Supplemental Remedial Investigation & Feasibility Study

Volume 1: RI Report

Whatcom Waterway Site
Bellingham, Washington

Prepared by:

The RETEC Group, Inc.
1011 SW Klickitat Way, Suite 207
Seattle, Washington 98134-1162

RETEC Project Number: PORTB-18876-240

Prepared for:

The Port of Bellingham
1801 Roeder Avenue
Bellingham, Washington 98225

Public Review Draft

October 10, 2006

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Prepared by:

Jamie C. Stevens for:

Anne Fitzpatrick, Environmental Scientist

Jamie C. Stevens

Jamie Stevens, Environmental Engineer

Reviewed by:

Mark Larsen , Senior Project Manager

October 10, 2006

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Abbreviations and Acronyms

AET	apparent effects threshold
ASB	aerated stabilization basin
BEP	bis-2-ethylhexylphthalate
BSL	bioaccumulation screening level
BT	bioaccumulation trigger
CAP	Cleanup Action Plan
Corps	Army Corps of Engineers
cm	centimeter
cm/yr	centimeters per year
Cs-137	cesium
CSL	cleanup screening level
CSM	site conceptual model
CSO	combined sewer overflow
CST	column settling tests
DNR	Department of Natural Resources
dpm/g	disintegrations per minute per year
DRET	dredge elutriate test
Ecology	Department of Ecology
ECRT	electro-chemical reductive technology
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
ESA	Endangered Species Act
FEMA	Federal Emergency Management Agency
FIRMS	flood insurance rate maps
g/cm^2 yr	grams per square centimeter per year
g/cm^3	grams per cubic meter
GP	Georgia Pacific
HPAH	high polycyclic aromatic hydrocarbon
IRIS	Integrated Risk Information System
km^2	square kilometers
LAET	lowest apparent effects threshold
LPAH	low polycyclic aromatic hydrocarbon
m/sec	meters per second
M^3	cubic meters
MCUL	minimum cleanup level
MET	modified elutriate test
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MLLW	mean lower low water
MTCA	Model Toxics Control Act
ng/Kg	nanograms per kilogram
NMFS	National Marine Fisheries Service
NOAA	National Oceanic & Atmospheric Administration
NPDES	non-point discharge
^oC	degrees Celsius

Abbreviations and Acronyms

OMMP	Operations, Maintenance, and Monitoring Plan
PAH	polyaromatic hydrocarbons
Pb-210	lead
PCLT	pancake column leach test
Pilot	Bellingham Bay Demonstration Pilot
PMA	Port Management Agreement
ppt	parts per thousand
PRDE	pre-remedial design evaluation
PSDDA	Puget Sound dredge disposal analysis
RfD	reference dose
RI/FS	Remedial Action/Feasibility Study
RTDF	Remediation Technologies Development Forum
SAP	sampling and analysis plan
SEPA	State Environment Policy Act
SMP	Shoreline Master Program
SMS	sediment management standards
SPM	settled particulate matter
SQS	sediment quality standard
TCDD	tetrachlorodibezodioxin
TCLP	toxicity characteristics leaching procedure
TEC	toxicity equivalent concentration
TOC	total organic carbon
TSS	total suspended solids
USFWS	US Fish and Wildlife Service
USGS	United States Geological Survey
WASP	Water Quality Analysis Simulation Program
WW	Whatcom Waterway
WWTP	wastewater treatment plant
μg/L	micrograms per liter

1 Introduction

This document is Volume 1 of the Draft Supplemental Remedial Investigation and Feasibility Study (RI/FS) for the Whatcom Waterway Site in Bellingham. Together with the companion Draft Supplemental Environmental Impact Statement (EIS), the RI/FS document describes the results of environmental investigations of the Whatcom Waterway Site, describes and evaluates a range of potential remedial alternatives, and identifies a preferred remedial alternative.

This document (Volume 1) contains the Remedial Investigation component of the RI/FS, which describes the nature and extent of contamination and the environmental setting at the site. The Feasibility Study (Volume 2) contains the evaluation of cleanup technologies and alternatives that can be used to conduct cleanup of the site. Volume 2 also identifies a preferred remedial alternative that best meets regulatory requirements. This document was prepared consistent with the requirements of the Model Toxics Control Act (MTCA) regulations and the Sediment Management Standards (SMS).

After considering public comment, the RI/FS will be finalized and the Washington Department of Ecology (Ecology) will preliminarily select a cleanup alternative for the site that will be articulated for public review in a draft Cleanup Action Plan (CAP). Following public review of the CAP, the cleanup will move forward into design, permitting, construction, and long-term monitoring.

1.1 Site Description and Background

The Whatcom Waterway Site is located within Bellingham Bay. The locations and characteristics of the site are shown in Figure 2-1. The site includes lands that have been impacted by contaminants historically released from industrial waterfront activities, including mercury discharges from the former Georgia Pacific (GP) Chlor-Alkali Plant. The Chlor-Alkali Plant was constructed by GP in 1965 to produce chlorine and sodium hydroxide for use in bleaching and pulping wood fiber. The Chlor-Alkali Plant discharged mercury-containing wastewater into the Whatcom Waterway during the late 1960s and 1970s. Initial environmental investigations of the site identified mercury in sediment at concentrations that exceed applicable standards, as well other contaminants from industrial releases.

The main state law that governs the cleanup of contaminated sites is the MTCA. When contaminated sediments are involved, the cleanup levels and other procedures are also regulated by the SMS. MTCA regulations specify criteria for the evaluation and conduct of a cleanup action. SMS regulations dictate the standards for cleanup. Under both laws, a cleanup must protect human health and the environment, meet environmental standards in other laws that apply, and provide for monitoring to confirm compliance with site cleanup levels.

The key MTCA decision-making document for site cleanup actions is the RI/FS. In the RI/FS, different potential alternatives for conducting a site cleanup action are defined. The alternatives are then evaluated against MTCA remedy selection criteria, and one or more preferred alternatives are selected. After reviewing the RI/FS study, and after consideration of public comment, Ecology then selects a cleanup method and documents that selection in a document known as the CAP. Following public review of the CAP, the cleanup will move forward into design, permitting, construction and long-term monitoring.

The RI/FS process for the Whatcom Waterway Site was initiated under Ecology oversight in 1996 consistent with Agreed Order DE 95TC-N399. The RI/FS study process initially included detailed sampling and analysis in 1996 and 1998. These sampling events formed the basis for development of an RI/FS report in 2000.

In parallel with the RI/FS activities, the Bellingham Bay Comprehensive Strategy EIS was prepared. The EIS was both a project-specific EIS, evaluating a range of cleanup alternatives for the Whatcom Waterway Site, and a programmatic EIS, evaluating the Bellingham Bay Comprehensive Strategy. The Comprehensive Strategy was developed by an interagency consortium known as the Bellingham Bay Demonstration Pilot (Pilot). The Pilot brought together a partnership of agencies, tribes, local government, and businesses known collectively as the Pilot Work Group, to develop a cooperative approach to expedite source control, sediment cleanup and associated habitat restoration in Bellingham Bay. As part of the approach, the Pilot Work Group developed a Comprehensive Strategy that considered contaminated sediments, sources of pollution, habitat restoration, and in-water and shoreline land use from a Bay-wide perspective. The strategy integrated this information to identify priority issues requiring action in the near-term and to provide long-term guidance to decision-makers. The Comprehensive Strategy was finalized as a Final Environmental Impact Statement in October 2000 prepared under the State Environmental Policy Act (SEPA). It was a companion document to the 2000 RI/FS for the Whatcom Waterway Site.

Since 2000, the Bellingham Waterfront has undergone a series of dramatic land use changes, including the closure of the Georgia Pacific pulp mill and chemical plant, the sale of 137 acres of GP-owned waterfront property to the Port of Bellingham (Port), additional property ownership changes in the Central Waterfront Area, and City of Bellingham/Port land use planning initiatives that shift waterfront uses from industrial to mixed-use development and zoning.

This RI/FS incorporates the results of environmental investigations conducted since completion of the original RI/FS in 2000, updates previously evaluated cleanup alternatives, and describes and evaluates new cleanup alternatives that reflect changes in land use. The EIS companion document to this RI/FS is also currently available for public review. This RI/FS, the companion EIS and public comment on both documents will inform Ecology's preliminary selection of a cleanup alternative for the Whatcom Waterway Site. The preliminary selected alternative will be articulated for public review in a draft CAP. Following public review of the CAP, the cleanup will move forward into design, permitting, construction, and long-term monitoring.

1.2 Document Organization

This document is intended to be read in conjunction with the Feasibility Study report (Volume 2 of the RI/FS) and in conjunction with the companion EIS document (bound separately). This document contains periodic references to those other two documents.

This Remedial Investigation was prepared consistent with the process defined under MTCA and SMS. The RI document is organized as follows:

- Section 2 of this report provides a history of the site, an overview of previous environmental studies, and cleanup actions conducted to date.

- Section 3 of the document then summarizes the environmental site setting, including the physical site features, natural resources, and area land use and navigational uses.

- Site screening levels developed as part of the RI/FS are summarized in Section 4. This section summarizes the principal environmental receptors and exposure pathways for which the screening levels are protective.

- The nature and extent of site contamination problems are defined in Section 5. This section summarizes environmental data collected during the previous RI/FS activities (1996-2000) and during supplemental studies between 2002 and 2004. Information discussed in this section includes contaminant distribution in surface and subsurface sediments.

- Section 6 summarizes processes that affect the fate and transport of site contaminants. This section includes an assessment of sediment source control and natural recovery processes, and the other factors that may impact sediment stability.

- Section 7 contains the results of pre-design engineering evaluations performed in support of the Feasibility Study.

- Section 8 provides an overall summary of the RI, including the presentation of an overall Conceptual Site Model. The Conceptual Site Model incorporates the key findings of the RI study including contaminants and sources, the nature and extent of contamination, contaminant fate and transport processes, and the principal human health and ecological receptors.

- Section 9 lists references cited in the RI document. Backup data and relevant supporting information are attached as appendices to this report.

2 Project Background

This section provides an overview of the history of the Whatcom Waterway Site, including the results of previous investigation and cleanup actions. The purpose of this Supplemental RI/FS is discussed, along with the relationship between the RI/FS and the companion EIS. This information is provided as background and context to assist the reader in understanding the significance of the RI findings that are presented in the subsequent sections of this report.

2.1 Whatcom Waterway Site History

The Whatcom Waterway Site ("Site") consists of lands located within and adjacent to the Whatcom Waterway in Bellingham, Washington (Figure 2-1). Current land ownership patterns are summarized in Figure 2-2. Mercury and other contaminants have been detected within the site at concentrations that exceed cleanup standards defined under MTCA and SMS regulations.

2.1.1 Site-Area Historic Uses

The vicinity of the Whatcom Waterway Site area has been used for industrial activities by multiple parties since the late 1800s. Industrial operations conducted within the area include, but are not limited to, the following:

- Coal shipping
- Log rafting
- Pulp and paper mill operation
- Chemical manufacturing
- Cargo terminal operations
- Grain shipment
- Fish processing and cannery operations
- Bulk petroleum terminal operations (two facilities)
- Boatyard operation
- Handling of sand, gravel, and other mineral ores
- Municipal landfill operations
- Multiple lumber mills and a wood products manufacturing operations
- Operation of a co-generation power plant.

Pulp and paper mills have been operated on the Pulp and Tissue Mill Site (Figure 2-1). In the early 1900s the mills were operated by Puget Sound Pulp and Timber. The mills were later sold to GP in the 1960s.

In 1965 GP constructed a Chlor-Alkali Plant adjacent to the Log Pond. The plant operated between 1965 and 1999 using a mercury cell process to produce chlorine, sodium hydroxide, and hydrogen. Between 1965 and 1971, mercury-containing wastewaters from the Chlor-Alkali Plant were discharged directly into the Log Pond. Between 1971 and 1979 pretreatment measures were installed to reduce mercury discharges. Chlor-alkali plant wastewater discharges to the Log Pond area were discontinued in 1979, following construction of the Aerated Stabilization Basin (ASB).

The ASB facility was constructed by GP during 1978 and 1979 for management of wastewaters in compliance with the Clean Water Act. The outfall from the ASB continues to be owned by GP and wastewater and sediment quality in that area are monitored under the National Pollutant Discharge Elimination System (NPDES) permit program (Permit No. WA-000109-1).

The Whatcom Waterway was listed by Ecology as a contaminated site in the early 1990s. The site RI/FS process was initiated after completion of a site hazard assessment by Ecology, and after development of an Agreed Order between Ecology and GP.

2.1.2 Previous RI/FS and EIS Studies

In 1996, the RI/FS process for the Whatcom Waterway Site was initiated under a MTCA Agreed Order (DE 95TC-N399) between GP and Ecology. Detailed sampling and analysis was performed in 1996 and 1998, and an RI/FS report was completed in July 2000 following public notice and opportunity to comment. Sediment data summaries from the 2000 RI/FS are attached as Appendix B.

In parallel with the RI/FS activities, the Bellingham Bay Comprehensive Strategy EIS was prepared. The EIS was both a project-specific EIS, evaluating a range of cleanup alternatives for the Whatcom Waterway Site, and a programmatic EIS, evaluating the Bellingham Bay Comprehensive Strategy. The Comprehensive Strategy was developed by an interagency consortium known as the Pilot. The Pilot brought together a cooperative partnership of agencies, tribes, local government, and businesses known collectively as the Pilot Work Group, to develop a cooperative approach to expedite source control, sediment cleanup and associated habitat restoration in Bellingham Bay. As part of the approach, the Pilot Work Group developed a Comprehensive Strategy that considered contaminated sediments, sources of pollution, habitat restoration and in-water and shoreline land use from a Bay-wide perspective. The strategy integrated this information to identify priority issues requiring action in the near-term and to provide long-term guidance to decision-makers.

The Comprehensive Strategy was finalized as a Final Environmental Impact Statement (FEIS) in October 2000 prepared under SEPA. While it was published as a companion document to the 2000 RI/FS for the Whatcom Waterway site, and while it addressed project impacts associated with the MTCA cleanup of the Whatcom Waterway site, the 2000 EIS contained other contemplated actions above-and-beyond the regulatory requirements of the MTCA site cleanup process.

Consistency with the Pilot Comprehensive Strategy and the Pilot Goals is voluntary. However, the use of the Pilot goals provides an additional basis by which the qualitative benefits or short-comings of a remedial alternative can be measured. The Comprehensive Strategy included a number of Baywide recommendations for achieving the seven goals of the Pilot. These Baywide general recommendations were programmatic in nature and were not tied to specific project alternatives or actions. The Comprehensive Strategy also includes specific strategy recommendations for each of nine geographic subareas within Bellingham Bay. These Subarea Strategies provided greater detail on priorities and recommended actions for land use, habitat, sediment cleanup and source control within each geographic subarea (Appendix A of the 2006 Supplemental EIS for the Whatcom Waterway Site). The SEPA evaluation included in the 2000 FEIS have been updated in the EIS to include the updated site data, area land use changes, and actions taken at other cleanup sites. These changes do not affect the programmatic elements of the Pilot which are addressed by the 2000 FEIS.

Absent significant changes or new information, the 2000 RI/FS and EIS documents would have formed the basis for Ecology's selection of a cleanup approach for the Whatcom Waterway Site. That selection would have been formalized in a CAP. However, subsequent events and new information have made it necessary to complete this supplemental RI/FS and the companion Supplemental EIS, as described in Section 2.2 below.

In 2001 GP closed its pulp mill which dramatically reduced the wastewater treatment needs associated with process operations. The ASB was constructed in 1978 within the Whatcom Waterway Site area, on lands impacted by mercury discharges from the Chlor-Alkali Plant. In addition, the ASB facility has received effluent from the Chlor-Alkali Plant and the pulp and tissue mills. The ASB contamination from these sources was not addressed in the 2000 Whatcom Waterway RI/FS investigations of remedial alternatives, because at that time it was an operational wastewater treatment facility. However, with the reduced treatment needs resulting from the 2001 closure of the GP pulp mill, the contamination issues could be addressed as part of the cleanup of the Whatcom Waterway Site.

To address this new portion of the Whatcom Waterway Site, a new remedial alternative was evaluated in 2002 through a Supplemental FS (Anchor, 2002a) and companion Supplemental EIS (Anchor, 2002b). The new remedial alternative proposed using a portion of the ASB as a near shore fill disposal facility for disposal of contaminated materials removed from areas of the Whatcom Waterway Site outside the ASB and from other contaminated sediment sites in Bellingham Bay. The proposal included maintenance of a down-sized wastewater treatment facility constructed within the footprint of the existing ASB.

2.1.3 Log Pond Interim Remedial Action

In late 2000 and early 2001, Georgia Pacific implemented a combined sediment cleanup and habitat restoration action at the Log Pond, part of the Whatcom Waterway Site. The work was performed under the terms of a MTCA Interim Action Agreed Order with Ecology and as authorized under Clean Water Act Permit No. 2000-2-00424 administered by the U.S. Army Corps of Engineers (Corps). The Log Pond project beneficially reused 43,000 cubic yards of clean dredging materials from the Swinomish navigation channel and from the Squalicum Waterway. The materials were used to cap contaminated sediments in the Log Pond, and to improve habitat substrate and elevations for use by aquatic organisms. The habitat restoration component of the project was voluntarily implemented by GP in accordance with the Bellingham Bay Comprehensive Strategy.

Monitoring of the Log Pond Interim Action has been performed in Year 1, Year 2 and Year 5. The results of the Year 5 monitoring event are attached as Appendix I to this RI. Results of monitoring have confirmed that the cap is successfully meeting most performance objectives, with the exception of some erosion at the shoreline edges of the cap. Enhancements to the shoreline edges of the Log Pond cap to correct these erosional areas cap have been incorporated into the Feasibility Study. Monitoring results have documented the development of habitat functions within the Log Pond (Anchor, 2001b and 2002c). The Year 5 Monitoring Report is attached as Appendix I.

2.1.4 New Site Data

In spring and summer of 2002, following completion of the 2002 Supplemental FS and EIS, additional site data were collected to inform future remedial design activities. The results of these investigations were summarized in a Pre-Remedial Design Evaluation (PRDE) report (attached as Appendix A). The PRDE data collection included the following major work elements:

- Surface sediment sampling to document natural recovery rates and refine the boundaries of the area of sediment exceeding site cleanup levels
- Subsurface testing of samples located in the Outer Waterway area
- Contaminant mobility testing for use in evaluation and design of confined disposal alternatives

- Geotechnical testing, column settling tests and consolidation tests of site sediments for use in dredging, capping and confined disposal alternatives evaluations

In 2003 Ecology requested additional data collection to better characterize contamination within the ASB. This work was conducted under Addendum 4 of the RI/FS Work Plan and included testing of chemical and physical properties of the ASB sludges and underlying native sands. This sampling was performed in the summer of 2003. Data collected during that investigation are attached as Appendix C.

During 2004 additional site characterization data were collected at the ASB facility. This work was conducted under Addendum No. 5 of the RI/FS Work Plan. The investigation included testing of the chemical and physical properties of the ASB berm sands, bathymetric surveys of the ASB, and dewatering tests of the ASB sludges. Sampling was performed between July and September of 2004. Data collected during the 2004 investigations are attached as Appendix D.

2.1.5 Recent Land Use Changes

Extensive changes have occurred between completion of the 2000 RI/FS and EIS and the present, including the following:

- 1999 closure of the GP Chlor-Alkali Plant.

- 2001 closure of the GP pulp mill and chemical plant.

- 2004 development of the Waterfront Vision and Framework Plan by the Waterfront Futures Group, a community land use visioning effort initiated by the City and the Port and involving Bellingham citizens. The group developed a suite of Guiding Principles and Recommendations that addressed land use priorities for six areas of Bellingham Bay.

- Completion of marina demand studies and marina alternatives sitting analyses by the Port, including identification of the ASB as a preferred location for development of a future small boat marina.

- January 2005 Port acquisition of 137 acres of GP waterfront property, including portions of the Whatcom Waterway Site, in accordance with the Waterfront Vision and Framework Plan.

- Additional evaluations of navigation and waterfront infrastructure needs by the Port, DNR and the Army Corps of Engineers relating to the Whatcom Waterway. These evaluations included development of a November 2005 Port-DNR Memorandum of

Understanding relating to changing waterfront land use needs, development of a May 2006 Port Resolution #1230 and corresponding federal legislation to make adjustments to the dimensions of the federal channel within the Whatcom Waterway. These changes are intended to support the development of waterfront land use, public access, navigation, and habitat restoration improvements consistent with the Waterfront Vision and Framework Plan, while maintaining the viability of the Bellingham Shipping Terminal.

- Initiation of a joint Port-City Master Planning process for the waterfront area in the vicinity of the Whatcom Waterway site. This process is being implemented consistent with Port-City interlocal agreements dated January 2005 and July 2006. The interlocal agreements and the planning actions implemented by those agreements propose to redevelop the area to support mixed residential, commercial, light industrial, institutional and recreational uses and to support the development of transportation, utilities, public access, parks and open space and marine infrastructure including a marina, boat launch, transient moorage and associated parking. Consistent with the interlocal agreements, the properties within the New Whatcom planning area have been rezoned to mixed-use zoning, contingent on finalization of an approved Master Plan.

- Pending update to the City Shoreline Master Program (SMP). The SMP is a state-mandated shoreline land use planning effort. The SMP update is expected to embrace and elaborate on the work of the Waterfront Futures Group.

2.2 Objective of this Supplemental RI/FS

This Supplemental RI/FS integrates new site data with the project historical data, providing a comprehensive summary of site information. The RI/FS also presents and evaluates a modified range of cleanup alternatives for the site. Lastly, since 2000 a number of other changes have occurred that require updating through this Supplemental RI/FS;

- **Changes to Cleanup Costs:** Updated unit cost information is available from multiple sediment cleanup projects that have been completed since 2000. The RI/FS incorporates this updated cost information.

- **Endangered Species Listings:** The RI discussion of natural resources has been updated to reflect current information, including the recent listing of Puget Sound Orcas as endangered under the Endangered Species Act.

- **Multi-User Disposal Site Status:** The initial concept presented in the 2000 RI/FS and the companion EIS proposed the development of a multi-user disposal facility in Bellingham Bay for management of locally-generated contaminated sediments. However, the multi-user disposal facility has proven to be infeasible. The RI/FS and EIS require updating to reflect current project alternatives independent of the multi-user disposal facility concept.

2.3 Relationship between the RI/FS and the EIS

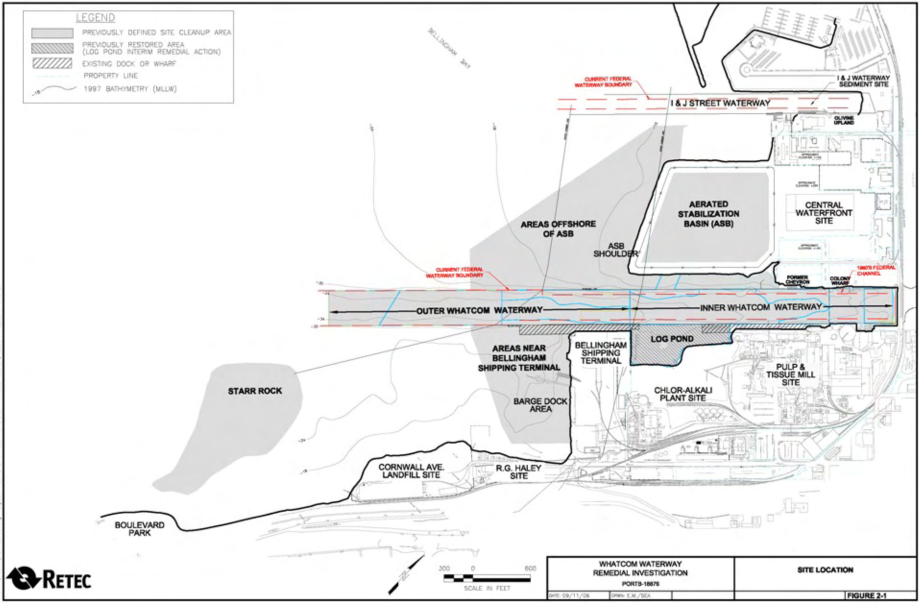
The RI/FS and the EIS documents are both used by Ecology, in conjunction with public and stakeholder comments, to inform its decision regarding the cleanup of impacted sites. However, the RI/FS and EIS documents each address different regulatory and policy requirements, and inform different aspects of the cleanup decision as summarized in Table 2-1.

Table 2-1 Relationship between the RI/FS and the EIS

	RI/FS	EIS
Regulatory Basis	Model Toxics Control Act (WAC 173-340) Sediment Management Standards (WAC 173-204)	State Environmental Policy Act (WAC 197-11)
Information Analysis Roles	Assess the Site Environmental Setting (RI) Document the Nature & Extent of Contamination (RI) Define Applicable Cleanup Requirements (FS) Screen cleanup technologies for potential application (FS)	Document the Characteristics of the Affected Environment within which the cleanup project is to be performed Determine how the environment may be affected by the project.
Alternatives Analysis Functions	Detailed analysis of multiple cleanup alternatives (FS): • Development of engineering design concepts Schedule projections • Cost estimates	Assessment of measures that may be used to mitigate environmental impacts of the project alternatives as required by SEPA regulations. Determine differences in environmental impacts and mitigation needs between the different project alternatives.
Selection of Preferred Alternative(s)	Ranking of cleanup alternatives using MTCA and SMS regulatory criteria.	Provides the environmental impact analysis component of the SMS regulatory criteria.[1]

Note:

[1] The EIS also evaluates alternatives against the seven goals developed by the Pilot Work Group. Consistency of a project with these goals is not required by MTCA or other applicable regulations. Rather the Pilot goals are voluntary, reflecting the collective interests of the Work Group and the desired outcome of the Pilot. They provide additional benchmarks against which the appropriateness of project alternatives can be measured.



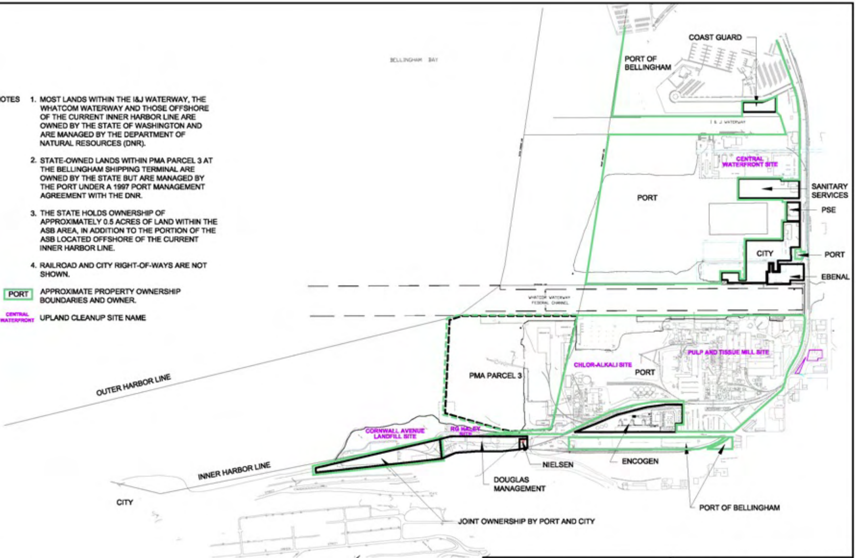
File: H:\18876\18876ST1.1.dwg Layout: FIGURE 2-1 User: emarshall Plotted: Oct 04, 2006 - 8:25am Xref's:

NOTES

1. MOST LANDS WITHIN THE I&J WATERWAY, THE WHATCOM WATERWAY AND THOSE OFFSHORE OF THE CURRENT INNER HARBOR LINE ARE OWNED BY THE STATE OF WASHINGTON AND ARE MANAGED BY THE DEPARTMENT OF NATURAL RESOURCES (DNR).
2. STATE-OWNED LANDS WITHIN PMA PARCEL 3 AT THE BELLINGHAM SHIPPING TERMINAL ARE OWNED BY THE STATE BUT ARE MANAGED BY THE PORT UNDER A 1997 PORT MANAGEMENT AGREEMENT WITH THE DNR.
3. THE STATE HOLDS OWNERSHIP OF APPROXIMATELY 0.5 ACRES OF LAND WITHIN THE ASB AREA, IN ADDITION TO THE PORTION OF THE ASB LOCATED OFFSHORE OF THE CURRENT INNER HARBOR LINE.
4. RAILROAD AND CITY RIGHT-OF-WAYS ARE NOT SHOWN.

PORT — APPROXIMATE PROPERTY OWNERSHIP BOUNDARIES AND OWNER.

CENTRAL WATERFRONT — UPLAND CLEANUP SITE NAME



RETEC

WHATCOM WATERWAY	SUMMARY OF PROPERTY OWNERSHIP
DATE: 08/09/06 DRWN: E.M./SEA	FIGURE 2-2

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3 Environmental Setting

This section describes the environmental setting of the Whatcom Waterway Site. Information discussed in this section includes the physical site features, area natural resources, and land use and navigation patterns.

3.1 Physical Conditions

Physical conditions are relevant at contaminated sites because they affect the fate of impacted sediments and because they are relevant to the discussion of natural resources, land use and navigation patterns. Physical conditions discussed below include the following:

- Site bathymetry and shoreline characteristics (Section 3.1.1)
- Surface water circulation patterns (Section 3.1.2)
- Area groundwater studies (Section 3.1.3)
- Sediment physical properties (Section 3.1.4)
- Sediment lithology (Section 3.1.5).

3.1.1 Bathymetry and Shorelines

Figure 3-1 presents existing bathymetric conditions within the site area. This map incorporates 1996 bathymetric soundings collected as part of the RI/FS, a 2004 survey of the ASB, and a 2005 survey of the Log Pond. The following general elevation trends were observed within the different areas of the site:

- **Outer Whatcom Waterway.** The water depths within the Outer Whatcom Waterway are the result of historic navigation dredging activities. As described in Section 3.3.2, dredging activities have been performed within the federal navigation channel and in associated berth areas. Current water depths average between 28 and 38 feet below Mean Lower Low Water (MLLW) within the federal channel. Depths outside the federal channel vary.

- **Inner Whatcom Waterway.** Water depths within the Inner Whatcom Waterway have also been affected by historic navigation dredging activities. As described in Section 3.3.2, the project depths for the federal navigation channel have varied over time, as has the water depth in berth areas. Current water depths in the Inner Waterway generally decrease toward the head of the waterway, with maximum depths greater than 26 feet below MLLW in offshore areas. Extensive shoaled areas exist at the head of the channel and along its sides with some areas of sediments that are exposed at low tides.

- **Log Pond.** Water depths in the Log Pond are relatively shallow, ranging from approximately 10 feet below MLLW to intertidal areas exposed at low tide. The existing Log Pond bathymetry is the result of an interim cleanup action performed in 2000/2001 which isolated contaminated sediment and enhanced habitat quality for juvenile salmonids and invertebrates.

- **Areas Offshore of ASB.** The areas offshore of the ASB have not been subject to significant dredging or fill activity. The mudline elevations in the area immediately offshore of the ASB are relatively shallow, ranging from 6 feet to 8 feet below MLLW. The bottom elevations increase gradually in offshore areas, consistent with the natural bathymetric contours of Bellingham Bay.

- **Areas Near Bellingham Shipping Terminal.** Water depths in the barge dock area near the Bellingham Shipping Terminal have been affected by historical dredging events near the Port docks, and fill activities along the Shipping Terminal shoreline. Water depths range in elevation from 0 to over 28 feet below MLLW.

- **Starr Rock.** The water depths in the Starr Rock area are generally between 30 and 40 feet below MLLW and are consistent with the natural contours of Bellingham Bay. The area includes a natural navigation obstruction (Starr Rock) which protrudes upward over 20 feet above the surrounding bay floor. Water depths in the eastern portion of the Starr Rock areas have also been affected by its use as an authorized sediment disposal site for navigation dredging during the 1960s.

- **ASB.** The GP ASB was initially constructed with a berm enclosing a dredged basin. Water depths in the basin area were initially dredged to elevations at least 12 feet below MLLW. Recent bathymetry indicates that wastewater treatment sludges have accumulated in the ASB. The mudline elevations are irregular, ranging from 4 to 14 feet below MLLW.

- **I&J Waterway.** Like the Whatcom Waterway, the depths in the I&J Waterway have been influenced by navigation dredging in the federal channel and berth areas. The current project depth for the federal channel is 18 feet below MLLW. Water depths within the channel are generally within approximately 2 feet of the project depth. Areas of shoaling area present at the head of the waterway and along the sides of the channel in berth areas.

Shoreline features within the Whatcom Waterway Site area are summarized in Figure 3-2. A brief summary of key shoreline characteristics is provided below.

- **Outer Whatcom Waterway.** The Outer Waterway consists primarily of deep-water areas. At the Bellingham Shipping Terminal, the shoreline has been engineered to support deepwater navigation. The shoreline conditions include an armored slope and bulkhead, topped by an over-water industrial wharf structure. These features are required to provide maintenance of an effective water depth at the pierhead line consistent with the federal navigation channel, and to provide for loading/offloading of vessels at the wharf. The pierhead line is a construction limit line established as part of the federal navigation channel land use restrictions.

- **Inner Whatcom Waterway.** The shorelines of the Inner Whatcom Waterway are varied. Along the southeastern side of the channel at the former GP mill site, the shoreline has historically been engineered with armored slopes, bulkheads and over-water wharf structures. Along the northwestern shoreline, adjacent to the Central Waterfront area, the shoreline was constructed with a mixture of wooden and concrete bulkheads, and steep armored slopes. Over-water wharves are located at the former Chevron property and near the head of the waterway. However, shoaling has occurred along much of the Central Waterfront shoreline area, and many of the bulkheads and wharf structures are in poor condition. At the head of the waterway near Roeder Avenue, an emergent tideflat has developed.

- **Log Pond.** The shoreline conditions in the Log Pond have been modified by the Log Pond interim remedial action completed in 2000 and 2001. A wooden bulkhead remains along the western side, adjacent to the Port terminal. Water depths along this bulkhead are shallow, including a mix of intertidal and subtidal areas. The southwestern and eastern shorelines of the Log Pond include beach areas that were established as part of the cleanup/restoration action. The central shoreline of the Log Pond is more exposed to western wave action and consists of an armored slope. The southwestern, central, and eastern areas transition to a shallow-water tideflat surface created as part of the Log Pond project.

- **Areas Offshore of ASB.** The area immediately north of the ASB includes a shallow tideflat area that has been colonized by eel grass. The eel grass flat transitions to a gravel beach at the foot of Hilton Avenue. Armoring is located in the high intertidal area. The area offshore of the ASB consists of sandy sediments that slope offshore toward deep water, transitioning to fine silt sediments in deeper water. The south side of the ASB, along the Whatcom Waterway, slopes from the base of the ASB berm toward the Whatcom Waterway channel. Sediments in this area consist of a mix of sand and silt sediments. The armor stone of the ASB berm transitions to the Bay sediments at depths of between -2 and -5 feet along this shoreline.

- **Areas Near Bellingham Shipping Terminal.** The shoreline of the barge dock area has been engineered with a steep armored slope to resist wave action. Over-water wharves associated with the Bellingham Shipping Terminal include the main Port wharf, a barge loading terminal and bulkhead constructed in the 1970s, and the barge and chemical loading dock structure. A small natural beach exists in the elbow between the Barge Dock Area and the RG Haley site.

- **Starr Rock.** The Starr Rock area is located in deep-water offshore areas, and is not contiguous with area shorelines. There are no structures in this area other than a navigation float at the Starr Rock navigation obstruction.

- **ASB.** The berm of the GP ASB consists of a composite structure including armor stone, a thick internal sand bedding layer and an internal lining system including asphalt (upper portion), and bentonite clay (lower portion). The characteristics of the berm are described in the cross section in Figure 3-6. The interior of the ASB has been disconnected from Bellingham Bay since 1978 when the berm was completed. Water elevations in the ASB are maintained between 19 and 20 feet above sea level as part of ASB operations. The shoreline surface at that elevation consists of an asphalt erosion control surface. The exterior of the ASB consists of armor stone. The armor stone continues to elevations of between -2 and 8 feet below MLLW where the stone transitions to sandy intertidal and subtidal sediments of Bellingham Bay.

- **I&J Waterway.** The northern shoreline of the I&J Waterway, located along the Bellweather Peninsula, consists of an armored slope. Dock structures have been constructed as part of the Coast Guard facility located near the head of the waterway. An emergent beach and intertidal area has accumulated at the head of the waterway. The southern shoreline of the I&J Waterway, located along the Central Waterfront shoreline, has been engineered for industrial navigation uses using wooden and metal bulkheads and armored slopes. Over-water dock structures are located at the Borstein Seafoods facility and at the Hilton Harbor location.

- **Cornwall and RG Haley Areas.** The Cornwall Avenue Landfill and the RG Haley sites are located south of the Barge Dock areas. Shorelines in this area consist of stone and rubble armoring in high intertidal areas, transitioning to Bay sediments at varying depths.

3.1.2 Surface Water and Circulation Patterns

Bellingham Bay is part of a system of interconnected bays that exchange water with the Rosario Strait and ultimately the Pacific Ocean through a complex network of channels and passages (Figure 3-3). Collias et al. (1966), Shea et al. (1981), and Broad et al. (1984) have previously described the physical oceanography of Bellingham Bay. In addition, a recent study of inner Bellingham Bay currents was performed by Colyer (1998).

Watershed Characteristics

The Whatcom Waterway Area lies principally within the Whatcom Creek Watershed, near the Whatcom Creek mouth. Here, a salt water wedge migrates upstream with the progression of high tides.

The inner Bellingham Bay area is primarily influenced by the drainage from three watersheds. The largest is the Nooksack River Watershed, which drains approximately 1,500 square kilometers (km^2). All of the Nooksack flow does not, however, reach Bellingham Bay. Part of it enters Lummi Bay by way of the Lummi River. The Nooksack River is also the primary source of sediments to the bay, with an annual discharge of 650,000 cubic meters (m^3). The Nooksack River is influenced by anthropogenic factors that include agriculture and logging.

The Whatcom Creek Watershed drains an area of approximately 26 km^2. Whatcom Creek flows from Lake Whatcom through the City of Bellingham to the bay. The City occupies much of the watershed. Presently, Whatcom Creek is influenced by channelization, vegetation removal, and urban storm water runoff.

The Squalicum Creek Watershed drains an area of 65 km^2 via Squalicum Creek; this creek originates at Squalicum Lake and also flows through the City. The creek is influenced by channelization, vegetation removal, and urban storm water runoff. Five other smaller watersheds also contribute fresh water to Bellingham Bay.

Regional Bottom Currents

Most oceanic waters enter Bellingham Bay at depth through the northern end of Rosario Strait between Lummi and Vendovi Islands. Some water also enters through Bellingham Channel. Exchange of water to the west through Hale Passage is limited by a shallow sill. The residence time for water in Bellingham Bay is typically four to five days, but varies between one and eleven days.

The available data indicate that there is a net southward flow throughout Bellingham Bay at depth, largely resulting from the lateral and vertical spreading of the Nooksack River discharge. Overall, bottom currents are relatively consistent throughout the year and typically range from 0.2 to 0.3 m/sec. As described by Colyer (1998), deep current velocities typically range from 0.04 to 0.18 meters per second (m/sec) in the inner bay and can be as high as 0.40 m/sec. Based on generalized relationships between bottom current velocities and sediment re-suspension thresholds, bottom velocities above approximately 0.3 to 0.4 m/sec may be capable of re-suspending fine-grained sediments (i.e., silt and clay particles). Accordingly, inner Bellingham Bay appears to be primarily a net depositional environment, though periodic resuspension of sediments in the inner bay is possible, particularly in shallow-water areas where bottom velocities can be influenced by wave action. This interpretation is consistent with the predominance of fine-grained sediment textures throughout the inner bay, except in higher-energy shallow-water areas.

Relative to the inner Bellingham Bay area, bottom and near-bottom currents within the more protected Whatcom Waterway are slower, and typically range between 0.04 and 0.10 m/sec. The maximum bottom velocity reported by Colyer (1998) in this area is 0.16 m/sec. Thus, the Whatcom Waterway is also predominantly a depositional environment with even less resuspension of bottom sediments by ambient oceanographic currents.

Regional Surface Currents

Surface currents throughout Bellingham Bay vary primarily in response to wind stress (Shea et al., 1981). Winds over the bay are from the south or southwest during much of the year, typical of foul-weather low-pressure systems in winter months, resulting in the forcing of surface water toward the northern part of the bay with return flow along the shorelines of the Lummi Peninsula, Portage Island, and Lummi Island. Fair-weather winds from the west or northwest cause surface flow to the east and south along the eastern shoreline.

In response to seasonal wind forcing, both clockwise and counter-clockwise circulation patterns are set up in Bellingham Bay. The salinity distribution maps of Collias et al. (1966) delineate freshwater discharges from the Nooksack River. The brackish river plume sometimes exits the bay along the western shoreline near Lummi Peninsula and Lummi Island (counter-clockwise circulation), but at other times exits primarily along the eastern shoreline near the City of Bellingham and Post Point where it is then directed southwestward across the bay toward the southern tip of Lummi Island (clockwise circulation). In both configurations, surface water enters Rosario Strait mainly near the southern tip of Lummi Island and Vendovi Island. The compensating inflow of seawater to the Bellingham Bay occurs partly via surface waters along the opposite shoreline from the brackish river plume and partly via bottom waters.

Typical surface currents range between 0.02 to 0.06 m/sec in the inner bay, reaching maximum velocities of 0.36 m/sec. Within the Whatcom Waterway, currents typically range from 0.04 to 0.06 m/sec. Maximum surface velocities exceeded 0.4 m/sec (Colyer, 1998).

Currents in the Whatcom Waterway Area

Surface water and deep water circulation patterns in the vicinity of the Whatcom Waterway Site have been developed from the data of Colyer (1998). Circulation patterns are very transient, changing quickly over the tidal cycle, and further complicated by the influence of discharge from Whatcom Creek. Nevertheless, some consistent patterns can be discerned.

