10. FEASIBILITY STUDY REPORT ORGANIZATION

The Feasibility Study (FS) builds upon the results of the RI presented in Volume I of this report. The FS is intended to provide sufficient data, analysis, and engineering evaluations to enable Ecology to select a cleanup action alternative that is protective of human health and the environment.

There are five sections of the FS Report following this introduction section, as summarized below:

- **SECTION 11 – Sediment Cleanup Requirements.** This section provides a review of the available data, including summary assessments of SMS cleanup criteria comparisons, source control, and potentially applicable laws, to provide a framework of appropriate sediment cleanup requirements for the WW Area.
- **SECTION 12 – Establishment of Site Sediment Units.** This section reviews the RI data presented in Volume I and establishes site sediment units (SSU) based on unique physical, chemical, biological, and navigational/land use characteristics.
- **SECTION 13 – Identification and Assembly of Cleanup Technologies.** This section identifies and screens potential cleanup technologies, applies them to the appropriate SSUs identified in Section 12, and assembles potential remedial action alternatives.
- **SECTION 14 – Detailed Evaluation of Cleanup Action Alternatives.** This section evaluates the different remedial action alternatives identified in Section 13 based on SMS evaluation criteria as generally described in the Sediment Cleanup Standards User Manual and the MTCA Cleanup Standards Regulation.
- **SECTION 15 - References.** This section presents references used in the development of the RI/FS.

Volume III of the report contains technical appendices for both the RI and FS reports. Appendices A-J provide additional information supporting the RI, and Appendices K-N provide additional information supporting this FS.

Appendix K provides additional information on the natural recovery modeling used to evaluate alternatives. Appendix L summarizes the Puget Sound Dredged Disposal Analysis (PSDDA) evaluation completed as part of the FS, following Addendum No. 2 to the RI/FS Project Plans (Hart Crowser, 1997b). Appendix M summarizes the sequential batch leaching test data completed as part of the FS, also following Addendum No. 2 to the RI/FS Project Plans. Appendix N presents FS-level cost estimates and costing assumptions for each of the remedial action alternatives evaluated in Section 14.

11. SEDIMENT CLEANUP REQUIREMENTS

The SMS sets forth a sediment cleanup decision process for identifying contaminated sediment areas and volumes, and determining appropriate cleanup responses. The SMS governs the identification and cleanup of contaminated sediment sites and establishes two sets of numerical chemical criteria against which surface sediment concentrations are evaluated. The more conservative SQSs provide a regulatory goal by identifying surface sediments that have no adverse effects on human health or biological resources. The MCUL, numerically equivalent to the Cleanup Screening Level (CSL), represents the regulatory level for minor adverse effects. The SQS is Ecology's preferred cleanup standard, though Ecology may approve an alternate cleanup level within the range of the SQS and the MCUL if justified by a weighing of environmental benefits, technical feasibility, and cost. Chemical concentrations or confirmatory biological testing data may define compliance with the SQS and MCUL criteria.

11.1 Sediment Management Standards – Criteria Comparisons

As described in Section 4.0 of this RI/FS Report, chemicals of potential concern identified in surface (0 to 10 cm) sediments at the WW Area include mercury, 4-methylphenol, phenol, and wood material. These chemicals or parameters were regularly detected in surface sediments at concentrations that exceeded existing SQS and MCUL chemical criteria.

Sediment samples from 40 site locations were submitted during the conduct of this RI/FS for confirmatory biological testing to verify or refute sediment toxicity predicted on the basis of sediment chemical concentrations or the presence of wood material (see Section 5.0 of this RI/FS report). As set forth in the Whatcom Waterway RI/FS Project Plans, all surface samples that exceeded the current MCUL chemical criterion for mercury (0.59 mg/kg) or other SMS chemicals were submitted for confirmatory biological testing. In addition, consistent with a 1997 SMS Clarification Paper (Kendall and Michelsen, 1997), confirmatory biological testing was also performed on samples collected within the general WW Area that exceeded 20 percent wood material by volume.

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 SQS minor biological effects criteria). The remaining 40 percent of the locations exceeded SQS biological effects criteria, though only 15 percent (6 locations) exceeded the MCUL based on more than minor biological effects. Sediment toxicity was not correlated with mercury or with other chemical parameters. The spatial distribution of observed sediment toxicity is depicted on Figure 11-1.

Areas of the site that contained the highest mercury concentrations (greater than 1.2 mg/kg) were also considered for cleanup to address potential bioaccumulation risks to human health and to high trophic level wildlife receptors. Although the maximum fish and shellfish tissue concentrations detected in the WW Area are below benchmark concentrations calculated to protect tribal fishers and sensitive wildlife, sediments exceeding the derived bioaccumulation screening level for mercury of 1.2 mg/kg have the potential to contribute to bioaccumulation (see Section 6.0; Volume I). Further, as described in Section 6.6, Volume I, cleanup necessary to comply with sediment toxicity criteria would be slightly expanded to address potential human health and wildlife food web concerns.

Potential remediation areas were delineated using confirmatory biological testing data and bioaccumulation screening level comparisons to address food web concerns. Prospective remediation areas delineated in this manner are depicted on Figure 11-1.

It should be noted that Ecology is currently revising the SMS rule. A number of substantive changes are being considered, including updates of the chemical concentration criteria and the addition of human health criteria. Of particular interest to the WW Area is the possibility of an increase to the MCUL chemical criteria for mercury and area averaging of sediment concentrations for human health comparisons. These changes could decrease the area and volume of sediments currently targeted for cleanup. However, bioassay testing and interpretation procedures, which formed the basis for much of the site delineation within the WW Area, are not expected to change substantively in the revised rule. The rule revisions may be adopted in 2001, and cannot be implemented until they are adopted.

11.2 Source Control

As discussed in Section 8.0, Volume I of this RI/FS Report, and in the Sediment Site and Source Control Documentation Report (BBWG, 1999c) developed by the Pilot Project, no ongoing, significant sources of mercury, 4-methylphenol, phenol, or wood material have been identified within the WW Area that have the potential to recontaminate sediments beyond the immediate discharge location. Assessments of point source, surface water, groundwater, and other non-point sources of sediment contamination and potential localized water quality concerns are presented below. The Pilot's Sediment Site and Source Control Documentation Report (BBWG, 1999b) provides additional information on source control.

11.2.1 Point Source and Industrial Stormwater Discharges

A variety of point source and stormwater discharges into the WW Area are monitored and regulated by Ecology under the National Pollutant Discharge Elimination System (NPDES). Source control concerns identified by the Pilot Project, including potential localized water quality issues, are presented below:

- **Bellingham Marine Industries** (BMI; Whatcom Waterway). A stormwater runoff sample collected from this site contained concentrations of copper, mercury, silver, and zinc that exceeded water quality criteria (see Section 8.0, Volume I). However, because these contaminants have not been detected in adjacent sediments at concentrations exceeding SQS chemical criteria, and since nearshore sediments in this area did not exceed SQS biological effects criteria, the BMI site is not an identified ongoing source of sediment contamination.

- **Bornstein Seafoods** (I&J Waterway). Wet and dry season runoff samples collected from this site contained concentrations of arsenic, cadmium, copper, silver, and zinc that exceeded water quality criteria (see Section 8.0, Volume I). However, because these contaminants have not been detected in adjacent sediments at concentrations exceeding SQS chemical criteria, the site is not an identified ongoing source of sediment contamination. Exceedances of SQS biological effects criteria in nearshore sediments in this area appear to be attributable to bis(2-ethylhexyl)phthalate releases from the adjacent Olivine Nearshore Area (see Section 11.2.3).
- **G-P WWTP Outfall**. Detailed sampling and analysis of the G-P effluent discharge is presented in Section 8.0, Volume I of this RI/FS Report. Based on detailed modeling, the G-P Outfall has not been identified as an ongoing source of mercury to Bellingham Bay. Near-term natural recovery of relatively small historical (1993) areas of contaminated sediments at this site is anticipated (1993 exceedances of SQS criteria are depicted on Figure 11-1, based on data presented in BBWG, 1999b). Nevertheless, further discharge controls are being implemented by G-P, including the pending closure of the chlor-alkali plant. These pending controls will reduce mercury releases from the outfall by at least another 50 percent (based on G-P's NPDES monitoring data). Ongoing discharge monitoring is being performed under Ecology's NPDES program to ensure continued protection of sediment and water quality. Additional sediment sampling will occur to further evaluate sediment quality and to document the effectiveness of source controls at the outfall site.

11.2.2 <u>Groundwater Discharges</u>

Groundwater flows into Bellingham Bay from the surrounding uplands. Once groundwater reaches the bay, it discharges both vertically (upwards) and laterally, primarily into shoreline areas. As groundwater moves through contaminated upland soil areas, concentrations of contaminants increase. Four regions within the WW Area site are known to be sources of localized groundwater contamination. Focused cleanup investigations have been performed or are ongoing at each of these sites (BBWG, 1999b). These sites and the contaminants identified in groundwater include:

- **G-P Log Pond**. Low-level (part-per-billion) mercury concentrations have been detected in shallow groundwater adjacent to the G-P Log Pond (ENSR, 1994). Shoreline seepage may contain similar or lower concentrations due to tidal mixing and chemical attenuation (see Section 14.0 below). Even without attenuation, the low-level mercury concentrations detected in shallow groundwater represent a low mass loading to the Log Pond. Further, substantial source control is indicated in the Log Pond area, as evidenced by the progressive reduction in surface sediment mercury concentrations over time. Nevertheless, control of potential seepage releases to the G-P Log Pond is being addressed as a component of remedial alternatives carried forward into detailed evaluation (Section 14.2.3). The need for further groundwater controls will be evaluated as part of chlor-alkali facility closure follow up actions.

- **Roeder Avenue Landfill.** This historic municipal landfill is located between the Whatcom and I&J Waterways. Groundwater quality monitoring performed at locations adjacent to the landfill detected elevated levels of chromium (above MTCA cleanup levels and marine water quality criteria) migrating towards Bellingham Bay (Cubbage, 1996). However, sediment samples collected within the projected groundwater discharge area have not exceeded SQS chemical criteria for chromium. The Port is addressing control of groundwater seepage releases as a component of a focused RI/FS for this site.
- **Cornwall Avenue Landfill.** This site is located at the foot of Cornwall Avenue. Groundwater and shoreline seepage samples collected in this area have contained low concentrations of copper, lead, and fecal coliform exceeding water quality criteria (Landau, 1999). Nearshore sediments in this area also exceed SQS chemical criteria for metals, PCBs, and solid waste. Continued erosion of solid waste from the exposed landfill shoreline is an ongoing source of sediment contamination. Control of seepage and erosion releases from the Cornwall Avenue Landfill is being addressed separately from this RI/FS, both as a component of the Pilot Project's Near-term Remedial Alternatives, and by a concurrent focused FS of the Cornwall Landfill.
- **R.G. Haley**. This site is directly north of Cornwall Avenue Landfill. Groundwater and shoreline seepage in the vicinity of this former wood treating facility have contained detectable concentrations of pentachlorophenol and polynuclear aromatic hydrocarbons (PAHs; Ecology and Environment, 1991). In addition, wet and dry season runoff samples collected from the site contained concentrations of copper that exceeded water quality criteria (see Section 8.0, Volume I). However, because copper, pentachlorophenol, and PAHs have not been detected in adjacent sediments at concentrations exceeding SQS chemical criteria, the site is not an identified ongoing source of sediment contamination.

11.2.3 Other Non-Point Sources

In addition to discrete point sources and discernable areas of groundwater contamination, several non-point sources of contamination have also been identified within Bellingham Bay:

- **Urban Stormwater Runoff - "C" Street and R.G Haley Area Outfalls.** Surface water runoff from these and other City storm drains contain concentrations of dissolved copper and other metals that exceed freshwater and marine ambient water quality criteria (Ostergaard, 1992; McCourt, 1998; see also Section 8.0; Volume I). The highest concentrations of metals have been reported during "first flush" storm events preceded by extended dry weather periods. Similarly elevated metal concentrations in urban runoff have also been documented throughout Puget Sound, and appear to be the result of normal vehicle releases (e.g., due to tire wear). Although metal concentrations in stormwater runoff currently exceed marine water quality criteria at the outfall point of discharge, preliminary outfall modeling suggests that the extent of such exceedances within nearshore areas of Bellingham Bay are limited to an area of less than 1 acre (BBWG, 1999b). Further, because copper, lead, zinc and other metals (excluding mercury) have not been detected in adjacent sediments at concentrations exceeding SQS chemical criteria, urban stormwater runoff is not an identified ongoing source of sediment metal contamination. Moreover, with the exception of those outfalls located near historical wood material deposits, sediment samples collected immediately adjacent to urban stormwater runoff outfalls discharging to the WW Area (e.g., at the head of the Whatcom Waterway and at Boulevard Park), did not exceed SQS biological effects criteria.

In addition to metals, accumulated particulate matter present within the City's stormwater runoff conveyance system has periodically contained elevated (above SQS criteria) concentrations of phenol and 4-methylphenol (Cubbage, 1994). Sediment samples collected adjacent to several stormwater runoff outfalls within the WW Area have also contained localized phenol and 4-methylphenol accumulations that could be partly attributable to discharges from the storm drains. However, preliminary outfall modeling suggests that the extent of such exceedances within nearshore areas of Bellingham Bay are limited to an area of less than 1 acre (BBWG, 1999b). Moreover, the overall distribution of phenol and 4-methylphenol in Bellingham Bay, and particularly within the WW Area, appears more closely associated with the historical deposits of wood material. Both phenol and 4-methylphenol are known degradation products of natural wood products (Hodson et al., 1983; Hatcher et al., 1988), and accumulations of these compounds in regional sediments is frequently associated with wood material deposits (EPA, 1989; PTI, 1998). All information considered, ongoing discharges from storm drain sources do not appear to represent a significant ongoing source of contamination to sediments.

Urban stormwater runoff is not currently regulated through permits. However, consistent with Ecology requirements, the City of Bellingham is developing a Comprehensive Stormwater Management Program to provide appropriate urban runoff controls and improve water quality. The plan is scheduled to be released in summer, 1999.

- **Wood Waste and Wood Material**. Accumulations of bark and associated wood material near the G-P Log Pond and in other areas of the Whatcom Waterway appear to be associated with historical practices. Although relatively limited log rafting operations continue in some areas of the Whatcom Waterway site (e.g., within the "Port Log Rafting Area" depicted on Figure 1-2), historically there was much more extensive log rafting throughout inner Bellingham Bay (PTI, 1989). In addition, historical discharges of pulp and other materials from the G-P facility are now controlled by a variety of improved handling, collection, and wastewater treatment processes, all of which are regulated under G-P's existing NPDES permit. Wood material releases to the G-P Log Pond, for example, have been controlled for more than 6 years.

- **Olivine Nearshore Area** (I&J Waterway). Chemicals of potential concern identified in surface sediments at this site include bis(2-ethylhexyl)phthalate and acenaphthene (see Section 4.0). Exceedances of SQS biological effects criteria in nearshore sediments within this area and also at the adjacent Bornstein Seafoods site, appear to be attributable to bis(2-ethylhexyl)phthalate releases from the Olivine site. Integrated upland and nearshore sediment cleanup and source control of the Olivine Site is being addressed as part of a RI/FS currently being performed by the Port of Bellingham.

  The source control data summarized above have not identified any ongoing, significant sources of mercury, 4-methylphenol, phenol, or wood material within the WW Area that will recontaminate sediments. Although continuing decay of historical wood material deposits may represent an "internal" source of 4-methylphenol and phenol, these concerns can be addressed through sediment cleanup.

Other programs are also underway to continue source controls within the WW Area. As summarized above, these other programs include:

- Pending closure of the G-P chlor-alkali plant.
- Integration of groundwater seepage controls to the G-P Log Pond with remedial alternatives developed in this RI/FS.
- Upland cleanup and source control actions being performed by other parties (e.g., Cornwall Avenue Landfill RI/FS, Olivine RI/FS; and Roeder Avenue Landfill RI/FS).
- Ongoing monitoring and control of NPDES permit discharges. and
- Pending development by the City of Bellingham of a Comprehensive Stormwater Management Program.
- Existing and pending source control actions within the WW Area appear to be sufficient to prevent future sediment recontamination following a cleanup action. However, this condition would need to be verified as a component of final remedial design prior to commencing a cleanup action.

11.3 Potentially Applicable Laws

Many environmental laws may apply to a sediment cleanup action. In addition to meeting SMS and MTCA requirements, a cleanup action must also meet the environmental standards in other *applicable laws* (this is required under both *cleanup standards* and *remedy selection criteria*). In addition, even though Ecology and the Pilot Project may select the cleanup remedy under the state hazardous waste cleanup and sediment laws, the cleanup action will require, at a minimum, environmental review and remedial permitting. The cleanup action is exempt from the procedural requirements of certain state and local environmental laws if conducted under an Ecology consent decree, but must meet the substantive requirements of such laws. Various agencies therefore review or approve the cleanup plan. Potentially applicable federal, state and local laws that may influence cleanup levels and remedial action(s) for the WW Area are summarized below.

11.3.1 Federal Requirements

Potential federal requirements are specified in several statutes, codified in the U.S. Code (USC), and promulgated in the Code of Federal Regulations (CFR), as discussed in the following sections.

The **National Environmental Policy Act (42 WSC 4321 *et seq.)***. The National Environmental Policy Act (NEPA) is intended to help the federal lead agency make decisions based on an understanding of the environmental consequences of their actions, and to help the federal government take actions that protect, restore, and enhance the environment. Any federal project, or a private or state project requiring a permit from a federal agency, must meet the NEPA requirements. If a proposal is determined by a federal lead agency to have a "probable significant adverse impact," the agency must prepare an EIS. The EIS is a public disclosure document that analyzes alternative means of attaining the applicant's goal for the proposal, and analyzes the environmental consequences of each alternative and the potential options for mitigating the impacts.

The **Clean Water Act (CWA) (33 USC Section 1251 *et seq.*)** requires the establishment of guidelines and standards to control the direct or indirect discharge of pollutants to waters of the United States. Effluent limitations developed for the regulated pollutants are applied to point source discharges on a case-by-case basis.

Section 304 of the CWA (33 USC Section 1314) requires EPA to publish **Water Quality Criteria**, which are developed for the protection of human health and aquatic life. Federal water quality criteria are published as they are developed, and many of them are included in *Quality Criteria for Water 1986*, EPA 440/5-86-001, May 1, 1986 (51 FR 43665), commonly known as the "Gold Book." Publications of additional criteria established since the Gold Book was printed are announced in the Federal Register. Federal water quality criteria are used by states, including Washington State, to set water quality standards for surface water. These standards are relevant and appropriate for possible sediment cleanup projects in the WW Area.

Sections 301, 302, and 303 of the CWA (33 USC Sections 1311, 1312, and 1313), and 40 CFR Part 131, require states to develop **Water Quality Standards** and to control direct discharges by establishing effluent limitations as necessary to meet applicable water quality standards. Numerical state water quality standards are usually based on federal ambient water quality criteria developed by EPA (discussed above). Washington State water quality standards are promulgated under the Washington Water Pollution

Control Act (Chapter 90.48 RCW; Chapter 173-201 WAC), discussed in Section 3.5.2.

National Pollution Discharge Elimination System (NPDES), State Waste Discharge Program (33 USC 1432; 40 CFR 21-25; RCW 90.48.260; WAC 173-216). The NPDES and State Waste Discharge programs implement permit systems applicable to industrial and commercial operations that discharge to groundwater, surface water, or municipal sewerage systems. In Washington, EPA has delegated the responsibility of administering the NPDES program to Ecology.

Safe Drinking Water Act (42 USC Section 300f *et seq.*; 40 CFR Parts 141 and 143). The Safe Drinking Water Act (SDWA) establishes standards designed to protect human health from the potential adverse effects of drinking water contaminants. Primary drinking water regulations include maximum contaminant levels (MCLs) for specific contaminants. Since MCLs are only applicable to suppliers of public drinking water, they are not applicable to the WW Area. However, MCLs for surface water or groundwater that are current or potential sources of drinking water are generally relevant and appropriate for ensuring that contaminant levels in the water are adequately protective. Groundwater may be impacted by remediation alternatives that include upland disposal options.

Discharges of Material into Navigable Waters are regulated under Sections 401 and 404 of the CWA (33 USC Sections 1341 and 1344), 40 CFR Part 230 [Section 404(b)(1) guidelines], 33 CFR Parts 320 (general policies), 323 and 325 (permit requirements), and 328 (definition of waters of the United States). These requirements regulate the discharge of dredged or fill material to waters of the United States, implemented by the U.S. Army Corps of Engineers (Corps). Under the Section 404(b)(1) guidelines, 40 CFR 230.10(b), no such discharge shall be allowed if it:

- Causes or contributes to violations of any additional state water quality standard, pursuant to Section 401 of the CWA, after consideration of disposal site dilution and dispersion;
- Violates any applicable toxic effluent standard or discharge prohibition under Section 307 of the CWA;
- Jeopardizes the continued existence of any endangered or threatened species, or contributes to the destruction or modification of any critical habitat for such species; or
- Violates any requirement imposed by the Secretary of Commerce to protect any marine sanctuary.

The guidelines in 40 CFR 230.10(c) also provide that no discharge will be authorized that contributes to significant degradation of the waters of the United States. Where there is no practicable alternative to a discharge, 40 CFR 230.10(d) requires the use of appropriate mitigation measures to minimize potential adverse impacts of the discharge on the aquatic ecosystem. The term "practicable" is defined in 40 CFR 230.3(q) to mean "available and capable of being done after taking into consideration cost, existing technology, and logistics in light of overall project purposes." Examples of specific steps that may be taken to minimize adverse impacts are set forth in 40 CFR Part 230, Subpart H. Section 401 and Section 404 requirements of the CWA may be applicable to a sediment cleanup project if capping, dredging, and/or confined disposal facility construction is (are) implemented.

Rivers and Harbors Act (33 USC Section 403; 33 CFR Parts 320, 322). This Act prohibits unauthorized activities that obstruct or alter a navigable waterway. In particular, Section 10 of the Act applies to any dredging and/or disposal activity in navigable waters of the U.S., which would include the Whatcom and I&J Waterways.

Current authorized navigation depths for the WW Area are -18 feet below MLLW for the I&J Waterway and the head of the Whatcom Waterway, and -30 feet MLLW in the middle and outer channel reaches of the Whatcom Waterway. Navigation needs for commerce and other activities within Whatcom Waterway and I&J Waterway are important considerations for remediation in these areas.

Authorization of dredging and/or disposal activities follows a public interest review of the proposed activity. This review is based on an evaluation of probable impacts (including cumulative impacts), which in turn is based on a balancing of the benefits of the proposal against its reasonably foreseeable detriments. The parameters on which this decision is based are outlined in 40 CFR Part 320.4. They include effects on wetlands; fish and wildlife; historic, cultural, scenic, and recreational values; coastal zones; marine sanctuaries; other federal, state, and local requirements; navigation; environmental benefits; economics; as well as mitigation to minimize adverse project impacts. Section 10 requirements of the Rivers and Harbors Act may be applicable to capping projects.

Coastal Zone Management Act (CZM) (16 USC 1451 *et seq.*; 15 CFR 923) is a federal law requiring federal agencies to act consistently with state and local shoreline regulations.

Memorandum of Agreement between EPA and U.S. Army Corps of Engineers [Mitigation under Clean Water Act Section 404(b)(1)]. The Agreement sets forth policy and procedures for developing mitigation for compliance under Section 404, but does not alter any of the requirements under this section. These guidelines for mitigation include, in order of importance, avoidance, minimization, and compensatory mitigation.

Resource Conservation and Recovery Act. The Resource Conservation and Recovery Act (RCRA) addresses the generation and transportation of hazardous waste, and waste management activities at facilities that treat, store, or dispose of hazardous wastes. Subtitle C (Hazardous Waste Management) mandates the creation of a cradle-to-grave management and permitting system for hazardous wastes. RCRA defines "solid wastes" (even though the waste may be liquid in physical form) that may cause or significantly contribute to an increase in mortality or serious illness, or that pose a substantial hazard to human health or the environment when improperly managed as hazardous wastes. In Washington State, RCRA is implemented by the authorized state agency, Ecology under the State's Dangerous Waste Regulations Chapter 173-303 WAC.

One objective of RCRA is to minimize the generation of hazardous waste and the land disposal of hazardous waste by encouraging process substitution, materials recovery, properly conducted recycling and reuse, and treatment (see RCRA Section 3003). To further this objective, EPA has set various goals for the Waste Minimization National Plan, including reducing the generation and mobility of hazardous wastes containing mercury. EPA has established treatment standards for mercury-bearing wastes as part of several rulemakings under the Land Disposal Restrictions (LDR) in 40 CFR Part 268.

Low concentration mercury-bearing wastes are not subject to specific treatment technologies, but must meet Toxicity Characteristic Leaching Procedure (TCLP) designation limits. The TCLP designation limits define when a waste is hazardous and are used to determine when more stringent management standards apply than would be applied to typical solid wastes. Thus, the TCLP contaminant-specific criteria may be used to determine cleanup levels or when RCRA-equivalent waste management standards must be met (including LDR). Existing TCLP and other sediment quality data available for the WW Area do not indicate any exceedance of characteristic dangerous or hazardous waste criteria within the prospective sediment cleanup area. The materials are also not subject to upland landfill disposal restrictions, either under existing regulations or proposed revisions to the LDR (Federal Register: May 28, 1999 [Volume 64, Number 103]).

Endangered Species Act (16 USC 1536 (a) – (d); 50 CFR Part 402). Section 7(a) of this Act grants authority to and imposes requirements upon Federal agencies regarding endangered or threatened species of fish, wildlife, or plants ("listed species") and habitat of such species that has been designated as critical. The Act also applies to species that have been proposed for listing (such as spring Chinook salmon in the Whatcom Creek system). Federal agencies must confer with the National Marine Fisheries Service (NMFS) on any action that is likely to jeopardize the continued existence of any proposed species, or result in the destruction or adverse modification of any critical habitat important to the proposed species. The conference/consultation process is directed at making a biological opinion regarding the proposed action. The opinion evaluates whether or not the action will jeopardize the continued existence of a species, or result in the destruction or adverse modification of critical habitat; and may include modification to the action that would avoid the likelihood of adverse effects to listed species or their critical habitat.

The Pilot Project has considered the Endangered Species Act, particularly the listing of Puget Sound Chinook, and will continue the early consultation process (50 CFR 402.11) with NMFS and the U.S. Fish and Wildlife Service (USFWS) through preparation of a State Environmental Policy Act (SEPA) EIS (see below). The Pilot Project anticipates preparing a Biological

Assessment (BA) as part of the consultation process to ensure resolution of potential conflicts.

Federal and State Clean Air Acts (42 USC 7401 *et seq.*; 40 CFR 50; RCW 70.94; WAC 173-400, 403). The Clean Air Act regulates emissions of hazardous pollutants to the air. Controls for emissions are implemented through federal, state and local programs. The Clean Air Act is implemented in the state of Washington through the Washington Clean Air Act (RCW 70.94). The regional air pollution contract authorities, activated under the Washington Clean Air Act, have jurisdiction over regulation and control of the emission of air contaminants and the requirements of state and federal Clean Air Acts in their districts. In 1993, EPA issued a rule that requires federal agencies to demonstrate that projects they are involved with are in compliance with federally-approved Clean Air Act state implementation plans.

U.S. Fish and Wildlife Mitigation Policy (46 FR 7644). This policy establishes guidance for U.S. Fish and Wildlife personnel involved in making recommendations to protect or conserve fish and wildlife resources.

Fish and Wildlife Coordination Act (16 USC 661 *et seq.*). This Act is a federal law requiring consultation with fish and wildlife agencies on activities that could affect fish and wildlife.

Protection of Wetlands, Executive Order 11990 (40 CFR Part 6, Appendix A). This executive order requires that federal agencies avoid adversely impacting wetlands wherever possible, minimize wetland destruction, and preserve the value of wetlands. Appendix A of 40 CFR Part 6 provides EPA procedures for managing floodplains and protecting wetlands.

Environmental Justice (E.O. 12989). Environmental justice concerns arise from environmental impacts on minority populations, low-income populations, and Indian Tribes. Executive Order 12989, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations", requires that each federal agency research, collect data and analyze the environmental effects (which may be cumulative and multiple) of federal actions on low-income populations, minority populations, and Indian Tribes. Environmental and human health impacts must be evaluated to ensure that any federal actions do not have disproportionately high or adverse effects on the populations of concern.

Environmental justice issues are addressed during the NEPA process. Agencies are required to work to ensure effective public participation, community and Tribal representation, and information access. EIS preparation must consider both impacts on the natural or physical environment and interrelated social, cultural, and economic impacts on low-income and minority populations or Indian Tribes. Mitigation measures may include steps to avoid, reduce, or eliminate impacts.

National Historic Preservation Act (36 CFR 800). When proponents seek a federal approval, the responsible federal agency must consult with the State Historic Preservation Officer and the federal Advisory Council on

Historic Preservation to determine if the project would affect cultural or historic sites on or eligible for the National Register of Historic Places.

11.3.2 Washington State Requirements

Potential state requirements are specified in several standards, codified in the Revised Code of Washington (RCW) and promulgated in the Washington Administrative Code (WAC).

State Environmental Policy Act (SEPA) (RCW 43.21C; WAC 197-11). The State Environmental Policy Act is intended to ensure that state and local government officials consider environmental values when making decisions. The SEPA process begins when someone submits a permit application to an agency, or an agency proposes to take some official action such as implementing a plan or policy. Prior to taking any action on a proposal, agencies must follow specific procedures to ensure that appropriate consideration has been given to the environment. The severity of potential environmental impacts associated with a project determines whether an EIS is required. Like NEPA, the EIS is a public disclosure document that analyzes alternative means of attaining the applicant's goal for the proposal, and analyzes the environmental consequences of each alternative and the potential options for mitigating the impacts. This assessment includes looking at alternatives that would meet the project's objectives with less environmental damage.

State cleanup action plans for contaminated sediments typically require SEPA compliance. Decisions by federal agencies to permit these actions require NEPA compliance, as outlined above. Both NEPA and SEPA require government agencies to cooperate as much as possible to integrate environmental studies with permitting requirements and encourage public involvement in the EIS process.

Consistent with these requirements and objectives, the Pilot Project has prepared a SEPA EIS that analyzes and compares the major environmental differences among implementing a Comprehensive Strategy in Bellingham Bay and not implementing the Comprehensive Strategy (the No-Action alternative). Several project-specific Integrated Near-Term Remedial Action Alternatives included within the Comprehensive Strategy are also analyzed and compared.

By analyzing both the planning level (Comprehensive Strategy v. no Comprehensive Strategy) and the project-specific (Integrated Near-Term Remedial Action Alternatives), the Pilot Project's EIS is both a "plan EIS" and a "project EIS". The use of plan and project environmental analysis is commonly called "phased review" under SEPA. While this type of review is more traditionally done in two separate documents, the Pilot Project felt it was more appropriate and useful to reviewers to combine this analysis in one document. Combining these non-project and project actions also helps to expedite cleanup.

The EIS is intended to provide sufficiently detailed environmental analysis to support permit review for any of the Integrated Near-Term Remedial Action Alternatives, along with the detailed plans, specifications, and application materials that will be prepared for final permit applications. Ecology and G-P have agreed that the Bellingham Bay Comprehensive Strategy EIS will serve the SEPA requirements for the cleanup of the Whatcom Waterway Site. Additional environmental review is not anticipated for selection of a preferred alternative.

Washington Water Pollution Control Act (Chapter 90.48 RCW; Chapter 173-201A WAC). This Act provides for the protection of surface water and groundwater quality. Chapter 173-201A WAC establishes water quality standards for surface waters of the state. The surface water quality criteria established under the federal CWA are not state requirements unless promulgated in these regulations.

Toxic substance criteria for marine acute and marine chronic exposure, and criteria for human consumption of aquatic organisms, have been established under WAC 173-201A-047. These criteria are in effect beyond the "dilution/mixing/release zone," which is limited under WAC 173-201A-035(7) to the zone that will 1) not cause acute mortalities of sport, food, or commercial fish and shellfish species or important species to a degree that damages the ecosystem, and 2) not diminish aesthetic values or other beneficial uses disproportionately.

Consistent with the requirements of Chapter 90.48 RCW, Ecology issues a water quality certification for any activity, including federally permitted actions, which may result in a discharge to state water. Sediment capping, dredging, and disposal actions typically constitute a "discharge" under this state regulation. The need for mitigation resulting from these activities has been further defined by the Washington State Legislature in the section below entitled "Compensatory Mitigation Policy for Aquatic Resources".

Model Toxics Control Act (Chapter 70.105D RCW). The Model Toxics Control Act (MTCA) authorized Ecology to adopt cleanup standards for remedial actions at hazardous sites. The processes for identifying, investigating, and cleaning up hazardous sites are defined and cleanup standards are set for groundwater, soil, surface water, and air in Chapter 173-340 WAC. The cleanup of contaminated sediments is reserved for the SMS process.

Washington Sediment Management Standards (Chapter 173-204 WAC). The Washington Sediment Management Standards (SMS) establish numerical values for chemical constituents in sediments. The SMS sets forth a sediment cleanup decision process for identifying contaminated sediment areas and determining appropriate cleanup responses. The SMS governs the identification and cleanup of contaminated sediment sites and establishes two sets of numerical chemical criteria against which surface sediment concentrations are evaluated. The more conservative Sediment Quality Standards (SQSs) provide a regulatory goal by identifying surface sediments that have no adverse effects on human health or biological resources. The

SQS is Ecology's preferred cleanup standard, though Ecology may approve an alternate cleanup level within the range of the SQS and the Minimum Cleanup Level (MCUL), if justified by a weighing of environmental benefits, technical feasibility, and cost. The Sediment Cleanup Standard's Users Manual provides guidance for the implementation of Section 5 of the SMS, Sediment Cleanup Standards.

The SMS defines the point of compliance for sediment cleanup as "surface sediments", which is normally operationally defined as those sediments located in the top 10 cm of the sediment column. Surface sediments defined under the SMS include settled particulate matter located in the predominantly biologically active zone, or exposed to the water column. The point of compliance with sediment quality standards also includes settled particulate matter exposed by human activity (e.g., dredging) to the biologically active zone or to the water column.

As discussed in Section 11.1, Ecology is considering substantive revisions to the SMS rule. Some of these changes could decrease the area and volume of sediments currently targeted for cleanup in the WW Area. However, the proposed rule revisions cannot be implemented until they become law.

Washington Shoreline Management Act (Chapter 90.58 RCW; Chapter 173-14 WAC); Bellingham Bay Shoreline Master Program. The Shoreline Management Act and regulations promulgated thereunder establish requirements for substantial developments occurring within water areas of the state or within 200 feet of the shoreline. The City of Bellingham has set forth requirements based on local considerations such as shoreline use, economic development, public access, circulation, recreation, conservation, historical and cultural features. Local shoreline management plans are adopted under state regulations, creating an enforceable state law.

The WW Area is located within the jurisdictional area of the Bellingham Bay Shoreline Master Program (BBSMP). This program is currently being updated. Therefore, the information contained in this section is subject to change. The BBSMP has designated the shoreline of Whatcom Waterway up to the mouth of Whatcom Creek for urban maritime use. The BBSMP has designated the south shoreline as urban maritime use and the north shoreline as urban multi-use. Sediment cleanup within the WW Area will need to address the requirements of the BBSMP and land use authorizations.

Regulations for dredging are addressed in Section 27 Part G of the BBSMP and are summarized below:

- Maintenance dredging is permitted for navigable waters and established boat basins as long as it is conducted in a manner that minimizes adverse effects on marine habitat;
- Dredging is permitted to maintain/establish appropriate shoreline development that is considered essential;
- Dredging activities necessary to maintain the carrying capacity of streamways are permitted provided approvals are granted from the State of Washington Department of Fisheries and Wildlife (WDFW);

- Dredge spoils shall not be stockpiled or disposed on any shorelines of the City, provided dredge spoils can be disposed as landfill. Such landfill disposal shall meet the regulations pertaining to landfills contained in Section 27 Part J; and
- Applicants must provide information from a qualified expert indicating that the disruption of contaminated bottom sediments due to dredging activities will not adversely affect water quality.

  Regulations for shoreline landfills are addressed in Section 27 Part J of the BBSMP and are summarized below:

- Landfills resulting in water surface reduction are permitted to accommodate water dependent and/or public uses only;
- The construction of all landfills must include erosion preventative measures such as vegetation, retaining walls, bank protection, and/or other mechanisms;
- Retaining walls or bank protection must conform to regulations pertaining to bulkheads;
- If dredge spoils are used for fill materials, the fill must be placed behind an impermeable dike or bulkhead, or it must be demonstrated that the fill material will not pose a potential threat to water quality;
- Landfills must blend in with existing topography such that the landfill does not interfere with the visual and/or physical shoreline access of public or adjacent residences; and
- Landfills located within 200-feet of the entrance of a freshwater stream into marine waters will not interfere with or endanger the migration of anadromous fish species nor reduce the area of estuarine mudflats which are exposed at low tide.

Washington Solid Waste Management Act (RCW 70.95; Chapter 173-304 WAC) establishes standards for the handling and disposal of solid waste, including requirements applying to landfill location, design, maintenance, monitoring, and closure.

Washington Hydraulics Code (Chapter 75.20 RCW; Chapter 220-110 WAC) establishes requirements for performing work that would use, divert, obstruct, or change the natural flow or bed of any salt or fresh waters. Mitigation is required for projects that directly or indirectly harm fish.

Consistent with the requirements of Chapter 75.20 RCW, WDFW issues a Hydraulic Project Approval (HPA) for any project that will use or change the natural flow of any waters of the state. Sediment capping, dredging, and disposal actions typically require a HPA under this state regulation. In addition, WDFW typically requires that impacts to wetlands or aquatic resources occurring as a result of sediment cleanup actions be mitigated on the project site and with a similar habitat type. The need for mitigation resulting from these activities has been further defined by the Washington State Legislature in the section below entitled "Compensatory Mitigation Policy for Aquatic Resources".

Washington Hazardous Waste Management Act (Chapter 70.105 RCW; Chapter 173-303 WAC). The Act, and regulations promulgated thereunder, are the state equivalent of RCRA requirements for designating solid wastes to determine whether they are "dangerous waste." It also presents requirements for management of those solid wastes that are determined to be "dangerous waste."

Puget Sound Water Quality Act (RCW 90.70.011). The Puget Sound Water Quality Action Team (PSWQAT) has been authorized under this Act to develop a comprehensive plan for water quality protection in Puget Sound to be implemented by existing state and local agencies. Several elements of the Plan provide pertinent guidance:

- Elements P-2 and P-3. Sediment quality standards and sediment impact zones;
- Elements P-6 and P-7. All known and reasonable forms of treatment (AKART) guidelines and effluent limits for toxicants and particulates; and
- Elements S-4, S-7, and S-8. Guidelines for confined disposal, cleanup decisions, and investigations, respectively.

Washington Standards for Confined Disposal of Contaminated Sediments (Ecology, 1990) establish the Confined Alternative Assessment Procedure (CAAP), a six-step decision-making process for evaluating the ability of a confinement alternative to provide an adequate level of protection and to comply with applicable requirements.

Washington Department of Fisheries Habitat Management Policy, POL-410. This policy includes the following provisions:

- Achieve no net loss of productive capacity of the habitat of food fish and shellfish resources of the state
- Create productive capacity of habitats that have been damaged or degraded by natural causes or as a result of human activities
- Improve the productive capacity of existing habitat and create new habitat

  In addition, in-water actions will need to address the requirements of a Hydraulic Project Approval, including seasonal fisheries closures and water quality and habitat protection.

Compensatory Mitigation Policy for Aquatic Resources (Chapters 75.20 and 90.48 RCW). In 1997, the Legislature added new sections to Chapters 75.20 and 90.48 RCW to establish a clear state policy relating to the mitigation of wetlands and aquatic habitat for infrastructure development and the cleanup of aquatic resources. Compensatory mitigation is defined to include mitigation that occurs in advance of a project's planned environmental impacts, either on or off the project site, and that may provide different biological functions from the functions impacted by the project. The new policy encourages mitigation proposals that are timed, designed, and located in a manner to provide equal or better biological functions and values compared to "traditional" on-site, in-kind mitigation proposals. In addition, the new policy provides that the state shall not require mitigation for sediment dredging or capping actions that result in a cleaner aquatic environment and equal or better habitat functions and values, if the actions are taken under a state or federal cleanup action.

Water Resources Act (Chapter 90.54 RCW). The Water Resources Act establishes fundamental water resource policies for preservation of Washington State water resources.

Growth Management Act (GMA) (RCW 36.70A; RCW 36.70.A.150; RCW. 36.70.A.200). The Growth Management Act requires counties and cities to classify and designate natural resource lands and critical areas (which include "waters of the state"). Additionally, the state's fastest growing cities and counties must adopt comprehensive plans and development regulations regarding land use within their jurisdiction. In particular, each plan must identify land within the jurisdiction that is useful for public purposes, and include a process for siting essential public facilities, including solid waste handling facilities.

State Aquatic Lands Management Laws Washington State Constitution Articles XV, XVII, XXVII (RCW 79.90 through 79.96; WAC 332-30). The management of state-owned aquatic lands is intended to provide a balance between:

- Encouraging direct public use and access
- Fostering water-dependent uses
- Ensuring environmental protection
- Utilizing renewable resources

The Washington Department of Natural Resources (DNR) has the authority to lease state-owned aquatic lands. It has the responsibility to consider the natural values of the land before it leases it and the authority to withhold land from leasing if it determines it has significant natural values.

Public Trust Doctrine. The purpose of the Public Trust Doctrine is to preserve and continuously assure the public's ability to fully use and enjoy public trust lands, waters, and resources for certain public uses (Slade, 1997). The U.S. Supreme Court has determined that as each state entered the Union, it took title to the navigable aquatic lands subject to the Public Trust Doctrine. While not a state law *per se*, the discussion of the doctrine is included here because of its relationship to the WW Area cleanup and the Pilot Project.

The Public Trust Doctrine provides that tidal and navigable freshwaters, and the lands beneath and the resources within the waters are held by the state in trust for the benefit of the public. Washington's property laws enable the Washington State Department of Natural Resources (DNR) to act as the trustee of state-owned aquatic lands on behalf of the people of Washington (DNR, 1994).

Following a finding of the state legislature that: "This (1984) legislature finds that state-owned aquatic land is a finite natural resource of great value and irreplaceable public heritage" (RCW 79.90.450), management of state-owned aquatic lands and sediments must be in accordance with constitutional and statutory requirements. It must also strive to provide a balance of varied public benefits for all citizens of the state, including (RCW 79.90.455):

(1) Encouraging direct public use and access

(2) Fostering water-dependent uses

(3) Ensuring environmental protection

(4) Utilizing renewable resources

(5) Generating revenue in a manner consistent with these benefits

Consistent with these objectives, DNR strives to manage state-owned aquatic lands to maximize overall public benefits. Within the context of possible sediment disposal sites, DNR also recognizes the finding of the state legislature that dredged material "disposal sites are essential to the commerce and well being of the citizens of the State of Washington" (RCW 79.90.550).

