X
WW01A MS/MSD	Waste Water	Harbor-wide	6/19/2008	11:59	Grab	Surface	MS/MSD						X	X			X	X	X	
RF01A	Reference	Reference	6/10/2008	12:03	Grab	Surface	Gray sand. No odor	X	X	X	X	X	X	X	X	X	X	X	X	X
RF02A	Reference	Reference	6/10/2008	13:32	Grab	Surface	Gray sand. No odor	X	X	X	X	X	X	X	X	X	X	X	X	X
RF03A	Reference	Reference	6/10/2008	10:12	Grab	Surface	No odor. Streaks of oxidation in sediment. Brown surface, then Olive, Brown, Gray, and Black.	X	X	X	X	X	X	X	X	X	X	X	X	X
EI08TH	Eastern Intertidal	Harbor-wide	6/14/2008	11:16	Tissue	Tissue	Five horse clams		X^1		X	X	X			X	X			
IE17TH	Inner Ediz	Harbor-wide			Tissue	Tissue	ABANDONED													
IE18TH	Inner Ediz	Harbor-wide	6/21/2008	10:01	Tissue	Tissue	One horse clam		X^1			X	X			X	X			
IE19TH	Inner Ediz	Harbor-wide			Tissue	Tissue	ABANDONED													
IE20TH	Inner Ediz	Harbor-wide	6/21/2008	13:58	Tissue	Tissue	Five horse clams		X^1			X	X			X	X			
IE21TL	Inner Ediz	Harbor-wide	6/14/2008	12:18	Tissue	Tissue	Four pounds-lingcod		X^1			X^2	X			X	X			
IE22TL	Inner Ediz	Harbor-wide	6/14/2008	12:25	Tissue	Tissue	Three pounds-lingcod		X^1			X^2	X			X	X			
IE23TL	Inner Ediz	Harbor-wide	6/14/2008	12:32	Tissue	Tissue	Three pounds-lingcod		X^1			X^2	X			X	X			
IE24TL	Inner Ediz	Harbor-wide	6/14/2008	12:49	Tissue	Tissue	20 pounds-lingcod		X^1			X^2	X			X	X			
IE25TM	Inner Ediz	Harbor-wide	6/21/2008	13:04	Tissue	Tissue	Laminaria macroalgae		X^1			X^2	X			X	X			
IE26TM	Inner Ediz	Harbor-wide	6/14/2008	13:52	Tissue	Tissue	Eel grass macroalgae		X^1			X^2	X			X	X			
RL04TH	Red Lion	Harbor-wide			Tissue	Tissue	ABANDONED													
RF04TH	Reference	Reference	7/12/2008	10:30	Tissue	Tissue	Four horse clams (Two areas)		X^1		X	X	X			X	X			
RF05TH	Reference	Reference	7/12/2008	11:59	Tissue	Tissue	Five horse clams		X^1		X	X	X			X	X			
RF06TG	Reference	Reference	7/12/2008	11:59	Tissue	Tissue	One geoduck		X^1		X	X	X			X	X			

1. These samples were re-analyzed for PAH using a low-detection limit SIM Method.
2. These samples were analyzed for both PCB congeners and PCB Aroclors.

X = Analysis Performed

A = Archived Sample

MS/MSD Sample

Abandoned/Not Collected

Analysis conducted by laboratory but not requested

Archive analyzed

Radioisotope sample

Table 3–4. Rayonier Mill Sample Analysis Summary

Sample ID	Station Name	Location Name	Sample Date	Sample Time	Collection Method	Sample Interval (inches)	Substrate/Other Remarks	TOC/Grain Size	SVOC	Resin Acids	Pesticides	PCBs	Dioxin/ Furan	NWTPH-Dx	Organotin	SMS Metals	Mercury	Sulfides	Ammonia	Bioassay
CO01A	Outfalls	Rayonier	6/22/2008	13:15	Grab	Surface	Sweet, unidentified odor. Few shell fragments. No apparent biota.	X	X	X	X	X	X	X		X	X	X	X	X
CO01B	Outfalls	Rayonier			Vibracore		ABANDONED													
CO02A	Outfalls	Rayonier	6/22/2008	14:13	Grab	Surface	Light gray at surface. Significant shell debris. No odor.	X	X	X	X	X	X	X		X	X	X	X	X
CO02B	Outfalls	Rayonier	7/17/2008	14:05	Vibracore	12-Jun	Dark brown silty sand. Small and large gravel/small and large cobbles. Natural detritus material. No odor.	X	X	X	X	X	X	X		X	X			
CO03A	Outfalls	Rayonier	6/22/2008	16:42	Grab	Surface	Brown and gray sand with cobble/gravel. Juvenile fish, amphipods.	X	X	X	X	X	X	X		X	X	X	X	
CO03B	Outfalls	Rayonier	7/20/2008	11:10	Vibracore	24-36	Dark gray medium sand, slight amount of small and large gravel, Very strong sulfur odor. Pockets of wood material.	X	X	X	X	X	X	X		X	X			
CO04A	Outfalls	Rayonier	6/20/2008	14:03	Grab	Surface	Slight hydrogen sulfide and another chemical (unsure, but sweet) odor.	X	X	X	X	X	X	X		X	X	X	X	X
CO04B	Outfalls	Rayonier	7/18/2008	19:00	Vibracore	24-Dec	Dark brown coarse sand with small and large gravel/cobble. Shell fragments, trace natural detritus, trace wood chips. Black staining at approx. 23". No odor.	X	X	X	X	X	X	X		X	X			
CO05A	Outfalls	Rayonier	6/20/2008	13:19	Grab	Surface	Gray sand/silt with cobble and shell debris. No odor.	X	X	X	X	X	X	X		X	X	X	X	
CO05B	Outfalls	Rayonier	7/15/2008	18:11	Vibracore	24-36	Silt and clay to 27". After 27", it is black clay with possible pulp material from 27" to 36". Strong petroleum odor.	X	X	X	X	X	X	X		X	X			
D001B	Deep Outfall	Rayonier			Vibracore		ABANDONED													
D001E	Deep Outfall	Rayonier			Vibracore		ABANDONED													
DO01A	Deep Outfall	Rayonier	6/19/2008	15:28	Grab	Surface	Drab olive/brown surface. Sand/silt. No odor.	X	X	X			X			X	X	X	X	
DO01C	Deep Outfall	Rayonier			Vibracore		ABANDONED													
DO01D	Deep Outfall	Rayonier			Vibracore		ABANDONED													
DO02A	Deep Outfall	Rayonier	6/19/2008	14:54	Grab	Surface	Drab olive/brown surface. Sand/silt/cobble/gravel/shell debris/wood debris/organic matter.	X	X	X			X			X	X	X	X	
DO02B	Deep Outfall	Rayonier			Vibracore		ABANDONED													
DO02C	Deep Outfall	Rayonier			Vibracore		ABANDONED													
DO02D	Deep Outfall	Rayonier			Vibracore		ABANDONED													