The circulation within Whatcom Waterway appears to be typical of a two-layer estuary with discharge to the bay of brackish, riverine water at the surface and recharge into the waterway of saline marine water at depth. Thus, the surface water layer is dominated by seaward flow out of the waterway, and the deep water layer is dominated by landward flow into the waterway, although tidal currents may overwhelm this general pattern. The currents in the inner bay, both shallow and deep, are dominated by east-southeasterly along-shore flow. However, the influence of freshwater discharge or ebbing tidal currents from the Whatcom Waterway creates transient and complex counter-currents, eddies, and shear zones in the inner bay, and displaces the southeasterly ambient flow field farther into the bay.

Tides, Flooding, Storm Surge and Tsunamis

The mean tidal range within Bellingham Bay is 5.2 feet. The typical diurnal tidal range is about 8.6 feet. Flooding, storm surge, and tsunamis (in decreasing order of probability of occurrence) may increase the water levels in Bellingham Bay on rare occasions. Information on flooding in the Whatcom Waterway is obtained from the Federal Emergency Management Agency (FEMA) flood insurance rate maps (FIRMs) for Bellingham (FEMA, 2004). FIRM Panel 1213D shows a base flood elevation at the mouth of Whatcom Creek of 8 feet (National Geodetic Vertical Datum 29). This elevation represents a conservatively high 100-year flood elevation of between 12 and 13 feet above MLLW.

Empirical estimates of storm surge are obtained by subtracting the highest observed tide on January, 5 1975 from the predicted tide for that day. The predicted high tide as obtained from NOAA (per Nobeltec, 2004) for 5

January 1975 was 9.6 feet. The actual measured high tide was 10.4 feet above MLLW. The difference is a storm surge of 0.8 feet. The effects of storm surge on final water elevations vary with wind speed, wind direction, and tidal cycle (e.g., storm surges only produce extraordinary water elevations if they occur coincident with a high tide that is already near the maximum for the water body).

Tsunami inundation for Bellingham Bay is given by Walsh et al (2004). In the Whatcom Waterway Site area, the tsunami depth of inundation is estimated to be between 0 and 0.5 m (0 to 1.6 feet) based on the modeled seismic event. If a tsunami were to occur, this inundation depth would be added to the water elevation in the bay at that time. This means that the water elevation in the site area may increase by up to 1.6 feet above the tidal elevation at the time. This assumes that the tsunami occurs independently from either flooding or storm surge.

Salinity, Temperature, and Total Suspended Solids

In the top 30 feet of the water column, salinity varies with depth and over time. The observed variability is primarily the result of fresh water input, wind-induced circulation, and wind-induced mixing. Because most fresh water comes from the Nooksack River, brackish water (salinity less than about 26 parts per thousand [ppt]) is most extensively distributed in the upper part of Bellingham Bay, but a lower salinity surface layer has been observed to extend throughout the bay and south of Post Point. This surface layer is typically less than 6 feet thick, but high winds may occasionally deepen the surface layer to 12 feet. The deepest waters in Bellingham Bay are similar in character to those of Rosario Strait. Bottom water salinities typically range from 29 to 31 ppt, and are relatively stable throughout the year.

Colyer (1998) recorded surface salinities in inner Bellingham Bay ranging from approximately 10 to 25 ppt. Colyer also observed higher surface salinities during the incoming tide, and recorded deep water salinities in the inner Bellingham Bay area in the range of 26 to 30 ppt.

Water temperatures in Bellingham Bay vary with depth and over time primarily as the result of seasonal air temperature changes. Water temperatures range from 8 to 13 degrees Celsius (ºC) and are warmest in the summer and early fall and coldest during winter and spring.

The concentration of total suspended solids (TSS) within the inner Bellingham Bay area was recently measured by Colyer (1998). Surface water TSS concentrations ranged from 3 to 25 milligrams per liter (mg/L). Deep water TSS concentrations were similar and ranged from 1 to 32 mg/L. TSS concentrations averaged approximately 10 mg/L in both surface and deep waters.

3.1.3 Area Groundwater Studies

Groundwater in the vicinity of the Whatcom Waterway Site generally discharges to surface waters of Bellingham Bay, or Whatcom Creek. Groundwater patterns and water quality in the area have been extensively studied as part of area environmental and geotechnical studies.

Central Waterfront Groundwater Studies

Under Ecology's Voluntary Cleanup Program, the Port conducted an environmental investigation of the former Roeder Avenue Landfill site. The preliminary draft RI/FS for the Roeder Avenue Landfill Site (RETEC, 2001) described generalized groundwater flow features within the Central Waterfront area, between the I&J Waterway and the Whatcom Waterway. Key observations from that study included the following:

- Groundwater is predominantly present as a shallow unconfined layer within shallow fill material and underlying native sandy soils. The fill/sand layer varies from approximately 15 feet to over 40 feet in thickness. Silty clay soils of the glacial marine drift are located beneath the sandy soils and these soils do not contain significant water-bearing zones. The depths to bedrock are over 100 feet below ground surface in most of the Central Waterfront area.

- Groundwater in the Central Waterfront area consists of groundwater flow from across Roeder Avenue and infiltration from precipitation within the Central Waterfront area. Some water is also generated from seepage from the ASB.

- Gradients are generally toward the I&J and Whatcom Waterways, with the exception of the area near the ASB where gradients are affected by the ASB.

- Groundwater discharges in shoreline areas are subject to significant tidally-influenced mixing. This mixing is greatest in the area within 100 and 200 feet of the shoreline.

The study also included three-dimensional groundwater flow modeling for the Central Waterfront area, groundwater quality testing and a source control analysis. Groundwater was determined not to represent a sediment source control problem, provided that appropriate institutional controls were applied as part of the cleanup of the Central Waterfront site.

The information in the preliminary draft RI/FS for the former Roeder Avenue Landfill site will be included in a future public review draft RI/FS for the Central Waterfront site. The Central Waterfront site is comprised of four historically separate cleanup sites: the Roeder Avenue Landfill site, the

Chevron site, the Colony Wharf site, and the Olivine Uplands site. These individual sites have been combined into a single site by Ecology to comprehensively address commingled groundwater contamination.

Chlor-Alkali Plant Groundwater Studies

With Ecology oversight groundwater studies have been performed as part of the investigation of the Chlor-Alkali Plant site located east of the Bellingham Shipping Terminal. Those studies included measurements of area stratigraphy and groundwater gradients, testing of groundwater quality and completion of a sediment source control analysis (ENSR, 1994; Aspect, 2004; Anchor, 2001a).

Groundwater within the Chlor-Alkali Plant site is generally present in shallow fill soils and underlying native sandy soils. These soils are underlain by glaciomarine drift and bedrock of the Chuckanut sandstone formation. The depth to bedrock varies from less than 40 feet to over 100 feet, and generally increases offshore toward the Whatcom Waterway. Groundwater gradients are generally offshore toward the Whatcom Waterway. Gradients are affected by shoreline conditions and localized features.

A sediment source control analysis was included as part of the Engineering Design Report for the Log Pond Interim Remedial Action (Anchor, 2001a). That analysis indicated that groundwater discharging to the Log Pond is unlikely to cause sediment recontamination. Monitoring of sediment pore-water has been included in the monitoring program for the Log Pond cap. Recent pore-water monitoring data confirm the findings of the source control analysis. Mercury levels in groundwater discharging to the Log Pond have been below applicable surface water quality criteria and source impact levels (Appendix I).

Further evaluation of soil and groundwater conditions will be performed as part of the investigation and cleanup of the Chlor-Alkali Plant site.

Cornwall Landfill Area Groundwater Studies

Groundwater studies have been performed as part of ongoing investigation and cleanup actions at the Cornwall Avenue Landfill and RG Haley sites. The findings of the Cornwall studies were documented in a preliminary draft RI/FS (Landau, 2003). RG Haley site information is contained in the preliminary draft RI/FS (GeoEngineers, 2006). The Cornwall Avenue Landfill and RG Haley sites are in the RI/FS stage of the MTCA cleanup process with Ecology and public review drafts of the RI/FS are anticipated to be released in late 2006 or early 2007. Work performed to date indicates that there is no overlap between these sites and the Whatcom Waterway Site.

The Cornwall Avenue Landfill site includes municipal solid waste, overlying a layer of wood waste and sandy soils. Chuckanut sandstone is present at depths between 15 and over 70 feet below ground surface. Groundwater generally flows offshore toward Bellingham Bay. Nearshore groundwater discharges have been monitored directly using groundwater wells and intertidal seep monitoring. The cleanup of this site will be performed after finalization of the RI/FS and will address potential ongoing sources of contamination to surface water and site associated sediments.

At the RG Haley site, soil and groundwater at this upland contaminated site contain concentrations of pentachlorophenol, petroleum, and associated constituents. In 2001, a visible release of contamination from the site into Bellingham Bay was controlled through the installation of a barrier wall and a product recovery system. The temporary contaminant recovery system continues to operate. An RI/FS is being conducted at the site by the upland property owner, Douglas Management, under an Agreed Order with Ecology. The cleanup of this site will be performed after finalization of the RI/FS and will address potential ongoing sources of contamination to surface water and site-associated sediments.

3.1.4 Sediment Physical Properties

The physical properties of Bellingham Bay sediments have been characterized during RI/FS investigations and pre-design studies. RI/FS sampling locations are shown in Figure 3-4. That figure also shows the locations of testing performed adjacent to the Colony Wharf property on behalf of Ecology (Appendix F), in studies parallel to the RI investigations. The Colony Wharf sampling data are incorporated for completeness, as this area is being addressed as part of the Whatcom Waterway Site.

Surface Sediment Grain Size

Visual descriptions and grain size analysis information from RI/FS sampling locations were compiled to describe generalized sediment distribution patterns. Figure 3-5 illustrates the general distribution of fine-grained sediment (percent by weight less than No. U.S. 230 sieve size) from RI/FS data.

In general, the surface (0 to 12 centimeters [cm]) sediment grain size distribution in the deepwater portions of the Whatcom Waterway Site area consists of fine-grained materials. Coarser sediments are noted in higher-energy shallow-water areas. This pattern is likely a function of water depth, with higher wave energies impinging on the bottom in shallow water and winnowing out the finer sediments. The grain size distribution in the I&J Street Waterway is similar and grades from coarser at the head of the waterway to finer near the mouth. Surface sediment samples outside of the main waterway channels generally consisted of clayey silt to slightly sandy, very clayey silt with sandier material located near the intertidal banks.

Wood Material Distribution

Figure 3-5 also summarizes the areas where woody material was identified in the upper 1 foot of sediments during 1996 sediment investigations. The areas were localized in former log rafting areas, and in the Log Pond.

ASB Sludge and Berm Materials

The ASB sludges consist of wastewater solids containing mixtures of pulp solids, wood chips, ash, and microbial biomass. The materials are characterized by low solids content, averaging 17 percent by weight. The total organic carbon content of the sludges is also very high, averaging 33 percent. The sediment grain size varies with location and depth, ranging from relatively coarse material (18 percent fines) to very fine material (greater than 96 percent fines). Excluding the bentonite lining and the ASB sludges, the ASB berms consist of armor stone and sand material. A typical cross-section through a portion of the ASB berm is shown in Figure 3-6.

Sediment Organic Carbon

The distribution of total organic carbon (TOC) content in surface sediment ranges from 0.82 percent (HC-SS-48) to 13.0 percent (AN-SS-305). Most of the samples contained TOC concentrations between 2 and 4 percent, with an average concentration of 3.2 percent. The highest concentrations of TOC were noted in sediments containing woody materials.

Subsurface (0 to 20 feet) sediment TOC concentrations within the site sediments ranged from a low of 0.16 percent to a maximum of 49 percent (HC VC 77 S2; 2.1 to 3.9 feet depth). The average TOC concentration in subsurface sediment in remaining site remediation areas is 4.3 percent. In general, elevated TOC concentrations correlated with the presence of wood materials in the subsurface.

Subsurface Sediment Physical Properties

Throughout most of the site, core samples of subsurface sediments encountered clayey, very sandy silt. This silt layer is dominant in deepwater depositional areas and in portions of the waterway that were historically dredged and have accumulated recent sediment deposits.

In shallower water areas and certain under-pier areas, the mean sediment type for under-pier sediments is a slightly gravelly, slightly clayey, silty sand. The distribution of subsurface sediment textures varies with the wave energy environment and is also influenced by native subsurface geologic patterns and patterns of historic dredge and fill activity. Sediments beneath the ASB and adjacent offshore areas consist predominantly of sandy sediments.

Some geotechnical testing has been performed on sediments from the site. Observations from these tests include the following:

- **Atterburg Limits:** Atterberg limit analyses were completed on ten selected cohesive core samples representing a variety of depths and locations. Atterberg limits, which include the liquid limit, plastic limit, and the plasticity index, were used to define plasticity characteristics of clays and other cohesive sediments. These results help define dredgability and compression properties of fine-grained sediments. The majority of cohesive samples were classified as a medium to high elastic silt or clay. Two samples (HC-VC-72-S4 and HC-VC-79-S4) were classified as clay with low plasticity. These samples are from the compact Glacial Marine Outwash unit.

- **Sediment Density:** Profiles of sediment density were determined for the natural recovery cores HC-NR-100, HC-NR-101, and HC-NR-102 (Figure 3-5). Sediment wet density was calculated using an empirical formula derived by Battelle (1995) for sediment compositions typical of Puget Sound. This formula relates the percent dry weight of sediments to the wet density through the following equation:

  Wet density = 0.1737(5.0245 + e0.0238 x percent dry weight)

  Sediment wet density calculations were volumetrically corrected for compaction compression which occurred during coring. Average surface (0 to 2 cm) wet density in inner Bellingham Bay ranged from approximately 1.23 to 1.30 grams per cubic centimeter (g/cm^3). Wet density increased with depth in the cores to a maximum of approximately 1.32 to 1.42 g/cm^3 at a depth of 1 meter below the mudline.

3.1.5 Sediment Lithology

The subsurface geology of the Whatcom Waterway Site area is complex, due to the large site area, natural variations in subsurface geologic conditions, and the results of anthropogenic changes to waterway conditions over the last century. The discussion below is based on RI/FS investigation findings, historical and current bathymetry maps, dredging histories for the waterways, and upland borings and reports from area environmental and geotechnical studies.

Waterway Area Lithology

The sedimentary sequence within the site sediments is a function of fluvial sediment loads, deltaic growth rate, and the local depositional environment. A rapidly advancing delta front is characterized by an abundance of sands. Slower growth periods are characterized by finer grained sediments, principally silts, being deposited in lower energy environments. The distributary channels within a delta also meander and shift, resulting in erosion and channel backfilling. Discharges from the Nooksack River, Whatcom Creek, and Squalicum Creek all contribute to the WW Area sediment profiles, which commonly display sediment stratigraphy consisting of inter-layered sands, gravelly sands, silty sands, and sandy silts.

The natural depositional environment of the waterway has been altered by dredging (including excavation of the original waterway,) maintenance dredging, and fill replacement during nearshore construction. Excluding the ASB structure and accumulated sludges, the waterway area sediments can be divided into the following major sediment units (Figures 3-7 through 3-9):

- **Post Dredge Recent Deposits:** Recent deposits consist primarily of very soft, brown-black, slightly sandy, clayey silt with shell fragments and varying amounts of wood debris overlying a soft, dark gray silt with trace wood fragments. The thickness of the recent deposits varies between less than 1 and over 7 feet. In some cases the physical sequences of the sediments have been disturbed, for example by the trenching and backfilling of the G-P pipeline installation in 1979, or by shoreline erosion along the Central Waterfront shoreline. The post-dredge recent deposits contain the majority of the impacted sediments. Mercury concentrations in these sediments are consistently cleaner in the surface sediment, than in underlying sediments as shown on Figure 3-7. This pattern is the result of natural recovery, through deposition of clean sediment over the top of historic, impacted sediments.

- **Post Glacial (Pre-Dredge) Fluvial Deposits:** This unit consists of medium dense, gray, non-silty to silty, fine to medium sand with multi-colored grains, shell fragments, and occasional gravel and silt lenses grading to gray silt with clay. Deposits are coarser near the head of the waterway, described as slightly gravelly sand with shell fragments. This unit represents native fluvial sediments, primarily from Whatcom Creek, deposited prior to the deepest dredging event and prior to industrialization of the area. The base of this sand unit is gradational in nature but generally occurs at an elevation of approximately 22 feet above MLLW near the head of the Whatcom Waterway and deepens to an elevation of 36 feet near the mouth of the Whatcom Waterway. In the I&J Street Waterway, the base of the sand unit ranges from elevation 22 to 25 feet below MLLW. The base of the sand unit is at elevation 40 feet below MLLW near the 1979 pipeline trench.

- **Glacial Marine Drift:** The third major unit is a stiff to very stiff, damp to moist, gray, silty clay to clay with scattered gravels and occasional fine to medium sand layers. The drift was encountered at elevations ranging from 28 feet below MLLW near the head of both waterways to 50 to 60 feet below MLLW near the mouth of the waterways. This glacial outwash unit was confirmed by adjacent upland borings advanced through fill, lagoon silts, alluvial sands, and then into glacial sequences. Anthropogenic Changes to Waterway Area

Lithology

The waterway dredging history was summarized as part of the development of the RI/FS Work Plan (Hart Crowser, 1996b). Additional changes to area lithology are associated with nearshore filling, shoreline infrastructure construction and the development of the ASB. Major events affecting lithology in the site area include the following:

- **Early Waterway Dredging and Filling:** The Whatcom and I&J Street Waterways were identified on state land maps as early as 1891. Early dredging activities in the Whatcom and I&J Waterway areas included dredging of shallow channels, with side-casting of the dredge materials behind bulkheads for creation of shoreline fill areas. Portions of the Central Waterfront and GP mill site areas were filled in this manner.

- **Whatcom Waterway Dredging:** The initial Whatcom Waterway channel was authorized in 1902 and was dredged by the Corps to a width of 200 feet and a depth of 12 feet below MLLW. A wider, deeper waterway was authorized for dredging by the River and Harbors Act of June 15, 1910. At that time the Port operations were conducted by the City of Bellingham. The dredging of the 1910-authorized channel was completed in 1913, with an Inner Waterway channel depth of 18 feet below MLLW and an Outer Waterway depth of 26 feet below MLLW. The federal channel dimensions were modified in 1958 by the Harbor Act of July 3, 1958. That modification shortened the 18-foot channel section, increased the Outer Waterway authorized depth from 26 feet to 30 feet, and precluded federal dredging activities within 50 feet of the pierhead lines. Dredging events were performed in 1961 and 1969. Most of the berth areas at the head of the Inner Waterway were never upgraded to comply with the new channel dimensions. The Starr Rock sediment disposal site was used during the 1969 dredging activities. Additional localized dredging events were performed in 1974 and 1979. Sediments generated during the 1974 dredging event were placed in a confined disposal facility at the Chlor-Alkali Plant site. Dredge depths varied from project to project, depending on the methods used and the objectives of the project.

- **I&J Waterway Dredging:** The I&J Waterway was initially dredged to depths of approximately 12 feet below MLLW in the early 1900s. The federal channel in that waterway was authorized in May of 1965, with a project depth of 18 feet below MLLW. The federal dredging of the I&J Waterway was completed in 1966, with subsequent dredging by the Corps in 1992 in selected areas.

- **Central Waterfront Shoreline Changes:** The Central Waterfront shoreline was initially created during early development of the Whatcom Waterway. The shoreline was subsequently reconstructed in places to replace or upgrade bulkheads and wharf structures. The shoreline infrastructure was never upgraded to support the deepening of the federal navigation channel in 1961. Since that time the shoreline infrastructure has generally deteriorated, with shoaling of berth areas, collapse or rupture of certain bulkheads and collapse of some over-water wharf structures.

- **Filling near the Port Terminal:** The Bellingham Shipping Terminal area was filled between 1920 and the 1990s using a variety of materials. These included sediments dredged to create the Log Pond area, sediments dredged from the Whatcom Waterway and Barge Dock areas, imported soils generated during construction of Interstate 5 near Lake Samish, and soils imported from other upland sites. The docks and wharves of the terminal area have been upgraded and replaced periodically since the early 1900s.

- **Filling at the GP Mill Site:** Filling activities at the GP site have included placement of dredge materials and imported soils. The last major fill event there included the placement of dredged materials in a confined disposal facility adjacent to the Log Pond in 1974.

- **Filling Along the Cornwall Area Shoreline:** The shoreline area near the Cornwall and RG Haley sites was filled initially during operation of the Bellingham Bay Improvement Company lumber mill in the late 1800s and early 1900s, and the later Bloedell Donovan Lumber Mill through the mid 1940s. Filling at the Cornwall Landfill site included placement of municipal solid waste between 1953 and 1965 by the City of Bellingham. Soil fill was placed at the RG Haley site during the 1950s and early 1960s. Armor materials were placed along the shorelines of both sites during the 1970s and 1980s to control shoreline erosion. Additional erosion control materials were placed at the RG Haley site as part of the Interim Remedial Action there.

- **ASB Construction:** The ASB was constructed in 1978 and 1979, along with installation of wastewater pipelines beneath the Whatcom Waterway, and installation of an outfall line offshore of the ASB. Dredging activities included excavation of trenches for the pipeline crossing and outfall line, and dredging of the ASB basin to a minimum neat-line depth of 12 feet below MLLW. Berm construction included placement of imported stone and sand materials, placed as shown in Figure 3-6.

As discussed in Section 5, the vertical extent of chemical contamination at the Whatcom Waterway site varies with location. The above-listed anthropogenic changes to area lithology, bathymetry and shoreline composition has affected the locations and thicknesses of the post-dredge recent sediments that contain elevated contaminant levels.

The depth of chemical contamination below mudline ranged from less than 2 feet at the mouth of the Whatcom Waterway to 9 feet in the Log Pond. While site conditions vary with location, the following represent generalized estimates of the thicknesses of the recent sediment deposits:

- Outer Whatcom Waterway (offshore of BST): 1 to 3 feet below mudline

- Inner Whatcom Waterway (between BST and Laurel Street): 3 to 6 feet below mudline

- Head of Whatcom Waterway (between Laurel Street and Roeder Avenue): 5 to 8 feet below mudline

- Log Pond (prior to interim remedial action): 6 to 9 feet below mudline

- I&J Street Waterway: 2 to 6 feet below mudline.

ASB Area Lithology

The following paragraphs document the subsurface stratigraphic units encountered within the ASB during the exploration program. Figure 3-6 provides an interpreted geologic cross section through the ASB and adjacent site areas and depicts the relative thickness of each unit at the exploration locations. Site characteristics at locations between explorations were based on interpolation.

- **ASB Berm Structure:** The ASB berm structure was constructed in 1978 under an Corps Permit. The berm is a composite structure of stone and sand, with surface dressings of asphalt and bentonite clay. The outer core of the berm consists of various grades of stone. The stone core was constructed on top of the former tidelands and extends to a height of 16 feet above MLLW in most areas. A thick sequence of imported sand material is present along the inside of the berm, extending upward to elevations of 22 to 24 feet above MLLW. This sand is covered on the outer edge by armor stone. The inner portion of the berm is covered by dressings of asphalt (16 to 24 feet above MLLW) and bentonite clay (elevations below 16 feet above MLLW) to reduce berm permeability and protect against wave-induced erosion.

- **ASB Sludges:** The ASB sludge consist of surface and near-surface secondary sludge deposited since 1979 as part of the operation of the ASB for wastewater treatment. These materials were identified as olive green to gray, very soft, highly organic silt-sized materials, with total solids averaging 14 percent and high TOC content typically between 30 and 50 percent. The base of the ASB sludge layer was assessed by probing and coring and averaged just over 14 feet below MLLW, (Appendix D) consistent with the historical dredging of the basin in 1978.

- **Limited Recent Sediment Deposits:** In most areas of the ASB, recent sediments were removed by dredging in 1978, as part of the construction of the ASB facility. Dredging was conducted in order to provide for ASB volume capacity. Recent sediments may be present in a thin layer beneath portions of the berm structure. The dredging established a target neat-line elevation of 12 feet below MLLW, with one to several feet of over-dredging. Because of this dredging, recent sediment deposits are not present throughout the main ASB area and sequences transition rapidly from ASB sludges to post-glacial fluvial deposits.

- **Native Post Glacial Fluvial Deposits:** Underlying the recent deposits is the Fluvial Deposit unit, which consists of native medium dense, gray, non-clayey to clayey, fine to medium sand with multi-colored grains, shell fragments, and occasional gravel and clay lenses grading to gray silt with clay. Total solids range from approximately 70 to 91 percent in the Fluvial Deposits. This native unit ranges from 8 to 22 feet thick within the footprint of the ASB.

- **Native Glacial Marine Drift:** Underlying the native post-glacial fluvial deposits is a deposit of glacial marine drift, which is a stiff to very stiff, damp to moist, gray, silty clay to clay with scattered gravels and occasional fine to medium sand layers. Results from lab tests indicate that this unit is a lightly to moderately over-consolidated lean clay, with total solids ranging from approximately 60 to 90 percent. The native Glacial Marine Outwash layer was the deepest unit encountered during the exploration program. The top elevation of this unit ranged from 25 to 36 feet below MLLW, and slopes generally from north (shallower) to south and southwest (deeper). Based on area geotechnical studies, Chuckanut sandstone is known to underlie the marine drift layer at depths in excess of 100 feet below MLLW.

3.2 Natural Resources

This section summarizes information on natural resources in the Whatcom Waterway Site area, including fish and wildlife, existing habitats, and plant and animal species.

3.2.1 Types and Functions of Habitats

Detailed information on Bay-wide habitat conditions and habitat maps can be found in the Data Compilation Report (Pacific International Engineering and Anchor Environmental, 1999). Most of the habitats in Bellingham Bay are used by a variety of marine and terrestrial species for feeding, reproduction, rearing, and refuge. The Whatcom Waterway specifically hosts various benthic macroinvertebrates (bivalves, crabs, polychaetes), as well as providing habitat or passage for various fish species (both bottom fish and pelagic species such as salmon).

The different elevations of habitat are discussed below in three groups: intertidal, shallow subtidal, and subtidal. Although separated by only a few feet, these three strata have distinct soil textures and support varying plant and animal communities. Each stratum has two types of substrata: sand/mud/ cobble and gravel/rocky shore. The habitat typically found in these strata is summarized here to preface more detailed descriptions of fish and wildlife habitat in the Bay.

- **Intertidal: 4 feet below to 11 feet above MLLW**
  - **Sand/mud/cobble.** This area supports rooted plants to varying degrees, with increased numbers and variety occurring at higher elevations. Native eelgrass is most commonly found at 0 to 4 feet below MLLW, while rushes, sedges, and pickleweed can be found at 11 to 8 above MLLW. These plants provide food and refuge to various organisms, including juvenile salmon, shrimp, crab, and flat fish. Mudflats found in this substratum support epibenthic prey that are consumed by juvenile salmon migrating through the area. Pacific herring may also use the eelgrass and macroalgae found in the intertidal zone as spawning habitat. The finer substrate at

higher elevations (8 to 11 feet above MLLW) provides spawning habitat for sand lance and surf smelt. Intertidal habitat of this kind is limited in the Whatcom Waterway area to areas at the head of the Whatcom and I&J Waterways, areas along portions of the sides of the Whatcom Waterway, in beach areas at the foot of Hilton Avenue and at the foot of Pine Street and in portions of the Log Pond following completion of the Interim Remedial Action.

- **Gravel/rocky shore.** Native eelgrass is occasionally found in pools and channels on the rocky shores at about 0 feet MLLW. Brown, green, and red algae are also found throughout this area. The higher elevations of this substratum are affected by higher tides; plant material can consist of lichens, some flowering plants, and leadwort. Animals commonly encountered include crabs, shrimp, sponges, sea anemones, worms, sea stars, oysters, and various fish (e.g., perch, prickleback, flat fish, and some juvenile salmon). Fish use this area for feeding, refuge, and reproduction. Armored and rocky areas of the Whatcom Waterway with this type of habitat are located along the sides of the Whatcom and I&J waterways, along the shoreline of the ASB, and in portions of the Log Pond.

- **Shallow Subtidal: 4 to 10 feet below MLLW**

  - **Sand/mud/cobble.** The plant and animal communities and functions in this substratum are similar to those described in lower elevations of the intertidal habitat; a notable exception is native eelgrass, which is typically more common within the -4 to 10 feet below MLLW zone. Mudflats within this substratum support epibenthic prey that is consumed by juvenile salmon migrating through the area. The substrate within this elevation can also provide suitable habitat for Dungeness crab mating and egg brooding. Shallow subtidal areas are located at the heads and along portions of the sides of the Whatcom and I&J waterways, in areas at the foot of Hilton Avenue and Pine Street, in the shoulder of the ASB and in the Log Pond.

  - **Gravel/rocky shore.** Native eelgrass is occasionally found in this area, as are a variety of brown, red and green algae. Animals common to this substratum include crabs, shrimp, sponges, sea anemones, worms, sea stars, oysters, and a variety of fish such as perch, prickleback, flat fish, and some juvenile salmon. The fish use this area for feeding, refuge and reproduction. Rocky shallow subtidal habitats are located along portions of the Whatcom and I&J Waterways and along the shorelines of the ASB and in portions of the Log Pond.

- **Subtidal: Greater than 10 feet below MLLW**
  - **Sand/mud/cobble.** Native eelgrass is still relatively common between 10 and 20 feet below MLLW; however, beyond 20 feet below, light is limited and eelgrass and macroalgae are less prevalent. Some varieties of hard-shell clams are also less abundant with increased depth, while the geoduck clam tends to be more abundant in deeper water. The substrate within this elevation can provide suitable habitat for Dungeness crab mating and egg brooding. The substrate and water column are also used for feeding by a variety of fish, including sub-adult and adult juvenile salmon. Most portions of the Site consist of subtidal habitat with sand or mud bottom.
  - **Gravel/rocky shore.** Larger-sized fish and shellfish often occur in deeper waters. Greater than 20 feet below MLLW, light reaching the sea floor limits the abundance and growth of macroalgae. In addition, the occurrence of some species such as oyster is rare. Rocky subtidal shorelines within the site predominantly occur along the developed shorelines of the Whatcom and I&J Waterways. Some rocky outcroppings occur at subtidal elevations at Starr Rock.

Portions of the Whatcom Waterway Site area have been developed for navigation uses with infrastructure improvements. This infrastructure affects the types of habitat conditions that are present in these areas. Other than depth modifications (i.e., dredging) the main types of navigation infrastructure that exist in the Whatcom Waterway Site area include bulkheads, armored slopes, and over-water structures. Habitat considerations associated with these features are described below:

- **Bulkheads**: The term bulkhead refers to constructed sheer vertical walls that stabilize the shoreline. Typically they are concrete or metal sheet pile, although many older bulkheads are constructed from treated timber. In the Whatcom Waterway, bulkheads are a common feature in the intertidal zone. Most extend from above mean higher high water to the structure design depth (varies from mean lower low water to depths greater than 10 feet below MLLW depending on the required water depth at the face of the bulkhead). Bulkheads are often installed in conjunction with armored slopes below the toe of the bulkhead. A bulkhead yields a habitat with no depth variability and no horizontal surfaces to support primary production, secondary production, or processing of detritus. While sessile organisms, including barnacles and some macroalgae, can attach to the vertical bulkheads, it is not suitable for producing epibenthic prey organisms for juvenile salmon. The vertical slope also means that juvenile salmon using the top one to two meters of the water column are in much deeper water during most or all tidal cycles, depending on the bottom elevation of the bulkhead, compared to a naturally sloping nearshore area. This may increase their susceptibility to predators. Juvenile salmon use waters adjacent to bulkheads, and can forage on prey items derived from planktonic or neustonic sources. However, due to the lack of epibenthic organisms, overall prey resources are typically considered to be reduced relative to sloped habitat.

- **Armored Slopes:** Slopes armored with large stones or "riprap" are typically steep and compress the horizontal habitat profile yielding less habitat within the desired zones for juvenile salmonids than do more gently sloped habitats. Unlike bulkheads, the resulting habitat does have surfaces to support primary productions, secondary production, and processing of detritus. Substrate size of riprap slopes differs from the fine silts or sands that would have been typical of the depositional delta area in the historic Whatcom Creek, or even more coarse gravel or cobble substrates farther from the mouth of the creek. At elevations that are exposed to regular, significant wave energy, riprap has essentially no ability to retain water or organic material on its own, except in depressions in individual pieces. Exposed rock surfaces at these elevations eventually develop sessile biological matrices, including macroalgae and invertebrates, which reduce desiccation at small scales and allows for an assemblage including mobile invertebrates. At lower elevations that do not have significant wave exposure, riprap can provide a suitable substrate for many different species of macroalgae and also provides habitat areas in its interstices for invertebrates. A common means of improving the productivity of riprap slopes is to fill the interstices of the rock with a finer material (e.g., gravel) that can increase both water and organic material retention, and increase the ability of the bulkhead slope to support an assemblage include juvenile salmon prey organisms. This method may not be appropriate in higher energy areas where substrate may not be retained at mid and higher elevations. The biological assemblages on riprap substrate are more comparable to that of a rocky nearshore area than beaches. While there are epibenthic prey available for juvenile salmon in these areas, habitat function is reduced compared to areas with smaller substrate. Juvenile salmon use waters adjacent to riprap and can forage on prey items derived from planktonic or neustonic sources as well as the limited epibenthic prey.

- **Overwater Structures:** Intertidal and shallow subtidal shading has decreased light levels underneath and around overwater structures. Shading is of primary concern because it reduces light available for photosynthesis by aquatic vegetation. Reduced primary productivity has implications both in terms of habitat structure and complexity (reduction or loss of aquatic vegetation), and in terms supporting productivity elsewhere in the food web, including juvenile salmon prey organisms. Shading impacts extend beyond the structural footprint of the structure as the sun's movement across the sky over a day or season results in a larger shaded area as it is oriented in different aspects. Small structures, such as narrow piers, shade relatively less area than large or wide structures such as pier aprons. Depending on the orientation of the narrow structure, direct sunlight can reach most the shade footprint over the course of a day or season. The distance from the lighted edge to the center of the structure footprint is also relatively smaller than at a wider structure, resulting in higher levels of ambient light. In contrast with wide structures, large proportions of the shade footprint may never receive direct sunlight. Wider structures also decrease the ratio of lighted edge to shaded area, and increase the distance from the lighted edge to the center of the structure footprint. This results in less ambient light under wider structures and therefore more intense impacts associated with shading. This has implications for productivity and can reduce the habitat function of an area for juvenile salmon foraging. Nearshore habitat function may be reduced underneath and immediately adjacent to overwater structures. For juvenile salmon, this impact is relatively greater at the typically highly productive low to middle intertidal zone, although impacts on macroalgae in the shallow subtidal and salt tolerant plants in the supratidal splash zone also can affect productivity in these zones. As with bulkheads, foraging function around overwater structures may be reduced due to decreased productivity but alternative food sources (plankton, neuston) are available. Those juvenile salmon that move into deeper water to avoid overwater structures may be more susceptible to deeper water predators, but this behavior is not always the response to encountering a structure.

3.2.2 Plant and Animal Species

The Bellingham Bay area is utilized by a wide range of plant and animal species. Documented uses for significant plant and animal species are summarized below.

Fisheries and Invertebrate Resources

Documented fisheries resources for Bellingham Bay include the following:

- **Surf Smelt and Sand Lance:** Surf smelt and Pacific sand lance are common fish that spawn in the high intertidal portions of coarse sand and gravel beaches (WDF, 1992). Surveys by Washington Department of Fish and Wildlife (WDFW) have documented spawning beaches in Bellingham Bay. However, no surf smelt or sand lance spawning has been documented in inner Bellingham Bay, presumably because suitable substrates are not available.

- **Pacific Herring:** Pacific herring spawn in inland marine waters of Puget Sound between January and June in specific locations. There is typically a 2-month peak within the overall spawning season. Herring, which deposit their eggs on marine vegetation such as eelgrass and algae in the shallow subtidal and intertidal zones between 1 foot above and 5 feet below MLLW, are known to congregate in the deeper water of Bellingham Bay. However, only relatively low-density spawning deposition occurs in the Bay, and none of that has been documented in the vicinity of the Whatcom Waterway.

- **Salmonids:** Bellingham Bay is used extensively by anadromous salmon species (Shea et al., 1981). Each of the streams flowing into Bellingham Bay is used by one or more of the economically important species listed in Table 3-1. The Nooksack River has the largest salmon runs in Bellingham Bay, followed by Squalicum and Whatcom creeks. Concentrations of chum, coho, and chinook salmon along the shoreline and in offshore waters in Bellingham Bay peak annually about mid-May. Juvenile coho and chinook salmon appear to have different migration habits. Coho remain in the Bay for approximately 30 to 35 days, while chinooks remain about 20 days. More recent studies on the distribution of chinook salmon (Ballinger and Vanderhorst, 1995) indicate relatively high numbers of juvenile chinook salmon and average numbers of coho salmon use the area in the vicinity of the Whatcom Waterway.

- **Groundfish:** Several species of groundfish occur in both shallow and deep waters in Bellingham Bay for part or all of their life. Detailed information on groundfish species and their timing and use of Bellingham Bay is not available. Key characteristics of groundfish occurring in northern Puget Sound are generally applicable to Bellingham Bay.

Bellingham Bay supports a variety of marine invertebrates, ranging from infauna (worms, clams, and small ghost shrimp that penetrate benthic sediments) to epibenthic plankters (organisms such as very small crustaceans that move off the substrate surface) to larger invertebrates such as oysters, crabs, and shrimp.

- **Clams, Geoduck and Oysters:** The predominant bivalves in Bellingham Bay are intertidal and subtidal hard-shell clams. Intertidal shell clam types include butter, littleneck, horse, and soft-shell clams and cockles. Subtidal clam resources consist of butter, littleneck, and horse clams. Native oyster and Pacific geoduck are also known to occur in Bellingham Bay (Palm, 1995; WDF, 1981; WDFW, 1992; Webber, 1974). Shellfish densities are relatively low along the eastern shore of Bellingham Bay in the vicinity of the Whatcom Waterway, although bivalves are the dominant benthic organism within the Waterway (Anchor Environmental, 1999). Scattered oysters also occur along the shoreline of the Whatcom Creek estuary (Palm, 1995). Geoduck, which is only present in a handful of locations in the Bay, does not occur within the Whatcom Waterway.

- **Shrimp:** Seven species of pandalid shrimp, including, pink, coonstripe, dock, and spot shrimp, occur in nearshore and deeper waters of Bellingham Bay. For example, coonstripe shrimp have been observed in intertidal areas immediately offshore of the Cornwall Avenue Landfill (which is just south of the Whatcom Waterway), and this species is common around piers and floats. Shrimp densities in the areas surrounding the Whatcom Waterway are moderate when the Bay is viewed as a whole.

- **Crab:** Crab trawls conducted for the Puget Sound Dredge Disposal Analysis (PSDDA) investigations indicate that the predominate crab resources in Bellingham Bay are the non-edible purple or graceful crab, the edible red rock crab, and the edible Dungeness crab. The highest densities of rock crab occur in relatively shallow water (30 to 45 feet below MLLW) in areas extending from the Lummi Peninsula to inner Bellingham Bay. Rock and Dungeness crab are likely to occur in shallower waters of Bellingham Bay not sampled as part of the PSDDA investigations. Dungeness crab is generally abundant in most areas of Bellingham Bay, and has been documented in the Whatcom Waterway (Ecology, 2003). The northern and eastern shorelines of Bellingham Bay serve as nursery/rearing areas for juvenile Dungeness crab. A shell substrate is a preferred habitat for the first 8 to 10 weeks after larvae settle. However, other substrates, such as small cobbles and gravel, algae, and eelgrass, are also recognized as important rearing habitat for juvenile crab. Because the Whatcom Waterway has relatively limited quantities of these habitats, its usefulness as a nursery/rearing area is likely limited.

Table 3-1 Salmon and Trout Fisheries in Bellingham Bay

Species	Fishery
Coho	mid-September to mid-November
Chum	early November to mid-December
Chinook	late July to mid-September
Pink	July in odd years
Sockeye	no fishery
Steelhead	mid-December to January
Cutthroat	no commercial fishery
Bull trout	no fishery

Sea Birds and Marine Mammals

The greater Bellingham Bay area and its shallow estuarine habitats support a number of birds at all seasons. Although Bellingham Bay is not used extensively by large populations of waterfowl, wintering populations tend to be 10 to 15 times larger than summer populations for migratory species (Manual et al., 1979). The Bay is located on the flight path between the Fraser River estuary and Skagit Bay, and is used as a stopover for seabirds and waterfowl migrating between these two areas. Waterfowl sited in Bellingham Bay include brant, snow geese, mallard, widgeon, green-winged teal, and pintail. Bellingham Bay is also used as an over-wintering area for diving birds such as scoter and golden eye. A variety of both natural and man-made habitats provide protection from winter storms habitat to migrant and wintering birds.

Glaucous-winged gulls use inner Bellingham Bay for resting and foraging. Pigeon guillemonts use the shoreline area in and around the Whatcom Waterway for nesting and foraging. The Habitat Restoration Documentation Report (Pacific International Engineering, 1999) describes the individual bird species and their use of Bellingham Bay by season.

Limited information is available on the presence and residence time of marine mammals in Bellingham Bay (PTI, 1989). Bay-wide, several species have been reported: the harbor seal, sea lions, Orca whale, gray whale, and harbor porpoise. As described below, the local population of Orca whale is being listed as endangered under the Endangered Species Act (ESA). The other marine mammals are not threatened or endangered species under ESA, but they are protected from hunting under the Marine Mammal Protection Act. Seals and sea lions have been noted using the Log Pond and portions of the I&J Waterway for resting areas. Migrating gray whales have been noted to enter Bellingham Bay and to feed in subtidal areas of Puget Sound. Orca whales are occasionally observed in and near Bellingham Bay, though they are more typically observed in Rosario Strait and near the San Juan Islands.