Washington Water Quality Standards (WAC 173-200; 173-201A; 173-220 to 255). Ecology has promulgated state-wide water quality standards under the Washington Water Pollution Control Act. Under these standards, all surface waters of the state were first divided into classes (AA, A, B, C, and Lake) based on the beneficial uses of that water body. Then water quality criteria were defined for different types of pollutants and the characteristic uses for each class of surface water.

Dredged Material Management Program Guidelines (RCW 79.90; WAC 332-30). The Dredged Material Management Program (DMMP), formerly Puget Sound Dredged Disposal Analysis (PSDDA) is a federal/state program that classifies and governs what dredged material can be put back into open water. The collaborative program provides a consistent and predictable approach to disposing of dredged sediments in unconfined open water areas and monitoring the condition of the open water disposal sites. DNR approval is required for material disposal on state-owned aquatic lands.

State Historic Preservation Act (Chapter 27, 34, 44, 53, RCW) is a state law to ensure that cultural resources, such as historical and archaeological sites, are identified and protected.

11.3.3 Other Requirements

Treaty of Point Elliott (12 Stat. 927), Treaty of Medicine Creek (10 Stat. 1132). In 1854 and 1855, Native American Tribes, in what is now the state of Washington, signed treaties with the United States government conveying their right, title, and interest in and to the lands occupied by them. These treaties and subsequent court decisions protect Indian tribes' property and water rights, including their rights to fish and co-manage fishery resources in Puget Sound.

11.3.4 Potential Requirements

Shorelines, Surface Waters, and Wetlands. A number of requirements constrain activities in proximity to shorelines, surface waters, and wetlands. Some of these are prohibitions against siting certain types of facilities (e.g., solid or hazardous waste disposal units) too close to a shoreline. Other requirements describe precautions that must be taken to minimize potential impacts on surface waters when conducting operations near these environments. Since the WW Area includes shorelines and surface waters, these requirements may be potential regulations for remediation decisions and will need to be addressed as a part of cleanup.

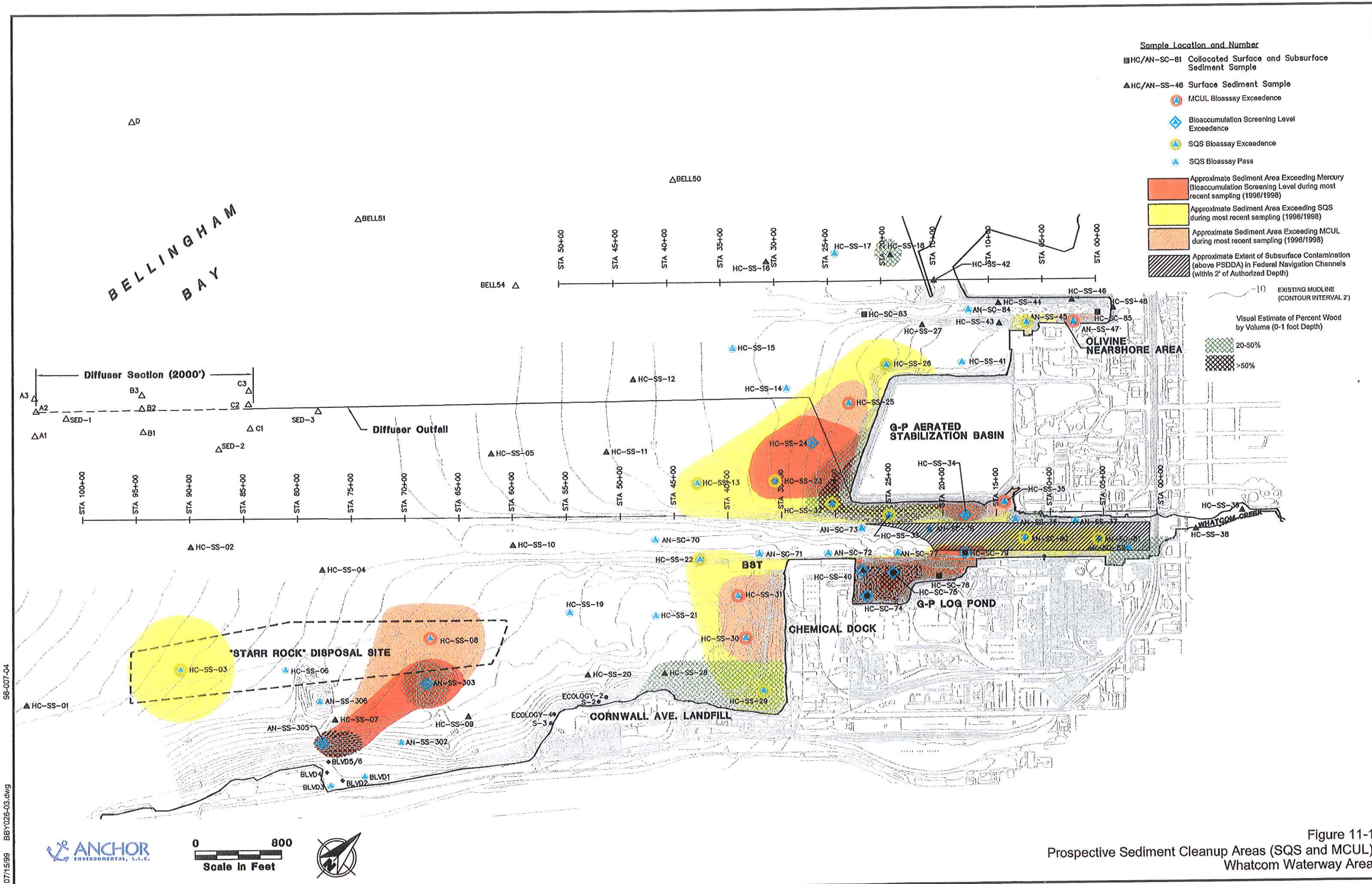


Figure 11-1
Prospective Sediment Cleanup Areas (SQS and MCUL)
Whatcom Waterway Area

98-007-04
07/15/99 BBY026-03.dwg

12. ESTABLISHMENT OF SITE SEDIMENT UNITS

In order to develop appropriate remedial alternatives for this RI/FS, the WW Area was first subdivided into individual SSUs with unique characteristics. The project site, because of its configuration, has inherent broad units. These broad units include (see Figure 1-2):

- Whatcom Waterway
- Log Pond
- I&J Waterway
- Areas offshore of the G-P ASB
- Port of Bellingham log rafting area
- Former Starr Rock disposal site

The next step was to further subdivide these broad units into unique subunits. This was accomplished by considering the following:

- Biological factors
- Chemical factors
- Physical factors
- Navigational/site use factors

The RI/FS data were used, as discussed below, to establish SSUs with unique biological, chemical, physical, and/or navigation/site use characteristics.

12.1 Biological and Chemical Factors

The areal extent of surface sediments exceeding SMS criteria was delineated for this RI/FS primarily using confirmatory biological data, and incorporating potential bioaccumulation considerations. Similarly detailed biological testing of subsurface sediments is not available to characterize the vertical extent of toxicity, though subsurface chemistry profile data and a limited number of subsurface bioassays were collected for this purpose. Thus, the extent of sediments within the WW Area that may potentially require remediation was delineated using a combination of sediment toxicity and chemistry data. SSUs with unique contaminant characteristics were identified based on the available information, as summarized below.

Sediment toxicity and chemical characteristics within different regions of the WW Area are summarized below.

12.1.1 Whatcom Waterway

Only two of the 10 surface sediment samples collected from the Whatcom Waterway navigation channel exceeded SQS biological effects criteria (Figure 11-1). These two samples were collected between Stations 5+00 and 13+00 near the head of the waterway. However, neither of these two samples exceeded MCUL effects criteria. The SQS exceedances were marginally associated with elevated mercury concentrations (slightly above the MCUL chemical criterion), and with low levels of wood material (typically less than 20 percent by volume).

The remaining eight surface sediment samples collected from the Whatcom Waterway navigation channel, including all stations located offshore of Station 20+00, did not exceed SQS biological effects criteria, even though subsurface sediments within these areas contained elevated concentrations of mercury, 4-methylphenol, and wood material (see below). These data confirm the protectiveness of the natural sediment cap that has formed in the channel as the result of source controls and natural recovery, concurrent with active navigation use of the channel.

In contrast to mid-channel areas, nearshore (off-channel) areas within the middle reach of the Whatcom Waterway (i.e., between Stations 13+00 and 30+00) exceeded SQS, MCUL, and/or bioaccumulation screening criteria in surface sediments. These nearshore areas, located adjacent to the G-P ASB and Log Pond, also contained some of the highest mercury and wood material levels reported within the WW Area.

All four subsurface samples collected from the Whatcom Waterway navigation channel exceeded SQS and MCUL biological effects criteria. Chemicals of potential concern identified in these subsurface sediments included mercury, 4-methyphenol, and wood material. Vertical distributions of mercury and a representative wood material degradation product (4-methylphenol) in Whatcom Waterway subsurface sediment coring samples are depicted in Figures 4-3 and 4-4 (Volume I). In addition, relatively low concentrations of tributyltin (to 0.2 ug/L; slightly above the PSDDA screening level of 0.15 ug/L) in interstitial water, have been detected in 0 to 4-foot composite sediment samples collected from several areas of the Whatcom Waterway (see Appendix K, Volume III; and Striplin, 1997). The overall vertical extent of sediment contamination within the Whatcom Waterway is summarized on Figure 12-1. However, as discussed previously, a clean (below SQS biological effects criteria) surface sediment cap has formed naturally within most of the channel area.

12.1.2 G-P Log Pond

No sediment toxicity analyses were performed for this RI/FS on sediment samples collected from the G-P Log Pond. Surface and subsurface sediment samples collected from this area contained the highest site-wide mercury concentrations, which exceeded the mercury bioaccumulation screening level

(1.2 mg/kg). Relatively high percentages of wood material also occur in this area. Elevated phenol concentrations detected in this area (above the SQS and MCUL) appear to be associated with the wood material deposits.

12.1.3 I&J Waterway

With the exception of nearshore sediment areas immediately adjacent to the Olivine (bis[2-ethylhexylphthalate) site, all surface and subsurface sediment samples collected from the I&J Waterway did not exceed SQS biological effects criteria. Screening-level subsurface sediment composite samples also passed PSDDA interpretive criteria for unconfined open water disposal (Appendix K; Volume III). In addition, three surface sediment samples collected on either side of the mouth of the I&J Waterway (Samples HC-SS-15 and HC-SS-17; see Figure 5-1; Volume I), and within the adjoining eelgrass bed (HC-SS-41) also did not exceed SQS criteria. However, several subsurface sediment samples collected within the middle of the I&J Waterway exceeded the mercury bioaccumulation screening level (Figure 4-5; Volume II).

Concentrations of tributyltin ranging between less than 0.05 and 0.11 ug/L were reported in 0 to 4-foot sediment composite samples collected in the I&J Waterway (Appendix K; Volume III). However, these concentrations did not exceed the current PSDDA screening level of 0.15 ug/L.

12.1.4 Area Offshore of G-P ASB

In addition to the samples collected adjacent to the I&J and Whatcom Waterways, as discussed above, six surface sediment samples collected offshore of the G-P ASB were submitted for confirmatory biological testing. Four of these samples exceeded SQS interpretive criteria. One of these samples, located towards the middle of the ASB (Sample HC-SS-25), also exceeded MCUL interpretive criteria. The bioaccumulation screening criterion for mercury (1.2 mg/kg) was also exceeded at two sample locations (HC-SS-23 and –24) off the southwest corner of the G-P ASB (Figure 11-1).

12.1.5 Log Rafting Area

Three of the five bioassay samples collected within and immediately offshore of the Port of Bellingham Log Raft area exceeded SQS interpretive criteria. Two of these samples (HC-SS-30 and HC-SS-31) located within the middle of the Log Raft area also exceeded MCUL criteria.

12.1.6 Starr Rock

Nine surface sediment samples collected within the Starr Rock area were submitted for confirmatory biological testing. Two samples located at the southwest (HC-SS-03) and northwest (HC-SS-08) ends of the former disposal site exceeded SQS interpretive criteria. Sample HC-SS-08 also exceeded MCUL interpretive criteria. However, several samples collected from the middle of the former disposal area (HC-SS-06; AN-SS-303, and -305), which also contained the highest concentrations of mercury, phenol, 4-methylphenol, and wood material, passed the SQS criterion.

12.2 Physical Factors

Physical factors at a site may influence the range of remediation alternatives that are available in different areas of the site. These physical factors include water depth, structures, slopes, and sediment physical properties such as grain size, Atterberg limits, total organic carbon (TOC) content, and wood material distribution.

12.2.1 Bathymetric Conditions

Figure 12-2 presents existing bathymetric conditions within the WW Area. This map incorporates bathymetric soundings collected as part of the RI/FS (1996 soundings), and surveys completed by the Corps in the Whatcom Waterway and I&J Waterway navigation channels (1996 soundings in the Whatcom Waterway; 1992 sounding in the I&J Waterway). Figure 12-2 includes a comparison of existing mudline elevations within the federally-authorized navigation channel to authorized depths, identifying shoaling areas within the waterways. Shoaling areas are discussed in more detail below.

The following general elevation trends were observed within the different areas of the project:

- **Whatcom Waterway.** Mudline elevations within the Whatcom Waterway navigation channel (1996 soundings) range from approximately 6 to -38 feet MLLW. Relative to the federally authorized channel depth of -18 feet MLLW at the head of the waterway (Station 0 to 7+50) and -30 feet for the rest of the waterway, significant areas of shoaling are present, as depicted on Figure 12-2. The primary shoaling areas occur near the head of the waterway, where mudline elevations are as much as 24 feet shallower than the authorized depth of -18 feet MLLW. By comparison, relatively few areas of shoaling were noted in middle and outer Whatcom Waterway. These data are consistent with the observed increase in net sedimentation rates proceeding into the more protected areas of the Whatcom Waterway navigation channel (Figure 12-2). Beyond Station 15+00, mudline elevations within the waterway range from approximately -20 to -38 feet MLLW. The northern edge of the waterway offshore of the G-P ASB is generally shallower by 5 to 15 feet than the southern edge from Stations 15+00 to the mouth. The deeper portions are generally located along the WIST pier.
- **G-P Log Pond.** Mudline elevations in the G-P Log Pond ranged from 0 to -15 feet below MLLW with an average elevation of -10 feet MLLW.

- **I&J Waterway.** Based on 1992 soundings, mudline elevations within the main channel of the I&J Waterway currently range from -5 feet MLLW at the head of the waterway to -18 feet MLLW near the mouth. However, most of I&J Waterway was within 2 feet of the authorized navigation depth of -18 feet MLLW (Figure 12-1).
- **Area Offshore of G-P ASB.** The non-channel area southwest of the G-P ASB ranges in elevation from 0 to -18 feet MLLW.
- **Log Rafting Area.** The log rafting area ranges in elevation from 0 to -28 feet MLLW.
- **Starr Rock.** The mudline elevation in the Starr Rock area ranges from elevation -20 to -40 feet MLLW. The area generally deepens to the northwest. The former sediment disposal site (1969 Whatcom Waterway maintenance dredging) is evident as two discrete mounds, as depicted on Figure 12-2. The mounds rise approximately 10 to 20 feet above the surrounding seafloor.

12.2.2 Structures, Shoreline and Slope Survey

Over-water, nearshore, and shoreline structures, shoreline matrices, and slopes were inventoried during the 1996 RI/FS sampling activities. These activities included observations made during the shoreline video reconnaissance, site walks, bathymetry survey, boat tours, water sampling, and sediment sampling. Specific features documented for use during the evaluation of remedial options included features such as piling size, construction, dimensions, and spacing; bent spacing; slope integrity; slope construction; and substrate. The Whatcom Waterway area shorelines were divided into 22 segments of similar substrates and/or physical features and are summarized in Table 3-1 and Figure 3-6 (Volume I).

The following significant structures, shoreline features and slopes were observed within the different areas of the project:

- **Whatcom Waterway.** Shoreline structures in the Whatcom Waterway between Station 00+00 and Station 12+50 primarily consist of vertical bulkheads on the north and south shorelines. Steep to moderately steep (2H:1V slope) riprap armored beaches consisting of gravel and concrete debris occur between Station 00+00 and 05+00 on the north shoreline. The south shoreline, from Station 11+00 to 18+00 and Station 24+00 to 35+00, primarily consists of moderately steep to steep (3H:1V to 1H:1V slopes) gravel and riprap armored beaches, grading into subtidal soft silt substrate.
- **G-P Log Pond.** Shoreline structures in the G-P Log Pond consist of moderately steep (2H:1V slope) gravel and riprap armored beaches between Station 17+00 and Station 23+00, steep (0.5H:1V slope) riprap and concrete debris between Station 23+00 and Station 27+50, and vertical bulkhead and soft silt substrate on the southwest shoreline.

- **I&J Waterway.** The I&J Waterway shoreline structures primarily consist of moderately steep to steep (1H:1V slope) gravel and riprap beaches, except for the south shoreline from Station 00+00 to 02+00 and Station 05+50 to 08+00 which consists of vertical bulkheads. A large eelgrass bed is situated southeast of the I&J Waterway (northwest shore of the G-P ASB) between Stations 08+00 and 17+50.
- **Area Offshore of G-P ASB.** Moderately steep (3H:1V slope) riprap and concrete debris slopes surround the G-P ASB. A large eelgrass bed extends along the northwest shoreline of the G-P ASB up to the I&J Waterway.
- **Log Rafting Area.** Shoreline structures primarily consist of steep (1H:1V slope) gravel and riprap armored beaches along the north shoreline of the Log Rafting area. The area underneath the Bellingham Shipping Terminal Pier, which serves as the northwest boundary of the Log Rafting area, consists of sand and small gravel mixed with soft silt.
- **Starr Rock.** The Starr Rock area is located offshore and thus is not associated with shoreline structures. The shoreline southeast of the Starr Rock area between Boulevard Park and Cornwall Avenue Landfill consists of moderately steep to steep (1H:1V slope) gravel and riprap armored beaches mixed with sand and small gravel. There are small eelgrass patches east of the Starr Rock area (near Boulevard Park and along the shoreline of the Cornwall Avenue Landfill).

12.2.3 Grain Size Characteristics

Visual sediment descriptions and grain size analysis data were collected during the RI/FS and presented in Volume I of this report. Table 3-2 summarizes the sediment grain size results for surface and subsurface sediment samples. Figure 3-7 (Volume I) illustrates the general distribution of surficial fine-grained sediment (percent by weight less than No. U.S. 230 sieve size) from RI/FS data. Figure 3-8 (Volume I) is a facies map of sediment textures as described in American Society for Testing and Materials (ASTM) classification. Figures 3-11 through 3-14 (Volume I) illustrate the cross sectional sediment textures as described by ASTM classification.

The following general surface sediment gradation trends were observed within the different study areas of the project:

- **Whatcom Waterway.** Whatcom Waterway surface sediments generally consist of slightly sandy, clayey to very clayey silt. Small areas of sandy to very sandy silt with varying amounts of clay were observed near the head of the waterway and just off of the northeast corner of the G-P ASB. Surface sediments along the northwest reaches of Whatcom Waterway from Stations 00+00 to 13+50 and 16+00 to 30+00 consist primarily of slightly clayey, silty sand with varying amounts of gravel.
- **G-P Log Pond.** The surface sediments of the G-P Log Pond primarily consist of sandy to very sandy silt with varying amounts of clay. Near the southwest shoreline the sediment gradation changes to a slightly clayey,

silty sand with varying amounts of gravel. Sediments consisting of greater than 50 percent shell fragments were observed near the northeast end of the Log Pond.

- **I&J Waterway.** From the shoreline structures to approximately 200 feet out, sediments in the I&J Waterway consist of slightly clayey, silty sand with varying amounts of gravel. The inner channel of the I&J Waterway from Station 00+00 to 05+00 consists of sandy to very sandy silt with varying amounts of clay. From Station 05+00 to 24+00, the inner channel consists of slightly sandy, clayey to very clayey silt.
- **Area Offshore of G-P ASB.** The sediments surrounding the G-P ASB area (within 200 to 400-feet) consist of slightly clayey, silty sand with varying amounts of gravel. As distance from the G-P ASB increases, the sediments become finer grained primarily consisting of clayey silt.
- **Log Rafting Area.** The Log Rafting Area primarily consists of slightly sandy, clayey to very clayey silt with coarser grained material along the north shore. Sediments consisting of clayey silts were observed in a 400-foot diameter area near the north shore southeast of Slip 3 Dock. Sediments consisting of greater than 50 percent shell fragments were observed under the WIST Pier on the northwest end of the Log Raft area.
- **Starr Rock.** The Starr Rock area sediments primarily consist of slightly sandy, clayey to very clayey silt with areas of clayey silt.

12.2.4 Atterberg Limit Results

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 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 plastic silt or clay. The liquid and plastic limits test reports for the ten selected samples are presented in Figures D-151 and D-152 in Appendix D (Volume III).

12.2.5 Total Organic Carbon

The distribution of TOC concentrations in surface sediment samples (0-10 cm) is presented in Figure 3-7 (Volume I). The following general surface sediment TOC trends were observed within the different areas of the project:

- **Whatcom Waterway.** TOC concentrations in Whatcom Waterway ranged from 1.8 to 4.8 percent with an average of 3.5 percent. The highest TOC concentrations were observed near the head of the Whatcom Waterway and offshore of the G-P ASB and G-P Log Pond areas.

- **G-P Log Pond.** TOC concentrations in the G-P Log Pond area ranged from 4.6 to 8.3 percent with an average of 6.6 percent. The highest TOC concentrations of all areas were observed in the G-P Log Pond area.
- **I&J Waterway.** TOC concentrations in the I&J Waterway ranged from 0.82 to 4 percent with an average of 2.6 percent. Highest TOC concentrations were observed along the Bornstein Dock.
- **Area Offshore G-P ASB.** TOC concentrations near the G-P ASB ranged from 2.2 to 4.1 percent with an average of 2.7 percent. Highest TOC concentrations were observed along the perimeter of the G-P ASB.
- **Log Rafting Area.** TOC concentrations in the Log Rafting area ranged from 2.4 to 4.4 percent with an average of 3.3 percent. Highest TOC concentrations were observed along the southeast shoreline and out in the middle of the Log Rafting area.
- **Starr Rock.** TOC concentrations in the Starr Rock area ranged from 2.3 to 13 percent with an average of 4.9 percent.

12.2.6 Wood Material Distribution

Estimates of wood material distribution in near-surface sediments of the WW Area were developed based on visual observations in van Veen surface grab samples collected from depths of 0 to 10 cm, and in core samples collected at greater depths. The distribution is described as percent wood by volume. Figure 3-9 (Volume I) presents the distribution of wood material in the near-surface sediments across the site. The type of wood materials observed in the surface samples included the following descriptions in descending order of frequency: wood chips and fragments up to 2-foot long; wood bark; twigs; pulp or fibrous material; wood lumber; and wood timbers. All wood materials were observed in various states of decomposition.

The following general near-surface wood distribution trends were observed within the different areas of the project:

- **Whatcom Waterway.** Surface sediments throughout most of the Whatcom Waterway navigation channel contained less than two percent wood material by volume. However, a greater percentage of wood material, in some areas exceeding 50 percent by volume, occurred in nearshore, off-channel areas of the waterway, particularly in areas adjacent to the G-P ASB. The head of the Whatcom Waterway contained wood material levels up to approximately 20 percent by volume. In addition, subsurface sediments present several feet below the mudline throughout the head and middle areas of the waterway also contained relatively high percentages of wood material.
- **G-P Log Pond.** Surface and subsurface sediments within the G-P Log Pond contain greater than 50 percent wood material by volume.
- **I&J Waterway.** Surface and subsurface sediments at the head of the I&J Waterway contain 5 to 20 percent wood material by volume, decreasing to less than 2 percent at more offshore locations.

- **Area Offshore G-P ASB.** Surface and shallow subsurface sediments along the southeast and southwest periphery of the G-P ASB contain greater than 50 percent wood material by volume, gradually decreasing to less than 2 percent further offshore.
- **Log Rafting Area.** The sediments in the Log Rafting area contain 20 to 50 percent wood material by volume along the southeast shoreline, gradually decreasing to 2 to 5 percent at the outer harbor line.
- **Starr Rock.** Sediments in the Starr Rock area contain variable levels of wood material, ranging from greater than 50 percent near the southern disposal mound, to less than 2 percent by volume the periphery of this area.

12.3 Navigational/Site Use Factors

Both the Whatcom and I&J Waterways are federal navigational channels. The I&J Waterway is a 100 foot wide channel centered within the waterway. The authorized depth is -18 feet MLLW. The Whatcom Waterway channel is approximately 360 feet wide. The authorized navigational depth is -18 feet MLLW from Station 0+00 to 7+50 and -30 feet MLLW from Station 7+50 outward. The most recent (1958) federal authorization of the Whatcom Waterway also provided that no dredging would be performed by the U.S. within 50 feet of the pierhead lines. Mudline elevations (primarily 1996 soundings) are compared with the federally authorized channel depths in Figure 12-2.

The Port of Bellingham uses the Whatcom Waterway channel southeast of the Bellingham Shipping Terminal Pier for ship/barge unloading and loading operations. Existing depths within most of this area are marginally compliant with the federally authorized channel depths (i.e., current mudline elevations within this area of the channel are very close to -30 feet MLLW; Figure 12-2). However, the Port of Bellingham has reported a shoaling area immediately adjacent to the Pier. The Port has considered deepening the channel area next to the Pier as part of future development plans.

Whatcom Waterway channel areas adjacent to the G-P pier from Station 7+50 to 22+00 do not fully achieve the authorized navigational depth of -30 feet MLLW with respect to shipping. The head of the Whatcom Waterway is also an area that does not achieve the authorized navigational depth of -18 feet MLLW (Figure 12-2). Consequently, there may be some navigation-related impacts to existing and possible future uses of this area of the Whatcom Waterway as a result of shoaling. The Port of Bellingham has considered maintaining or deepening the middle and upper Whatcom Waterway channel as part of future Central Waterfront development plans, particularly along the northwest shoreline of the Whatcom Waterway.

The I&J Waterway currently marginally achieves the federally authorized channel depth of -18 feet MLLW (i.e., existing mudline elevations generally vary between -16 and -18 feet MLLW). These depths appear to be adequate for existing and planned future uses at the head of the I&J Waterway by existing fish/seafood operators and the U.S. Coast Guard (J. Vogel, 1998). However, the Port of Bellingham has considered maintaining or deepening the I&J Waterway channel as part of future Central Waterfront development plans, particularly along the eastern shoreline of the I&J Waterway.

12.4 Site Sediment Units

The preceding sections reviewed unique properties of different areas of the WW Site. This subsection summarizes these properties and establishes a total of 20 different SSUs for the purpose of developing and evaluating remediation alternatives. Figure 12-3 presents the 20 SSUs established for the project area. Table 12-1 summarizes the characteristics of each of these units. Below, each of the SSUs is briefly discussed:

- **Outer/Middle Whatcom Waterway**
  - **Site Unit 1A.** This unit is located near the outer Whatcom Waterway navigation channel. Surface sediments located within this area do not exceed SQS or MCUL criteria (0 to 10 cm point of compliance). The bottom elevation of SQS/MCUL exceedances is generally -37 feet MLLW (typical depths of 0 to 3 feet). Existing mudline depths within this unit (-34 to -32 feet MLLW) are compliant with the current authorized channel depth of -30 feet MLLW.
  - **Site Unit 1B.** This unit is located shoreward of Unit 1A and is also characterized by surface sediments that do not exceed the SQS biological effects criterion. Subsurface sediments in this area contain higher chemical concentrations of mercury and 4-methylphenol than Site Unit 1A. The bottom elevation of SQS/MCUL exceedances is generally -37 feet MLLW (typical depths of 0 to 2 feet). Existing mudline depths within this unit (-36 to -32 feet MLLW) are compliant with the current authorized channel depth of -30 feet MLLW.
  - **Site Unit 1C**. This Whatcom Waterway channel unit is located adjacent to the Bellingham Shipping Terminal Pier. Surface sediments within the navigation channel did not exceed SQS biological effects criteria. Similar to Site Unit 1B, subsurface sediments in this area contain elevated chemical concentrations of mercury and 4-methylphenol. The bottom elevation of SQS/MCUL exceedances is generally -39 feet MLLW (typical depths of 0 to 4 feet). Existing mudline depths within the Bellingham Shipping Terminal Pier area currently range from approximately -36 to -30 feet MLLW, marginally compliant with the current authorized channel depth of -30 feet MLLW, though localized shoaling areas have been reported in this area by the Port. Channel depths on the northwest side of the channel (near the G-P ASB) are shallower, ranging from approximately -36 to -20 feet MLLW. The Port has considered deepening the channel area next to the Bellingham Shipping Terminal Pier as part of future development plans, perhaps deepening this area of the waterway to as low as -40 feet MLLW.

- **Site Unit 1D1**. This unit is located adjacent to the G-P Log Pond. Surface sediments within the navigation channel did not exceed SQS biological effects criteria. The bottom elevation of SQS/MCUL exceedances is generally -35 feet MLLW (typical depths of 2 to 10 feet). Existing mudline depths within this site unit, particularly on the northwest side of the channel near the G-P ASB, range from approximately -32 to -16 feet MLLW, shallower than the current authorized channel depth of -30 feet MLLW.
- **Site Unit 1D2**. This unit, located southeast of 1D1, contains higher concentrations of mercury than 1D1, exceeding the bioaccumulation screening level of 1.2 mg/kg. Also unlike unit 1D1, which contains SQS/MCUL chemical criteria exceedances to a depth of approximately -35 feet MLLW, the subsurface extent of elevated sediment concentrations in unit 1D2 extends to an elevation of approximately -42 feet MLLW. The typical thickness of contaminated sediment in unit 1D2 is over 10 feet, roughly 7 feet deeper than in 1D1 (Table 12-1). Existing mudline depths within this site unit range from approximately -34 to -20 feet MLLW, shallower than the current authorized channel depth of -30 feet MLLW.
- **Site Unit 1E.** This unit is not located within the existing Whatcom Waterway navigation channel, but extends immediately southeast of the Bellingham Shipping Terminal pier in an area used by the Port of Bellingham for berthing of shallow draft vessels. This unit currently contains surface sediments exceeding MCUL chemical criteria. Existing mudline depths within this site unit currently range from approximately -30 to -8 feet MLLW.

- **Head of Whatcom Waterway (30-foot-deep navigation channel)**
  - **Site Unit 2A**. This area is located just northeast of units 1D1 and 1D2, and still within the -30 foot MLLW authorized channel depth area. Surface sediments within this area currently exceed the SQS biological effects criterion, but are below the MCUL criterion. The bottom elevation of SQS/MCUL exceedances is generally -34 feet MLLW (typical depths of 6 to 10 feet). Existing water depths within this area (-26 to -10 feet MLLW) are shallower than the authorized navigational depth of -30 feet MLLW. Various harbor uses including moorage and barge loading/offloading operations occur within this area of the waterway. In addition, the Port of Bellingham has considered maintaining or deepening the channel area in unit 2A as part of its Central Waterfront development plan.
  - **Site Unit 2B**. This area of the site is located along the northeastern corner of unit 2A. Surface sediments and depths within this area are similar to those of Unit 2A. The bottom elevation of SQS/MCUL exceedances is generally -34 feet MLLW (typical depths of 6 to 10 feet).
- **Head of Whatcom Waterway (18-foot-deep navigation channel)**

- **Site Unit 3A**. This area is located just northeast of unit 2A. Portions of the unit contain surface sediments that exceed the SQS biological effects criterion, though no samples have exceeded the MCUL criteria. The bottom elevation of SQS/MCUL exceedances is generally -23 feet MLLW (typical depths of 2 to 5 feet). The boundary between the 2A and 3A units is the change in navigational depth from -18 feet to -30 feet MLLW. The existing water depths in this area (-20 to -4 feet MLLW) are at or below the authorized navigational depth of -18 feet MLLW. Similar to unit 2A, various harbor uses including moorage occur within this area of the waterway.

- **Site Unit 3B**. This area is located just northeast of units 3A and 2B. Surface sediment quality within this area is similar to that of Unit 3A discussed above. The bottom elevation of SQS/MCUL exceedances is generally -23 feet MLLW (typical depths of 2 to 5 feet).

- **Site Unit 3C.** Surface sediment quality within this area complies with SQS biological effects criteria. Subsurface contaminated sediments exceeding SQS biological effects criteria in screening-level bioassays (Appendix K) are present at a depth below approximately 4 feet, and extend to depths exceeding 12 feet below mudline. Although the head of the waterway is clearly shallower than the authorized channel depth of -18 feet MLLW (Figure 12-1), this area has been identified in the Bellingham Bay Comprehensive Strategy DEIS for possible long-term use as shallow water habitat providing connection to Whatcom Creek. The habitat that has developed naturally within this area could provide important rearing habitat for spring Chinook salmon and other species of concern. Various public and private uses of this area are also being considered.

- **G-P Log Pond (Site Unit 4)**

  This unit has the highest surface mercury levels at the site. The surface sediments currently exceed MCUL and bioaccumulation criteria. The bottom elevation of SQS/MCUL exceedances is generally -20 feet MLLW. Sediments in this unit contain greater than 50 percent wood material by volume. The configuration and adjacent uses of the log pond also makes this area potentially suitable as a sediment disposal site (Section 13.0).

- **Area Offshore of G-P ASB**

  - **Site Unit 5A**. This unit contains existing (1996 sampling) SQS biological exceedance areas located immediately offshore of unit 5B (see below).

  - **Site Unit 5B**. This unit contains existing MCUL or bioaccumulation screening level exceedance areas located immediately offshore of the G-P ASB. Unit 5A encompasses this unit. Sediments at the south corner of the G-P ASB contain greater than 50 percent wood material by volume. The remainder of the area contains less than 2 percent wood material.

  - **Site Unit 5C.** This area is located just southeast of the G-P ASB. Different reaches of this SSU contain surface sediments that exceed the mercury bioaccumulation screening levels, biological SQS, and biological MCUL criteria. Wood material varies from 5 to greater than 50 percent by volume.

- **Site Unit 5D.** This area is located on the southwestern edge of the G-P ASB. Surface sediments within this area are similar to SSU 5B and 5C. Wood material by volume varies from 20 to greater than 50 percent.

- **Log Rafting Area**
  - **Site Unit 6A**. Similar to unit 5A discussed above, this unit contains existing (1996 sampling) biological SQS exceedance areas located immediately offshore of unit 6B.
  - **Site Unit 6B**. This unit contains existing biological MCUL exceedance areas located immediately offshore of the Port of Bellingham property, and is encompassed by unit 6A. Sediments along the shoreline contain 20 to 50 percent wood material by volume with the remainder of the area gradually decreasing to 2 to 5 percent at the outer harbor line.
  - **Site Unit 6C**. This unit is located immediately north of SSU 6B. Surface sediments within this area are similar to SSU 6B. The Port has considered deepening this area as part of possible future navigation improvements.

- **Starr Rock**
  - **Site Unit 7A**. Surface sediments within this unit currently exceed the biological SQS criterion.
  - **Site Unit 7B**. Surface sediments within the northwest portion of this unit currently exceeded biological MCUL criteria. The former dredged sediment disposal mounds within this area also exceed the bioaccumulation screening level. Wood material by volume varies from 0 to greater than 50 percent.

- **I&J Waterway (Site Unit 8)**

  Surface sediments within this area do not exceed SQS biological effects criteria. Biological testing within this area performed on subsurface composite samples also indicate compliance with SQS criteria, though some subsurface samples exceeded the bioaccumulation screening level of 1.2 mg/kg. The bottom elevation of SQS/MCUL exceedances is generally -24 feet MLLW. The existing water depths in this area (-16 to -18 feet MLLW) are marginally at the authorized navigational depth of -18 feet MLLW. Screening-level PSDDA analysis indicates that the subsurface sediments within this area are likely suitable for open water disposal or beneficial reuse.

12.5 Remediation Areas and Volumes

As outlined above, this RI/FS considered a range of prospective cleanup criteria for the WW Area between the SQS and MCUL, consistent with SMS guidelines. A summary of surface/SSU areas that currently (1996 to 1998 sampling) exceed SQS or MCUL confirmatory biological criteria (including bioaccumulation screening level exceedances) is provided in Table 12-1. Areas were estimated using the data presented in Figures 11-1 and 12-4.

The area that currently exceeds the SQS criterion is more than two times larger than the area that currently exceeds the MCUL (incorporating bioaccumulation screening level exceedances). As a result, the choice of sediment cleanup levels will have a major effect on the scope and cost of sediment remediation within the WW Area.

As stated above, the SQS is Ecology's preferred cleanup standard, though Ecology may approve an alternate cleanup level within the range of the SQS and the MCUL if justified by a weighing of environmental benefits, technical feasibility, and cost. These considerations are presented in Section 14.0 of this RI/FS.

Although the areal extent of surface sediments exceeding SMS criteria has been delineated for this RI/FS primarily using confirmatory biological data, similarly detailed biological testing of subsurface sediments is not available to characterize the vertical extent of contamination. For the purpose of determining the depth or thickness of subsurface sediments potentially exceeding SMS criteria, a combination of chemical and available biological data were used.

Table 12-1 presents the estimated volume of impacted sediments for the different SSUs. Volumes of impacted *in situ* sediments in each sediment site unit were estimated as follows:

- In the absence of confirmatory biological testing data, the extent of subsurface contamination in the WW Area was estimated using existing MCUL chemical criteria. As discussed in Section 11, the MCUL chemical criteria (i.e., for mercury and 4-methylphenol) provide a conservative means to estimate of the extent of sediments exceeding SQS biological criteria. The existing MCUL chemical criterion for mercury of 0.59 mg/kg enclosed a significantly larger area than that defined by confirmatory SQS biological testing data (see Figure 5-1; Volume I). That is, the existing MCUL chemical criterion for mercury of 0.59 mg/kg substantially overestimates the actual extent of sediment toxicity at the site.
- Volumes of SSUs within the Whatcom and I&J Waterways were estimated using sediment coring data collected within each SSU. The thickness of contamination within each core was assumed to be the distance from the mudline down to the top of the first sample with concentrations below the SQS/MCUL chemical criterion. If multiple cores

were located within a SSU, the deeper core with contamination was assumed to govern the contamination depth within that SSU.

- Volumes of SSUs outside Whatcom and I&J Waterways were estimated from adjacent cores. Natural recovery cores were completed in different locations around the WW Area. These served as the primary source of information to estimate contamination depth outside the navigational channels

Because of the inherent inaccuracies of dredging, a contractor typically has to overdredge below the depth of contamination ("neat line") to ensure removal. Typical dredging contracts allow the contractor 1 foot of overdredge below the neat line. That is, the owner will normally pay the contractor for the extra 1 foot of overdredging to allow better removal of the contaminated material. To obtain this 1 foot of overdredge the contractor can take up to an additional foot of material. The likely depth removed will range from 1 to 2 feet below the neat line on average. The standard approach to estimating dredge volumes for disposal facility sizing is to assume 2 feet of overdredge below the neat line. That is the approach used for this RI/FS.

When a contractor makes a dredge cut deeper than 1 to 2 feet, the side slopes of that excavation will typically slough into the dredge cut. This material will then need to be removed. The dredge volumes presented in this document assume side slopes on dredge cuts of 3 horizontal to 1 vertical (3H:1V). In some locations adjacent to existing slopes the side slopes were assumed to be equal to the existing slope (typically 2H:1V).

Although additional testing could be performed during remedial design to refine the volume estimates, the approach used for this RI/FS should lead to conservatively high estimates of potential sediment remediation volumes. Estimated volumes of contaminated sediments present within each of the SSUs are presented in Table 12-1.

Table 12-1 - Summary of Site Sediment Unit Characteristics.