Table 3–4. Rayonier Mill Sample Analysis Summary

Sample ID	Station Name	Location Name	Sample Date	Sample Time	Collection Method	Sample Interval (inches)	Substrate/Other Remarks	TOC/Grain Size	SVOC	Resin Acids	Pesticides	PCBs	Dioxin/ Furan	NWTPH-Dx	Organotin	SMS Metals	Mercury	Sulfides	Ammonia	Bioassay
DO02E	Deep Outfall	Rayonier			Vibracore		ABANDONED													
DO03A	Deep Outfall	Rayonier	6/19/2008	14:06	Grab	Surface	Drab olive/brown surface. Gray below. Sand/silt, trace clay.	X	X	X			X			X	X	X	X	X
DO03B	Deep Outfall	Rayonier			Vibracore		ABANDONED													
DO03C	Deep Outfall	Rayonier			Vibracore		ABANDONED													
DO03D	Deep Outfall	Rayonier			Vibracore		ABANDONED													
DO03E	Deep Outfall	Rayonier			Vibracore		ABANDONED													
DO04A	Deep Outfall	Rayonier	6/19/2008	12:46	Grab	Surface	Drab olive/brown surface. Sand/silt. No odor.	X	X	X			X			X	X	X	X	X
DO04B	Deep Outfall	Rayonier	7/22/2008	15:00	Vibracore	12-Jun	Dark brown silt with clay. Trace shell fragments, no gravel, no odor, no wood material.	X	X	X			X			X	X	X	X	
DO04C	Deep Outfall	Rayonier	7/22/2008	15:00	Vibracore	24-Dec	Dark brown silt with clay. Trace shell fragments, no gravel, no odor, no wood material.	X	X	X			X			X	X	X	X	
DO04D	Deep Outfall	Rayonier	7/22/2008	15:00	Vibracore	24-32	Dark brown silt with clay, trace shell fragments, trace gravel, one small cobble (2.5"), No odor, no wood material.	X	X	X			X			X	X	X	X	
DO04E	Deep Outfall	Rayonier			Vibracore		ABANDONED													
DO05A	Deep Outfall	Rayonier	6/19/2008	13:21	Grab	Surface	Drab olive/brown surface. Sand/silt. No odor.	X	X	X			X			X	X	X	X	X
DO05B	Deep Outfall	Rayonier	7/22/2008	16:57	Vibracore	12-Jun	Dark brown silt with some clay and trace cobble. Polychaetes and shell fragments present. Trace wood material. No odor.	X	X	X			X			X	X	X	X	
DO05C	Deep Outfall	Rayonier	7/22/2008	16:57	Vibracore	16-Dec	Dark brown silt with some clay and trace cobble. Shell fragments present. No wood material, no odor.	X	X	X			X			X	X	X	X	
DO05D	Deep Outfall	Rayonier			Vibracore		ABANDONED													
DO05E	Deep Outfall	Rayonier			Vibracore		ABANDONED													
EC01A	Ennis Creek	Rayonier	6/21/2008	12:24	Grab	Surface	Brown sand with cobble/gravel. No odor.	X	X	X	X	X	X	X		X	X	X	X	X
EC01B	Ennis Creek	Rayonier			Vibracore		ABANDONED													
EC01C	Ennis Creek	Rayonier			Vibracore		ABANDONED													
EC02A	Ennis Creek	Rayonier	6/21/2008	12:57	Grab	Surface	No odor. Apx x0% gravel and cobbles.	X	X	X	X	X	X	X		X	X	X	X	X
EC02B	Ennis Creek	Rayonier			Vibracore		ABANDONED													
EC02C	Ennis Creek	Rayonier			Vibracore		ABANDONED													

Table 3–4. Rayonier Mill Sample Analysis Summary

Sample ID	Station Name	Location Name	Sample Date	Sample Time	Collection Method	Sample Interval (inches)	Substrate/Other Remarks	TOC/Grain Size	SVOC	Resin Acids	Pesticides	PCBs	Dioxin/ Furan	NWTPH-Dx	Organotin	SMS Metals	Mercury	Sulfides	Ammonia	Bioassay
EC03A	Ennis Creek	Rayonier	6/20/2008	11:52	Grab	Surface	Gray sand/silt. No odor.	X	X	X	X	X	X	X		X	X	X	X	
EC03A MS/MSD	Ennis Creek	Rayonier	6/20/2008	11:52	Grab	Surface	MS/MSD	X	X	X	X	X	X	X		X	X	X	X	
EC03B	Ennis Creek	Rayonier	7/16/2008	11:35	Vibracore	12-Jun	Dark brown silt, no shell fragments, no wood material. Slight petroleum and sulfur odor. Trace kelp.	X	X		X	X	X	X		X	X			
EC03C	Ennis Creek	Rayonier	7/16/2008	11:35	Vibracore	24-Dec	Trace natural detritus. Moderate petroleum odor. Medium plasticity (non mineral material may be causing plasticity). Trace clam shells, old worm tubes.	X	X	X	X	X	X	X		X	X	X	X	
EC04A	Ennis Creek	Rayonier	6/20/2008	12:24	Grab	Surface	Gray/black sand/silt. No odor.	X	X	X	X	X	X	X		X	X	X	X	X
EC04B	Ennis Creek	Rayonier	7/16/2008	13:20	Vibracore	24-Dec	Grayish Black silt with trace sand and some clay. Strong sulfur odor, trace shell fragments, some pebbles.	X	X		X	X	X	X		X	X			
EC04C	Ennis Creek	Rayonier			Vibracore		ABANDONED													
EC05A	Ennis Creek	Rayonier	6/21/2008	12:40	Grab	Surface	No biota.	X	X	X	X	X	X	X		X	X	X	X	
EC05B	Ennis Creek	Rayonier			Vibracore		ABANDONED													
EC05C	Ennis Creek	Rayonier			Vibracore		ABANDONED													
ED01A	East of Dock	Rayonier	6/21/2008	14:56	Grab	Surface	No odor. Apx 5% wood debris.	X	X			X	X	X		X	X	X	X	
ED01B	East of Dock	Rayonier	6/19/2008	9:55	Vibracore	24-36	Wood waste with some sand. Dark brown.	X	X			X	X	X		X	X			
ED01C	East of Dock	Rayonier	6/19/2008	9:06	Vibracore	72-84	Small and large gravel, some sand. No wood, no odor.	X	X			X	X	X		X	X			
ED02A	East of Dock	Rayonier	6/19/2008	15:53	Grab	Surface	Organic matter and shell debris. Slight odor, type not noted. Light brown at surface.	X	X			X	X	X		X	X	X	X	
ED02B	East of Dock	Rayonier	6/18/2008	15:42	Vibracore	24-Dec	Mixed sand and organic muck. Mild sulfur odor. Gray/brown.	X	X			X	X	X		X	X			
ED02C	East of Dock	Rayonier	6/18/2008	15:42	Vibracore	36-48	Mixed sand and organic muck. Mild sulfur odor. Gray/brown. Shell debris.	X	X			X	X	X		X	X			
ED03A	East of Dock	Rayonier	6/20/2008	16:13	Grab	Surface	Moderate hydrogen sulfide and sweet odor.	X	X			X	X	X		X	X	X	X	X
ED03B	East of Dock	Rayonier	6/18/2008	9:07	Vibracore	18-Jun	Dark brown silt with large amount of wood waste	X	X			X	X	X		X	X			
ED03C	East of Dock	Rayonier	6/18/2008	8:13	Vibracore	33-45	Sand (very fine-coarse). Gray, mild sulfur odor.	X	X			X	X	X		X	X			
ED04A	East of Dock	Rayonier	6/20/2008	15:16	Grab	Surface	Organic matter. Overwhelming hydrogen sulfide and methane odor.	X	X			X	X	X		X	X	X	X	X

Table 3–4. Rayonier Mill Sample Analysis Summary

Sample ID	Station Name	Location Name	Sample Date	Sample Time	Collection Method	Sample Interval (inches)	Substrate/Other Remarks	TOC/Grain Size	SVOC	Resin Acids	Pesticides	PCBs	Dioxin/ Furan	NWTPH-Dx	Organotin	SMS Metals	Mercury	Sulfides	Ammonia	Bioassay
ED04B	East of Dock	Rayonier	6/18/2008	12:05	Vibracore	36-48	Mixed fines (clay/silt). Reddish brown wood debris. Gray/brown silt.	X				X	X	X		X	X			
ED04C	East of Dock	Rayonier			Vibracore		ABANDONED													
ED05A	East of Dock	Rayonier	6/20/2008	10:40	Grab	Surface	Penetration depth noted as 16 feet. Small pieces of shell debris. Brown surface. No odor.	X	X			X	X	X		X	X	X	X	X
ED05B	East of Dock	Rayonier	7/16/2008	17:25	Vibracore	24-Dec	Dark gray/black sandy silt, shell fragments, polychaete tubes, moderate sulfur odor, wood waste	X	X		X	X	X	X		X	X			
ED05C	East of Dock	Rayonier			Vibracore		ABANDONED													
EE01A	East of Ennis	Rayonier	6/20/2008	9:57	Grab	Surface	Gray/black sand with cobble/gravel. No odor.	X	X		X	X	X	X		X	X			
EE01B		Rayonier	7/16/2008	15:00	Vibracore	12-Jun	Medium-coarse sand with some small and large rounded pebbles. Some small cobble, some shell fragments. One dead Pacific sand lance. No odor, no wood material, no organic material.	X	X		X	X	X	X		X	X			
EE01C	East of Ennis	Rayonier			Vibracore		ABANDONED													
EE02A	East of Ennis	Rayonier	6/20/2008	9:21	Grab	Surface	Brown surface. No odor.	X	X		X	X	X	X		X	X			
EE02B	East of Ennis	Rayonier	7/21/2008	9:03	Vibracore	24-Dec	Dark gray coarse and medium sand with some small gravel. Some staining throughout interval. No odor, no wood material, no organic material.	X	X		X	X	X	X		X	X			
EE02C	East of Ennis	Rayonier	7/21/2008	9:03	Vibracore	24-36	Dark gray mostly medium sand with some coarse. Small gravel and shell fragments. No odor, no wood material, no organic material.	X	X		X	X	X	X		X	X			
EE03A	East of Ennis	Rayonier	6/20/2008	14:44	Grab	Surface	Gray fine sand. No odor.	X	X		X	X	X	X		X	X			
EE03B	East of Ennis	Rayonier	7/16/2008	15:58	Vibracore	12-Jun	Medium sand, some angular pebbles, some shell frags, polychaete tubes. No odor, no organic material, no wood material.	X	X		X	X	X	X		X	X			
EE03C	East of Ennis	Rayonier	7/16/2008	15:58	Vibracore	24-Dec	Medium sand, some angular gravel, some cobble (2 in). Large shell fragments, polychaete tubes. No organic material, no wood material, no odor.	X	X		X	X	X	X		X	X			