Threatened, Endangered, Sensitive and Candidate Species

Under the ESA, a species likely to become extinct is categorized as "endangered." A species likely to become endangered within the foreseeable future is categorized as "threatened." This section provides information on the occurrence of threatened and endangered bird, fish and marine mammal species in Bellingham Bay.

- **Bald Eagle:** The majority of bald eagle nest sites occur in the eastern portion of Bellingham Bay, primarily in the Nooksack River delta along the shoreline and in inland areas of the Lummi Peninsula. There are also some nests along the shoreline of Portage Island and Chuckanut Bay. Nest trees in the Pacific Northwest are typically tall conifers located in forested or semi-forested areas within about 1 mile of large bodies of water with adequate food supplies. Marine and freshwater fish are eagles' preferred prey; birds contribute a smaller proportion of the eagle diet. Prey may also include small mammals. Nesting eagles generally forage within 10 square miles of their nest site. Thus, while the Whatcom Waterway vicinity does not appear to provide eagle habitat, it may serve as a food source. The bald eagle was proposed for delisting as of July 6, 1999 due to apparent recovery of the species in the U.S. (Federal Register 50 CFR Part 17). The bird is still be protected by the Migratory Bird Treaty Act and the Bald and Golden Eagle Protection Act. The United States Fish and Wildlife Service (USFWS) also works with state wildlife agencies to monitor the status of the species as required by the ESA.

- **Peregrine Falcon:** Peregrine falcons are also found in Bellingham Bay. They feed almost exclusively on birds captured in flight, particularly waterfowl, shorebirds, and game birds. Peregrine falcons typically nest on cliff ledges greater than 150 feet in height that are close to the water. The Whatcom Waterway has no documented Peregrine falcon nests.

- **Marbled Murrelet:** Open water concentrations of marbled murrelets have been recorded in the central portion of Bellingham Bay. Murrelets forage in the marine environment typically up to 2 miles near a coastline. The species forages year round in waters generally less than 90 feet deep, sometimes congregating in well-defined areas where food is abundant. These birds generally do not utilize shallower waters less than 30 feet deep. Marbled murrelets reportedly feed on a wide variety of prey, including sand lance, Pacific herring, and other marine taxa such as crustaceans. Murrelets require old growth or mature forest composed of conifers, including Douglas fir, western red cedar, Sitka spruce, and western hemlock. There are no known nest sites along the shoreline of Bellingham Bay, and no clear association between these birds and the Whatcom Waterway.

- **Salmon:** On March 16, 1999, the National Marine Fisheries Service (NMFS) added nine West Coast salmon to the Endangered Species List. Of the nine listed species, one occurs within the project area: the Puget Sound chinook salmon, which was listed as a threatened species. Two races of chinook salmon (spring and fall) are found in Bellingham Bay. The timing of adult migration to freshwater differs between these two races, but the timing of the return of adult fish, spawning, and emigration of juveniles overlap. Fall chinook is the most common run of chinook salmon observed in Puget Sound. Juvenile fall chinook generally emigrate to the estuary between February and August as sub-yearlings (within the first year after being spawned) or as yearlings. Individual fish may only use Bellingham Bay for a period of days to a few weeks before heading into the greater Puget Sound estuary. They may use the estuaries and intertidal areas between April and November for further rearing and growth. As juvenile fish move into neritic habitats, they preferentially consume emergent insects and epibenthic crustaceans in salt marsh habitat or decapod larvae, larvae, and other prey (Simenstad et al., 1991). Whatcom Creek and the Whatcom Waterway are utilized by salmon (Ecology, 2003), although the Whatcom Waterway serves more as a migration corridor between Whatcom Creek and the Whatcom Creek Estuary than nursery/rearing habitat given the lack of suitable substrate and refuge.

- **Bull Trout:** Bull trout, listed as a threatened species under the ESA by the USFWS, are a member of the North American salmon family. Bull trout occur in the Nooksack River, and presumably spend some time in Bellingham Bay. Many are resident to a single stream; others migrate on a fluvial (i.e., spawn in headwaters streams and live downstream in larger rivers) or adfluvial basis (spawn in streams but live in lakes). Bull trout tend to prefer cold, clear waters (no more than 64 degrees Fahrenheit). Whatcom Creek does host bull trout, indicating that the trout use the Whatcom Waterway as a migratory path if not a refuge and rearing area.

- **Orca Whales:** On November 15, 2005, the National Oceanic and Atmospheric Administration (NOAA) Fisheries announced its decision to list the North Pacific Southern Resident Orca whale (*Orcinus orca*) population as endangered under the ESA. The listing was effective on February 6, 2006 (50CFR 223/224). The listing is specific to the three resident whale pods (J, K, and L pod) with spring through fall ranges in Puget Sound and the Straits of Georgia and Juan de Fuca. This population was previously (December 16, 2004) proposed for listing as threatened. NOAA Fisheries has announced that they are preparing language for proposed Orca whale critical habitat for this population. A number of factors have been identified by NOAA Fisheries as having resulted in the listing of these Orca whales as endangered. Sound and disturbance from vessel traffic, toxic chemicals which accumulate in top predators, and uncertain prey availability (primarily salmon) all have been identified as concerns for the continued survival of this population. The small number of whales in this group, and relatively slow rate of population recovery since a 20 percent population decline during the 1990s also puts this historically small group at risk of extinction during a catastrophic event such as an oil spill or disease outbreak.

3.3 Land and Navigation Uses

Land within the Whatcom Waterway Site is owned by both public and private entities. Existing uses and use designations are currently changing, and are the subject of an intense community planning effort. Section 3.3.1 below describes current property ownership within and adjacent to the Whatcom Waterway Site. Section 3.3.2 then provides an overview of current land use regulations and planning activities. Section 3.3.3 then discusses in detail the land use and navigation issues for each portion of the site.

3.3.1 Waterfront Land Ownership

A land ownership map is included as Figure 2-2 of this report. That figure represents current waterfront land ownership at the time this report was prepared.

Following completion of the GP-Port transaction in 2005, the majority of the waterfront property located adjacent to the site is owned by the Port. The Port also owns the aquatic lands underlying and adjacent to the majority of the ASB. In addition to property ownership, the Port and Department of Natural Resources (DNR) entered into a cooperative agreement in September 1997 to allow the Port to manage certain state-owned lands through a Port Management Agreement (PMA) (RCW 79.90.475). The Port is responsible for managing the lands covered under the PMA consistent with federal and state regulations and laws, and DNR's land management goals. Parcel 3 of the current PMA includes portions of the Bellingham Shipping Terminal and adjacent submerged aquatic lands near the Barge Dock area.

The majority of the Whatcom Waterway navigation channel and the submerged aquatic lands located offshore of the Whatcom Waterway Site are owned by the State of Washington. The State of Washington also owns the outer corner of the ASB, and filled lands along the shoreline of the RG Haley and Cornwall Avenue Landfill sites.

The City of Bellingham owns the former Colony Wharf site located along the head of the Whatcom Waterway. The City also owns a joint interest with the Port in upland property located adjacent to the Cornwall Landfill.

The U.S. Coast Guard owns a parcel of property located near the head of the I&J Waterway.

Three privately-owned shoreline properties are located in the immediate vicinity of the Whatcom Waterway Site. These include the following:

- Ebenal property located between the Colony Wharf site and the Roeder Avenue bridge
- Douglas Management property, located within a portion of the RG Haley site
- Nielson property, located in between the RG Haley site and Pine Street.

3.3.2 Overview of Land Use Planning Activities

The Bellingham Waterfront areas located within and adjacent to the Whatcom Waterway site are undergoing a transition from historic industrial land uses to mixed use development. This section provides an overview of the land use planning activities that are shaping, and are being shaped by, this change in land use.

Bellingham Bay Comprehensive Strategy

As described in Section 2.1.2, the Bellingham Bay Comprehensive Strategy was developed by a cooperative partnership of agencies, tribes, local government, and businesses known collectively as the Pilot Work Group. The Comprehensive Strategy was intended to provide long-term guidance to decision-makers relating to implementation of sediment cleanup, source control, and habitat restoration actions in Bellingham Bay. The Comprehensive Strategy was finalized as a Final Environmental Impact Statement in October 2000, and it preceded some of the significant land-use changes that have occurred since that time. Yet much of the work of the Pilot, especially that regarding potential habitat restoration actions, remains relevant. While the Port and City are not bound by regulation to implement these potential restoration actions, many of the habitat restoration actions that were identified in Appendix A of the 2000 EIS as furthering Pilot goals have been either implemented, or have been carried forward as part of community land use planning efforts since 2000. These habitat goals are reflected in the Waterfront Futures Group Vision and Framework Plan, and in marine infrastructure planning for the Whatcom Waterway area. The Port, City and other Pilot Work Group members have sought ways to implement the Pilot goals in the context of changing community land use needs.

Shoreline Master Program Update

The City is currently updating their state-mandated SMP which regulates and manages uses and activities within 200 feet of the shorelines of the City. The City and Port are working with the Bellingham community to ensure that the land use vision articulated in the Waterfront Vision and Framework Plan is reflected in the SMP update. The SMP update is expected to be completed in early 2007.

Port Land Use Planning Activities

The Port of Bellingham is responsible to the citizens of Whatcom County for providing shipping and marine cargo facilities, general boating, and maritime industry facilities, as well as assisting in maintaining and developing a healthy regional economy. The Port's main planning tools are area Master Plans, and the Port's Comprehensive Scheme of Harbor Improvements. Over the past 10 years the Port has led and participated in extensive land use planning activities related to Bellingham's waterfront areas. Examples of these activities include the following:

- Land use studies conducted during 1999 and 2000 for the Central Waterfront area

- Master Planning efforts for the Bellingham Shipping terminal and vicinity, also completed in 1999 and 2000

- Alternatives evaluations for sitting of new marina facilities to meet regional moorage demand

- Outreach activities conducted by the Port of Bellingham as part of the GP due diligence process during 2004, including soliciting of extensive stakeholder and public input on potential waterfront cleanup actions, land use alternatives and navigation priorities for the Whatcom Waterway

- Amendment to the Port Comprehensive Scheme of Harbor Improvements identifying the need for future aquatic use of the ASB area for marina development

- Ongoing Port and City leadership land use planning efforts for the redevelopment of the New Whatcom area, including pending development of a final area Master Plan for the "New Whatcom" area of Bellingham's Waterfront. The Master Planning process will include SEPA environmental review of the Master Plan elements.

Waterfront Vision and Framework Plan

In 2004, the Waterfront Vision and Framework Plan was developed by the Waterfront Futures Group, a community land use visioning effort supported by the City and the Port. Key elements of that plan for the areas of the Whatcom Waterway Site (described in the Framework Plan as the City Center area) include the following:

- Develop a mixed-use waterfront neighborhood including new job opportunities and urban housing
- Complete the cleanup and opening of the ASB to accommodate either a new marina or new marine habitat combined with stormwater treatment or some combination of those uses
- Maintain deepwater moorage in the Whatcom Waterway, consistent with other uses and preservation of critical habitat areas.
- Reinforce the Inherent Qualities of Each Place on the Waterfront including integration of water-dependent uses with new commercial, institutional, educational, and residential uses and public spaces
- Restore the Health of Land and Water including enhancement of natural systems, tailoring of cleanup strategies and remediation to planned uses, and restoration and enhancement of beaches wherever possible
- Improve Waterfront Access including connections between uplands and waterfront areas and links to regional trail systems, while respecting natural habitat
- Encourage and promote fisheries and ocean-related research industrial and facilities
- Promote a health and Dynamic Waterfront Economy including mixed-use redevelopment of the former GP Mill site and the uplands area adjacent to the Cornwall Avenue Landfill site
- Provide transient moorage in the Inner waterway, while avoiding impacts to critical habitat in this area
- Provide hand-carry boat landing opportunities within the project area, including at the Cornwall Avenue Landfill and near the ASB
- Enhance the system of connected public open spaces between the Whatcom Waterway and the south end of the Cornwall Avenue Landfill, including open spaces along the waterfront and

completion of the over-water walkway between the Cornwall Avenue Landfill and Boulevard Park

3.3.3 Area-Specific Navigation and Land Use Issues

Land use, navigation, and shoreline public access issues are summarized below by geographic area for different portions of the Whatcom Waterway Site (Figures 2-1 and 3-2). Habitat restoration opportunities consistent with the Bellingham Bay Comprehensive Strategy are also discussed in this section (Subarea Strategies developed as part of the 2000 EIS are attached as Appendix A of the 2006 Draft Supplemental EIS).

Outer Whatcom Waterway

Navigation uses in the Outer Waterway offshore of the Bellingham Shipping Terminal are largely transitory, with vessels coming into and traveling out of the Waterway. Vessels are generally not anchored in these areas, and there are no permanent dock structures or mooring dolphins.

A federal navigation channel is located in the Outer Waterway. Federal navigation channels represent a conditional agreement between the Corps and a local entity (the "local sponsor," in this case the Port of Bellingham) under which the federal government shares the cost and assists with the implementation of certain defined navigation maintenance activities. The limits of the federal commitment are defined geographically by the dimensions of the "project." For the Outer Waterway, the project depth is defined as 30 feet below MLLW and the width varies from 263 feet near the Shipping Terminal to 363 feet in offshore areas.

Under the federal channel maintenance program, the local sponsor can request the Corps to maintain the project depths by periodic maintenance dredging. Subject to federal funds availability, the Corps conducts such dredging under its Operations and Maintenance program. The federal participation is subject to a navigation needs analysis that must show that the dredging is in the national economic interest. This needs analysis considers industrial and commercial navigation uses (e.g., cargo operations, commercial fishing, institutional users) but does not consider recreational, public access, or habitat uses.

If maintenance dredging is performed by the Corps in a federal channel, the local sponsor must provide for sediment disposal and must share certain other costs. The sponsor is responsible for coordinating the costs of development and maintenance of "berth" areas and shoreline infrastructure with local property owners and other interests. The berth areas are the areas located along-side the federal channel that are used for mooring of vessels. In order for the water depth of a federal channel to be usable, the depths in berth areas must be consistent with those in the channel. Otherwise a vessel traveling in the channel would not be able to moor along-side a wharf.

The current water depths in the Outer Waterway are at or slightly below the "project depth" of 30 feet in the federal channel areas. The federal channel boundaries are offset from the wharf areas by approximately 50 feet. This "berth" area is defined along the inshore edge by the "pierhead line" and along the offshore edge by the federal channel boundary. Depths in this area are maintained by local interests. Construction is generally prohibited in areas offshore of the pierhead line, and is regulated by the Corps and the Coast Guard. The pierhead line runs along the face of the docks at the Bellingham Shipping Terminal.

The maintenance of water depths in the berth areas of the Shipping Terminal requires maintenance of substantial shoreline infrastructure. That infrastructure includes bulkheads, engineered armored slopes, and over-water wharves that provide for mooring and loading/unloading of vessels moored at the berths. In order to meet the economic needs test of the Corps maintenance dredging program, upland land uses have been restricted and are designated in the Shipping Terminal area for appropriate water-dependent uses consistent with the federal channel designation.

The Bellingham Shipping Terminal has been used since the early 1900s for cargo shipping and warehousing activities. Multiple future uses have been considered as part of the evaluation of land use changes in the New Whatcom planning area. The Shipping Terminal areas are currently anticipated to continue in water dependent uses. Potential future uses include operation of appropriate institutional users (e.g., Coast Guard or NOAA), limited cargo shipping, or other deep draft navigation uses. It is anticipated that the federal channel will be maintained in the Outer Waterway areas consistent with its current dimensions. The presence of contaminated sediments at depths shallower than 5 feet below the authorized channel depth in this area would interfere with these types of uses by interfering with channel maintenance activities. The shoreline infrastructure required for operation of a shipping terminal is present in this area, though significant maintenance and potential upgrades may be required prior to resumption of deep draft uses.

Shallow-water nearshore habitats in the Outer Waterway area are limited to under-dock areas along the Bellingham Shipping Terminal. Potential habitat restoration opportunities in these areas are limited by the infrastructure needs associated with operation of a deep draft moorage area in support the operations of the federal navigation channel. The Bellingham Bay Comprehensive Strategy reflects this and has no specific restoration recommendations for this area.

Existing habitat conditions are discussed in section 3.2.1 and figure 3-2 shows the shore line features including bulkheads, armored slopes, and overwater structures.

Inner Whatcom Waterway

Like the Outer Waterway, the Inner Waterway has historically been used for industrial water-dependent uses. These have included operation of lumber mills, the GP pulp and paper mill, gravel shipping, fish processing and bulk petroleum terminal operations. The federal navigation channel was initially established in the early 1900s with project depths of 18 feet below MLLW (Inner Waterway) and 26 feet (Outer Waterway). This deeper portion of the channel was expanded between 1958 and 1961. Most of the Central Waterfront area was developed when the project depth was 18 feet below MLLW.

The federal project boundaries prohibit Corps dredging within 50 feet of the pierhead lines and structures. This limits the effective water depth in this area due to the lack of supporting berth area depths and requisite shoreline infrastructure. The width of the Waterway is constrained by developed fill areas and upland features adjacent to the Waterway.

Effective water depths in the Inner Waterway are currently limited by the restrictions of the federal navigation channel to the depths at the pierhead line. These depths range from less than zero in some shoaled areas to as much as 22 feet in outer portions of the GP dock. In areas offshore of the Log Pond, the water depths are usable only for transit (i.e., vessels entering or leaving the Inner Waterway), because no shoreline land areas or over-water infrastructure exists in these areas.

The land use restrictions associated with the historic federal channel boundaries are in conflict with both current and planned uses of the Inner Waterway as a result the Port has initiated consultations with the Department of Natural Resources, the Corps, and other parties to update channel designations.

During 2005 the Port and DNR signed a Memorandum of Understanding which included a proposal to update harbor area and Whatcom Waterway channel dimensions. The objective is to provide for a range of uses within the Inner Waterway consistent with local land and navigation uses. The Inner Waterway would be managed by local interests as a Multi-Purpose Waterway, providing a wider range of uses than those supported by the current federal channel designations.

In addition, in May 2006 the Port Commission, after public comment, issued Resolution 1230 which requests that the U.S. Congress de-authorize the Inner Waterway from head of the federal channel at the Roeder Avenue Bridge to Bellingham Shipping Terminal, in order to allow implementation of a Multi-Purpose Waterway, and to focus federal funding participation on the deep draft terminal areas of the Outer Waterway. Language proposing the modifications to the federal channel has been drafted and included in congressional legislation that is expected to be finalized during 2006.

The Inner Waterway includes deepwater areas, and emergent shallow-water habitat at the head of the waterway. The preservation and enhancement of these areas is recommended in the Bellingham Bay Comprehensive Strategy. Recent marine infrastructure planning by the Port has additionally discussed opportunities to preserve and enhance shallow-water habitat along the sides of the Inner Waterway. Existing habitat conditions are discussed in section 3.2.1 and Figure 3-2 shows the shore line features including bulkheads, armored slopes, and overwater structures.

Log Pond

As its name implies, the Log Pond was historically used as a log pond for lumber and pulp mill operations. These uses have been discontinued since the completion of the Log Pond Interim Remedial Action in 2000/2001.

The Log Pond has been designated for cleanup and habitat restoration uses. Some public access enhancements to upland shoreline areas are likely as part of future redevelopment of the former GP Mill site. These uses would likely include development of a shoreline promenade along portions of the Log Pond. No in-water navigation uses are contemplated for the Log Pond.

The habitat restoration component of the Log Pond Interim Remedial Action was voluntary implemented by GP in accordance with the recommendations of the Bellingham Bay Comprehensive Strategy.

Since its completion monitoring has confirmed the use of the restored area by juvenile salmonids, juvenile Dungeness crabs, and other aquatic organisms and marine mammals.

In addition some eel grass colonization has occurred. A pilot program has been funded under the Bellingham Bay Demonstration Pilot to enhance natural colonization rates through seeding of the area with eel grass. This pilot test is ongoing.

Existing habitat conditions are discussed in section 3.2.1 and figure 3-2 shows the shore line features including bulkheads, armored slopes, and overwater structures.

Areas Offshore of the ASB

The offshore areas near the ASB were historically used for log rafting, prior to construction of the ASB. Future navigation use of these areas is considered limited by water depths and the lack of available upland adjacent to these areas.

To the north of the ASB, along Hilton Avenue, an eel grass bed has become established. The Bellingham Bay Comprehensive Strategy recommends creating shallow water habitat along the remaining perimeter of the ASB to connect with the existing eel grass bed. This area has elevations generally shallower than 5 feet below MLLW, and the area is partially protected from wave energies by the ASB and by a shallow-water leading edge along the bed.

Existing habitat conditions are discussed in section 3.2.1 and figure 3-2 shows the shore line features including bulkheads, armored slopes, and overwater structures.

Areas Near the Bellingham Shipping Terminal

Navigation uses in the Barge Dock area have historically included log rafting, barge traffic, and tug boat mooring. Some propeller wash effects may be significant in this area, depending assuming future barge and tug uses. Two docks are located within this area including the barge dock and the former GP Chemical dock. The northern side of the Barge Dock area is bounded by the back side of the Bellingham Shipping Terminal wharf structure.

Some dredging activities have historically been performed in the Barge Dock area, including dredging for establishment of cargo terminal berth areas, as well as dredging to obtain fill material for use in development of a portion of the Bellingham Shipping Terminal. Regular maintenance dredging such as that considered for the Whatcom Waterway areas is not expected. As described above for the Outer Waterway, the Bellingham Shipping Terminal is anticipated remain under industrial water-dependent use, including potential reuse by institutional users and cargo operations.

Like the Outer Whatcom Waterway area, potential habitat restoration opportunities in the Barge Dock area are limited by the navigation uses. The Bellingham Bay Comprehensive Strategy reflects this and has no specific restoration recommendations for this area. Existing habitat conditions are discussed in section 3.2.1 and figure 3-2 shows the shore line features including bulkheads, armored slopes, and overwater structures.

Starr Rock

Historic navigation uses in the Starr Rock area were limited to Log rafting. These uses were discontinued in the 1970s with the development of Boulevard Park nearby. Future navigation uses in the Starr Rock area are not anticipated other than transit uses by recreational vessels. Deepwater navigation is restricted in this area due to the proximity of the natural shallow-water obstruction at Starr Rock, and by the lack of adjacent upland navigation support facilities.

The Starr Rock area consists of a deepwater habitat area. The depths in this area do not allow for enhancement of shallow-water habitat uses.

ASB

The ASB facility was constructed by Georgia Pacific for treatment of wastewater and stormwater. It also provides cooling water management for the Encogen energy production facility. These uses are expected to continue through June of 2008, consistent with Port-GP agreements. After that time these uses are likely to be discontinued.

The Bellingham Bay Comprehensive Strategy included a recommendation for removal of the ASB in order to establish intertidal and shallow sub-tidal habitat. However, no funding mechanisms have been identified to implement this type of project, and alternative uses of the ASB have formed the basis of recent land use planning efforts.

During 2004 the ASB was identified by the Port as the preferred site in Bellingham Bay for construction of a new marina facility (Makers, 2004). The preference for the site was based on several factors, including the ability to develop a marina with net gains in both habitat and public access opportunities. Preliminary design concepts for a marina incorporating public access and habitat enhancements were developed by the Port after consultation with resource agencies and project stakeholders. One of these design concepts is presented in the current Feasibility Study and in the Draft Supplemental EIS. The design concept incorporates development of intertidal and shallow sub-tidal habitat, consistent with the general intent of the Bellingham Bay Comprehensive Strategy recommendation. If completed according to that design concept, the ASB marina would reconnect the 28-acre ASB area to Bellingham Bay, and restore nearly 4,500 linear feet of salmonid migration corridors. The acreage of premium nearshore aquatic habitat developed as part of marina reuse would vary depending on final design and berm configurations, with potential habitat bench areas located on the inside and the outside of the berm.

The Port updated its Comprehensive Scheme of Harbor Improvements in 2004 to reflect the future planned use of the ASB for marina development. The Port further developed a funding plan to conduct the cleanup of the ASB and the development of the marina project. The majority of the ASB was acquired by the Port as part of the 2005 GP property transaction. The City has supported the marina development concept as documented in the July 2006 Interlocal Agreement between the Port and the City. Development of a marina in the ASB, and the final design of any such marina, is subject to additional design and permitting evaluations.

The City also evaluated the ASB for potential future stormwater or wastewater treatment uses, but it determined that it is not well suited for these uses due to its location, elevation, and the operational characteristics of the current GP-owned outfall structure.

I&J Street Waterway

The I&J Street Waterway includes a federal navigation channel, with a width of 100 feet and a project depth of 18 feet below MLLW. Berth areas adjacent to the federal channel include a mixture of state-owned and privately-owned lands.

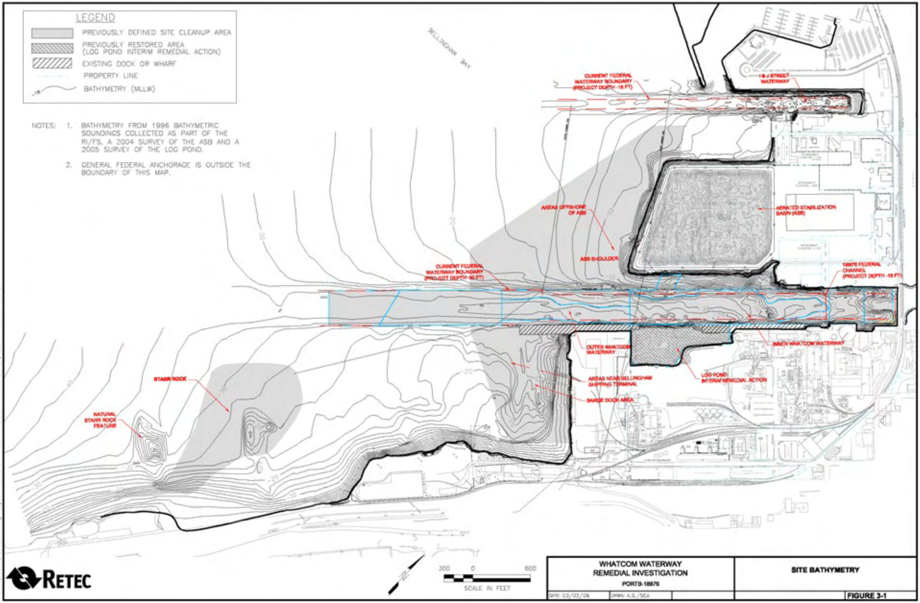
Historic navigation uses in the waterway have included log shipping and navigation in support of lumber mill operations, ore processing facilities, and seafood processing plants. Current navigation uses in the waterway include navigation by commercial fishing vessels destined for the Bornstein Seafoods processing facility, and Coast Guard vessels associated with the Coast Guard station at the head of the waterway. The waterway also provides navigation access for vessels entering Squalicum Inner Harbor, or visiting the Hilton harbor facilities.

At this time there are no anticipated changes to the project depths or location of the federal channel within the I&J Street Waterway, current project depths are shown on Figure 3-1. The shoreline of the area has been maintained with the requisite infrastructure to allow utilization of this water depth, and the mix of uses currently located along the channel are consistent with the Corps Operation and Maintenance program requirements. Maintenance dredging is performed periodically by the Corps of Engineers in conjunction with the Port and other parties. Sediment testing performed as part of the RI/FS (Appendix H) has indicated that recently accumulated sediments within the outer waterway are consistent with criteria for open-water disposal. The Corps most recently dredged portions of the I&J Waterway in 1992. No additional actions associated with Whatcom Waterway constituents are required in the outer waterway areas. Based on site data regular Corps operation and maintenance program requirements contain adequate material characterization.

Accumulated sediments located near the head of the waterway are being evaluated as part of the RI/FS process for the I&J Waterway site.

The I&J Street Waterway is similar to portions of the Inner Waterway, in that the main waterway area consists of deepwater areas, and most shorelines along the sides of the waterway are currently engineered to support navigation uses. However, there is a shallow intertidal area that has developed at the head of the state waterway, past the end of the federal channel. The future uses of this area are subject to evaluation in ongoing area land use planning activities. Land at the head of the I&J Street Waterway has been considered as a potential public access location.

Existing habitat conditions are discussed in Section 3.2.1 and Figure 3-2 shows the shore line features including bulkheads, armored slopes, and overwater structures.


LEGEND
PREVIOUSLY DEFINED SITE CLEANUP AREA
PREVIOUSLY RESTORED AREA (LOG POND INTERIM REMEDIAL ACTION)
EXISTING DOCK OR WHARF
PROPERTY LINE
BATHYMETRY (MLLW)
NOTES: 1. BATHYMETRY FROM 1996 BATHYMETRIC SOUNDINGS COLLECTED AS PART OF THE RI/FS, A 2004 SURVEY OF THE ASB AND A 2005 SURVEY OF THE LOG POND.
2. GENERAL FEDERAL ANCHORAGE IS OUTSIDE THE BOUNDARY OF THIS MAP.
BELLINGHAM BAY
CURRENT FEDERAL WATERWAY BOUNDARY (PROJECT DEPTH -18 FT)
I & J STREET WATERWAY
AREAS OFFSHORE OF ASB
AERATED STABILIZATION BASIN (ASB)
ASB SHOULDER
CURRENT FEDERAL WATERWAY BOUNDARY (PROJECT DEPTH -30 FT)
1960'S FEDERAL CHANNEL (PROJECT DEPTH -18 FT)
OUTER WHATCOM WATERWAY
INNER WHATCOM WATERWAY
AREAS NEAR BELLINGHAM SHIPPING TERMINAL
LOG POND INTERIM REMEDIAL ACTION
BARGE DOCK AREA
STARR ROCK
NATURAL STARR ROCK FEATURE
RETEC
300 0 600
SCALE IN FEET
WHATCOM WATERWAY
REMEDIAL INVESTIGATION
PORTB-18876
DATE: 03/02/06
DRWN: A.S./SEA
SITE BATHYMETRY
FIGURE 3-1

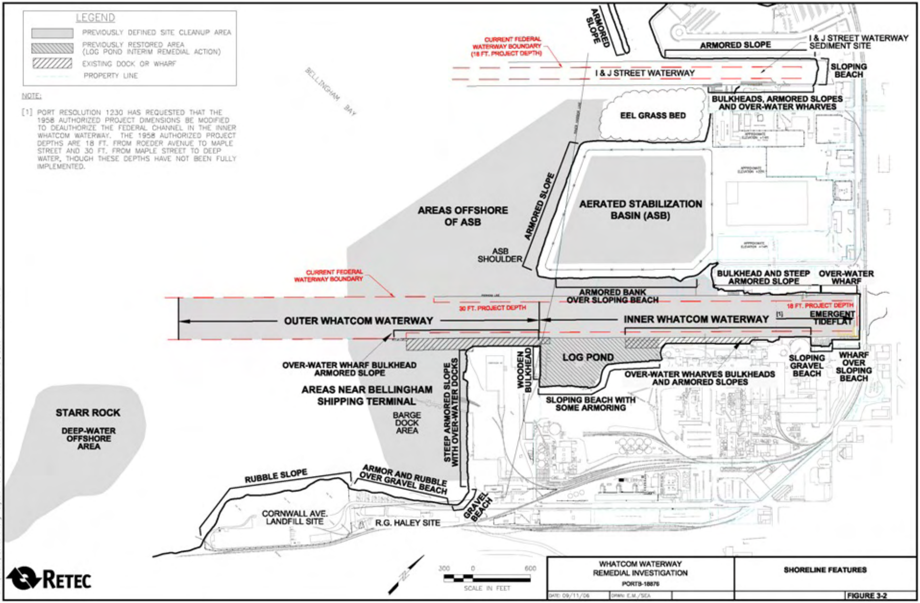
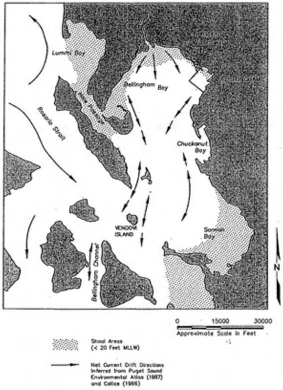

LEGEND
PREVIOUSLY DEFINED SITE CLEANUP AREA
PREVIOUSLY RESTORED AREA (LOG POND INTERIM REMEDIAL ACTION)
EXISTING DOCK OR WHARF
PROPERTY LINE
NOTE:
[1] PORT RESOLUTION 1230 HAS REQUESTED THAT THE 1958 AUTHORIZED PROJECT DIMENSIONS BE MODIFIED TO DEAUTHORIZE THE FEDERAL CHANNEL IN THE INNER WHATCOM WATERWAY. THE 1958 AUTHORIZED PROJECT DEPTHS ARE 18 FT. FROM ROEDER AVENUE TO MAPLE STREET AND 30 FT. FROM MAPLE STREET TO DEEP WATER, THOUGH THESE DEPTHS HAVE NOT BEEN FULLY IMPLEMENTED.
BELLINGHAM BAY
CURRENT FEDERAL WATERWAY BOUNDARY (18 FT. PROJECT DEPTH)
ARMORED SLOPE
ARMORED SLOPE
I & J STREET WATERWAY SEDIMENT SITE
I & J STREET WATERWAY
SLOPING BEACH
BULKHEADS, ARMORED SLOPES AND OVER-WATER WHARVES
EEL GRASS BED
ARMORED SLOPE
AREAS OFFSHORE OF ASB
AERATED STABILIZATION BASIN (ASB)
ASB SHOULDER
CURRENT FEDERAL WATERWAY BOUNDARY
BULKHEAD AND STEEP ARMORED SLOPE
OVER-WATER WHARF
ARMORED BANK OVER SLOPING BEACH
30 FT. PROJECT DEPTH
18 FT. PROJECT DEPTH
OUTER WHATCOM WATERWAY
INNER WHATCOM WATERWAY
[1]
EMERGENT TIDEFLAT
OVER-WATER WHARF BULKHEAD ARMORED SLOPE
LOG POND
WOODEN BULKHEAD
SLOPING GRAVEL BEACH
WHARF OVER SLOPING BEACH
OVER-WATER WHARVES BULKHEADS AND ARMORED SLOPES
AREAS NEAR BELLINGHAM SHIPPING TERMINAL
STEEP ARMORED SLOPE WITH OVER-WATER DOCKS
SLOPING BEACH WITH SOME ARMORING
BARGE DOCK AREA
STARR ROCK
DEEP-WATER OFFSHORE AREA
RUBBLE SLOPE
ARMOR AND RUBBLE OVER GRAVEL BEACH
GRAVEL BEACH
CORNWALL AVE. LANDFILL SITE
R.G. HALEY SITE
300 0 600
SCALE IN FEET
RETEC
WHATCOM WATERWAY REMEDIAL INVESTIGATION
PORTB-18876
SHORELINE FEATURES
DATE: 09/11/06
DRWN: E.M./SEA
FIGURE 3-2

Figure 3-3 Bellingham Bay Circulation Patterns

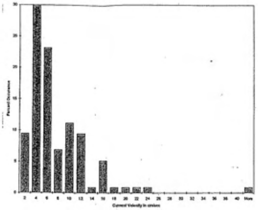
Net Current Directions in Greater Bellingham Bay



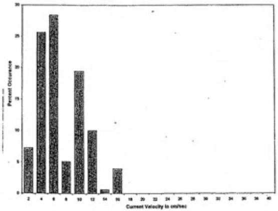
Distribution of Current Velocities

Whatcom Waterway

Shallow Current Velocities

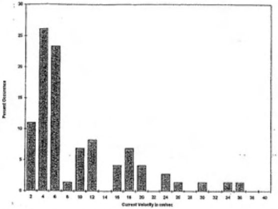


Deep Current Velocities

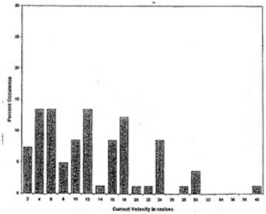


Inner Bellingham Bay

Shallow Current Velocities

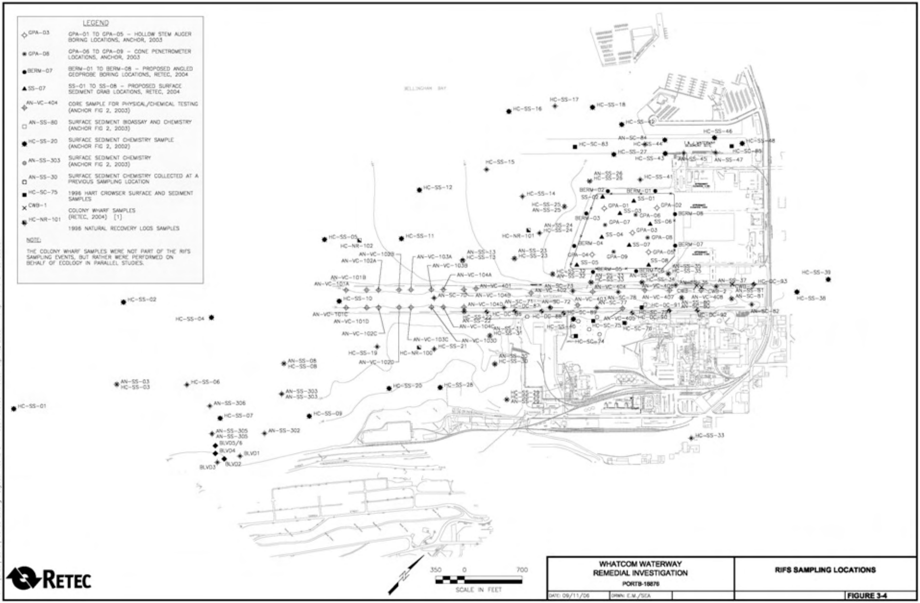


Deep Current Velocities



Note: Shallow velocities from less than 2 meter depth below water surface.
Deep velocities from greater than 2 meter depth below water surface.

Data from Colyer (1998)

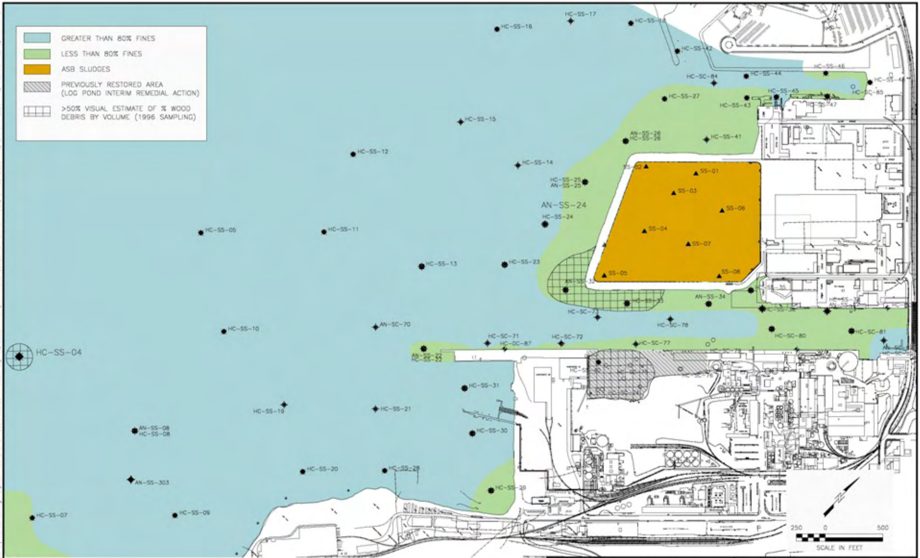


WHATCOM WATERWAY
REMEDIAL INVESTIGATION
PORTB-18876

DATE: 09/11/06 DRWN: E.M./SEA

RIFS SAMPLING LOCATIONS

FIGURE 3-4



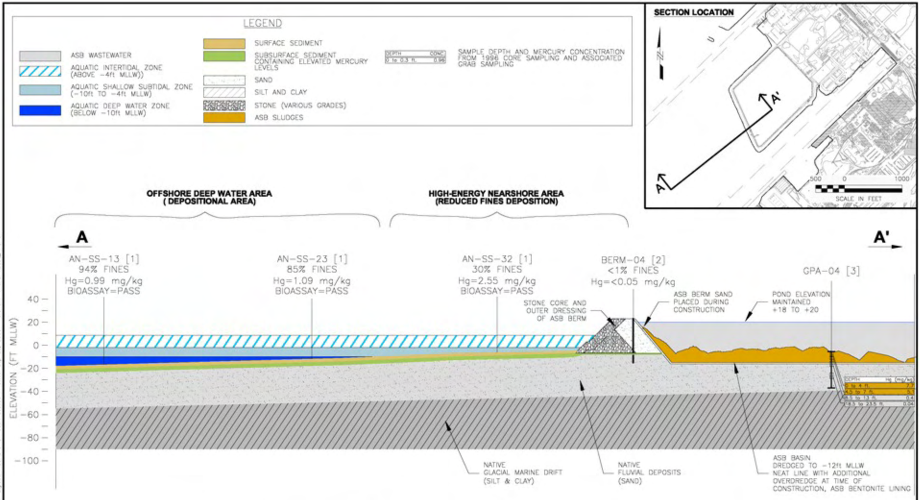
RETEC

WHATCOM WATERWAY
REMEDIAL INVESTIGATION
PORTB-18876

DATE: 09/11/06 DRWN: E.M./SEA

DISTRIBUTION OF FINE GRAINED SEDIMENTS AND WOOD DEBRIS

FIGURE 3-5



NOTES:

1. SURFACE SEDIMENT SAMPLING DATA FOR SAMPLES AN-SS-13, AN-SS-23 AND AN-SS-22 ARE FROM THE 2002 PRDE STUDY (APPENDIX A).
2. BERM-04 DATA ARE FOR SAMPLE COLLECTED 8-14 FEET BELOW GROUND SURFACE (REFER TO APPENDIX D).
3. GPA-03 DATA ARE FROM ASB CORE SAMPLES.