Sediment Site Unit	Total Area in Acres	SQS[1] area in Acres	MCUL[1] Area in Acres	BSL[2] Area in Acres	Wood Material in percent by volume	Approximate Thickness of SQS/MCUL[3] Exceedance in Feet	Approximate Volume of SQS/MCUL[3] Exceedance in CY	Chemicals Exceeding MCUL Criteria at depth	Typical Mudline Elevation in Feet	Authorized Channel Depth in Feet (MLLW)
1A	7.9	-	-	-	0 to 2	3	70,000	Mercury	-34 to -32	30
1B	9.8	0.4	-	-	0 to 2	0-2	101,000	Mercury	-36 to -32	30
1C	12.7	1.9	-	-	0 to 20	0-4	217,000	Mercury and 4-Methylphenol	-36 to -20	30
1D1	6.8	1.3	0.2	0.2	0 to 50	2-10	153,000	Mercury and 4-Methylphenol	-32 to -16	30
1D2	2.2	2.0	1.2	1.2	0 to 20	10+	29,000	Mercury and 4-Methylphenol	-34 to -20	30
1E	4.0	3.1	0.4	-	2 to 20	4[2]	34,000	Mercury	-30 to -8	-
2A	5.6	3.9	0.2	0.1	0 to 50	6-10	63,000	Mercury, 2,4-Dimethylphenol, and 4-Methylphenol	-26 to -10	30
2B	1.2	1.2	-	-	0 to 2	6-10	14,000	Mercury	-24 to -14	30
3A	1.8	1.1	-	-	0 to 20	2-5	23,000	Mercury and 4-Methylphenol	-20 to -4	18
3B	1.7	1.1	-	-	0 to 50	2-5	24,000	Mercury	-20 to 0	18
3C	2.1	-	-	-	0 to 50	12+	43,000	Mercury	-20 to 0	18
4	8.1	8.1	8.1	7.6	5 to >50	10+	150,000	Mercury, 2,4-Dimethylphenol, and 4-Methylphenol	-12 to 0	-
5A	14.0	12.8	0.1	-	0 to 5	3[4]	181,000	Mercury	-30 to 0	-
5B	28.1	28.1	14.0	11.0	0 to >50	4[4]	259,000	Mercury	-24 to 0	-
5C	6.4	6.4	3.2	2.8	5 to >50	4[4]	22,000	Mercury	0 to -16	-
5D	1.8	1.8	0.9	0.9	20 to >50	4[4]	6,000		0 to -16	-
6A	8.6	7.1	-	-	2 to 50	3[4]	92,000	Mercury	-30 to +4	-
6B	12.3	7.2	5.2	-	5 to 50	4[4]	104,000	Mercury	-28 to 0	-
6C	6.6	6.0	4.6	-	0 to 20	4[4]	22,000		-10 to -20	-
7A	18.0	18.0	-	-	0 to 2	3[4]	103,000	Mercury	-42 to -38	-
7B	26.4	26.4	26.4	-	0 to >50	3[4]	181,000	Mercury	-32 to -22	-
8	8.6	0.7	0.4	-	0 to 20	-	110,000	Mercury	-18 to -16	18
Total	195	138	65	24	-	-	2,000,000	-	-	-

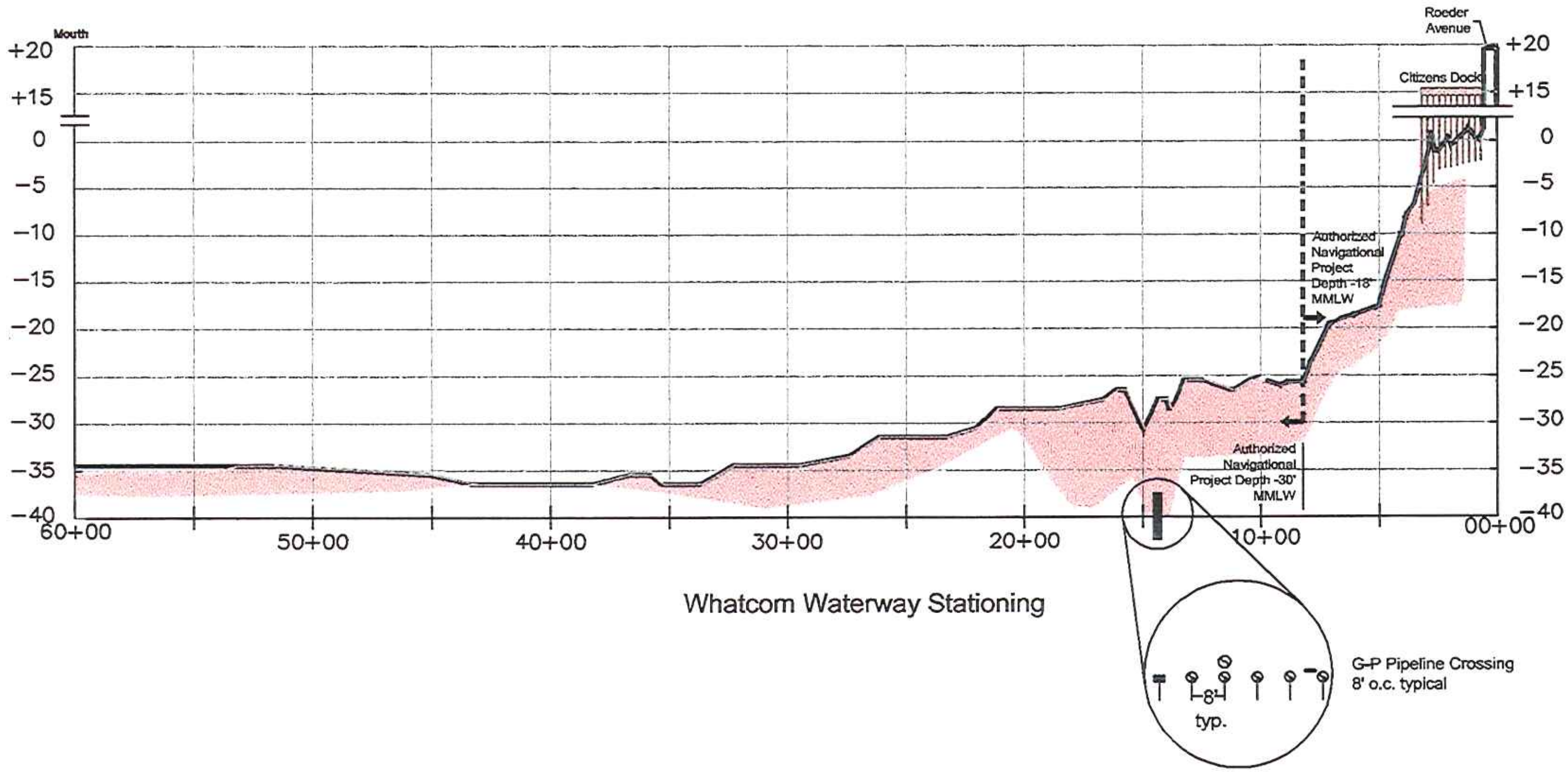
Notes:

[1]SQS and MCUL surface exceedances are based on chemical and/or confirmatory biological testing results for surface samples, and incorporate bioaccumulation screening criteria.

[2]BSL - Surface exceedances are based on screening level exceedances for mercury in sediment (1.2 mg/kg).

[3]In absence of confirmatory biological testing data, the extent of subsurface contamination in the WW Area was estimated using MCUL chemical criteria. As discussed in Section 11, the MCUL chemical criteria provide a conservatively high estimate of the extent of sediments exceeding SQS biological criteria. Testing could be performed during remedial design to refine the volume estimates. Estimated volumes include a 2-foot overdredge allowance (see text).

[4]Estimated depth to the bottom of the contaminated sediment below mudline based on nearby natural recovery cores.



Legend

Existing Mid-Channel Mudline (1996 Soundings)

Subsurface Sediment Exceeding Sediment Quality Standards (SQS) Chemical Criteria

Horizontal Scale in Feet 0 400 800

0 10 20
Vertical Scale in Feet
Vertical Exaggeration x 40

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Figure 12-1
Subsurface Sediment Contamination
Whatcom Waterway

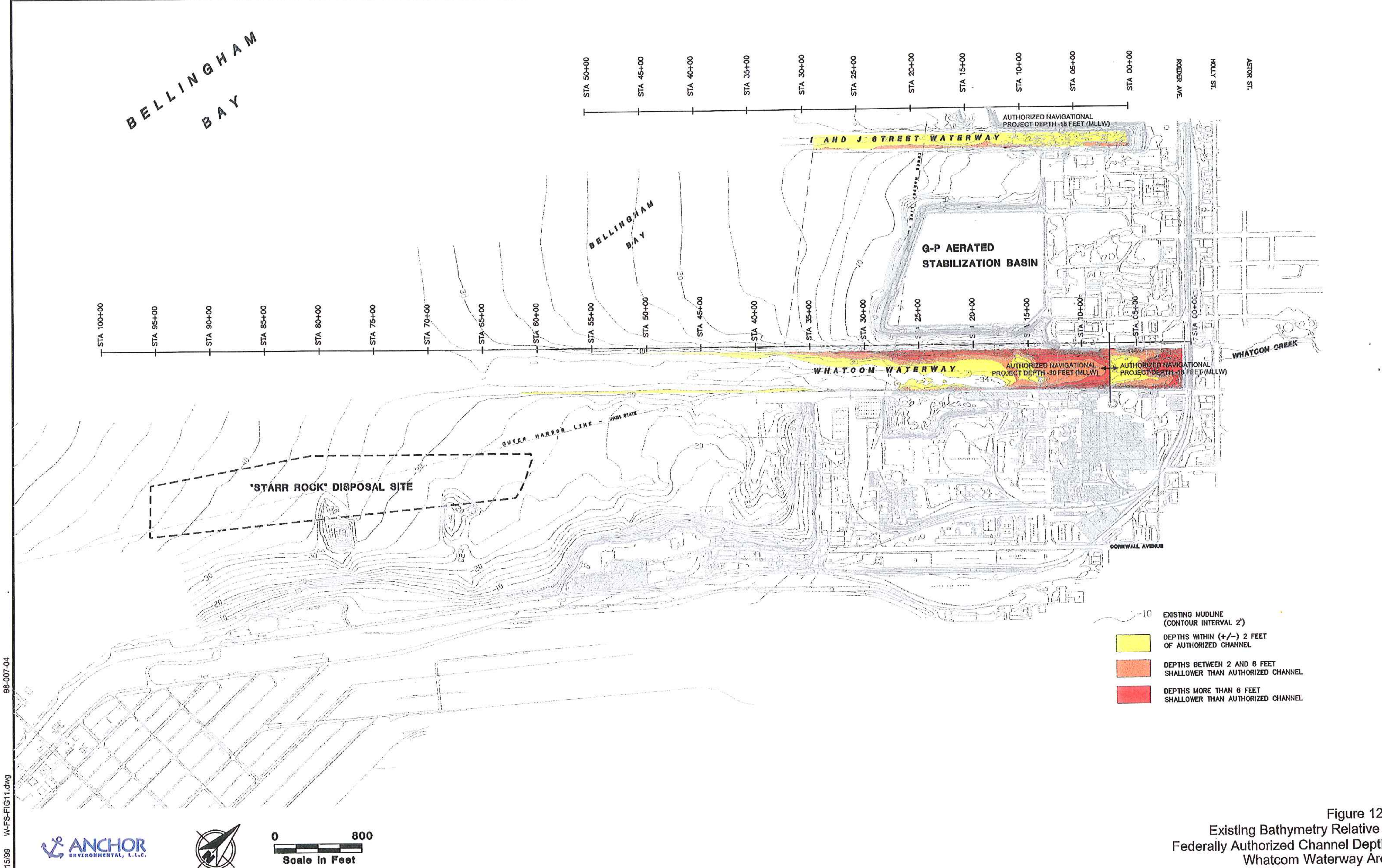


Figure 12-2
Existing Bathymetry Relative to
Federally Authorized Channel Depths
Whatcom Waterway Area

07/15/99 W-FS-FIG11.dwg 98-007-04

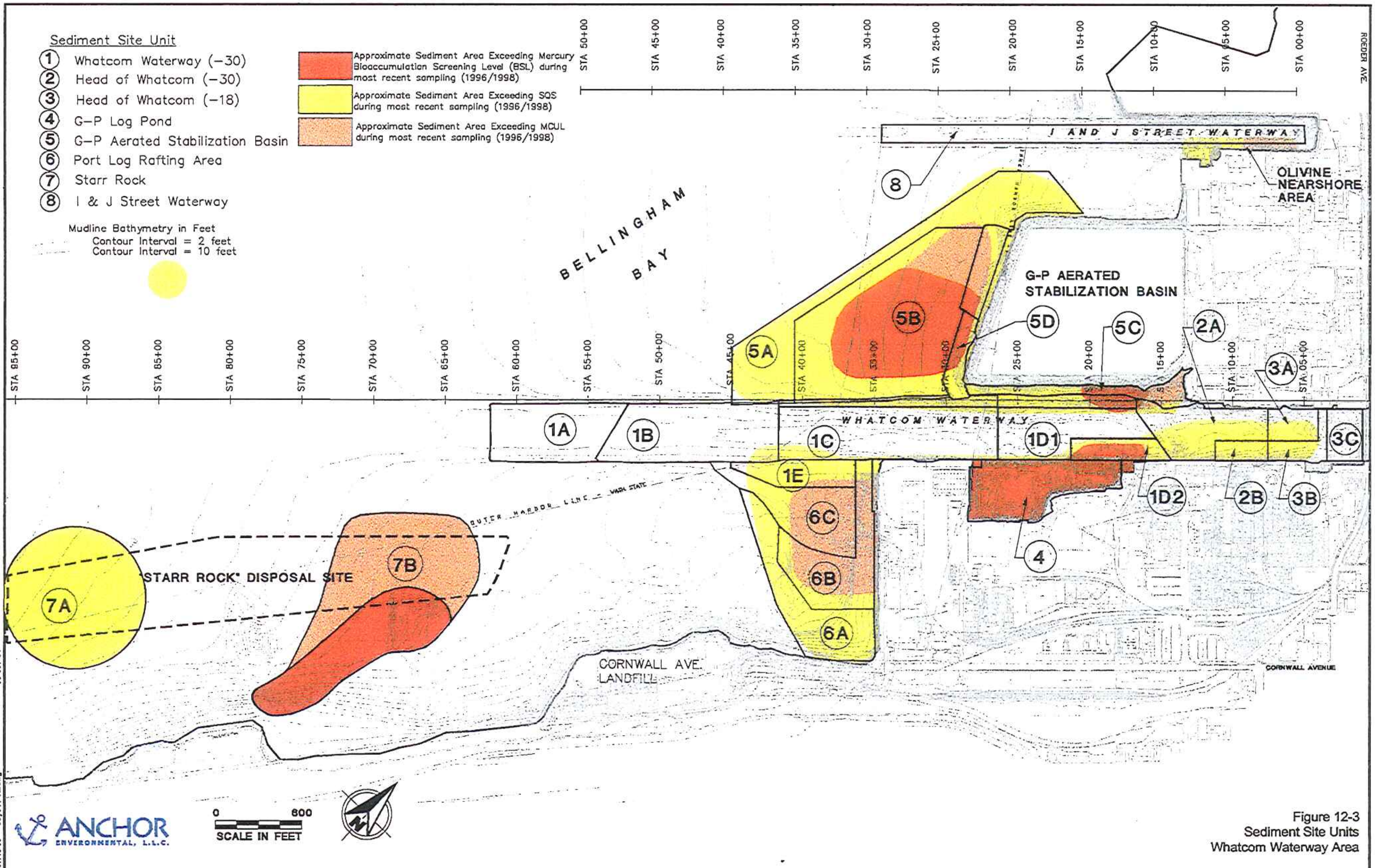


Figure 12-3
Sediment Site Units
Whatcom Waterway Area

13. IDENTIFICATION AND ASSEMBLY OF CLEANUP TECHNOLOGIES

In this section of the RI/FS, cleanup alternatives are developed for possible application to the WW Area. The identification and assembly of cleanup technologies into site-specific alternatives followed both SMS guidance and additional direction provided by Ecology through the Pilot Project(see below).

Alternatives for sediment cleanup generally have three components:

- **General response actions** – major categories of cleanup activities such as natural recovery, containment, or treatment;
- **Cleanup technologies** - general categories of technologies such as dredging coupled with confined disposal in upland, nearshore, or submerged aquatic disposal facilities; and
- **Process options** – specific technologies within each technology type such as mechanical versus hydraulic dredging.

The results of the cleanup technology and process option screening evaluations are presented in Sections 13.1 and 13.2. Screening of potential sediment disposal sites is summarized in Section 13.3. The Pilot Project completed a disposal siting report that was the basis of the disposal site screening (BBWG, 1998a). Finally, retained technologies are assembled into cleanup alternatives in Section 13.4. The subsequent Section 14.0 of this RI/FS presents a detailed evaluation of each alternative relative to MTCA/SMS evaluation criteria.

13.1 Identification and Screening of General Response Actions

As discussed above, there are three forms (response actions) of remediation that can be performed on contaminated sediments:

- Natural recovery;
- Containment; and
- Treatment.

Natural recovery of contaminated sediment may occur over time through a combination of physical and chemical processes that lower the surface concentrations. Natural recovery of sediments in the WW Area has been well documented by the historical record of declining surface concentrations of mercury over the past 25 years (see Section 9.0 of this RI/FS; Volume I). Thus, natural recovery is a proven technology and was considered further in this RI/FS.

Containment involves either confining the contaminated sediments in place or confining dredged materials within a disposal site after removal. Containment technologies have been used extensively in remediation of contaminated sediments elsewhere in Puget Sound (Sumeri, 1996). Thus, containment is a proven technology and was considered further in this RI/FS.

Treatment technologies can potentially reduce contaminant concentration, contaminant mobility, and/or toxicity of the sediments. Most prospective treatment technologies rely on *ex situ* methods that first require sediment removal, followed by chemical destruction, conversion, separation, extraction, or stabilization. Although most treatment techniques are still being evaluated and refined, others have been used successfully (e.g., stabilization). Sediment treatment research has also been promoted by incentives in the 1992 and 1996 Water Resources Development Acts (WRDA), including an ongoing demonstration project to examine the feasibility of treating contaminated sediments from the New York/New Jersey Harbor. This applied research could potentially lead to faster development of sediment treatment technologies.

With the exception of certain technologies such as stabilization, the feasibility of most treatment technologies has not yet been demonstrated for application to contaminated sediments. Based on the current status of these technologies, if a sediment treatment alternative were to be explored for development and implementation within the WW Area or elsewhere on the West Coast, venture capital may need to be made available in the private sector in order to make it economically feasible. In addition, considering the potential scale of operations in the WW Area, these technologies would likely not be available for another 5 to 6 years. Nevertheless, the more promising technologies were evaluated further in this RI/FS (Section 13.2.3).

13.2 Assessment Of Cleanup Technologies

As described in the Sediment Cleanup Standards User Manual, the identification of applicable remedial technologies and process options for each general response action should initially consist of a broad evaluation of the applicable remedial technologies that are available and effective in remediating threats identified at the site. Process options and cleanup technologies may be eliminated from further evaluation on the basis of technical implementability. Subsequent to this initial screening, process options may be further screened on the basis of the following criteria:

- **Effectiveness** – Ability to handle estimated volumes and meet cleanup levels, ability to reduce potential human health and environmental risks, and reliability;
- **Implementability** – Technical and administrative feasibility, such as the ability to obtain permits for offsite actions and availability of treatment, storage, and disposal facilities; and
- **Cost** – Differences among process options within particular technology types.

The remainder of this section presents the evaluation and screening of natural recovery, *in situ* and *ex situ* containment, and sediment treatment technologies.

13.2.1 Natural Recovery

Natural recovery of contaminated sediment may occur over time through a combination of processes including chemical degradation, diffusion from sediments into the water column, burial of contaminated sediment under newly deposited clean material, and mixing of the contaminated sediment with clean sediments above and below through bioturbation (see Figure 13-1). Consistent with Ecology's Sediment Management Standards User Manual, the effectiveness of natural recovery within the WW Area was initially assessed through a combination of historical trend/regression analyses (Section 9.0; Volume I). More detailed modeling of natural recovery is presented in Section 14.2.1 and Appendix K.

Typically, the natural recovery period would begin when adequate source controls are attained, and would continue for an additional period of roughly 10 years (see Sediment Cleanup Standards User Manual). However, in order to achieve Ecology's goal to complete cleanup projects as quickly as practicable, an expedited natural recovery time frame was considered. The year 2005 represents the most rapid time frame for recovery of biological resources following more active cleanup (e.g., dredging). Included in this recovery time frame estimate are the times required for expedited remedy selection (0.5 year), remedial design, permitting, and legal agreements (1.5 years), remedial action implementation/construction (2 years), and biological recovery following construction (2 years).

If natural recovery were to be implemented as a response action in the WW Area, periodic long-term sediment quality monitoring would need to be performed to confirm model predictions and verify that sediment quality recovers to below the cleanup level. Compliance with the cleanup level may be performed using chemical and/or biological testing. The SMS/MTCA also requires that Ecology review cleanups no less than every five years in those cases where contamination has been left in place, to ensure the remedy remains protective.

Subject to a balancing of environmental benefits and cost compared to other practicable alternatives, as defined by the SMS, natural recovery is considered implementable and highly cost effective. Therefore, natural recovery was carried forward for more detailed analysis in this RI/FS.

13.2.2 Containment

Containment can involve both *in situ* actions, such as *in situ* caps, and *ex situ* actions, such as removal and disposal in a confined disposal facility.

13.2.2.1 *In Situ* Capping Technologies

Since the deposition of overlying clean sediment plays a role in the process of natural recovery, this process can be enhanced by actively providing a layer of clean sediment to the target area. This is often referred to as "enhanced" natural recovery or thin-layer capping, and generally consists of placing a nominal 1-foot-thick layer of clean sediment over the existing contaminated sediments. Alternatively, a thicker cap (typically up to 3-feet-thick) could be constructed over the contaminated sediments to provide more immediate isolation of underlying contaminated sediments. (See Figure 13-1).

If selected as part of the overall cleanup remedy in the WW Area, the final cap thickness would be determined as part of remedial design. The cap would be designed to effectively contain and isolate the contaminated sediments from the overlying water column and benthic habitat. In navigational areas where the total thickness of contaminated sediment may not be removed, a cap could be placed over the dredged area. The cap would be designed to be thick enough and of sufficient grain size to resist erosion from mechanical scour, wave action, or burrowing organisms. In addition, the cap would be designed to prevent contaminant migration through the cap into the surrounding water body.

The most common type of capping materials used for either thin-layer or thick capping are dredged materials (including Corps maintenance material) and upland sand. The capping material would be clean (below SQS) sand, and could be placed by a number of mechanical and hydraulic methods (see Section 14.2.2).

Capping has been utilized relatively frequently in sediment cleanup projects conducted in Puget Sound. Monitoring results to date in the region have shown capping can provide an opportunity for effective and economical sediment remediation, without the risks involved in removing contaminants by dredging (Sumeri, 1996). A detailed evaluation of the capping technology, including cap stability considerations within the WW Area, is provided in Section 14.2.2.

Subject to a balancing of environmental benefits and cost, capping is considered implementable and highly cost effective. Therefore, *in situ* capping was carried forward for more detailed evaluation in this RI/FS.

13.2.2.2 Removal and Disposal Technologies

Removal and disposal of contaminated sediments has been performed within the Puget Sound region and elsewhere using a range of different process options appropriate for site-specific conditions. Presented below is an overview of the available process options, followed by a brief review of key technical considerations relevant to application of these technologies within the WW Area.

Contaminated sediments can be removed by dredging using either of the following process options:

- **Mechanical Dredging and Transport.** Typical Puget Sound mechanical dredging involves the use of a clamshell bucket on a derrick barge. Given the prospective dredging volumes in the WW Area, a contractor would most likely use a 7 to 10 cubic yard (CY) bucket. The dredged material would be placed on a 2,000 to 6,000 ton flat deck barge or 1,500 to 3,000 CY split hull dump barge depending on the disposal site. Because of water depth requirements, split hull dump barges would likely be used to transport dredged sediments for disposal at submerged contained aquatic disposal (CAD) and nearshore confined disposal facility (CDF) sites where the mudline is below -5 feet MLLW. Flat deck barges could be used for CAD, and/or nearshore CDF disposal where the mudline is above –5 feet MLLW or for upland disposal. Anticipated daily production rates would be 5,000 to 7,000 CY per day per clamshell.

  Backhoes have been used in some sediment removal projects, though their application is limited to nearshore sites in shallow water. Backhoes generally have higher turbidity associated with dredging and have significantly slower production rates. Because of this, backhoe dredging was not considered an appropriate removal technique for this project.

- **Hydraulic Dredging and Transport.** For the WW Area, a contractor could utilize a 16- to 24-inch-diameter hydraulic cutterhead dredge to accomplish dredging and delivery of contaminated sediments to the disposal site. However, because of water quality control requirements, hydraulic dredging would probably be limited to those options involving a relatively large nearshore CDF. Because only relatively small CDFs were retained by the Pilot Project as prospective disposal sites (see below), hydraulic dredging was not considered a representative removal technique for this project.

There are generally three types of confined disposal facilities (CDFs) available for the disposal of contaminated sediments (see Figure 13-1):

- **Upland.** With this option, contaminated sediments are dredged and placed in a specially designed landfill that is on dry land, away from the aquatic environment. The landfill would include liners and a special water collection system so that leachate draining through the landfill does not escape and contaminate groundwater.

- **Nearshore.** A nearshore CDF is constructed underwater along the shoreline. A berm is constructed of clean material near the shoreline. The lower layer of the area between the berm and the shoreline is then filled with contaminated sediment delivered by barge. The upper layer of the area is covered with clean sediment or fill material until it is above tidal level. Nearshore fills create new land that can be used for public shoreline access or for businesses that depend on being near water. But because they convert aquatic land to dry land, they eliminate aquatic habitat, requiring compensatory mitigation. Nearshore CDFs constructed in Puget Sound have often been integrated with upland redevelopment, and can also be sited on existing contaminated sediment areas to provide further efficiencies.

- **Contained aquatic disposal (CAD).** This type of CDF entails building a submerged berm or depression, filling the constructed basin with contaminated sediments delivered by barge, and then capping the facility with clean sediment. If located in an appropriate site, a CAD could be constructed to convert deeper water substrate into shallower water (e.g., intertidal and shallow subtidal) habitat, concurrently providing habitat creation. CAD facilities can also be sited on existing contaminated sediment areas to provide further efficiencies.

13.2.2.3 Disposal Site Identification and Screening

Through the Pilot Project, a "short list" of prospective CAD, nearshore, and upland disposal sites that may be suitable for the disposal of contaminated sediments dredged from Bellingham Bay (BBWG, 1998a) was developed. Disposal site identification and screening involved a three-step process that resulted in sequential winnowing of the spectrum of potential sites down to a short list of seven sites.

The first step in the process was to develop and apply exclusion and avoidance criteria to the spectrum of potential sites. The development of these criteria followed a screening process similar to the ongoing Multi-user Confined Disposal Site (MUDS) Program (Corps of Engineers, 1999). The initial site screening focused on both exclusionary and avoidance criteria, with the objective of eliminating early in the process those areas which are technically unsuitable, legally precluded, or obviously less optimal as prospective contaminated sediment disposal sites. Following the application of the exclusionary and avoidance criteria to sites throughout the Whatcom and Skagit County area (and beyond), 68 potentially viable sites remained. Of these 68 sites, 36 were upland sites, 15 were nearshore CDFs, and 17 were CAD sites.

The second step in the process was to develop and apply evaluation criteria that would determine which of the 68 potentially viable sites were most desirable. A goal setting exercise was performed to determine overall bay-wide goals to help facilitate this step in the process. Evaluation criteria were then developed for each goal, and used to score and rank the 68 sites. This process identified seven viable disposal sites as follows:

Upland Sites:

- **Roosevelt Landfill**, a large, active sub title D solid waste landfill located in eastern Washington approximately 220 miles by rail from Bellingham; and
- **Whatcom-Skagit Phyllite Quarry**, a currently-operated rock quarry located immediately east of Interstate 5 near the Whatcom-Skagit County line (Figure 1-1).

Nearshore CDF Sites (Figure 13-2):

- G-P Log Pond; and
- **Cornwall Avenue** nearshore areas.

CAD Sites (Figure 13-2):

- G-P Log Pond;
- **G-P ASB** subtidal areas; and
- Starr Rock/Cornwall subtidal areas.

Based on the Pilot Team's preliminary evaluation of various Integrated Near-Term Remedial Action Alternatives, two of the seven disposal sites were removed from further consideration. These sites included:

- **Cornwall Avenue Nearshore CDF.** This nearshore CDF was removed from further consideration primarily because additional uplands were not needed to facilitate potential site redevelopment plans, and the need for filling these aquatic sites could be avoided by using other viable disposal sites. Contaminant mobility controls and structural integrity components common to existing nearshore CDFs in the Puget Sound region have also been built into the retained nearshore CAD alternatives (see Section 14.2.3). In addition, the high cost of habitat mitigation, along with relatively high CDF construction costs at this site, resulted in total unit (i.e., per CY) costs for this nearshore CDF ($120/CY) that exceeded the retained upland disposal alternatives (BBWG, 1998).

- **G-P ASB CAD.** This CAD site was removed from further consideration primarily since a disposal site at this location could potentially interfere with future navigation, and would not provide concurrent habitat restoration benefits. The Subarea Strategy developed by the Pilot Project for this area of Bellingham Bay (Central Waterfront Subarea) identified maritime uses and water-dependent commerce and navigation, balanced with habitat protection and restoration, as primary uses that should be maintained and enhanced (BBWG, 1999c). Construction of a CAD at this site could potentially restrict these land uses, and can be avoided by using CAD sites located in other areas that would not adversely affect primary uses and which provide opportunities for habitat restoration.

Thus, the outcome of the Disposal Siting and Integrated Near-Term Remedial Action Alternative development processes was a final "short" list of five disposal sites that were retained for further, detailed evaluation. The retained sites include two upland facilities (Roosevelt Landfill and Whatcom/Skagit Phyllite Quarry), one nearshore CDF (G-P Log Pond), and two CADs (G-P Log Pond and Starr Rock Cornwall CADs). "Ballpark" cost estimates per unit of sediments dredged and confined at these facilities ranged from approximately $26 per cubic yard (CY) of *in situ* sediment disposed at the Starr Rock/Cornwall CAD, to $72/CY (*in situ* volume basis) for disposal at the Roosevelt Regional Landfill (BBWG, 1998).

Consistent with the Pilot Project process, and subject to a balancing of environmental benefits and costs, these four disposal sites were considered implementable and have also been incorporated into cleanup alternatives considered in this RI/FS (Section 13.3). The detailed evaluation of these alternatives and associated disposal sites is presented in Section 14.0.

13.2.3 Sediment Treatment Technologies

In addition to natural recovery and containment technologies, sediment treatment technologies were also evaluated in this RI/FS. However, with the exception of certain technologies such as stabilization, the feasibility of most treatment technologies has not yet been demonstrated for application to contaminated sediments. Nevertheless, the more promising technologies were evaluated further. Based on technology reviews by EPA (1994 and 1999), supplemented with additional technology reviews performed for this project, some of the more promising treatment methods potentially suitable for sediments containing mercury include:

- Acid Extraction;
- Phytoremediation;
- Soil/Sediment Washing;
- Thermal Desorption;
- Light Weight Aggregate Production;
- Plasma Vitrification;
- Stabilization; and
- ElectroChemicalGeoOxidation.

Each of these potential treatment technologies is discussed below.

- **Acid Extraction.** This process selectively extracts targeted metals such as mercury, while non-regulated metals remain in the treated soil or sediment. Under optimal conditions, metals are concentrated from the process as a 50 to 99 percent pure concentrate that may be suitable for recycling. The process is semi-continuous and consists of three key treatment steps: physical separation, chemical extraction, and liquids processing.

  In the physical separation step, the dredged sediments are segregated at a land-based facility into various size fractions (typically using a 1/16 to 1/4 inch screen), to exclude relatively clean coarse materials such as sands and gravels from further treatment. The chemical extraction step typically consists of a multistage solvent extraction which utilizes proprietary additives in an acidic solvent to preferentially remove metals such as mercury. A slurry consisting of sediment and the acidic solvent is vigorously agitated in closed-top tanks to ensure thorough contact between the soil and solution. Mechanical mixing and/or air sparging accomplish the agitation.

  The rate at which the mercury ions are solubilized and enter the liquid phase is determined by controlling the residence time, solid particle size, degree of agitation, and the extraction solution composition. The optimal solvent/additives formulation, the required number of stages, and the key operating parameters are site specific and are determined by performing bench-scale treatability studies. In the liquids processing step, the metal-laden solvent may be treated by filtration and electro-chemical processes to selectively recover the metal contaminants in a concentrated form. The solvent is treated and recycled back to the chemical extraction portion of the process.

To date, slurry extraction technology has been used successfully to remediate several upland soil sites containing elevated concentrations of mercury and other metals. Typically, these sites have contained much higher concentrations (e.g., greater than 100 mg/kg) and much lower volumes (e.g., less than 10,000 CY) of mercury-containing materials than those present in the WW Area. The presence of organic materials and naturally occurring metals (e.g., iron) that are typical of WW Area sediments are of significant concern when applying this process, and can affect performance and increase costs. A "ballpark" cost estimate per unit of sediments treated, including upland disposal of residues is approximately $200 to $500 per CY of *in situ* sediment (EPA, 1999).

- **Phytoremediation.** Phytoremediation includes a variety of processes that use natural or genetically altered terrestrial plant species to accomplish chemical transformation, accumulation in plant tissue, and/or volatilization to the atmosphere. In previous experimentation and pilot-scale testing specific to soils with relatively high mercury concentrations, gene isolation and introduction methods have been used to genetically engineer various plant species to accomplish such transformations. For example, strains of "hyperaccumulator" species such as Yellow poplar and cattail have been developed that release enzymes into soils, converting (over several steps) methylmercury forms to the less toxic, elemental and volatile form of mercury (Phytoworks, Inc., unpublished data, 1998). The elemental mercury is then transpired through the plant tissue, and released into the atmosphere. Because elemental mercury is normally considered to be less toxic than other forms of mercury (especially methylmercury forms), atmospheric release of volatile mercury may not pose a significant health risk. Nevertheless, the potential health hazards associated with application of this technology would need to be addressed in any full-scale operation.

  Use of phytoremediation technologies within the WW Area would require transfer of sediments to an upland treatment/disposal facility, and spreading of the sediments in a relatively thin layer (e.g., up to several feet thick) that would be seeded with freshwater or brackish hyperaccumulator species. Currently, field-scale phytoremediation of mercury soils has only been performed in the southeast (characterized by relatively long growing seasons), though bench-scale testing is currently underway in other areas of the U.S. Similar to the acid extraction technology, these sites have contained much higher concentrations (greater than 100 mg/kg) and much lower volumes (less than 10,000 CY) of mercury-contaminated materials than those present in the WW Area. Based on these previous applications, a range of plant tissue manipulations, bench-scale laboratory analysis, and pilot-scale testing would likely be necessary to determine the feasibility of this process for application to WW Area sediments. Finally, because low-level contaminant residues could continue to persist in the treated material (e.g., above MTCA groundwater protection criterion of 1 mg/kg total mercury), the final residue may still require containment or upland landfill disposal. A "ballpark" cost estimate per unit of sediments treated, including upland disposal of residues, would likely exceed roughly $100 per cubic yard of *in situ* sediment.

- **Soil/Sediment Washing.** Soil/sediment washing is a water-based, volumetric reduction process whereby chemicals such as mercury are extracted and concentrated into a smaller residual volume using physical and chemical methods. Similar to the acid extraction process summarized above, an initial physical separation step is used at a land-based facility to exclude relatively clean coarse materials such as sands and gravels from further treatment. Subsequently, chemical extraction agents are added to the water-based "washing" medium, and may include surfactants, chelating agents, coagulants, flocculants, and pH modifiers.

  Under optimal conditions, the washing process permits concentration of hazardous chemicals into a residual liquid (water-based) product representing 10 to 30 percent of the original sediment volume. However, these volumetric reductions can become more difficult to achieve for sediments such as those within the WW Area, which typically contain more than 80 percent fines. The presence of wood material, also characteristic of subsurface sediments in the WW Area, may further reduce the effectiveness of soil/sediment washing.

  The residual liquid (water-based) product produced by the soil/sediment washing process requires further treatment by appropriate immobilizing processes such as chemical extraction, thermal treatment, or stabilization. Chemical extraction is discussed above, while thermal treatment and stabilization are described below. In some cases, the wastewater may be discharged to an off-site treatment plant. A "ballpark" cost estimate per unit of sediments treated, including treatment of residues, may range from approximately $50 to $500 per cubic yard of *in situ* sediment, depending on site conditions (EPA, 1999; Weston/BioGenesis, 2000).

- **Thermal Desorption.** Several vendors have developed and commercialized medium-temperature thermal desorption processes for removing mercury from soils and sediments to below the MTCA groundwater protection criterion of 1 mg/kg. The process can recover a range of inorganic forms of mercury in up to 99 percent pure metallic form suitable for reuse. Further, the process can operate without producing liquid or solid secondary wastes, and can be designed to meet clean air standards.

  In the process, soils/sediments are blended with a proprietary additive, which promotes decomposition of stable mercury compounds, and the blended sediments are then loaded into a batch-operated furnace for processing. Thermal processing is divided into two stages: feed drying and mercury desorption. The furnace temperature is ramped to a temperature at which moisture in the feed can be removed with minimum volatilization of mercury. During this stage, the process off gas is routed through a gas filtration system. After the feed has been dried, the furnace temperature is raised to, and held at, a temperature at which the mercury is driven off as a dry vapor. In this stage, the process gas stream is routed through a heat exchanger to condense metallic mercury from mercury vapor before the gas is routed through a gas filtration system. The operating temperature for the process typically ranges from 300 to 1,400 degrees Fahrenheit, depending on the moisture content of the soil/sediment and other site characteristics. The furnace and air handling components are typically protected by secondary containment, which operates under an air treatment system separate from that of the process air.

The medium-temperature thermal desorption process has been used successfully to remediate a range of upland soil sites containing mercury and other metals. Typically, these sites have contained much higher concentrations and much lower volumes of mercury-containing materials than those present in the WW Area. Considering the relatively high moisture content of WW Area sediments, relative to upland soils, a "ballpark" cost estimate per unit of sediments treated, including disposal of residues, is approximately $500 to $2,000 per cubic yard of *in situ* sediment (EPA, 1999).

- **Light Weight Aggregate Production.** Several commercial ventures have developed processes that use mostly or all contaminated sediments as the raw material to produce light weight aggregate (LWA) with 30 percent less weight than regular rock but with the same strength. Typical LWA is made by heating pellets of compacted sediment (supplemented with clay or shale as required) to about 1,100 °C in a kiln. The material tends to break along fracture lines and therefore has inherent weak points.

  A typically process flow consists of the following steps: 1) screen or filter dredged sediments to separate out sands, gravels, and other coarse materials; 2) grind, mix (possibly with clay or shale), and dry the material; 3) process the material through an extruder to make homogenous pellets; 4) further dry the pellets (optional); 5) process the pellets through a kiln; and 6) cool the pellets prior to transport and use.

  Some of the issues that would need to be addressed in a full-scale application of LWA production include: 1) energy required to run the plant and possible use of waste heat in the drying process at a fixed plant location; 2) transportation costs; 3) kiln temperatures of 1,100 °C may not be sufficient to destroy organic contaminants such as PCBs; and 4) the limited regional "market" for contaminated sediment treatment that may result in increased costs. In addition, possible atmospheric release of volatile mercury from the treatment process may need to be controlled to prevent a significant health risk. Given these parameters, a "ballpark" cost estimate per unit of sediments treated could range from approximately $30 to $100 per cubic yard of *in situ* sediment, depending on operating parameters (HarborRock, 2000).

- **Plasma Vitrification.** Several companies are currently developing higher-temperature processes in which contaminated sediments may be converted to a useful glass product by direct injection into the plume of a high-power, non-transferred-arc plasma torch (McGlaughlin et al., 1999). The sediments are first pretreated by conventional sorting and washing processes to remove large particles and debris, and to reduce the salt content. The sediment is then partially dewatered to produce a slurry or paste with as low a moisture content as possible while still being pumpable. Inexpensive fluxing agents such as lime and soda ash are then added to adjust the final properties of the glass to be produced (melting point, viscosity, thermal expansion, and leachability).

  The mixture is then melted in the plasma reactor at temperatures exceeding 2,000 °C. The resulting molten glass for many sediments is granulated, producing an aggregate product which typically has low leachability. The glass product may then be used as the feedstock for a variety of products, including sandblasting grit, fiberglass, insulation fiber, roofing granules, and road aggregate. However, the application that appears to exhibit the best economics is ceramic tile. Pilot testing and preliminary market studies suggest that revenue from the sale of tile may significantly offset the cost of sediment treatment. For high production facilities, a "ballpark" cost estimate per unit of sediments treated is approximately $150 to 200 per cubic yard of *in situ* sediment (McGlaughlin et al., 1999). However, a large market (i.e., treatment of contaminated sediments from numerous sites), along with venture capital, may need to be made available in the private sector in order to make this technology economically feasible. The results of the demonstration program in the New York/New Jersey harbor area, including production of roughly 1 ton of ceramic tile, suggest that markets may be developed for sale of this product.

- **Stabilization.** A number of different companies have developed manufacturing technologies for producing construction-grade cements or lightweight aggregate materials from a wide variety of contaminated waste materials, including sediments (Rehmat et al., 1999). Using various proprietary additives and processes, metals and organic chemicals can be immobilized and sequestered within the stabilized product. The material can be transformed into construction-grade cement.

  While stabilization has been used successfully using relatively coarse soils and sediments, the fine-grained characteristics of WW Area sediments (i.e., greater than 80 percent fines) would require the addition of sand and/or gravel material to achieve typical structural requirements.

Further, the presence of organic materials that are typical of WW Area sediments are of significant concern when applying this process, and can substantially affect performance and increase costs. Finally, since the stabilization process does not permanently destroy chemical contaminants, the permanence (e.g., long-term durability) of the stabilized matrix would need to be addressed in bench-scale testing. A "ballpark" cost estimate per unit of sediments treated is approximately $100 per cubic yard of *in situ* sediment (EPA, 1999).

- **ElectroChemicalGeoOxidation (ECGO).** This technology, originally developed in Europe, 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. The technology appears capable 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 ECGO technology has been used successfully to remediate a range of upland soil sites and a one sediment site in Europe containing elevated concentrations of mercury and other metals. However, the technology has not yet been applied in the U.S.

  One issue that would need to be addressed to evaluate *in situ* applications of the ECGO technology in Bellingham Bay are the possible environmental effects of releasing currents to the aquatic environment, including behavioral effects on electrosensitive cartilaginous fish such as spiny dogfish (*Squalus acanthias*) and spotted ratfish (*Hydrolagus colliei*). The ECGO technology also apparently results in increased metal mobility during treatment, which allows the metals to migrate towards the electrodes. Although theoretical considerations suggest that relative metal mobility will return to pre-treatment levels following cessation of ECGO, this condition may need to be verified. Based on an initial review, and pending pilot testing to confirm the effectiveness of this technology, a "ballpark" cost estimate per unit of sediments treated using ECGO may range from roughly $25 to $100 per CY of in situ sediment (Weiss, 2000).

As discussed above and in various Water Resources Development Act (WRDA) project reports, a range of different treatment technologies have been evaluated and some are being carried forward for additional analysis. Although several existing treatment technologies are feasible, the potential implementability and effectiveness on various types of contaminants and volumes of sediment has not yet been demonstrated. Specifically, the high sediment volumes and low contaminant concentrations present within the WW Area may be difficult to address using available treatment technologies. For these reasons, treatment of sediments was not carried forward for more detailed analysis in this RI/FS.

In spite of these potential limitations, there are nevertheless a number of promising treatment technologies that could possibly be developed for application to the WW Area and other areas of Puget Sound. The Cooperative Sediment Management Program (CSMP), a consortium of federal and state agencies formed in 1994 to oversee the management of Puget Sound sediments, recently initiated a study to assess the feasibility and practicability of developing a multi-user treatment program or facility to help manage contaminated sediments in Puget Sound. The multi-user treatment and disposal study was initiated in spring, 2000. The study will:

- Assess the market feasibility of treating contaminated sediments in the Puget Sound area;
- Identify the most technically feasible treatment methods;
- Characterize potential environmental impacts associated with the more promising alternatives;
- Compare sediment properties associated with typical urban sediments in Puget Sound with East Coast sediments that have previously been used in bench- and pilot-scale treatment demonstrations;
- Determine the feasibility of a regional treatment facility, including identification of barriers to a constant minimum flow of contaminated dredged material (or alternative raw materials) required to maintain facility operation;
- Identify and suggest options for private or public-private funding of a regional treatment facility, including government incentives to encourage private sector development; and
- Perform public outreach to solicit public comments on the feasibility of treating contaminated sediments in the Puget Sound region.

The results, of the CSMP study, expected in draft form by early 2001, may recommend one of three possible courses of action:

1. Pursue a public or private management option to construct and implement the most promising treatment technology(ies);
2. Issue a Request for Proposals for a private/public partnership to construct and implement the most promising treatment technology(ies); or
3. Implement a pilot study of the most promising treatment technology(ies), and use that information to determine the feasibility of a future public management or private/public partnership option.