Table 3–4. Rayonier Mill Sample Analysis Summary

Sample ID	Station Name	Location Name	Sample Date	Sample Time	Collection Method	Sample Interval (inches)	Substrate/Other Remarks	TOC/Grain Size	SVOC	Resin Acids	Pesticides	PCBs	Dioxin/ Furan	NWTPH-Dx	Organotin	SMS Metals	Mercury	Sulfides	Ammonia	Bioassay
EE04A	East of Ennis	Rayonier	6/20/2008	8:47	Grab	Surface	Gray/black cobble/gravel/sand. No odor.	X	X		X	X	X	X		X	X			
EE04B	East of Ennis	Rayonier	7/17/2008	17:45	Vibracore	12-Jun	Grayish brown fine-medium sand; rounded small and large cobble. Shell fragments. No wood, no odor, no organic material.	X	X		X	X	X	X		X	X			
EE04C	East of Ennis	Rayonier	7/17/2008	17:45	Vibracore	24-Dec	Grayish brown fine-medium sand; rounded small and large cobble. Shell fragments. No wood, no odor, no organic material.	X	X		X	X	X	X		X	X			
EE05A	East of Ennis	Rayonier	6/20/2008	8:40	Grab	Surface	Gray sand with cobble/gravel. No odor, no biota.	X	X		X	X	X	X		X	X			
EE05B	East of Ennis	Rayonier			Vibracore		ABANDONED													
EE05C	East of Ennis	Rayonier			Vibracore		ABANDONED													
LP01A	Log Pond	Rayonier	6/22/2008	12:36	Grab	Surface	Shell debris. Olive at surface. No odor.	X	X	X			X			X	X	X	X	
LP01B	Log Pond	Rayonier			Vibracore		ABANDONED													
LP01C	Log Pond	Rayonier			Vibracore		ABANDONED													
LP02A	Log Pond	Rayonier			Grab		ABANDONED													
LP02B	Log Pond	Rayonier			Vibracore		ABANDONED													
LP02C	Log Pond	Rayonier			Vibracore		ABANDONED													
LP03A	Log Pond	Rayonier	6/22/2008	11:07	Grab	Surface	Apx 30% wood debris (small fibers) and shell debris. No odor.	X	X	X			X			X	X	X	X	
LP03B	Log Pond	Rayonier			Vibracore		ABANDONED													
LP03C	Log Pond	Rayonier			Vibracore		ABANDONED													
LP04A	Log Pond	Rayonier	6/22/2008	10:07	Grab	Surface	Apx 40% wood debris (chips, little bark). No odor.	X	X	X			X			X	X	X	X	
LP04B	Log Pond	Rayonier			Vibracore		ABANDONED													
LP04C	Log Pond	Rayonier			Vibracore		ABANDONED													
LP05A	Log Pond	Rayonier	6/22/2008	9:01	Grab	Surface	Apx 50% wood debris (bark). Strong odor.	X	X	X			X			X	X	X	X	
LP05B	Log Pond	Rayonier	7/19/2008	10:02	Vibracore	12-Jun	Dark brown wood material, some silt. Sulfide odor, some kelp, petroleum odor, petroleum sheen.	X	X	X								X	X	

Table 3–4. Rayonier Mill Sample Analysis Summary

Sample ID	Station Name	Location Name	Sample Date	Sample Time	Collection Method	Sample Interval (inches)	Substrate/Other Remarks	TOC/Grain Size	SVOC	Resin Acids	Pesticides	PCBs	Dioxin/ Furan	NWTPH-Dx	Organotin	SMS Metals	Mercury	Sulfides	Ammonia	Bioassay
LP05C	Log Pond	Rayonier			Vibracore		ABANDONED													
MD01A	Mill Dock	Rayonier	6/22/2008	15:42	Grab	Surface	Brown at surface. No odor.	X	X	X		X	X	X		X	X	X	X	X
MD01B	Mill Dock	Rayonier	7/17/2008	12:00	Vibracore	12-Jun	Dark brown sandy silt with large and small gravel/large and small cobbles. No odor, no wood material. Some kelp.	X	X	X		X	X	X				X	X	
MD01C	Mill Dock	Rayonier	7/17/2008	12:00	Vibracore	24-Dec	Gray silty sand with large and small gravel/large and small cobbles. No odor, no wood material.	X	X	X		X	X	X		X	X	X	X	
MD02A	Mill Dock	Rayonier	6/21/2008	17:14	Grab	Surface	Gray surface. Moderate odor.	X	X	X		X	X	X		X	X	X	X	X
MD02B	Mill Dock	Rayonier	7/17/2008	9:20	Vibracore	24-Dec	Dark brown/black silt with trace sand. Moderate sulfur odor and slight petroleum odor. Highly degraded tan and brown wood chips.	X	X	X		X	X	X					X	
MD02C	Mill Dock	Rayonier	7/17/2008	9:20	Vibracore	48-60	Gray silty sand with large and small gravel/large and small cobbles. Trace shell fragments, no wood material.	X	X	X		X	X	X		X	X	X	X	
MD03A	Mill Dock	Rayonier	6/22/2008	16:08	Grab	Surface	Olive at surface. Slight hydrogen sulfide odor.	X	X	X		X	X	X		X	X	X	X	X
MD03B	Mill Dock	Rayonier	6/17/2008	14:18	Vibracore	48-60	Very dark brown sandy silt with large amount of wood waste.	X	X	X		X	X	X				X	X	
MD03C	Mill Dock	Rayonier	6/17/2008	12:57	Vibracore	35-47	Mixed gravel/sand and fines. Dark gray/brown. Strong sulfur odor, some shell debris.	X	X	X		X	X	X		X	X	X	X	
MD04A	Mill Dock	Rayonier	6/22/2008	14:59	Grab	Surface	Light brown at surface. No odor.	X	X	X		X	X	X		X	X	X	X	
MD04B	Mill Dock	Rayonier	6/22/2008	15:35	Vibracore	18-Jun	Dark gray/brown. Organic muck and fine sand. Lots of wood debris. Moderate sulfur odor.	X	X	X		X	X	X				X	X	
MD04C	Mill Dock	Rayonier			Vibracore		ABANDONED													