RETEC

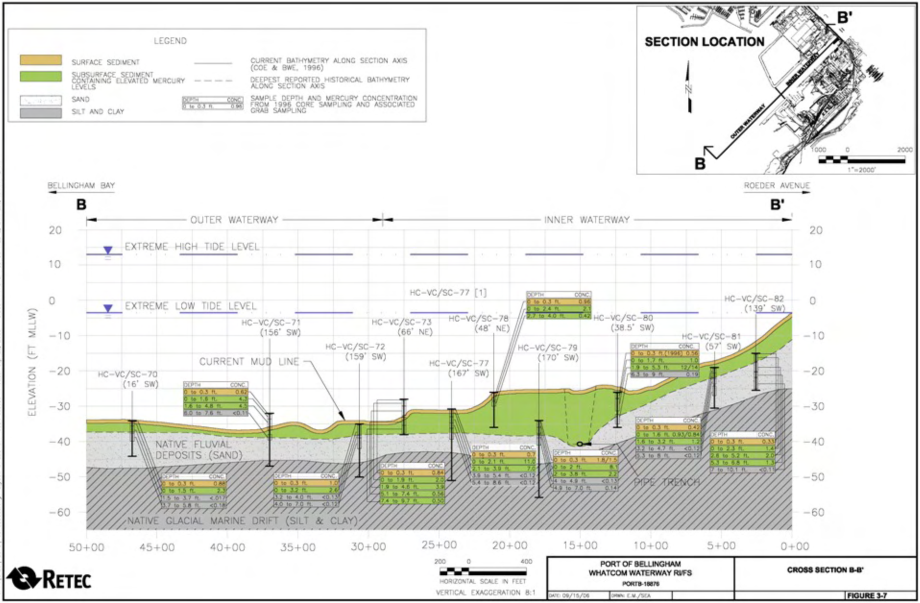
WHATCOM WATERWAY REMEDIAL INVESTIGATION

PORTB-18876

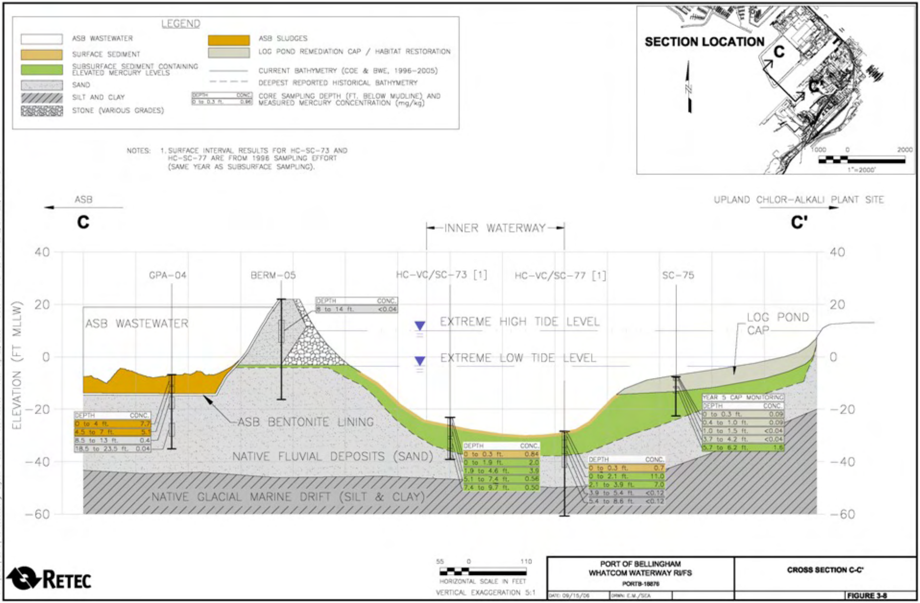
DATE: 08/03/06 | DRWN: A.S./SEA

ASB AREA CROSS SECTION A-A'

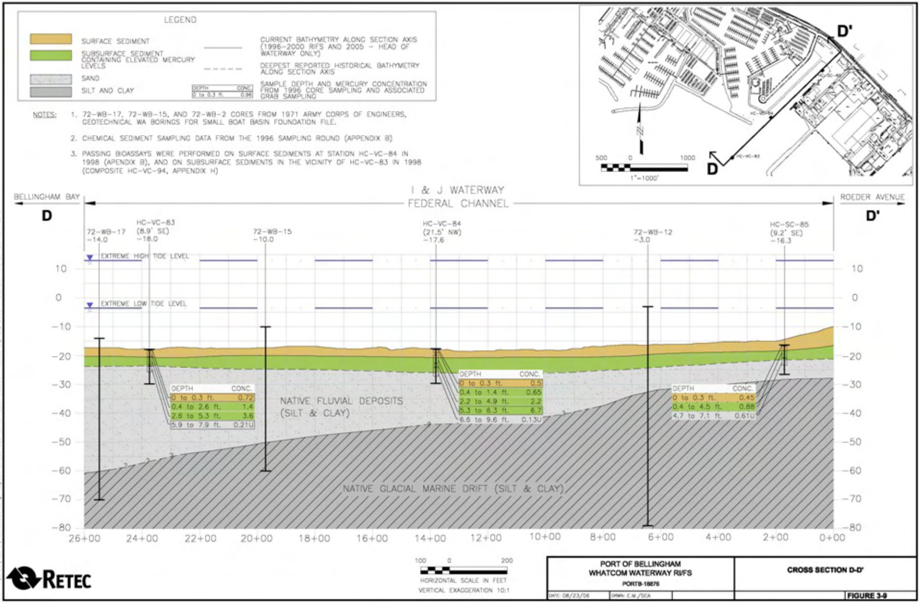
FIGURE 3-6



LEGEND
SURFACE SEDIMENT
SUBSURFACE SEDIMENT CONTAINING ELEVATED MERCURY LEVELS
SAND
SILT AND CLAY
CURRENT BATHYMETRY ALONG SECTION AXIS (COE & BWE, 1996)
DEEPEST REPORTED HISTORICAL BATHYMETRY ALONG SECTION AXIS
SAMPLE DEPTH AND MERCURY CONCENTRATION FROM 1996 CORE SAMPLING AND ASSOCIATED GRAB SAMPLING
SECTION LOCATION
B
B'
1"=2000'
BELLINGHAM BAY
ROEDER AVENUE
OUTER WATERWAY
INNER WATERWAY
EXTREME HIGH TIDE LEVEL
EXTREME LOW TIDE LEVEL
ELEVATION (FT MLLW)
CURRENT MUD LINE
NATIVE FLUVIAL DEPOSITS (SAND)
NATIVE GLACIAL MARINE DRIFT (SILT & CLAY)
PIPE TRENCH
HC-VC/SC-70 (16' SW)
HC-VC/SC-71 (156' SW)
HC-VC/SC-72 (159' SW)
HC-VC/SC-73 (66' NE)
HC-VC/SC-77 [1]
HC-VC/SC-77 (167' SW)
HC-VC/SC-78 (48' NE)
HC-VC/SC-79 (170' SW)
HC-VC/SC-80 (38.5' SW)
HC-VC/SC-81 (57' SW)
HC-VC/SC-82 (139' SW)
50+00 45+00 40+00 35+00 30+00 25+00 20+00 15+00 10+00 5+00 0+00
HORIZONTAL SCALE IN FEET
VERTICAL EXAGGERATION 8:1
RETEC
PORT OF BELLINGHAM
WHATCOM WATERWAY RI/FS
PORTB-18876
CROSS SECTION B-B'
FIGURE 3-7



LEGEND
ASB WASTEWATER
SURFACE SEDIMENT
SUBSURFACE SEDIMENT CONTAINING ELEVATED MERCURY LEVELS
SAND
SILT AND CLAY
STONE (VARIOUS GRADES)
ASB SLUDGES
LOG POND REMEDIATION CAP / HABITAT RESTORATION
CURRENT BATHYMETRY (COE & BWE, 1996–2005)
DEEPEST REPORTED HISTORICAL BATHYMETRY
CORE SAMPLING DEPTH (FT. BELOW MUDLINE) AND MEASURED MERCURY CONCENTRATION (mg/kg)
NOTES: 1. SURFACE INTERVAL RESULTS FOR HC-SC-73 AND HC-SC-77 ARE FROM 1996 SAMPLING EFFORT (SAME YEAR AS SUBSURFACE SAMPLING).
SECTION LOCATION
C
C'
1000 0 2000
1"=2000'
ASB
C
UPLAND CHLOR-ALKALI PLANT SITE
C'
INNER WATERWAY
GPA-04
BERM-05
HC-VC/SC-73 [1]
HC-VC/SC-77 [1]
SC-75
ELEVATION (FT MLLW)
40
20
0
-20
-40
-60
ASB WASTEWATER
EXTREME HIGH TIDE LEVEL
EXTREME LOW TIDE LEVEL
LOG POND CAP
ASB BENTONITE LINING
NATIVE FLUVIAL DEPOSITS (SAND)
NATIVE GLACIAL MARINE DRIFT (SILT & CLAY)
DEPTH CONC.
0 to 4 ft. 7.7
4.5 to 7 ft. 5.1
8.5 to 13 ft. 0.4
18.5 to 23.5 ft. 0.04
DEPTH CONC.
8 to 14 ft. <0.04
DEPTH CONC.
0 to 0.3 ft. 0.84
0 to 1.9 ft. 2.0
1.9 to 4.6 ft. 3.9
5.1 to 7.4 ft. 0.56
7.4 to 9.7 ft. 0.50
DEPTH CONC.
0 to 0.3 ft. 0.7
0 to 2.1 ft. 11.0
2.1 to 3.9 ft. 7.0
3.9 to 5.4 ft. <0.12
5.4 to 8.6 ft. <0.12
YEAR 5 CAP MONITORING
DEPTH CONC.
0 to 0.3 ft. 0.09
0.4 to 1.0 ft. 0.09
1.0 to 1.5 ft. <0.04
3.7 to 4.2 ft. <0.04
5.7 to 6.2 ft. 1.6
55 0 110
HORIZONTAL SCALE IN FEET
VERTICAL EXAGGERATION 5:1
RETEC
PORT OF BELLINGHAM
WHATCOM WATERWAY RI/FS
PORTB-18876
DATE: 09/15/06
DRWN: E.M./SEA
CROSS SECTION C-C'
FIGURE 3-8



CROSS SECTION D-D'

FIGURE 3-9

4 Site Screening Levels

This section discusses screening levels applicable to the investigation and cleanup of the Whatcom Waterway Site. These screening levels are used in Section 5 in the evaluation of the nature and extent of contamination, and in the Feasibility Study to set the goals for remedial actions at the site.

4.1 Overview of Exposure Pathways and Receptors

The cleanup of the Whatcom Waterway Site must ensure protection of human health and the environment. The MTCA and the SMS provide the regulatory context for evaluating site contamination and cleanup goals. These goals address protection of sensitive receptors under various potential exposure pathways as identified in Table 4-1. The subsequent text in this section provides a discussion of each of the principal screening levels applicable to the site and carried forward in the RI/FS.

Table 4-1 Principal Receptors and Exposure Pathways

Receptor	Exposure Pathway	Protective Screening Level
Benthic Organisms	Direct Toxic Effects to Organisms Present in Site Sediment	SMS chemical and biological criteria (Section 4.2)
Human Health	Chemical Exposure through Consumption of Site Seafood	Site-Specific Bioaccumulation Screening-Level (Section 4.3)
Ecological Health	Chemical Exposure through Consumption of Site Seafood	Bioaccumulation Screening-Level (Section 4.4)
Other Receptors (Human Health and Ecological Receptors)	Waste Management During Site Remedial Actions	Other Applicable Regulatory Requirements (Section 4.5)

4.2 Protection of Benthic Organisms

The SMS provide a uniform set of rules and procedures to evaluate the cleanup of contaminated sediment sites (WAC 173-204). The SMS regulations are enforced under the MTCA (Chapter 70.105D RCW). These regulations provide numeric and narrative standards that provide a basis for determining when contaminants are present at levels of potential significance.

4.2.1 SMS Chemical Screening Levels

Under the SMS, two sets of numeric standards have been established for chemical contaminants. The first of these, the sediment quality standard

(SQS), is a criterion at which no adverse effects "including no acute or chronic adverse effects on biological resources and no significant health risk to humans occur" (Ecology, 1995). The SQS are a regulatory and management goal for the quality of sediments throughout the state. The second criteria, the minimum cleanup level (MCUL), is a minor adverse effects level, which is the minimum level to be achieved in all cleanup actions under SMS. SMS regulations apply different restoration time-frame expectations to cleanup actions for compliance with the SQS and MCUL. SMS regulations expect that cleanup actions will comply with the MCUL immediately following active remediation, whereas the regulations allow typically 10 years for compliance with the SQS following the completion of active cleanup.

Compliance with SMS criteria can be assessed using chemical testing methods defined under the Puget Sound Protocols (Puget Sound Estuary Program, 1986) and in amendments to those protocols as established by Ecology. During the Whatcom Waterway RI/FS investigations, extensive chemical testing was performed for surface and subsurface sediments.

SMS marine SQS chemical criteria are defined in WAC 173-204-320 and numerical values are presented in Table I under that section of the regulations. The chemical parameter criteria are defined on either a dry weight basis or on an organic carbon normalized basis for certain organic compounds. To normalize to total organic carbon, the dry weight concentration for each parameter is divided by the decimal fraction representing the percent total organic carbon content of the sediment.

SMS marine sediment MCUL chemical criteria are defined in WAC 173-240-520 and numerical values are presented in Table III under that section of the regulations. As with the SQS criteria, the values are defined on either a dry weight basis or on an organic-carbon normalized basis, depending on the properties of the chemical.

4.2.2 SMS Biological Criteria

SMS regulations define bioassay testing procedures and interpretive criteria that can be used to directly test sediments for adverse effects. Test methods and interpretive criteria have been developed, and provide for definition of two different thresholds of effect. The more stringent SQS provide a regulatory goal by identifying levels below which surface sediments have no adverse effects on human health or biological resources. The MCUL (equivalent to the Cleanup Screening Level or CSL), represents the level above which minor adverse effects may be observed.

Bioassays have been used to directly screen sediments in the site area for the presence of elevated contaminant levels or combinations of contaminants, or conditions suspected by Ecology to result in toxicity. Bioassays have also been used in a confirmatory role when chemical testing demonstrates the presence of elevated contaminant levels. As illustrated with Figure 4-1, the widespread use of whole-sediment bioassays as part of the RI/FS testing program ensures that any potential site impacts to benthic organisms are measured. This includes effects of specific potential contaminant fractions not directly quantified (e.g., methylmercury as a fraction of total sediment mercury), additive or synergistic effects associated with multiple contaminants, or effects of other contaminants not specifically included in the RI/FS chemical testing program.

Bioassay test methods that have been used at the site are defined in current Ecology regulations and include tests performed with amphipods, larval organisms, and juvenile polychaete worms.

4.3 Protection of Human Health

In addition to the evaluation of benthic effects and compliance with the SQS, cleanup levels at the site must protect against other adverse effects to human health and the environment, including food chain effects associated with the potential bioaccumulation of mercury.

Development of the BSL

Mercury is a compound that is known to bioaccumulate in aquatic organisms. The RI/FS activities included evaluation of mercury bioaccumulation, and defined a protective area-wide sediment concentration that would ensure protection of human health. This analysis was performed under very conservative assumptions. This protective area-wide sediment mercury concentration is known as the Bioaccumulation Screening Level (BSL). Figure 4-2 illustrates potential routes of potential mercury bioaccumulation and exposures applicable to Bellingham Bay.

Previous RI/FS testing data for surface waters in Bellingham Bay has shown that surface water complies with the most stringent of the State criteria (WAC 173-201a) for mercury. These criteria are based on prevention of bioaccumulation in seafood. Measurements for surface water were summarized in Section 8 of the 2000 RI/FS (Anchor, 2000). Results showed that surface water mercury levels were consistently below 0.025 µg/L. Since these measurements were taken, additional source control measures have been implemented, including the closure of the Chlor-Alkali Plant, and the implementation of the Interim Remedial Action within the Log Pond. The primary routes of potential bioaccumulation at the site are associated with remaining impacted sediments.

The BSL was originally developed as part of the RI/FS Work Plan, and the basis for the BSL was described in the 2000 RI/FS, which was subjected to public comment and was approved by the Department of Ecology. The BSL provides an additional measurement (in addition to the SMS chemical and biological criteria) which is relevant for measuring the performance of the site cleanup. The derivation of the BSL was completed in three steps.

First, paired fish tissue and sediment data from Bellingham Bay and other Puget Sound embayments with documented mercury contamination sources were tabulated. Sediment measurements for total mercury were used, because these data incorporate all potential chemical fractions and speciation of mercury, and are the most widely available and consistent measurements. Similarly, tissue measurements of mercury were based on total mercury measurements to ensure data comparability and to ensure complete capture of potential forms of mercury in the seafood. The sediment data are summarized in Appendix E. The data included bottom fish (English Sole), crabs (Dungeness and Red Rock Crab), clams, and mussels. Synoptic, quality-assured tissue and sediment data collected in Puget Sound areas characterized by elevated mercury concentrations (i.e., above the SQS) are primarily available from five information sources (generally listed in chronological order):

- Dungeness crab muscle tissue data collected during 1990 and 1997 in the greater Bellingham Bay area by the State of Washington (Ecology, WDFW, and DNR) (SAIC, 1990; Cubbage, 1991; L. Weiss, written communication, 1997)

- Red rock crab muscle tissue data collected in 1974 from the WW Area by Huxley College (Nelson et al., 1974), and in 1990 from Port Madison and West Eagle Harbor by EPA (CH2M Hill, 1991)

- English sole muscle tissue data collected over the period from 1991 to 1995 at numerous sites in Puget Sound by PSAMP (O'Neill et al., in preparation)

- Mixed hard-shell whole body clam tissue data collected over the period from 1990 to 1993 in Bellingham Bay and Puget Sound reference areas by Ecology and DOH (Cubbage, 1991).

Second, the relationship between tissue and sediment concentrations of mercury was determined using a regression analysis (Appendix E). To estimate sediment exposure corresponding to each tissue sample, available surface sediment samples collected within the estimated home range radius of the tissue sampling location were used to calculate an area-weighted average surface sediment concentration. For the purpose of the analysis, an average unconstrained home range of approximately 10 km^2 was used for these three mobile species evaluated (Red Rock Crab, Dungeness Crab, English Sole). The 10 km^2 area can be approximated as a circle with a radius of 1.8 km (1.1 miles). Regression analyses were performed for each of the three synoptic data sets. Of the regression analyses performed, the Dungeness crab regression yielded the most conservative bioaccumulation estimate of the species evaluated. The Dungeness crab regression line bounded the maximum English sole and Red rock crab muscle tissue projections. The Dungeness crab muscle regression equation thus provided a conservative upper-bound estimate of mercury bioaccumulation for a range of species.

Third, using conservative, screening-level risk assessment techniques, a conservative tissue benchmark mercury level was calculated to protect both recreational and tribal fishers who may consume relatively large amounts of seafood from Bellingham Bay. Screening-level risk assessment procedures outlined in MTCA (WAC 173-340-708) were used to estimate a human health benchmark dose and fish/shellfish tissue concentration which is protective of individuals who may consume relatively large amounts of seafood. The screening-level evaluation incorporated conservative exposure and risk assumptions, as follows:

- **Protective Mercury Intake Based on EPA Value.** The existing oral reference dose (RfD) for methylmercury used in this assessment was obtained from the U.S. Environmental Protection Agency's (EPA) Integrated Risk Information System (IRIS) database. The RfD is an estimate of daily methylmercury intake to a population, including sensitive subgroups, which is likely to be without an appreciable risk of deleterious effects during a lifetime. The methylmercury RfD (1×10^{-4} milligrams per kilogram per day [mg/kg-day]) was conservatively applied to assess total mercury concentrations in fish and shellfish tissues. This provides an additional level of conservatism to the estimates (i.e., the total mercury RfD is 3 times less stringent than that for methylmercury, and actual mercury speciation is unlikely to be 100 percent methylmercury in fish and shellfish tissue).

- **Crab, Bottomfish, Clams, and Mussels Assumed to be Harvested Entirely on Site.** The risk assessment calculations assumed that the fisher obtained 100 percent of their crab, bottomfish, clam, and mussel intake solely from the Site area (i.e., 100 percent diet fraction). Actual fishing activity is likely to be more varied, with fish and shellfish obtained from a variety of locations within the greater Bellingham Bay and Rosario Straits areas. For example, tribal fish consumption surveys (Toy et al., 1996) have documented that a significant portion of seafood consumed by tribal fishers is obtained form areas outside of Puget Sound, and that the fishing locations vary within Puget Sound. The assumption that all seafood is obtained from the Whatcom Waterway Site area (a small portion of Bellingham Bay) results in a significant overestimate of potential human health exposure via seafood consumption.

- **Conservative Tribal Fish and Shellfish Consumption Rates Assumed.** The most comprehensive evaluation of seafood consumption rates by regional tribal fishers is contained in Toy et al. (1996) based on studies of the Tulalip and Squaxin Island Tribes of Puget Sound. The conservative upper-bound (90th percentile) combined consumption rate of crab, bottomfish, clams, and mussels from that study is approximately 70 grams per day (23.4 grams Dungeness crab, 7.8 grams total bottomfish and 38.5 grams clams and mussels), with additional consumption of salmonid, pelagic and freshwater fish. The overall seafood consumption rate used is equivalent to 173 grams per day of total seafood (rates normalized to a 70 kg adult). The seafood consumption rates used for BSL development are more conservative than the mean and median ingestion rates, and are substantially higher than the 95 percent upper confidence limit around the mean from the Toy study. The rates are also substantially higher than the rates currently used in the state MTCA regulations (27 grams/day). EPA risk assessment guidance for use with Superfund sites (EPA, 1997) recommends a mean *total* fish/shellfish intake rate of 70 grams per day, and a 95th percentile consumption rate of 170 grams per day for protection of sensitive subsistence fisher populations, which is less than the assumed ingestion rates (173 grams per day) used for the BSL development. It is also important to note that the rates from the Toy (1996) study represent the *higher* of the adult and child seafood ingestion rates (normalized to body weight). This ensures that the BSL development is protective of both adult and non-adult populations.

Using the bioaccumulation regression analyses and the seafood consumption rates summarized above, the area-wide sediment screening level that ensures a mercury intake at or below the RfD were calculated. The resultant sediment screening levels calculated in this manner varied from 1.2 to 3.7 mg/kg, depending on the fish consumption rate and the regression analysis used (Appendix E). Using each of the most conservative assumptions produced a sediment bioaccumulation screening level of 1.2 mg/kg. The BSL has been carried forward in the Supplemental RI/FS for determination of required cleanup areas and for use in long-term monitoring of cleanup performance.

In applying the BSL to the site, it is important to understand the conservatism associated with the use of this value as applied by Ecology. Because of the conservatism of the assumptions on which the BSL was developed, the BSL is protective of human health even if one or more of the underlying assumptions were to change significantly. Examples of highly conservative assumptions used in the development and application of the BSL, and that tend to overestimate seafood consumption health risks, include the following:

- **Area-Weighted Averaging versus Point-by-Point Application:** The BSL was originally developed using tissue uptake exposures and area-wide sediment concentrations. However, the BSL has been applied by Ecology to determine cleanup requirements on a point-by-point basis (i.e., samples exceeding the BSL are considered contaminated, even if the area-weighted average mercury concentration within the site is far below the BSL). This application results in over-protectiveness by a factor of two to threefold (i.e., surface weighted average mercury concentrations within the site have been well below the BSL, and have been falling over time due to natural recovery processes and the implementation of the Interim Remedial Action within the Log Pond).

- **Mercury Speciation Assumptions:** As noted above, the assumption of 100 percent methylmercury speciation tends to overestimate exposure risk by 10 to 30 percent.

- **Diet Fraction Assumptions:** Also as noted above, 100 percent of the seafood ingestion is assumed to be harvested from the Whatcom Waterway Site, even though the site represents a small portion of Puget Sound, and seafood consumption surveys have documented a diversity of tribal fishing locations both within and outside of Puget Sound. This assumption is expected to overestimate exposure risks by over 50 percent.

Due to the conservatism of the assumptions underlying the BSL, the actual seafood exposure risks associated with mercury are expected to be substantially lower than estimated by the BSL. No mercury-associated seafood consumption advisories have been issued at the Whatcom Waterway Site, and none of the documented seafood tissue sampling data exceed safe mercury levels recommended by EPA (0.3 mg/kg wet weight).

4.4 Protection of Ecological Receptors

The application of the BSL as part of Whatcom Waterway Site investigation and cleanup activities ensures protection of both human health, and also provides protection of higher trophic-level wildlife exposures. For example, the BSL provides substantial margin of protection for marine mammals as described below.

As discussed in Section 3.1, some grey whales have been observed to enter Bellingham Bay and other portions of Puget Sound to feed opportunistically along their annual migrations between breeding ground in Baja, Mexico and their summer Arctic feeding grounds. Extensive monitoring of grey whale migrations, standings, and biological monitoring data has been performed by public and private organizations, including but not limited to NOAA, Cascadia Research, and the Ocean Sciences Institute. Direct testing of blood, tissue and body fat chemical levels have been performed on stranded, deceased whales and biopsies of living animals. Comparisons of heavy metal composition in stranded Puget Sound whales and whales in the Arctic feeding ground demonstrated no evidence of increased exposures for standard whales (Varanasi, 1993). Mercury levels in whale tissues were not significantly different between the two populations, and mercury levels were generally very low with no detectable mercury in neurological tissues which are the most sensitive to mercury exposures.

The observations from direct testing of marine mammals are consistent with quantitative exposure estimates based on feeding rates, measured invertebrate tissue levels, and mammalian effects levels for chronic and subchronic effects. Federal studies have established lowest-effects level and no effects levels for mercury of 0.8 mg/kg/day and 0.42 mg/kg/day respectively for mammalian studies (ATSDR, 1989). These studies are directly supported by experiments performed with felines, mice and rats including pre-natal exposure studies and long-term feeding studies (USAF, 1990; Chang et al, 1977; Fowler & Woods, 1977). At peak feeding rates of 2 percent of body weight per day, and using the maximum invertebrate tissue/sediment relationships as used to derive the BSL, average sediment concentrations equal to the BSL (1.2 mg/kg) would ensure a maximum estimated mercury exposure (0.02 kg food consumption/kg whale per day times maximum estimated crab tissue concentration from Appendix E) to the feeding grey whale (0.0036 mg/kg/day) that is over 100 times below the published mammalian no effects level (0.42 mg/kg/day). Actual exposures would be much lower due to the wide range included in whale feeding and the lower feeding rates typically observed during opportunistic feeding behavior.

Additional verification of the ecological protectiveness of the BSL is evident from review of other bioaccumulation screening levels, and from the results of direct bioaccumulation testing. The PSDDA program maintains bioaccumulation trigger (BT) values for a variety of contaminants. The Whatcom Waterway BSL (1.2 mg/kg) is more stringent than the current PSDDA BT for mercury (1.5 mg/kg). Additionally, direct bioaccumulation testing has been performed on Whatcom Waterway area sediments with mercury concentrations as high as 1.8 mg/kg, significantly above the BSL (Appendix H). These tests have shown no significant mercury bioaccumulation in the test conditions, in comparison to clean reference materials, confirming that the maintenance of mercury levels at or below the BSL minimizes the potential for significant bioaccumulation to occur.

4.5 Other Screening Levels

Specific evaluations performed as part of the RI/FS also included comparisons to other screening levels. These comparisons include the following:

- **Upland MTCA Cleanup Levels:** As part of the Feasibility Study evaluations, some scenarios were evaluated in which sediments could be reused in upland land use applications or could be used to create new upland areas. Under these scenarios, MTCA cleanup levels for soils and groundwater could apply and were used to evaluate the feasibility, implementability and costs of specific remedial alternatives.

- **PSDDA Program Standards:** The PSDDA program provides a comprehensive program for characterizing materials for open-water disposal or beneficial reuse. The program includes chemical and biological testing protocols to address toxicity of contaminants to benthic organisms and risk-based screening levels for use in evaluating potential bioaccumulation risks. The RI/FS evaluations included screening of materials from the Outer Waterway and the I&J Waterway against PSDDA program criteria. These results are specific to PSDDA program evaluations.

- **Regulatory Criteria for Other Media**: Some of the RI/FS activities included pre-design evaluations of contaminant mobility under simulated confined disposal alternatives. These evaluations included comparisons of leachate concentrations against state and federal water quality criteria. Disposal evaluations included testing of materials against disposal criteria established under other state and federal regulatory programs. These screening levels are discussed where applicable.

In addition to the screening levels listed above, background values were used where available to document natural background and regional background concentrations of chemical constituents.

PORT OF BELLINGHAM

Figure 4-1
Verifying Protection of Benthic Organisms

RETEC

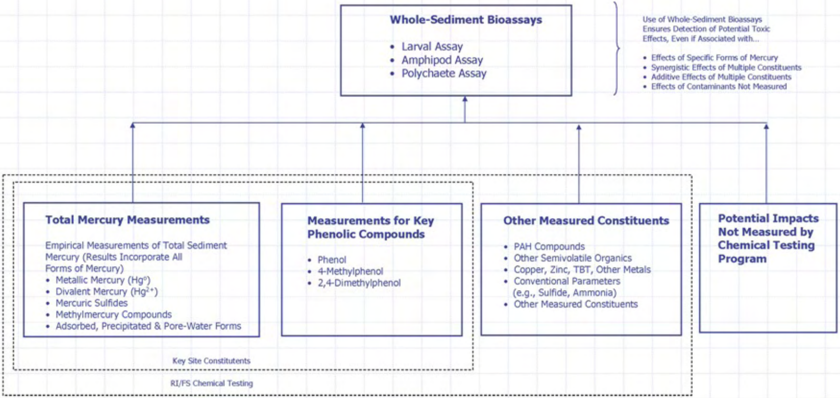
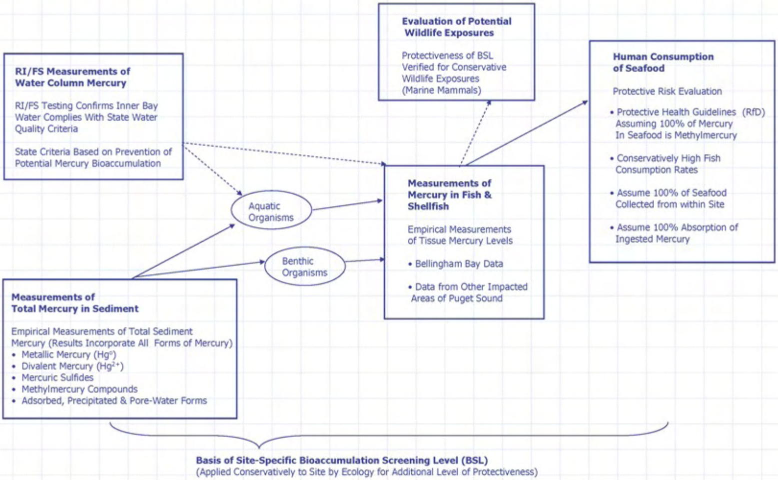


Figure 4-2
Ensuring Protection from Potential Mercury Bioaccumulation



5 Nature and Extent of Contamination

This section describes the results of investigations performed between 1996 and 2004 documenting the nature and extent of contamination in sediments at the Whatcom Waterway Site. Information covered in this section includes the following:

- Constituents of Concern (Section 5.1)
- Quality of Surface Sediments (Section 5.2)
- Quality of Subsurface Sediments (Section 5.3).

5.1 Constituents of Concern

The constituents of concern present within the Whatcom Waterway Site are described in this section. Section 5.1.1 describes constituents present in areas outside of the ASB. Section 5.1.2 then describes constituents present in the ASB areas.

5.1.1 Areas Outside the ASB

Key Constituents of Concern

Based on the series of sediment investigations performed for surface and subsurface sediments in 1996, 1998, and 2002, the key constituents of concern for the sediments in the Whatcom Waterway Site areas include mercury and phenolic compounds. It is these compounds that most frequently exceeded the chemical SQS values, the site screening levels applicable to aquatic areas of the Site.

Mercury has natural background sources, and a portion of the mercury present at the site is derived from natural sources. Based on United States Geological Survey (USGS) studies of natural background levels of heavy metals (USGS, 2001), soils in the greater Bellingham area exhibit natural background mercury concentrations between 0.05 and 0.20 mg/kg. The USGS database of natural background concentrations of heavy metals in United States river systems (Rice, 1999) similarly indicates a background concentration for most western river systems between 0.05 and 0.25 mg/kg. Regional deposition of mercury from atmospheric sources (i.e., combustion of fossil fuels and resultant deposition of mercury by fallout and precipitation) contributes to this background loading. However, these natural and regional sources are not likely to cause exceedances of MTCA and SMS screening levels within the site.

The chemical SQS for mercury is 0.41 mg/kg. The chemical MCUL for mercury is 0.59 mg/kg. These levels apply to total mercury, which is the parameter measured directly with the RI chemical testing program. As shown in Figure 4-1, the potential effects of the various geochemical forms of mercury (i.e., metallic mercury, divalent mercury, mercuric sulfides, methylmercury) were addressed using whole-sediment bioassays. Bioaccumulation affects of mercury (in its various forms) were addressed conservatively in the development of the site-specific BSL as illustrated in Figure 4-2, and discussed in Section 4.3 and 4.4.

Throughout the Whatcom Waterway Site areas, mercury was the compound most frequently detected above SMS numeric screening levels. These levels are greater than natural background concentrations, and the patterns of contamination are consistent with a localized source for the incremental sediment mercury content. The highest concentrations of mercury correlate with historical mercury discharges from the Chlor-Alkali Plant between 1965 and 1970 when pollution control upgrades were implemented by GP and to a lesser extent between 1970 and 1979 when direct discharge of mercury-containing wastewaters to the Whatcom Waterway area was terminated.

The main phenolic compound detected at elevated concentrations at the site was 4-methylphenol. The SQS and MCUL values for 4-methylphenol are both 0.67 mg/kg. This compound can be produced from a variety of natural and anthropogenic sources. Methylphenol compounds are produced in the absence of oxygen by the decomposition of organic matter such as leaves, wood, and other vegetation. Under appropriate conditions the compound is readily biodegraded and does not accumulate. Within the Whatcom Waterway Site, elevated concentrations of 4-methylphenol were noted predominantly in subsurface sediments with accumulations of former pulp waste discharges, wood waste accumulations, and debris from historic log rafting activity. These activities can produce deposits of organic matter that in turn produce 4-methylphenol as a decomposition product.

The phenolic compounds phenol and 2,4-dimethylphenol were noted sporadically in surface sediments. The SQS and MCUL values for 2,4-dimethylphenol are both 0.029 mg/kg. The compound 2,4-dimethylphenol can be generated from a variety of natural and anthropogenic sources, including stormwater discharges. These compounds were present predominantly in surface as opposed to subsurface sediments.

Other Constituents

Several other compounds were detected above screening levels sporadically during the Whatcom Waterway Site investigations. These compounds include the following:

- **PAH Compounds:** Several PAH compounds were detected intermittently in areas near creosote-treated wood structures and in subsurface rather than surface sediments. Concentrations of seven high molecular weight polycyclic aromatic hydrocarbons (HPAHs) and four low molecular weight polycyclic aromatic hydrocarbons

(LPAHs) exceeded their SQS criteria in at least one subsurface sediment sample. Only one HPAH, flouranthene, was present at concentrations above the MCUL (sample HC-DC-87-S1). Two LPAHS (fluorene and phenanthrene), as well as total LPAHs were also present at concentrations above the MCUL in sample HC-DC-87-S1.

- **Hexachlorobenzene:** The compound hexachlorobenzene was detected in excess of the SQS in one surface sample (HC-SS-34) and in several subsurface samples (HC-DC-89, -90, -91 and -92 and in HC-VC-80). This compound can be present in some pentachlorophenol treated wood structures.

- **Benzoic Acid:** One sample result (HC-SC-76) exceeded the SQS and MCUL criteria for benzoic acid (650 micrograms per kilogram (µg/kg) for both criteria). Like phenolic compounds, benzoic acid can be produced from the natural decomposition of plant debris or wood materials. It can also be present in stormwater discharges. Benzoic acid is readily biodegradable.

- **Copper and Tributyl Tin:** Localized detections of copper and tributyl tin were noted in surface and subsurface sediments along the shoreline of the Colony Wharf site (Appendix F). These detections appear to be associated with former boat maintenance activities that took place historically on and adjacent to the Colony Wharf site and historical operation of a foundry at the Colony Wharf site. The areas of sediment contamination located in this area are included within the investigation and cleanup area of the Whatcom Waterway Site.

- **Bis(2-ethylhexyl)phthalate:** This compound was detected in several samples located in the I&J Waterway area during initial RI investigations. Later Phase 2 investigations performed in 2001 by the Port determined that these detections were associated with a localized release along the I&J Waterway shoreline. This area has been designated as a separate cleanup site and is currently being investigated by the Port (the I&J Waterway Sediments site) under an Agreed Order with the Department of Ecology.

Constituents Not Analyzed

As shown in Figure 4-1 and discussed in Section 4, bioassay testing using SMS whole-sediment bioassays has been used to assess potential toxicity associated with other contaminants that could potentially be present but that were not specifically analyzed with the RI chemical testing program. The bioassays also provide a mechanism for evaluating potential additive or synergistic effects between tested chemicals.

Additional testing for dioxins and furans was not performed during the RI chemical testing program outside of the ASB. Testing for those compounds has been regularly performed as part of sediment monitoring of the outfall area by GP as part of their NPDES permit requirements. The GP outfall is managed separately from the Whatcom Waterway site, as part of GP NPDES permit requirements. No evidence of benthic toxicity as measured by sediment bioassays (Anchor, 2000b) at the outfall area. Testing of tissue concentrations in fish and shellfish performed on behalf of EPA and the Puget Sound Estuary Program (PTI, 1991) and the DNR (SAIC, 1991) have not shown any differences in Bellingham Bay fish and shellfish muscle tissue and that collected from background reference sites. These studies demonstrate the lack of any significant benthic toxicity or bioaccumulation effects associated with these compounds. Whole-sediment bioassay testing as described in Section 5.2, coupled with the existing Bellingham tissue data were determined by Ecology to be sufficient for evaluation of dioxin/furan effects during the RI investigations.

5.1.2 ASB

The ASB sludges include wastewater solids produced during secondary treatment of wastewater from the GP pulp, tissue, chlor-alkali, and chemical plant operations between 1979 and the completion of the RI/FS investigations. Wastewater loadings to the ASB have been substantially reduced by closure of the pulp and chemical plants, and closure of the Chlor-Alkali Plant. Wastewaters currently managed by the ASB include stormwater, cooling water from the Encogen facility, and low-solids wastewaters from the tissue plant operations.

The ASB also includes subsurface sediment contamination associated with historic releases from the Chlor-Alkali Plant. This contamination is present in sediments beneath the ASB berm.

Key Constituents of Concern

Based on relative concentration and frequency of detection, the main contaminants present in the ASB sludges include the following:

- **4-Methylphenol:** The ASB sludges contained very high concentrations of 4-methylphenol. These concentrations ranged from 11 to over 250 times the SQS value. The abundance of this compound is associated with the accumulation of pulp solids and other woody materials in the ASB in the presence of anaerobic conditions. The ASB design maintained both aerobic and anaerobic conditions for optimization of wastewater treatment.

- **Mercury:** Most ASB sludge samples contained elevated concentrations of mercury from discharges of Chlor-Alkali Plant wastewaters and stormwaters. With the closure of the Chlor-Alkali Plant and pulp mill, the main source of mercury to the ASB has been terminated.

- **Phenol:** The compound phenol was present in most ASB sludge samples at concentrations above the SQS, though the relative concentrations and frequency of detection for phenol were lower than for 4-methylphenol. The phenol is associated with pulp mill and other effluents managed in the ASB.

- **Zinc and Cadmium:** Elevated concentrations of zinc and cadmium were detected in most of the ASB sludge samples. These compounds were most likely associated with operations of the chemical byproducts plant at the GP mill site. The chemical plant has been closed, terminating the main sources of these contaminants to the ASB.

Other Constituents

Several additional compounds were detected sporadically in the ASB sludges at concentrations in excess of the SQS. These compounds included bis(2-ethylhexyl)phthalate and butyl-benzyl-phthalate (each detected above their respective SQS values in two ASB sludge samples) and naphthalene which was detected above the SQS in one sample.

Chlorinated dibenzodioxins and dibenzofurans were also present in the ASB sludges at low but significant concentrations. These compounds do not have numeric SQS or MCUL values under SMS regulations. Their effects are measured directly using bioassays and measurements for bioaccumulation. These compounds are produced during the production of chlorine-bleached pulp and paper products. The compounds readily adsorb to high-organic particulates such as the pulp solids present in the ASB sludges, resulting in retention of these constituents within the ASB sludges.

5.2 Surface Sediment Quality

Sediment quality at the Whatcom Waterway Site was directly measured during sampling events in 1996 and 1998, and later in follow-up sampling performed in 2002. Sampling has demonstrated a reduction in both surface sediment chemical concentrations, including observed areas of surface sediment toxicity as measured by bioassay testing. Results for initial surface sediment quality from the first two sampling events (1996 and 1998) is presented in Section 5.2.1. Section 5.2.2 presents the updated sediment quality data collected in 2002, and discusses observed changes in sediment quality between these sampling events.

ASB sludges have been analyzed using sediment coring which composites surface and subsurface sediments together. For that reason, ASB sludges are not discussed in this section. ASB sludge sampling data, including data for the quality of the ASB berm materials are presented in Section 5.3.

5.2.1 Surface Sediment Quality in 1996-1998

During the 1996 and 1998 investigations, chemical testing was performed at 82 surface sediment sampling locations. Sediment samples from 40 site locations were then submitted for confirmatory biological testing to verify or refute sediment toxicity predicted on the basis of sediment chemical concentrations or the presence of wood material (Anchor and Hart Crowser, 2000). As set forth in the Whatcom Waterway RI/FS Project Plans, all surface samples that contained mercury concentrations above 0.59 mg/Kg (dry weight) or other chemicals that exceeded SMS screening criteria were submitted for confirmatory biological testing. In addition, confirmatory biological testing was also performed on those surface sediment samples collected from the Site contained elevated quantities of wood debris.