Beginning in fall 2000, and in concert with the CSMP study, DNR is planning to initiate a pilot study to evaluate treatment technologies specific to Bellingham Bay sediments. Those promising treatment technologies identified by DNR will be evaluated to assess production, cost and effectiveness. This site-specific study, coupled with the CSMP described above will provide an updated determination of the practicability of sediment treatment for WW Area sediments. These evaluations could amend the

RI/FS analysis described herein, and may be integrated into the overall Cleanup Action Plan developed for the WW Area.

13.3 Assembly Of Different Cleanup Technologies

A variety of potentially applicable response actions, remedial technologies, and process options for the WW Area were screened and described in Section 13.2, and those technologies that would be effective and implementable were identified. In this section, these technologies are combined to formulate a range of remedial action alternatives.

The cleanup technologies suitable for each (SSU can be grouped in numerous combinations. However, the remedial alternatives are limited to compatible cleanup technologies that protect human health and the environment. The technologies applied to each SSU also need to be complementary when implemented in combination. Finally, the alternatives were designed to be consistent with Subarea Strategies for different regions of Bellingham Bay (BBWG, 1999c). As discussed above, preliminary habitat mitigation requirements and restoration priorities, key land use concerns, and sediment cleanup priorities were blended into the alternatives. This was used to form the primary basis of the remedial alternatives.

For the purpose of this RI/FS, a broad range of remediation alternatives that represent a wide spectrum of potentially appropriate remedial technologies and process options was developed. These alternatives include different combinations of natural recovery, capping, removal, and disposal. When viewed together, the alternatives present a full range of potential remediation options available within the WW Area, and highlight tradeoffs associated with implementation of different remedial technologies, consistent with the objectives of the RI/FS. However, it should be noted that elements of all of the alternatives are subject to modification, based on ongoing agency, landowner, and public review.

The alternatives developed and evaluated in this RI/FS were also designed to be fully consistent with the Integrated Near-Term Remedial Alternatives developed by the Pilot Team and presented in the Bellingham Bay Comprehensive Strategy EIS (BBWG, 1999c). The Pilot Team used a consensus-based decision making approach to identify and assemble a range of bay-wide cleanup alternatives, including alternatives addressing the WW Area. All of the Pilot Project remedial alternatives are addressed in this RI/FS, in addition to alternatives developed independently (Alternatives B through D; see below). Differences between the alternatives involve cleanup volumes, disposal methods, habitat restoration opportunities, and aquatic land use implications, all of which are addressed in the draft EIS. This RI/FS is intended to supplement the EIS.

Following are brief descriptions of each of the alternatives carried forward into the detailed RI/FS evaluation, arranged in order of generally increasing removal/disposal volumes and costs (Pilot Project alternative numbers are provided in parentheses for cross-referencing). Chapter 14 presents a more detailed description of each alternative.

- **Cleanup Alternative A: No Action.** Under this alternative, there would be no sediment cleanup, habitat restoration, monitoring activities, or land use actions. The existing bay sediments would continue to recover naturally over time.

- **Cleanup Alternative B: Source Control & Natural Recovery with Capping.** All "action" alternatives evaluated in this RI/FS (i.e., Alternatives B through I) include source controls. This alternative would utilize natural recovery in those parts of the WW Area that are predicted to naturally achieve SQS criteria by 2005, which is as rapid as biological resources would recover at the site following a more active cleanup (e.g., dredging). Those areas of the site that are not predicted to recover, and which occur outside of the navigation channel, would be capped with a 1- to 3-foot sand layer. A relatively small area in the middle of the Whatcom Waterway that is predicted to recover by 2005, partly as a result of resuspension-related transport, would be left to recover naturally. Other site units within the WW Area that currently exceed the BSL would be capped to accelerate the natural recovery process. All cleanup areas of the site would be monitored to document sediment recovery using a combination of chemical and biological testing methods. No dredging would occur under this alternative. A layout of Alternative B is presented in Figure 13-3.

- **Cleanup Alternative C: Capping & Removal to Improve Navigation (Log Pond Nearshore CDF).** This alternative combines capping and limited dredging within the middle of the Whatcom Waterway navigation channel to achieve SQS criteria throughout the WW Area. As in Alternative B, those areas of the site that are not predicted to recover (using conservative modeling assumptions), and which occur outside of the navigation channel, would be capped with a 1- to 3-foot sand layer. No further action would be undertaken in the outer Whatcom Waterway reach where surface sediments currently meet SQS criteria *and* where channel depths are consistent with the federally authorized elevations.

  Surface and subsurface sediments within the middle of the Whatcom Waterway adjacent to the G-P Log Pond would be dredged to a depth of at least 5 feet below the currently authorized channel depths. Since subsurface contaminants would still be present below the dredge depth, the dredge cut would be capped with a 2-to-3-foot clean sand layer, resulting in a final channel elevation at least 2 feet below the authorized depth. This dredge-and-cap action would leave sufficient tolerance to allow unencumbered future maintenance dredging of the authorized federal channel in this area, considering typical overdredge allowances. No action would be undertaken at the head of the Whatcom Waterway (i.e., above Station 15+00), as this area (currently exceeding SQS but below MCUL biological criteria) would be left to recover naturally to below the SQS by 2005.

An estimated 160,000 CY of sediments would be dredged under this alternative. Dredged sediments would be reused to create a nearshore CDF in the G-P Log Pond. Excess sediments that do not fit into the nearshore fill would be disposed at an off-site upland landfill. Habitat mitigation actions including at least 6 acres of area-for-area replacement by fill removal and/or acquisition and enhancement at high priority habitat creation sites would be performed as a part of implementation of this alternative. A layout of Alternative C is presented in Figure 13-4.

- **Cleanup Alternative D: Capping & Removal to Improve Navigation (Upland Disposal).** This alternative is identical to Alternative C except that all of the dredged material would be disposed at an upland landfill instead of in the G-P Log Pond nearshore CDF. The dredge material would either be reused to restore a wetland habitat at the Whatcom-Skagit Phyllite Quarry, or, alternatively, disposed at the Roosevelt Regional landfill. A layout of Alternative D is presented in Figure 13-5.

- **Cleanup Alternative E: Capping & Removal to Achieve Authorized Channel Depths (CAD Disposal) (Pilot Project No. 2A).** The overall objective of this alternative is to achieve SQS criteria in the WW Area while concurrently maintaining existing navigation channels, minimizing dredging and disposal of contaminated sediment, and maximizing the areal extent and diversity of intertidal aquatic habitat by using caps and CAD facilities. Enough material would be dredged from the Whatcom Waterway to remove contaminated sediments from the existing federal channel (including overdredge allowances) in all areas of the waterway that are currently used for navigation. Except for the extreme head of the Whatcom Waterway that currently contains mudflat habitat, surface and subsurface sediments throughout much of the waterway would be dredged to a depth of at least 5 feet below the currently authorized channel depths. However, no further action would be undertaken in the outer Whatcom Waterway reach where surface sediments currently meet state standards and where channel depths are consistent with the federally authorized elevations. Other contaminated sediment areas would be capped with a 1-to-3-foot clean sand layer. In this alternative a 3-acre area of mudflat and adjacent shallow subtidal habitat would be left intact at the head of the Whatcom Waterway.

  Approximately 360,000 CY of contaminated sediment from navigation areas within the Whatcom Waterway would be dredged. In this alternative, the sediment disposal capacity would be provided by two CAD facilities (Figure 13-2):

  1. A small (up to 50,000 CY) CAD sited in the G-P Log Pond; and

  2. A larger 500,000 CY CAD sited in the Starr Rock/Cornwall area. The Starr Rock/Cornwall CAD could also be implemented as a multi-user disposal facility to contain contaminated sediments that may be dredged from other sites in Bellingham Bay.

Both CAD facilities would provide opportunities for concurrent habitat restoration. Largely because of the CADs, approximately 42 acres of subtidal area would be converted into intertidal habitat. A layout of Alternative E is presented in Figure 13-6.

- **Cleanup Alternative F: Capping & Removal to Achieve Authorized Channel Depths (Upland Disposal) (Pilot Project No. 2B).** The overall objective of Alternative F is to achieve SQS criteria in the WW Area while maintaining existing navigation channels and minimizing dredging and disposal of contaminated sediment. This alternative includes the same amount of dredging as Alternative E, but would dispose of the materials at one or more off-site upland landfills. Other contaminated sediment areas would be capped with a 1-to-3-foot clean sand layer.

  All dredged sediments would be offloaded on shore, dewatered as necessary to facilitate transport, and hauled by rail, truck, and/or barge outside of the Bellingham Bay watershed to upland disposal facilities. Approximately 360,000 CY of contaminated sediment from navigation areas within the Whatcom Waterway would be dredged. In this alternative, the Whatcom-Skagit Phyllite Quarry or the Roosevelt Regional Landfill would provide the sediment disposal capacity. A layout of Alternative F is presented in Figure 13-7.

- **Cleanup Alternative G: Full Removal from Navigation Areas (CAD Disposal) (Pilot Project No. 2C).** The overall objective of this alternative is to achieve SQS criteria in the WW Area, allowing for possible future deepening of the navigation channels, and maximizing the areal extent and diversity of intertidal aquatic habitat by using caps and CAD facilities. Unlike Alternative E, minimizing dredging and disposal volumes is not a primary objective of Alternative G. Contaminated sediments that are located within the Whatcom Waterway, even if present below the currently authorized depths, would be dredged, removing potential encumbrances to channel deepening, should such a deepening project be undertaken in the future. Dredging would be performed throughout the Whatcom Waterway, including a 1-acre area at the head of the waterway.. The extreme head of the Whatcom Waterway near Citizens Dock, consisting of a 2-acre area of mudflats that has formed naturally within this area, would be left intact.

  Approximately 760,000 CY of contaminated sediment from navigation areas within and adjacent to the Whatcom Waterway would be dredged. In this alternative, the sediment disposal capacity would be provided by two CAD facilities (Figure 13-2):

  1. A small (up to 50,000 CY) CAD sited in the G-P Log Pond; and

  2. A larger 1,100,000 CY CAD sited in the Starr Rock/Cornwall area. The Starr Rock/Cornwall CAD could also be implemented as a multi-user disposal facility to contain contaminated sediments that may be dredged from other sites in Bellingham Bay.

Both CAD facilities would provide concurrent habitat restoration. Largely because of the CADs, approximately 63 acres of subtidal area would be converted into intertidal area. A layout of Alternative G is presented in Figure 13-8.

- **Alternative H: Full Removal from Navigation Areas and Partial Removal from the G-P ASB and Starr Rock Areas (Upland Disposal) (Pilot Project No. 2D).** Similar in some respects to Alternative G, the overall objective of Alternative H is to achieve SQS criteria in the WW Area, allowing for potential future deepening of the navigation channels. This alternative includes a dredging of those areas included in Alternative G, but also includes the dredging of an additional 320,000 CY of sediments exceeding the site-specific bioaccumulation screening level criteria that are located offshore of the G-P ASB and at the former Starr Rock disposal site. The dredged sediments would be disposed at one or more off-site upland landfills. Other contaminated sediment areas would be capped with a 1-to-3-foot clean sand layer.

  All dredged sediments would be offloaded on shore, dewatered as necessary to facilitate transport, and hauled by rail, truck, and/or barge outside of the Bellingham Bay watershed to upland disposal facilities. Approximately 1,080,000 CY of contaminated sediment from the WW Area would be dredged. In this alternative, the sediment disposal capacity would occur at the same upland disposal facilities described for Alternative F. A layout of Alternative H is presented in Figure 13-9.

- **Cleanup Alternative I: Full Removal (Upland Disposal).** The overall objective of Alternative I is to completely remove all contaminated sediment within the WW Area, and totally avoid disposal in the aquatic environment. This alternative would also allow for possible future deepening of the navigation channels and state-owned harbor areas. Like Alternative H, avoiding disposal in the aquatic environment is a primary objective. With the exception of sediments located immediately adjacent to the existing G-P wastewater pipeline, dredging would be performed within all reaches of the WW Area, including the extreme head of the federal channel, encompassing Citizens Dock and associated mudflat areas. All dredged sediments would be offloaded on shore, dewatered as necessary to facilitate transport, and hauled by rail and/or truck outside of the Bellingham Bay watershed to upland disposal facilities. Approximately 2,060,000 CY of contaminated sediment from the WW Area would be dredged. In this alternative, the sediment disposal capacity would be provided by the same upland disposal facilities described for Alternative F. A layout of Alternative I is presented in Figure 13-10.

A summary matrix of remedial alternatives by SSU within the WW Area is presented in Table 13-1. Detailed analyses of the individual alternatives are presented in Section 14.0.

Table 13-1 - Matix of Remedial Alternatives by SSU

Pilot Project	NA	NA	NA	NA	2A	2B	2C	2D	NA
	A	B	C	D	E	F	G	H	I
	Remedial Action (Dredge Cut Elevation[1])								
Site Sediment Unit	**No Action/ Natural Recovery**	**Natural Recovery w/ Capping**	**Limited Removal with Log Pond Disp.[4]**	**Limited Removal with Upland Disp.**	**Removal & Cap to Achieve Auth. Channel w/ CAD**	**Removal & Cap to Achieve Auth. Channel w/ Upland**	**Full Removal from Navigation Areas w/ CAD**	**Full Removal from Navigation Areas w/ Upland**	**Full Removal with Upland Disp.**
1A	No Action (NA)	No Action (NA)	No Action (NA)	No Action (NA)	No Action (NA)	No Action (NA)	**Dredge** -37	**Dredge** -37	**Dredge** -37
1B	No Action (NA)	No Action (NA)	**Cap** (NA)	**Cap** (NA)	No Action (NA)	No Action (NA)	**Dredge** -37	**Dredge** -37	**Dredge** -37
1C	No Action (NA)	No Action (NA)	**Cap** (NA)	**Cap** (NA)	**NA, Dredge+Cap** -35	**NA, Dredge+Cap** -35	**Dredge** -39	**Dredge** -39	**Dredge** -39
1D1	No Action (NA)	No Action (NA)	**Dredge+Cap** -35	**Dredge+Cap** -35	**Dredge** -35	**Dredge** -35	**Dredge** -35	**Dredge** -35	**Dredge** -35
1D2	No Action (NA)	No Action (NA)	**Dredge+Cap** -35	**Dredge+Cap** -35	**Dredge+Cap** -35	**Dredge+Cap** -35	**Dredge** -42	**Dredge** -42	**Dredge** -42
1E	No Action (NA)	No Action (NA)	No Action (NA)	No Action (NA)	**Dredge** 3[2]	**Dredge** 3[2]	**Dredge** 3[2]	**Dredge** 3[2]	**Dredge** 3[2]
2A	No Action (NA)	No Action (NA)	No Action (NA)	No Action (NA)	**Dredge+Cap** -35	**Dredge+Cap** -35	**Dredge+Cap** -35	**Dredge+Cap** -35	**Dredge+Cap** -35
2B	No Action (NA)	No Action (NA)	No Action (NA)	No Action (NA)	**Dredge+Cap** -35	**Dredge+Cap** -35	**Dredge+Cap** -35	**Dredge+Cap** -35	**Dredge+Cap** -35
3A	No Action (NA)	No Action (NA)	No Action (NA)	No Action (NA)	**Dredge** -23	**Dredge** -23	**Dredge** -23	**Dredge** -23	**Dredge** -23
3B	No Action (NA)	No Action (NA)	No Action (NA)	No Action (NA)	No Action (NA)	No Action (NA)	**Dredge** -23	**Dredge** -23	**Dredge** -23
3C	No Action (NA)	No Action (NA)	No Action (NA)	No Action (NA)	No Action (NA)	No Action (NA)	No Action (NA)	No Action (NA)	**Dredge** -23
4	No Action (NA)	**Cap** (NA)	**Nearshore Fill** (NA)	**Cap** (NA)	**CAD** (NA)	**Cap** (NA)	**CAD** (NA)	**Cap** (NA)	**Dredge** -14
5A	No Action (NA)	No Action (NA)	No Action (NA)	No Action (NA)	**Cap** (NA)	**Cap** (NA)	**Cap** (NA)	**Cap** (NA)	**Dredge** 2[2]
5B	No Action (NA)	**Cap** (NA)	**Cap** (NA)	**Cap** (NA)	**Cap** (NA)	**Cap** (NA)	**Cap** (NA)	**Dredge, Cap** (NA)	**Dredge** 3[2]
5C	No Action (NA)	**Cap** (NA)	**Cap** (NA)	**Cap** (NA)	**Dredge+Cap, Cap** (NA)	**Dredge+Cap, Cap** (NA)	**Dredge+Cap, Cap** (NA)	**Dredge, Cap** (NA)	**Dredge** 3[2]
6A	No Action (NA)	No Action (NA)	No Action (NA)	No Action (NA)	**Cap** (NA)	**Cap** (NA)	**Cap** (NA)	**Cap** (NA)	**Dredge** 2[2]
6B	No Action (NA)	No Action (NA)	No Action (NA)	No Action (NA)	**Cap** (NA)	**Cap** (NA)	**Cap** (NA)	**Cap** (NA)	**Dredge** 3[2]
7A	No Action (NA)	No Action (NA)	No Action (NA)	No Action (NA)	**Cap** (NA)	**Cap** (NA)	**Cap** (NA)	**Cap** (NA)	**Dredge** 3[2]
7B	No Action (NA)	No Action (NA)	No Action (NA)	No Action (NA)	**Cap[3]** (NA)	**Cap** (NA)	**Cap[3]** (NA)	**Dredge, Cap** 3[2]	**Dredge** 3[2]
8	No Action (NA)	No Action (NA)	No Action (NA)	No Action (NA)	No Action (NA)	No Action (NA)	No Action (NA)	No Action (NA)	No Action (NA)

Sediment Site Unit Descriptions

1: Outer Whatcom Waterway (-30)
2: Inner Whatcom Waterway (-30)
3: Inner Whatcom Waterway (-18)
4: G-P Log Pond
5: G-P Aerated Stabilization Basin (ASB)
6: Port Log Rafting Area
7: Starr Rock
8: I & J Street Waterway

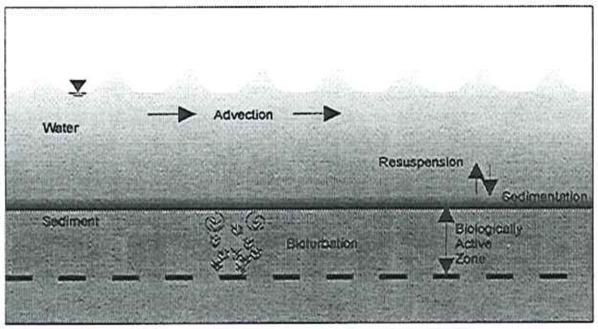
Notes:

[1]Elevations are feet MLLW to the bottom of contaminated sediment. These elevations do not include any overdredging.
[2]Estimated depth to the bottom of the contaminated sediment below mudline. These depths do not include any overdredging.
[3]Part of the site would support a CAD.
[4]Excess disposal volume to Roosevelt Landfill

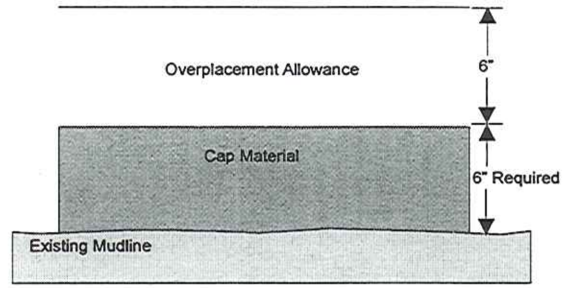
NA - Not applicable.
Cap - thickness varies from 1 to 3 feet and will be determined during remedial design.

Sediment Remediation Technologies, Bellingham Bay Demonstration Pilot Project

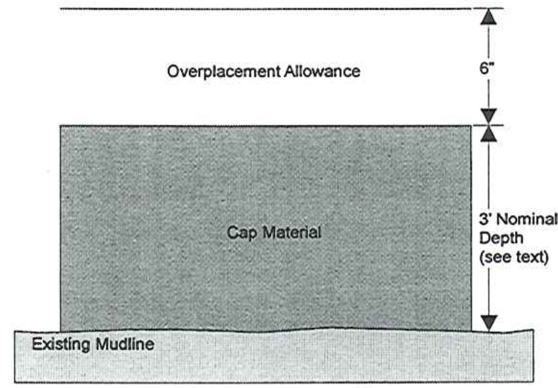
Non-Removal Technologies



General Schematic of Natural Recovery Process

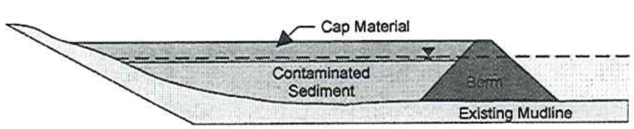


Thin-Layer Cap Section (Typ.)

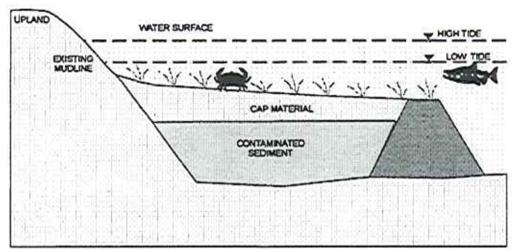


Thick Cap Section (Typ.)

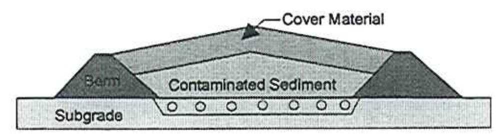
Removal and Disposal Technologies



Nearshore Confined Disposal



Confined Aquatic Disposal



Upland Confined Disposal

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Disposal alternatives 1.CDR
07/15/99