Table 3–4. Rayonier Mill Sample Analysis Summary

Sample ID	Station Name	Location Name	Sample Date	Sample Time	Collection Method	Sample Interval (inches)	Substrate/Other Remarks	TOC/Grain Size	SVOC	Resin Acids	Pesticides	PCBs	Dioxin/ Furan	NWTPH-Dx	Organotin	SMS Metals	Mercury	Sulfides	Ammonia	Bioassay
MD05A	Mill Dock	Rayonier	6/21/2008	15:39	Grab	Surface	Olive at surface. No odor. Shell debris.	X	X	X		X	X	X		X	X	X	X	
MD05B	Mill Dock	Rayonier	6/19/2008	15:39	Vibracore	10-Apr	Sand/fines/gravel. Silt and clay. Brown. Some shell debris.	X	X	X		X	X	X				X	X	
MD05C	Mill Dock	Rayonier	6/19/2008	15:39	Vibracore	22-Oct	Sand/fines/gravel. Silt and clay. Brown. Some shell debris.	X	X	X		X	X	X		X	X	X	X	
EC06TH	Ennis Creek	Rayonier	6/22/2008	13:10	Tissue	Tissue	Two horse clams		X[1]		X	X	X			X	X			
EC07TH	Ennis Creek	Rayonier			Tissue	Tissue	ABANDONED													
EC08TH	Ennis Creek	Rayonier			Tissue	Tissue	ABANDONED													
LP06	Log Pond	Rayonier			Tissue	Tissue	ABANDONED													
LP07	Log Pond	Rayonier			Tissue	Tissue	ABANDONED													
LP08	Log Pond	Rayonier			Tissue	Tissue	ABANDONED													
MD06TH	Mill Dock	Rayonier	6/22/2008	11:30	Tissue	Tissue	Six horse clams		X[1]			X	X			X	X			
MD07TH	Mill Dock	Rayonier	6/22/2008	12:35	Tissue	Tissue	One horse clam		X[1]			X	X			X	X			
MD08TG	Mill Dock	Rayonier	7/12/2008	15:09	Tissue	Tissue	Three geoducks		X[1]		X	X	X			X	X			
MD08TH	Mill Dock	Rayonier	7/12/2008	15:09	Tissue	Tissue	Three horse clams		X[1]		X	X	X			X	X			
MD09TH	Mill Dock	Rayonier	7/12/2008	16:19	Tissue	Tissue	One horse clam		X[1]		X	X	X			X	X			

1. These samples were re-analyzed for PAH using a low-detection limit SIM method.

X = Analysis Performed

MS/MSD Sample

Abandoned/Not Collected

Analysis conducted by laboratory but not requested

Table 4–1. Reference and Control Sample Performance Summary

Test Conditions		Test Results				
Eohaustorius estuarius	**Recommended Guideline**	**Batch 1**	**Batch 2**	**Batch 3**	**Batch 4**	**Batch 5**
SMS Control Performance Standard	Control mortality <10%	2%	6%	6%	0%	2%
SMS Reference Performance Standard	Reference mortality <25%	RF01A 6%, RF02A 6%, RF03A 11%	RF01A 5%, RF02A 3%, RF03A 11%	RF01A 6%, RF02A 10%, RF03A 23%	RF01A 5%, RF02A 4%, RF03A 12%	RF01A 3%, RF02A 3%, RF03A 5%
Neanthes arenaceodentata	**Recommended Guideline**	**Batch 1**	**Batch 2**	**Batch 3 UV**	**NA**	**NA**
SMS Control Performance Standard	Control mortality < 10%	0%	0%	0%	NA	NA
	MIGControl >= 0.72 mg/ind/day	0.72	0.50	0.82	NA	NA
SMS Reference Performance Standard	MIGReference/MIGControl > 80%	RF01A 94%, RF02A 99%, RF03A 78%	RF01A 129%, RF02A 86%, RF03A 97%	RF01A 91%, RF02A 95%, RF03A 84%	NA	NA
Dendraster excentricus	**Recommended Guideline**	**Batch 1**	**Batch 2**	**Batch 3**	**Batch 4 UV**	**NA**
SMS Control Performance Standard	Normal survival > 70%	84%	93%	91%	94%	NA
SMS Reference Performance Standard	Reference/Control > 65%	RF01A 91%, RF02A 89%, RF03A 73%	RF01A 90%, RF02A 88%, RF03A 80%	RF01A 84%, RF02A 87%, RF03A 67%	RF01A 100%, RF02A 96%, RF03A 88%	NA

SMS = Sediment Management Standard

Table 5.1–1. Surface Sediment Conventionals Summary

Region	Study Area	Field ID	Number of Samples	% Fines		% TOC		Total Sulfides (mg/kg)		Ammonia (mg/kg)	
				Mean	Max	Mean	Max	Mean	Max	Mean	Max
Northern Harbor	Ediz Hook Point	EH	4	19	32	0.93	1.6	3.6	3.6	5.1	5.1
	Fish Pen Area	FP	3	29	69	1.5	1.9	32.6	32.6	7.3	7.3
Central Harbor	Barge Area	BA	2	77	83	1.9	2	702	702	12	12
Western Harbor	Inner Ediz Hook Area	IE	14	64	81	7.6	33	1670	2310	23	42
	Lagoon Area	LA	3	55	70	10	12	918	1220	27	38
	Inner Harbor Area	IH	6	41	46	10	25	1070	3080	19	36
	Port Angeles Marina	MA	6	61	74	3.3	8.5	794	1890	20	29
Southern Harbor	Boat Launch & Standard Oil Area	BL	8	56	71	2.4	5	1180	2220	23	43
	K-Ply/Valley Creek	KP	8	57	71	2.5	5.3	504	758	15	20
	Landing Pier (Ferry Terminal)	FT	12	48	69	1.6	2.6	287	860	14	22
	Red Lion Inn	RL	3	8.1	15	0.53	0.76	6.5	7.2	9.1	11
Outer Harbor	City of Port Angeles Wastewater Treatment Plant	WW	1	21	21	0.74	0.74	7.6	7.6	7.5	7.5
	Outer Harbor	OH	3	27	29	0.61	0.73	71	175	5.3	6.5
	Eastern Intertidal/Subtidal Shore	EI	6	7.5	16	0.3	0.63	71	383	7.8	14
Rayonier	Log Pond	LP	4	18	50	3.1	3.8	337	1010	15	31
	Mill Dock	MD	5	48	69	2.2	3.6	619	1020	31	71
	East of Mill Dock	ED	5	56	77	2.9	5.1	1130	3240	100	403
	Nearshore Outfalls	CO	5	13	40	0.79	2	204	805	6.4	9.8
	Deep Outfall	DO	5	22	29	0.52	0.68	16	46	12	17
	Ennis Creek	EC	5	11	34	0.67	1.4	31	94	7.1	14
	East of Ennis Creek	EE	5	1.9	5.6	0.23	0.31	--	--	--	--
Reference	Dungeness Bay	RF		26	73	0.68	1.4	137	408	13	25

Table 5.2–1. Subsurface "B" Sediment Conventionals Results

Region	Station	Sample Interval (inches)	% Fines	% TOC	Sulfide (mg/kg)	Ammonia (mg/kg)
Western Harbor	IE01B	30–42	39.2	14.8	790	46.2
	IE05B	12–24	65.6	11.7	1030	46.5
	IE09B	36–48	35.2	78.5	342	282
	IE12B	12–24	71.7	5.76	966	63.4
	IE14B	12–24	76.7	3.61	809	112
	IE16B	12–24	61.7	0.656	3.62	13.9
	LA02B	24–36	18.5	4.41	73.6	25.1
	IH02B	12–24	52.7	23.1	1110	19.7
	IH06B	12–24	34.2	4.85	494	27
	MA02B	6–12	60.4	5.84	--	--
Southern Harbor	BL02B	36–48	72	3.41	496	73.5
	BL08B	12–24	61	0.483	--	--
	KP02B	12–24	55.4	8.7	--	--
	KP03B	24–36	30.2	3.12	--	--
	KP07B	12–24	61.1	0.529	--	--
	KP08B	36–48	30.3	0.749	84.2	3.35
	FT04B	12–24	63.1	1.39	--	--
	FT06B	12–24	24.5	0.463	--	--
	FT12B	6–12	21.9	0.843	--	--
Outer Harbor	EI02B	6–12	0.1	0.207	33.6	0.67
Rayonier	LP05B	6–12	35.2	13.9	1050	24.3
	CO02B	6–12	7.7	1.27	--	--
	CO03B	24–36	11.8	1.27	--	--
	CO04B	12–24	9.2	1.12	--	--
	CO05B	24–36	48.9	3.4	--	--
	MD01B	6–12	13.1	1.88	281	2.89
	MD02B	12–24	60.4	5.12	--	309
	MD03B	48–60	25.6	2.86	122	30.8
	MD04B	6–18	19.9	1.22	177	3.13
	MD05B	4–10	6.4	0.803	1.22	2.93
	ED01B	24–36	19.4	0.712	--	--
	ED02B	12–24	24	0.548	--	--
	ED03B	6–18	30.4	3.46	--	--
	ED04B	36–48	76.3	4.21	--	--
	ED05B	12–24	23.8	3.71	--	--
	DO04B	6–12	25.5	0.695	392	3.03
	DO05B	6–12	22.7	0.539	87.8	2.47
	EC03B	6–12	9.3	2.3	--	--
	EC04B	12–24	60.4	3.11	--	--
	EE01B	6–12	33	0.25	--	--
	EE02B	12–24	0.7	0.583	--	--
	EE03B	6–12	9.9	0.498	--	--
	EE04B	6–12	6.5	0.63	--	--