Sixty percent of the sediment samples submitted for biological testing (collected from 24 locations) were determined to be non-toxic (i.e., did not exceed SMS minor biological effects criteria). The remaining 40 percent of the locations exceeded SQS biological effects criteria, though only 15 percent (six locations) exceeded MCUL criteria based on more than minor biological effects. Apparent sediment toxicity correlations with specific contaminants are discussed in Section 5.2.3 below.

Figure 5-1 summarizes the surface sediment data from the 1996 and 1998 investigations, including the extent of surface mercury impacts. The results of confirmatory bioassays are shown in Figure 5-3. The following presents a summary of these distributions by analyte.

- **Mercury:** Mercury exceeded the MCUL criteria of 0.59 mg/kg in 39 of 82 surface samples. Concentrations of mercury were highest in the GP Log Pond. In general, mercury concentrations in surface sediments were significantly less than concentrations detected at depth, reflecting the implementation of source controls by GP beginning in the early 1970s, and associated natural recovery of sediments in response to these source reductions.

- **Phenolic Compounds**: In general, concentrations of phenolic compounds appeared to be correlated with accumulations of wood or organic debris, historic pulp mill wastes, and to some extent storm drains. Phenol can be derived from the natural degradation of plant matter. In addition, these compounds are fairly ubiquitous in storm drains near the site, based on data collected during Ecology's Drainage Basin Tracing Study (Cubbage, 1994).

Concentrations of phenolic compounds concentrations generally increased with depth indicating both a historical source as well as the tendency of these compounds to biodegrade readily when present in surface sediments.

5.2.2 Current Surface Sediment Quality

Figure 5-2 shows the surface sediment sampling data for mercury collected during the 2002 sampling event. Concentrations of site contaminants in surface sediments throughout the site were significantly lower during the 2002 sampling event, compared to previous 1996-1998 RI/FS samples.

As shown in Table 5-1, significant reductions in mercury concentrations were noted in 84 percent (all but three) of the samples which were co-located with previous sampling stations. The average concentration reduction observed in the co-located samples was 31 percent. The reduction in concentrations between the two sets of RI/FS sampling events is slightly greater than earlier natural recovery modeling predictions (Anchor and Hart Crowser, 2000). The reductions confirm other lines of evidence documenting the performance of natural recovery throughout portions of the site. These lines of evidence are discussed further in Section 6.0.

Only a single surface sampling station exceeded the mercury BSL during the 2002 sampling event. That station was located at Station SS-32 in the relatively high energy environment offshore of the ASB. The sediments in this area showed a lower fines content which are consistent with higher levels of wave energy. The higher wave energies in this area likely reduce rates of natural recovery and sedimentation that are present in other areas of the site. One sample station that previously exceeded the BSL in 1998 (HC-SC-79) was not resampled as part of the 2002 sampling effort. That station is carried forward in the RI/FS assuming that it continues to exceed the BSL.

Confirmatory biological testing of selected 2002 stations was performed to further evaluate compliance with SMS criteria (Figure 5-4). Of the 16 confirmatory bioassays conducted within the Whatcom Waterway Site, only one location, Station SS-30, did not meet SQS biological criteria during the 2002 sampling event. That station exhibited the presence of wood wastes and the presence of 2,4-dimethylphenol. Previous testing in 1996 and 1998 had exhibited the presence of wood waste, phenolic compounds, and bioassay toxicity at this same location.

Figure 5-3 and 5-4 also incorporate the results of chemical and bioassay testing performed at the Colony Wharf site on behalf of the Department of Ecology in 2004. The data report for that sampling event is attached as Appendix F. Contamination in that area is localized and will be remediated as part of coordinated cleanup of the Whatcom Waterway and Central Waterfront sites.

Surface sediments within the I&J Waterway Sediments Site are being managed separately from the Whatcom Waterway Site. Additional surface and subsurface testing is ongoing in this area as part of the I&J Waterway RI/FS.

Figure 5-5 summarizes the results of recent sampling of the Log Pond area. These data are from the Year-5 Monitoring Report (Appendix I). As discussed in that appendix, cap performance has been within design targets for most parameters. All surface sampling stations called for in the Operations Maintenance and Monitoring Plan (OMMP) passed the chemical or biological testing performance criteria, with one exception. Some sediment erosion has been noted around the cap edges along the Central Log Pond shoreline, and in the southwest corner of the Log Pond. Recontamination of a small portion of the cap surface was noted in the southwest corner of the Log Pond. Effects in this area were caused by wave-induced resuspension of impacted sediments from an area south of the cap limits, and migration of those sediments onto the cap surface. The affected area was delineated as part of the Year-5 monitoring event, and corrective actions are proposed as part of the remedial alternatives presented in the Feasibility Study. For a full discussion of the Year-5 monitoring event, refer to Appendix I of this RI report.

5.2.3 Review of Bioassay Test Data

Bioassay testing data from the 1996, 1998, and 2002 sampling events are summarized in Figures 5-6 through 5-9, and in Table 5-2. The data analysis is performed using the apparent effects threshold (AET) method on which the Sediment Management Standards SQS and MCUL criteria were initially developed (PSDDA, 1996). The method plots bioassay exceedances as a function of contaminant concentration. The AET is identified as the concentration above which toxic effects are consistently observed (after addressing "outlier" data points and other data issues).

The bioassay correlations shown in figures 5-6 through 5-9 incorporate all three bioassay methods (amphipod, larval, polychaete), plotting the toxicity result based on the overall SMS interpretive result. Using this method, a sample that passes two bioassays, but fails the third bioassay is plotted as a failure on the chart. This method is shown conservatively, given the relatively small number of data points. If individual organism test results are plotted, the conclusions about bioassay correlations are similar to those discussed below, with the exception of the amphipod test. The amphipod tests generated the fewest number of test failures, indicating that these organisms are generally less sensitive to the site contaminants in comparison to the larval and polychaete test organisms.

The bioassay correlations for 4-methylphenol (Figure 5-6) showed the strongest correlation between contaminant concentration and toxicity. At the highest concentrations measured, all bioassays failed SQS or MCUL/CSL performance standards. While the data are not likely sufficient for development of a site-specific AET, the results of testing suggest that the effects thresholds for 4-methylphenol are intermediate between the standard SMS SQS/CSL concentrations (0.67 mg/kg) and approximately 3.9 mg/kg.

The bioassay correlations were also fairly strong for phenol (Figure 5-7). Most samples containing phenol concentrations above the numeric SQS exhibited toxicity during conformational bioassays. There was one exception to this pattern at the highest phenol concentration measured. However, this sample would be treated as an “outlier” in the AET development process. The results suggest that site-specific phenol toxicity may be similar to the numeric SQS.

A poor correlation was observed between toxicity and 2,4-dimethylphenol concentrations (Figure 5-8). Passing bioassay results were observed for the majority of the samples that exceeded the numeric SQS and MCUL. The results suggest that the numeric SQS and MCUL overestimate the toxicity of this compound at the Whatcom Waterway Site. The site-specific data suggest that the toxicity threshold for this compound is above 0.19 mg/kg.

Bioassay correlations for mercury (Figure 5-9) are also poor. Site-specific bioassay testing confirmed that no toxic effects were observed at concentrations below the numeric SQS, except where elevated phenol or 4-methylphenol was present. However, the majority of samples tested between the SQS (0.41 mg/kg) and 2.9 mg/kg also exhibited no toxicity. Sporadic toxic results were observed in this range primarily in samples containing elevated phenolic compound. The results suggest that mercury concentrations are not toxic to benthic organisms at concentrations below the SQS or CSL, and that a site-specific AET, if developed, would likely be greater than 2.9 mg/kg. Sporadic toxicity observed between the numeric CSL and 2.9 mg/kg may be associated with synergies between multiple chemicals, or between chemical toxicity and conventional parameters.

The bioassay correlations discussed above are provided for discussion purposes only, to assist in the understanding of site conditions. The correlations were not used to develop site-specific numeric cleanup levels. As described further in the Feasibility Study, the cleanup levels for the site will continue to be based on a combination of SMS numeric standards, and conformational bioassay testing for samples with elevated chemical constituents. The continued use of whole-sediment bioassays in the monitoring process for samples containing elevated mercury or other contaminants ensures that any synergistic effects of multiple contaminants can be detected. The use of whole sediment bioassays also ensures that should toxicity be induced by an indirect mechanism (e.g., toxicity through methylmercury production rather than toxicity from inorganic mercury) this effect would be documented. The absence of toxicity in whole sediment bioassays provides a robust demonstration that the benthic organisms are being protected.

5.3 Subsurface Sediment Quality

Surface conditions in sediments at the Whatcom Waterway Site are generally compliant with sediment screening levels as measured using chemical and biological testing. The extent of natural recovery has been significant, resulting in attenuation of contaminant levels in the sediment bioactive zone and in immediately underlying sediments.

The purpose of the SMS is to reduce and ultimately to eliminate adverse effects on biological resources and significant health threats to humans from surface sediment contamination. Surface sediments are defined by the sediment bioactive zone, which was determined to be 12 centimeters (cm) for the Whatcom Waterway Site. However, if subsurface sediment has the potential to become surface sediment, through natural processes or through anthropogenic influences, it also must be addressed. Some of the factors affecting sediment stability include wave induced erosion, bioturbation, propeller wash, and anchor drag. These factors are discussed in Section 6 of this report. Area land use and navigation patterns and issues that have potential bearing on subsurface sediment exposure due to navigation dredging and/or land use actions are described in Section 3.3.

The RI/FS investigations included extensive testing of subsurface sediments. These subsurface data were developed to assist in the evaluation of long-term sediment stability, and also to support site remedial alternatives evaluations in the Feasibility Study.

Figures 5-10 through 5-13 and Table 5-3 summarize the subsurface data collected at the site during the RI/FS process. These data are discussed below for the areas outside the ASB (Section 5.3.1) and for the ASB (Section 5.3.2). Detailed data summaries and backup data are provided for each site area as part of the appendices to this report. Selected subsurface mercury concentrations are also shown on the geologic cross sections contained in Section 3 of this report (Figures 3-6 through 3-9).

5.3.1 Areas Outside the ASB

Figures 5-10 through 5-13 summarize average sediment quality within the shallow subsurface sediments throughout the site. The figures specifically show the average sediment quality at depths 0.4 feet to 4 feet below the sediment mud-line. Backup calculations are summarized in Appendix G. Note that the Log Pond area is shown prior to completion of sediment capping, to provide the reader with a better overall sense of subsurface contaminant distribution throughout the site prior to initiation of remedial efforts.

The 0.4 to 4 foot depth was selected because it represents the maximum depth of subsurface sediment that has a significant potential to be disturbed by natural or anthropogenic activities, in the absence of navigation dredging activities or anthropogenic shoreline changes. Such disturbance events are sporadic and are unlikely to result in complete mixing with the bioactive zone. Therefore, the information in Figures 5-10 through 5-13 provide a gross summary of shallow subsurface conditions, and are not direct measurements of potential risks to human health or ecological receptors.

Figure 5-10 summarizes subsurface sediment mercury concentrations. Mercury concentrations are highest in the remediated Log Pond area, which is where the historic discharge of mercury-containing wastewater was located during the 1960s and 1970s. Concentrations of mercury in the Waterway sediments decrease rapidly with distance from the Log Pond source area. Figure 5-11 illustrates the relationship between average subsurface mercury concentration and distance from the Log Pond.

Concentrations of 4-methylphenol are shown in Figure 5-12. This compound is present at elevated concentrations in areas near historic pulp mill wastewater discharges, including the head of the Whatcom Waterway and the ASB. Concentrations within the Whatcom Waterway are relatively low, reflecting the success of previous remedial efforts implemented in the 1970s, and the results of wastewater pollution controls implemented under the NPDES program. However, concentrations of 4-methylphenol remain very high in the ASB sludges, as described in Section 5.3.2 below.

Figure 5-13 presents an integrated view of all subsurface sediment contaminants in the 0.4 to 4 foot interval. The relative sediment composition is described using the cumulative enrichment ratio approach. The enrichment ratio for an individual compound is calculated by dividing the measured concentration by the SQS value for that compound. A compound present at the SQS has an enrichment ratio of one times, and a compound present at a concentration 10 times the SQS has an enrichment ratio of 10 times. Chemicals present below the SQS are assigned a value of zero, because the concentrations are below the no effects level for that compound. The enrichment ratios of individual compounds can then be compared on a risk-normalized basis to assess relative contributions of different contaminants to the overall impacts in a sample. The individual enrichment ratios can also be summed to produce an overall estimate of sample contamination, taking into account the additive effects of different compounds in the sediment sample. This cumulative enrichment ratio is plotted in Figure 5-13 using depth-weighted sediment concentrations.

By far, the highest average subsurface concentrations were noted in the ASB sludges. These materials are described in detail in Section 5.3.2 below. These materials contained elevated mercury, phenolic compounds, zinc, cadmium, and other contaminants.

In the outlying areas of the site, subsurface sediment concentrations were very low. These areas included the Outer portions of the Whatcom Waterway, areas offshore of the ASB, and in the I&J Waterway areas. As described in Section 7, subsurface testing of sediments in the Outer Whatcom Waterway has indicated that these sediments are likely suitable for beneficial reuse or PSDDA disposal.

Average sediment concentrations in the Whatcom Waterway are relatively low, with cumulative enrichment ratios averaging 10 times lower than those of the ASB sludges.

5.3.2 ASB Sludges, Berm Sands and Underlying Sands

Comprehensive sampling of the ASB sludges was completed in 2003, under an amendment to the RI Work Plan. That sampling event included core sampling of sludges and underlying sandy native sediments. This testing also included some testing of geotechnical properties of these materials. Additional testing was completed in 2004 and Amendment 5 to the RI Work Plan. That testing included physical and chemical testing of the ASB berm materials. Dewatering tests of the ASB sludges also performed as part of that sampling event are described separately in Section 7 of this report.

Appendix C contains the field information and detailed data summaries from the 2003 sampling event. Appendix D contains the detailed field information and data summaries from the 2004 sampling event.

ASB Sludge Composition

The ASB sludges consist of a soft, wet, high-organic sludge matrix, consistent with wastewater treatment biosolids mixed with settled pulp solids. The elevation of the base of the sludge layer was evaluated directly by probing to define the contact between the sludge materials and the underlying native sands at the base of the 1978 dredge prism. At that time the ASB basin had been dredged to a neat-line elevation of 12 feet below MLLW. Consistent with this target dredge elevation and associated overdredge allowances (typically 2-3 feet for historical production dredging), the base of the sludge bed was measured between 13 and 16 feet throughout the majority of the basin. Assuming an average sludge bed base elevation of 15 feet below MLLW, the volume of ASB sludges was estimated at approximately 378,000 cubic yards.

Table 5-3 summarizes the average composition of the ASB sludges. The average composition is compared to the results for subsurface waterway sediments in remaining remediation areas (excluding the I&J Waterway and the remediated Log Pond area), the materials underlying the ASB sludges, and the ASB berm sands. Results presented in Table 5-3 include the average measured concentration, as well as the average enrichment ratios for each compound.

The ASB sludges are characterized by a low solids content and a high organic carbon content. The average sludge dry weight measurements were 17 percent. Some gradations in solids content were observed, with deeper sludges generally higher in solids content than shallow layers, suggesting some consolidation of the sludge bed has occurred. Some gradations were also observed in the different ASB areas, consistent with differential settling of wastewater solid fractions. The TOC content of the ASB sludges averaged 33 percent, over six times greater than the average Waterway sediment composition. As with the solids content, some variation in the TOC content was observed.

The key constituents in the ASB sludges included mercury, 4-methylphenol, phenol, zinc, and cadmium. The mercury concentrations in the ASB sludges were greater than the average concentration in the Waterway sediments. The enrichment ratios for mercury averaged 14 times in the ASB sludges, compared to less than nine times for the Waterway sediments. Mercury concentrations ranged to a maximum value of 20.2 mg/kg in the ASB sludges. The 4-methylphenol concentrations averaged over 54,000 µg/kg, with an average enrichment ratio of over 80 times. The abundance of 4-methylphenol is consistent with the use of the basin for secondary treatment of wastewaters containing pulp solids, and the presence of anaerobic zones within the basin as part of dual aerobic/anaerobic treatment process. Phenol concentrations were lower, with an average enrichment ratio of approximately two times. The related compound 2,4-dimethyl phenol was present with an average enrichment ratio between three times and four times.

Other than mercury and phenolic compounds, the key constituents present in the ASB sludges included zinc and cadmium. These compounds had average enrichment ratios of 2.5 times and 4.5 times, respectively.

Other constituents present in the ASB sludges included two phthalate compounds and selected polyaromatic hydrocarbons (PAH) compounds. The phthalate compounds included bis(2-ethylhexyl)phthalate and butyl-benzyl-phthalate. These compounds were each present above the SQS in only two of 10 sludge samples. The PAH compounds detected above the SQS included acenaphthene, naphthalene and phenanthrene. Each compound was present above the SQS in only one of 10 sludge samples.

The 2003 sampling included testing for dioxin and furan compounds. Testing was performed on a single ASB sludge composite sample. The composite sample results are presented in Appendix C. The results of these analyses are expressed as the toxicity equivalent concentration (TEC) of 2,3,7,8-tetrachlorodibenzodioxin (TCDD) the compound with the greatest biological activity. The TEC concentration for the composite sludge sample was 0.230 µg/kg (230 ng/kg or parts per trillion). As described in Section 4.2, there currently is no SQS for dioxin compounds. For comparison, the measured concentration is greater than the PSDDA screening level for dioxins (15 ng/kg as TEC) and is intermediate between the MTCA upland direct-contact cleanup levels for dioxins (6.67 ng/kg for unrestricted land use, and 875 ng/kg for industrial land uses).

Composition of ASB Berm Sands

Table 5-3 also summarizes the average composition of the ASB berm sands and the sandy native sediments beneath the ASB sludges. As described in Section 3.1, the ASB berm is a composite structure constructed of stone, sand and other materials. The sand layer includes over 200,000 tons of imported quarry sands placed within the inner portions of the ASB berm structure in 1978 and 1979. Some contaminated sediments are remain beneath portions of the berm structure, but the dredging of the ASB basin in 1978 removed most contaminated materials from this area prior to ASB construction (Figures 3-6 and 3-8).

As shown in Table 5-3, the average concentrations in the ASB berm sands were all well below screening levels. Average berm sand mercury concentrations were well below the SQS of 0.41 mg/kg. The average concentrations of 4-methylphenol were also well below the SQS. Using a TOC-normalized basis, one compound (bis-2-ethylhexylphthalate or BEP) was detected slightly above the SQS in one of eight samples. However, this is mainly a result of the low TOC content of the berm sands. The measured dry weight concentration of BEP was below the corresponding lowest apparent effects threshold (LAET) which is used for evaluation of effects thresholds for low TOC sediments. Testing results confirm that the ASB berm sands have not been significantly affected by wastewater or sludge contaminants from the ASB operation.

Dioxin concentrations were tested in two berm composite samples. Results of testing are summarized in Appendix D. The measured concentrations (reported on a TEC concentration basis) are well below all applicable reference values (PSDDA screening level, MTCA upland soil Method B level for unrestricted land use).

Composition of Sandy Sediments Underlying ASB Sludges

The average composition of the sandy native sediments underlying the ASB sludges is shown in Table 5-3. As shown in Table 5-3, the average concentrations of the ASB sludge and Waterway sediment contaminants were below the screening levels. Results indicate that the contaminants of the ASB sludges have not significantly impacted the underlying sandy sediments, and that the ASB sludges transition rapidly to clean underlying sands.

The average mercury concentration in the underlying sand unit is approximately 0.1 mg/kg, well below the SQS of 0.41 mg/kg. The average concentration of 4-methylphenol is 177 µg/kg, well below the SQS of 670 µg/kg.

Some contaminated sediments are expected to be present at the former mud-line elevations beneath the outer portions of the ASB berm. These areas were not historically dredged at the time of ASB construction. If berm materials are removed as part of future remediation or redevelopment activities, these sediments will be tested to determine appropriate management options. These testing and material management costs are incorporated into the Feasibility Study.

Table 5-1. Observed Reduction in Mercury Concentrations Between RI/FS Sampling Events

Location ID	Sample ID	Sample Date	Mercury Concentration (mg/kg)	Reduction in Mercury Concentration (mg/kg)	Reduction in Mercury Concentration (%)	Compliance with Biological SQS and Site BSL*
Depositional Areas						
HC-SS-03	HC-SS-03	9/6/1996	0.32			
AN-SS-03	AN-SS-03	6/7/2002	0.20	0.12	38%	Yes
HC-SS-08	HC-SS-08	9/6/1996	0.53			
AN-SS-08	AN-SS-08	6/7/2002	0.42	0.11	21%	Yes
HC-SS-13	HC-SS-13	9/4/1996	1.00			
AN-SS-13	AN-SS-13	6/6/2002	0.99	0.01	1%	Yes
HC-SS-22	HC-SS-22	9/6/1996	0.93			
AN-SS-22	AN-SS-22	6/6/2002	0.30	0.63	68%	Yes
HC-SS-23	HC-SS-23	9/6/1996	2.00			
AN-SS-23	AN-SS-23	6/6/2002	1.09	0.91	46%	Yes
HC-SS-24	HC-SS-24	9/6/1996	1.90			
AN-SS-24	AN-SS-24	6/6/2002	1.10	0.80	42%	Yes
HC-SS-25	HC-SS-25	9/6/1996	1.00			
AN-SS-25	AN-SS-25	6/6/2002	0.80	0.20	20%	Yes
HC-SS-26	HC-SS-26	9/5/1996	0.38			
AN-SS-26	AN-SS-26	6/6/2002	0.26	0.12	32%	Yes
HC-SS-29	HC-SS-29	9/6/1996	0.70			
AN-SS-29	AN-SS-29	6/7/2002	0.50	0.20	29%	Yes
HC-SS-30	HC-SS-30	9/6/1996	0.49			
AN-SS-30	AN-SS-30	6/7/2002	0.40	0.09	18%	No/Yes**
HC-SS-31	HC-SS-31	9/9/1996	0.37			
AN-SS-31	AN-SS-31	6/7/2002	0.40	-0.03	-8%	Yes
HC-SS-33	HC-SS-33	9/9/1996	0.89			
AN-SS-33	AN-SS-33	6/7/2002	1.02	-0.13	-15%	Yes
HC-SS-34	HC-SS-34	9/9/1996	1.50			
AN-SS-34	AN-SS-34	6/7/2002	0.56	0.94	63%	Yes
HC-SS-35	HC-SS-35	9/3/1996	0.73			
AN-SS-35	AN-SS-35	6/7/2002	0.50	0.23	32%	Yes
HC-SC-80	HC-SC-80	9/9/1996	0.56			
AN-SS-80	AN-SS-80	6/7/2002	0.40	0.16	29%	Yes
HC-SC-81	HC-SC-81	9/9/1996	0.42			
AN-SS-81	AN-SS-81	6/7/2002	0.27	0.15	36%	Yes
AN-SS-303	AN-SS-303	10/26/98	2.90			
AN-SS-303	AN-SS-303	6/7/2002	0.82	2.08	72%	Yes
AN-SS-305	AN-SS-305	10/26/98	1.50			
AN-SS-305	AN-SS-305	6/7/2002	1.00	0.50	33%	Yes
				Average	31%	
				Median	32%	
Nearshore, High-Energy Areas						
HC-SS-32	HC-SS-32	9/5/1996	0.73			
AN-SS-32	AN-SS-32	6/6/2002	2.55	NA	NA	No

Notes:

*: Based on most recent sampling event.

**: Sample passed chemical SQS for mercury, but failed the amphipod bioassay.

Table 5-2 Concise Summary Site Bioassay Data

Bioassay Sample	Concentrations of Key Constituents (mg/kg) Mercury (SQS = 0.41)	Phenol (SQS = 0.42)	4-Methylphenol (SQS = 0.67)	2,4-Dimethylphenol (SQS = 0.029)	Other Contaminants Detected Above SQS	Amphipod *Eohaustorius estuaris*	Larval Bivalve *Mytilus sp. or Dendraster sp.*	Juvenile Polychaete *Neanthes sp.*	Overall SMS Interpretive Result
1996 Bioassays (see Appendix B)									
HC-SS-03	0.32	**0.9** E	**1.6** E	0.023 UE	none	Pass	Pass	**SQS**	**SQS**
HC-SS-06	0.39	**2.2** E	**1.9** E	0.024 UE	none	Pass	Pass	Pass	Pass
HC-SS-08	**0.53**	**1** E	**0.87** E	0.0023 E	none	Pass	**MCUL**	Pass	**MCUL**
HC-SS-13	**1**	na	na	na	none	Pass	Pass	**SQS**	**SQS**
HC-SS-14	**0.77**	na	na	na	none	Pass	Pass	Pass	Pass
HC-SS-15	**0.67**	na	na	na	none	Pass	Pass	Pass	Pass
HC-SS-17	**0.58**	na	na	na	none	Pass	Pass	Pass	Pass
HC-SS-19	**0.62**	na	na	na	none	Pass	Pass	Pass	Pass
HC-SS-21	**1.2**	na	na	na	none	Pass	Pass	Pass	Pass
HC-SS-22	**0.93**	na	na	na	none	Pass	Pass	**SQS**	**SQS**
HC-SS-23	**2**	na	na	na	none	Pass	Pass	**SQS**	**SQS**
HC-SS-24	**1.9**	na	na	na	none	Pass	Pass	Pass	Pass
HC-SS-25	**1**	na	na	na	none	Pass	**MCUL**	Pass	**MCUL**
HC-SS-26	0.38	na	na	na	none	Pass	**SQS**	Pass	**SQS**
HC-SS-29	**0.7**	**1** E	0.41 E	0.0063 E	none	Pass	**SQS**	Pass	**SQS**
HC-SS-30	**0.49**	**1.3** E	**0.68** E	0.0021 E	none	Pass	**MCUL**	Pass	**MCUL**
HC-SS-31	0.37	na	na	na	none	Pass	**MCUL**	Pass	**MCUL**
HC-SS-32	**0.73**	na	na	na	none	Pass	**SQS**	Pass	**SQS**
HC-SS-33	**0.89**	0.27	0.2	0.0023 E	none	Pass	**SQS**	Pass	**SQS**
HC-SS-34	**1.5**	0.23	**0.87**	0.0042 E	Hexachlorobenzene	Pass	**MCUL**	Pass	**MCUL**
HC-SS-35	**0.73**	**1.5**	0.34	0.023 U	none	Pass	**MCUL**	Pass	**MCUL**
HC-SS-41	0.13 U	na	na	na	none	Pass	Pass	Pass	Pass
1998 Bioassays (see Appendix B)						Pass	Pass	Pass	Pass
AN-SS-36	**0.61**	0.036	0.3	0.019 U	none	Pass	Pass	Pass	Pass
AN-SS-37	**0.5**	0.019 U	0.2	0.019 U	none	Pass	Pass	Pass	Pass
AN-SC-70	**0.85**	0.019 U	0.24	0.019 U	none	Pass	Pass	Pass	Pass
AN-SC-71	**1.2**	0.02 U	0.29	0.02 U	none	Pass	Pass	Pass	Pass
AN-SC-72	**0.9**	0.02 U	0.24	0.02 U	none	Pass	Pass	Pass	Pass
AN-SC-73	**0.81**	0.02 U	0.17	0.02 U	none	Pass	Pass	Pass	Pass
AN-SC-77	**1.2**	0.02 U	0.14	0.02 U	none	Pass	Pass	Pass	Pass
AN-SC-78	**1**	0.02 U	0.16	0.02 U	none	Pass	Pass	Pass	Pass
AN-SC-80	**0.71**	0.039 U	0.14	0.039 U	none	Pass	**SQS**	Pass	**SQS**
AN-SC-81	**0.62**	0.02 U	0.089	0.02 U	none	Pass	**SQS**	Pass	**SQS**
AN-SC-82	**0.52**	0.02 U	0.084	0.02 U	none	Pass	Pass	Pass	Pass
AN-SC-84	**0.45**	0.034	0.062	0.02 U	none	Pass	Pass	Pass	Pass
AN-SS-301	**1**	0.04 U	0.086	0.04 U	none	Pass	Pass	Pass	Pass
AN-SS-302	**0.45**	0.024 G	0.19	0.02 U	none	Pass	Pass	Pass	Pass
AN-SS-303	**2.9**	0.033 G	0.07	0.02 U	none	Pass	Pass	Pass	Pass
AN-SS-304	0.062	0.036 G	0.12	0.019 U	none	Pass	Pass	Pass	Pass
AN-SS-305	**1.5**	0.052 G	0.19	0.022 U	none	Pass	Pass	Pass	Pass
AN-SS-306	**0.74**	0.058 G	0.036	0.019 U	none	Pass	Pass	Pass	Pass

Table 5-2 Concise Summary Site Bioassay Data

Bioassay Sample	Concentrations of Key Constituents (mg/kg) Mercury (SQS = 0.41)	Phenol (SQS = 0.42)	4-Methylphenol (SQS = 0.67)	2,4-Dimethylphenol (SQS = 0.029)	Other Contaminants Detected Above SQS	Amphipod *Eohaustorius estuaris*	Larval Bivalve *Mytilus sp. or Dendraster sp.*	Juvenile Polychaete *Neanthes sp.*	Overall SMS Interpretive Result
1998 Subsurface Bioassays (see Appendix H)									
HC-VC-94-C1	**1.3**	0.034 B	0.13	0.014 E	none	Pass	Pass	Pass	Pass
HC-VC-94-C2	**1.8**	0.023 B	0.078	0.0084 E	none	Pass	Pass	Pass	Pass
HC-VC-95-C1	**0.68**	0.16 B	0.46	0.19 E	2-Methylphenol	Pass	Pass	Pass	Pass
HC-VC-95-C2	0.15	0.063 B	0.26	0.12 E	2-Methylphenol	Pass	Pass	Pass	Pass
HC-VC-96-C1	**2.7**	0.21 B	**4.6**	0.008 E	Hexachlorobenzene	Pass	**MCUL**	**MCUL**	**MCUL**
HC-VC-96-C2	**4.3**	0.23 B	**12**	0.046	Cadmium	Pass	**MCUL**	**MCUL**	**MCUL**
HC-VC-97-C1	**1.8**	0.19 B	**3.9**	0.0088 E	none	Pass	Pass	Pass	Pass
HC-VC-96-C2	**2.5**	0.29 B	**7.6**	0.019 E	none	**MCUL**	**MCUL**	**MCUL**	**MCUL**
2002 Bioassays (see Appendix A)									
AN-SS-03	0.2	0.1 U	0.29	0.04 U	none	Pass	Pass	Pass	Pass
AN-SS-08	**0.42**	0.099 U	0.07	0.04 U	none	Pass	Pass	Pass	Pass
AN-SS-13	**0.99**	0.1 U	0.045	**0.046**	none	Pass	Pass	Pass	Pass
AN-SS-22	0.3	0.1 U	0.069	0.04 U	none	Pass	Pass	Pass	Pass
AN-SS-23	**1.09**	0.1 U	0.036	**0.053**	none	Pass	Pass	Pass	Pass
AN-SS-25	**0.8**	0.099 U	0.055	**0.075**	none	Pass	Pass	Pass	Pass
AN-SS-26	0.26	0.098 U	0.022	0.039 U	none	Pass	Pass	Pass	Pass
AN-SS-29	**0.5**	0.13	0.11	0.04 U	none	Pass	Pass	Pass	Pass
AN-SS-30	0.4	0.099 U	0.093	**0.05**	none	**MCUL**	Pass	Pass	**MCUL**
AN-SS-31	0.4	0.1 U	0.048	0.04 U	none	Pass	Pass	Pass	Pass
AN-SS-32	**2.55**	0.099 U	0.046	0.039 U	none	Pass	Pass	Pass	Pass
AN-SS-33	**1.02**	0.099 U	0.083	0.04 U	none	Pass	Pass	Pass	Pass
AN-SS-34	**0.56**	0.1 U	0.092	**0.087**	none	Pass	Pass	Pass	Pass
AN-SS-35	**0.5**	0.12 U	0.14	0.04 U	none	Pass	Pass	Pass	Pass
AN-SS-80	0.4	0.1 U	0.13	0.04 U	none	Pass	Pass	Pass	Pass
AN-SS-81	0.27	0.099 U	0.31	**0.042**	none	Pass	Pass	Pass	Pass
AN-SS-305	**0.82**	0.099 U	0.086	0.039 U	none	Pass	Pass	Pass	Pass
AN-SS-306	**1**	0.1 U	0.077	**0.077**	none	Pass	Pass	Pass	Pass
Year-5 Log Pond Monitoring									
SC-76	**0.58**	0.059 U	0.059 U	0.059 U	none	Pass	Pass	Pass	Pass

Notes:

This table excludes bioassay testing performed for the I&J Waterway site and in the nearshore area adjacent to the Colony Wharf site. Bioassay failures in these areas are attributable to localized sources.

Bolded and underlined results indicate a detected contaminant concentration in excess of the numeric SQS.

na: Sample not analyzed for indicated parameter.

Table 5-3. Average Properties of Site Subsurface Sediments and ASB Materials

Parameter	Units	SQS	Remaining Waterway Site Sediments [1]		ASB Sludges		Native Sands Underlying ASB Sludges [2]		ASB Berm Sands	
			Avg Conc.	Enrichment Ratio	Avg Conc.	Enrichment Ratio	Avg Conc.	Enrichment Ratio	Avg Conc.	Enrichment Ratio
CUMULATIVE ENRICHMENT RATIO			--	**12**	--	**120**	--	**< 1**	--	**< 1**
Conventional Parameters										
Total Solids	%	--	48	--	17.4	--	82.9	--	96.0	--
Total Organic Carbon	%	--	4.3	--	33.2	--	0.51	--	0.15	--
Heavy Metals										
Mercury	mg/kg dwt	0.41	3.5	**8.6**	5.7	**14**	0.1	< 1	0.05	< 1
Cadmium	mg/kg dwt	5.1	1.7	< 1	12.6	**2.5**	0.4	< 1	0.2	< 1
Zinc	mg/kg dwt	410	161	< 1	1840	**4.5**	29.7	< 1	33.2	< 1
Phenolic Compounds										
4-Methylphenol	ug/kg dwt	670	1,995	**3.0**	54373	**81**	177	< 1	19 U	< 1
Phenol	ug/kg dwt	420	92	< 1	866	**2.1**	8.9	< 1	19 U	< 1
2-4-Dimethylphenol	ug/kg dwt	29	15	< 1	102	**3.5**	9.3	< 1	19 U	< 1
PAH Compounds										
Naphthalene	ppm TOC	99	12	< 1	28	< 1	13	< 1	15 U	< 1
Fluorene	ppm TOC	23	9.4	< 1	1.0	< 1	1.5 U	< 1	15 U	< 1
Acenaphthene	ppm TOC	16	7.4	< 1	1.4	< 1	1.2 U	< 1	15 U	< 1
Phenanthrene	ppm TOC	100	54	< 1	18	< 1	11.6	< 1	15 U	< 1
Fluoranthene	ppm TOC	160	81	< 1	17	< 1	11.8 U	< 1	15 U	< 1
Chrysene	ppm TOC	110	39	< 1	1.9	< 1	1.8	< 1	15 U	< 1
Pyrene	ppm TOC	1000	82	< 1	17	< 1	10.3	< 1	15 U	< 1
Benzo(a)anthracene	ppm TOC	110	27	< 1	1.0	< 1	1.4 U	< 1	15 U	< 1
Benzo(b&k)fluoranthenes	ppm TOC	230	34	< 1	6.5	< 1	3.4 U	< 1	30 U	< 1
Dibenz(a,h)anthracene	ppm TOC	12	4.4	< 1	0.70	< 1	1.3 U	< 1	15 U	< 1
Other Semivolatile Organics										
Bis(2-ethylhexyl)phthalate	ppm TOC	47	10	< 1	83	**1.8**	36	< 1	27.6	< 1
Butyl-benzyl-phthalate	ppm TOC	4.9	2.2	< 1	51	**10.4**	10.3 U	< 1	19 U	< 1
Hexachlorobenzene	ppm TOC	0.38	0.3	< 1	< 0.01	< 1	0.2	< 1	15 U	< 1
Dibenzofuran	ppm TOC	15	8.2	< 1	nt	nc	nt	nc	15 U	< 1

Notes:

U: Compound not detected in any samples. Posted result is the average reporting limit of analyzed samples.
--: No applicable value
nc: Not calculated
nt: Not tested
Refer to Appendix G for detailed enrichment ratio calculations
1. Excludes previously remediated portions of the Log Pond.
2. Excludes ASB sludges and the sludge/sediment contact layer samples. Generally consists of sandy sediments below -16 ft MLLW elevation in ASB area.