Figure 13-1
Sediment Remediation Technologies

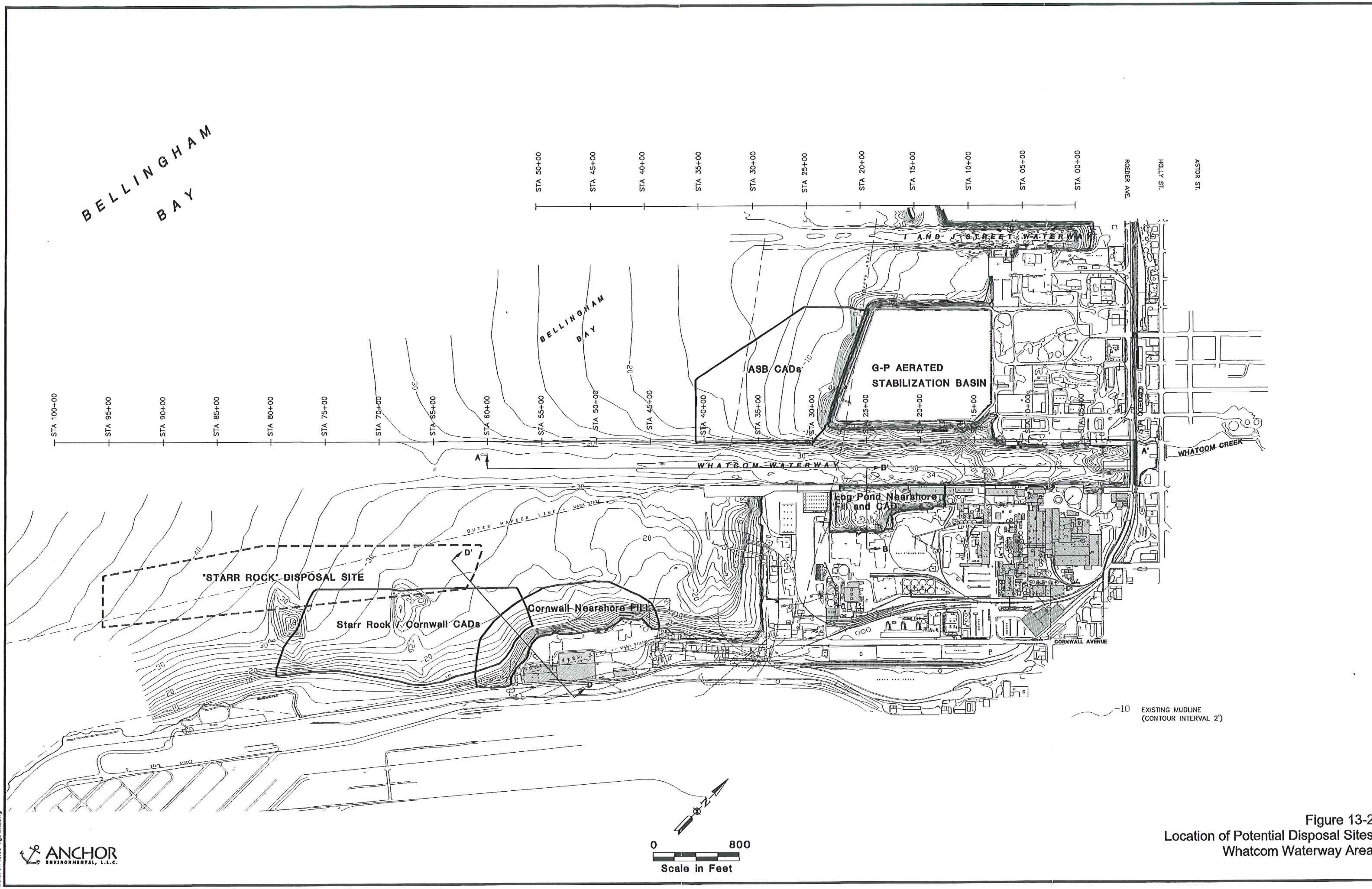


Figure 13-2
Location of Potential Disposal Sites
Whatcom Waterway Area

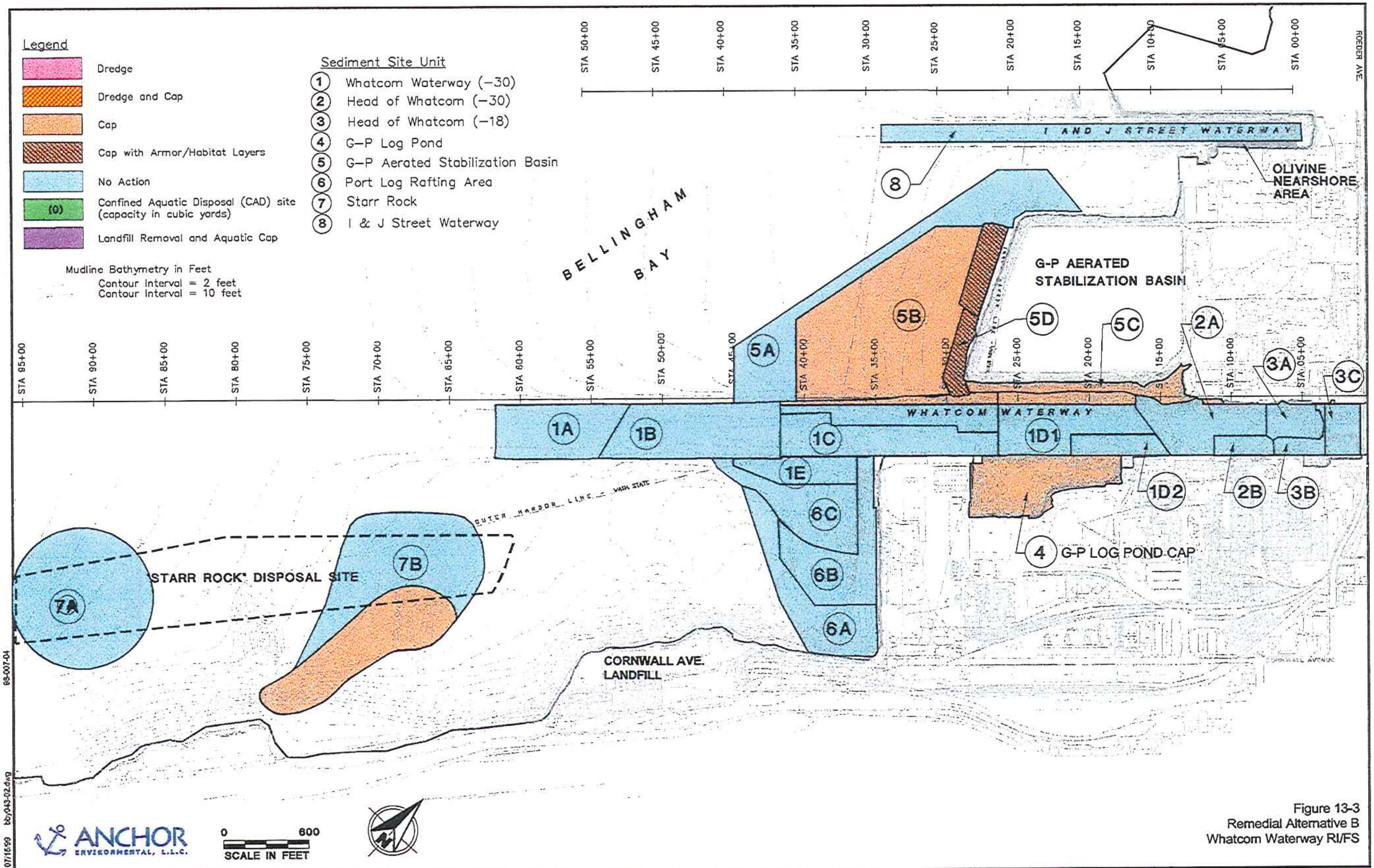


Figure 13-3
Remedial Alternative B
Whatcom Waterway RI/FS

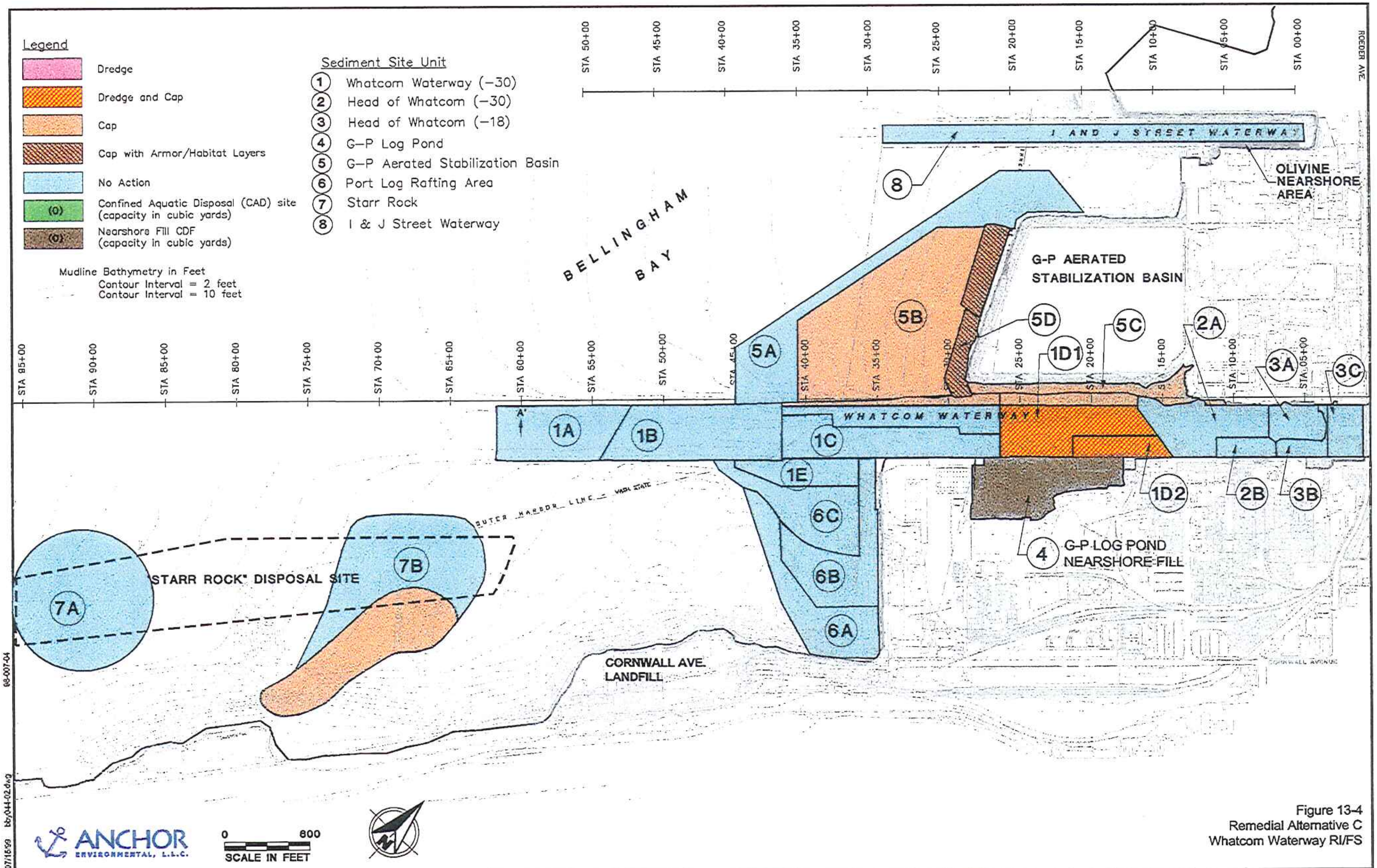


Figure 13-4
Remedial Alternative C
Whatcom Waterway RI/FS

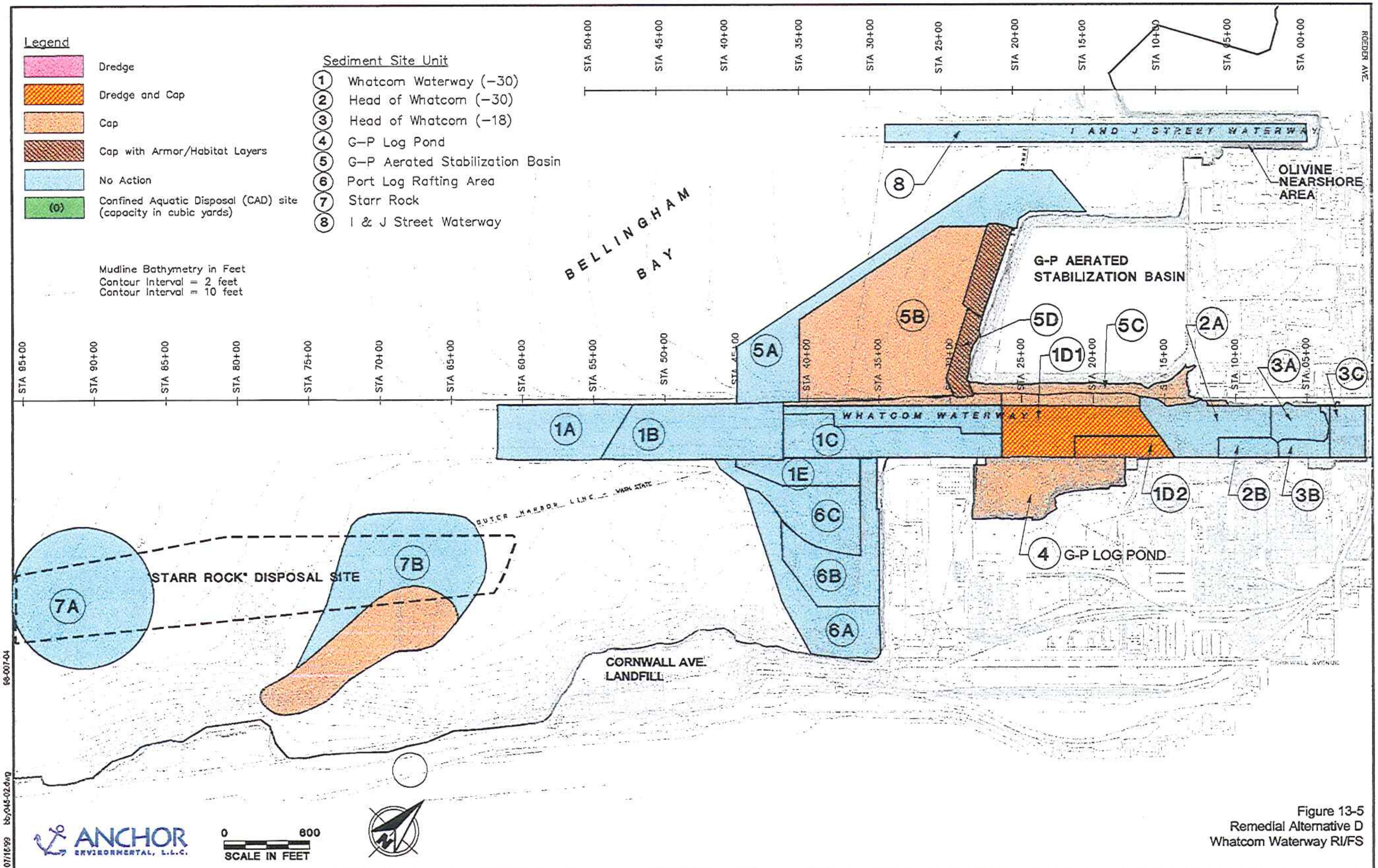


Figure 13-5
Remedial Alternative D
Whatcom Waterway RI/FS

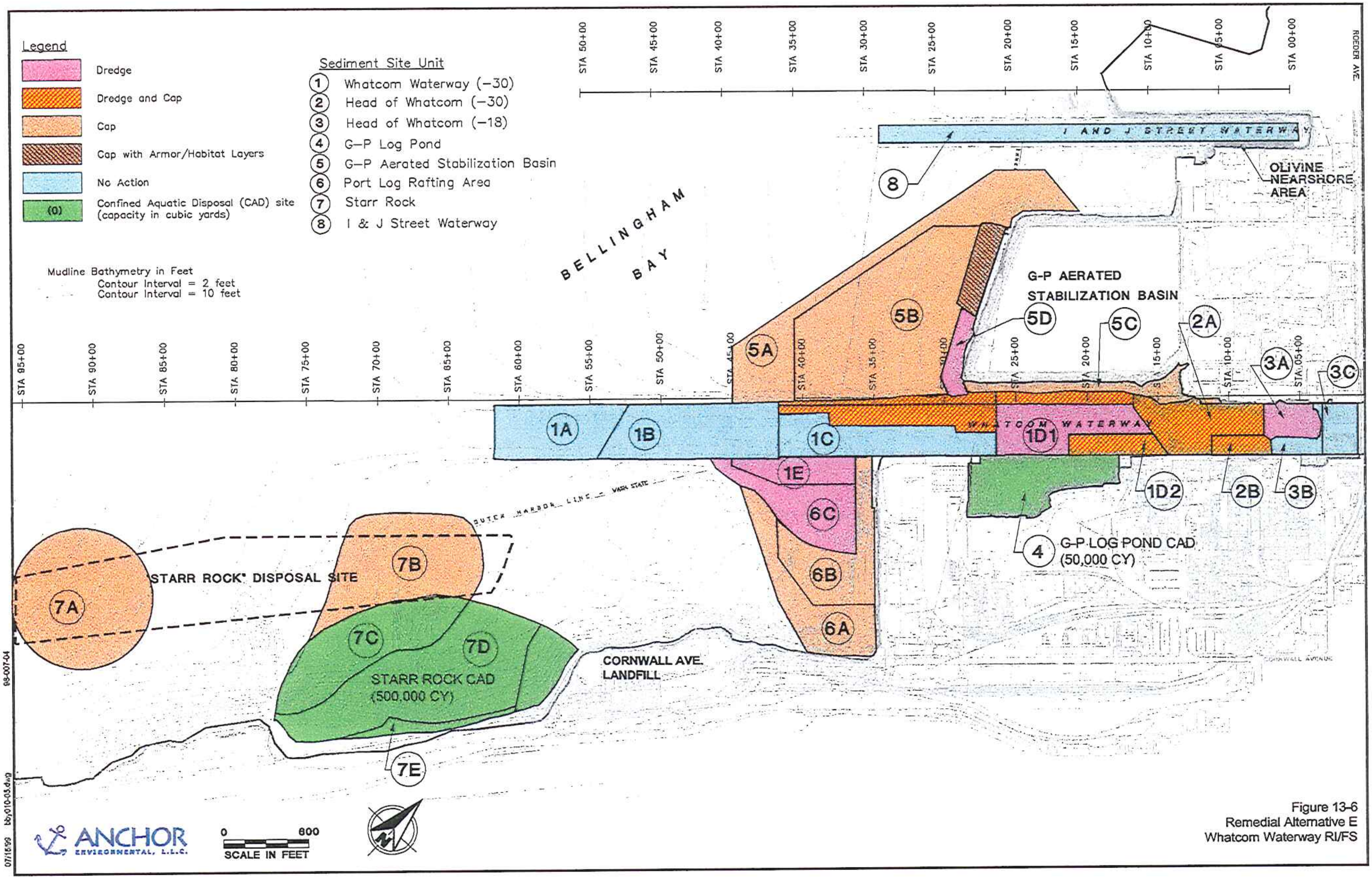


Figure 13-6
Remedial Alternative E
Whatcom Waterway RI/FS

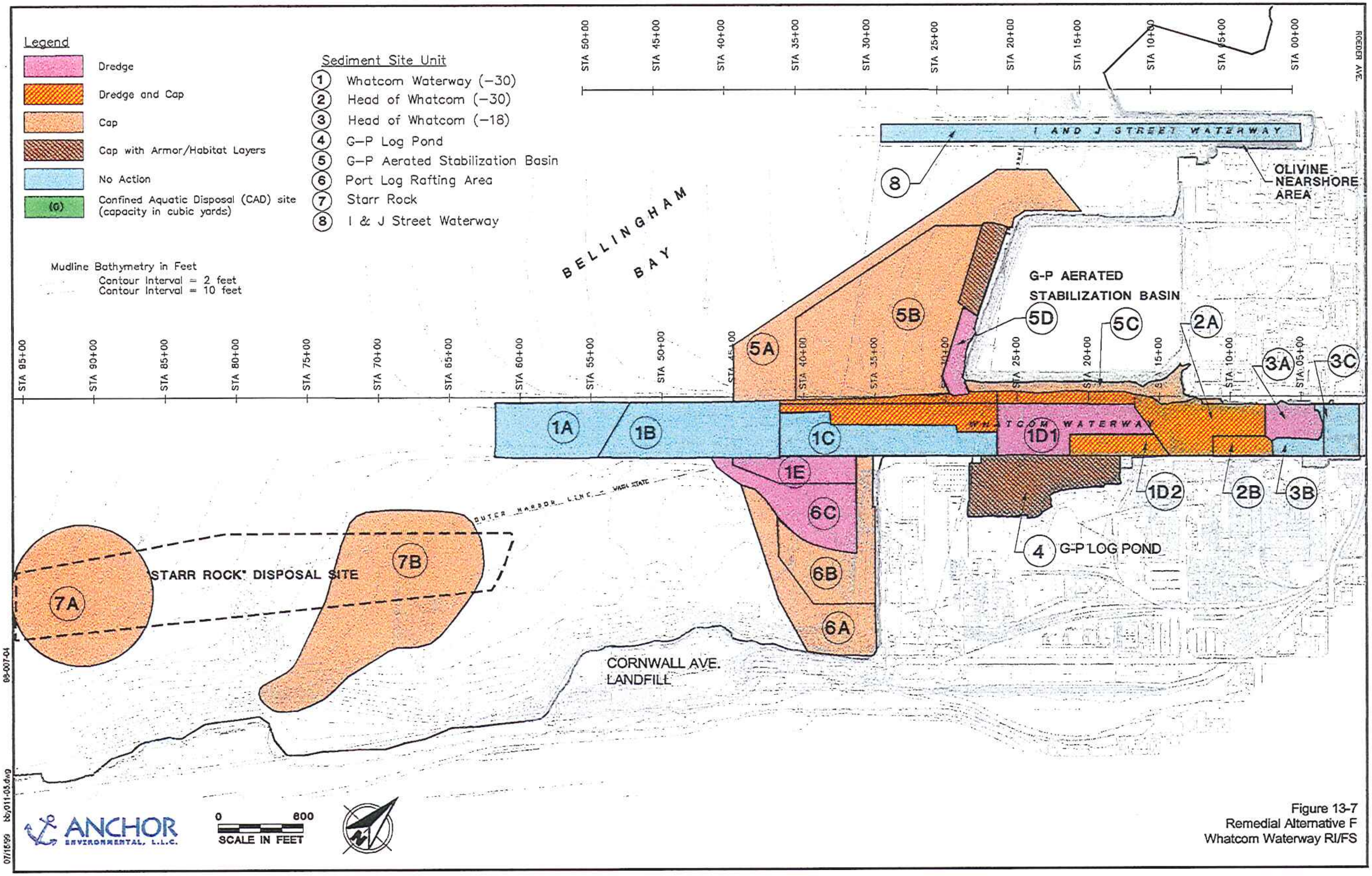


Figure 13-7
Remedial Alternative F
Whatcom Waterway RI/FS

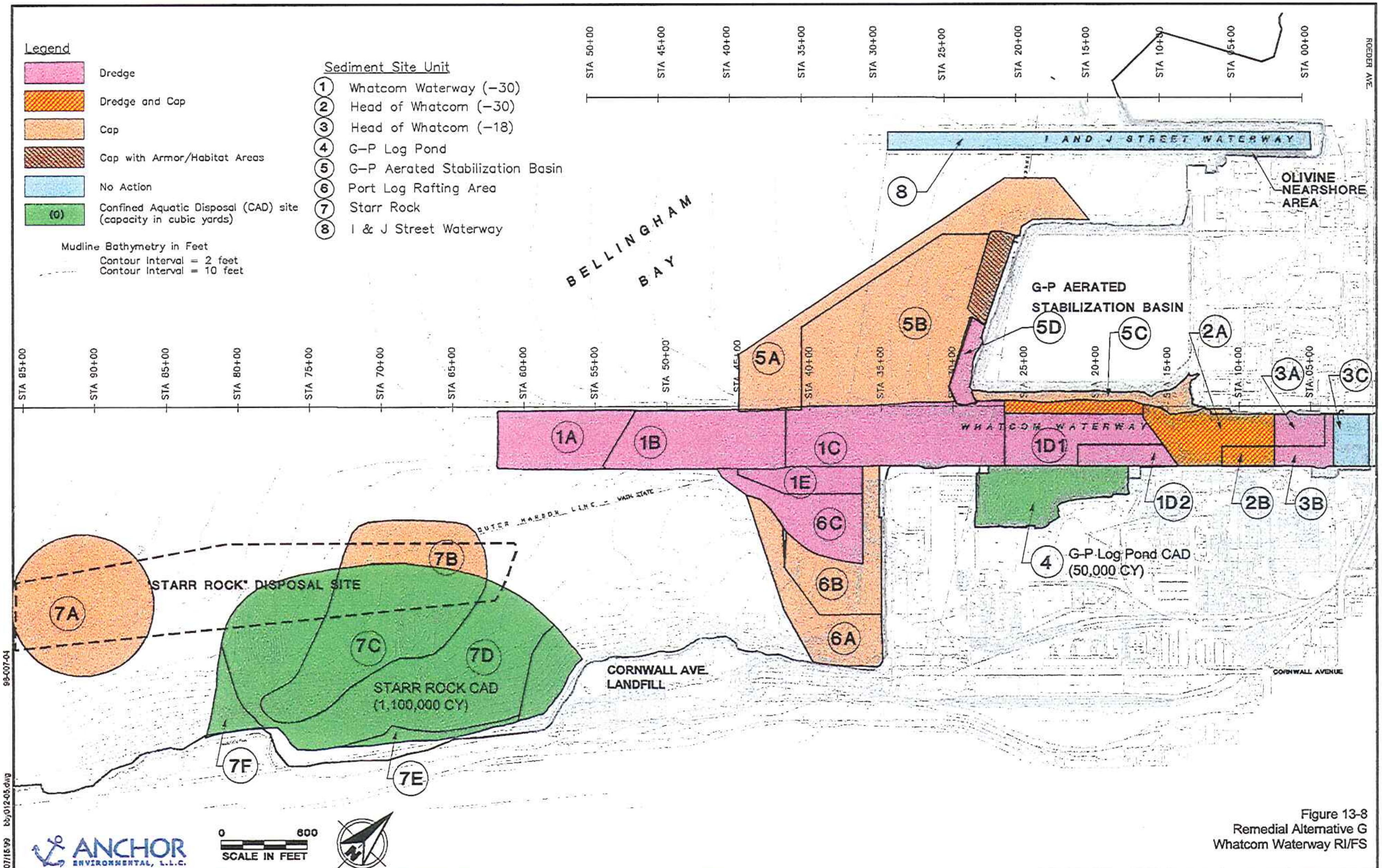


Figure 13-8
Remedial Alternative G
Whatcom Waterway RI/FS

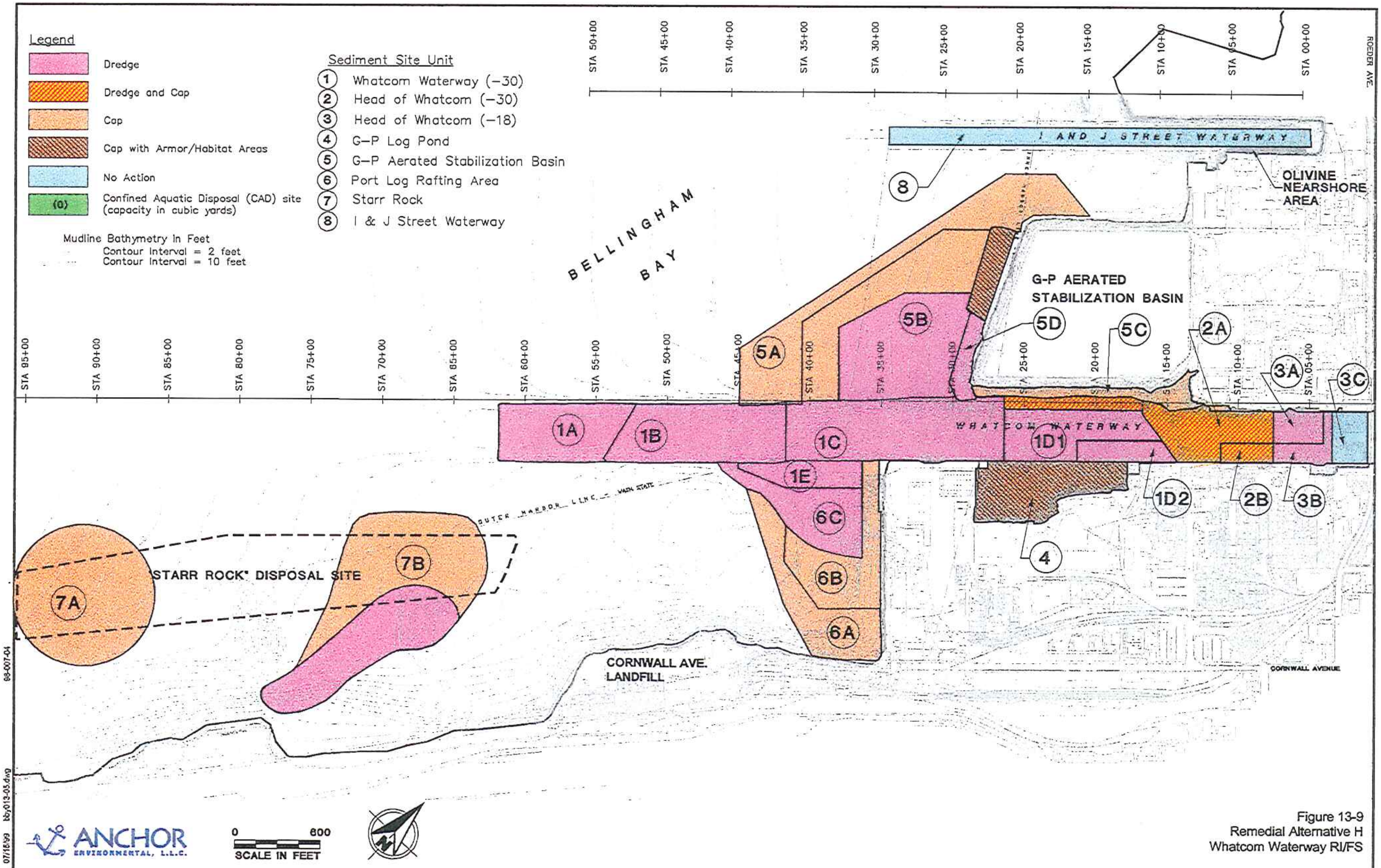


Figure 13-9
Remedial Alternative H
Whatcom Waterway RI/FS

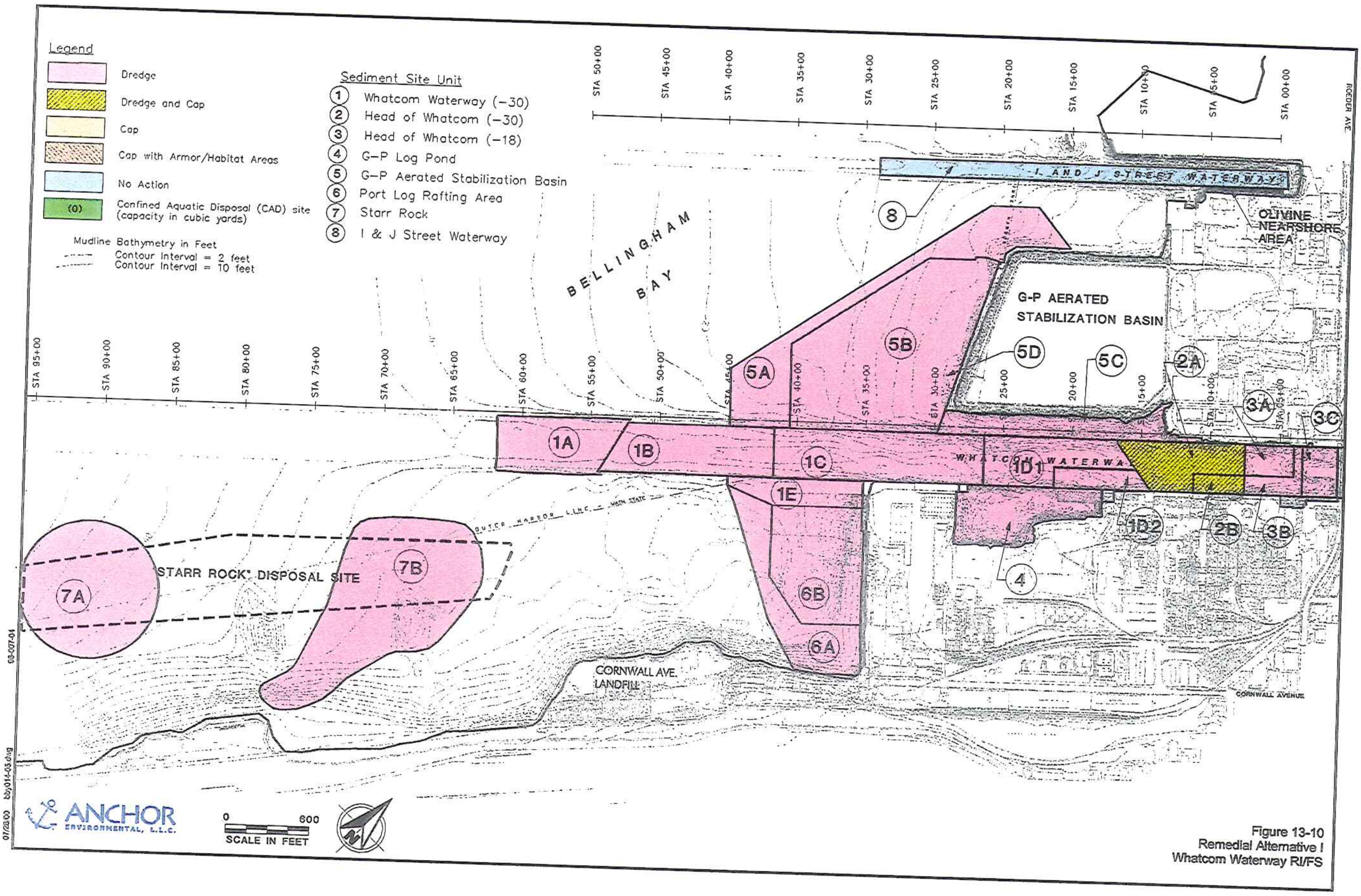


Figure 13-10
Remedial Alternative I
Whatcom Waterway RI/FS

14. EVALUATION OF CLEANUP ACTION ALTERNATIVES

In this section the criteria that will be used to evaluate the nine project alternatives are presented, followed by a detailed analysis of cleanup alternatives. The section concludes with a comparative analysis of alternatives. Table 13-1 presents a comparison summary matrix of the individual remedial actions occurring in each SSU for the different alternatives evaluated.

14.1 Evaluation Criteria For Alternatives

Each of the 9 cleanup alternatives listed above was assessed against SMS/MTCA criteria (Ecology, 1991). Relevant criteria included in the evaluation can be grouped into three categories:

- Overall Environmental Quality;
- Ability to be Implemented; and
- Cost Effectiveness.

Each of these criteria categories is summarized below.

Overall Environmental Quality

- **Compliance with Cleanup Standards and Applicable Laws.** The assessment against this criterion describes how the alternative complies with applicable cleanup standards and laws.
- **Protection of Human Health and the Environment.** The evaluation assesses the degree to which the cleanup alternative may perform to a higher level than regulatory criteria, and also considers the on-site and off-site risks resulting from implementation of the alternative.
- **Reasonable Restoration Time Frame.** As defined in MTCA (Chapter 173-340-360[6]), this criterion evaluates when cleanup criteria will be met and potential risks alleviated, and when natural resources will be restored to baseline levels. The practicability of achieving a shorter time frame is also assessed with this criterion.
- **Use of Permanent Solutions.** As defined in MTCA (Chapter 173-340-360[5]), a permanent solution is one in which the cleanup standards can be met without further action being required at any site involved with the cleanup action. Among the retained containment technologies included in this RI/FS, the MTCA preference for permanent solutions ranks sediment disposal at an engineered containment facility higher than *in situ* containment.
- **The Degree to which Recycling, Reuse, and Waste Minimization are Employed.** This assessment investigates the extent that recycling, reuse, and waste minimization are employed. These factors not only include the recycling and reuse of any removed materials, but also the degree to which construction materials are reused and recycled. For

example, after a CDF is filled, it may be reused for habitat creation. Or, capping material may consist of clean dredged sediments from a navigation project in the area. Waste minimization includes the extent that wastes generated as part of the remedial action are reduced in volume.

- **Short-term Effectiveness.** The assessment against this criterion examines the effectiveness of alternatives in protecting human health and the environment during the construction and implementation of the alternative.
- **Long-term Effectiveness.** The long-term effectiveness assessment generally examines the degree of certainty that the alternative will be successful on a long-term basis. Factors constituting long-term effectiveness include long-term reliability, a consideration of the magnitude of residual human health and biological risks, the effectiveness of controls for ongoing discharges, the ability to manage treatment residues, and the consideration of disposal site risks.
- **Net Environmental Benefits.** This criterion evaluates overall benefits to the natural environment that result from the alternative, such as restoration of water quality, habitat, and fisheries; and people's use of the environment, such as public access, recreation, aesthetics, spiritual and cultural values and the ability to use the land in the future. Important factors in this evaluation are significant short-term and long-term environmental consequences, significant irrevocable commitments of natural resources, significant environmental impacts that cannot be mitigated, and habitat restoration provided by the alternative. The Bellingham Bay Comprehensive Strategy DEIS has been designed to further investigate these and other environmental impacts. The DEIS also includes additional sites, actions, and evaluation criteria to address baywide strategic environmental planning and project integration to incorporate sediment cleanup, source control, sediment disposal, habitat restoration, and shoreline property management components.

Ability to be Implemented

- **Implementability.** This assessment includes an evaluation of technical feasibility, availability of disposal facilities, the potential for land owner cooperation, required services, required materials, administrative requirements, regulatory requirements, schedule, monitoring requirements, accessibility, operation and maintenance, and the ability to integrate existing facility operations with current or potential cleanup actions. This assessment evaluates the technical and administrative feasibility of alternatives and the availability of required goods and services.
- **The Degree to which Community Concerns are Addressed.** This assessment provides for the inclusion of the community's preferences among or concerns about alternatives. ***Since the public has not yet commented on this cleanup study report, this component of the evaluation is reserved.***

Cost Effectiveness

- **Cost.** Costs in this RI/FS were evaluated on a net present worth basis. Capital cost estimates include both direct and indirect (overhead, etc.) costs, costs associated with engineering and administration and a 30 percent contingency factor to account for construction conditions not currently identified. Habitat mitigation and operation and maintenance costs, and other foreseeable costs are also included. Appendix N presents the detailed cost estimates.

  Site acquisition and easement costs, including the use of state owned aquatic lands (SOAL), may be associated with some of the alternatives, depending on landowner and operator requirements. However, such costs are difficult to estimate and can vary widely depending on specific circumstances. For example, disposal site property owners, including DNR, G-P, or the Port, may charge for long-term easements on their land in those cases where the disposal site would reduce the value of the land to the owner.

  On a case-by-case basis, the various fees and costs could be reduced or waived if the project(s) meet the interests of the landowners and makes them "whole". In the case of the state, these landowner interests are generally set forth in DNR's land management regulations and Public Trust Doctrine (see below). Other property owners (e.g., G-P and the Port relative to disposal at the G-P Log Pond) would likely make similar landowner interest determinations.

  Aquatic Land Management Laws and Public Trust Doctrine. Following a legislative finding that "SOAL is a finite natural resource of great value and irreplaceable public heritage", management of SOAL must be in accordance with constitutional and statutory requirements. It must also strive to provide a balance of public benefits for all citizens of the state, including:

  - Fostering harbor uses;
  - Encouraging direct public use and access;
  - Enhancing the use of renewable resources;
  - Ensuring environmental protection; and
  - Generating revenue consistent with these benefits (economics).

  Consistent with these objectives, DNR strives to manage SOAL to maximize overall public benefits, also recognizing that dredged material disposal sites are "essential to the commerce and well being of the state of Washington". Although specific decision criteria for disposal site selection have not yet been developed for Bellingham Bay, in making its public interest determination, DNR assesses whether the action is clearly in the long-term interest of the public and how the disposal action fits into the vision for the entire bay. Investments in navigation and commerce along harbor areas and waterways will be maintained to provide for economic growth, and to avoid development elsewhere. Finally, the full costs will be evaluated as part of DNR's public interest determination, including habitat restoration.

Because of the complexities of landowner interest determinations, the long-term costs of property easements for disposal and/or mitigation, including SOAL, have not been included in this RI/FS. Appropriate costs for these elements are expected to be determined as part of ongoing Pilot Project implementation discussions.

- **Cost Effectiveness.** As set forth in MTCA (Chapter 173-340-360[5]), a cleanup action shall not be considered practicable if the incremental cost of the cleanup action is substantial and disproportionate to the incremental degree of protection it would achieve over a lower preference cleanup action. When selecting from among two or more cleanup action alternatives that provide a sufficient and equivalent level of protection, as defined above, preference may be given to the least cost alternative, subject to an evaluation of public concerns and technical uncertainties.

14.2 Technical Analysis of Cleanup Elements

Many of the cleanup alternatives evaluated in this RI/FS share common elements. The section below provides a summary of the technical analysis of several key elements of the alternatives, including natural recovery, capping, and confined disposal.

14.2.1 Natural Recovery

Natural recovery of sediments in the WW Area is well documented by declining surface concentrations of mercury over the past 25 years. As discussed in Section 9 of the RI/FS (Volume I) and by Officer and Lynch (1989), surface sediment concentrations of mercury at the WW Area have exhibited a significant decline since the early 1970s. This condition reflects ongoing natural recovery processes such as sedimentation, and also reflects the success of existing source controls implemented by G-P. Mercury concentrations at the site are expected to continue to decline over the next 10 years and beyond.

The remainder of this section addresses the following:

- The natural recovery model (Officer and Lynch 1989) applied during this RI/FS to forecast future natural declines in sediment mercury concentrations;
- Input parameters used in the model; and
- Modeling results.

14.2.1.1 Officer and Lynch Natural Recovery Model

The Officer and Lynch (1989) model is a one-dimensional analytical equation that simulates sediment natural recovery. Detailed information on the model and its application to Bellingham Bay can be found in Appendix K. An overview of the components of the model and technical evaluation is provided here.

The model simulates natural recovery by incorporating a number of concurrent processes, including:

- Burial of contaminated sediments;
- Mixing of cleaner sediments to the surface by benthic organisms; and
- Exchanges between the bottom sediments and water column.

In the Officer and Lynch model, bioturbation effects are represented by a constant diffusion coefficient applied over the mixed layer interval, below which is a non-diffusive medium. The model also allows for non-advective concentrate exchange due to periodic and episodic resuspension of bottom sediments and exchanges across the bottom boundary layer. As one element of the model sensitivity analysis, the effects of resuspension-related exchange was evaluated by varying this parameter from zero (i.e., no resuspension transport) to more realistic values determined for the site (see Section 14.2.1.2).

The Sediment Cleanup Standards User Manual provides a description of how natural recovery modeling is generally applied under the SMS. The Officer and Lynch model was previously verified in Bellingham Bay, based on simulations of the observed initial recovery of sediment mercury concentrations in the bay immediately following G-P's completion of source controls in the early 1970s (Officer and Lynch 1989). This model was also successfully applied and verified for atmospheric inputs of ^{137}Cs in Blelham tarn, Lake Michigan, and Long Island Sound (Officer and Lynch, 1982); and in Sitcum Waterway Problem Area of the Commencement Bay Nearshore/ Tideflats Superfund Site (Port of Tacoma, 1992).

14.2.1.2 Natural Recovery Model Input Parameters

The Officer and Lynch model, was applied to each individual sampling station located within prospective sediment cleanup areas delineated in Figure 11-1. Input parameters used in the RI/FS application of the model are summarized below. Site-specific inputs to the Officer and Lynch sediment natural recovery model were derived from three sources:

- Model parameters presented in Officer and Lynch (1989);
- Parameter values presented in Section 9 (Volume I); and
- Additional estimates of net sedimentation rates within the Whatcom Waterway navigation channel, determined by calculating net changes in the mudline elevation of the Whatcom Waterway between 1975 and 1996

Parameter values used in the natural recovery modeling are described below.

Net Sedimentation Rates. One of the more important sediment natural recovery modeling parameters is the net sedimentation rate, which is a measure of the long-term burial rate of contaminated sediments beneath cleaner, more recent sediment materials. Net sedimentation rate estimates in inner Bellingham Bay (i.e., outside of the protected Whatcom Waterway channel) were based on ^{210}Pb, ^{137}Cs, and total mercury core profiles within and adjacent to the prospective Whatcom Waterway sediment cleanup area (see Section 9 of the RI Report and Bothner et al., 1980). Net sedimentation rates measured in three inner bay coring locations were very similar, ranging from 1.5 to 1.8 cm/yr. Using channel condition survey data, similar (within statistical limits) sedimentation rates were also estimated in the outer Whatcom Waterway navigation channel, offshore of Station 27+00 (Figure 14-1). An average sedimentation rate of 1.6 cm/yr was therefore assumed to be representative of all prospective sediment cleanup areas outside of the protected channel areas.

Sedimentation rate estimates were calculated for sites within the protected Whatcom Waterway navigation channel area based on the net change in the mudline elevation of the WW Area observed between the 1975 and 1996 U.S. Corps of Engineers channel condition surveys. Considerable variability in sedimentation rates was evident within some areas of the channel. Therefore, for the purpose of this RI/FS analysis, sedimentation rate estimates were calculated as the average measured value within a 50-foot grid area that surrounded each sampling station. At some stations within the channel, there was no discernable sedimentation rate. Station-specific net sedimentation rates calculated in this manner are summarized on Table 14-1. Overall, these data revealed that net sedimentation rates increased in the more protected areas of the Whatcom Waterway navigation channel and Log Pond (Figure 12-2).

Gross Sedimentation and Resuspension Rates. As discussed in Section 9 (Volume I), the net sedimentation rates outlined above represent only a fraction of the total quantity of material that settles through the water column (i.e., relative to the gross sedimentation rate, as determined by sediment trap measurements). Up to ninety percent of the settleable material collected in sediment traps appears to be resuspended back into the water column by ambient currents and waves. For the purpose of the natural recovery calculations, the average gross sedimentation rate measured in sediment traps (16 cm/yr, or 7.5 gm/cm^2-yr; consistent with values reported by Officer and Lynch, 1989) was assumed to apply throughout the prospective WW sediment cleanup area. Resuspension rates were then calculated as the difference between the gross and net sedimentation measurements, ranging from approximately 50 to 90 percent of gross sedimentation.

Non-Advective Concentrate Exchange. The non-advective concentrate exchange represents processes that contribute to the exchange of contaminants without contributing to the sedimentation rate. Examples include the periodic and/or episodic resuspension and subsequent settling of sediments due to tidal cycles, storm events, and propeller wash. For the purposes of natural recovery modeling, this parameter was calculated as the product of the resuspension rate and the fraction of resuspended sediments that, due to tidal advection and dispersion processes, are not provided sufficient time to resettle within the vicinity of the resuspension area. Representative settling velocities for different sized sediment material (e.g., sand, silt, and clay fractions) were calculated using Stoke's relationship.

During the time interval that elapses between resuspension and settling, suspended sediments are transported away from the resuspension area.

Dispersion caused by bottom layer (landward) transport by the oscillatory motions of the tides contributes to water movement and sediment transport. Based on the available current velocity data (Collyer, 1998), and WASP model runs for the Whatcom Waterway and Bellingham Bay area (Section 8; Volume I), bottom velocities typically average 3 cm/s.

Using the data outlined above, the average residence time for a resuspended particle of sand, silt, and clay was calculated. The residence time estimates assumed a conservative resuspension mixing depth of half the depth of the bottom-water layer (typically 30 feet) , and used a maximum transport distance to "clean" (below SQS criteria) sediment areas in the inner bay of 3,000 feet (Figure 11-1). Using this information, the fractional component for each sediment type was combined to yield a representative fraction based on the measured sediment component breakdown for each station. Finally, the interface concentrate exchange parameter was estimated as the fraction of sediments suspended and transported out of the entire mouth segment, multiplied by the resuspension rate.

Because sediment exchange will likely occur over a smaller spatial scale following active sediment remediation of relatively high concentration areas, the relatively large mixing cell approximation (3,000 foot distance) used in this analysis was conservative, likely underestimating the true rate of natural recovery that would occur following active remediation. Values of the interface concentrate exchange coefficient derived in this manner ranged from 0 to 3.5 g-cm^2/yr, or approximately 35 percent of the resuspension rate, consistent with values reported for Bellingham Bay by Officer and Lynch (1989) (Table 14-1).

Bioturbation. The bioturbation zone within surface sediments was observed to extend over the surface 11 to 24 cm, based on interpretations of ^{210}Pb core profiles at the site (see Section 9; Volume I). This is consistent with the average bioturbation depth of 16 cm assumed by Officer and Lynch; the Officer and Lynch value was used in the model. Within this zone, a bioturbation diffusion coefficient of 34 cm^2/yr was applied in the model, based on values presented in Officer and Lynch (1989) (Table 14-1).

Source Concentrations in Settling Particulate Matter. Sediment concentrations in recently deposited material, including locally resuspended sediments, were estimated using sediment trap data collected in inner Bellingham Bay (see Section 9; Volume I). The average mercury concentration measured in the traps was 0.34 mg/kg. The concentration of settling particulate matter (SPM) in the traps was only 33 percent of the concentration in underlying sediments—which were approximately 1 mg/kg mercury—further evidence that mercury in the bay is declining in response to source controls. In areas where sediment trap data were not available, including interior parts of the waterway, the concentration of SPM was assigned a value equal to 33 percent of the underlying sediment concentrations (Table 14-1).

Surface Sediment Concentrations. Surface sediment concentrations were primarily based on 0 to 10-cm grab samples collected in August and

September 1996, and in October 1998 (see Section 2; Volume I). The average value of all available RI samples within areas of the WW Area was used as the initial concentration for that particular model segment (Table 14-1).

Recovery Time Frame. For the purposes of this FS, natural recovery was evaluated through the year 2005. Typically, the natural recovery period would begin when adequate source controls are attained, and would continue for an additional period of roughly 10 years (see Sediment Cleanup Standards User Manual). However, since source controls may already be adequate for the purpose of the WW Area cleanup (see above), and in order to achieve Ecology's goal to complete cleanup projects as quickly as practicable, an expedited natural recovery time frame was considered. The year 2005 generally represents the minimum estimated time frame for recovery of biological resources following active cleanup (e.g., capping or dredging), including preliminary estimates of the time required for remedy selection (0.5 year), remedial design, permitting, and legal agreements (1.5 years), remedial action implementation/construction (2 years), and biological recovery following construction (2 years).

14.2.1.3 Natural Recovery Modeling Results

The Officer and Lynch model was applied to all sediment stations within prospective sediment cleanup areas of the WW Area. The results of the modeling were presented for two cases:

1. Assuming zero non-advective concentrate exchange (i.e., no consideration of periodic and/or episodic resuspension and subsequent settling of sediments due to tidal cycles, storm events, and propeller wash).
2. Using a more realistic (though still conservative) value for non-advective concentrate exchange.

A representative output of the Officer and Lynch model is presented in Figure 14-2, which compares the sediment mercury profile measured in 1996 at Station HC-NR-101 within SSU 5B (offshore of the ASB) with the profile predicted for 2005. The model output clearly reveals the significant decline in mercury concentrations expected prior to 2005. The previously observed declines in mercury concentrations were corroborated with detailed mathematical modeling of natural recovery processes performed for this RI/FS. Most of this predicted decline was associated with sediment burial, and secondarily was attributable to non-advective exchange processes.

Based on the natural recovery model output listed in Table 14-7, the extent of the WW Area that is predicted to recover to below SQS criteria is depicted graphically on Figure 14-3. As discussed above, in absence of confirmatory biological testing data, the extent of prospective SQS exceedances within the WW Area was estimated using existing MCUL chemical criteria. That is, the existing MCUL chemical criterion for mercury of 0.59 mg/kg enclosed a significantly larger area than that defined by confirmatory SQS biological testing data (see Figure 5-1; Volume I).

Figure 14-2a
Measured 1996 Mercury Profile

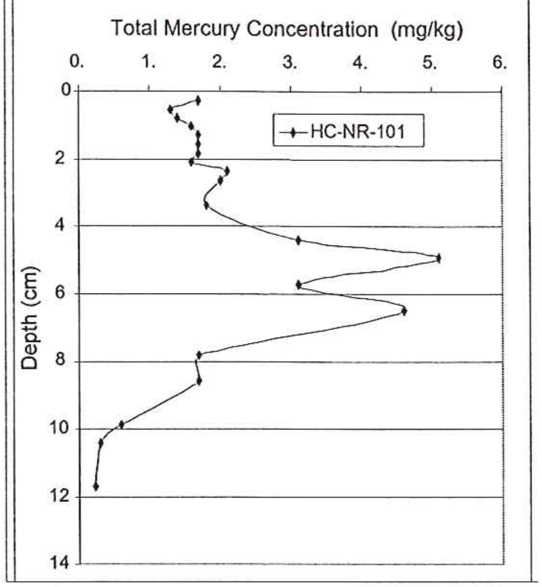
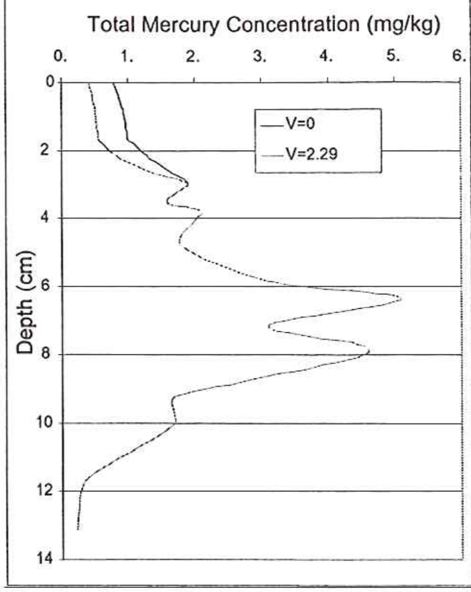


Figure 14-2b
Predicted 2005 Mercury Profile



Most areas of the WW Area that currently exceed SQS criteria (based on chemical or confirmatory biological testing results collected in 1996 and 1998) are expected to recover to below the prospective SQS criterion by the year 2005 (Figure 14-3). However, based on conservative modeling scenarios (i.e., assuming no resuspension-related sediment transport), four sediment site units may not recover to below SQS criteria by the year 2005. These areas are:

- G-P Log Pond (SSU 4);
- Nearshore areas located adjacent to the Whatcom Waterway immediately offshore of the G-P ASB (parts of SSUs 5B and 5C);
- A portion of the middle Whatcom Waterway navigation channel located between Stations 11+00 and 20+00 (portions of SSUs 1D1, 1D2, and 2A); and
- The former Starr Rock sediment disposal site (a portion of SSU 7B).

However, under more realistic modeling scenarios that incorporated (conservatively) resuspension-related exchange, only the first two site units (G-P Log Pond and nearshore areas adjacent to the ASB) may not recover to below SQS criteria by the year 2005. These two areas contained the highest mercury (and also wood material) concentrations reported within inner Bellingham Bay, and encompass much of the area that currently (1996 to 1998 sampling) exceeds Ecology's MCUL based on biological effects.

14.2.1.4 Source Control Integration

A key component of the effectiveness of the natural recovery (or any other) sediment remediation alternative is source control. Detailed sampling and analysis of more than ten potential contaminant sources in inner Bellingham

Bay was undertaken as a part of this RI/FS (see Section 9; Volume I). No ongoing, significant sources of mercury were identified within the WW Area that have the potential to recontaminate sediments beyond the immediate discharge area. The Pilot's Sediment Site and Source Control Documentation Report (BBWG, 1999b) provides additional information on source control integration.

Although ongoing urban stormwater inputs of 4-methylphenol and phenol have been documented in the area, the available data suggest that sediment concentrations of these compounds are more closely associated with the degradation of historical wood material deposits present in several nearshore areas of the site. In the case of Alternative B (and all other "action" alternatives), capping of sediments in the G-P Log Pond and in nearshore areas adjacent to the ASB would directly address sediment toxicity and residual wood material concerns, and thus would likely alleviate this "internal" source of 4-methylphenol and phenol.

Low-level (part-per-billion) mercury concentrations have been detected in shallow groundwater adjacent to the G-P Log Pond. Shoreline seepage may contain similar or lower concentrations due to tidal mixing and chemical attenuation. Although the low rate of groundwater mercury loading to the Log Pond does not appear sufficient to result in sediment recontamination, control of potential seepage releases to the G-P Log Pond would nevertheless be addressed as a component of the implementation of all "action" alternatives. For example, under Alternative B, the sediment cap constructed in the Log Pond would be thickened and constructed of permeable materials within the seepage discharge pathway to take advantage of a range of effective physical and geochemical attenuation process to significantly reduce mercury concentrations (see Section 14.2.3.2 below). G-P is also planning further mercury controls as part of forthcoming chlor-alkali facility closure actions. Final source control elements would be evaluated in greater detail during remedial design.

14.2.2 Capping (In-situ and CDF)

This technical analysis section describes the following:

- Isolation/long-term integrity of the cap;
- Design considerations;
- Relevant project examples of caps and CDFs; and
- Conceptual design and anticipated construction sequence of Bellingham Bay caps.

14.2.2.1 Isolation/Long-Term Integrity of the Cap

Detailed design procedures have been developed by the Corps, EPA, and others to ensure that capping provides permanent containment of contaminated sediments and isolation from surface or near-surface biological exposures. The most recent regulatory guidance for sediment capping includes:

- "Guidance for Subaqueous Dredged Material Capping" (Palermo et al., 1998a, U.S. Army Corps of Engineers)
- "Guidance for *In-Situ* Subaqueous Capping of Contaminated Sediments" (Palermo et al., 1998b, EPA Assessment and Remediation of Contaminated Sediment [ARCS] Program) and
- "Multiuser Disposal Sites (MUDS) for Contaminated Sediments from Puget Sound – Subaqueous Capping and Confined Disposal Alternatives" (Palermo et al., 1998c).

Other requirements have also been developed for application within the Puget Sound region, including considerations of cap thickness necessary to prevent exposure to indigenous burrowing aquatic organisms, and other design factors such as propeller wash. The available guidance thus define a wide range of design considerations, including:

- Required cap thickness;
- Material placement; and
- Long-term cap stability considerations.

Engineering is performed to ensure isolation and integrity of the cap at a selected risk level (e.g., 100-year storm event). The selection of appropriate containment material for isolation and erosion protection is developed to protect to that level. Design considerations are briefly reviewed below.

14.2.2.2 Design Considerations

Cap Thickness. As set forth in the available regional and national guidance, determination of the minimum required cap thickness depends on a number of interrelated factors, including:

- Physical properties of the contaminated and capping sediments;
- Chemical properties of the contaminated and capping sediments;
- Hydrodynamic conditions such as currents and waves;
- Potential for bioturbation of the cap by burrowing aquatic organisms;
- Potential for consolidation of the cap and underlying sediments; and
- Operational considerations including constructability.

Design of cap thickness is normally based on a combination of laboratory tests, mathematical models of the various processes involved (e.g., contaminant flux, bioturbation, consolidation, and erosion), field experience, and monitoring data. The design approach presently utilized in the Puget Sound region (and elsewhere) has been based on the conservative premise that the cap thickness components are additive. No dual function performed by cap components has been considered to date. Typically, within the Puget Sound region, a capping thickness of one to three feet has been determined (during both design and post-construction monitoring phases) to provide permanent containment of contaminated sediments. Consistent with this information, regional caps have normally been constructed at thicknesses ranging from 1 to 4 feet (see Relevant Project Examples below). The physical and chemical properties of WW Area are consistent with this "standard" design (e.g., see "Water Quality Protection" section below). As more data become available during remedial design, including further refinement of the interaction of processes affecting cap effectiveness, the additive design approach may be reassessed.

Cap Material Placement

The material to be confined within prospective Bellingham Bay facilities is likely to range from fine sandy silt to silty sand. Therefore, to stabilize the sediments and to prevent resuspension, the capping material must be of similar grain size or slightly coarser grain size. For instance, a coarse grained material such as gravel or cobble, without any finer material, could penetrate the soft sediment being confined during placement. In addition, coarse-grained material may not be able to prevent the migration of the finer grained sediment up through the cap with time. A fine to medium sand applied at a slow rate will confine the underlying sediments, preventing upward migration of the contaminated sediments. A finer grained cap has less void spaces to be filled by the underlying smaller grain sized contaminated sediment than a coarser grained cap material. If a coarser sized material is needed for erosion protection, then a bed of fine to medium sand may be required below the coarser material and above the confined sediments to serve as a barrier to migration.

The rate and method of placement of cap material can also have a significant impact on the stability of a cap. Cap material placed too fast and unevenly can cause a temporary increase in pore pressure, reducing the strength of the sediment in that area (Palermo et al., 1998b). This reduction in strength and the addition of load could lead to isolated pockets of bearing failure, resulting in a mixed layer of cap material and contaminated sediment. In addition, long-term deformation and mixing of the cap can occur if an uneven distribution of cap material is placed over the soft sediment. However, if the capping material is placed slowly and evenly, the confined sediment will build up pore pressure more evenly, avoiding pockets of lower strength. With time, as the pore pressure dissipates, the confined sediment becomes denser through consolidation, gaining strength. Murray et al. (1998) observed that longer wait periods between confined sediment placement and capping improve successful capping.

Long-Term Cap Stability Considerations

Capped facilities must be designed to satisfactorily resist a range of forces including waves, currents, propeller wash, and anchor drag. This section describes these elements in more detail.

- **Wave Action/Currents**. The cap design must withstand peak waves or tidally induced currents. Cap material has a critical value, called the critical shear stress for initiation of motion, where the particles will start to erode under this applied force. EPA and the Corps (Palermo, et al., 1998a/b) present design procedures and several references for assessing the critical shear stress under different conditions. Knowledge of design waves, as well as current conditions at the proposed capping site, is required to complete this analysis. Design data (waves, currents, sediment strength, etc.) for a potential capping site can be obtained from field measurements and numerical models; these data are normally evaluated in detail during remedial design.

In inner Bellingham Bay, a 100-year occurrence design wave height of seven feet has been estimated (Baker, 1997). Based on these data and considering the design wave height used in other similar port construction projects (e.g., Squalicum Harbor breakwater), caps and CADs constructed within the intertidal zone (e.g., to -4 ft MLLW) may require cover stone approximately the same size as that used for a breakwater (i.e., riprap; Short, 1997) to resist and help break the design wave. Preliminary application of the available guidance to the WW Area under the 7-foot wave height scenario suggests that caps constructed at a depth of approximately -10 feet MLLW may require gravel and cobble-sized armoring to resist erosion under this design condition. Progressively less armoring (i.e., requiring only sand-size materials) would be necessary at deeper depths. Detailed analysis of cap armor requirements would be performed as a part of remedial design.

If necessitated based on detailed design analyses, shallow-water caps and CADs can also be stabilized and protected from a design storm wave(s) by constructing an intertidal reef at the edge of the cap to break incoming waves. The conceptual design of the Starr Rock/Cornwall CAD discussed in this RI/FS currently includes both an armor layer within the cap as well as a stabilizing reef structure to provide sufficient protection from wave action and currents (Figure 14-6). The reef in this application may also provide further habitat enhancement, and may be effective at protecting the adjacent Cornwall Avenue Landfill site from future wave-induced erosion.