Table 5.3–1. Subsurface "C" and "D" Sediment Conventionals Results

Region	Station	Sample Interval	% Fines	% TOC	Sulfide (mg/kg)	Ammonia (mg/kg)
Western Harbor	IE01C	48–60	14.6	0.698	18.7	6.87
	IE05C	98–110	58.1	0.89	138	30
	IE12C	107–119	28.5	0.638	2.68	20
	IE14C	62–74	81.1	1.1	304	70.6
	IE16C	36–48	55.9	0.484	2.96	14.7
	LA02C	NA	6.5	1.77	7.25	8.93
	IH02C	70–82	81.2	2.24	123	147
	IH06C	98–100	39.6	0.696	19.1	24.3
	MA02C	12–24	72.7	3.52	—	—
Southern Harbor	BL02C	60–78	10.8	1.1	105	9.41
	BL08C	36–48	52.2	0.438	--	--
	KP02C	54–66	29.9	0.336	--	--
	KP03C	78–90	87.6	6.47	--	--
	KP07C	36–48	52.1	0.506	--	--
	KP08C	48–60	18.8	0.622	171	2.54
	FT04C	36–48	66.6	2.43	--	--
	FT06C	36–48	13.9	0.2	--	--
	FT12C	36–48	29.3	0.506	--	--
Rayonier	MD01C	12–24	5.4	0.21	6.76	0.49
	MD02C	48–70	21	0.244	1.09	65.5
	MD03C	35–47	25.4	2.46	131	36.6
	MD05C	10–22	4.3	0.359	2.8	1.2
	ED02C	36–48	18.1	1.32	--	--
	ED03C	33–45	8.7	0.548	--	--
	DO04C	12–24	22.6	0.593	76.3	2.28
	DO04D	24–32	20.8	0.424	17.9	3.23
	DO05C	12–16	11.9	0.534	8.38	1.32
	EC03C	12–24	48.5	2.78	3030	175
	ED01C	72–84	2.1	0.255	--	--
	EE02C	24–36	3.9	0.128	--	--
	EE03C	12–24	4.9	0.329	--	—
	EE04C	12-24	7.5	0.263	--	--

Table 5.4–1. Surface Sediment Exceedances of SMS and LAET Criteria

Region	Location	TOC	SMS Exceedances							LAET Exceedance
			Arsenic	Cadmium	Mercury	Zinc	4-Methyl phenol	Phenol	Bis(2-ethylhexyl) phthalate	Butyl benzyl phthalate
			SQS = 57 CSL = 93	SQS = 5.1 CSL = 6.7	SQS = 0.41 CSL = 0.59	SQS = 410 CSL = 960	SQS = 670 CSL = 670	SQS = 420 CSL = 1200	SQS = 47 CSL = 78	LAET = 63 2LAET = 900
		wt %	mg/kg				µg/kg		mg/kg OC	µg/kg
Western Harbor	LA01A	11.7	–	5.90	0.45	–	–	–	–	–
	LA02A	10.3	–	–	0.59	–	–	–	–	–
	LA03A	9.2	–	–	0.59	–	–	–	–	73
	IH01A	17.2	–	7.4	3.50	1600	–	–	–	–
	IH02A	25.4	69.0	–	1.30	460	–	–	–	–
	IE09A	3.3	–	–	1.20	860	–	–	–	–
	IE13A	8.3	–	–	1.90	610	–	–	–	–
	IE16A	4.9	–	–	1.30	–	–	–	–	–
Southern Harbor	MA01A	1.1	–	–	–	–	–	–	49.6	–
	MA03A	4.0	–	–	–	–	–	610	–	–
	MA04A	8.5	–	–	–	–	–	740	–	670
Rayonier	MD04A	2.2	–	–	–	–	–	760	–	–
	ED04A	5.1	–	–	–	–	41000	–	–	–

Key:

> 3.5% TOC

Exceeds SQS/LAET criteria

Exceeds CSL/2LAET criteria

– : concentration below SMS criteria

Table 5.4–2. Subsurface Sediment Exceedances of SMS and LAET Criteria

Region	Location	Depth Interval (cm)	TOC	SMS Exceedances												LAET Exceedances				
				Cadmium	Mercury	Zinc	PCB, Sum of Aroclors	2-Methylnaphthalene	Acenaphthene	Dibenzofuran	Fluorene	Naphthalene	Phenanthrene	Total LPAH	4-Methyl phenol	PCB, Sum of Aroclors	Butyl benzyl phthalate	Bis(2-ethylhexyl) phthalate	4,4'-DDD	4,4'-DDE
				SQS = 5.1 CSL = 6.7	SQS = 0.41 CSL = 0.59	SQS = 410 CSL = 960	SQS = 12 CSL = 65	SQS = 38 CSL = 64	SQS = 16 CSL = 57	SQS = 15 CSL = 58	SQS = 23 CSL = 79	SQS = 99 CSL = 170	SQS = 100 CSL = 480	SQS = 370 CSL = 780	SQS = 670 CSL = 670	LAET = 130 2LAET = 1000	LAET = 63 2LAET = 900	LAET = 1300 2LAET = 1900	LAET = 16 2LAET = 43	LAET = 9 2LAET = 15
			wt %	mg/kg			mg/kg OC								µg/kg	µg/kg				
Western Harbor	IH02B	30 - 61	23.1	12	8.9	1900	–	–	–	–	–	–	–	–	–	–	–	–	na	na
	IH06B	30 - 61	4.9	–	0.53	–	–	–	–	–	–	–	–	–	–	–	–	2800	na	na
	IE05B	30 - 61	11.7	–	0.86	–	–	–	–	–	–	–	–	–	–	–	–	–	na	na
	IE09B	91 - 122	78.5	–	–	–	–	–	–	–	–	–	–	–	–	–	91	–	na	na
	MA02C	12 - 24	3.5	–	0.5	–	–	–	–	–	–	–	–	–	–	–	–	–	na	na
Southern Harbor	FT04C	36 - 48	2.4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	65	14
Rayonier	ED05B	30 - 61	3.7	–	–	–	–	–	–	–	–	–	–	–	–	250	–	–	–	–
	EC03B	6 - 12	2.3	–	–	–	13.5	–	47.8	24.8	40.0	–	117.0	–	690	–	–	–	–	–
	EC03C	12 - 24	2.8	–	–	–	14.7	107.9	176.3	97.1	147.5	226.6	348.9	925	–	–	–	–	–	–

Key:

> 3.5% TOC

Exceeds SQS/LAET criteria

Exceeds CSL/2LAET criteria

– : concentration below SMS criteria

na : not analyzed

Table 6–1. Bioassay Criteria Used to Evaluate the Port Angeles Harbor Bioassay Data

Test	Control/Reference Performance Standards	Biological Effects Criteria (SMS)	No. of Stations Exceeding SMS Criteria
10-Day Amphipod Bioassay	Mean Control Mortality < 10 percent	SQS: Test sediment >25% mortality and statistically significant (alpha = 0.05)	1
E. estuaries	Mean Reference sediment mortality < 25 percent	CSL: Test sediment >30% mortality over reference and Statistically significant (alpha = 0.05)	1
20-Day Juvenile Polychaete	Mean Control Mortality < 10 percent MIG Control >= 0.72 mg/ind/day	SQS: Test sediment MIG / Reference MIG <70% and Statistically significant (alpha = 0.05)	1
N. arenaceodentata	MIG Reference/MIG Control > 80%	CSL: Test sediment MIG / Reference MIG <50% and Statistically significant (alpha = 0.05)	0
Larval Bioassay	Mean Control Survival >70 percent	SQS: Test sediment <85% of normal development at reference and Statistically significant (alpha = 0.10)	29
D. excentricus	Mean Reference/Control >=65 percent over control	CSL: Test sediment <70% of normal development at reference and Statistically significant (alpha = 0.10)	12

Key:

CSL = Cleanup Screening Level

SQS = Sediment Quality Standards

Source: WAC 173-204-315(2)

Table 6–2. Results of the Sediment Bioassays from 68 Samples Representing 59 Stations in the Harbor-Wide Study Area