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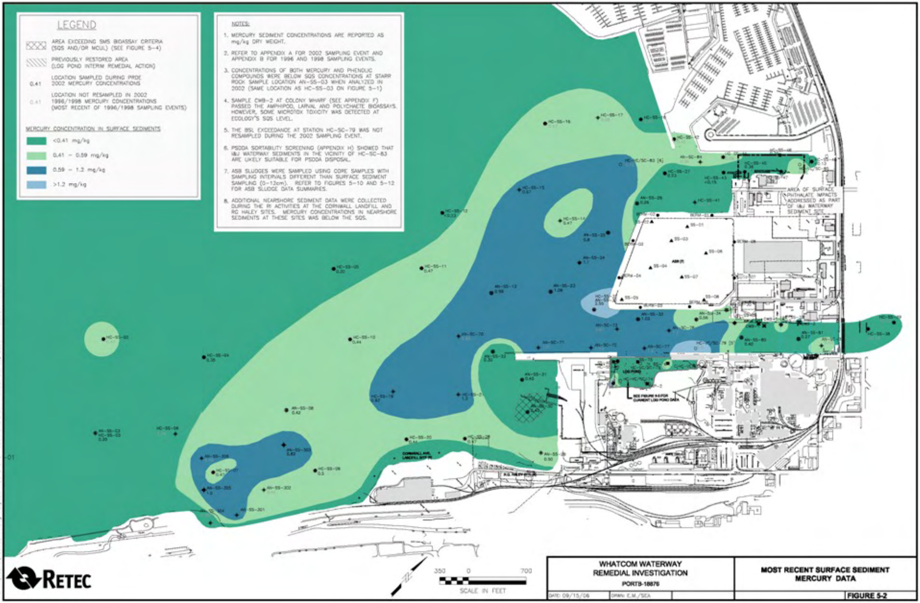
WHATCOM WATERWAY
REMEDIAL INVESTIGATION
PORTB-18876

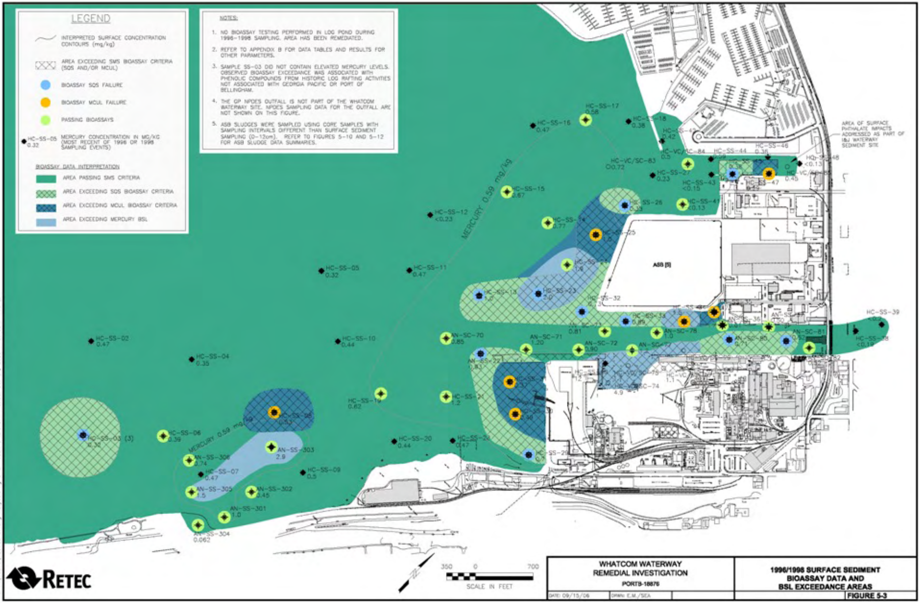
DATE: 09/15/06 | DRWN: E.M./SEA

1996/1998 SURFACE SEDIMENT
CHEMICAL DATA
MERCURY CONCENTRATIONS

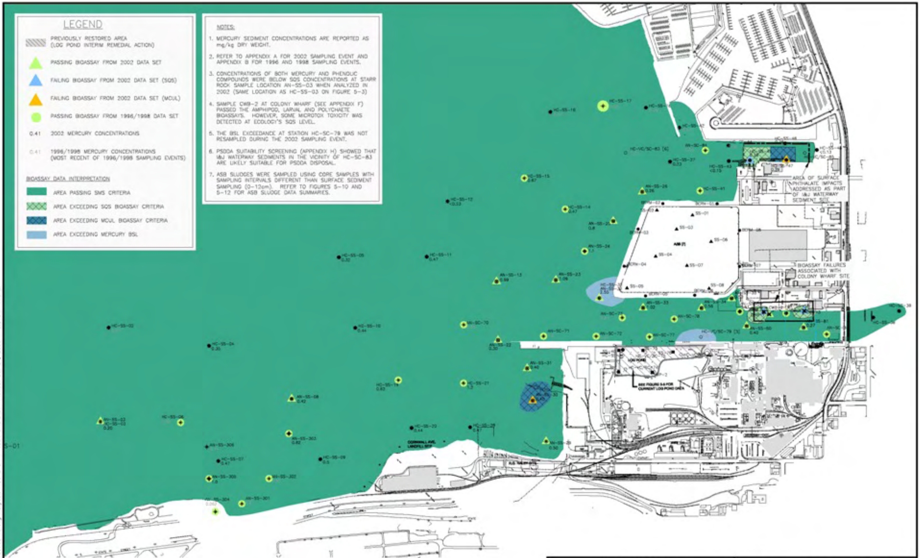
FIGURE 5-1



File: H:\18876\18876S141.dwg Layout: FIGURE 5-2 User: emarshall Plotted: Oct 03, 2006 - 10:35am Xref's:



LEGEND
INTERPRETED SURFACE CONCENTRATION CONTOURS (mg/kg)
AREA EXCEEDING SMS BIOASSAY CRITERIA (SQS AND/OR MCUL)
BIOASSAY SQS FAILURE
BIOASSAY MCUL FAILURE
PASSING BIOASSAYS
HC-SS-05 0.32 MERCURY CONCENTRATION IN MG/KG (MOST RECENT OF 1996 OR 1998 SAMPLING EVENTS)
BIOASSAY DATA INTERPRETATION
AREA PASSING SMS CRITERIA
AREA EXCEEDING SQS BIOASSAY CRITERIA
AREA EXCEEDING MCUL BIOASSAY CRITERIA
AREA EXCEEDING MERCURY BSL
NOTES:
1. NO BIOASSAY TESTING PERFORMED IN LOG POND DURING 1996-1998 SAMPLING. AREA HAS BEEN REMEDIATED.
2. REFER TO APPENDIX B FOR DATA TABLES AND RESULTS FOR OTHER PARAMETERS.
3. SAMPLE SS-03 DID NOT CONTAIN ELEVATED MERCURY LEVELS. OBSERVED BIOASSAY EXCEEDANCE WAS ASSOCIATED WITH PHENOLIC COMPOUNDS FROM HISTORIC LOG RAFTING ACTIVITIES NOT ASSOCIATED WITH GEORGIA PACIFIC OR PORT OF BELLINGHAM.
4. THE GP NPDES OUTFALL IS NOT PART OF THE WHATCOM WATERWAY SITE. NPDES SAMPLING DATA FOR THE OUTFALL ARE NOT SHOWN ON THIS FIGURE.
5. ASB SLUDGES WERE SAMPLED USING CORE SAMPLES WITH SAMPLING INTERVALS DIFFERENT THAN SURFACE SEDIMENT SAMPLING (0-12cm). REFER TO FIGURES 5-10 AND 5-12 FOR ASB SLUDGE DATA SUMMARIES.
MERCURY 0.59 mg/kg
ASB [5]
AREA OF SURFACE PHTHALATE IMPACTS ADDRESSED AS PART OF I&J WATERWAY SEDIMENT SITE
350 0 700
SCALE IN FEET
RETEC
WHATCOM WATERWAY
REMEDIAL INVESTIGATION
PORTB-18876
DATE: 09/15/06
DRWN: E.M./SEA
1996/1998 SURFACE SEDIMENT
BIOASSAY DATA AND
BSL EXCEEDANCE AREAS
FIGURE 5-3

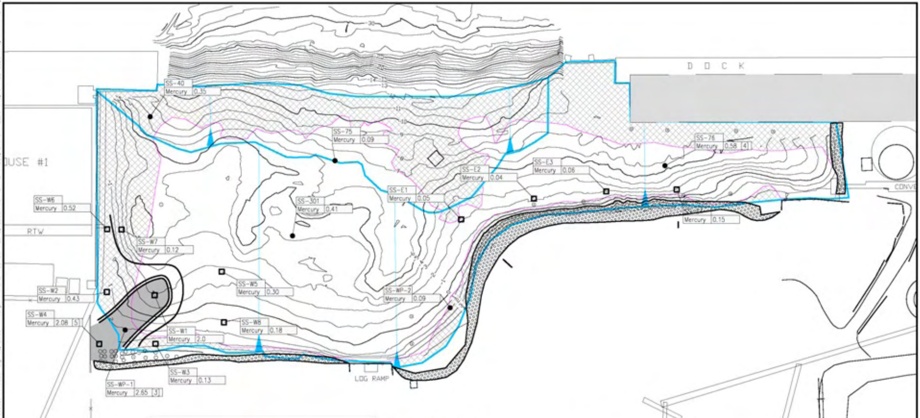


WHATCOM WATERWAY
REMEDIAL INVESTIGATION
PORTB-18876

DATE: 09/15/06 | DRWN: E.M./SEA

MOST RECENT SURFACE SEDIMENT BIOASSAY DATA AND BSL EXCEEDANCE AREAS

FIGURE 5-4



LEGEND

- APPROXIMATE AREAS OF ARMORED SLOPES
- MERCURY > BSL (1.2 mg/kg)
- PHASE I AND II CAP LIMITS FROM ENGINEERING DESIGN REPORT (ANCHOR 2000)
- THIN LAYER CAPPING AREA (0.5' TO 3') FROM ENGINEERING DESIGN REPORT (ANCHOR 2000)
- OCTOBER 2005 MUD-LINE ELEVATION (FT.MLLW)
- YEAR 5 SURFACE SAMPLE LOCATION
- SUPPLEMENTAL SAMPLING LOCATION

REFERENCE VALUES

SMS	SQS	CSL	BSL
Mercury-mg/kg	0.41	0.59	1.2

40 0 80
SCALE IN FEET

NOTES:

1. MERCURY SEDIMENT CONCENTRATIONS ARE REPORTED AS mg/kg DRY WEIGHT.
2. BATHYMETRY SHOWN FROM OCTOBER 12, 2005 SURVEY. (FT. MLLW)
3. MEAN RESULTS OF DUPLICATE ANALYSES, INDIVIDUAL SAMPLE RESULTS WERE 2.7 AND 2.6 mg/kg.
4. MEAN RESULTS OF DUPLICATE ANALYSES, INDIVIDUAL SAMPLE RESULTS WERE 0.55 AND 0.60 mg/kg. SAMPLE HAS PASSED CONFIRMATIONAL BIOASSAYS.
5. MEAN RESULTS OF DUPLICATE ANALYSES, INDIVIDUAL SAMPLE RESULTS WERE 2.7 AND 1.45 mg/kg.

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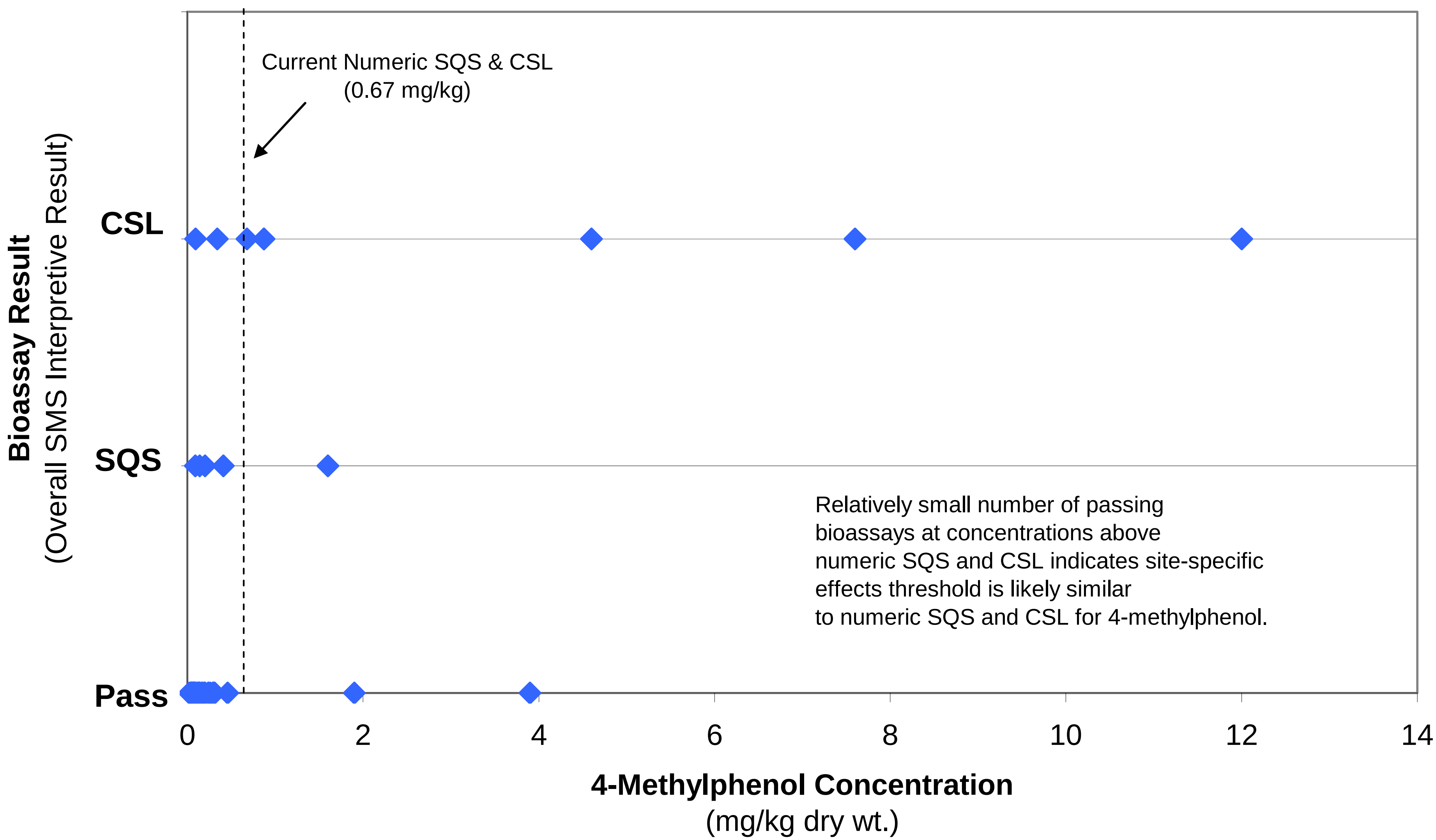
WHATCOM WATERWAY
REMEDIAL INVESTIGATION
PORTB-18876-260

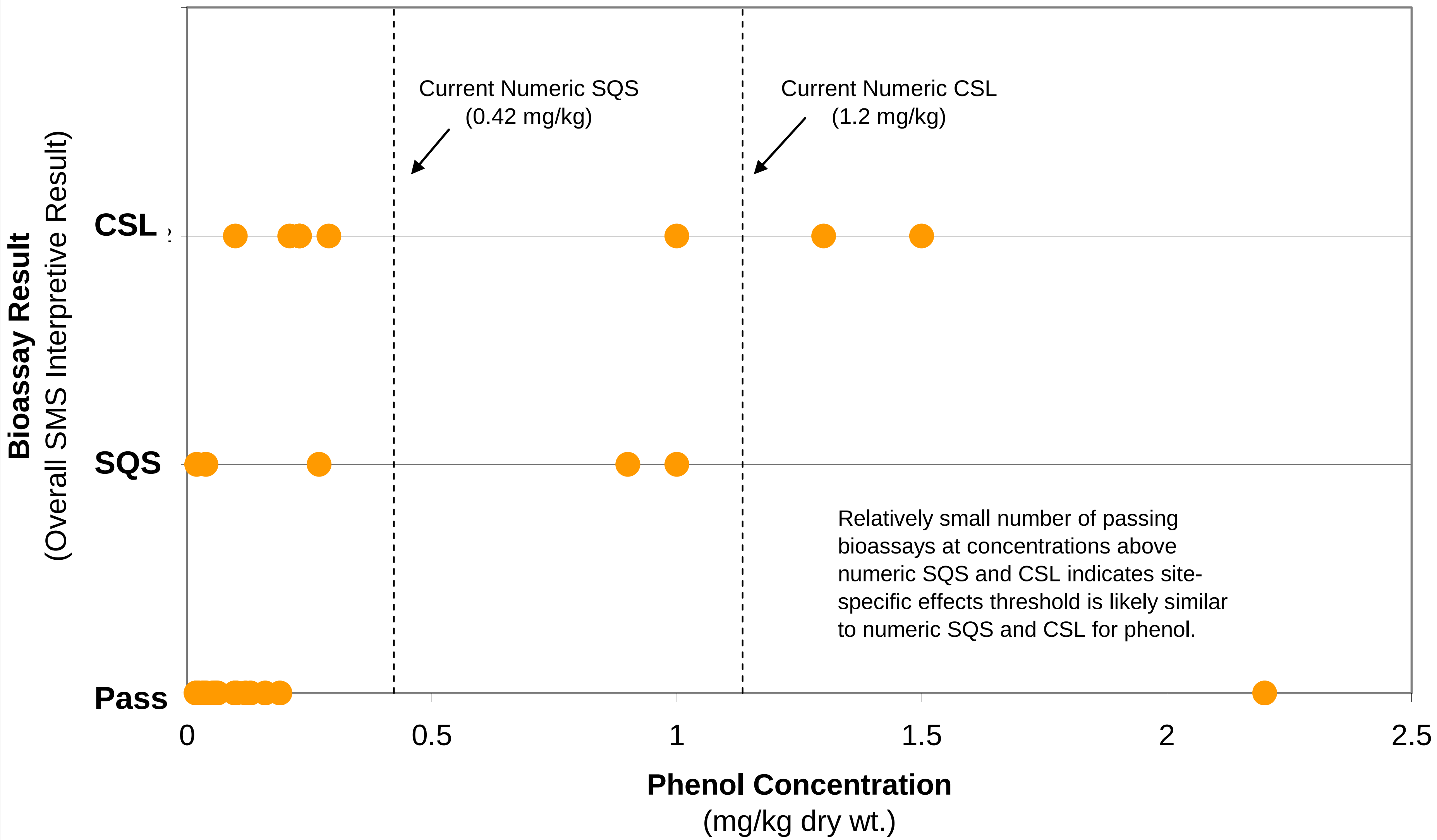
DATE: 09/15/06 DRWN: E.M./SEA

MOST RECENT SURFACE MERCURY DATA FOR LOG POND

FIGURE 5-5



PORT OF BELLINGHAM WHATCOM WATERWAY		CORRELATION OF BIOASSAY RESULTS AND 4-METHYLPHENOL CONCENTRATIONS
Date: 8/2006	File: 8876 RIFS	FIGURE 5-6



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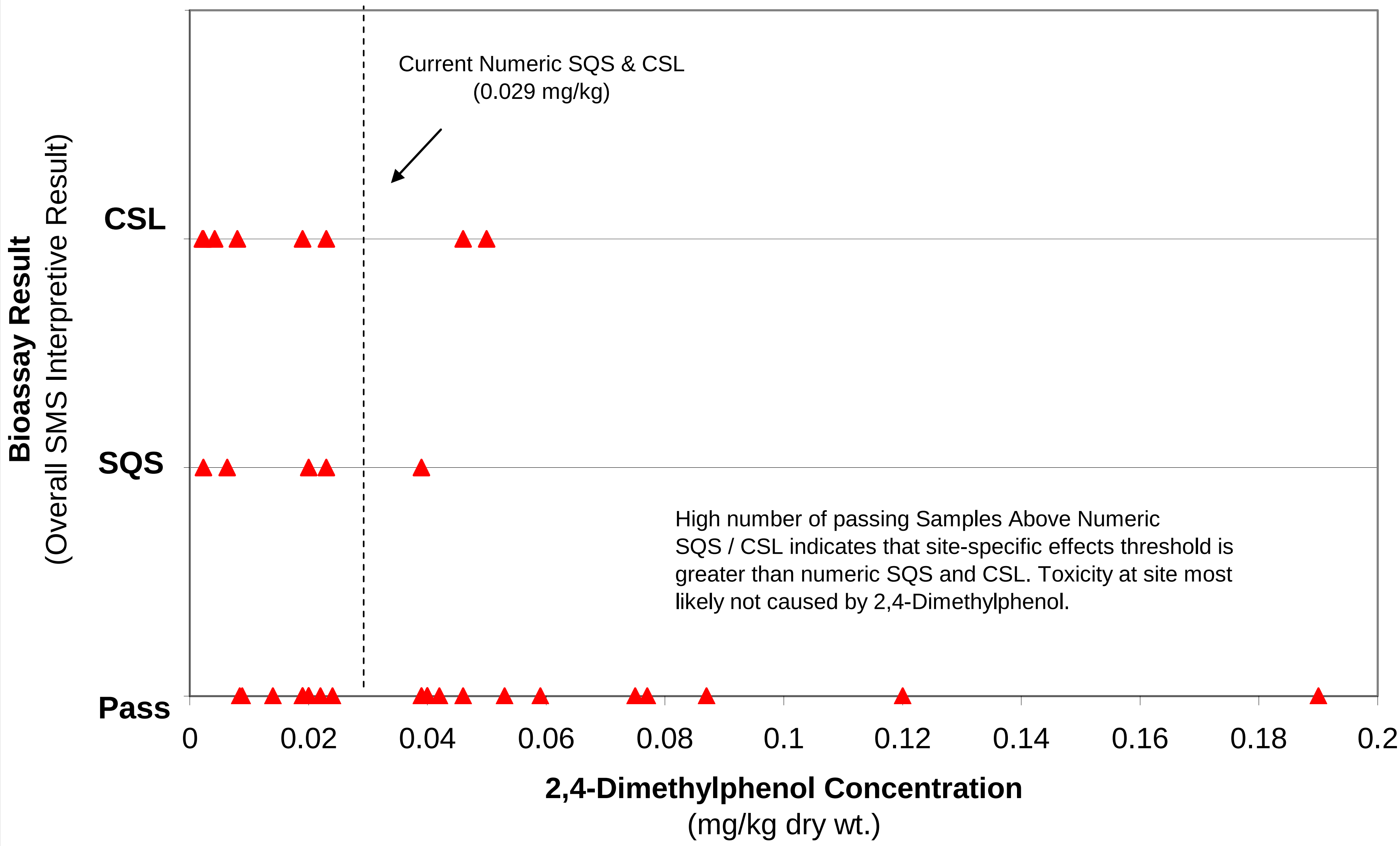
PORT OF BELLINGHAM
WHATCOM WATERWAY

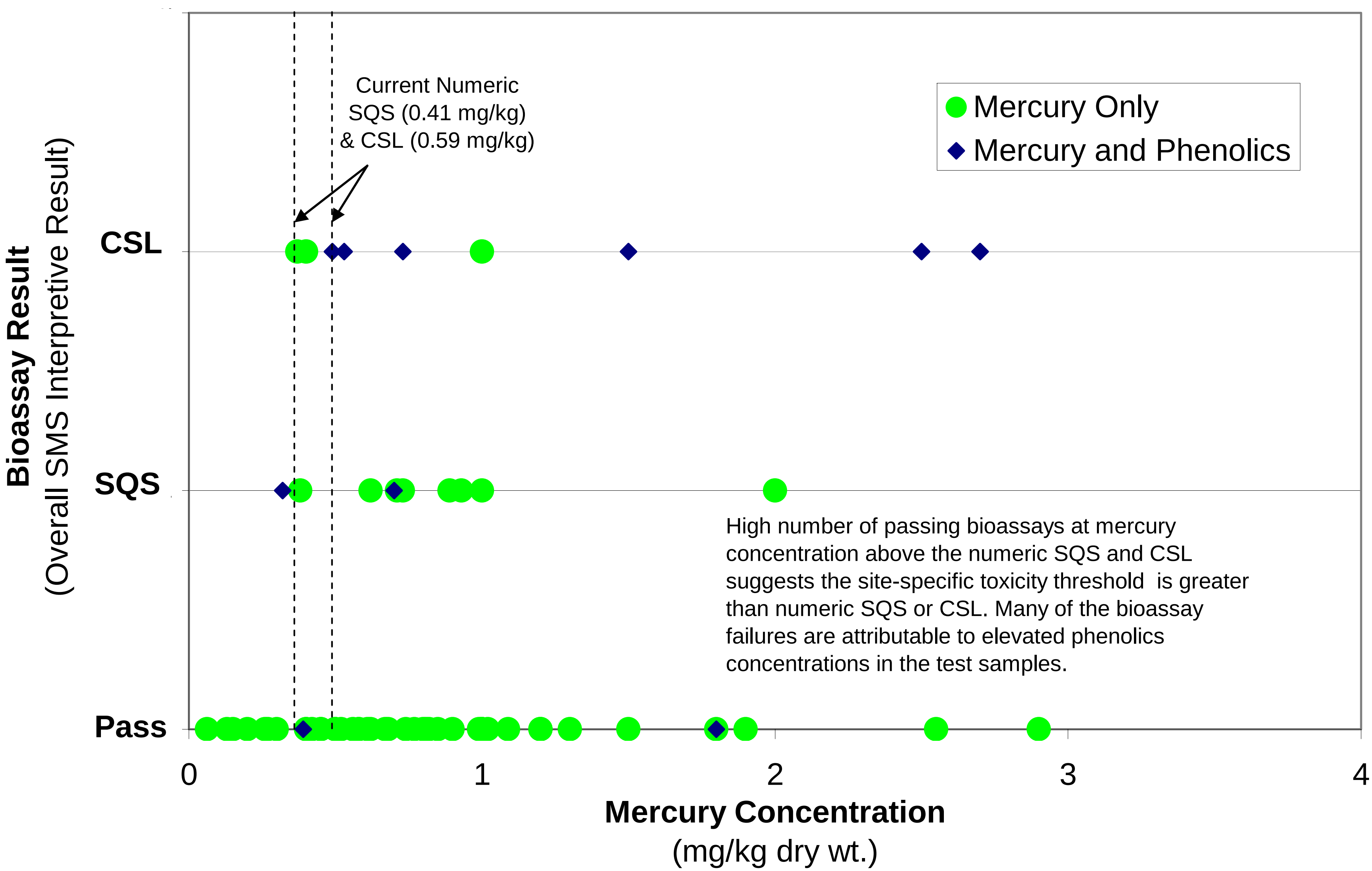
CORRELATION OF BIOASSAY RESULTS AND PHENOL CONCENTRATIONS

Date: 8/2006 | File: 8876 RIFS

FIGURE 5-7

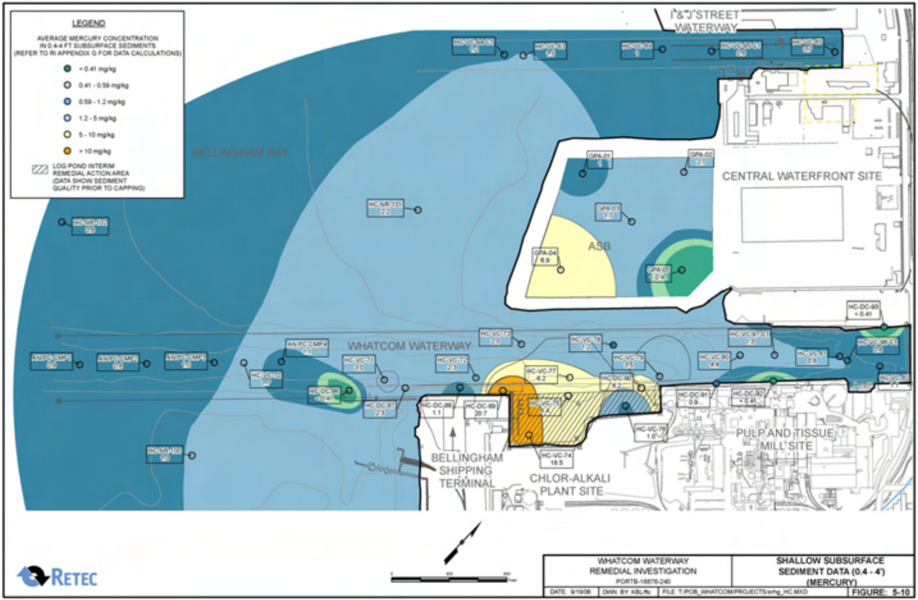


PORT OF BELLINGHAM WHATCOM WATERWAY		CORRELATION OF BIOASSAY RESULTS AND 2,4-DIMETHYLPHENOL CONCENTRATIONS
Date: 8/2006	File: 8876 RIFS	FIGURE 5-8

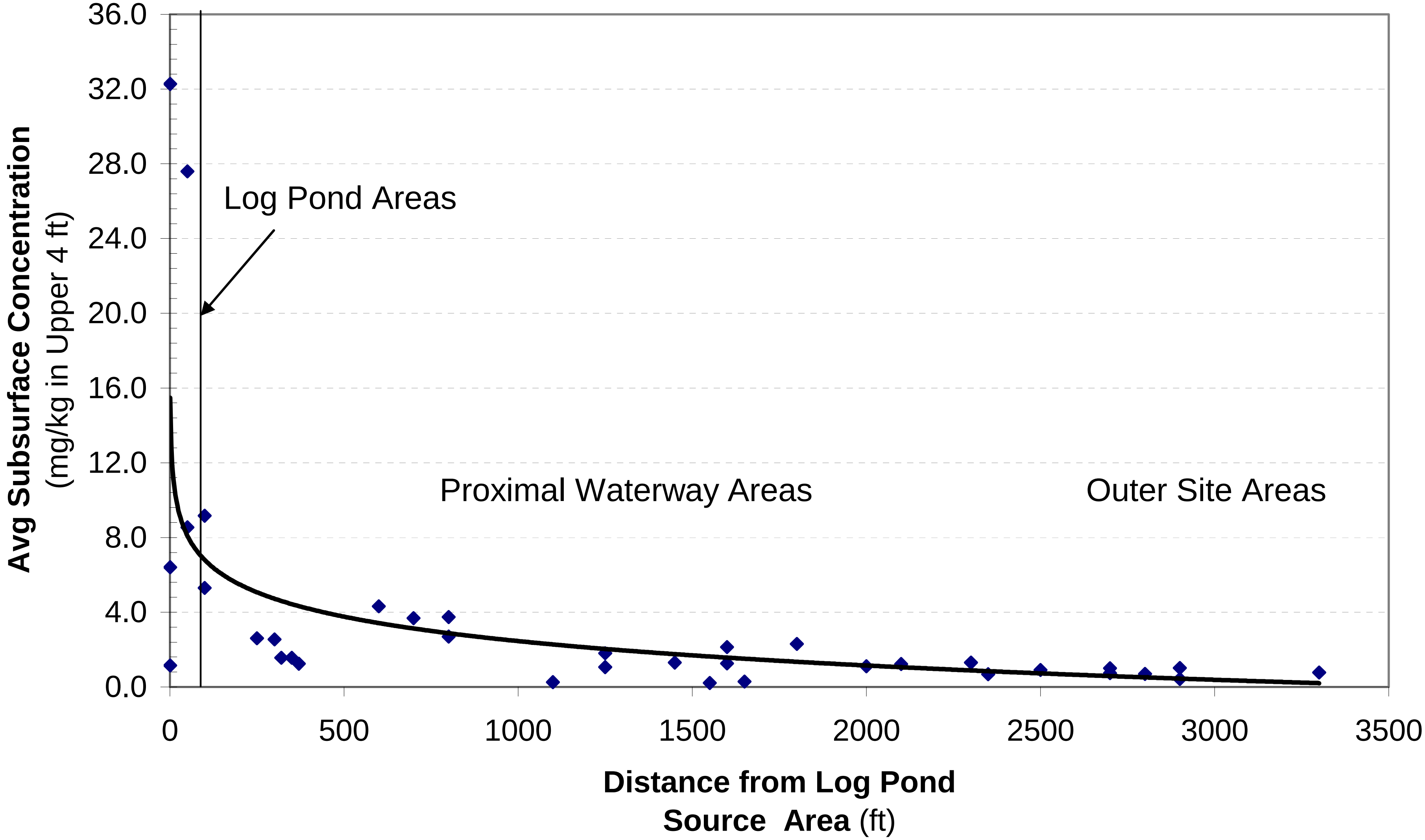


RETEC

PORT OF BELLINGHAM WHATCOM WATERWAY		CORRELATION OF BIOASSAY RESULTS AND MERCURY CONCENTRATIONS
Date: 8/2006	File: 8876 RIFS	FIGURE 5-9

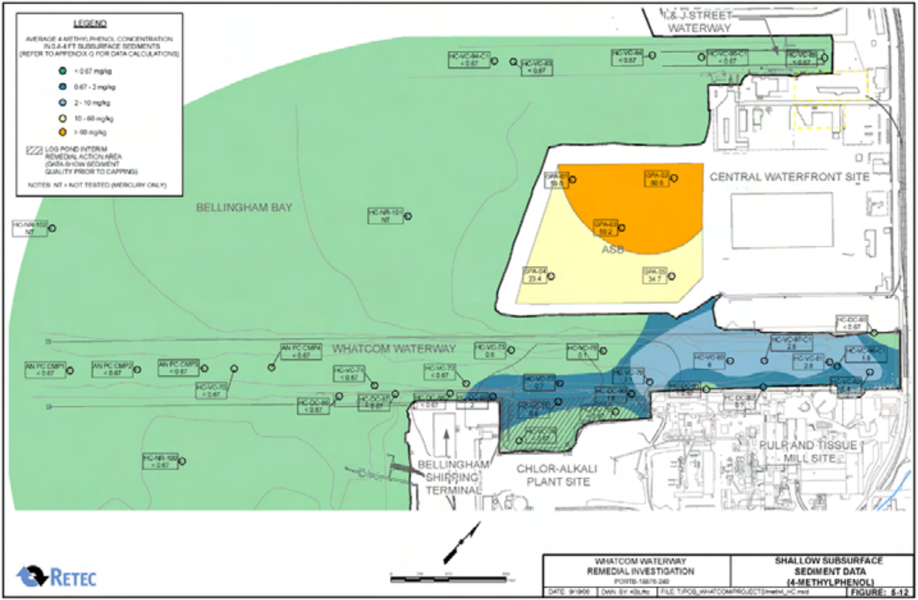


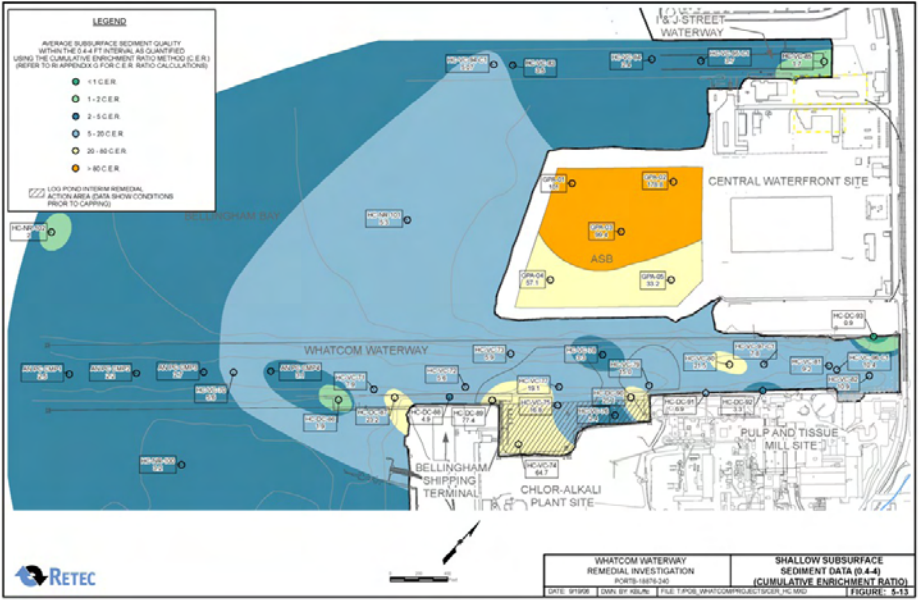
LEGEND
AVERAGE MERCURY CONCENTRATION
IN 0.4-4 FT SUBSURFACE SEDIMENTS
(REFER TO RI APPENDIX G FOR DATA CALCULATIONS)
< 0.41 mg/kg
0.41 - 0.59 mg/kg
0.59 - 1.2 mg/kg
1.2 - 5 mg/kg
5 - 10 mg/kg
> 10 mg/kg
LOG POND INTERIM REMEDIAL ACTION AREA (DATA SHOW SEDIMENT QUALITY PRIOR TO CAPPING)
"I"&"J" STREET WATERWAY
BELLINGHAM BAY
CENTRAL WATERFRONT SITE
ASB
WHATCOM WATERWAY
BELLINGHAM SHIPPING TERMINAL
CHLOR-ALKALI PLANT SITE
PULP AND TISSUE MILL SITE
GPA-01 1
GPA-02 2.7
GPA-03 1.7
GPA-04 6.9
GPA-05 < 0.41
HC-NR-101 2.2
HC-VC-73 2.0
HC-VC-71 3.0
HC-VC-72 2.3
HC-VC-77 6.2
HC-VC-79 3.5
HC-VC-80 4.4
HC-DC-87 2.3
HC-DC-88 1.1
HC-DC-89 20.7
HC-VC-74 18.5
HC-VC-76 1.0
HC-DC-91 0.9
HC-DC-92 < 0.41
HC-DC-93 < 0.41
WHATCOM WATERWAY
REMEDIAL INVESTIGATION
PORTB-18876-240
SHALLOW SUBSURFACE
SEDIMENT DATA (0.4 - 4')
(MERCURY)
DATE: 9/19/06
DWN. BY: KBL/ftc
FILE: T:/POB_WHATCOM/PROJECTS/erhg_HC.MXD
FIGURE: 5-10
RETEC



RETEC

PORT OF BELLINGHAM WHATCOM WATERWAY	DECREASE IN SUBSURFACE MERCURY CONCENTRATIONS WITH DISTANCE FROM LOG POND SOURCE AREA
Date: 8/2006 File: 8876 RIFS	FIGURE 5-11


LEGEND
AVERAGE 4-METHYLPHENOL CONCENTRATION IN 0.4-4 FT SUBSURFACE SEDIMENTS (REFER TO APPENDIX G FOR DATA CALCULATIONS)
< 0.67 mg/kg
0.67 - 2 mg/kg
2 - 10 mg/kg
10 - 60 mg/kg
> 60 mg/kg
LOG POND INTERIM REMEDIAL ACTION AREA (DATA SHOW SEDIMENT QUALITY PRIOR TO CAPPING)
NOTES: NT = NOT TESTED (MERCURY ONLY)
I & J STREET WATERWAY
BELLINGHAM BAY
CENTRAL WATERFRONT SITE
ASB
WHATCOM WATERWAY
BELLINGHAM SHIPPING TERMINAL
CHLOR-ALKALI PLANT SITE
PULP AND TISSUE MILL SITE
RETEC
WHATCOM WATERWAY
REMEDIAL INVESTIGATION
SHALLOW SUBSURFACE SEDIMENT DATA (4-METHYLPHENOL)
FIGURE: 5-12



LEGEND
AVERAGE SUBSURFACE SEDIMENT QUALITY
WITHIN THE 0.4-4 FT INTERVAL AS QUANTIFIED
USING THE CUMULATIVE ENRICHMENT RATIO METHOD (C.E.R.)
(REFER TO RI APPENDIX G FOR C.E.R. RATIO CALCULATIONS)
<1 C.E.R.
1 - 2 C.E.R.
2 - 5 C.E.R.
5 - 20 C.E.R.
20 - 80 C.E.R.
> 80 C.E.R.
LOG POND INTERIM REMEDIAL ACTION AREA (DATA SHOW CONDITIONS PRIOR TO CAPPING)
I & J STREET WATERWAY
CENTRAL WATERFRONT SITE
ASB
GPA-04
57.1
GPA-05
33.2
BELLINGHAM BAY
WHATCOM WATERWAY
HC-DC-93
0.9
HC-DC-88
4.9
HC-DC-89
77.4
HC-VC-74
64.7
BELLINGHAM SHIPPING TERMINAL
CHLOR-ALKALI PLANT SITE
PULP AND TISSUE MILL SITE
RETEC
WHATCOM WATERWAY
REMEDIAL INVESTIGATION
SHALLOW SUBSURFACE
SEDIMENT DATA (0.4-4)
(CUMULATIVE ENRICHMENT RATIO)
FIGURE: 5-13

6 Contaminant Fate and Transport

This section summarizes processes that may affect concentrations of sediment contaminants. The status of source control efforts within Bellingham Bay is discussed. Also discussed are the processes that may improve site sediment quality (e.g., sediment natural recovery) and those processes that can degrade sediment quality or trigger sediment recontamination. The contaminant fate and transport topics covered in this section include the following:

- Sediment Source Control Activities (Section 6.1)
- Natural Recovery Processes (Section 6.2)
- Other Factors Affecting Sediment Stability (Section 6.3).

6.1 Source Control Activities

Identification and control of sources of sediment contamination is a key objective of the SMS regulations. The RI/FS and Bellingham Bay Pilot activities have included significant source control evaluations and corrective actions. One of the drivers for implementation of the Log Pond Interim Remedial Action was to control secondary releases from this area to the other portions of the Site.

Site source control data have not identified any ongoing, significant sources of mercury, 4-methylphenol, phenol, or wood waste material to the Whatcom Waterway Site area. A summary of the source control information is provided below.

6.1.1 Control of Historical Contaminant Sources

The primary sources of sediment contamination within the Whatcom Waterway Site are historical in nature. These historical sources have been controlled through changes in practices and through pollution control improvements.

- **Chlor-Alkali Plant Wastewaters:** Wastewater discharges from the GP Chlor-Alkali Plant operations were the primary source of elevated mercury concentrations within the Whatcom Waterway Site sediments. As described in Section 2.2.1, the main period of mercury release was between 1965 and 1971 when mercury-containing wastewaters from the Chlor-Alkali Plant were discharged directly into the Log Pond. Between 1971 and 1979 pretreatment measures were installed to reduce mercury discharges. Chlor-alkali plant wastewater discharges to the Log Pond area were discontinued in 1979 after the ASB facility was constructed and put into operation. The Chlor-Alkali Plant operations were terminated in 1999 and the plant was subsequently demolished. Demolition of the Chlor-Alkali Plant terminated this source of mercury-containing wastewaters.

- **GP Mill Wastewater:** Since 1979 the wastewater and stormwater from the GP mill site have been discharged via the GP ASB secondary treatment system and associated outfall, consistent with operating requirements of the facility NPDES permit. Pollution controls and corrective actions implemented under the NPDES program dramatically reduced organic loadings to the Whatcom Waterway area, reducing sources of phenolic compounds to site sediments. Wastewater loadings to the GP wastewater system have also decreased dramatically due to the closure of the pulp mill, the chemical plant, and the Chlor-Alkali Plant. The combined wastewater and cooling-water flows from the remaining tissue mill operations and from the adjacent Encogen co-generation plant average less than 20 percent of the previous daily flows. The organic and inorganic composition of the wastewater stream has also improved significantly. Sediment monitoring, wastewater monitoring and source control analyses have been performed as part of the NPDES monitoring requirements. Source control analyses summarized in the 2000 Whatcom Waterway RI/FS indicated that the outfall would not result in sediment contamination in the area around the outfall. Sampling data from 1999 confirmed model predictions and demonstrated that the sediments within the vicinity of the G-P outfall comply with SQS cleanup criteria for mercury. Biological confirmatory tests were run on the samples from the three highest-concentration stations in the station cluster. All biological tests passed SQS biological screening criteria. Therefore, the confirmatory biological testing procedures under SMS do not qualify this station cluster as a contaminated sediment site and demonstrates compliance with the SQS criteria.

- **Wood Products Handling and Log Rafting:** In addition to the GP pulp and tissue mill operations, historical land uses in the Whatcom Waterway area included extensive wood products manufacturing activities, including lumber and shingle mills, box factories, and log-yard operations. Extensive portions of the harbor area were historically leased from the State of Washington for log rafting operations. Since that time there have been extensive changes in the Bellingham economy and the types of industrial activities on the waterfront that have resulted in closure of the wood products mills and termination of log rafting operations. In addition, Ecology has developed best management practices for log yard operations, and protocols have been developed to reduce wood debris release from in-water handling of logs and log bundles. These changes have combined to largely eliminate the release of new wood waste or woody debris within the Whatcom Waterway Site area.

- **Improvements in Waterfront Construction Practices:** Some of the detected PAH and semivolatile organic compound contamination in sediments in GP and Bellingham Shipping Terminal wharf areas appears to be associated with the historical use of pilings treated with creosote and pentachlorophenol preservatives. More recent construction activities have favored the use of concrete or metal pilings where practicable to reduce potential water quality and sediment impacts and improve overall project design performance and usable life.

6.1.2 Other Stormwater and Industrial Discharges

Stormwater discharges are a potential source of water and sediment contamination to the bay and the city is regulated under Phase II of the federal NPDES Storm Water Program. The City of Bellingham stormwater program, along with other permitted discharges described in the Inner Bellingham Bay Sediment TMDL, are described below. A total of 40 waterfront or surface water discharge source locations to the bay were identified. The potential sources included 10 waterfront NPDES discharges, 12 suspected or confirmed contaminated sites, and 18 city storm water outfalls. However, no ongoing sources have been identified that have the potential to affect water or sediment quality beyond the immediate discharge zone. A summary of the main identified stormwater and wastewater discharges is provided below:

- **City of Bellingham Stormwater System:** The City of Bellingham originally developed a local stormwater program and submitted it to the Department of Ecology in 1999. It included an extensive source cleanup program, which incorporated vactor truck waste activities. After review of the program, Ecology recommended that the city concentrate on improvements in following two areas: 1) coordinate the stormwater program with the planned sediment cleanup in Bellingham Bay; and 2) improve the stormwater plan requirements for redevelopment. Bellingham is also a "Phase II" city in the federal stormwater NPDES permitting program, which requires stormwater programs meeting the federal requirements to be in place (Ecology, 2001).

- **Port of Bellingham Stormwater Program:** The Port leads environmental protection efforts at its properties around Bellingham Bay. As part of this role, the Port recently created a Stormwater Master Plan for Squalicum Harbor. The Plan conforms to the City of Bellingham's stormwater requirements as well as the Department of Ecology's Puget Sound Stormwater Technical

Manual for all development and redevelopment activities in the Harbor. The Stormwater Master Plan includes a series of pollution prevention operational and structural BMPs and treatment alternatives to reduce or eliminate adverse impacts from Port activities on stormwater and receiving waters. The planned efforts for Squalicum Harbor and Marina are intended to provide a model for Port source control activities throughout Bellingham Bay. The Port also carries three baseline general stormwater NPDES permits for facilities that drain to or otherwise potentially impact Bellingham Bay. One general permit is for the Bellingham Airport. The Port also has coverage for the maintenance shop near the shipping terminal on Whatcom Waterway and for the Alaska ferry terminal in Fairhaven. Data for these facilities covered under the general permit does not show they are a source of sediment contamination (Ecology, 2001).