- **Propeller Wash**. Modeling is required to estimate the potential for scour of the cap and to determine cap grain size and/or thickness specifications. EPA (Palermo, et al., 1998b) provides suggested models to predict scour. In addition, other Puget Sound studies have developed suggested procedures (EBDRP, 1995), including the use of a model developed by Verhey (1983) and Blaauw and van de Kaa (1978). The model was calibrated using results of scale model tests. This model has been verified in field trials performed by the U.S. Army Corps of Engineers Waterways Experiment Station (WES) and Washington State Ferries, and was recently used to estimate the maximum depth of scour to remedial *in situ* caps from vessels in Puget Sound (EBDRP, 1995). EPA (Palermo, et al. 1998b) also suggests the use of the Blaauw and van de Kaa approach when designing a cap to resist prop wash. Caps have been successfully designed and constructed to resist prop wash in Puget Sound, even in the immediate vicinity of Washington State Ferry operations (e.g., West Eagle Harbor; Hart Crowser, 1996c).

One important note about propeller wash models is that the estimated scour depths assume that the scouring is carried out until equilibrium conditions are met. That is, the model assumes that a boat would remain stationary during engine operations until the prop wash and scour depth reached equilibrium for the input conditions. In reality, a boat prop wash on a certain location will only occur for a short duration. Therefore, scour depths predicted using this model are considered conservative.

- **Anchor Drag**. Boat moorage can possibly lead to cap erosion. As anchors are dropped onto the cap and dragged they can plow the cap. Site use above the capped facility for recreational boating is normally associated with limited anchor drag depths (typically less than 1 foot), though larger commercial vessel anchors can penetrate to deeper depths. However, all of the prospective sediment cleanup areas within the WW Area are located outside of the designated "General Anchorage" area of Bellingham Bay (see Figure 3.3-1 of the DEIS; BBWG, 1999c). Cap thicknesses exceeding 1 foot can be used to resist anchor impacts. Alternatively, coarser cap material or an intermediate armor layer (Figure 14-6) can also be used to resist anchor impacts. Because the G-P Log Pond and Starr Rock/Cornwall CAD facilities discussed in this RI/FS would be completed at intertidal elevations, anchor drag is not anticipated at these facilities. However, anchor drag could occur within other areas of the harbor, and would be assessed as a component of detailed cap designs applied in these areas.

14.2.2.3 Relevant Project Examples of Caps and CAD Caps

Design, construction, and post-construction monitoring of cap performance has been accomplished at a large number of contaminated sediment remediation sites, and particularly at sites within Puget Sound (Sumeri, 1996; Verduin et al., 1998). To date, more than ten caps have been successfully constructed and monitored within the Puget Sound region. As discussed above, most of these caps have been constructed to achieve a final thickness ranging from 1 to 4 feet. All of the caps have been determined to provide effective, long-term containment of underlying contaminated sediments. Some of the relevant *in situ* cap and CAD examples include:

- **West Waterway CAD – Seattle, WA**. The Corps placed 1,000 CY of PCB contaminated dredged material into a long subaqueous depression within the West Waterway navigation channel in 1984. Over the following two days, capping material was placed to produce an average 2-foot-thick cap over the contaminated sediment. The cap was constructed of maintenance-dredged material obtained from the adjacent Duwamish River. The cap material was placed from an incrementally opened split-hull bottom-dump barge. In 1995, eleven years after construction, cores confirmed that the confined contaminants had not migrated into the cap sediments (Ecology, 1990; Sumeri, 1996; Palermo, et al., 1998a/b).
- **One Tree Island Marina CAD – Olympia, WA**. This CAD project was constructed in 1987 to facilitate deepening of the area for marina construction. A conical pit 46 feet deep and 150 feet in diameter at the surface was excavated into clean sediment. The CAD was located within the marina and was excavated using mechanical dredges. Contaminated

sediments that were dredged to construct the CAD were temporarily stored in two bottom-dump barges. After the pit was excavated, the stored sediment was placed within the CAD. Other contaminated sediment areas were also removed mechanically and disposed in the CAD. A 4-foot layer of clean sediment dredged from the project was used to cap the contaminated sediments placed in the CAD (Ecology, 1990; Sumeri, 1996; Palermo, et al., 1998a/b).

- **Boston Harbor Navigation and Improvement CAD Project – Boston, MA.** This project involved construction of an initial in-channel CAD cell for containment of unsuitable dredged material from shipping berths in South Boston. The first CAD cell, located in the main ship channel south of the Inner Confluence near the East Boston shoreline, was excavated below the maximum channel depth anticipated for Boston Harbor (35 to 40 feet) to an average total depth of 58 feet. The cell was excavated into native low permeable, high strength clay. Roughly 30,000 CY of fine-grained sediments were dredged and disposed in the CAD cell. The unsuitable maintenance material from both the surface of the cell and the shipping berths was placed within the CAD to an average thickness of 9 feet. Capping material was placed from a slightly opened bottom-dump scow stationed in different locations. The cap thickness after placement ranged from 1 to 7 feet. Mixing of the cap and confined material was observed to be up to two feet in areas of highly variable sand thickness. In this case, mixing was attributable to a lack of sufficient consolidation between sediment disposal and capping, as well as post cap dredging operations that attempted to adjust cap thickness. The current plan includes disposal of dredged material in approximately 50 in-channel CAD cells, averaging 10 to 20 feet deep, dredged below the federal navigation channels in the Mystic River, Chelsea River, and the Inner Confluence. The CADs will be capped with 3 feet of clean sand material (Murray, et al., 1998).

- **Denny Way CSO, Seattle** (Sumeri, 1996). The Corps capped this site in 1990 using 20,000 CY of navigational dredge material from the Duwamish River. The cap was 2.5 feet thick on average. The Corps used a 1,300 to 1,900 CY split-hull barge pushed sideways to slowly release the 128-foot wide blanket of sand.

- **Pier 53 CSO, Seattle** (Sumeri, 1996). METRO (now King County) placed 4,500 CY of a 1- and 3-foot-thick cap over a 1.6-acre site along the Seattle Waterfront. This 1992 project was implemented using clean navigational dredge material dumped from a seven-compartment barge slowly towed over the disposal site.

- **Eagle Harbor – East Harbor Operable Unit (EHOU), Bainbridge** (Sumeri, 1996). Between September 1993 and March 1994 the Corps placed 425,000 CY of capping material over a 54-acre site. A uniform cap thickness of 3 feet was the objective. Clean navigational dredged material was used as cap material. The cap was divided into two areas based on sediment physical and chemical conditions. The first area was 30 acres in size and required 275,000 CY of capping material. Capping material was placed in this area by towing partially opened bottom-dump barges. The second area was 24 acres in size and required 150,000 CY of capping material. Capping material was placed in this area by washing the dredged material off flat-deck barges with a high-pressure water jet. This placement method was used to minimize resuspension of the fine-grained contaminated bottom material.

- **Eagle Harbor – West Harbor Operable Unit (WHOU), Bainbridge** (Verduin, et al., 1998). In 1997, 20,000 tons of commercial sand was placed over contaminated sediment material as a 6-inch-thick cap across 6 acres and a 3-foot-thick cap across 1 acre. The material was placed by clamshell bucket in open water areas and hydraulically in areas located under piers. The hydraulic system consisted of an 8-inch dredge pumping capping material through an 8-inch line. The end of the line was plugged and a 6-inch wide slot, 3-feet long was cut near the plug on the top of the line. The capping slurry would spray upward through the slot and sprinkle down over the capping area.
- **Simpson Tacoma Kraft Co., Tacoma** (Sumeri, 1996). In 1988, Simpson placed 238,000 CY of capping material over a 6-acre site.. The cap ranged in thickness from 5 to 20 feet. The contractor used 10- and 12-inch hydraulic dredges to mine the material from a sand bar in the adjacent Puyallup River. The dredged material was discharged into a horizontal diffuser at the water surface. The material was sprinkled through the diffuser over the impacted area.

Post construction monitoring of these *in situ* caps and CAD sites has shown that execution of established design procedures leads to effective, permanent containment of contaminated material. Field studies of the long-term (up to 15 years in some areas) effectiveness of similar capping designs indicate that there is minimal long-term transport of contaminants up into the caps. Vibracore samples collected at these sites in close proximity, over time, have shown no change in vertical contamination over the monitoring period. Table 14-2 summarizes completed CAD projects located within Puget Sound and elsewhere in the U.S., as well as other projects currently under design.

The conditions within inner Bellingham Bay are such that the prospective capping and CAD sites are similar to other successfully approved and constructed projects of similar magnitude. At other regional capping and CAD sites, physical stability concerns have been effectively addressed by incorporating into the early design some very conservative elements. For this RI/FS, construction of barrier reefs or inclusion of armor rock in intermediate layers of the capping system have been included in conceptual designs presented and evaluated herein. Conceptual confined disposal facility designs are discussed in more detail below.

14.2.3 Confined Disposal Facilities

14.2.3.1 Conceptual Design and Anticipated Construction Sequence

The conceptual designs of the aquatic CDFs under consideration in Bellingham Bay have been developed based on preliminary, conservative applications of the engineering analyses completed at other Puget Sound

CDF sites discussed in this document. These analyses would be refined during the remedial design phase based on site-specific sampling and analysis. The following conceptual designs and construction sequences are anticipated:

- **G-P Log Pond Nearshore CDF**. In this location, a containment berm would be built across the mouth of the Log Pond, contaminated sediment would be placed behind the berm, and the site would be capped with four feet of clean fill. The outside (northern toe) of the berm would be along the pierhead line of Whatcom Waterway. The berm along the northeastern portion of the site would be offset from the existing G-P pier to minimize settlement effects on the pier. The southwestern edge of the berm would be offset from the WIST pier to also minimize settlement to that pier. The berm would be constructed at a slope of 2H:1V with select fill (greater than 40 percent gravels and less than 3 percent finer than the #200 sieve) up to a top elevation of +14 or +15 feet MLLW. A key (a five-foot-deep trench beneath the toe of the berm) may be required for stability. Training dikes consisting of riprap would likely be required to facilitate construction of the berm. The crest of the berm would be approximately eight feet wide. Once the berm is constructed, sediments would be placed behind the berm up to elevation +10 feet MLLW. As discussed below, long-term water quality protection is expected, based on the expected attenuation of leachate as it is transported through the containment berm. After the contaminated sediments are placed, a four-foot-thick layer of clean structural fill would be placed over the site. A geotextile lining may be required in some locations to help bridge the contaminated sediments. Depending on the final upland use of the site, either a pavement/gravel section and/or buildings would be constructed over the site.

  Construction of the nearshore fill would result in the net loss of approximately 5 acres of existing aquatic habitat in the Log Pond, which would require mitigation. The Pilot Project has identified several possible fill removal projects in the inner Bellingham Bay area that may result in area to area replacement and functional habitat improvements, thus providing aquatic habitat compensation. The estimated costs of these generalized habitat mitigation actions were incorporated into this RI/FS (see Appendix N).

  Figure 14-4 presents a typical cross section through the Log Pond Nearshore CDF. The figure also identifies the existing containment berm constructed by G-P in 1974. Sediments dredged from the Whatcom Waterway were disposed behind the berm at that time. Tidally averaged water levels within this area are approximately +6 feet MLLW (ENSR, 1994).

- **Log Pond CAD**. A small berm would be built across the mouth of the log pond, contaminated sediment would be placed behind the berm, and the site would be capped with a minimum of three feet of clean fill. The outside (northern toe) of the berm would be placed along the pierhead line of the Whatcom Waterway. The berm along the northeastern portion of the site would be offset from the existing G-P pier to minimize settlement effects on the pier. The southwestern edge of the berm would be offset from the Bellingham Shipping Terminal Pier to also minimize settlement to the pier. The berm would be constructed at a slope of 2H:1V with select fill up to a top elevation of 0 feet MLLW. A key (a five-foot-deep trench beneath the toe of the berm) may be required for stability. Training dikes consisting of riprap would likely be required to facilitate construction of the berm. The crest of the berm would likely be 5 to 8 feet wide. Following construction of the containment berm, contaminated sediment would be placed behind the berm up to elevation -3 feet MLLW. The sediment would be placed with either bottom dump barges or flat barges. Bottom dump barges could be used until the contaminated sediment reached an elevation of -10 to -2 feet MLLW within the CAD. At that point, depending on tide conditions, a bottom-dump barge would likely not be able to access the site. Flat barges would then be used. The barges would be off-loaded with either end-loaders placed on the barge or with clamshells.

The disposed sediments would be allowed to settle under self-weight for 2 to 8 weeks. This wait period will allow the sediments to consolidate and gain strength. After the sediments are at suitable strength, the capping material would be placed, consisting of 3 feet of sand material. The material would either be clean maintenance dredged material, locally mined sub-aqueous material, or an upland pit material. Water depths would likely limit placement techniques to either by clamshell bucket or hydraulic means. Hydraulic means of placement could include diffuser systems similar to those used for the Simpson Tacoma Kraft cap (Sumeri, 1996) or the Eagle Harbor – West Harbor Operable Unit cap (Verduin, et al., 1998).

Figure 14-5 presents a typical cross section through the Log Pond CAD.

- **Starr Rock/Cornwall CAD.** Depending on the CAD layout, a small containment berm would be built near the former Starr Rock disposal site and/or subtidal portions of the existing Cornwall Avenue Landfill, contaminated sediment would be placed behind the berm, and the site would be capped with three feet of clean fill. The final grade of the site could be designed to range from approximately -10 to -2 feet MLLW, and may be suitable for subtidal habitat, including eelgrass meadows. The berm would be constructed at a slope of 3H:1V with select fill up to a height of 12 to 20 feet above existing mudline. The crest of the berm would likely be 5 feet wide. Contaminated sediment would be placed behind the berm back up to an elevation of -13 to -5 feet MLLW. The contaminated sediment would be capped with a three-foot-thick layer of material.

  The contaminated sediment would be placed behind the berm with similar methods described above for the Log Pond CAD. The cap design and construction would also be similar to the Log Pond CAD cap. However, the wait period between placement and capping at the Starr Rock CAD would likely be longer, up to 12 weeks, because of the increased thickness of the confined sediment layer.

The Starr Rock CAD is less protected than the Log Pond CAD, and is potentially subject to the 7-foot storm wave (100-year recurrence interval) described above. Because of this exposure, a riprap reef may be necessary to provide long-term protection. The reef would be constructed on the outer edge of the containment berm and would extend up to elevation 0 feet MLLW (Figure 14-6). Occasional openings in the reef would be designed to minimize trapping of fish during low tides. The reef would "trip" incoming waves, dissipating the wave energy on the reef instead of further inshore on the cap. If necessary to provide additional protection, armor rock could be included as an intermediate layer of the capping system (e.g., between the underlying sand cap and overlying surface habitat layers; see Figure 14-6).

Figure 14-6 presents a typical cross section through the Starr Rock/Cornwall CAD.

14.2.3.2 Design and Long-Term Stability of the Aquatic CDFs

Seismic Stability. Washington State has a history of relatively large earthquakes. Damage to constructed facilities can result from ground liquefaction or differential settlement during these events. High seismic hazard areas such as sites along major known fault lines were not considered as possible sediment disposal sites in the initial screening (BBWG 1998). Although the fill located along much of the Bellingham waterfront is susceptible to seismic shaking, past experience at other similar sites in Puget Sound (e.g., Elliott and Commencement Bays) indicates that this condition can be addressed through appropriate design.

Much is known about the seismicity of Puget Sound and information concerning the magnitude, accelerations and impacts associated with design level seismic events has been well established. The historical approach taken within Puget Sound in design of marine facilities is very similar to that taken by other major west coast ports in seismically active areas, including the ports of Seattle and Tacoma. In essence, major marine structures must be able to withstand, with possible damage but without failure, an earthquake that has an approximate 500-year recurrence interval (i.e., 10 percent chance of being exceeded in 50 years).

Nearshore CDFs and similar CAD berm facilities must be designed to perform satisfactorily during and after a design level seismic event. For this reason, contaminated sediments are contained within buttress fills or berms of select higher strength import fill (typically a mixture of clean sand and gravel armored with light riprap). This buttress is designed to maintain the stability of the fill during construction and during strong seismic motion.

Typically, the most critical factor for CDF design is seismic-induced liquefaction of the CDF subgrade and confined materials within the CDF. Liquefaction occurs as a result of the buildup of hydrostatic pressures within the submerged sediment mass such that the dredged materials lose a portion of their strength and become less stable and more prone to movement. Liquefaction will tend to result in some movement of the fill. By using various geotechnical modeling techniques which take into account the geometry of the fill, the strength and drainage characteristics of the berm and dredged material, and the intensity and duration of seismic motion, the geotechnical engineer can estimate the amount of lateral and vertical deformation of the CDF facility. An analysis is performed to determine the horizontal ground acceleration values that are appropriate for the specific site. Strength parameters needed for the analysis are obtained from standard field explorations and laboratory tests, which are normally performed during final design of the CDF.

Based on the design-level modeling, the size and thickness of the berm and cap are designed to prevent "failure" of the system. In the case of a CDF, failure is defined as a breach in the berm and/or the cap such that contaminants are released to the environment. By matching the required size and thickness of the berm/cap system, the anticipated amount of deformation can be accommodated such that exposure of the contaminated dredged material does not occur following a seismic event. Using flatter slopes, constructing the berm material out of coarser material, over-excavating beneath the berm, and/or slowing the construction process can further address short-term and long-term stability concerns.

Modeling of seismic stability has been accomplished as a part of remedial design at all of the major sediment confined disposal facilities (CDFs) constructed in Puget Sound. These facilities include:

- Terminal 91 CDF, Seattle;
- Slip 3 CDF, Tacoma;
- Milwaukee Waterway CDF, Tacoma (Port of Tacoma, 1992);
- West Eagle Harbor CDF, Bainbridge Island (Hart Crowser, 1996c); and
- Stage I Marine Terminal Improvements, Everett.

Table 14-2 summarizes completed CDF projects located within Puget Sound and elsewhere in the U.S., as well as other projects currently under design (not yet constructed), including the Southwest Harbor CDF in Seattle and several sites in Commencement Bay. All information considered, the conditions within inner Bellingham Bay are such that the prospective CDF and CAD sites are no more susceptible to "failure" than other successfully approved and constructed CDF projects of similar size.

Conceptual designs of the containment berms for the Log Pond Nearshore CDF and CADs (see below) under consideration in Bellingham Bay have been developed based on preliminary, conservative applications of the engineering analyses completed at other Puget Sound CDF sites. These analyses would be refined during the remedial design phase based on site-specific sampling and analysis to ensure satisfactory performance during a seismic event.

Water Quality Protection. Detailed procedures have been developed by the Corps, EPA, and others that address long-term water quality protection requirements of CDFs and CADs (Palermo et al., 1998a and 1998b). Those design considerations that apply to water quality protection are briefly reviewed below.

CDF Discharges and Chemical Transport. Consistent with the Clean Water Act and other federal and state authorities, discharges from a CDF or CAD site must not result in exceedance of water (or sediment) quality criteria at the point of discharge into the receiving water (i.e., in seeps that discharge through the berm and/or cap sections). In making this determination, the designer and agency reviewers normally use a combination of laboratory tests, mathematical models of the various processes involved (e.g., chemical attenuation and dispersion), field experience, and monitoring data.

The list of potentially relevant transport processes that control chemical transport and resultant water quality at the point of discharge and from the CDF or CAD include the following:

- Contaminant dissolution and colloidal release;
- Groundwater transport;
- Hydrodynamic dispersion;
- Chemical adsorption;
- Metal sulfide precipitation;
- Ferrous iron oxidation/precipitation;
- Organic biodegradation; and
- Tidal dispersion.

All of these processes have been determined to be quantitatively important in controlling water quality within Puget Sound CDFs. However, the design approach presently utilized in the Puget Sound region (and elsewhere in the U.S.) has been based on the conservative premise that only a few of the simpler physical/chemical processes listed above control chemical attenuation and resultant water quality at a CDF site. A relatively straightforward laboratory testing and chemical transport modeling-based evaluation that focuses on these simpler processes is normally applied to evaluate water quality protection provided by regional CDFs. These assessments, which represent conservative, screening-level evaluations, have typically demonstrated that those cap and berm systems which provide structural stability (see above) also provide more than adequate water quality protection. In those cases where additional laboratory tests are performed or where more mathematical modeling is undertaken to address more complex processes, these additional efforts have served to demonstrate even greater water quality protection of CAD systems (e.g., Port of Seattle, 1994a/b). A focused laboratory testing and chemical transport modeling-based evaluation is normally conducted during the remedial design phase.

Leaching Test Methods. In order to provide for an early assessment of the protectiveness of CDFs and CADs in Bellingham Bay, subsurface core samples from the central Whatcom Waterway (containing the highest mercury concentrations) were collected to assess potential contaminant mobility of sediments being considered for possible confined disposal within Bellingham Bay. Sequential batch leaching tests (SBLT; Appendix M) were used to evaluate leachate quality from dredged sediments, and aid in the assessment of potential water quality impacts associated with long-term operation of a CDF. Consistent with current Corps guidance (Fuhrman, 1997), more detailed testing may need to be performed during remedial design to refine the initial SBLT-based assessments. Nevertheless, the initial SBLT data provide a good indication of potential sediment contaminant leachability, particularly at those CDF or CAD locations where the primary source of water for leaching is seawater with similar ionic strength to existing sediments (Myers et al., 1996). Based on conceptual hydrogeologic analyses of the Log Pond CDF, Log Pond CAD, and Starr Rock/Cornwall CAD sites (see below), a seawater leaching mechanism is anticipated.

Four SBLTs were performed on one composite sediment sample collected from the central Whatcom Waterway. Two anoxic (anaerobic) SBLTs and one oxic (aerobic) SBLT were performed for the analysis of metals, and one anoxic SBLT was performed for the analysis of organic constituents. The leachant used to perform each test consisted of either seawater or distilled deionized water. From the SBLT results, the potential long-term water quality impacts of various CDF options and possible design engineering controls necessary to meet applicable water quality criteria were evaluated. Results of the SBLT studies are presented in Appendix M.

Leaching Test Results. The SBLT results were evaluated with respect to the three different disposal scenarios: upland disposal; nearshore CDF; and CAD. The prospective CDF and CAD sites identified within Bellingham Bay are all located in saline, anaerobic environments. Based on conceptual hydrogeologic analyses of these sites, a seawater leaching mechanism is anticipated. Thus, the CAD and CDF scenarios were evaluated using the anoxic saline SBLT. However, no contaminants (including mercury) were detected in the anoxic saline leachate at concentrations above marine water quality criteria. Based on these preliminary results, no further treatment controls beyond those necessary to ensure anoxic and saline conditions, are likely necessary at the CDF and CAD site(s) to ensure water quality protection.

Based on the SBLT data, the relative leachability of contaminants present in Whatcom Waterway sediments identified for possible disposal is expected to vary depending on which type of CDF is used. Assuming that the Whatcom Waterway sediments may be conservatively representative of sediments targeted for disposal, greater contaminant mobility is anticipated at upland sites as compared with the prospective CAD facilities (see below).

Contaminant Transport Modeling. Detailed contaminant transport modeling results and verification monitoring data are available for a wide range of CDFs and CADs constructed in the Puget Sound region. Based on these data, mercury and other metals are expected to attenuate to a large degree (greater than 100-fold) during transport through berm and cap layers (Port of Tacoma, 1992; Hart Crowser, 1996c; and Boatman and Hotchkiss, 1994 and 1997). Considerable chemical attenuation in this case occurs as a result of chemical adsorption and tidal-induced mixing processes that occur during groundwater transport from the CDF. As discussed above, at those locations where additional processes have been evaluated, even greater attenuation has been predicted and observed. For example, at the Terminal 91 CDF in Seattle, a variety of attenuation reactions occurring within the containment berm confirmed the high degree of efficiency of tidally-influenced berms to significantly inhibit contaminant mobility and transport to the receiving water (Boatman and Hotchkiss, 1997). Similar modeling-based results were reported at the Southwest Harbor CAD site. CDF and CAD designs can be optimized to provide further water quality protection, incorporating some of the chemical attenuation design features proven to be successful at other CDF sites.

Detailed hydrogeologic data are available for the G-P Log Pond and Cornwall Landfill (ENSR 1994 and Landau 1999). Based on these data, only relatively low groundwater discharge rates are anticipated in the vicinity of the CDFs and CADs. Further, because of density differences at the freshwater/seawater interface, and because of hydraulic conductivity differences within the CAD (based on current conceptual designs), nearly all of the less saline groundwater flux through the CAD is expected to discharge through the intertidal zone (similar to Southwest Harbor; see above). Due to the configuration of the CADs, local groundwater flows are not expected to discharge through the confined sediment layer. The conceptual model of groundwater flow in the vicinity of the Log Pond and Starr Rock/Cornwall CADs is depicted on Figures 14-4 through 14-6.

Based on the available pre-design data, the two prospective Bellingham Bay CDF/CADs are likely to provide long-term water quality protection due to:

1) The expected discharge of less saline groundwater through the intertidal zone, above the confined sediment layer;

2) The observation, based on modeling results, that maximum leachate (SBLT) concentrations of prospective worst-case sediments to be confined within the CDFs and CADs do not significantly exceed marine water quality criteria; and

3) The high degree of efficiency of tidally influenced berms and caps to significantly inhibit contaminant mobility and transport to the receiving water, based on detailed modeling and water quality monitoring of similar contaminants (e.g., mercury) in similar CDF and CAD environments.

Design and Post-Construction Monitoring. A detailed long-term water quality assessment of the disposal site is normally performed during remedial design, using the results of thin-layer column leachate testing, as appropriate for the disposal scenario, as input to verified analytical models (Myers et al., 1996; Fuhrman, 1997). These evaluations assess the need for and scope of design requirements at the disposal site to ensure water quality protection.

However, as discussed above, screening-level contaminant transport assessments that rely on only the more basic (and easily modeled) attenuation mechanisms have typically demonstrated more than adequate protectiveness of CADs and CDFs in providing permanent water quality protection.

Design-level modeling and/or post-construction water quality monitoring has been accomplished at several contaminated sediment remediation sites within Puget Sound, and at other similar facilities in the U.S. In addition to the facilities already described in the section above, representative CDF and CAD systems include:

- Terminal 91 CDF, Seattle;
- Southwest Harbor CAD, Seattle;
- Los Angeles Shallow Water Habitat Site – Los Angeles and
- Thea Foss Waterway – Tacoma.

These previous applications are briefly described below:

- **Terminal 91 CDF – Seattle, WA**. In 1984, the Port of Seattle constructed the Terminal 91 CDF to provide safe containment of approximately 100,000 CY of sediments contaminated with a variety of metals (including mercury), polynuclear aromatic hydrocarbons, and polychlorinated biphenyls (PCBs). The dredged materials were placed in an anaerobic, saturated region of the CDF, but were also subjected to relatively large local groundwater inflows. Based on a combination of hydraulic simulations and conservative contaminant transport modeling, no water quality exceedances were predicted. These results were later confirmed through detailed water quality monitoring of the fill and berm systems. Much of the observed chemical attenuation was attributable to co-precipitation of metals (including mercury) from solution through several biogeochemical mechanisms (Boatman and Hotchkiss, 1997). More than a 100-fold attenuation of sediment leachate concentrations was observed due a combination of chemical and physical attenuation mechanisms.
- **Southwest Harbor – Seattle, WA**. As part of the Port of Seattle's Southwest Harbor project, two CAD facilities were carried through a feasibility study that included detailed contaminant transport modeling. The study evaluated contaminated sediment disposal capacity options ranging from 85,000 to up to 600,000 CY. The smaller CAD facility had surface elevations ranging from -12 to 0 feet MLLW, while the larger CAD facility was laid out with the final cap surface at roughly 3 feet MLLW. Detailed modeling results revealed that groundwater flow through the CAD would be strongly influenced by density differences at the freshwater/seawater interface. In consideration of these and other processes, nearly all (greater than 95 percent) of the chemical flux through the CAD was predicted to discharge through the intertidal zone (similar to the expected condition in Bellingham Bay; see below). However, the maximum predicted contaminant concentrations that may discharge through the CAD were fully protective of potential human health and ecological risks (Port of Seattle, 1994a/b).

- **Los Angeles Shallow Water Habitat Site – Los Angeles, CA**. In 1994-95, the Port of Los Angeles constructed a CAD facility to confine 57,000 CY of contaminated sediment from Corps maintenance dredging, along with additional contaminated materials resulting from Port dredging projects. The confined material was generally poorly graded sands and silty sands containing approximately 8 percent fines. Contaminants of concern included copper, lead, zinc, and petroleum hydrocarbons. The CAD, known as the Permanent Shallow Water Habitat (PSWH) site, was located within Los Angels Harbor and was constructed as mitigation for the Pier 400 filling development project. The PSWH raised the natural seabed from 45 feet to less than 20 feet MLLW, creating shallow water foraging area for the California Least Tern, a coastal bird listed as an endangered species. The CAD was constructed by placing a rubble-mound containment dike along the perimeter of the site. Contaminated sediments were then placed behind the berm, some within geotextile tubes dumped from bottom-dump barges. Once the contaminated sediment was placed, the site was capped with suitable dredge materials (MESU, 1995a/b; Palermo, et al., 1998b). Long-term monitoring of the site has confirmed the protectiveness of the CAD and the significant habitat enhancements provided by the facility.
- **Thea Foss Waterway – Tacoma, WA**. The Thea Foss CAD was carried through pre-remedial design for containment of roughly 576,000 CY of contaminated sediment to be dredged as part of remediation of the Thea Foss and Wheeler-Osgood Waterways. The CAD layout extended approximately 35 to 45 feet below mudline. The cap surface would be below the authorized navigational depth at the site. Propeller wash studies determined no effect to the cap from ship activities. Detailed water quality modeling demonstrated the protectiveness of the CAD, even though column leachate tests of the contaminated sediments revealed concentrations of mercury approximately 60 times higher than the corresponding water quality criterion (City of Tacoma, 1998).

  Table 14-2 summarizes completed CAD projects located within Puget Sound and elsewhere in the U.S., as well as other projects currently under design.

14.2.4 Upland Disposal Facilities

As discussed above, the Pilot Project identified two potential upland disposal sites for consideration in this WW Area RI/FS. Although other potential upland sites may be available within the region that have not yet been identified, the two retained sites are likely representative of the range of potentially viable disposal sites. The two retained sites are briefly summarized below.

- **Roosevelt or Columbia Ridge Landfills**. The Roosevelt Regional Landfill and Columbia Ridge Landfill are solid waste landfills located in eastern Washington and Oregon, respectively. If either of these disposal sites were selected, sediments dredged from the WW Area would be offloaded from barges on to rail units positioned at existing facilities. The sediments would then travel 200+ miles via rail to the landfill(s). The sediment would likely be placed in the landfill immediately upon arrival and would be covered at the end of the day with daily cover material. The landfills are lined with a system that exceeds the landfill design requirements of the Minimum Functional Standards for Solid Waste Handling, Chapter 173-304 WAC.

- **Phyllite Quarry**. This site is a quarry scheduled for closure, located roughly 15 miles from the WW Area. The current estimated capacity of the disposal site is roughly 200,000 to 240,000 CY. The sidewalls of the quarry range from 90 to 120 feet high and are steep, ranging from 1H:1.7V to nearly vertical. The sidewalls consist primarily of phyllite. The floor of the quarry is relatively flat, except for a vertical step of approximately 20 feet near the center, which separates the deeper southern part of the quarry from the shallower northern part. The floor of the quarry consists of greenstone. Measured at the top, the quarry is approximately 500 feet by 200 feet in size. There do not appear to be any groundwater seeps within the quarry.

  Detailed procedures have been developed by Ecology, EPA, and others to address long-term water quality protection requirements at upland disposal sites. Sequential batch leaching tests (SBLT; Appendix M) were used to evaluate leachate quality from dredged sediments, and aid in the assessment of potential water quality impacts associated with long-term operation of an upland disposal facility at the Pyllite Quarry or other similar site. In order to address the potential of interstitial water from the disposed sediments to leach through the upland disposal facility to freshwater and/or groundwater sources, the upland disposal scenario was evaluated using the oxic freshwater SBLT test. The maximum detected leachate concentration in these tests was approximately 520 times higher than the most restrictive freshwater quality criterion (mercury). As discussed above, greater contaminant mobility is anticipated at upland sites as compared with the prospective CAD facilities. Given the SBLT results, a leachate collection and treatment/disposal system would likely be required at the Pyllite Quarry upland disposal site to ensure water quality protection.

  The sides and bottom of the quarry would first be graded and a synthetic liner over a protection layer would be placed on the bottom and sides of the CDF. A leachate collection system consisting of piping within bedding sand would be placed beneath the sediments. The system would connect to a sump where the leachate would be pumped to the regional (City of Burlington) sewer connection that runs along the property line.

  Sediments would be offloaded from barges and placed into trucks for hauling to the site. Sediment would be spread throughout the site. Once all of the sediments are placed, the sediments would be graded. After the sediments are graded, a cover would be placed over the site consisting of a geotextile liner, soil, and wetland vegetation. The quarry disposal site could be restored to wetlands, contiguous with adjacent wetlands in the area. The estimated level of long-term site operation and monitoring would consist of maintaining the pump station and monitoring the site for leaks.

14.3 Detailed Analysis Of Cleanup Alternatives

The results of the detailed analysis of each cleanup alternative were used to compare the alternatives and identify key tradeoffs. This approach to assessing the alternatives was designed to provide agencies, stakeholders, and the public with sufficient information to adequately compare the alternatives, select an appropriate remedy for the WW Area, and demonstrate compliance with SMS remedy requirements. For each alternative, a description of the action is presented, followed by a technical analysis of key assessment factors, and concluding with a summary evaluation of the alternative relative to each criterion listed above.

14.3.1 Cleanup Alternative A – No Action

14.3.1.1 Description

Under this alternative, there would be no sediment cleanup, habitat creation, monitoring activities, or land use actions. Figure 14-7 presents a cross-section down the middle of Whatcom Waterway illustrating what the waterway would look like after implementation of this alternative.

14.3.1.2 Evaluation

The assessment of Alternative A against the evaluation criteria is summarized below.

Overall Environmental Quality

- **Compliance with Cleanup Standards and Applicable Laws.** Alternative A would not result in compliance with chemical-specific cleanup standards and applicable laws for all sediment areas. As described in Section 14.2.1, although most of the site will recover to below SQS criteria by the year 2005, some regions of the WW Area are not predicted to recover within the next 6 to 10 years to levels that would alleviate potential risks to the environment. These residual risk areas include shallow-water areas adjacent to the G-P ASB and within the Log Pond, and are depicted on Figure 14-3.
- **Protection of Human Health and the Environment.** This alternative does not provide full protection of human health or the environment, since surface sediments exceeding SQS and MCUL biological effects criteria and bioaccumulation screening levels would remain within portions of the WW Area (Figure 14-3).
- **Reasonable Restoration Time Frame.** As discussed above, some regions of the WW Area are not predicted to recover within the next 6 to 10 years to levels that would alleviate potential risks to the environment. All of the other alternatives evaluated in this RI/FS are capable of achieving a shorter restoration time frame.

- **Use of Permanent Solutions.** The No Action alternative is the least permanent technology defined in MTCA.
- **The Degree to which Recycling, Reuse, and Waste Minimization are Employed.** With the no action alternative, no recycling, reuse, or waste minimization practices are included.
- **Short-term Effectiveness.** Alternative A would not result in any adverse impacts to on-site workers or the community during implementation, because no remedial action would take place.
- **Long-term Effectiveness.** Although natural recovery may ultimately achieve risk-based criteria and cleanup standards, in some areas of the site these processes may require an extended period of time to be effective (see Section 14.2.2).
- **Net Environmental Benefits.** Relative to the other alternatives evaluated, minimal additional benefits to the natural environment would result from the No Action alternative.

Ability to be Implemented

- **Implementability.** Alternative A is implementable, since no remedial action, permits, or landowner approvals would be required. However, there is little potential for cooperation from the land owner/manager, and other stakeholders with this alternative.

Cost Effectiveness

- **Cost.** There are no capital or operating costs associated with the no action alternative.
- **Cost Effectiveness.** Because there are no remedial actions and associated costs, cost effectiveness cannot be defined.

14.3.2 Cleanup Alternative B – Source Control & Natural Recovery with Capping

14.3.2.1 Description

This alternative would utilize natural recovery in those parts of the WW Area that are predicted to naturally achieve SQS criteria by 2005. Outside of a small region of the Whatcom Waterway, natural recovery areas were delineated using conservative modeling assumptions that did not consider resuspension-related transport (see Section 14.2.1). Those areas of the site that are not expected to naturally recover using this conservative analysis would be capped. This alternative would achieve restoration of biological resources as rapidly as the more active cleanup alternatives (e.g., dredging).

Those areas of the site that are not predicted to naturally recover by 2005, and which occur outside of the navigation channel, would be capped with a 1- to 3-foot sand layer. Other site units within the WW Area that currently exceed the BSL would be capped to accelerate the natural recovery process. Section 14.2.2 discusses the design requirements for *in situ* caps. For example, the caps would be designed to withstand peak waves, tidally induced currents, propeller wash, and other forces. Preliminary analysis suggests that caps constructed in the WW Area at a depth of approximately -10 feet MLLW may require gravel and cobble-sized armoring to resist worst-case erosion. Progressively less armoring (i.e., requiring only sand-size materials) may be necessary at deeper depths. Detailed analysis of cap armor requirements and thicknesses would be performed as a part of remedial design.

A relatively small area in the middle of the Whatcom Waterway that is predicted to recover by 2005, partly as a result of resuspension-related transport, would be left to recover naturally under this alternative. All cleanup areas of the site would be monitored to document sediment recovery using a combination of chemical and biological testing methods. No dredging would occur under this alternative. The 3-acre area of mudflat and adjacent shallow subtidal habitat would be left intact at the head of the Whatcom Waterway. A layout of Alternative B is presented in Figure 13-3. Figure 14-7 presents a cross-section through the Whatcom Waterway under Alternative B.

Alternative B (as well as all other action alternatives) also includes control of sources of contamination. For example, by integrating a seepage attenuation layer into the Log Pond capping system (Section 14.2.3), and by capping nearshore wood material deposits, control of several identified external and internal sources of contaminants to the WW Area would be achieved. Other source control programs would be integrated into this alternative, including:

- Pending closure of the G-P chlor-alkali plant;
- Integration of upland cleanup and source control actions being performed by other parties (e.g., Cornwall Avenue Landfill RI/FS, Olivine RI/FS; and Roeder Avenue Landfill RI/FS);
- Ongoing monitoring and control of NPDES permit discharges; and
- Pending development by the City of Bellingham of a Comprehensive Stormwater Management Program.

Existing and prospective source control actions within the WW Area appear to be sufficient to prevent future sediment recontamination following implementation of Alternative B (and other active cleanup alternatives). However, this condition would be verified as a component of final remedial design.

14.3.2.2 Evaluation

The assessment of Alternative B against the RI/FS evaluation criteria is summarized below.

Overall Environmental Quality

- **Compliance with Cleanup Standards and Applicable Laws.** Alternative B would comply with MTCA and with other applicable cleanup standards and laws. Those areas of the site that would be remediated by natural recovery are predicted to achieve SQS criteria by 2005, within the recovery period allowable under the SMS. All areas that are not predicted to naturally recover (using conservative modeling assumptions) would be capped.

- **Protection of Human Health and the Environment.** This alternative would provide overall protection of human health and the environment by 2005, and would achieve restoration of biological resources as rapidly as the more active cleanup alternatives. The presence of a clean sediment layer throughout most of the Whatcom Waterway overlying contaminated sediments, as determined by the 1998 sampling, provides additional evidence on the protectiveness of the natural sediment cap that has formed in the channel as the result of source controls and natural recovery. These natural caps have also developed and persisted concurrent with active navigation use of the channel.

- **Reasonable Restoration Time Frame.** Alternative B, by design, would achieve cleanup within a period at least as short as all of the other "action" alternatives. The year 2005 generally represents the minimum estimated time frame for recovery of biological resources following active cleanup (e.g., dredging), including preliminary estimates of the time required for remedy selection (0.5 year), remedial design, permitting, and legal agreements (1.5 years), remedial action implementation/ construction (2 years), and biological recovery following construction (2 years).

- **Use of Permanent Solutions.** Natural recovery is a low-preference alternative under MTCA. However, Alternative B includes active containment (i.e., *in situ* capping) of areas of the site that currently exceed MCUL criteria (incorporating the bioaccumulation screening level). Containment is a more permanent technology than natural recovery (but less permanent than engineered confinement). Alternative B applies the more permanent containment technology to higher concentration sediments present within the Log Pond, ASB, and Starr Rock areas. Natural recovery is only used to address relatively low concentration sediments.

- **The Degree to which Recycling, Reuse, and Waste Minimization are Employed.** Under this alternative, clean dredge material potentially available from the Squalicum Waterway and other regional navigation dredging projects may be reused for cap construction. The practice of beneficially reusing dredged sediment for capping materials has occurred on other Puget Sound capping projects (Sumeri 1996). Waste is minimized to the extent that *in-situ* capping is used in lieu of dredging.

- **Short-term Effectiveness.** During the construction of a sediment cap, contaminated sediments are typically not significantly redistributed into the water column; minimizing potential environmental impact. Also, since the contaminated sediments remain in place, the risk of exposure or potential threats to workers and the community are minimal. With cap placement, remedial objectives are met immediately.

  In areas targeted for natural recovery, no construction or remedial actions are proposed; this also eliminates the potential for environmental impact, risk of exposure, or threats to workers and the community during the construction phase. For areas that are allowed to naturally recover, the short-term exposure is minimal at the beginning and reduces with time as the sediments recover.

- **Long-term Effectiveness.** Compared with more engineered containment alternatives, there is a greater risk under Alternative B of long-term erosion or future dredging, which could result in removal of the surface clean sediment layer, and potentially exposing higher concentration underlying sediments. Although the constructed caps would be designed to resist propeller wash and/or other disruptive events, there is a greater risk of exposure in natural recovery areas. Though the degree of such risk is reduced considering the 1998 observations of a clean sediment cap in the Whatcom Waterway navigation channel, monitoring would be required to confirm the integrity of the cap over time and to ensure attainment of cleanup levels throughout the site. If contaminant concentrations do not naturally recover to acceptable levels, additional measures such as dredging or capping of these areas may be required.

- **Net Environmental Benefits.** Implementation of Alternative B would restore biological functions of chemically degraded habitats as rapidly as the more active cleanup alternatives (i.e., by 2005). However, relative to several of the other action alternatives evaluated below, minimal additional benefits to the natural environment would result from Alternative B. No habitat enhancement actions would be performed as part of this alternative.