Sample	% Fines	% Total Organic Carbon	Reference Station & Batch Number for Comparison	*E. estuarius*	Reference Station & Batch Number for Comparison	*N. arenaceodentata*			Reference Station & Batch Number for Comparison	*D. excentricus*		Overall Station Status
				% Mean Mortality		% Mean Mortality	MIG (mg/ind/day)	MIG Relative to Reference		Mean Normal Survivorship (%) Control Adjusted	Mean Normal Survivorship (%) Relative to Reference	
EH02A	9.7	0.62	RF02A (1)	5	RF02A (1)	8	0.71	1	RF02A (1)	74.4	84	**SQS**
FP01A	10.3	1.03	RF02A (1)	6	RF02A (1)	8	0.63	1.47	RF02A (1)	73.6	83	**SQS**
BA01A	71.5	2.04	RF03A (1)	14	RF03A (1)	0	0.75	1.34	RF03A (1)	36.6	50	**CSL**
IE03A	65.5	6.48	RF03A (1)	20	RF03A (1)	12	0.72	1.29	RF03A (1)	57	78	**SQS**
IE04A	67.9	4.81	RF03A (1)	9	RF03A (1)	8	0.67	1.2	RF03A (1)	53.4	73	**SQS**
IE06A	42.6	33.2	RF03A (1)	7	RF03A (1)	8	0.66	1.18	RF03A (1)	47.2	65	**CSL**
IE07A UV	17.9	15.4	RF02A (4)	15	RF02A (3)	0	0.77	0.99	RF02A (4)	69	72	**SQS**
IE09A	66.5	3.33	RF03A (2)	5	RF03A (2)	4	0.77	1.6	RF03A (2)	55.9	70	**CSL**
IE14A	78.2	2.79	RF03A (1)	17	RF03A (1)	0	0.59	1.05	RF03A (1)	42.4	58	**CSL**
IE15A	74.7	2.48	RF03A (1)	17	RF03A (1)	0	0.68	1.21	RF03A (1)	45	62	**CSL**
LA02A UV	69.7	10.3	RF03A (4)	5	RF03A (3)	8	0.79	1.16	RF03A (4)	29.5	34	**CSL**
IH01A	31	17.2	RF03A (2)	0	RF03A (2)	4	0.69	1.44	RF03A (2)	80.7	100	Pass
IH02A	62	25	RF03A (2)	14	RF03A (2)	4	0.68	1.42	RF03A (2)	57.2	71	**SQS**
IH03A	42.9	11.7	RF03A (2)	22	RF03A (2)	0	0.57	1.19	RF03A (2)	58.3	73	**SQS**
IH05A	30.1	1.8	RF03A (2)	0[1]	RF02A (2)	0	0.58	1.35	RF03A (2)	76.9	96	Pass
IH06A	45.9	2.09	RF03A (2)	6	RF03A (2)	0	0.52	1.08	RF03A (2)	64.1	80	**SQS**
MA01A	23.9	1.13	RF02A (2)	7	RF02A (2)	0	0.69	1.6	RF02A (2)	73.5	84	**SQS**
MA02A	74.1	4.02	RF03A (1)	7	RF03A (1)	4	0.38*	0.68	RF03A (1)	46.5	64	**CSL**
MA05A	73.5	2.46	RF03A (1)	7	RF03A (1)	0	0.63	1.13	RF03A (1)	55.5	76	**SQS**
MA06A	66.7	1.36	RF03A (1)	22	RF03A (1)	4	0.78	1.39	RF03A (1)	37.3	51	**CSL**
BL01A	57.2	5.03	RF03A (2)	12	RF03A (2)	0	0.69	1.44	RF03A (2)	44.5	55	**CSL**
BL02A	55.9	2.72	RF03A (2)	9	RF03A (2)	0	0.66	1.38	RF03A (2)	76	95	Pass
BL03A	71.1	2.51	RF03A (2)	10	RF03A (1)	4	0.44*	0.79	RF03A (2)	56.4	70	**SQS**
BL04A	5.6	0.64	RF02A (2)	6	RF02A (2)	4	0.58	1.35	RF02A (2)	68	77	**SQS**
BL06A	62.3	1.89	RF03A (1)	15	RF03A (1)	0	0.49*	0.88	RF03A (1)	39	54	**CSL**
KP01A	70.7	4.21	RF03A (2)	11	RF03A (2)	0	0.47	0.98	RF03A (2)	61.4	76	**SQS**
KP02A	61.4	5.31	RF03A (2)	7	RF03A (2)	0	0.59	1.23	RF03A (2)	63.2	79	**SQS**
KP03A	23.7	1.8	RF02A (2)	7	RF02A (2)	0	0.44	1.02	RF02A (2)	86	98	Pass
KP05A	70.9	1.09	RF03A (1)	6	RF03A (1)	0	0.64	1.14	RF03A (1)	52.2	72	**SQS**
KP06A	61.4	1.72	RF03A (1)	6	RF03A (1)	0	0.6	1.07	RF03A (1)	58.4	80	**SQS**
FT01A	69.1	2.44	RF03A (2)	12	RF03A (2)	0	0.64	1.33	RF03A (2)	68.5	85	Pass
FT04A	49.8	1.12	RF03A (2)	9	RF03A (2)	0	0.75	1.56	RF03A (2)	88.1	110	Pass
FT06A	52.3	1.47	RF03A (1)	8	RF03A (1)	0	0.49*	0.88	RF03A (1)	66.8	92	Pass
FT11A	45.2	2.4	RF03A (1)	11	RF03A (1)	4	0.54	0.96	RF03A (1)	62	85	Pass
RL01A UV	6.8	0.414	RF02A (4)	4	RF02A (3)	0	0.96	1.23	RF02A (4)	99.8	104	Pass
RL02A UV	2.9	0.425	RF01A (4)	2	RF02A (3)	0	0.9	1.15	RF01A (4)	99.8	100	Pass
CO01A UV	2.2	0.588	RF01A (4)	5	RF02A (3)	0	0.73	0.94	RF01A (4)	87.6	88	Pass
CO02A	40.1	2	RF03A(3)	3	RF03A(2)	0	0.52	1.08	RF03A(3)	66.6	100	Pass
CO04A UV	0.3	0.182	RF01A (4)	7	RF01A (3)	0	0.74	0.99	RF01A (4)	98.1	99	Pass
MD01A	38.6	2.36	RF03A (3)	9	RF03A (2)	8	0.45	0.94	RF03A (3)	75.9	114	Pass
MD02A	69.6	3.62	RF03A (3)	14	RF03A (2)	0	0.6	1.25	RF03A (3)	36.3	55	**CSL**

Table 6–2. Results of the Sediment Bioassays from 68 Samples Representing 59 Stations in the Harbor-Wide Study Area

Sample	% Fines	% Total Organic Carbon	Reference Station & Batch Number for Comparison	*E. estuarius*	Reference Station & Batch Number for Comparison	*N. arenaceodentata*			Reference Station & Batch Number for Comparison	*D. excentricus*		Overall Station Status
				% Mean Mortality		% Mean Mortality	MIG (mg/ind/day)	MIG Relative to Reference		Mean Normal Survivorship (%) Control Adjusted	Mean Normal Survivorship (%) Relative to Reference	
MD03A	67.2	1.24	RF03A (3)	10	RF03A (2)	0	0.52	1.08	RF03A (3)	48	72	**SQS**
ED03A	71.5	4.23	RF03A (3)	11	RF03A (3)	4	0.51	1.06	RF03A (3)	61.7	93	Pass
ED04A	76.7	5.13	RF03A (3)	100[1]	RF03A (2)	4	0.43	0.9	RF03A (3)	21.4	32	**CSL**
ED05A	16.5	1.32	RF03A (3)	2	RF03A (2)	0	0.61	1.27	RF03A (3)	77	116	Pass
WW01A	20.9	0.742	RF02A (3)	7	RF02A (2)	4	0.49	1.14	RF02A (3)	84.3	96	Pass
OH02A	28	0.679	RF02A (1)	14	RF02A (1)	4	0.61	0.86	RF02A (1)	79.2	89	Pass
DO03A	31.1	0.542	RF02A (3)	11	RF02A (2)	4	0.52	1.21	RF02A (3)	80.5	92	Pass
DO04A	26.7	0.438	RF02A (3)	10	RF02A (2)	4	0.48	1.12	RF02A (3)	90.5	104	Pass
DO05A	21.9	0.495	RF02A (3)	6	RF02A (2)	0	0.41	0.95	RF02A (3)	94.8	108	Pass
EC01A Acc UV	1.5	0.469	RF01A (4)	5	RF01A (3)	4	0.7	0.93	RF01A (4)	89.1	90	Pass
EC01A Unacc UV	1.5	0.469	RF01A (4)	7	RF01A (3)	4	0.66	0.88	RF01A (4)	89.9	90	Pass
EC02A UV	0.1	0.239	RF01A (4)	9	RF01A (3)	0	0.8	1.07	RF01A (4)	87.6	88	Pass
EC04A	18.3	1.35	RF02A (3)	1	RF02A (2)	0	0.49	1.14	RF02A (3)	84.1	96	Pass
EI02A UV	8.3	0.182	RF02A (4)	4	RF02A (4)	0	0.89	NA	RF02A (4)	100	104	Pass
EI07A	16	0.628	RF02A (2)	15	RF02A (2)	0	0.38	0.88	RF02A (2)	79.4	90	Pass
RF01A (1)	1.3	0.213		6		0	0.68			90.9		
RF01A(2)	1.3	0.213		5		0	0.65			90		
RF01A (3)	1.3	0.213		6		0	0.75			83.5		
RF01A (4)	1.3	0.213		5		NA	NA			99.5		
RF02A (1)	2.2	0.403		6		4	0.71			88.9		
RF02A (2)	2.2	0.403		2		0	0.43			88		
RF02A (3)	2.2	0.403		10		0	0.78			87.4		
RF02A (4)	2.2	0.403		4		NA	NA			95.9		
RF03A (1)	73.7	1.42		11		16	0.56			72.8		
RF03A (2)	73.7	1.42		11		0	0.48			80.3		
RF03A (3)	73.7	1.42		23		4	0.68			66.5		
RF03A (4)	73.7	1.42		12		NA	NA			87.8		