- **C-Street Combined Sewer Overflow (CSO):** The C Street CSO is regulated under the Bellingham Post Point NPDES Permit (No. WA-002374-4). Post Point is the location of the city's Waste Water Treatment Plant (WWTP). Department of Ecology records show that there have been three CSO overflow events since 1995. However, the City has made substantial system improvements in recent years to minimize overflow events. In addition the C Street stormwater discharge was identified as an outfall of concern in the development of the City of Bellingham Comprehensive Stormwater Program and under the NPDES general stormwater program.

- **Bornstein Seafoods:** Bornstein Seafoods carries a State Waste Discharge Permit (ST7304) for the discharge of screened seafood processing wastewater to the Bellingham Post Point WWTP. They have a Baseline General Permit for Industrial Stormwater (SO3-000679). The Department of Ecology administers both permits. Bornstein Seafoods is not identified as an ongoing source of contaminated sediments (Ecology, 2001).

6.1.3 Other Area Cleanup Sites

Ecology is conducting cleanup activities at a number of sites located adjacent to the Whatcom Waterway Site, including the following:

- **I&J Waterway:** The results of Whatcom Waterway RI/FS studies performed in 1996 and 1998 demonstrated that surface sediment impacts were present in certain nearshore locations of the I&J Waterway, but that these impacts were primarily associated with contaminants different than those of the Whatcom Waterway sediments. Later studies performed in 2001 confirmed that the surface sediment impacts were predominantly associated with elevated bis(2-ethylhexyl)phthalate and nickel in a localized area adjacent to the Bornstein Seafoods facility and the former Olivine lease area, respectively. The sources of these compounds appear to be historical events, including the destruction of the seafood processing plant by fire in 1985, and historical Olivine dust and wastewater discharges from the ore crushing plant during the 1960s, 1970s, and 1980s. Ecology and the Port have entered into a legal agreement for completion of a sediment RI/FS study. The RI/FS is scheduled to be released for public review during late 2006.

- **Cornwall Avenue Landfill:** The Cornwall Avenue Landfill site, located at the south end of Cornwall Avenue, measures approximately eight acres and is adjacent to Bellingham Bay. Most of the site was originally tide flats and sub-tidal areas of Bellingham Bay. From 1888 to 1946, the site was used for sawmill operations, including log storage and wood disposal. From 1946 to 1965, the Port of Bellingham held the lease on the state-owned land. The property was subleased to the City of Bellingham from 1953 to 1962. The City used the Site for municipal waste disposal. The City continued waste disposal at the site under a sublease from American Fabricators from 1962 until 1965. Landfill operations ended at the Site in 1965, and a soil layer was placed on top of the municipal waste (Ecology, 2004a). Previous environmental investigations of the site indicate the presence of hazardous substances in groundwater, surface water, soil and sediments above state cleanup standards. These substances include arsenic, copper, lead, mercury, silver, zinc, cyanide, polychlorinated biphenyls (PCB), bis(2-ethylhexyl)phthalate, polycyclic aromatic hydrocarbon (PAH) compounds and fecal coliform. The Port is leading the completion of an RI/FS for cleanup of this site in coordination with the City and DNR. The completion of this study is expected during 2006 and will include remediation measures for impacted uplands and nearshore sediments. Ecology is ensuring that cleanup activities are appropriately coordinated with the adjacent RG Haley site.

- **RG Haley:** Soil and groundwater at this upland contaminated site contain concentrations of pentachlorophenol, petroleum and associated constituents that exceed water quality and sediment protection criteria, respectively. In 2001, an oil seep was observed discharging into Bellingham Bay from the shoreline along the northern boundary of the site. An investigation revealed that portions of the site were contaminated with chemicals consistent with the site’s former use as a wood treatment facility. The contaminants were found at levels exceeding state regulatory cleanup levels in surface water, shallow groundwater, sediment and soil (Ecology, 2004a). The visible release of contamination from the site into Bellingham Bay was controlled through the installation of a barrier wall and a product recovery system. The temporary contaminant recovery system continues to operate. An RI/FS is being conducted under an Agreed Order with Ecology and a draft report is scheduled to be released for public review during 2006. The cleanup at this site will include remediation of impacted uplands and nearshore sediments. Ecology is ensuring that cleanup activities are appropriately coordinated with the adjacent Cornwall Avenue Landfill site.

- **Holly Street Landfill:** The Holly Street Landfill site is a 13-acre historic solid waste landfill located in the Old Town district of Bellingham. In the late 1800s, the site was part of the original Whatcom Creek estuary and mudflat. Around 1905, private property owners began filling portions of the site with dredge spoils and other materials to increase useable upland areas. From 1937 to 1953, municipal waste was used by owners to fill private tidelands within the former Whatcom Creek estuary. Wastes, including debris and scrap materials, were disposed of according to landfill disposal practices of the time (Ecology, 2004a). Solid waste covers approximately 9.1 acres on the northwest side of Whatcom Creek and 3.8 acres on the southeast side (Maritime Heritage Park). The City of Bellingham currently owns 8.3 acres of the 13-acre landfill site, including all landfill properties located along the Whatcom Creek shoreline (Ecology, 2004a). Refuse along the northern shoreline of Whatcom Creek was excavated in conjunction with construction of an engineered cap, and material will be placed along the southern shoreline to stabilize the bank. The northern shoreline excavation and cap system controls releases of copper and zinc to Whatcom Creek that occur when estuary water mixes with the solid waste in the bank. The cleanup also included long term protection through legal restrictions on property use and monitoring of the cleanup action. Excavation for the project removed approximately 12,400 tons of solid waste, primarily from the northern bank prior to constructing the cap with clean materials (Ecology, 2004a).

- **Central Waterfront Site:** The Central Waterfront site includes four former cleanup sites that have been combined into a single site to comprehensively manage commingled groundwater contamination. The site includes properties formerly known as the Roeder Avenue Landfill, the Chevron Bulk Fuels Facility, The Boat Yard at Colony Wharf, and the Olivine Uplands site (Ecology, 2004a). The

Roeder Avenue Landfill was a bermed municipal landfill operated between 1965 and 1974. The Chevron Bulk Fuels Facility is located along C-Street and is an area where soils and groundwater are impacted by petroleum hydrocarbons associated with historic fuel handling practices. This has been purchased by the Port of Bellingham. The Boatyard at Colony Wharf is an operational boatyard. Soils and groundwater at the site are impacted by low levels of metals contamination, principally copper. Petroleum has also been detected in soil and groundwater. The site has been purchased by the City of Bellingham, and cleanup activities are being managed by the Port under an Interlocal Agreement with the City. The Olivine site was formerly used by previous Port tenants for operation of a lumber mill, and later for operation of a rock crushing plant. Contaminants identified at the site include petroleum hydrocarbons, polynuclear aromatic hydrocarbons, and low levels of heavy metals, principally nickel. The Port and City are conducting the cleanup of the Central Waterfront site and expect to complete an uplands RI/FS for public review in early 2007 under an Agreed Order with Ecology.

- **Chlor-Alkali Plant Site:** The Chlor-Alkali Plant site was recently acquired by the Port from GP. Soils and groundwater at that site contain elevated levels of mercury from historic operations of the Chlor-Alkali Plant by Georgia Pacific. Two rounds of RI/FS investigations have been performed at the site, and additional studies were performed as part of the Whatcom Waterway Log Pond Interim Action. Results indicate that soil and groundwater conditions at the site do not represent a current source control concern for Whatcom Waterway site sediments or surface water quality. The Port, GP, and Ecology plan to amend an existing Agreed Order to complete an RI/FS of this site.

- **Former GP Pulp and Tissue Mill Site:** The Pulp and Tissue Mill site was also recently acquired by the Port from GP. This property has been used since the early 1900s for pulp and tissue mill operation. Some impacts to soil and groundwater were identified at the site during environmental investigations performed at the site during 2004, and the site was listed by Ecology as a contaminated site. The key issues at the site include petroleum contamination near old bunker fuel storage areas, and low-level metals impacts in groundwater near the former acid plant area of the pulp mill. Based on patterns of sediment contamination in the Whatcom Waterway, neither of these areas appears to represent an ongoing source of contamination to Whatcom Waterway sediments. However, additional actions will be required to address these contamination problems and finalize plans for site cleanup and redevelopment of the Pulp and Tissue Mill site. Under the terms of the GP property acquisition, the Port will conduct the investigation and cleanup of this site, with oversight by the Department of Ecology.

6.2 Natural Recovery Processes

Natural recovery of aquatic sediments can occur through physical processes, biological processes, and chemical processes. Natural recovery is defined as the effects of natural processes that permanently reduce risks from contaminants in surface sediments (Apitz et al., 2002) and effectively reduces or isolates contaminant toxicity, mobility, or volume. At the Whatcom Waterway Site, natural recovery through the physical process of sediment deposition has been highly effective at restoring sediment quality in the bioactive zone throughout much of the Whatcom Waterway Site.

The potential for natural recovery of sediment is determined through multiple lines of evidence. A thorough assessment of natural recovery was performed as part of the 2000 RI/FS (Hart Crowser and Anchor Environmental, 2000). That work is summarized below, including measurements of sediment profiles, estimates of deposition rates, and the findings of natural recovery modeling. In addition to the work summarized in the 2000 RI/FS, the performance of natural recovery was empirically demonstrated through the improvement in sediment conditions that occurred between the 1996/1998 and the 2002 sediment monitoring events.

6.2.1 Measured Sedimentation Rates

Sedimentation studies were completed as part of the 1996 investigation activities, as summarized in the 2000 RI/FS.

Sedimentation Studies

As part of the RI/FS sampling effort, three natural recovery cores (HC-NR-100, HC-NR-101, and HC-NR-102) were collected and two sediment traps (HC-ST-100 and HC-ST-101) were deployed and sampled within the study area. Sediment traps HC-ST-100 and HC-ST-101 were co-located with natural recovery cores HC-NR-100 and HC-NR-101, respectively; the traps were deployed for three periods, each approximately four months in duration. Sampling locations are shown on Figure 3-4.

The natural recovery cores were sectioned in approximately 2 cm increments as described in the approved Sampling and Analysis Plan (SAP; Hart Crowser, 1996a). Selected subsamples were submitted for isotopic analysis of lead-210 (Pb-210), and cesium-137 (Cs-137), and chemical analysis of total mercury, and total solids. Data from the natural recovery cores were used to estimate the net sedimentation rates in the study area, and to evaluate mercury concentration trends through time (Table 6-1).

Sediment traps were deployed, retrieved, and sampled to characterize settling particulates. Settled particulate matter (SPM) that had accumulated in the traps was analyzed for total mercury, phenols, TOC, and total solids. Data from the sediment trap study were used to estimate gross sedimentation rates, and to characterize the chemical and physical properties of SPM in the study area. In addition, comparison of gross sedimentation rates in sediment traps with net sedimentation rates in co-located, radio-dated cores provides an estimate of resuspension rates.

The gross sedimentation rate (settling rate, see Table 6-2) was estimated from sediment trap data and provide a measurement of the flux of suspended solids through the water column. The net sedimentation rate (Table 6-2) was estimated from sediment cores dated with radioisotopes (Cs-137 or Pb-210) or chemical tracers which can be correlated with specific historical events (i.e., mercury in Bellingham Bay). Net sedimentation describes the rate at which sediments are permanently incorporated into the seabed. The difference between gross sedimentation rates and net sedimentation rates provides information on the rate at which bottom sediments are resuspended to the overlying water column where they may be subject to horizontal advection or resettling.

Sediment in the natural recovery cores has been subjected to both coring-induced compaction (an artifact of the sampling process) and burial-induced compaction (the natural consolidation of sediments). The effect of sampling induced compaction was removed from the data, and actual sampling depths were reconstructed based on the ratio of core penetration to core recovery.

Sedimentation rates are often presented in mass-based accumulation units of grams per square centimeter per year (g/cm^2-yr) to implicitly account for burial-induced compaction and porosity reduction with depth in the sediment. However, the density gradients in the natural recovery cores are slight; therefore, sedimentation rate calculations were performed using length based units in centimeters per year (cm/yr) without introducing significant errors. Length-based units were preferred for the following reasons: (1) the point of compliance for biological effects is defined on the basis of length, not mass, and is typically assumed to be the depth of the biological mixing zone (approximately 12 cm); and (2) length-based sedimentation rates are simpler, more intuitive, and more easily compared to geologic events in the sediment stratigraphy.

Net Sedimentation Rates

An example of the measured profile of Pb-210 is presented on Figure 6-1. Net sedimentation rates can be calculated from Pb-210 activity based on a model of constant and uniform sediment accumulation (Battelle, 1995). Sediment accumulation rates, however, are affected by seasonal variations in sedimentation resulting from river discharges, vessel traffic, and biological activities, as well as long-term variations resulting from changing land use patterns in the watersheds. Therefore, the interpretation of Pb-210 profiles is often subject to model assumption violations, particularly in shallow urban waterways such as inner Bellingham Bay. Non-uniform sedimentation probably accounts for much of the observed scatter in the profiles, although radioisotope counting errors also contribute to the uncertainty.

The supported Pb-210 activity for the natural recovery cores was estimated to be 0.75 disintegrations per minute per gram (dpm/g). This estimate is based on the range of published, supported Pb-210 values (0.5 to 1 dpm/g) typical for Puget Sound sediments (Battelle, 1995). An estimated value for the supported Pb-210 activity because a baseline Pb-210 value could not be established with certainty in the lower sections of the cores. The estimated supported value of 0.75 dpm/g is believed to be representative of Bellingham Bay conditions. Uncertainty associated with the supported Pb210 values have very little effect on the calculation output, since the slope of the regression analysis drives the output.

The net sedimentation rate was calculated from the slope of natural logarithm of excess Pb-210 activity versus depth below the mixing layer. The slope was statistically determined using linear regression techniques. The estimated Pb-10 sedimentation rates ranged from 1.4 to 2.07 centimeters per year (cm/yr). These rates are generally consistent with sedimentation rates estimated using Cs-137 or mercury, as described below.

Cs-137 has entered the oceans over the last 55 years as the result of nuclear weapons testing. The peak in Cs-137 profiles is believed to reflect the major global input of Cs-137 to the earth's atmosphere during the period of active bomb testing, and is correlated with a date of 1962. An additional index depth is the point where Cs-137 concentrations begin to increase sharply from a background or non-detectable concentrations to measurable concentrations. This point can be time labeled because Cs-137 is anthropogenic in origin and no background concentrations occurred in sediments prior to the nuclear weapon testing. The depth representing the onset of the introduction of Cs-137 to the sediments is correlated with 1950. Figure 3-7 shows a profile including Cs-137 activity.

The sedimentation rates calculated from the Cs-137 profiles using both of the time indices (i.e., the onset and the peak of atmospheric fallout) were generally consistent between the natural recovery cores and ranged from 1.52 to 1.99 cm/yr based on the introduction of Cs-137 activity, and from 1.43 to 1.52 cm/yr based on the peak of Cs-137 activity. These sedimentation rates are generally consistent with the estimates derived using Pb-210 or mercury profiles. Modern sedimentation rates appear to be relatively stable, based on consistency across different datums, and thus are appropriate for use in future projections.

Selected subsamples from each natural recovery core were analyzed for total mercury. Mercury was selected as a chemical tracer because it is a primary constituent of concern in Bellingham Bay and the period of maximum discharge to the bay is well-documented. Maximum discharges of mercury to Bellingham Bay occurred between 1965 and 1970 (Bothner et al., 1980). Sediment mercury accumulations likely reached their maximum in approximately 1970, allowing a few years of lag time for mercury to flux through the water column and become incorporated in the sediment. Figure 6-1 includes a measured mercury profile. Estimated sedimentation rates based on the mercury profiles are generally consistent among the natural recovery cores and range from 1.54 to 1.98 cm/yr. These sedimentation rates are also consistent with estimates based on radioisotopic dating methods.

In summary, the average net sedimentation rates were calculated using the mean of the four estimation methods: (1) onset of Cs-137 activity, (2) peak of Cs-137 activity, (3) Pb-210 decay, and (4) peak mercury concentration. Average sedimentation rates calculated for inner Bellingham Bay are generally consistent among the three natural recovery cores and range from 1.52 cm/yr at HC-NR-100 and HC-NR-101 to 1.77 cm/yr at HC-NR-102. The uncertainty in the sedimentation rate estimates is about 0.5 cm/yr.

Gross Sedimentation Rates

Gross sedimentation, or particle settling rate, is the sum of the net sedimentation and sediment resuspension. Gross sedimentation rates were determined by measuring the flux of particulate matter into sediment traps deployed about one meter above the seabed. Gross sedimentation rates are often higher than net sedimentation rates, because only a fraction of the particles settling through the water column are permanently incorporated into the seabed.

As part of the RI sampling program, two sediment traps (HC-ST-100 and HC–ST-101) were deployed in inner Bellingham Bay for three periods, each of approximately four months duration. The entire deployment period spanned from October 1996 to September 1997; however, sediment trap HC-ST-101 tipped over during the second deployment period and no sample was recovered.

Particle mass accumulation rates were generally consistent between the two sediment trap locations. Mass accumulation rates ranged from 3.69 to 9.59 g/cm^2-yr, and from 3.55 to 9.16 g/cm^2-yr at locations HC-ST-100 and HC-ST-101, respectively. Surface sediment dry densities in co-located natural recovery cores were used to convert from mass-based accumulation units (g/cm^2-yr) to length-based units (cm/yr). The dry density of surface sediments at the sediment trap locations is 0.47 g/cm^3 at HC-NR-100 and 0.42 g/cm^3 at HC-NR-101. Thus, estimated gross sedimentation rates ranged from 7.85 to

20.4 cm/yr, and from 8.45 to 21.8 cm/yr at locations HC-ST-100 and HC-ST-101, respectively.

Gross sedimentation rates varied by almost a factor of three between the fall/winter and summer deployment periods. Higher settling rates in summer may be caused by a more direct influence from Nooksack River runoff, which is carried to the site in clockwise, fair-weather circulation patterns that are more typical of summer months. Settling of suspended sediments from the turbid river plume is apparently enhanced during this time period. During winter months, prevailing counter-clockwise circulation patterns deflect the river plume toward Lummi Peninsula and away from the site, resulting in lower settling rates.

Resuspension Rates and Mixed-Layer Thicknesses

Resuspension rates were estimated by the difference between gross sedimentation rates measured in sediment traps and net sedimentation rates measured in dated cores (Resuspension = [Gross SR – Net SR]/Gross SR) (Baker et al., 1991). Resuspension describes the continuous exchange of sediments between the seabed and water column. The average of the net sedimentation rates estimated using the four different dating techniques was used in the resuspension rate calculations. Resuspension rates ranged from 81 to 93 percent throughout the year, averaging about 90 percent at both locations.

Mixing within the sediment column is a result of bioturbation, tidal wave-induced, or propeller-induced currents. The thickness of the surface mixed layer was interpreted from plots of the natural logarithm of excess Pb-210 activity with depth. The depth at which the Pb-210 activity indicates steady-state decay behavior (constant decrease with depth in the log activity) corresponds to the bottom of the mixed layer; within the mixed layer, Pb-210 activity is theoretically constant. In these cores, however, Pb-210 activity in the mixed layer is erratic, and may be complicated by propeller wash, anchor drag, construction events, and other bottom disturbances. Based on the Pb-210 profiles the base of the mixed-layer was estimated to range between 24 cm (core HC-NR-100) and 11 cm (core HC-NR-102). These values are in general agreement with studies conducted in other Puget Sound embayments (Battelle, 1995).

6.2.2 Consistent Recovery in Sediment Profiles

The patterns of sedimentation observed in the natural recovery cores can also be observed in core sampling data throughout the Whatcom Waterway portion of the Site. As shown in Figure 3-7, the mercury concentrations in surface sediments (0 to 0.3 feet) were consistently lower than in underlying subsurface sediment samples. This consistency of the pattern further confirms the findings of the natural recovery cores and sedimentation estimates.

6.2.3 Previous Natural Recovery Modeling

Bellingham Bay has been the subject of natural recovery studies performed by multiple investigators. Early studies were performed during the 1970s and 1980s, following initial source control efforts by GP (Bothner, 1973; Bothner et al., 1980; and Officer and Lynch, 1989). Those studies concluded that sediment deposition and natural recovery was occurring, as evidenced by declining surface concentrations and observed concentration trends in sediment profiles. This recovery was driven by the significant reduction in source inputs coupled with burial of contaminated sediment with cleaner sediment, mixing of cleaner surface sediments with deeper sediments by burrowing organisms and bottom currents, and exchange of sediments with the overlying water column through resuspension.

As described in the 2000 RI/FS, natural recovery modeling was performed to estimate whether continued sediment concentration reductions would be observed. That modeling projected future reductions in total mercury concentration based on observed changes in sediment concentrations since the 1970s. Those concentrations had decreased following an exponential decay curve. Based on detailed natural recovery modeling, calibrated to site empirical observations, the 2000 RI/FS estimated that over the next 10-year period, surface sediment mercury concentrations would likely decline by an additional 30 to 40 percent in depositional areas.

Actual concentration reductions were confirmed as discussed in Section 5.2. Concentration reductions were observed in 85 percent of the co-located samples retested for sediment mercury concentrations in 2002. Excluding nearshore high-energy areas adjacent to the ASB, average surface mercury concentrations declined by 31 percent (Table 5-1). The observed rates of recovery over this 4 to 6 year period were slightly more rapid than the modeled recovery rates (Table 6-3, originally calculated for a 10-year period). Differences in recovery rates may result from results of source control activities that have been implemented since the 1996 to 1998 time period.

6.2.4 Consistency with Natural Recovery Framework

A weight-of-evidence approach for evaluating natural recovery at contaminated sediment sites has recently been developed by the Remediation Technologies Development Forum (RTDF) Sediment workgroup (Davis et al., 2004), and has been adopted by EPA (2004) in its current draft sediment management guidance. The approach includes steps such as data assessment, modeling, and site monitoring, employing methods and approaches that have been successfully applied at other similar sites. The framework includes five interrelated elements, each of which is described below:

- **Characterize contamination sources and controls:** As described in Section 6.1, sources of contaminants at the Whatcom Waterway Site have been identified and controlled.

- **Characterize fate and transport processes:** Assessment of contaminant fate and transport processes in a natural recovery context requires understanding of environmental processes affecting both sediment and contaminants (Magar et al., 2003). Primary processes of interest include settling/deposition, long-term burial, bioturbation and biological mixing in the bed, pore water diffusion and advection, and chemical partitioning. Key sediment and mercury fate and transport processes were characterized in Bellingham Bay as part of the original RI/FS (Anchor and Hart Crowser, 2000). Following initial monitoring and modeling assessments suggesting the effectiveness of natural recovery at the Whatcom Waterway Site (Bothner et al., 1980; Officer and Lynch, 1989), the RI/FS provided more definitive characterization of the more important processes such as sedimentation, resuspension, and bioturbation. Based on earlier detailed flux measurements performed at the site by Bothner et al. (1980), chemical partitioning, pore water diffusion, and advective processes were not identified as significant mercury fate and transport processes at the site. As described in Section 6.3, most of the outer areas of the Whatcom Waterway site are in stable depositional areas. Exceptions to this general site finding include the nearshore sediments offshore of the ASB that are subject to higher wave energies, and potentially to localized nearshore areas subject to propeller wash in navigation berths.

- **Establish historical record for contaminants in sediments:** Chemical concentration data assembled from past sampling events or from radioisotope-dated cores can be used to establish a historical record for contaminated sediments, and provide important information on the rate and extent of prior natural recovery (Magar et al., 2003). As a result of a variety of academic research studies, regional monitoring programs, and RI/FS investigations, a considerable amount of surface and subsurface sediment chemistry data have been collected over time at the Whatcom Waterway Site. Sediment total mercury sampling data collected with proper quality control procedures are available for the site beginning in the 1970s, and provide a basis to assess historical changes in sediment quality over time. These data corroborate the findings of subsurface sediment sampling profiles and the results of recent surface sediment testing.

- **Corroborate recovery based on biological endpoint trends:** The objective of this evaluation element is to confirm that risk reduction, as indicated by evaluation of chemical conditions, is corroborated using relevant biological measurements. Under SMS, biological endpoints serve as the primary line of evidence for assessing environmental protection. Recovery of sediments has been directly assessed as part of the RI/FS using whole sediment acute and chronic bioassays. These measurements have documented improvement in sediment quality, consistent with the measured declines in contaminant concentrations.

- **Develop acceptable and defensible predictive tools:** The final element in evaluations of natural recovery is to develop defensible predictive tools. Natural recovery modeling and predictions have been corroborated between different modeling packages, including the Officer and Lynch model (1989) used to estimate mercury recovery in sediments of the inner bay, Water Quality Analysis Simulation Program (WASP) models used to estimate recovery of sediments associated with the GP-owned outfall area, and predictive modeling performed as part of the 2000 RI/FS (Anchor and Hart Crowser, 2000). These models have been shown to be effective at predicting the recovery behavior of the system.

The patterns of natural recovery of marine sediments have been well documented at the site. The availability of information for the Whatcom Waterway Site is consistent with all five lines of evidence developed by the RTDF Sediment workgroup (Davis et al., 2004), and adopted by EPA (2004) in its current draft sediment management guidance.

6.3 Factors Affecting Sediment Stability

Natural recovery of chemical and biological conditions within the Whatcom Waterway Site has been well documented, as outlined above. Additional information on factors that could influence future sediment stability was developed for evaluation of the effects of rare, extreme event conditions on contaminant and sediment mobility. Evaluation of future bed stability can be conducted in a number ways, including inference from empirical evaluation of historical data (e.g., core profiles), and prediction based on assessments of extreme event stresses and potential sediment mixing/transport conditions.

Sediments within the Whatcom Waterway Site have already been subjected to a range of bioturbation and hydrodynamic events, including mixing of sediments by benthos, periodic storm surges, and propeller wash. Despite these events the stability of sediments located in deepwater depositional areas is reflected in the core profile data (e.g., Figure 6-1) and the progressive reduction of surface sediment concentrations and toxicity as cleaner sediments have continued to deposit in these areas (Table 5-1). However, sediment stability in localized areas can differ depending on local conditions. Factors affecting sediment stability are discussed below.

6.3.1 Bioturbation

Bioturbation (sediment mixing) caused by the natural activities of aquatic organisms (e.g., benthos) can affect sediment stability concern in certain situations. At some locations, organisms may be capable of mixing underlying contaminated sediments to the surface, potentially affecting effective long-term isolation of underlying contaminants.

At the Whatcom Waterway Site, the depth of the biologically mixed (bioturbation) zone ranged from 10 to 15 cm (Bothner et al., 1980; Officer and Lynch, 1989; Anchor and Hart Crowser, 2000). In accordance with RI/FS Project Plans and SMS guidance, chemical analyses and confirmatory biological testing at the site has typically focused on samples composited over the top 12 cm of sediment.

Although effective isolation of sediment layers below 12 cm is common and widely reported in Puget Sound, in some situations it may not be an absolute depth of isolation in sediment. For example, some organisms may burrow in sediments deeper than 12 cm. At the particular locations of these burrows or burrowing activities, some mixing or other interaction of surface and deeper layers may occur. Researchers have noted that certain deep burrowing benthos can move material from their relatively deep burrows to the surface, where these reworked sediments accumulate as mounds around the burrow entrance.

Clarke et al. (2001) provide a review of sediment bioturbation issues as they relate to evaluation of long term isolation of contaminants in subsurface sediments. For example, in order to ensure long-term isolation, the overlying clean surface sediments should have a thickness equivalent to the depth where the future bioturbation rate is expected to be inconsequential. A common method of estimating the lower extent of bioturbation is to perform detailed radioisotope dating of sediment cores, as has been performed at the Whatcom Waterway Site (resulting in the 12 cm site-specific SMS point of compliance).

Another method is to examine those organisms present or likely to be present at the site and identify the deepest burrowers. For this reason, ghost shrimp (see below) are often singled out as a particular species of interest. However, it is important to note that identification of the deepest burrowers is a conservative approach to estimating bioturbation in general. That is, using the most extreme observation of burrowing depth available from any instance of any organism in any location may yield an extreme estimate of “bioturbation” for a particular location or situation. There may be little contribution to the overall bioturbation rate from a few deep burrowers if their density is very low. Observations of extreme burrowers thus provide little indication of the actual amount of sediments that might be disturbed by bioturbation, and how this relates to the overall stratification of sediments. Nevertheless, this approach can provide a starting point as a worst-case estimate of potential depths where bioturbation and mixing may be a future sediment stability concern.

Ghost shrimp (*Neotrypaea californiensis*; formerly *Callianassa californiensis*) are deep burrowing crustaceans whose activities have been suggested to be a particular concern in this context. This species (and other members of the genus) occur throughout Pacific coastal waters of North America, and are commonly noted as one of the deepest burrowers in such benthic environments (Posey, 1986). Their potential colonization and subsequent burrowing/mixing activity is often singled out as a primary uncertainty in regional contaminated sediment stability evaluations. While not numerically abundant within the Whatcom Waterway Site (Broad et al., 1984), ghost shrimp are nevertheless present within the site area.

Reported maximum burrowing depths for adult *N. californiensis* range from less than 40 cm to a maximum of approximately 90 cm (Stivers, 2002). However, typical burrow networks generally extend to less than 40 cm deep at their deepest point. Moreover, ghost shrimp burrow deepest in upper intertidal areas (particularly where the substrate is primarily sand) in order to stay submerged underwater within the burrow for longer periods during low tides. Ghost shrimp prefer intertidal to shallow subtidal locations within estuarine bays, and this is where relatively dense beds (and the deepest burrowing depths) of ghost shrimp can occur. Thus, some of the more extreme observations of ghost shrimp burrowing depths likely reflect a behavioral adaptation to intertidal habitats, which may not be representative of deeper subtidal sediments at the Whatcom Waterway Site.

As discussed in Stivers (2002), the deepest reported burrowing depth for ghost shrimp is approximately 90 cm, and only a small fraction of the shrimp even in a relatively dense intertidal bed reach these depths. The majority of shrimp would be expected to burrow to depths of 60 cm or less. Thus, even in a relatively dense shrimp bed, at depths between 60 and 90 cm, the overall bioturbation rate would be expected to be very low, since only a few individuals would enter this interval. Below 90 cm, the worst-case bioturbation rate is zero for all practical purposes, even in preferred intertidal habitats.

Marine mammals, particularly grey whales, have also been known to disturb shallow subsurface sediments as part of feeding activity. Since termination of commercial whaling in the eastern Pacific, the grey whale population in the eastern Pacific Ocean has recovered to near its historical level of approximately 20,000 individuals, with natural population fluctuations around that level (COSEWIC, 2004). Puget Sound is located adjacent to the migration route of the whales between their summer feeding grounds in the arctic and their calving ground in Baja, Mexico. Some individuals have been observed to enter Puget Sound and Bellingham Bay and to feed opportunistically. Typically the whales entering Puget Sound stay in the area only a few days, but some individuals have been documented to stay in the area between 50 and 70 days prior to resuming their migration.

Grey whales consume most of their annual diet by pelagic feeding of krill in the Arctic. During peak feeding periods, the whales may consume as much as 1-2 percent of their body weight per day. Grey whales also feed by suction feeding for benthic organisms, typically invertebrates such as shrimp and crab. Suction feeding behavior is generally not observed in intertidal areas, and is confined to subtidal and deep-water areas. The feeding takes place predominantly in the top 20-30 cm of the sediment column, though during some aggressive feeding events, whales can disturb sediments to depths of 90-120 cm. As described in Section 4.4, the concentrations sediment contaminants within the Whatcom Waterway Site are well below the concentrations that could result in potential health impacts to feeding whales. Therefore, the main consideration related to feeding whales within the site area is the potential disturbance of shallow surface and subsurface sediments during aggressive suction feeding that may occur from time to time.

For purposes of evaluating potential sediment disturbances through bioturbation, both sediment penetration by sediment dwelling invertebrates and potential periodic disturbances by feeding whales can result in disturbance of the upper 30-40 cm, and as deep as 90-120 cm of the sediment column in subtidal areas. These depths are similar to the depths potentially disturbed by anchor drag and navigation disturbances. These potential disturbance depths are useful in the analysis of sediment contaminant distribution and in the design and analysis of long-term effectiveness for potential remedial actions. Sediment contaminant distribution for these sediment depths was discussed in Section 5.3 of this RI report. The remedial alternatives evaluation in the Feasibility Study addresses long-term effectiveness considerations including sediment stability.

6.3.2 Wind and Wave Activity

The bioturbation discussion presented above provides an assessment of potential extreme sediment mixing events resulting from worst-case bioturbation forces, and possible implications of such a condition on sediment stability evaluations at the Whatcom Waterway Site. Possible additional hydrodynamic forces such as periodic storm surges, propeller wash, and anchor drag were also evaluated in this sediment stability evaluation, consistent with the evaluation framework presented in Palermo et al. (1998a and 1998b) and Erickson et al. (2003).

Sediments within the Whatcom Waterway Site have already been subjected to a range of hydrodynamic events. In general, the stability of these sediments as reflected in the core profile and natural recovery data discussed above suggests that sediment at the site has been stable over time under the range of dynamic processes that have occurred in the system over the past 30 years.

Wind and wave activity vary with water depth and location throughout the Whatcom Waterway Site. In relatively shallow water depths (e.g., less than 10-15 feet) wind-driven storm waves can produce increases in bottom velocities that can resuspend settled sediments. These forces are proportional to the sizes of the waves, which are in turn influenced by the wind direction, fetch, and duration and the localized geography and bathymetry. At the Whatcom Waterway Site, the greatest wind and wave exposures are experienced by the shorelines offshore of the ASB and of the Bellingham Shipping Terminal, because these areas are exposed to the prevailing offshore winds, and because these areas are exposed to wind-waves with the longest fetch in which to build. The predicted bottom velocities associated with a particular wave height and period generally increase as the water depth decreases. Intertidal sediments are exposed to breaking waves and are most subject to wave erosion, depending on the shoreline geometry and composition. Lower but significant levels of wave action occur along the sides of the Whatcom and I&J Waterway and in portions of the Log Pond. Vessel wakes can also generate waves of varying sizes depending on the type and speed of vessel movement and the location of the vessel relative to shoreline areas.

The effects of wind and wave activity can be observed to some degree in the particle size distribution in sediments throughout the site. In most deepwater areas, the sediments are composed of fine-grained sediments that have deposited over time. These areas are below the depths at which wind and wave effects are significant. In the shallow-water areas offshore of the ASB and in certain other shallow-water areas along the waterways, the particle size has a lower composition of fine-grained sediments, in part due to the resuspension of finer-grained materials by wind and wave effects. These patterns are also influenced by anthropogenic disturbances such as the placement or erosion of coarse grained materials in certain areas.

The potential for wind and wave disturbances is relevant to the evaluation of the long-term stability of impacted sediments in the absence of remedial actions, and also for the design of remedial actions involving capping or shoreline changes. These issues are discussed directly as part of the Feasibility Study and the evaluation of remedial alternatives for the Whatcom Waterway Site. Remedial design activities for the final cleanup action will also include additional evaluations of the impacts of wind and wave disturbances on sediment stability, including potential influences of vessel-induced wakes.

6.3.3 Propeller Wash and Anchor Drag

Propeller wash from vessels can produce increased bottom velocities and in some cases localized sediment resuspension. The propeller wash effects are generally proportionate to the size, draft, and power of vessels, with larger, deeper and more powerful vessels exhibiting propeller wash effects to greater depths. However, propeller wash effects are influenced by propeller type, orientation, water depth, and duration.

While some propeller wash effects can occur transiently in offshore areas, the effects are most significant in waterway and berth areas where navigation activity is concentrated, and where water depths are typically shallower and matched to the size of the vessels using the channels and berths. In extremely shallow-water intertidal or shallow subtidal areas, vessel access is limited or precluded. In these areas, propeller wash effects would typically be observed only as a result of indirect activities (e.g., vessel maneuvering in an adjacent deepwater area, with resultant propeller wash directed toward the shallow-water area). This type of effect was evaluated as part of the design of the Engineering Design Report for the Log Pond Interim Action (Anchor, 2001a).

As the water depth increases, an increased variety of vessel types, depths, and power can utilize a navigation area, increasing the range of potential propeller wash conditions that may be experienced. In deepwater areas, the propeller wash effects become insignificant due to the attenuation of propeller wash velocities with depth below the vessel. The specific significance thresholds vary with the types of vessels that may be present in the area, the water depth, and the sediment particle size.

The deepwater portions of the Whatcom Waterway navigation channel allow vessels with drafts up to about 30 feet. This depth is considered intermediate by current navigation standards. True deepwater vessels (e.g., post-Panamax container vessels, the largest cruise ships, or oil tankers) are incapable of entering the waterway or using the berth areas, or even entering many portions of Inner Bellingham Bay due to natural water depth limitations. The main propeller wash conditions relevant to the deepwater portions of the Whatcom Waterway are bow thruster activity on larger vessels with intermediate (i.e., 20-30 ft) drafts, or the propeller wash from tugs used in assisting the berthing of the larger vessels.

For the Inner Waterway with water depths of approximately 18 feet below MLLW, vessel traffic can include small tugs and barges, recreational vessels, sailboats, whale watching boats, passenger-only ferries, and other vessels ranging in draft from less than 5 feet to 18 feet. Based on the Log Pond design analysis, as well as other regional evaluations of propeller wash, the propeller wash created by these types of vessels would not be significant at water depths greater than around 30 feet below MLLW (Ecology, 1995; PIE, 1998;

WSF, 1999), but may be significant in shallow-water areas where depths are closer to the draft of the vessels (Anchor, 2000b).

When the bottom velocities created by propeller wash conditions exceed the stability threshold of the sediments present in the effected area, the surface sediments of the bed may begin to erode. The depth to which the erosion will occur varies with the velocity, the sediment type, the duration and the repetition of the event. Detailed propeller wash scour modeling and tracking performed at other similar sites in Puget Sound (Ecology, 1995; PIE, 1998; WSF, 1999), shows that the maximum depth of potential propeller wash scour can vary from shallow effects (i.e., less than 10 cm) to worst-case scour depths of approximately 90 cm. The greatest scour depths are observed when all factors are aligned, resulting in high bottom velocities in the same location and orientation and occurring repeatedly (e.g., repeated moderate to high power, localized propeller wash occurring at ferry terminals). Scour depths are generally much lower where propeller wash events are transient and in inconsistent orientations (e.g., in offshore areas where vessel traffic patterns are variable).

Anchor drag is the effect caused when vessel anchors become buried in surface and shallow-subsurface sediments. The burial and retrieval of the anchor can cause mixing of the sediments in the localized area around the anchor. Anchor drag is most significant in designated anchorage areas. In navigation areas where vessels are secured by “tying up” to docks, wharves, or floats, anchor drag is generally not significant. Anchor drag is also not generally significant when the use of anchors is reduced through the use of permanent moorage floats.

The depth at which anchor drag can cause mixing of sediments varies with the type and size of vessel, the size and type of anchor, and the bottom conditions in the anchorage area. For small vessels, the depth of anchor drag effects is commonly in the range of 10-30 cm in soft sediments. For larger vessels, the range of depths of localized mixing can be 10 to 90 cm (Palermo et al., 1998a and 1998b). This depth is similar to the range of potential disturbances associated with propeller wash and bioturbation.

6.3.4 Seismic Influences on Sediment Stability

The Whatcom Waterway site is located within the Puget Sound Basin, an area of active seismicity. The Site could be affected by earthquakes from three primary sources: shallow crustal faults, deep intraslab earthquakes, and interpolate (subduction) earthquakes. The contribution of each of these sources to ground shaking hazards has been evaluated by the U.S. Geological Survey (USGS; http://geohazards.cr.usgs.gov).

USGS disaggregation analyses indicate that the hazard in Bellingham is controlled predominantly by shallow crustal earthquakes at distances of less than 25 kM at a return period of 2,475 years. The relative contribution of crustal sources is expected to be even larger at the 475 year return period level.

Liquefaction can be observed in loose, saturated, cohesionless soils subjected to strong earthquake shaking. Cohesive soils, such as plastic silts and clays, are not susceptible to liquefaction, though sensitive clays may exhibit similar behavior. The potential for liquefaction to occur therefore varies from location to location with area lithology, and can affect certain site sediments, and upland soils adjacent to certain site sediment areas.

The primary effects of liquefaction are flow sliding or lateral spreading. Flow sliding occurs when the residual shear strength of a liquefied soil is lower than the shear stresses required to maintain static equilibrium. While it occurs relatively rarely, flow sliding can lead to large lateral soil movements, either during or following earthquake shaking. Lateral spreading can also produce horizontal soil movements during strong ground motion. The displacements produced by lateral spreading typically develop during earthquake shaking and are complete by the time earthquake shaking has ended.

Seismic stability analyses are typically incorporated into the design and permitting for implementation of cleanup actions, and for other types of construction. For example, the Engineering Design Report for the Log Pond Interim Remedial Action (Anchor, 2000) assessed quantitatively the potential for flow sliding and lateral spreading at the Log Pond cap area. Such analyses will be performed as part of the design of any remedial action at the Whatcom Waterway site.

Based on site lithology, and the generalized seismic information for the site, seismic issues are unlikely to significantly affect sediment conditions within most of the deepwater site areas. These areas are relatively flat, and lateral spreading and flow sliding are unlikely to occur. The potential for significant sediment movement increases for steep shoreline areas and bulkheaded waterfront areas, due to the lower stability of these steeper slopes. Engineering analyses during remedial design for site cleanup will address measures to mitigate potential seismic stability concerns in these areas.