  Overall, this alternative would have minimal impacts on aquatic habitat, since existing habitats are left undisturbed for all but 3 SSUs. During cap construction, the epibenthos and benthos would be disturbed and would require recolonization. Recolonization by epibenthic invertebrates is expected within a period of months following construction. Recolonization by benthic infauna may require approximately 2 to 3 years (BBWG, 1999c).

Ability to be Implemented

- **Implementability.** Where the water depth is shallow or obstructions are expected, caps would be constructed with a clamshell bucket. In deeper areas, the caps could be constructed with a bottom dump barge. Cap construction is a common remedial activity in Puget Sound (Sumeri 1996) and ranks high in terms of implementability. Bathymetric surveys would be conducted pre- and post-construction to verify the thickness of the cap. The necessary equipment and materials for cap placement are available in the Puget Sound area.

  The substantive provisions of various permit requirements would need to be addressed as part of implementation of this alternative. For Alternative B, these requirements would likely include: Section 10 of the Rivers and Harbors Act; Sections 401 and 404 of the Clean Water Act; Water Quality Certification under Chapter 90.48 RCW; and Hydraulic Project Approval under Chapter 75.20 RCW.

Relative to landowner and user concerns, actions taken during the implementation of Alternative B would not adversely affect navigation uses within the active remediation areas. Action would not be taken in other areas of the WW Site, including within the navigation channels. Should future dredging be required within the WW Area (e.g., to achieve federally authorized channel depths in the middle and head of the Whatcom Waterway), a suitable confined disposal site may be necessary. To facilitate effective resolution of this possible condition, an institutional control such as an agreement between G-P and the U.S. Army Corps of Engineers would be required.

Cost Effectiveness

- **Cost.** Appendix N summarizes the estimated capital and operational and maintenance (O&M) costs for Alternative B. The estimated cost of this alternative is $4.9 million, excluding land easements.

- **Cost Effectiveness.** Alternative B is very cost effective due to the limited dredge volumes and high utilization of natural recovery and capping.

14.3.3 Cleanup Alternative C – Capping & Removal to Improve Navigation (Log Pond Nearshore CDF)

14.3.3.1 Description

This alternative combines capping and limited dredging within the middle of the Whatcom Waterway navigation channel to achieve SQS criteria throughout the WW Area. As in Alternative B, those areas of the site that are not predicted to recover (using conservative modeling assumptions), and which occur outside of the navigation channel, would be capped with a 1- to 3-foot sand layer. See Section 14.2.1 for natural recovery discussion and 14.2.2 for capping discussion. No further action would be undertaken in the outer Whatcom Waterway reach where surface sediments currently meet SQS criteria *and* where channel depths are consistent with the federally authorized elevations.

However, unlike Alternative B, surface and subsurface sediments within the middle of the Whatcom Waterway adjacent to the G-P Log Pond (from Stations 15+00 to 27+00), would be dredged to a depth of at least 5 feet below the currently authorized channel depths. This area of the Whatcom Waterway is frequently used for navigation but has shoaled to depths that are shallower than the authorized -30 foot MLLW federal channel (Figure 12-2). Since subsurface contaminants including mercury and 4-methylphenol would still be present below the dredge depth, the dredge cut would be capped with a 1-to-3-foot clean sand layer, resulting in a final channel elevation at least 2 feet below the authorized depth. This dredge-and-cap action would leave sufficient tolerance to allow unencumbered future maintenance dredging of the authorized federal channel in this area, considering typical overdredge allowances.

No action would be undertaken at the head of the Whatcom Waterway (i.e., above Station 15+00). Surface sediments throughout most of this area are currently below SQS criteria. However, those areas of the waterway that exceeded SQS criteria in 1998 (but were below MCUL criteria) would be left to recover naturally to below the SQS by 2005. In this alternative a 3-acre area of mudflat and adjacent shallow subtidal habitat would be left intact at the head of the Whatcom Waterway.

An estimated 160,000 CY of sediments would be dredged under this alternative. Dredged sediments would be reused to create a nearshore CDF in the G-P Log Pond. Excess sediments that do not fit into the nearshore fill would be disposed at an off-site upland landfill. Habitat mitigation actions including at least 5 acres of area-for-area replacement by fill removal and/or acquisition and enhancement at high priority habitat creation sites would be performed as a part of implementation of this alternative. A layout of Alternative C is presented in Figure 13-4.

14.3.3.2 Evaluation

The assessment of Cleanup Alternative C against the RI/FS evaluation criteria is summarized below.

Overall Environmental Quality

- **Compliance with Cleanup Standards and Applicable Laws.** Alternative C would comply with MTCA and with other applicable cleanup standards and laws. Those areas of the site that would be remediated by natural recovery are predicted to achieve SQS criteria by 2005, within the recovery period allowable under the SMS. All areas that are not predicted to naturally recover (using conservative modeling assumptions) would be capped.

- **Protection of Human Health and the Environment.** Alternative C would provide overall protection of human health and the environment. This would be accomplished by removing or confining the two areas identified as not suitable for natural recovery (SSUs 4 and 5B) in addition to other SSUs currently with elevated contaminant concentrations. The low dredge volume minimizes short-term impacts associated with removal. Since no ongoing, significant sources of mercury are identified, sediment areas including the outer portion of the Waterway, the head of the Waterway, the Bellingham Shipping Terminal pier, and other areas of the site would naturally recover by 2005.

- **Reasonable Restoration Time Frame.** Alternative C, by design, would achieve cleanup within a period similar to the other alternatives.

- **Use of Permanent Solutions.** Natural recovery is a low-preference alternative under MTCA. However, Alternative C includes active containment (i.e., *in situ* capping or engineered confinement) of all areas of the site that currently exceed MCUL criteria (incorporating the bioaccumulation screening level). Engineered confinement, applied in this alternative to the Log Pond, is a more permanent technology than containment, while containment is more permanent than natural recovery.

Alternative C applies the most permanent technology to the highest concentration sediments present within the Log Pond, and uses containment for intermediate concentration sediments present within the ASB and Starr Rock areas. Natural recovery is applied only to relatively low concentration sediments.

- **The Degree to which Recycling, Reuse, and Waste Minimization are Employed.** Under this alternative, clean dredge material potentially available from the Squalicum Waterway and other regional navigation dredging projects may be reused for cap construction. The practice of beneficially reusing dredged sediment for capping materials has occurred on other Puget Sound capping projects (Sumeri 1996). Waste would be minimized to the extent that *in-situ* capping is used in lieu of dredging. Placing sediments dredged from the Whatcom Waterway in a nearshore fill created in the G-P Log Pond would also involve a beneficial reuse of dredge material. The filled area would provide additional useable upland property.

- **Short-Term Effectiveness.** Dredging would likely be completed with a mechanical dredge. Material would also be placed in the nearshore fill mechanically. Worker and community risks associated with the dredging and nearshore fill placement are expected to be minimal. Transport of excess sediments to the Roosevelt Regional Landfill would increase the potential worker and community exposure risk. Dredging activities resuspend sediments into the water column, allowing for contaminant migration and a potential impact to the environment (BBWG, 1999c). Resuspension may be controlled with silt curtains placed around the dredge and fill areas and/or with modification of the dredge process. In the areas targeted for dredging and capping, the protection against post-dredge residual contaminants is immediate.

  Turbidity controls and other construction best management practices (BMPs) would be implemented to protect the existing eelgrass bed adjacent to the G-P ASB and other special aquatic sites. Monitoring would be performed to verify that construction does not adversely affect these special aquatic sites, and to provide for appropriate mitigation, if necessary.

  During construction of a thick- or thin-layer cap, the contaminated sediments are not disturbed or redistributed into the water column; this eliminates potential environmental impact. Also, since the contaminated sediments remain in place, the risk of exposure or potential threats to workers and the community are minimal. With cap placement, remedial objectives are met immediately.

  In the areas targeted for natural recovery, the potential for environmental impact, risk of exposure, or threats to workers and the community during the construction phase is minimal. For the areas that are allowed to naturally recover, the short-term exposure is minimal at the beginning; this reduces with time as the sediments recover.

- **Long-term Effectiveness.** Under this alternative, a middle stretch of the Whatcom Waterway would be dredged to remove the contaminated sediments. The risk remaining after implementation of the dredging and fill activities would be negligible.

  The long-term risk associated with a cap generally involves the erosion or removal of the clean sediment layer. Day-to-day hydrodynamic and tidal conditions are not expected to disturb the constructed caps. The caps would be designed to resist propeller wash or other disruptive events. Cap monitoring would be required to confirm the integrity of the cap over time.

- **Net Environmental Benefits.** Relative to some of the other alternatives evaluated, this alternative offers an opportunity for significant environmental benefits. Approximately 4.8 acres of low intertidal and shallow subtidal habitat in the Log Pond would be lost from constructing nearshore fill facilities at these sites, converting aquatic habitat to upland. However, compensatory mitigation included as part of this alternative would convert an equivalent or greater area (at least 5 acres) of uplands elsewhere in inner Bellingham Bay to more productive aquatic habitat. If the constructed habitat were to be located such that it also improved connectivity with estuarine systems or achieved other priority habitat restoration actions identified by the Pilot Project (BBWG, 1999c), the mitigation actions may result in a net increase in overall biological functions in Bellingham Bay.

Ability to be Implemented

- **Implementability.** Mechanical dredging and placement of dredged sediments in a nearshore fill ranks high in terms of implementability. Regional contractors have completed dredging projects with contaminated sediments; these projects require additional operating measures outside of a typical navigational dredging project. Construction monitoring, such as water quality and post dredge sediment sampling, would be completed to assist the contractor during dredge operations.

  Where the water depth is shallow or obstructions are expected, caps would be constructed with a clamshell bucket. In deeper areas, the caps could be constructed with a bottom dump barge. Cap construction is a common remedial activity in Puget Sound (Sumeri 1996) and ranks high in terms of implementability. Bathymetric surveys would be conducted pre- and post-construction to verify the thickness of the cap. The necessary equipment and materials for cap placement are available in the Puget Sound area.

  The substantive provisions of various permit requirements would need to be addressed as part of implementation of this alternative. For Alternative C, these requirements would likely include: Section 10 of the Rivers and Harbors Act; Sections 401 and 404 of the Clean Water Act; Water Quality Certification under Chapter 90.48 RCW; Hydraulic Project Approval under Chapter 75.20 RCW; and Bellingham Bay Shoreline Master Program requirements. Consistent with the Clean Water Act 404(b)(1) guidelines, the purpose and need for nearshore fill disposal elements of the project would need to address avoidance, minimization, and public interest factors. As discussed above, compensatory habitat mitigation would also be needed, consistent with state and federal regulations.

Relative to landowner and user concerns, actions taken during the implementation of Alternative C would not adversely affect authorized navigation uses within the remediation areas. Following construction, navigation depths in the Whatcom Waterway from the mouth to approximately Station 15+00, excluding a relatively small strip of the channel immediately adjacent to the G-P ASB, would be at or below -32 feet MLLW, at least 2 feet lower than the currently authorized channel depth of -30 feet MLLW. However, action would not be taken within the Whatcom Waterway above approximately Station 15+00. Should future dredging be required within the WW Area, a suitable confined disposal site may be necessary. To facilitate effective resolution of this possible condition, an institutional control such as an agreement between G-P and the U.S. Army Corps of Engineers would be required. Such an agreement would likely be required as part of the Section 10 certification.

Cost Effectiveness

- **Cost.** Appendix N summarizes the estimated capital and O&M costs for Cleanup Alternative C. The estimated cost of this alternative is $19.4 million, excluding land easements.
- **Cost Effectiveness.** Although this alternative is one of the least expensive, it is less cost effective compared to some of the other alternatives due to the low volume of material confined within the nearshore CDF and the use of upland disposal for excess dredge material. Both the Log Pond nearshore CDF, because of its configuration, and upland disposal, because of rehandling costs, have relatively high unit costs for dredging and disposal.

14.3.4 Cleanup Alternative D – Capping & Removal to Improve Navigation (Upland Disposal)

14.3.4.1 Description

This alternative is identical to Alternative C except that all of the dredged material would be disposed at an upland landfill instead of in the G-P Log Pond nearshore CDF.

A layout of Alternative D is presented in Figure 13-5.

14.3.4.2 Evaluation

An assessment of Cleanup Alternative D against the FS evaluation criteria is summarized below.

Overall Environmental Quality

- **Compliance with Cleanup Standards and Applicable Laws.** Alternative D would comply with MTCA and with other applicable cleanup standards and laws. Those areas of the site that would be remediated by natural recovery are predicted to achieve SQS criteria by 2005, within the recovery period allowable under the SMS. All areas that are not predicted to naturally recover (using conservative modeling assumptions) would be capped.

- **Protection of Human Health and the Environment.** Alternative D would provide overall protection of human health and the environment. This would be accomplished by removing or confining the two areas identified as not suitable for natural recovery (SSUs 4 and 5B) in addition to other SSUs currently with elevated contaminant concentrations. The low dredge volume minimizes short-term impacts associated with removal. However, loading and transporting the contaminated sediments to an upland facility increases the chances of human exposure to the contaminated material and releases to the environment. Since no ongoing, significant sources of mercury are identified, sediment areas including the outer portion of the Waterway, the head of the Waterway, the Bellingham Shipping Terminal pier, and other areas of the site would naturally recover by 2005.

- **Reasonable Restoration Time Frame.** Alternative D, by design, would achieve cleanup within a period similar to the other alternatives.

- **Use of Permanent Solutions.** Natural recovery is a low-preference alternative under MTCA. However, Alternative D includes active containment (i.e., *in situ* capping or engineered confinement) of all areas of the site that currently exceed MCUL criteria (incorporating the bioaccumulation screening level). Engineered confinement, applied in this alternative as upland disposal of sediments dredged from the middle Whatcom Waterway, is a more permanent technology than containment, while containment is more permanent than natural recovery. Alternative D applies the most permanent technology to subsurface sediments dredged from the Whatcom Waterway, and uses containment for sediments present within the Log Pond, ASB, and Starr Rock areas. Natural recovery is applied only to relatively low concentration sediments.

- **The Degree to which Recycling, Reuse, and Waste Minimization are Employed.** Under this alternative, clean dredge material potentially available from the Squalicum Waterway and other regional navigation dredging projects may be reused for cap construction. The practice of beneficially reusing dredged sediment for capping materials has occurred on other Puget Sound capping projects (Sumeri 1996). Waste would be minimized to the extent that *in-situ* capping is used in lieu of dredging. Under this alternative, the sediments dredged from the Whatcom Waterway may be transported to the Whatcom-Skagit Phyllite Quarry for upland disposal. Once the Whatcom-Skagit Phyllite Quarry is full, the site would be restored to wetlands contiguous with adjacent wetlands in the area; this constitutes a beneficial reuse of dredge material.

- **Short-Term Effectiveness.** Dredging would likely be completed with a mechanical dredge. Material would also be placed in the nearshore fill mechanically. Worker and community risks associated with the dredging and nearshore fill placement are expected to be minimal. Transport of sediments to the Whatcom-Skagit Phyllite Quarry or Roosevelt Regional Landfill would increase the potential worker and community exposure risk. Dredging activities resuspend sediments into the water column, allowing for contaminant migration and a potential impact to the environment (BBWG, 1999c). Resuspension may be controlled with silt curtains placed around the dredge and fill areas and/or with modification of the dredge process. In the areas targeted for dredging and capping, the protection against post-dredge residual contaminants is immediate.

  Turbidity controls and other construction best management practices (BMPs) would be implemented to protect the existing eelgrass bed adjacent to the G-P ASB and other special aquatic sites. Monitoring would be performed to verify that construction does not adversely affect these special aquatic sites, and to provide for appropriate mitigation, if necessary.

  During construction of a thick- or thin-layer cap, the contaminated sediments are not disturbed or redistributed into the water column; this eliminates potential environmental impact. Also, since the contaminated sediments remain in place, the risk of exposure or potential threats to workers and the community are minimal. With cap placement, remedial objectives are met immediately.

  In the areas targeted for natural recovery, the potential for environmental impact, risk of exposure, or threats to workers and the community during the construction phase is minimal. For the areas that are allowed to naturally recover, the short-term exposure is minimal at the beginning; this reduces with time as the sediments recover.

- **Long-term Effectiveness.** Under this alternative, a middle stretch of the Whatcom Waterway would be dredged to remove the contaminated sediments. The risk remaining after implementation of the dredging and fill activities would be negligible.

  The long-term risk associated with a cap generally involves the erosion or removal of the clean sediment layer. Day-to-day hydrodynamic and tidal conditions are not expected to disturb the constructed caps. The caps would be designed to resist propeller wash or other disruptive events. Cap monitoring would be required to confirm the integrity of the cap over time.

- **Net Environmental Benefits.** Relative to some of the other alternatives evaluated, this alternative offers an opportunity for moderate environmental benefits. If used, the Whatcom-Skagit Phyllite Quarry upland disposal site would be restored to a freshwater wetland habitat. Relative to other alternatives evaluated, this alternative provides moderate net environmental benefits. Under this alternative, there would be no net loss of aquatic habitat. Limited conversion of habitat would occur as a result of dredging the navigable reaches of the middle Whatcom Waterway and capping the G-P Log Pond and G-P ASB. Habitat in the capping areas would be converted from subtidal to shallow subtidal habitat and from shallow subtidal to low to high intertidal habitat. It is expected that the cap at the Log Pond could also be configured to achieve no net loss of aquatic habitat. No habitat enhancement actions would be performed as part of this alternative, except that restoration of freshwater wetland habitat would be performed if the quarry disposal site were selected.

Ability to be Implemented

- **Implementability.** Mechanical dredging ranks high in terms of implementability. Area contractors have completed dredging projects with contaminated sediments; these projects require additional operating measures outside of a typical navigational dredging project. Construction monitoring, such as water quality and post dredge sediment sampling, would be completed to assist the contractor during dredge operations.

  Offloading of saturated sediments from barges to railcars or trucks, and offloading sediments from railcars or trucks to a CDF are difficult and intensive procedures. The logistics behind mechanical transfer of sediments to a barge, loading saturated sediments to a railcar or truck, and transferring them to the CDF are such that the implementability is moderate.

  In deep water areas, caps would be placed with a bottom dump barge. Where the water depth is shallow or obstructions are expected, caps would be constructed with a clamshell bucket. Cap construction is a common remedial activity in Puget Sound (Sumeri 1996) and ranks high in terms of implementability. Bathymetric surveys would be conducted pre- and post-construction to verify the thickness of the cap. The necessary equipment and materials for cap placement are available in the Puget Sound area.

  The substantive provisions of various permit requirements would need to be addressed as part of implementation of this alternative. For Alternative D, these requirements would likely include: Section 10 of the Rivers and Harbors Act; Sections 401 and 404 of the Clean Water Act; Water Quality Certification under Chapter 90.48 RCW; and Hydraulic Project Approval under Chapter 75.20 RCW. Solid Waste Management Act requirements, including permitting for landfill siting, design, maintenance, monitoring, and closure, may be applicable if the off-site Whatcom-Skagit Phyllite Quarry is used for sediment disposal.

  Similar to Alternative C, actions taken during the implementation of Alternative D would not adversely affect authorized navigation uses within the remediation areas. Following construction, navigation depths in the Whatcom Waterway from the mouth to approximately Station 15+00, excluding a relatively small strip of the channel immediately adjacent to the G-P ASB, would be at or below -32 feet MLLW, at least 2 feet lower than the currently authorized channel depth of -30 feet MLLW. However, action would not be taken within the Whatcom Waterway above approximately Station 15+00. Should future dredging be required within the WW Area, a suitable confined disposal site may be necessary. To facilitate effective resolution of this possible condition, an institutional control such as an agreement between G-P and the U.S. Army Corps of Engineers would be required. Such an agreement would likely be required as part of the Section 10 certification.

Cost Effectiveness

- **Cost.** Appendix N summarizes the estimated capital and O&M costs for Alternative D. The estimated cost of this alternative is $19.2 million, excluding land easements.
- **Cost Effectiveness.** Although this alternative is one of the least expensive, it is less cost effective than some of the other alternatives due to the relatively low volume of material confined within the upland landfill. Upland disposal, because of rehandling costs, has relatively high unit costs for dredging and disposal.

14.3.5 Cleanup Alternative E – Capping & Removal to Achieve Authorized Channel Depths (CAD Disposal) (Pilot Project No. 2A)

14.3.5.1 Description

The overall objective of this alternative is to achieve SQS criteria in the WW Area while concurrently maintaining existing navigation channels, minimizing dredging and disposal of contaminated sediment, and maximizing the areal extent and diversity of intertidal aquatic habitat by using caps and CAD facilities. Enough material would be dredged from the Whatcom Waterway to remove contaminated sediments from the existing federal channel (including overdredge allowances) in all areas of the waterway that are currently used for navigation. Except for the extreme head of the Whatcom Waterway, surface and subsurface sediments throughout much of the waterway would be dredged to a depth of at least 5 feet below the currently authorized channel depths. However, no further action would be undertaken in the outer Whatcom Waterway reach where surface sediments currently meet state standards and where channel depths are consistent with the federally authorized elevations. Other contaminated sediment areas would be capped with a 1-to-3-foot clean sand layer. In this alternative a 3-acre area of mudflat and adjacent shallow subtidal habitat would be left intact at the head of the Whatcom Waterway.

Approximately 360,000 CY of contaminated sediment from navigation areas within the Whatcom Waterway would be dredged. In this alternative, the sediment disposal capacity would be provided by two CAD facilities (Figure 13-2):

1) A small (up to 50,000 CY) CAD sited in the G-P Log Pond; and
2) A larger 500,000 CY CAD sited in the Starr Rock/Cornwall area. The Starr Rock/Cornwall CAD could also be implemented as a multi-user

disposal facility to contain contaminated sediments that may be dredged from other sites in Bellingham Bay.

Both CAD facilities would provide opportunities for habitat restoration. Largely because of the CADs, approximately 42 acres of subtidal area would be converted into intertidal habitat. A layout of Alternative E is presented in Figure 13-6.

14.3.5.2 Evaluation

An assessment of Cleanup Alternative E against the FS evaluation criteria is summarized below.

Overall Environmental Quality

- **Compliance with Cleanup Standards and Applicable Laws.** Alternative E would comply with MTCA and with other applicable cleanup standards and laws. All areas that currently exceed SQS criteria would be remediated either by containment (*in situ* capping) or with engineered confinement (CADs).

- **Protection of Human Health and the Environment.** Alternative E would provide overall protection for human health and the environment by removing or capping contaminated sediments within the Waterway. Relative to Alternatives C and D, the larger dredge volumes and implementation duration somewhat increases the short-term impacts associated with removal. The construction of caps prevents the exposure of contaminated sediments to aquatic life.

- **Reasonable Restoration Time Frame.** Alternative E, by design, would achieve cleanup within a period similar to the other alternatives.

- **Use of Permanent Solutions.** Alternative E includes active containment (i.e., *in situ* capping or engineered confinement) of all areas of the site that currently exceed SQS criteria (incorporating the bioaccumulation screening level). Engineered confinement, applied in this alternative to the Log Pond, Starr Rock area, and sediments dredged from the Whatcom Waterway, is a more permanent technology than containment, while containment is more permanent than natural recovery. Alternative E applies the most permanent technology to the highest concentration sediments present within the WW Area, and uses containment for lower concentration sediments present within other areas of the site.

- **The Degree to which Recycling, Reuse, and Waste Minimization are Employed.** Under this alternative, the potential to reuse clean dredge material for cap construction is feasible. This practice has occurred on other Puget Sound capping projects (Sumeri 1996). The amount of waste generated is moderate, however all dredged sediments would be placed in one of two constructed CAD facilities. Once a CAD is filled and capped, it would provide an opportunity to create an aquatic habitat for eelgrass and other shallow intertidal species that existed historically within inner Bellingham Bay. Using dredge material to create a habitat of this type constitutes a beneficial reuse of dredge material.

- **Short-term Effectiveness.** Dredging would be completed with a mechanical system and the dredge material mechanically loaded into the CAD facility. Worker and community risks associated with the dredging, transport, and disposal are expected to be minimal (BBWG, 1999c). Dredging activities resuspend sediments into the water column, allowing for contaminant migration and a potential impact to the environment. Resuspension may be controlled with silt curtains placed around the dredge areas and/or modification of the dredge process. However, with moderate dredge volumes, the duration of implementation somewhat decreases the short-term effectiveness for this alternative.

  During the construction of caps, the contaminated sediments are not disturbed or redistributed into the water column; this eliminates potential environmental impact. Also, since the contaminated sediments remain in place, the risk of exposure or potential threats to workers and the community are minimal. With cap placement, remedial objectives are met immediately.

- **Long-term Effectiveness.** Under this alternative, a moderate amount of dredging would be conducted to remove the contaminated sediments. The risk remaining after implementation of the dredging and fill activities would be negligible. Long-term risk associated with confined disposal (such as in a CAD) includes contaminant leaching; given the anoxic, saline environment of the CAD, the risk of contaminant migration is expected to be minimal (see Section 14.2.3.2).

  The long-term risk associated with a cap generally involves the erosion or removal of the clean sediment layer. Day to day hydrodynamics and tidal conditions are not expected to disturb the constructed cap. The cap would be designed to resist propeller wash or other disruptive events. Cap monitoring would be required to confirm the integrity of the cap over time.

- **Net Environmental Benefits.** Relative to the other alternatives evaluated, this alternative has significant net environmental benefits. Under this alternative, there would be no net loss of aquatic habitat. Locating CADs at the Log Pond, and near Starr Rock/Cornwall Avenue Landfill would convert subtidal substrates in these areas to shallow subtidal and/or low intertidal elevations, providing an opportunity to create more than 30 acres of eelgrass habitat that previously (historically) existed within the inner Bellingham Bay area. The Bellingham Bay Comprehensive Strategy EIS more fully evaluates the environmental impacts associated with this alternative.

Ability to be Implemented

- **Implementability.** Mechanical dredging and mechanical offloading of dredged sediments rank high in terms of implementability. Area contractors have completed a variety of dredging projects with contaminated sediments; these projects require additional operating measures outside of a typical navigational dredging project. Construction monitoring, such as water quality and post dredge sediment sampling, would be completed to assist the contractor during dredge operations.

In deep areas, caps would be placed with a bottom dump barge. Where the water depth is shallow or obstructions are anticipated, caps would be constructed with a clamshell bucket. Cap construction is a common remedial activity in Puget Sound (Sumeri 1996) and ranks high in terms of implementability. Bathymetric surveys would be conducted pre- and post-construction to verify the thickness of the cap. The necessary equipment and materials for cap placement are available in the Puget Sound area.

The substantive provisions of various permit requirements would need to be addressed as part of implementation of this alternative. For Alternative E, these requirements would likely include: Section 10 of the Rivers and Harbors Act; Sections 401 and 404 of the Clean Water Act; Water Quality Certification under Chapter 90.48 RCW; Hydraulic Project Approval under Chapter 75.20 RCW; and Bellingham Bay Shoreline Master Program requirements.

Actions taken during the implementation of Alternative E would improve authorized navigation uses within the remediation areas. Following construction, navigation depths in the Whatcom Waterway from the mouth to Station 3+00, excluding a small area of the channel near Station 5+00 immediately adjacent to G-P, would be at or below -32 feet MLLW, at least 2 feet lower than the currently authorized channel depth of -30 feet MLLW. In addition, because dredging would extend to the edge of the Port's Central Waterfront Redevelopment Project, it may be reasonable to accommodate pier access to this area. However, should future dredging be required within the WW Area, a suitable confined disposal site may be necessary. To facilitate effective resolution of this possible condition, an institutional control such as an agreement between G-P and the U.S. Army Corps of Engineers would be required. Such an agreement would likely be required as part of the Section 10 certification.

- **Cost.** Appendix N summarizes the estimated capital and O&M costs for Alternative E. The estimated cost of this alternative is $23.8 million, excluding land easements.
- **Cost Effectiveness.** Alternative E has high cost effectiveness due to the use of a large aquatic disposal site and moderate dredge volume. The total cost is similar to Alternatives C and D. The Starr Rock CAD coupled with the Log Pond CAD provide an effective disposal solution. The CADs also provide extensive new intertidal and shallow subtidal habitat.

14.3.6 Cleanup Alternative F – Capping & Removal to Achieve Authorized Channel Depths (Upland Disposal) (Pilot Project No. 2B)

14.3.6.1 Description

The overall objective of Alternative F is to achieve SQS criteria in the WW Area while maintaining existing navigation channels and minimizing dredging and disposal of contaminated sediment. This alternative includes the same amount of dredging as Alternative E, but would dispose of the materials at one or more off-site upland landfills. Other contaminated sediment areas would be capped with a 1-to-3-foot clean sand layer.

All dredged sediments would be offloaded on shore, dewatered as necessary to facilitate transport, and hauled by rail, truck, and/or barge outside of the Bellingham Bay watershed to upland disposal facilities. Approximately 360,000 CY of contaminated sediment from navigation areas within the Whatcom Waterway would be dredged. In this alternative, the Whatcom-Skagit Phyllite Quarry and the Roosevelt Regional Landfill would provide the sediment disposal capacity. A layout of Alternative F is presented in Figure 13-7.

14.3.6.2 Evaluation

An assessment of Cleanup Alternative F against the FS evaluation criteria is summarized below.

Overall Environmental Quality

- **Compliance with Cleanup Standards and Applicable Laws.** Alternative F would comply with MTCA and with other applicable cleanup standards and laws. All areas that currently exceed SQS criteria would be remediated either by containment (*in situ* capping) or with engineered confinement (upland CDFs).

- **Protection of Human Health and the Environment.** Alternative F would provide overall protection for human health and the environment by removing or capping contaminated sediments within the Waterway. As in Alternative E, the moderate dredge volumes and implementation duration results in short-term impacts associated with removal. The construction of caps prevents the exposure of contaminated sediments to aquatic life.

- **Reasonable Restoration Time Frame.** Alternative F, by design, would achieve cleanup within a period similar to the other alternatives.

- **Use of Permanent Solutions.** Alternative F includes active containment (i.e., *in situ* capping or engineered confinement) of all areas of the site that currently exceed SQS criteria (incorporating the bioaccumulation screening level). Engineered confinement, applied in this alternative to sediments dredged from the Whatcom Waterway, is a more permanent technology than containment or natural recovery. Alternative F applies the most permanent technology to moderate concentration sediments present within the WW Area, and uses containment for both higher and lower concentration sediments present within other areas of the site. Thus, compared with Alternative E, this alternative incorporates slightly less use of permanent technologies.

- **The Degree to which Recycling, Reuse, and Waste Minimization are Employed.** Under this alternative, the potential to reuse clean dredge material for cap construction is feasible. This practice has occurred on other Puget Sound capping projects (Sumeri 1996). The amount of waste generated is moderate, however all dredged sediments would be placed in an upland landfill. This disposal method does not constitute beneficial reuse.

- **Short-term Effectiveness.** Dredging would most likely be completed with a mechanical system and the dredge material would be mechanically offloaded and transported to an upland facility. Worker and community risks associated with the dredging, transport, and disposal are expected to be minimal. However, during transport and upland disposal of a moderate volume of contaminated sediments, the risks are expected to increase, primarily due to transport. Dredging activities resuspend sediments into the water column, allowing for contaminant migration and a potential impact to the environment. Resuspension may be controlled with silt curtains placed around the dredge areas and/or modification of the dredge process. However, with moderate dredge volumes, the duration of implementation decreases the short-term effectiveness for this alternative. Turbidity controls, BMPs, and monitoring would be performed to verify that construction does not adversely affect special aquatic sites, and to provide for appropriate creation if necessary.

  During the construction of caps, the contaminated sediments are not disturbed or redistributed into the water column; this eliminates potential environmental impact (BBWG, 1999c). Also, since the contaminated sediments remain in place, the risk of exposure or potential threats to workers and the community are minimal. With cap placement, remedial objectives are met immediately.

- **Long-term Effectiveness.** Under this alternative, a moderate amount of dredging would be conducted to remove the contaminated sediments. The risk remaining after implementation of the dredging and fill activities would be negligible. Long-term risk associated with upland disposal includes contaminant leaching; the Roosevelt Regional Landfill would be a fully lined facility making the risk negligible.

  The long-term risk associated with a cap generally involves the erosion or removal of the clean sediment layer. Day to day hydrodynamics and tidal conditions are not expected to disturb the constructed cap. The cap would be designed to resist propeller wash or other disruptive events. Cap monitoring would be required to confirm the integrity of the cap over time.

- **Net Environmental Benefits.** Relative to some of the other alternatives evaluated, this alternative offers an opportunity for moderate environmental benefits. If used, the Whatcom-Skagit Phyllite Quarry upland disposal site would be restored to a freshwater wetland habitat. Relative to other alternatives evaluated, this alternative provides moderate net environmental benefits. Under this alternative, there would be no net loss of aquatic habitat. Limited conversion of habitat would occur as a result of dredging the navigable reaches of the middle Whatcom Waterway and capping other areas of the site. Habitat in the capping areas would be converted from subtidal to shallow subtidal habitat and from shallow subtidal to low to high intertidal habitat. It is expected that the cap at the Log Pond could also be configured to achieve no net loss of aquatic habitat. No habitat enhancement actions would be performed as part of this alternative, except that restoration of freshwater wetland habitat would be performed if the quarry disposal site were selected. The Bellingham Bay Comprehensive Strategy EIS more fully evaluates the environmental impacts associated with this alternative.

Ability to be Implemented

- **Implementability.** Mechanical dredging and mechanical offloading of dredged sediments rank high in terms of implementability. Area contractors have completed a variety of dredging projects with contaminated sediments; these projects require additional operating measures outside of a typical navigational dredging project.

  Offloading of saturated sediments from barges to railcars or trucks, and offloading sediments from railcars or trucks are difficult and intensive procedures. The logistics behind mechanical transfer of a large quantity of sediments to a barge, loading saturated sediments to a railcar, and transferring them to the upland CDF are such that the implementability is low. Area contractors have not previously handled a quantity of contaminated sediments substantially over 1,000,000 CY for upland transport and disposal.

  In deep areas, caps would be placed with a bottom dump barge. Where the water depth is shallow or obstructions are anticipated, caps would be constructed with a clamshell bucket. Cap construction is a common remedial activity in Puget Sound (Sumeri 1996) and ranks high in terms of implementability. Bathymetric surveys would be conducted pre- and post-construction to verify the thickness of the cap. The necessary equipment and materials for cap placement are available in the Puget Sound area.

  The substantive provisions of various permit requirements would need to be addressed as part of implementation of this alternative. For Alternative F, these requirements would likely include: Section 10 of the Rivers and Harbors Act; Sections 401 and 404 of the Clean Water Act; Water Quality Certification under Chapter 90.48 RCW; Hydraulic Project Approval under Chapter 75.20 RCW; and Bellingham Bay Shoreline Master Program requirements.

  Actions taken during the implementation of Alternative F would improve authorized navigation uses within the remediation areas. Following construction, navigation depths in the Whatcom Waterway from the mouth to Station 3+00, excluding a small area of the channel near Station 5+00 immediately adjacent to G-P, would be at or below -32 feet MLLW, at least 2 feet lower than the currently authorized channel depth of -30 feet MLLW. In addition, because dredging would extend to the edge of the Port's Central Waterfront Redevelopment Project, it may be reasonable to accommodate pier access to this area. However, should future dredging be required within the WW Area, a suitable confined disposal site may be necessary. To facilitate effective resolution of this possible condition, an institutional control such as an agreement between G-P and the U.S. Army Corps of Engineers would be required. Such an agreement would likely be required as part of the Section 10 certification.

Cost Effectiveness

- **Cost.** Appendix N summarizes the estimated capital and O&M costs for Alternative F. The estimated cost of this alternative is $36.5 million, excluding land easements.
- **Cost Effectiveness.** Alternative F has low-to-medium cost effectiveness due to the moderate dredge volume and use of upland disposal. Upland disposal has a high unit cost for dredging and disposal.

14.3.7 Cleanup Alternative G – Full Removal from Navigation Areas (CAD Disposal) (Pilot Project No. 2C)

14.3.7.1 Description

The overall objective of this alternative is to achieve SQS criteria in the WW Area, allowing for possible future deepening of the navigation channels, and maximizing the areal extent and diversity of intertidal aquatic habitat by using caps and CAD facilities. Unlike Alternative E, minimizing dredging and disposal volumes is not a primary objective of Alternative G. Contaminated sediments that are located within the Whatcom Waterway, even if present below the currently authorized depths, would be dredged, removing potential encumbrances to channel deepening, should such a deepening project be undertaken in the future. Dredging would be performed throughout the Whatcom Waterway, including near the head of the waterway. The extreme head of the Whatcom Waterway near Citizens Dock, consisting of a 2-acre area of mudflats that has formed naturally within this area, would be left intact.

Approximately 760,000 CY of contaminated sediment from navigation areas within and adjacent to the Whatcom Waterway would be dredged. In this alternative, the sediment disposal capacity would be provided by two CAD facilities (Figure 13-2):

- A small (up to 50,000 CY) CAD sited in the G-P Log Pond; and
- A larger 1,100,000 CY CAD sited in the Starr Rock/Cornwall area. The Starr Rock/Cornwall CAD could also be implemented as a multi-user disposal facility to contain contaminated sediments that may be dredged from other sites in Bellingham Bay.

Both CAD facilities would provide concurrent habitat restoration. Largely because of the CADs, approximately 63 acres of subtidal area would be converted into intertidal area. A layout of Alternative G is presented in Figure 13-8.

14.3.7.2 Evaluation

An assessment of Cleanup Alternative G against the FS evaluation criteria is summarized below.

Overall Environmental Quality

- **Compliance with Cleanup Standards and Applicable Laws.** Alternative G would comply with MTCA and with other applicable cleanup standards and laws. All areas that currently exceed SQS criteria would be remediated either by containment (*in situ* capping) or with engineered confinement (CADs).

- **Protection of Human Health and the Environment.** Alternative G would provide overall protection for human health and the environment by removing or capping contaminated sediments within the Waterway. Relative to Alternatives E and F, the larger dredge volumes and implementation duration somewhat increases the short-term impacts associated with removal. The construction of caps prevents the exposure of contaminated sediments to aquatic life.

- **Reasonable Restoration Time Frame.** Alternative G, by design, would achieve cleanup within a period similar to the other alternatives.

- **Use of Permanent Solutions.** Alternative G includes active containment (i.e., *in situ* capping or engineered confinement) of all areas of the site that currently exceed SQS criteria (incorporating the bioaccumulation screening level). Engineered confinement, applied in this alternative to the Log Pond, Starr Rock area, and sediments dredged from the Whatcom Waterway, is a more permanent technology than containment. Alternative G applies the most permanent technology to the highest concentration sediments present within the WW Area, and uses containment for lower concentration sediments present within other areas of the site.

- **The Degree to which Recycling, Reuse, and Waste Minimization are Employed.** Under this alternative, the potential to reuse clean dredge material for cap construction is feasible. This practice has occurred on other Puget Sound capping projects (Sumeri 1996). The amount of waste generated is moderate, however all dredged sediments would be placed in one of two constructed CAD facilities. Once a CAD is filled and capped, it would provide an opportunity to create an aquatic habitat for eelgrass and other shallow intertidal species that existed historically within inner Bellingham Bay. Using dredge material to create a habitat of this type constitutes a beneficial reuse of dredge material.

- **Short-term Effectiveness.** Dredging would be completed with a mechanical system and the dredge material mechanically loaded into the CAD facility. Worker and community risks associated with the dredging, transport, and disposal are expected to be minimal (BBWG, 1999c). Dredging activities resuspend sediments into the water column, allowing for contaminant migration and a potential impact to the environment.

Resuspension may be controlled with silt curtains placed around the dredge areas and/or modification of the dredge process. However, with the larger dredge volumes under this alternative, the duration of implementation somewhat decreases the short-term effectiveness for this alternative.

During the construction of caps, the contaminated sediments are not disturbed or redistributed into the water column; this eliminates potential environmental impact. Also, since the contaminated sediments remain in place, the risk of exposure or potential threats to workers and the community are minimal. With cap placement, remedial objectives are met immediately.

- **Long-term Effectiveness.** Under this alternative, a moderate amount of dredging would be conducted to remove the contaminated sediments. The risk remaining after implementation of the dredging and fill activities would be negligible. Long-term risk associated with confined disposal (such as in a CAD) includes contaminant leaching; given the anoxic, saline environment of the CAD, the risk of contaminant migration is expected to be minimal (see Section 14.2.3.2).

  The long-term risk associated with a cap generally involves the erosion or removal of the clean sediment layer. Day to day hydrodynamics and tidal conditions are not expected to disturb the constructed cap. The cap would be designed to resist propeller wash or other disruptive events. Cap monitoring would be required to confirm the integrity of the cap over time.

- **Net Environmental Benefits.** Relative to the other alternatives evaluated, this alternative has significant net environmental benefits. Under this alternative, there would be no net loss of aquatic habitat. Locating CADs at the Log Pond, and near Starr Rock/Cornwall Avenue Landfill would convert subtidal substrates in these areas to shallow subtidal and/or low intertidal elevations, providing an opportunity to create more than 50 acres of eelgrass habitat that previously (historically) existed within the inner Bellingham Bay area. The Bellingham Bay Comprehensive Strategy EIS more fully evaluates the environmental impacts associated with this alternative.

Ability to be Implemented

- **Implementability.** Mechanical dredging and mechanical offloading of dredged sediments rank high in terms of implementability. Area contractors have completed a variety of dredging projects with contaminated sediments; these projects require additional operating measures outside of a typical navigational dredging project. Construction monitoring, such as water quality and post dredge sediment sampling, would be completed to assist the contractor during dredge operations.

  In deep areas, caps would be placed with a bottom dump barge. Where the water depth is shallow or obstructions are anticipated, caps would be constructed with a clamshell bucket. Cap construction is a common remedial activity in Puget Sound (Sumeri 1996) and ranks high in terms of implementability. Bathymetric surveys would be conducted pre- and post-construction to verify the thickness of the cap. The necessary equipment and materials for cap placement are available in the Puget Sound area.

The substantive provisions of various permit requirements would need to be addressed as part of implementation of this alternative. For Alternative G, these requirements would likely include: Section 10 of the Rivers and Harbors Act; Sections 401 and 404 of the Clean Water Act; Water Quality Certification under Chapter 90.48 RCW; Hydraulic Project Approval under Chapter 75.20 RCW; and Bellingham Bay Shoreline Master Program requirements.

Actions taken during the implementation of Alternative G would improve authorized navigation uses within the remediation areas. Following construction, navigation depths in the Whatcom Waterway from the mouth to Station 3+00 would be at or below -32 feet MLLW, at least 2 feet lower than the currently authorized channel depth of -30 feet MLLW. Between Station 15+00 and Station 62+00, the navigation channel would be dredged to depths of approximately 38 to 40 feet below MLLW, considerably deeper than the authorized channel depth (Figure 14-7). Dredging to this depth would likely obviate the need for future institutional controls such as an agreement between G-P and the U.S. Army Corps of Engineers.