Key:

Criteria for these bioassay results can be found in Table 6-1.

Shading represent samples that failed WA State Sediment Management Standards.

Exceeds SQS/LAET criteria

Exceeds CSL/2LAET criteria

The Number in Parentheses Following the RF Station Designation Refers to a Batch Number.

mg/ind/day = Mean Individual Growth Rate per Day

MIG = Mean Individual Growth

NA = Not Analyzed

*SQS Exceedance based on RF03A Batch 1 being recalculated without outlier replicate 3

[1] These results are from Batch 5, a retest batch run along with Batch 4

Table 6–3. Surface Sediment Exceedances of SMS and LAET Chemical Criteria and SMS Biological Criteria

Region	Location	TOC	SMS Exceedances							LAET Exceedance	Bioassay Results		
			Arsenic	Cadmium	Mercury	Zinc	4-Methyl phenol	Phenol	Bis(2-ethylhexyl) phthalate	Butylbenzylphthalate	Larval Development	Amphipod Mortality	Polychaete Growth
			SQS = 57 CSL = 93	SQS = 5.1 CSL = 6.7	SQS = 0.41 CSL = 0.59	SQS = 410 CSL = 960	SQS = 670 CSL = 670	SQS = 420 CSL = 1200	SQS = 47 CSL = 78	LAET = 63 2LAET = 900			
		wt %	mg/kg				µg/kg		mg/kg OC	µg/kg			
Western Harbor	LA01A	11.7	−	5.90	0.45	−	−	−	−	−	na	na	na
	LA02A	10.3	−	−	0.59	−	−	−	−	−	Fail	Pass	Pass
	LA03A	9.2	−	−	0.59	−	−	−	−	73	na	na	na
	IH01A	17.2	−	7.4	3.50	1600	−	−	−	−	Pass	Pass	Pass
	IH02A	25.4	69.0	−	1.30	460	−	−	−	−	Fail	Pass	Pass
	IE09A	3.3	−	−	1.20	860	−	−	−	−	Fail	Pass	Pass
	IE13A	8.3	−	−	1.90	610	−	−	−	−	na	na	na
	IE16A	4.9	−	−	1.30	−	−	−	−	−	na	na	na
Southern Harbor	MA01A	1.1	−	−	−	−	−	−	49.6	−	Fail	Pass	Pass
	MA03A	4.0	−	−	−	−	−	610	−	−	na	na	na
	MA04A	8.5	−	−	−	−	−	740	−	670	na	na	na
Rayonier	MD04A	2.2	−	−	−	−	−	760	−	−	na	na	na
	ED04A	5.1	−	−	−	−	41000	−	−	−	Fail	Fail	Pass

Key:
> 3.5% TOC
Exceeds SQS/LAET criteria
Exceeds CSL/2LAET criteria
− : concentration below SMS criteria

Key:
Passed SMS criteria
Failed SQS criteria
Failed CSL criteria
na = not analyzed

Table 6–4. Correlation Coefficients (r2) Identifying Relationships Among Conventional and the Most Frequently Detected Resin Acid Compounds

Correlation	% Amphipod Mean Mortality	% Neanthes Mean Mortality	Neanthes MIG (mg/ind/day)	Larval Mean Normal Survivorship (%) Control Adjusted
TOC	0.007	0.093	0.009	0.106
Fines	0.113	0.001	0.061	**0.634**
Sulfides	0.273	0.022	0.033	0.393
Ammonia	**0.87**	0.016	0.069	0.177
Wood Debris	0.1	0.05	0.003	0.183
Retene	0.01	0	0.001	0.002
Abietic Acid	0.126	0	0.002	0.045
Dehydroabietic Acid	0.128	0.022	0	0.072
Oleic Acid	0.001	0.004	0.022	0.067

Key:

Bold = Cells indicate a strong correlation.

Table 8–1. Number and Percent of Sediment Profile/Plane View Stations and their Characteristics Within Areas Identified by WA DNR as Lease Areas (SAIC 1999)

Lease Area	SPI/Plane View Stations	No Wood Debris	Bark	Logs	Sawdust Pulp	Bacterial Mats
Nippon	14	7 (50%)	5 (35.7%)	1 (7.1%)	12 (85.7%)	8 (57.1%)
PM Areas	14	9 (64.3%)	5 (35.7%)	0.0	5 (35.7%)	0.0
Rayonier Mill Dock	9	3 (33.3%)	6 (66.6%)	0.0	1 (11.1%)	0.0
Rayonier Log Storage	13	4 (30.8%)	7 (53.8%)	2 (15.4%)	3 (23.1%)	2 (15.4%)
Foss Marine	5	1 (20%)	4 (80%)	0.0	0.0	0.0
Net Pens	4	3 (75%)	2 (25%)	0.0	0.0	0.0
Central Harbor (No Leases)	34	18 (52.9%)	15 (44.1%)	1 (2.9%)	0.0	0.0
Total Number	**93**	**45 (48.4%)**	**43 (46.2%)**	**4 (4.3%)**	**21 (22.6%)**	**10 (10.8%)**

Key:

PM = Port Management

SPI = Sediment profile imaging

WA DNR = Washington Department of Natural Resources

Table 8–2. Number of Sediment Trend Analysis Samples that Contain Wood Debris (GeoSea 2008)

Amount of Wood Debris	Number of Samples	Percent of Total
No Wood Debris	532	69.5
Low	145	19.0
Medium	42	5.5
High	46	6.0
Total	765	100.0

Note: The 72 stations with hard substrate were not included in the table.

Table 8–3. Qualitative Characterization of Wood Debris Found in Surface Sediment at Harbor-Wide and Rayonier Mill Stations

Station	% Wood Debris	Sample ID	% Wood Debris	Station	% Wood Debris
EH01A	0	BL01A	30	CO05A	0
EH02A	0	BL02A	Trace	MD01A	0
EH03A	0	BL03A	Trace	MD02A	0
EH04A	0	BL04A	0	MD03A	0
FP01A	0	BL05A	Trace	MD04A	0
FP02A	Trace	BL06A	0	MD05A	0
FP03A	0	BL07A	0	ED01A	Trace
BA01A	0	BL08A	0	ED02A	0
BA02A	Trace	KP01A	0	ED03A	0
IE01A	85	KP02A	20	ED04A	0
IE03A	Trace	KP03A	0	ED05A	0
IE04A	50	KP04A	0	WW01A	0
IE05A	Predominantly Wood	KP05A	Trace	OH01A	0
IE06A	75	KP06A	0	OH02A	0
IE07A	95	KP07A	0	OH03A	0
IE08A	Trace	KP08A	Trace	DO01A	0
IE09A	Trace	FT01A	Trace	DO02A	0
IE10A	Trace	FT02A	Trace	DO03A	0
IE11A	Trace	FT04A	0	DO04A	0
IE12A	Trace	FT05A	0	DO05A	0
IE13A	75	FT06A	0	EC01A	0
IE14A	0	FT07A	0	EC02A	0
IE15A	Trace	FT08A	0	EC03A	0
IE16A	70	FT09A	0	EC04A	0
LA01A	80	FT10A	0	EC05A	0
LA02A	Trace	FT11A	0	EE01A	0
LA03A	Trace	FT12A	0	EE02A	0
IH01A	30	FT13A	0	EE03A	0
IH02A	Trace	RL01A	0	EE04A	0
IH03A	90	RL02A	0	EE05A	0
IH04A	70	RL03A	0	EI01A	0
IH05A	0	LP01A	0	EI02A	0
IH06A	0	LP03A	30	EI03A	0
MA01A	0	LP04A	40	EI04A	0
MA02A	80	LP05A	50	EI06A	0
MA03A	0	CO01A	0	EI07A	0
MA04A	90	CO02A	0	RF01A	0
MA05A	0	CO03A	0	RF02A	0
MA06A	Trace	CO04A	0	RF03A	0