Table 6-1 Summary of Estimated Sedimentation Rates from 2000 RI/FS

	Sedimentation Rate in cm/yr				
Natural Recovery Core Number	**Pb-210 Decay**	**Onset of Cs-137 (1950)**	**Peak of Cs-137 (1967)**	**Peak of Mercury (1970)**	**Average Sedimentation Rate**
HC-NR-100	1.4	1.69	1.43	1.54	1.52
HC-NR-101	1.06	1.99	1.41	1.61	1.52
HC-NR-102	2.07	1.52	1.52	1.98	1.77
	Overall Average Sedimentation Rate				1.6

Note:
Table from 2000 RI/FS Report (Table 9-1)

Table 6-2 Summary of Average Net Sedimentation, Gross Sedimentation, and Resuspension Rates from 2000 RI/FS

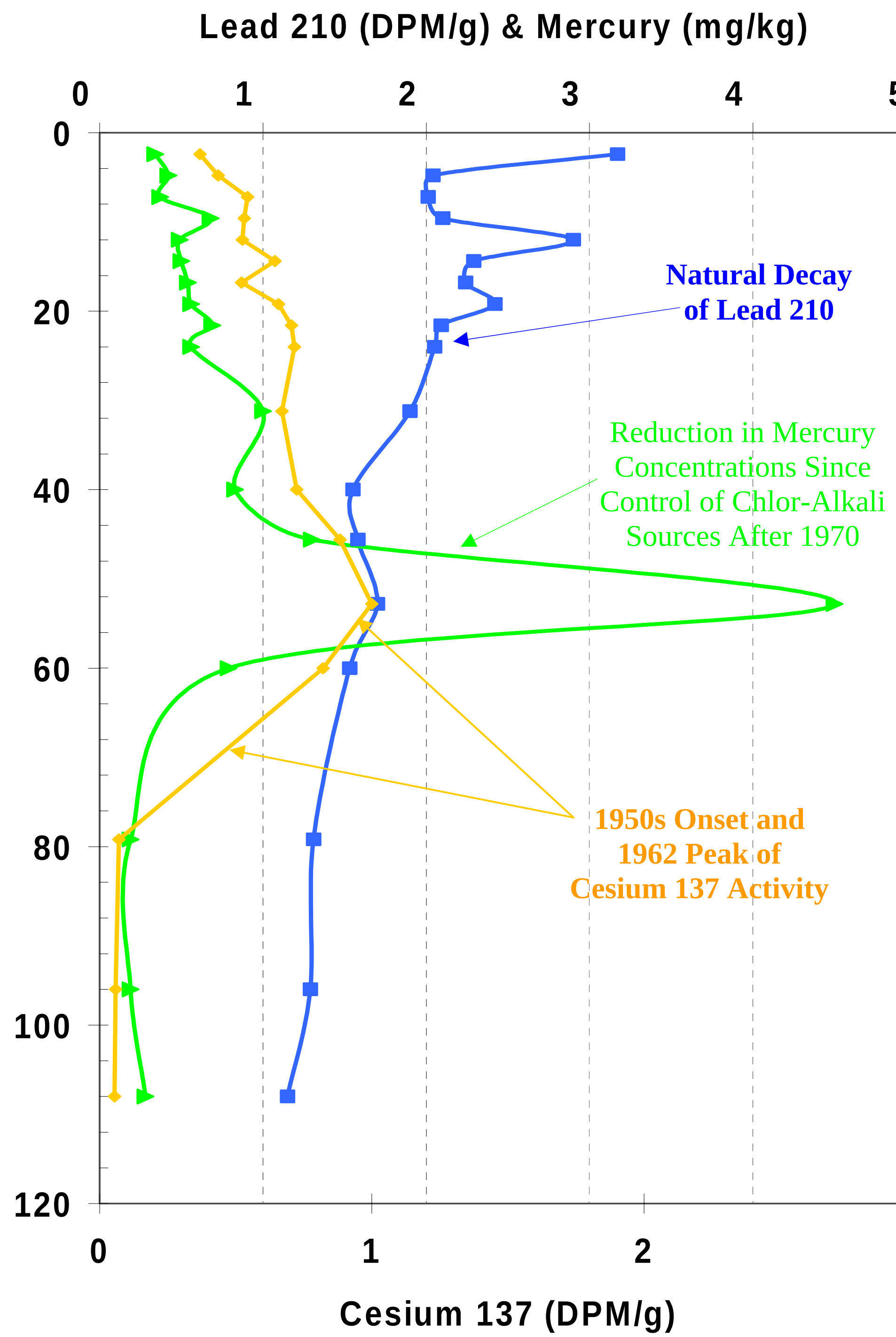
Natural Recovery Core Number	Average Estimated Net Sedimentation Rate in cm/yr	Estimated Gross Sedimentation Rate in cm/yr	Calculated Resuspension Rate in Percent
HC-NR-100, HC-ST-100	1.52	7.85	81
HC-NR-101, HC-ST-101	1.52	8.45	82

Note:
Table from 2000 RI/FS Report (Table 9-1)

Table 6-3 Ten-Year Recovery Projections of Mercury Concentrations from 2000 RI/FS

Natural Recovery Core Number	Maximum Sample Interval Used in Regression (in cm)	Number of Samples Used in Regression	Regression R2 Value	Standard Error	Average Net Sedimentation Rate (in cm/yr)	Sediment Mercury Concentration in mg/kg: Year 1995	Sediment Mercury Concentration in mg/kg: Year 2005 (+/- Standard Error)
HC-NR-100	-44.2	11	0.59	0.05944	1.52	1.3	0.80 (+/- 0.12)
HC-NR-101	-41.6	12	0.68	0.0751	1.52	1.7	1.12 (+/- 0.15)
HC-NR-102	-45.6	13	0.81	0.05679	1.77	0.34	0.23 (+/- 0.11)

Note:
Table from 2000 RI/FS Report (Table 9-1)



Notes:

Core data from sample station HC-NR-102.

Left axis data represents the depth beneath the mudline, in centimeters.

DPM: Disintegrations per minute – a measure of isotopic activity.

Refer to Appendix B for raw data summaries and data from other natural recovery cores.

RETEC

PORT OF BELLINGHAM WHATCOM WATERWAY		EXAMPLE CORE PROFILE FROM NATURAL RECOVERY EVALUATION
Date: 08/2006	File: 8876/RIFS	FIGURE 6-1

7 Results of Engineering Testing

In addition to the information contained in previous sections of this report, a number of engineering studies and other sediment evaluations were conducted to support development of a Feasibility Study, and to inform future remedial design activities. The following sections provide a summary of these engineering evaluations.

- Bench-Scale Engineering Studies (Section 7.1)
- Sediment Management Evaluations (Section 7.2)
- *In Situ* Sediment Treatment Testing (Section 7.3)
- Dewatering Tests for ASB Sludges (Section 7.4).

7.1 Bench-Scale Engineering Studies

In spring/summer 2002, a number of bench-scale studies were performed in support of the RI/FS evaluation of potential confined disposal remediation alternatives. The results of these studies were summarized in the Pre-Remedial Design Evaluation report (Appendix A). An overview of the bench-scale and engineering studies is provided below.

- **Geotechnical Testing of Waterway Sediment Composite:** A composite sample of sediments was tested for geotechnical properties. The purpose of the testing was to evaluate geotechnical properties of the materials that could affect the design and construction of a confined disposal facility. The tests performed on the sediment composite included consolidation tests, water content, grain size distribution, Atterberg limits, specific gravity, hydraulic conductivity, and effective porosity. The results are useful in defining the settlement and consolidation behavior of materials placed in a containment cell or fill, defining the dewatering behavior of the materials, and in defining the final bearing strength of the cap placed over the top of the containment cell.

- **Waterway Sediment Elutriate Testing and Settling Tests:** In additional to leaching tests performed as part of the 2000 RI/FS, two types of elutriate testing were performed as part of the PRDE study (Appendix A) for evaluation of potential water quality impacts during dredging. The testing included both the dredge elutriate test (DRET) method, and the Modified elutriate test (MET) method. Column settling tests were also performed on the composite. The column settling test (CST)_provides information on the settling behavior of suspended solids that can be generated during dredging either at the point of dredging, or at the point of disposal. Results of the DRET, MET, and CST bench-scale evaluations are described in Appendix A.

- **Multi-Site Pancake column leach testing (PCLT):** To support the feasibility study evaluation of on-site multi-user confined disposal alternatives, testing was performed using the PCLT protocol. The PCLT test evaluates chemical mobility associated with sediment porewater/leachate following placement of impacted materials in a confined disposal facility. The PCLT was conducted over the period from June to December 2002, during which a total of 27 leachate samples, constituting approximately 22 pore volumes, were collected from the column and analyzed for chemical properties. Peak leachate concentrations were observed in the PCLT concurrent with "salt wash-out" conditions, as described in Myers et al. (1996). Peak mercury concentrations in the PCLT leachate rose from initial low concentrations (less than 0.025 µg/L) to salt wash-out concentrations ranging from 0.800 µg/L to 1.29 µg/L. Washout increases were also observed for tributyl tin which was present in the test composite mainly due to sediments contributed from the Weldcraft and Marine Services Northwest sites. These sediments had been evaluated along with the Whatcom Waterway Site materials to assess the feasibility of joint management of impacted sediments as part of a multi-user disposal site operation. Results indicated that changes in sediment redox conditions and salinity conditions could enhance mercury and tributyl tin mobility, and that confined disposal site design would need to include evaluation of measures to ensure protection of groundwater and surface water quality adjacent to the containment site. Such measures would likely include confinement of the materials within the saturated zone to minimize redox condition changes, and evaluation of leachate/groundwater/surface water interactions, and the measures that can be taken to minimize contaminant flux from the confined disposal facility.

7.2 Sediment Management Evaluations

The potential suitability of sediments from the Outer Whatcom Waterway and from the I&J Waterway for PSDDA disposal or beneficial reuse was evaluated as part of previous RI/FS testing and parallel PSDDA evaluations (Appendix H). Two rounds of testing have indicated that the Outer Waterway and I&J Waterway sediments are likely suitable for management consistent with PSDDA program requirements. Final suitability determinations are subject to additional testing to comply with full PSDDA program requirements and data recency requirements.

In contrast to the sediments of the offshore portion of the Outer Waterway and the I&J Waterway, PSDDA evaluations performed previously on sediments at the Bellingham Shipping terminal (Striplin, 1997) and in portions of the Inner Waterway have demonstrated exceedances of criteria for beneficial use or

PSDDA disposal (Appendix H). Sediments dredged from these areas would be subject to use restrictions, likely requiring application of confined disposal or upland disposal methods. Leachability testing using the Toxicity Characteristic Leaching Potential (TCLP) test protocol was performed as part of the 1997 PSDDA evaluations. That testing demonstrated that Whatcom Waterway Site sediments would not exceed state or federal TCLP mercury limits for Subtitle D landfill disposal. Sediment management options are discussed in detail as part of the Feasibility Study.

7.3 ECRT Pilot Testing

Electro-chemical reductive technology (ECRT) was originally developed in Europe. The technology is based on imposing a direct electrical current with a superimposed alternating energy current via *in situ* electrodes, to optimize and utilize the electrical capacitance properties of soil and sediment particles.

Under optimum conditions, the technology purports the ability of oxidizing organic chemicals *in situ*, and concurrently enhancing the mobility of metals such as mercury, resulting in metal precipitation onto the electrodes. To date, the technology has been applied at one sediment site in Europe containing elevated concentrations of mercury and other metals. However, the technology has not yet been applied on a full scale in the U.S. for sediments.

A pilot test of ECRT was performed at the Log Pond area of the Whatcom Waterway Site. The test was funded by EPA's National Risk Management Research Laboratory and the Superfund Innovative Technology Evaluation program and Ecology. The pilot test was performed between August of 2002 and March of 2003, and involved the installation of a set of test electrodes (nine cathodes and nine anodes) within a 50-foot by 50-foot pilot test plot in the western corner of the Log Pond, near the Bellingham Shipping Terminal. The treatment cost for this 460 cubic yard test plot was approximately $388,000 or approximately $838 per cubic yard treated. Concentrations of subsurface sediment constituents were measured before, during, and after conclusion of the pilot test treatment period.

Results of testing demonstrated that there was no significant change in mercury concentrations in the test plot sediments over time. The ECRT process was determined to be ineffective at achieving reductions in mercury concentrations, which was the primary purpose of the technology. There were also no significant changes in the test plot sediment concentrations for phenolic compounds. Therefore, the secondary objectives of the test plot (to achieve concentration reductions for organic contaminants) were not achieved.

One factor that was cited by the technology vendor as being responsible for the poor performance of the technology was the corrosion of electrical connections to the treatment electrodes, even though the vendor took measures to isolate the connections from the marine environment. A final testing report is to be published by EPA as part of its Innovative Technology Evaluation Report series. The results of the ECRT test plot demonstrated that the technology is not ready for full-scale application at marine sediment sites, because it has not been demonstrated capable of achieving significant reductions in target contaminants. The treatment Pilot also demonstrated that the costs of the treatment may be very high, even if improvements to its performance can be achieved in the future.

7.4 Sludge Dewatering Tests

In support of the Feasibility Study evaluations of sediment removal, treatment and disposal options, dewatering tests were performed during 2004 for the ASB sludges. These tests were performed under Addendum No. 5 to the Project Work Plans. The testing report is included as Appendix D.

The dewatering tests were performed on the ASB sludges to evaluate the operational parameters for mechanically-enhanced dewatering technologies that could be used to separate ASB sludges from entrained waters. These technologies are not typically practical for application to aquatic sediments. But the ASB sludges have very high water content, increasing the practicability of these technologies for achieving mass and volume reduction. As noted in Table 5-3, the average solids content of the ASB sludges is 17 percent, over three times lower than the average solids content of the Whatcom Waterway materials. The practicability of sludge dewatering by solids separation was established both by these high initial water contents, as well as by the successful application of the technology during localized sludge removal performed previously as part of ASB maintenance activities.

The dewatering tests involved three steps. First, composite sludge samples were collected from the ASB. Second these samples were tested to identify dewatering additives that may enhance mechanical separation of the sludges. Finally, bench-scale separation testing was performed to identify the range of final solids content achievable through commercially-available centrifugation or hydrocyclone separation technologies. These technologies are commercially available and are used in the separation of wastewater treatment solids at wastewater treatment plants and industrial facilities around the country. The technologies are relatively costly, but can achieve a significant reduction in sludge mass and volume. The practical limits of the technology vary with the properties of the specific sludge materials. Generally wastewater treatment solids have a high water retention behavior, resulting in practical solids content limitations in the 30-50 percent range. As described in Appendix D, the dewatering tests indicated that the average solids content of the ASB sludges could be increased by a factor of two over its *in situ* solids content through enhanced dewatering.

8 Conceptual Site Model

This section summarizes the results of the Remedial Investigation, and provides a Conceptual Site Model (CSM) for the Whatcom Waterway Site. The CSM provides a concise summary of the information developed in the RI process. The key elements of the CSM include the following:

- Contaminants and Sources (Section 8.1)
- Nature and Extent of Impacts (Section 8.2)
- Contaminant Fate and Transport Processes (Section 8.3)
- Exposure Pathways and Receptors (Section 8.4)

Graphical illustrations of the CSM are included in Figures 8-1 and 8-2. The CSM is provided to assist the reader in review of site information, and to assist the reader in evaluating the appropriateness of potential remedial strategies discussed in the site FS (Volume 2 of the RI/FS). The reader should refer to previous sections of this report for the detailed information on which the CSM is based.

8.1 Contaminants and Sources

As measured by relative concentration and frequency of detection, the principal contaminants in the site sediments are mercury, 4-methylphenol, and phenol. Table 8-1 summarizes the principal contaminants and sources for the Whatcom Waterway Site. The table includes a summary of the status of source control activities. Refer to Section 6.1 of this report for a more detailed discussion of the site source control status.

- **Mercury Contamination is Predominantly from Historical Sources**: The primary source of mercury within the Whatcom Waterway Site sediments was the discharge of mercury-containing wastewaters from the Chlor-Alkali Plant between 1965 and the 1970s. This historic source of mercury contamination has been controlled. Following initial pollution control upgrades by Georgia Pacific in the early 1970s, direct discharge of Chlor-Alkali Plant wastewaters to the Whatcom Waterway was terminated. Then in 1999 the Chlor-Alkali Plant was closed by Georgia Pacific, eliminating the generation of mercury-containing wastewater. The clean up of the Log Pond area in 2000 and 2001 controlled the secondary source of mercury by capping contaminated sediments in this area. Some regional and natural sources of mercury continue to exist, but these sources are not expected to result in exceedances of Site screening levels.

- **Phenolic Compounds are Predominantly from Historical Sources:** The primary sources of phenolic compounds within the Whatcom

Waterway Site sediments include historical wood products handling and log rafting, historical pulp mill discharges prior to implementation of primary and secondary wastewater treatment, and potential lesser contributions from historical stormwater and wastewater discharges. These sources have been controlled. Wood products handling activities are less common than there were historically, and additional regulatory and permitting requirements minimize the potential for discharges of wood wastes to sediments. Pulp mill wastewater discharges were better controlled after the 1960s and 1970s, and discharge of process wastewaters to the Whatcom Waterway were terminated in 1979. The pulp mill was closed by GP in 2000, terminating the discharge of pulp and chemical plant wastewaters to the ASB.

Because primary contamination sources have been controlled, the main focus of the remaining site cleanup actions will be to address secondary contamination sources, the residual contamination in sediments at the site.

A number of other contaminated sites are located in the vicinity of the Whatcom Waterway Site and are being addressed by Ecology. These sites do not represent a current source control concern for Whatcom Waterway Site sediments or surface water quality.

8.2 Nature and Extent of Contamination

The nature and extent of contamination impacts within the Whatcom Waterway Site have been conclusively determined through over a decade of intensive investigations as part of the RI/FS and Bellingham Bay Pilot activities. These investigations in turn build on previous studies performed by academic researchers, regulatory agencies, local industry, and government. The result is a wealth of knowledge about site conditions, and the factors that influence the selection of a final site cleanup.

The findings of the site investigations are the focus of this RI report. Table 8-2 provides a quick summary of the principal RI activities and their findings. These findings are graphically displayed as a CSM in Figures 8-1 and 8-2.

- **Waterway Sediments:** The Whatcom Waterway sediments generally consist of a layer of soft, silty, impacted sediments. The elevation and thickness of the impacted layer varies with location, but is generally between 2 and 10 feet in thickness. The sediments are thickest in historically dredged and filled areas along the Inner Waterway. The impacted Waterway sediments are subject to natural recovery by ongoing deposition of clean sediments. Except in some high-energy, nearshore areas offshore of the ASB, the impacted sediments are covered by a layer of clean sediments. These clean sediments have been naturally deposited, and the surface sediments of the bioactive zone comply with sediment screening levels protective of environmental receptors. This process of natural recovery is expected to continue. Mercury concentrations within the site subsurface sediments are typically in the low part-per-million range, and average subsurface mercury concentrations decrease with distance from the Log Pond source area. Phenolic compounds are also present in the Waterway in the low part-per-million range. The highest phenolic concentrations were detected in subsurface sediments within the Inner Waterway, near the historic pulp mill effluent discharge locations from the 1950s and 1960s. The impacted sediments are underlain by clean, native sandy sediments of varying thicknesses.

- **Log Pond Sediments:** The Log Pond area was the site of the historic mercury-containing wastewater discharge from the Chlor-Alkali Plant during the 1960s and 1970s. Subsurface sediments in this area contain the highest mercury levels present at the site. This area was remediated by capping as part of an Interim Action that was implemented in 2000 and 2001. Sediment monitoring since that time has demonstrated that the cap is performing well, and is successfully preventing underlying contaminants from migrating upward through the cap. Monitoring of groundwater discharges in the cap area has demonstrated no ongoing impacts to surface water quality or cap conditions from the adjacent Chlor-Alkali Plant upland areas. Biological monitoring has demonstrated that the capped area has recovered biological functions for benthic and epibenthic organisms, for juvenile salmonids, and shellfish. Tissue monitoring has demonstrated that bioaccumulation risks have been successfully controlled, and crab tissue sampled from the area is not significantly different from crabs collected from clean reference sites. Some wave-induced erosion has been noted at the shoreline edges of the cap, and enhancements to these areas will be required to prevent cap recontamination and to maintain the long-term protectiveness of the remedy. The Feasibility Study includes proposed cap enhancements as part of the final remedial alternatives for the Whatcom Waterway Site.

- **ASB Areas:** Figure 8-2 provides a graphical summary of the conditions in the ASB area. The ASB was originally constructed as a stone, sand, and clay berm, enclosing a basin dredged in 1978. Some impacted sediments exist underneath portions of the berm. However, the berm consists primarily of clean materials imported at the time of construction. A thick layer of wastewater treatment sludges has accumulated within the ASB. These sludges are soft, flocculent, high-organic materials containing elevated levels of mercury, phenolic compounds and other contaminants. However, the sludges have not significantly impacted the clean native sands underlying the basin. The evaluation of potential remedial alternatives for the ASB area will take into account the special physical and chemical properties of the ASB materials, and the planned future uses of the ASB area.

- **Starr Rock Area:** Site investigations have documented the nature and extent of contamination present at the former Starr Rock dredge disposal site. This area is located in a deep-water, low energy portion of the Whatcom Waterway Site. Natural recovery has occurred in this area, with impacted mercury and phenol-impacted sediments being covered by clean sediments. There are no current exceedances of site screening levels in this area.

8.3 Fate and Transport Processes

Sediments within the Whatcom Waterway Site are acted upon by natural and anthropogenic forces that affect the fate and transport of sediment contaminants. Fate and transport processes are summarized on Table 8-3. Significant fate and transport processes evaluated as part of the RI include the following:

- **Sediment Natural Recovery:** Processes of natural recovery have been extensively documented within the Whatcom Waterway Site. Most areas of the site are stable and depositional, and clean sediments continually deposit on top of the sediment surface. RI investigations have documented depositional rates and have verified that patterns of deposition and natural recovery are consistent throughout most site areas. The exception to this general observation is in nearshore, high-energy areas where recovery rates are reduced by the resuspension of fine-grained sediments. In all other areas of the site, cleaner sediments are consistently observed on top of impacted sediments throughout most areas of the site. As part of the 2000 RI/FS, site data and recovery models were used to produce quantitative estimates estimate natural recovery rates. These estimates were then empirically verified by re-sampling surface sediments and comparing observed recover rates with model predictions.

- **Erosional Processes:** The effects of wind/wave erosional forces represent the principal natural process affecting sediment stability. RI investigations and FS engineering evaluations have identified high-energy, nearshore areas where the natural deposition of fine-grained sediments does not occur, or occurs at slower rates. In these areas, fine-grained sediments can be resuspended, mixed, or transported by wave energy. The erosional forces vary with location, water depth, sediment particle size, and shoreline geometry. These forces are minimal in deep-water areas which represent the majority of the Whatcom Waterway Site. The Feasibility Study incorporates analyses of erosional forces in consideration of site remediation areas and applicable technologies.

- **Navigation Dredging and Shoreline Infrastructure:** Navigation dredging and the construction of associated shoreline infrastructure has been a prominent feature of the Whatcom Waterway Site, and has shaped the current site lithology. The RI/FS includes extensive discussion of historic and future navigation and infrastructure issues that could affect site sediments. The FS incorporates potential future dredging activities as part of the evaluation of the long-term effectiveness of the remedial alternatives. The companion EIS document assesses the inter-relationships between site cleanup decisions and community land use and habitat enhancement objectives, consistent with the goals of the Bellingham Bay Demonstration Pilot.

- **Other Processes:** As part of the evaluation of sediment stability, the RI included a discussion of bioturbation, propeller wash, and anchor drag. These processes can result in periodic disturbances of the sediment column, and can enhance mixing of surface sediments with underlying sediments. These processes are all ongoing and are incorporated in the empirically measured rates and performance of natural recovery. However, they are relevant in the evaluation of the long-term stability of subsurface sediments. Propeller-wash in particular will affect sediment stability in near-shore navigation areas. These factors are incorporated into the FS analysis of remedial alternatives.

8.4 Exposure Pathways and Receptors

Section 4 of this RI report discusses the principal environmental receptors and exposure pathways applicable to the Whatcom Waterway Site. That section also discusses the site screening levels that are used to evaluate protection of these receptors. Exposure pathways and receptors are illustrated in Figures 8-1 and 8-2, and are summarized in Table 8-4.

- **Protection of Benthic Organisms:** The primary environmental receptors applicable to the Whatcom Waterway Site consist of sediment-dwelling organisms. These benthic and epibenthic invertebrates are located near the base of the food chain and are important indicators of overall environmental health. Both chemical and biological monitoring are used to test for toxic effects. Chemical and biological standards specified under the Sediment Management Standards are used to screen for such effects. The whole-sediment bioassays provide an ability to test for potential synergistic effects between multiple chemicals, and to test for potential impacts associated with parameters not measured as part of chemical testing.

- **Protection of Human Health:** Mercury is one of the primary contaminants present at the Whatcom Waterway Site. Mercury can be converted to methylmercury which in turn can bioaccumulate through the food chain. As part of the 2000 RI/FS a BSL was developed that would be protective of both recreational and tribal fishing and seafood consumption practices. The BSL was developed using very conservative exposure assumptions, to ensure that the value would be protective. An additional degree of protectiveness has been obtained in the way that the BSL is applied by Ecology to the site decision-making. Specifically the BSL has been applied as a "ceiling" value for all surface sediments at the site, including individual data points or clusters. This application provides a substantial additional degree of protectiveness, because it is the area-weighted average sediment mercury concentration that drives biological risks. Area-weighted average concentrations within the Whatcom Waterway Site are between two and three times lower than the BSL itself. The FS considers remediation of all areas exceeding the BSL on a point-by-point basis, even though the area-weighted average is already below the BSL. This application of the BSL further reduces the potential risks associated with the site.

- **Protection of Ecological Health:** As with human health, ecological receptors can be impacted by mercury bioaccumulation. However, the application of the BSL to cleanup at the site ensures protectiveness to ecological receptors. The protectiveness of the BSL to ecological receptors was evaluated in two ways. First, the protectiveness of the BSL was evaluated against potential marine mammal exposures. Second, bioaccumulation testing has been performed on sediments from the Whatcom Waterway Site at concentrations exceeding the BSL, demonstrating no significant bioaccumulation at these sediment concentrations. Third, tissue monitoring has been performed at the site as part of the Log Pond Interim Action. That monitoring has shown that compliance with the BSL prevents the accumulation of mercury in crab tissue in comparison to clean reference areas. Based on these three lines of evidence, the compliance with the mercury BSL and with SMS criteria for benthic organisms results in protection of ecological receptors.

- **Other Considerations:** The Feasibility Study includes evaluations of remedial technologies that may trigger new exposure pathway and receptor risks. For example, dredging of impacted sediments triggers short-term risks at the point of dredging and in material handling areas, and during transport of these materials to the disposal site. Additional exposure pathways and receptors are potentially affected at the location of dredge material disposal. The RI included engineering testing that was focused on providing empirical data necessary to evaluate these additional exposure pathways and receptor risks. These data are then used as part of the FS, in conjunction with applicable regulatory guidelines and requirements, to evaluate the feasibility, protectiveness, and costs of different remedial strategies.

8.5 RI Conclusions

In summary, the nature and extent of contamination at the Whatcom Waterway Site has been defined. Primary contaminant sources have been controlled, and sufficient information is available to define protective cleanup levels for final site cleanup. The final site cleanup will address areas of remaining sediment contamination, and will protect human health and environmental receptors by terminating remaining exposure pathways. The data collected in the RI are sufficient for development of the site FS. The CSM provides a summary of significant factors that must be addressed by the remedial alternatives evaluated in the FS.

Table 8-1 Summary of Principal Contaminants and Sources

Principal Site Contaminants	Principal Source(s)	Source Control Status
Mercury	Wastewater Discharges to Log	**Controlled**
		- Discharges terminated in the 1970s
	Groundwater Discharges to Log Pond	**Controlled**
		- Monitoring indicates no continuing discharges affecting Log Pond sediments or water quality
		- Additional actions to be evaluated as part of the chlor-alkali site RI/FS and site cleanup
	Log Pond Sediments	**Partially Controlled**
		- Area capped as part of successful interim action
		- Cap enhancements to be included in final site cleanup to ensure long-term stability of cap edges
	Historic Dredge Disposal	**Controlled**
		- Rigorous dredge material characterization and management protocols now required by regulation and permit for all dredging projects
	Chlor-Alkali Plant Discharges to ASB	**Controlled**
		- Chlor-alkali plant was closed and demolished by GP, with termination of wastewater discharges to the ASB.
Phenolic Compounds	Historic Pulp Mill Discharges to Waterway	**Controlled**
		- NPDES Wastewater improvements implemented in the 1970s, including primary & secondary treatment, and termination of waterway discharges.
		- Early remedial efforts completed in the Whatcom Waterway included sediment removal actions in 1974
	Pulp Mill Discharges to ASB	**Controlled**
		- Pulp mill and associated chemical plant were closed by by GP, with termination of associated wastewater discharges to the ASB.
	Wood Waste from Log Rafting	**Controlled** - Cargo shipments of logs and wood products have been reduced, and additional regulatory and permit-required pollution controls apply to log/wood handling activities.
	Historic Sewer Outfalls	**Controlled**
		- Sewage treatment and discharge improvements implemented in the 1960s and 1970s.
	Stormwater Discharges	**Controlled**
		- Ongoing stormwater system upgrades to reduce/eliminate CSO events.
		- No evidence of ongoing sediment impact in intermittent CSO area
		- Enhanced stormwater management practices, permitting and monitoring.

Table 8-1 Summary of Principal Contaminants and Sources

Principal Site Contaminants	Principal Source(s)	Source Control Status
Other Compounds	**Boatyard Wastes**	**Controlled**
	(Copper, Zinc, TBT)	- Closure of early over-water boat lift formerly located adjacent to Colony Wharf site.
		- Enhanced stormwater controls and permitting at Colony Wharf site.
	Creosoted Pilings (PAH Compounds)	**Controlled**
		- Changes in materials use for new construction
		- Ongoing pile removal programs being implemented by Port, DNR and Ecology.
	Cargo Spillage (PAH Compounds, Wood Waste)	**Controlled**
		- Reductions in Log/Wood/Chip handling
		- Changes in cargo handling practices
		- Proactive materials management planning for new cargos
	Phthalate & Nickel Sources (I&J Waterway Site Area)	**Controlled**
		- Elimination of historic sources of these compounds (i.e., Olivine ore, historic plant fire)
		- Investigation & Cleanup of the I&J Waterway site under an Agreed Order and Ecology oversight
Contaminants at Adjacent Sites		**Controlled**
		Actions at other waterfront sites coordinated under the Department of Ecology, these sites do not represent a current source control concern.

Notes:

This table summarizes primary sources of sediment contamination. Secondary sources of sediment contamination (i.e., volumes of impacted sediment present at the site) are to be addressed as part of the final remedial action evaluated in the RI/FS.

Section 2 of the RI contains an overall history of the Whatcom Waterway site.

Section 6.1 of the RI includes a detailed discussion of site source control activities.

Table 8-2   Nature & Extent of Impacts

Site Study Area	Study Topics	Principal RI Activities & Findings	Quick Reference to Relevant RI Sections
Waterway Sediments	Assess current site lithology, including the impacts of historic dredging and shoreline development activities	Site lithology characterized through review of historic records, review of historic sediment borigns, and completion of extensive subsurface physical and chemical testing	Section 3.1 includes a discussion of site lithology, with accompanying geologic cross-sections developed from subsurface explorations.
	Document the nature & extent of current impacts in the bioactive zone (surface sediments)	Surface sediment testing performed using chemical testing and whole-sediment bioassays	Section 5.2 figures, tables and text summarize the results of chemical and bioassay testing.
	Documentation the extent of natural recovery processes occurring at the site	Natural recovery processes studied with cores and sediment traps, modeled quantitatively and then verified through direct observation of decreasing sediment concentrations	Section 6.2 documents natural recovery processes evaluated at the site. Changes in surface sediment conditiosn over time are documented in Section 5.2.
	Quantify the nature & extent of subsurface sediment impacts	Core sampling used to directly assess the nature and extent of subsurface sediment impacts	Subsurface sediment quality summarized in Section 5.3. Refer also to the cross-sections and the lithology discussion in Section 3.1.
	Assess potential dredge disposal properties of waterway sediments	Dredge disposal suitability testing performed in support of the Feasibility Study	Previous dredge material evaluations summarized in Section 7, and in Appendix H.
Log Pond Sediments	Delineate surface & subsurface impacted sediments	RI activities included surface and subsurface testing prior to implementation of Log Pond Interim Action	Surface and subsurface sediment quality data are summarized in Section 5.2 and 5.3.
	Monitor effectiveness of Interim Action and assess any potentially appropraite cap enhancements	Effectiveness of Interim Action has been assesed through implementation of Year-1, Year-2 and Year-5 monitoring events	The Year-5 Log Pond Monitoring report is attached as Appendix I. Proposed enhancements to the Log Pond cap are discussed in the site Feasibility Study.
	Assess the potential performance of in situ treatment technologies for application at the site	In situ treatment pilot test performed in support of the Feasibility Study	Results of ECRT pilot testing are summarized in Section 7.
ASB Areas	Assess current site lithology, including the impacts of historic dredging and shoreline development activities	Site lithology characterized through review of historic records, review of historic sediment borings, and completion of extensive subsurface physical and chemical testing	Section 3.1 includes a discussion of site lithology, with accompanying geologic cross-sections developed from subsurface explorations.
	Assess the volume and thickness of the ASB sludges	Bathymetric and invasive physical testing used to quantify the volume of the ASB sludges	Bathymetric data are summarized in Section 3.1 and accompanying figures. Physical testing data are summarized in Appendix C and Appendix D to the RI.
	Assess the chemical Properties of ASB Sludges	Core sampling used to document concentrations of mercury, phenoloic compounds and other contaminants in ASB sludges.	Chemical properties of the ASB sludges are summarzied in Section 5.3 and the accompanying figures and tables, and in Appendix C.
	Evaluate the characteristics of the ASB berm materials	Berm sand quality assessed through direct chemical and physical testing, to assess potential for reuse of these materials.	Chemical properties of the berm sands are summarzied in Section 5.3 and the accompanying figures and tables, and in Appendix D.
	Quantify the characteristics of the sands underlying the ASB	Chemical and physical testing performed for the sands underlying the ASB sludges	Chemical properties of the berm sands are summarzied in Section 5.3 and the accompanying figures and tables, and in Appendix C.
	Assess the physical properties of the sludges relevant to site remedial decisions	Physical properties of the sludges assessed through physical and geotechnical testing, and during dewatering tests performed in support of the Feasibility Study.	Geotechnical properties of ASB materials are included in Appendix C. Dewatering test results are summarized in Section 7, and in Appendix D.
Starr Rock Area	Nature & extent of historic dredge disposal area	Area of dredge disposal documented through review of historic records, site bathymetric monitoring and delineation of sediment areas containing elevated mercury levels	Disposal site location identified in Figure 3-1. Sediment quality data are summarized in Section 5.2 and in associated figures and tables.
	Effectiveness of natural recovery	Site monitoring has verified compliance with sediment standards (biological SQS and site-specific BSL)	Current site data are summarized in Section 5.2 and in Figure 5-2.

Table 8-3 Fate & Transport Processes

Fate & Transport Process	Principal Issues & Observations	Summary of RI Findings
Natural Recovery	Deposition of clean surface sediments	Gross & net deposition rates quantified with sediment traps and natural recovery cores
		Reductions in contaminant concentrations documented and correlated to specific time signatures in sediment cores
		Consistent recovery pattern verified with core and grab sampling throughout site
	Measurement of natural recovery rates	Previous natural recovery studies by others
		Predictive recovery modeling as part of 2000 RI/FS
	Verification of recovery model outputs	Measured reduction of surface sediment contaminant levels between 1996/1998 and 2002 sampling events
		Observed contaminant reductions consistent with 2000 model outputs.
	Limitations of natural recovery	Areas of reduced natural recovery identified through physical and chemical mapping, and analysis of erosional properties.
Erosional Processes	Reduced natural recovery in high energy, shallow-water areas	Shallow-water, high energy areas with low natural recovery rates identified offshore of ASB
	Redistribution of fine-grained sediments in nearshore areas	Wind and wave energy analysis conducted as part of RI/FS activities to identify areas of potential significance
		Shoreline stability incoroporated into Feasibility Study and remedial design evaluations
	Shoreline infrastructure needs assessed in relation to navigation uses and shoreline/waterway geometry	Analysis of shoreline stability and potential future shoreline infrastructure needs incorporated into Feasibility Study
Navigation Dredging	Impacts to waterway and ASB bathymetry	Historic dredge contacts documented as part of site lithology
	Periodic re-exposure of subsurface sediments if remaining within proposed dredge units	Potential future navigation dredging needs incorporated into Feasibility Study and remedial design evaluations
	Historic dredge disposal areas	Extent of dredge disposal impacts quantified in Starr Rock area
	Potential disposal options for future navigation dredging	Dredge material characterizations incorporated into RI activities in support of Feasibility Study
Bioturbation	Formation of mixed bioactive zone	Bioactive zone thickness measured to be 12 cm
	Periodic deep sediment mixing	Analaysis of potential deep mixing events conducted
Propellor Wash	Potential sediment erosion in navigation areas	Propellor wash issues identified for evaluation as part of Feasibility Study and remedial design efforts
Anchor Drag	Periodic mixing of surface & subsurface sediments in anchorage areas	Limited impact due to limited use of anchors within principal site areas (i.e., availability of dock moorage, alternative anchorage sites)
		Potential for periodic deep mixing evaluated for consideration during RI/FS and remedial design

Notes:

Natural recovery and fate and transport processes are described in Section 6.2 and 6.3 of the RI report.

Land use and navigation issues are discussed in Section 3.3 of the RI report.

Table 8-4 Exposure Pathways and Receptors

Receptor	Exposure Pathway	Basis for Evaluating Protectiveness
Benthic Organisms	Direct toxicity to benthic/epibenthic invertebrates	Screening for areas of potential impact using SMS numeric standards
		Verification using whole-sediment bioassays and SMS interpretive criteria
Human Health	Contaminant exposure through consumption of seafood containing bioaccumulated mercury and/or methylmercury	Development of a site-specific BSL as part of 2000 RI/FS activities to identify sediment concentrations that will prevent significant bioaccumulation impacts
		Conservative application of BSL in site decision-making to ensure a substantial additional degree of protectiveness
Ecological Health	Exposure of higher trophic level wildlife (e.g., whales) through consumption of benthic organisms	BSL assessed to verify its protectiveness of potential wildlife exposures
		Verification of BSL protectiveness through sediment bioaccumulation tests and seafood tissue monitoring
Other Consideratio ns	Cross-media transfers (e.g., contaminant leaching) and subsequent exposure to human health or environmental receptors	Contaminant mobility studies conducted in support of Feasibility Study and Remedial Design efforts
	Direct contact of human health and ecologyical receptors at dredge disposal locations	Applicable regulatory standards for dredge disposal scenarios evaluated as part of Feasibility Study

Notes:

Section 4 contains a summary of exposure pathways and receptors, and a discussion of the screening levels used to evaluate the protectiveness of site conditions under these exposure conditions.

Figure 8-1
Conceptual Site Model – Part 1 of 2
(Log Pond and Waterway Areas)

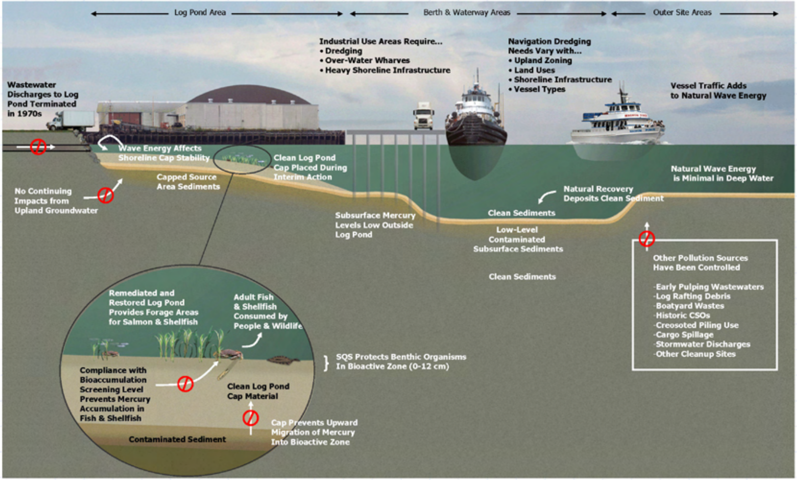
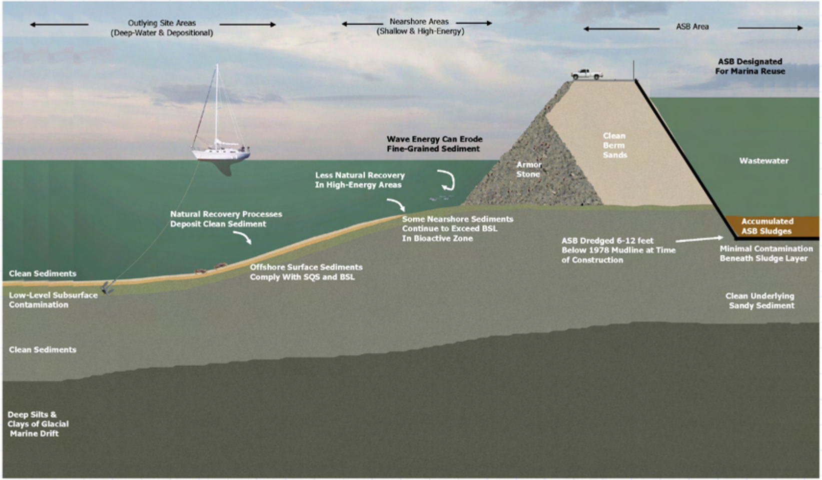


Figure 8-2
Conceptual Site Model – Part 2 of 2
(ASB and Outlying Site Areas)



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Appendix A

Pre-Remedial Design Evaluation Report (2003)

Appendix B

Sediment Data Summaries from 2000 RI/FS

Appendix C

2003 ASB Sampling Data

Appendix D

Results of 2004 Testing of ASB Sludges and Berm Sands

Appendix E

Data and Regression Analyses from BSL Development

Appendix F

Colony Wharf Sediment Sampling Report

Appendix G

Enrichment Ratio Summaries for Subsurface Sediments

Appendix H

Previous PSDDA Suitability Evaluations

Appendix I

Year 5 Log Pond Monitoring Report