Table 10–1. Summary of Excess Cancer Risk Results

Pathways	Subsistence Fisher	Subsistence Fisher	Recreational Fisher	Recreational Fisher	Residential User	Recreational User
	(RME)	**(CT)**	**(RME)**	**(CT)**		
Sediment - Ingestion	5.2E-06	5.2E-06	2.0E-06	6.0E-07	2.0E-06	2.8E-07
Sediment - Dermal	8.0E-06	8.7E-07	3.2E-06	1.1E-07	3.2E-06	4.7E-07
Tissue - Ingestion[1]	1.2E-02	6.1E-03	2.8E-04	2.0E-04	--	--
Total Excess Cancer Risk	**1.2E-02**	**6.1E-03**	**2.8E-04**	**2.0E-04**	**5.2E-06**	**7.5E-07**

Note: Shaded cell indicates excess cancer risk greater than 1 x 10-5.

1 – Includes PCBs as Aroclors

CPAH, TCDD TEQ, and PCBs were calculated using a concentration of one half the reporting limits for non-detected values.

Table 10–2. Summary of Compounds that Exceed Excess Cancer Risk Threshold of 1 in 1,000,000

Pathway	Compound	Subsistence Fisher (RME)	Subsistence Fisher (CT)	Recreational Fisher (RME)	Recreational Fisher (CT)
Sediment Ingestion	Arsenic	3.5E-06	3.5E-06	1.4E-06	
Sediment Ingestion	TCDD TEQ[1]	1.6E-06	1.6E-06	6.0E-06	
Sediment Dermal	Arsenic	4.4E-06			
Sediment Dermal	TCDD TEQ[1]	3.2E-06		1.3E-06	
Fish Ingestion	Arsenic (Inorganic)	7.0E-03	3.5E-03	2.2E-04	1.5E-04
Fish Ingestion	PCB - Aroclors[1]	1.4E-03	6.8E-04	1.3E-05	9.4E-06
Fish Ingestion	PCB TEQ[1]	2.9E-04	1.4E-04	9.0E-06	6.3E-06
Fish Ingestion	cPAH[1]	3.2E-04	1.6E-04	1.1E-06	7.8E-06
Fish Ingestion	TCDD TEQ[1]	2.8E-03	1.4E-03	1.9E-05	1.3E-05
Fish Ingestion	DDE	4.2E-06	2.1E-06		
Fish Ingestion	DDT	2.5E-05	1.3E-05		
Fish Ingestion	alpha-BHC	5.1E-04	2.6E-04	1.6E-05	1.1E-05
Fish Ingestion	beta-BHC	6.8E-05	3.4E-05	2.0E-06	1.4E-06
Fish Ingestion	Lindale	1.4E-05	7.1E-06		
Fish Ingestion	Pentachlorophenol	2.2E-05	1.1E-05		
Fish Ingestion	Hexachlorobenzene	2.0E-06	2.0E-06	2.0E-06	2.0E-06

Notes:

Compound exceeds cancer risk threshold of 1×10^{-6} at specified risk level.

1 - Values calculated including non-detected compounds at one-half detection limit.

Key:

RME = Reasonable maximum exposure.

CT = Central tendency.

Table 10–3. Summary of Compounds that Exceed Hazard Quotient Threshold

Pathway	Compound	Subsistence Fisher (RME)		Subsistence Fisher (CT)		Recreational Fisher (RME)		Recreational Fisher (CT)	
		Adult	Child	Adult	Child	Adult	Child	Adult	Child
Fish Ingestion	Arsenic (Inorganic)	14.4	28.5	7.2	14.2		1.8		1.3
Fish Ingestion	Cadmium	3.2	6.3	1.6	3.2				
Fish Ingestion	Cobalt	3.5	6.9	1.7	3.5				
Fish Ingestion	Copper	1.9	3.8		1.9				
Fish Ingestion	Iron	2.5	4.9	1.2	2.4				
Fish Ingestion	Selenium	1.2	2.5		1.2				
Fish Ingestion	Silver		1.3						
Fish Ingestion	Vanadium		1.2						
Fish Ingestion	Zinc		1.1						
Fish Ingestion	Methylmercury	5.1	10.2	2.6	5.1				
Fish Ingestion	PCBs - Aroclors[1]	31.3	62	15.6	31		1.3		
Fish Ingestion	PCB TEQ[1]	1.8	3.5		1.7				
Fish Ingestion	TCDD TEQ[1]	17.5	34.7	8.8	17.4				
All	Total HI (PCB Aroclors)	83	170	42	83	3.6	6.1	2.4	4.2
All	Total HI (PCB TEQs)	54	110	27	54	3	5	2	3.4

Notes:

Compound exceeds Ecology HQ threshold of 1.0 at specified level.

1 - Values calculated including non-detected compounds at one-half detection limit.

Key:

RME = Reasonable maximum exposure.

CT = Central tendency.

HI = Hazard index.

Table 10–4. Summary of Potential Risks to Assessment Endpoints in Port Angeles Harbor

Assessment Endpoint	Representative Species	Summary and Conclusion
Marine plants and macroalgae	Eel grass, kelp	About 25% of the near-shore environment in the harbor has been degraded by wood waste based on studies conducted in 1998 and 2008. The primary areas of accumulation are located in the western portion of the harbor along the base of Ediz Hook, in the Lagoon Area, along the waterfront at the Port of Port Angeles Management Area, and in the Log Pond Area and surrounding the west side of the Rayonier Mill Dock. In areas with adequate light penetration, the sediment environment provides important habitat for marine vegetation. Because a considerable portion of the near-shore sediment environment in Port Angeles Harbor has been degraded by wood waste, it seems reasonable to hypothesize that the ability of Port Angeles Harbor to support marine plants and marcoalgae has been compromised.
Benthic invertebrates	Clams, polychaetes, crabs	Three measures were used to assess potential risks to benthic invertebrates: (1) sediment chemical concentrations compared with benchmarks, (2) bioassay testing, and (3) evaluation of sediment habitat quality. All three measures suggest that the benthic invertebrate community may be impaired at the site. First, several metals (arsenic, cadmium, mercury, and zinc) and organic chemicals (bis[2-ethylhexyl]phthalate, butylbenzylphthalate, 4-methylphenol, and phenol) were found to exceed SMS criteria. Second, sediment samples from 29 stations submitted for bioassay testing failed to meet SMS criteria. Third, sediment habitat quality has been impaired by wood waste accumulation in about 25% of the harbor. Based on these three measures, benthic invertebrate community impairment is most evident in the Inner Harbor Area near the base of Ediz Hook, Lagoon Area, Marina Area, and near the Rayonier facility.
Fish	Rock sole, lingcod	Possible risk from arsenic.[2] No unacceptable risks from other chemicals.
Carnivorous birds	Bald eagle, cormorant	No unacceptable risks.[1]
Omnivorous birds	Greater scaup	No unacceptable risks.[1]
Herbivorous birds	Brant	No unacceptable risks.[1]
Carnivorous mammals	Harbor seal	No unacceptable risks.[1]
Omnivorous mammals	Raccoon	Possible risk from arsenic.[2] No unacceptable risks from other chemicals.

Key:

CSL = Cleanup Screening Level

SMS = Sediment Management Standards

Notes:

1 = Hazard quotient (HQ) marginally greater than 1.

2 = HQ < 1 for all chemicals evaluated.