Cost Effectiveness

- **Cost.** Appendix N summarizes the estimated capital and O&M costs for Alternative G. The estimated cost of this alternative is $36.0 million, excluding land easements.
- **Cost Effectiveness.** Because the cost of Alternative G is more than $12 million greater than Alternatives C through E, Alternative G has medium cost effectiveness. The CADs also provide extensive new intertidal and shallow subtidal habitat.

14.3.8 Cleanup Alternative H – Full Removal from Navigation Areas and Partial Removal from the G-P ASB and Starr Rock Areas (Upland Disposal) (Pilot Project No. 2D)

14.3.8.1 Description

Similar in some respects to Alternative G, the overall objective of Alternative H is to achieve SQS criteria in the WW Area, allowing for possible future deepening of the navigation channels. This alternative includes dredging of those areas included in Alternative G, but also includes the dredging of an additional 320,000 CY of sediments exceeding the site-specific bioaccumulation screening level criteria that are located offshore of the G-P ASB and at the former Starr Rock disposal site. The dredged sediments would be disposed at one or more off-site upland landfills. Other contaminated sediment areas would be capped with a 1-to-3-foot clean sand layer.

All dredged sediments would be offloaded on shore, dewatered as necessary to facilitate transport, and hauled by rail, truck, and/or barge outside of the Bellingham Bay watershed to upland disposal facilities. Approximately 1,100,000 CY of contaminated sediment from the WW Area would be dredged. In this alternative, the sediment disposal capacity would be provided by at the same upland disposal facilities described for Alternative F. A layout of Alternative H is presented in Figure 13-9.

14.3.8.2 Evaluation

An assessment of Cleanup Alternative H against the FS evaluation criteria is summarized below.

Overall Environmental Quality

- **Compliance with Cleanup Standards and Applicable Laws.** Alternative H would comply with MTCA and with other applicable cleanup standards and laws. All areas that currently exceed SQS criteria would be remediated either by containment (*in situ* capping) or with engineered confinement (upland CDFs).

- **Protection of Human Health and the Environment.** Alternative H would provide overall protection for human health and the environment by removing or capping contaminated sediments within the Waterway. The relatively large dredge volumes and implementation duration results in short-term impacts associated with removal. The construction of caps prevents the exposure of contaminated sediments to aquatic life.

- **Reasonable Restoration Time Frame.** The restoration time frame for this alternative may be limited to some degree by available landfill capacity. For example, the Roosevelt Landfill has an existing annual capacity of approximately 3 millions tons per year (for the next 35 years). Assuming that approximately 25 percent of this annual capacity is used for the disposal of WW Area sediments, sediment disposal alone may add roughly 2 to 3 years to the sediment cleanup schedule, compared to Alternatives B through G.

- **Use of Permanent Solutions.** Alternative H includes active containment (i.e., *in situ* capping or engineered confinement) of all areas of the site that currently exceed SQS criteria (incorporating the bioaccumulation screening level). Engineered confinement, applied in this alternative to sediments dredged from the Whatcom Waterway and portions of the ASB and Starr Rock areas, is a more permanent technology than containment or natural recovery. Alternative H uses containment for lower concentration sediments present within other areas of the site.

- **The Degree to which Recycling, Reuse, and Waste Minimization are Employed.** Under this alternative, the potential to reuse clean dredge material for cap construction is feasible. This practice has occurred on other Puget Sound capping projects (Sumeri 1996). The amount of waste generated is moderate, however all dredged sediments would be placed in an upland landfill. This disposal method does not constitute beneficial reuse.

- **Short-term Effectiveness.** Dredging would most likely be completed with a mechanical system and the dredge material would be mechanically offloaded and transported to an upland facility. Worker and community risks associated with the dredging, transport, and disposal are expected to be minimal. However, during transport and upland disposal of the relatively high volume of contaminated sediments dredged under this alternative, the risks are expected to increase, primarily due to transport. Dredging activities resuspend sediments into the water column, allowing for contaminant migration and a potential impact to the environment. Resuspension may be controlled with silt curtains placed around the dredge areas and/or modification of the dredge process. However, with moderate dredge volumes, the duration of implementation decreases the short-term effectiveness for this alternative. Turbidity controls, BMPs, and monitoring would be performed to verify that construction does not adversely affect special aquatic sites, and to provide for appropriate creation if necessary.

  During the construction of caps, the contaminated sediments are not disturbed or redistributed into the water column; this eliminates potential environmental impact (BBWG, 1999c). Also, since the contaminated sediments remain in place, the risk of exposure or potential threats to workers and the community are minimal. With cap placement, remedial objectives are met immediately.

- **Long-term Effectiveness.** Under this alternative, a relatively large amount of dredging would be conducted to remove the contaminated sediments. The risk remaining after implementation of the dredging and fill activities would be negligible. Long-term risk associated with upland disposal includes contaminant leaching; the Roosevelt Regional Landfill would be a fully lined facility making the risk negligible.

  The long-term risk associated with a cap generally involves the erosion or removal of the clean sediment layer. Day to day hydrodynamics and tidal conditions are not expected to disturb the constructed cap. The cap would be designed to resist propeller wash or other disruptive events. Cap monitoring would be required to confirm the integrity of the cap over time.

- **Net Environmental Benefits.** Relative to some of the other alternatives evaluated, this alternative offers low-to-moderate environmental benefits. If used, the Whatcom-Skagit Phyllite Quarry upland disposal site would be restored to a freshwater wetland habitat. Under this alternative, there would be no net loss of aquatic habitat, though limited conversion of habitat would occur. For example, under Alternative H there would be an overall (net) conversion of approximately 8 acres of intertidal and shallow subtidal habitat to deeper subtidal sediments (greater than -10 feet MLLW). No habitat enhancement actions would be performed as part of this alternative, except that restoration of freshwater wetland habitat would be performed if the quarry disposal site were selected. The Bellingham Bay Comprehensive Strategy EIS more fully evaluates the environmental impacts associated with this alternative.

Ability to be Implemented

- **Implementability.** Mechanical dredging and mechanical offloading of dredged sediments rank high in terms of implementability. Area contractors have completed a variety of dredging projects with contaminated sediments; these projects require additional operating measures outside of a typical navigational dredging project.

  Offloading of saturated sediments from barges to railcars or trucks, and offloading sediments from railcars or trucks are difficult and intensive procedures. The logistics behind mechanical transfer of a large quantity of sediments to a barge, loading saturated sediments to a railcar, and transferring them to the upland CDF are such that the implementability is low. Area contractors have not previously handled a quantity of contaminated sediments substantially over 1,000,000 CY for upland transport and disposal.

  In deep areas, caps would be placed with a bottom dump barge. Where the water depth is shallow or obstructions are anticipated, caps would be constructed with a clamshell bucket. Cap construction is a common remedial activity in Puget Sound (Sumeri 1996) and ranks high in terms of implementability. Bathymetric surveys would be conducted pre- and post-construction to verify the thickness of the cap. The necessary equipment and materials for cap placement are available in the Puget Sound area.

  The substantive provisions of various permit requirements would need to be addressed as part of implementation of this alternative. For Alternative H, these requirements would likely include: Section 10 of the Rivers and Harbors Act; Sections 401 and 404 of the Clean Water Act; Water Quality Certification under Chapter 90.48 RCW; Hydraulic Project Approval under Chapter 75.20 RCW; and Bellingham Bay Shoreline Master Program requirements.

  Actions taken during the implementation of Alternative H would improve authorized navigation uses within the remediation areas. Following construction, navigation depths in the Whatcom Waterway from the mouth to Station 3+00 would be at or below -32 feet MLLW, at least 2 feet lower than the currently authorized channel depth of -30 feet MLLW. Between Station 15+00 and Station 62+00, the navigation channel would be dredged to depths of approximately 38 to 40 feet below MLLW, considerably deeper than the authorized channel depth (Figure 14-7). Dredging to this depth would likely obviate the need for future institutional controls such as an agreement between G-P and the U.S. Army Corps of Engineers.

Cost Effectiveness

- **Cost.** Appendix N summarizes the estimated capital and O&M costs for Alternative H. The estimated cost of this alternative is $91.4 million, excluding land easements.

- **Cost Effectiveness.** Alternative H has low cost effectiveness due to the high dredge volume and use of upland disposal. Upland disposal has a high unit cost for dredging and disposal.

14.3.9 Cleanup Alternative I – Full Dredging (Upland Disposal)

14.3.9.1 Description

The overall objective of Alternative I is to completely remove all contaminated sediment within the WW Area, and totally avoid disposal in the aquatic environment. This alternative would also allow for unencumbered future deepening of the navigation channels and state-owned harbor areas. Like Alternative H, avoiding disposal in the aquatic environment is a primary objective. With the exception of sediments located immediately adjacent to the existing G-P wastewater pipeline, dredging would be performed within all reaches of the WW Area, including the extreme head of the federal channel, encompassing Citizens Dock and associated mudflat areas. All dredged sediments would be offloaded on shore, dewatered as necessary to facilitate transport, and hauled by rail and/or truck to upland disposal facilities. Approximately 2,060,000 CY of contaminated sediment from the WW Area would be dredged. In this alternative, the sediment disposal capacity would be provided by the same upland disposal facilities described for Alternative F. A layout of Alternative I is presented in Figure 13-10.

14.3.9.2 Evaluation

An assessment of Cleanup Alternative I against the FS evaluation criteria is summarized below.

Overall Environmental Quality

- **Compliance with Cleanup Standards and Applicable Laws.** Alternative I would comply with MTCA and with other applicable cleanup standards and laws. All areas that currently exceed SQS criteria would be remediated either by containment (*in situ* capping) or with engineered confinement (upland CDFs).

- **Protection of Human Health and the Environment.** Alternative I would provide overall protection for human health and the environment by removing or capping contaminated sediments within the Waterway. The relatively large dredge volumes and implementation duration results in short-term impacts associated with removal. The construction of caps prevents the exposure of contaminated sediments to aquatic life.

- **Reasonable Restoration Time Frame.** The restoration time frame for this alternative may be limited to some degree by available landfill capacity. For example, the Roosevelt Landfill has an existing annual capacity of approximately 3 millions tons per year (for the next 35 years). Assuming that approximately 25 percent of this annual capacity is used for the disposal of WW Area sediments, sediment disposal alone may add roughly 4 to 5 years to the sediment cleanup schedule, compared to Alternatives B through G.

- **Use of Permanent Solutions.** Alternative I includes active containment (i.e., *in situ* capping or engineered confinement) of all areas of the site that currently exceed SQS criteria (incorporating the bioaccumulation screening level). Engineered confinement, applied in this alternative to sediments dredged from the Whatcom Waterway, is a more permanent technology than containment or natural recovery. Alternative I applies the most permanent technology to contaminated sediments present within most SSUs within the WW Area, but uses containment for sediments present near the G-P wastewater pipeline crossing in the Whatcom Waterway navigation channel.

- **The Degree to which Recycling, Reuse, and Waste Minimization are Employed.** Waste is not minimized with this alternative since dredging is selected to remove nearly all contaminated sediments. Under this alternative, the sediments dredged from the WW Area are transported for upland disposal at the Roosevelt Regional Landfill. This disposal method does not constitute beneficial reuse.

- **Short-term Effectiveness.** Dredging would most likely be completed with a mechanical system and the dredge material would be mechanically offloaded and transported to an upland facility. Worker and community risks associated with the dredging, transport, and disposal are expected to be minimal. However, during transport and upland disposal of the relatively high volume of contaminated sediments dredged under this alternative, the risks are expected to increase, primarily due to transport.

  Dredging activities resuspend sediments into the water column, allowing for contaminant migration and a potential impact to the environment. Resuspension may be controlled with silt curtains placed around the dredge areas and/or modification of the dredge process. However, with the relatively large dredge volumes under this alternative, the duration of implementation decreases short-term effectiveness. In addition, because of relatively high mercury concentrations and extensive woody debris in the G-P Log Pond area, full closure of mechanical dredging equipment may be difficult at this location, leading to release of roughly 5 percent or more of such sediments into the water column during the dredging operation. Preliminary water and sediment transport modeling indicated that, because of the relatively high chemical concentrations within the Log Pond, such an event may result in exceedances of relevant water quality criteria, and could also contaminate adjacent sediment areas. Turbidity controls, BMPs, and monitoring would be performed to determine the need for contingency actions, and to verify that construction does not adversely affect special aquatic sites.

  During the construction of caps near the G-P wastewater pipeline crossing in the Whatcom Waterway navigation channel, the contaminated sediments would not be disturbed or redistributed into the water column; this eliminates potential environmental impact (BBWG, 1999c). Also, since the contaminated sediments remain in place, the risk of exposure or potential threats to workers and the community are minimal. With cap placement, remedial objectives are met immediately.

- **Long-term Effectiveness.** Under this alternative, the removal of contaminated sediments at the site is maximized. The risk remaining after implementation of the dredging, loading, and transport activities would be negligible. Long-term risk associated with upland disposal includes contaminant leaching; the Roosevelt Regional Landfill would be a fully lined facility making this risk negligible.

  The long-term risk associated with a cap generally involves the erosion or removal of the clean sediment layer. Day to day hydrodynamics and tidal conditions are not expected to disturb the constructed cap. The cap would be designed to resist propeller wash or other disruptive events. Cap monitoring would be required to confirm the integrity of the cap over time.

- **Net Environmental Benefits.** Relative to some of the other alternatives evaluated, this alternative offers low-to-moderate environmental benefits. If used, the Whatcom-Skagit Phyllite Quarry upland disposal site would be restored to a freshwater wetland habitat. Under this alternative, there would be no net loss of aquatic habitat, though conversion of habitat would occur as a result of dredging. For example, under Alternative I there would be an overall (net) conversion of approximately 12 acres of intertidal and shallow subtidal habitat to deeper subtidal sediments (greater than -10 feet MLLW). Most of the existing mudflat at the extreme head of the Whatcom Waterway, some of which is below and adjacent to Citizens Dock, would be converted to subtidal habitat. No habitat enhancement actions would be performed as part of this alternative, except that restoration of freshwater wetland habitat would be performed if the quarry disposal site were selected. The Bellingham Bay Comprehensive Strategy EIS more fully evaluates the environmental impacts associated with this alternative.

Ability to be Implemented

- **Implementability.** Mechanical dredging and mechanical offloading of dredged sediments rank high in terms of implementability. Area contractors have completed a variety of dredging projects with contaminated sediments; these projects require additional operating measures outside of a typical navigational dredging project.

  Offloading of saturated sediments from barges to railcars or trucks, and offloading sediments from railcars or trucks are difficult and intensive procedures. The logistics behind mechanical transfer of a large quantity of sediments to a barge, loading saturated sediments to a railcar, and transferring them to the upland CDF are such that the implementability is low. Area contractors have not previously handled a quantity of contaminated sediments substantially over 1,000,000 CY for upland transport and disposal.

  In deep areas, caps would be placed with a bottom dump barge. Where the water depth is shallow or obstructions are anticipated, caps would be constructed with a clamshell bucket. Cap construction is a common remedial activity in Puget Sound (Sumeri 1996) and ranks high in terms of implementability. Bathymetric surveys would be conducted pre- and post-construction to verify the thickness of the cap. The necessary equipment and materials for cap placement are available in the Puget Sound area.

The substantive provisions of various permit requirements would need to be addressed as part of implementation of this alternative. For Alternative I, these requirements would likely include: Section 10 of the Rivers and Harbors Act; Sections 401 and 404 of the Clean Water Act; Water Quality Certification under Chapter 90.48 RCW; Hydraulic Project Approval under Chapter 75.20 RCW; and Bellingham Bay Shoreline Master Program requirements.

Actions taken during the implementation of Alternative I would improve authorized navigation uses within the remediation areas. Following construction, navigation depths in the Whatcom Waterway from the mouth to Station 3+00 would be at or below -32 feet MLLW, at least 2 feet lower than the currently authorized channel depth of -30 feet MLLW. Between Station 15+00 and Station 62+00, the navigation channel would be dredged to depths of approximately 38 to 40 feet below MLLW, considerably deeper than the authorized channel depth (Figure 14-7). The navigation channel near Citizens Dock would also be dredged. These actions would likely obviate the need for future institutional controls such as an agreement between G-P and the U.S. Army Corps of Engineers. Alternative I would allow for unrestricted utilization of the Whatcom Waterway, and other areas.

Cost Effectiveness

- **Cost.** Appendix N summarizes the estimated capital and O&M costs for Alternative I. The estimated cost of this alternative is approximately $147 million (excluding relatively minor land easements).
- **Cost Effectiveness.** Alternative I has low cost effectiveness due to the high dredge volume and use of upland disposal. Upland disposal has a high unit cost for dredging and disposal.

14.4 Comparative Analysis Of Alternatives

The cleanup alternatives developed for the WW Area were evaluated in Section 14.3 using SMS criteria. In this section, a comparative analysis of the results of the alternative evaluation is presented. Table 14-3 summarizes the detailed evaluation of the cleanup alternatives.

Compliance with Cleanup Standards and Applicable Laws

All alternatives except Alternative A comply with MTCA and with other applicable cleanup standards and laws. All areas that are not predicted to naturally recover would be actively remediated. Areas remediated by natural recovery are predicted to recover by 2005.

Protection of Human Health and the Environment

All alternatives except Alternative A are protective of human health and the environment.

Reasonable Restoration Time Frame

All alternatives except Alternative A, H, and I are anticipated to be completed within 5 years (roughly 2005). Natural recovery alone will not achieve SQS or MCUL criteria in all areas of the site within 10 years, but its limited incorporation into Alternatives B through D is not likely to affect the overall restoration time frame. The time frame for implementation of Alternatives H and I may be limited to some degree by available landfill capacity. Assuming that approximately 25 percent of this annual capacity is used for the disposal of WW Area sediments, sediment disposal alone may add up to 3 and 5 years to the sediment cleanup schedule for Alternatives H and I, respectively.

Use of Permanent Solutions

Alternatives G, H, and I use more permanent engineered confinement technologies including CADs and upland CDFs to a greater degree than the other alternatives evaluated. However, by combining the most permanent technologies (engineered confinement in CADs) applied to the highest concentration sediments present within the WW Area, with *in situ* containment applied to lower concentration sediments, Alternative E achieves only a slightly lower degree of "permanence" as defined by MTCA. Because of their reliance on capping to remediate some of the highest concentration sediments within the WW Area, Alternatives B, C, D, and F are less permanent. Finally, since it relies extensively on natural recovery, Alternative A is the least permanent of the alternatives evaluated.

The Degree to which Recycling, Reuse, and Waste Minimization are Employed

Alternative I provides the lowest degree of recycling, reusing or minimizing waste due to the extensive dredging and disposing at the Roosevelt Landfill. The remaining alternatives rank medium to high with respect to this criteria, due to either minimizing the amount of removal or by reusing the dredged material as fill for upland development of aquatic/wetland habitat creation.

Short-term Effectiveness

Alternatives A and B have the highest short-term effectiveness due to the maximum use of *in situ* containment remedial measures and minimal dredging. Alternatives C through G have intermediate short-term effectiveness, while Alternative I scored the lowest with respect to this criterion due to the extensive amount of dredging (increasing chances for more water column impacts likely associated with dredging events) and the minimal use of aquatic disposal (higher likelihood of community and worker impacts with upland transport).

Long-term Effectiveness

Alternative A has the lowest long-term effectiveness since some sediment areas of the site may require an extended period for full natural recovery. Alternatives B, C, and D have medium to medium-to-high long-term effectiveness due in large part to the use of natural recovery in some areas of the site. Alternatives E through I have high long-term effectiveness due to the utilized CDFs. Alternatives E and G rely on CADs for disposal, which provide a near-optimal environment to minimize contaminant leaching, while Alternatives F, H, and I rely on upland CDFs, including leachate collection and treatment.

Net Environmental Benefits

Relative to the other alternatives evaluated, Alternatives E and G present the greatest opportunity for significant net environmental benefits. Under these alternatives, subtidal substrates at the CAD sites would be converted to shallow subtidal and/or low intertidal elevations, providing an opportunity to create 30 to 50 acres of eelgrass habitat that previously (historically) existed within the inner Bellingham Bay area. Alternatives B, C, D, and F provide intermediate environmental benefits, while Alternatives H and I scored lower because of the concurrent conversion of approximately 8 to 12 acres of intertidal and shallow subtidal habitat to deeper subtidal sediments (greater than -10 feet MLLW). Alternative A would provide the least net environmental benefits. The Bellingham Bay Comprehensive Strategy EIS more fully evaluates the environmental impacts associated with alternatives E through I.

Implementability

Alternatives A and B would be the easiest to implement due to the limited dredging and disposal involved. Alternatives E and G also scored relatively high with respect to this criterion, pending the availability of aquatic lands at the CAD sites. Alternatives C, D, and F would have medium implementability, owing in part to the perceived difficulties in obtaining landowner agreements for these alternatives. Alternatives H and I would have the lowest implementability due to the extensive dredge volume involved and upland transport requirements.

Cost Effectiveness

Alternatives A and B are the least expensive (up to $5 million), due to the limited active remediation involved. Alternatives C, D, and E are the next lowest priced alternatives ($19 to $24 million), because of the relatively low dredge volumes (Alternatives C and D) or the use of cost-effective CAD facilities (Alternative E). However, these alternatives are roughly 4 to 5 times the cost of Alternative B. Alternatives F and G are the next highest priced set of alternatives ($36 million) at roughly 1.5 times the cost of Alternatives C and D (due mainly to the increase dredge volume or the use of upland disposal sites). Alternative H is the second highest priced at 2 to 3 times the cost of the previous set of alternatives. Alternative I is the most expensive, nearly twice that of Alternative H. This is due to the extensive use of dredging and upland disposal.

Costs in this RI/FS were evaluated on a net present worth basis, including direct and indirect costs, engineering, habitat mitigation, long-term operation and maintenance, administration, and a 30 percent contingency factor to account for construction conditions not currently identified. However, potentially significant site acquisition and easement costs, including the use of state owned aquatic lands (SOAL), may be associated with some of the alternatives. Such costs are difficult to estimate and can vary widely depending on circumstances. On a case-by-case basis, landowner costs could potentially be reduced or waived if the overall alternative meets the interests of the landowner and makes them "whole". Because of the complexities of landowner interest determinations, the long-term costs of property easements for disposal and/or mitigation, including SOAL, have not been included in this RI/FS. Appropriate costs for these elements are expected to be determined as part of ongoing Pilot Project implementation discussions. Incorporation of these costs into the alternative analysis could influence the overall cost-effectiveness evaluation.

As set forth in MTCA (Chapter 173-340-360[5]), a cleanup action shall not be considered practicable if the incremental cost of the cleanup action (including landowner costs if known) is substantial and disproportionate to the incremental degree of protection it would achieve over a lower preference cleanup action. When selecting from among two or more cleanup action alternatives that provide a sufficient and equivalent level of protection, preference may be given to the least cost alternative, subject to an evaluation of public concerns and technical uncertainties.

14.5 Identification of A Preferred Alternative

The sections above present and evaluate 9 sediment remediation alternatives that represent a wide range of potentially appropriate remedial technologies and process options. These alternatives include different combinations of natural recovery, capping, removal, and disposal, and also reflect the work of the Pilot Project. When viewed together, the alternatives present the broad range of potential remediation, habitat enhancement, and land use options available within the WW Area, and highlight tradeoffs associated with implementation of different alternatives, consistent with the objectives of the FS.

The Pilot Project is designed to expand opportunities for achieving multiple goals in Bellingham Bay, using comprehensive strategic environmental planning and project integration to efficiently and effectively address multiple objectives including contaminated sediment cleanup, sediment disposal, habitat restoration, source control, and shoreline property management. The Comprehensive Strategy integrates each of these elements into a coordinated approach. In the EIS, the environmental consequences of implementing the Comprehensive Strategy, including most of the sediment remediation alternatives presented herein is analyzed (BBWG, 1999c). This FS supplements the Pilot Project EIS.

Through the Pilot Project EIS process, a preferred bay-wide sediment remediation alternative will be identified. It is important to note that, in the absence of the Comprehensive Strategy, the preferred sediment remediation alternative for the WW Area would necessarily focus on statutory selection criteria set forth in MTCA and the SMS. As discussed in Section 14.1, the statutory criteria include: 1) Overall Protection of Human Health and the Environment; 2) Compliance with Cleanup Standards and Applicable Laws;

3) Short-term Effectiveness; 4) Long-term Effectiveness; 5) Implementability; 6) Cost; 7) The Degree to which Community Concerns are Addressed; 8) The Degree to which Recycling, Reuse, and Waste Minimization are Employed; and 9) Environmental Impacts.

Of the alternatives evaluated, Alternatives C (Capping & Removal to Improve Navigation) and E (Removal & Capping to Achieve Authorized Channel Depth; Pilot Project No. 2A) appear most consistent with the MTCA/SMS selection factors and comply with statutory requirements. However, as discussed above, the Pilot Project EIS process - including public review and comment and a final determination by Ecology - will identify a preferred sediment remediation alternative, which achieves the multiple goals of the Pilot Project in an effective, cost-efficient way.

Table 14-1 - Natural Recovery Model Input Parameters and Results

Sample I.D.	Initial Mercury Surface (0-16 cm) Conc. (mg/kg dry wt)	Input Mercury Conc. (mg/kg dry wt)	Measured Net Sed. Rate (cm/yr)	Calc. Resusp. Rate (gm/cm²-yr)	Sand & Gravel (%)	Silt (%)	Clay (%)	Resusp. Fraction Advected Out (%)	Interface Conc. Exchange Coeff. (gms dry/ cm²-yr)	Porosity (%)	Bioturb. Rate (cm²/yr)	Depth of Mixed Layer (cm)	Time Period (yr)	OFFICER AND LYNCH MODEL PREDICTIONS (Year 2005 Surface [0-16 cm] Concentrations) Predictions assuming β = 1 (mg/kg dry wt)	Predictions using more realistic β (mg/kg dry wt)
AN-SC-80	0.71	0.34	0.1	7.5	16%	45%	39%	48%	3.61	83%	34	16	9	0.71	0.64
AN-SC-81	0.62	0.34	0.6	7.0	45%	40%	16%	23%	1.61	71%	34	16	9	0.53	0.44
AN-SC-82	0.52	0.34	9.4	2.6	36%	48%	16%	24%	0.85	84%	34	16	9	0.34	0.34
AN-SS-303	2.90	0.34	1.6	6.7	20%	44%	36%	43%	2.92	81%	34	16	9	1.27	1.12
AN-SS-305	1.50	0.34	1.6	6.9	39%	32%	29%	34%	2.38	87%	34	16	9	0.76	0.61
HC-SC-74	4.90	1.62	3.8	6.4	24%	59%	17%	25%	1.59	88%	34	16	9	1.83	1.68
HC-SC-75	1.70	0.56	3.8	5.9	21%	61%	18%	26%	1.55	84%	34	16	9	0.63	0.59
HC-SC-76	1.10	0.36	3.8	6.1	14%	69%	17%	26%	1.61	86%	34	16	9	0.41	0.37
HC-SC-79	1.80	0.34	0.4	7.3	16%	47%	37%	49%	3.56	82%	34	16	9	1.48	1.05
HC-SS-03	0.32	0.34	1.6	6.8	7%	64%	29%	47%	3.18	84%	34	16	9	0.33	0.34
HC-SS-08	0.53	0.34	1.6	6.7	8%	60%	32%	48%	3.19	80%	34	16	9	0.41	0.35
HC-SS-13	1.00	0.34	1.6	6.6	4%	75%	21%	34%	2.28	79%	34	16	9	0.58	0.42
HC-SS-22	0.93	0.34	1.6	6.8	7%	60%	33%	47%	3.23	84%	34	16	9	0.56	0.39
HC-SS-23	2.00	0.34	1.6	6.6	16%	69%	15%	27%	1.78	78%	34	16	9	0.94	0.54
HC-SS-24	1.90	0.34	1.6	6.6	18%	55%	27%	34%	2.28	79%	34	16	9	0.91	0.49
HC-SS-25	1.00	0.34	1.6	6.7	15%	56%	29%	36%	2.39	81%	34	16	9	0.58	0.40
HC-SS-29	0.70	0.34	1.6	6.7	18%	59%	23%	29%	1.91	81%	34	16	9	0.47	0.38
HC-SS-30	0.49	0.34	1.6	6.7	3%	71%	26%	41%	2.77	81%	34	16	9	0.39	0.35
HC-SS-32	0.73	0.34	1.6	6.1	73%	17%	10%	12%	0.74	67%	34	16	9	0.46	0.43
HC-SS-33	0.89	0.34	0.0	7.5	79%	17%	4%	6%	0.42	79%	34	16	9	0.89	0.81
HC-SS-34	1.50	0.34	0.0	7.5	77%	17%	6%	8%	0.60	73%	34	16	9	1.50	1.32
HC-SS-35	0.73	0.34	0.0	7.5	10%	64%	26%	31%	2.36	84%	34	16	9	0.73	0.65
HC-SS-40	11.80	3.89	3.8	5.4	48%	33%	19%	23%	1.28	79%	34	16	9	4.39	4.13

Table 14-2 - Currently Constructed and Evaluated Puget Sound and Major United States CDF and CAD Facilities

CAD Facility	Year Constructed	Cap Material and Thickness	Surface Elevation	Confined Sediment Volume in CY	Confined Sediment Contaminants	Placement Method	Long-term Observations	Other Notes	References
Constructed CADs									
Duwamish Waterway - Seattle, WA	1984	Clean dredged sand 1 to more than 3 feet thick (2 feet average)	-55 to -60 feet MLLW	1,100	PCBs (3.1 ppm) Heavy metals	Bottom dump barge	- No contaminant migration after 11 years - No indications of erosion	Cap also placed by bottom dump barge.	Ecology, 1990; Sumeri, 1996; Palermo, et al., 1998a/b
One Tree Island Marina - Olympia, WA	1987	Clean fine silt with shells dredged at site for navigation. Cap 4 feet thick.	-8 feet MLLW	4,000	PAHs Heavy metals	Bottom dump barge	- No immediate post-construction monitoring completed - Two year monitoring did not indicate any contaminant breakthrough	Conical pit 46 feet deep and 150 foot diameter at surface was dug in clean sediment located within the marina	Ecology, 1990; Sumeri, 1996; Palermo, et al., 1998a/b
Los Angeles Shallow Water Habitat Site - Los Angeles, CA	1995	Clean dredged material up to 20 feet thick	-20 feet MLLW	57,000 (Corps) plus Port volume	Cu, Pb, Zn, TPH Unsuitable for open-wate disposal	Bottom dump barge	- No contaminant migration indicated - Successful habitat function	Created shallow water foraging area for the California Least Tern. Used geotextile containers for the contaminated sediments (Corps portion only).	Mesa, 1995a/b; Palermo, et al., 1998b
Ross Island Sand and Gravel Pit - Portland, OR	Ongoing								
Boston Harbor Navigation and Improvent Project: Phase 1 - Boston, MA	1997	Clean, graunular material 3 feet thick.	Depth of 49 to 51 feet	30,000	Unsuitable for open-wate disposal	Bottom dump barge	Not applicable	This was a test CAD for Phase 2. Conclusions: - Allow sufficient time between material placement and cap placement for consolidation. - Better operational control during capping to improve cap material distribution.	Murray, et al., 1998 IDR, 1999
Boston Harbor Navigation and Improvent Project: Phase 1 - Boston, MA	Ongoing	Clean, graunular material 3 feet thick.	Depth of 49 to 51 feet	794,000	PAHs, Heavy metals, PCBs	Bottom dump barge	Not applicable	50 in-channel CADs are being constructed to confine contaminated maintenence dredged material. Three CADs are completed as of December, 1998.	Murray, et al., 1998
Port Authority of New York/New Jersey Newark Bay - New Jersey	Ongoing	Clean sand 3 feet thick.	5 to 6 feet deep at high tide.	1,500,000	Unsuitable for open-wate disposal	Bottom dump barge	Not applicable	CAD is excavated and currently being filled from multiple dredging projects around Newark Bay. Estimated to be filled in 1999.	Knoesel, et al., 1998
Evaluated Puget Sound CADs									
Thea Foss Waterway - Tacoma, WA	NA	Clean dredge sediment 3 feet thick	-37 feet MLLW	576,000	Metals, PAHs	Bottom dump barge	Not applicable		City of Tacoma, 1998
Hylebos Waterway - Tacoma, WA	NA	Three foot imported sand layer under two foot crushed rock armor layer over 2 foot sand and gravel habitat layer	0 feet MLLW	1,300,000	Metals, PAHs	Bottom dump barge	Not applicable		HCC, 1998
Southwest Harbor - Seattle, WA	NA	Six foot cap	- 0 to -12 for the smaller facility - -3 feet MLLW for the larger facility	85,000 to 600,000	Unsuitable for open-wate disposal	Bottom dump barge	Not applicable		Port of Seattle, 1994a/b

Table 14-3 - Summary of Evaluation Criteria for Cleanup Alternatives

Cleanup Alternative	BBWG	Alternative Description	Dredge Volume (CY)	EVALUATION CRITERIA: Compliance with Cleanup Standards and Applicable Laws	Protection of Human Health and Environment	Restoration Time Frame in Years	Use of Permanent Solutions	Degree to which Recycling, Reuse, and Waste Minimization are Employed	Short-term Effectiveness	Long-term Effectiveness	Net Environmental Benefit	Implementability	Cost (Present Worth) ($M)	Cost Effectiveness
A	NA	No action/natural recovery	0	No	No	>10	Low	High	High	Low	Low	High	$0.0	Low
B	NA	Natural Recovery with Capping	0	Yes	Yes	5	Low to Medium	Medium	High	Medium	Medium	High	$4.9	High
C	NA	Limited Dredging with Log Pond Disposal	160,000	Yes	Yes	5	Medium	Medium	Medium	Medium to High	Medium to High	Medium	$19.4	Medium to High
D	NA	Limited Removal with Upland Disposal	160,000	Yes	Yes	5	Low to Medium	Medium	Medium	Medium to High	Medium	Medium	$19.2	Medium to High
E	2A	Removal & Capping to Achieve Authorized Channel Depth w/ CAD	360,000	Yes	Yes	5	Medium to High	High	Medium	High	High	Medium to High	$23.8	High
F	2B	Removal & Capping to Achieve Authorized Channel Depth w/ Upland Disposal	360,000	Yes	Yes	5	Medium	Medium	Medium	High	Medium	Medium	$36.5	Low to medium
G	2C	Full Removal from Navigation Areas w/ CAD	760,000	Yes	Yes	5	High	High	Medium	High	High	Medium to High	$36.0	Medium
H	2D	Full Removal from Navigation Areas w/ Upland Disposal	1,100,000	Yes	Yes	8	High	Low to Medium	Low to Medium	High	Low to Medium	Low to Medium	$91.4	Low
I	NA	Full Removal with Upland Disposal	2,060,000	Yes	Yes	10	High	Low	Low	High	Low to Medium	Low	$157.0	Low

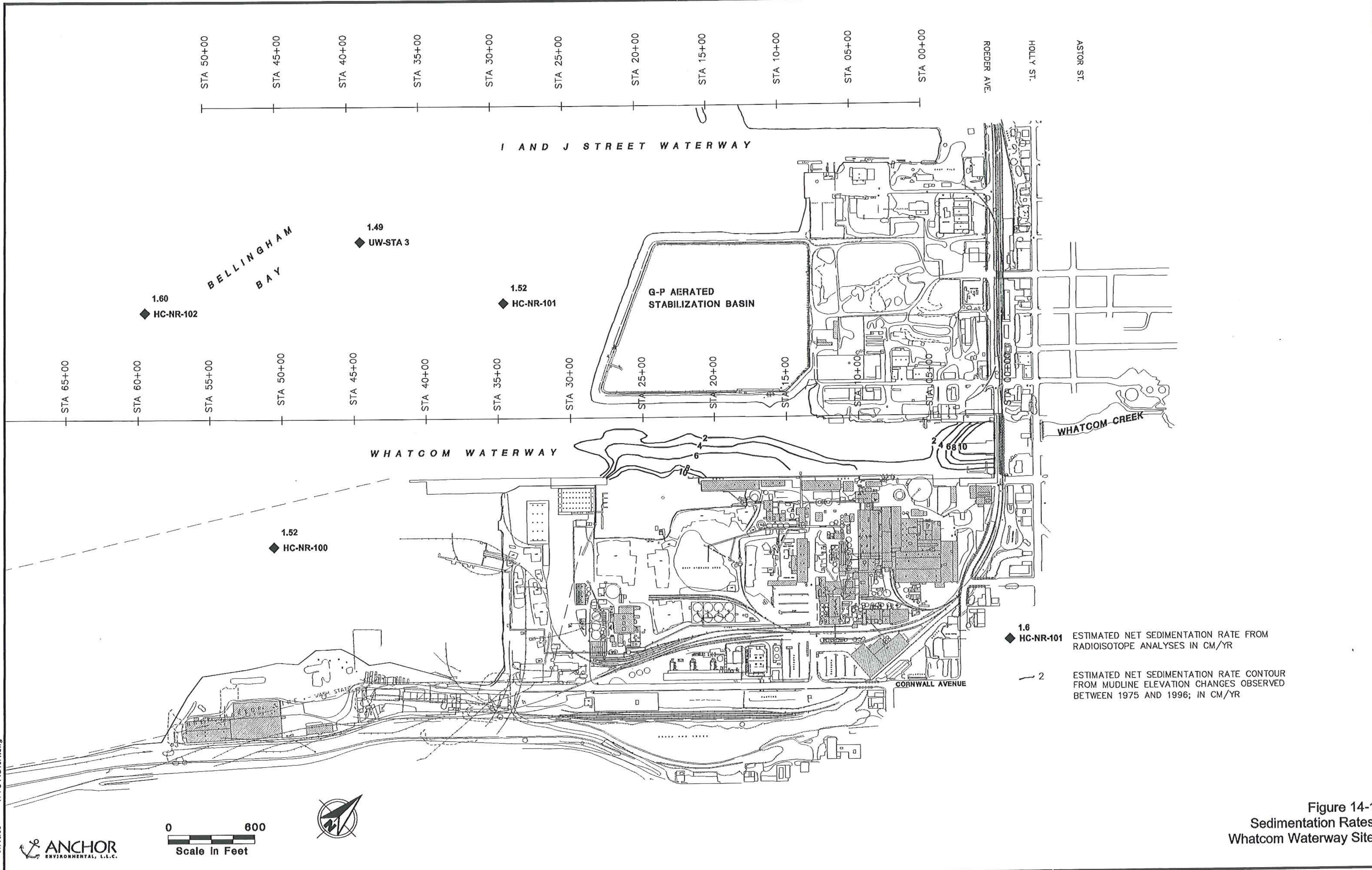


Figure 14-1
Sedimentation Rates
Whatcom Waterway Site

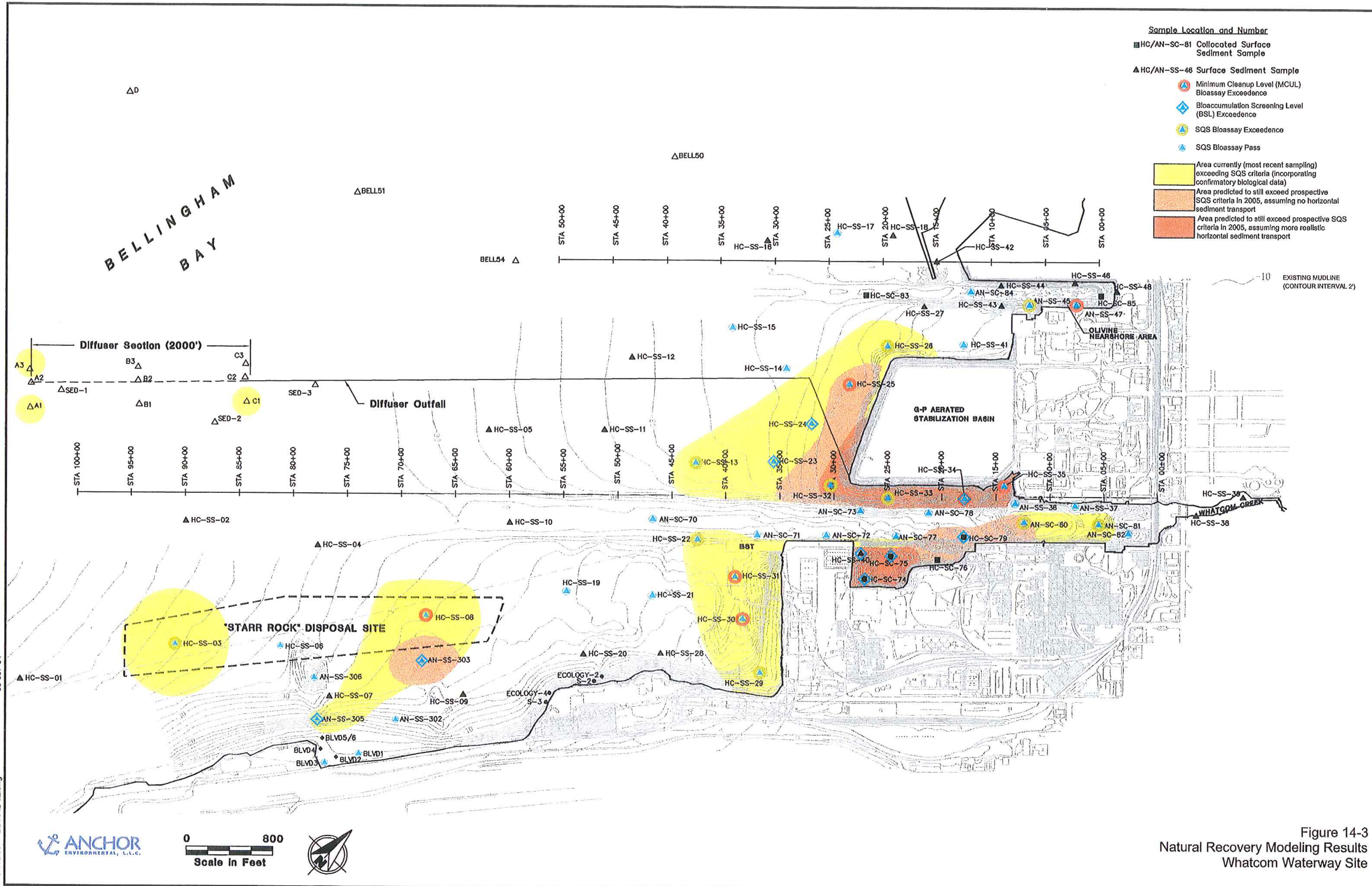
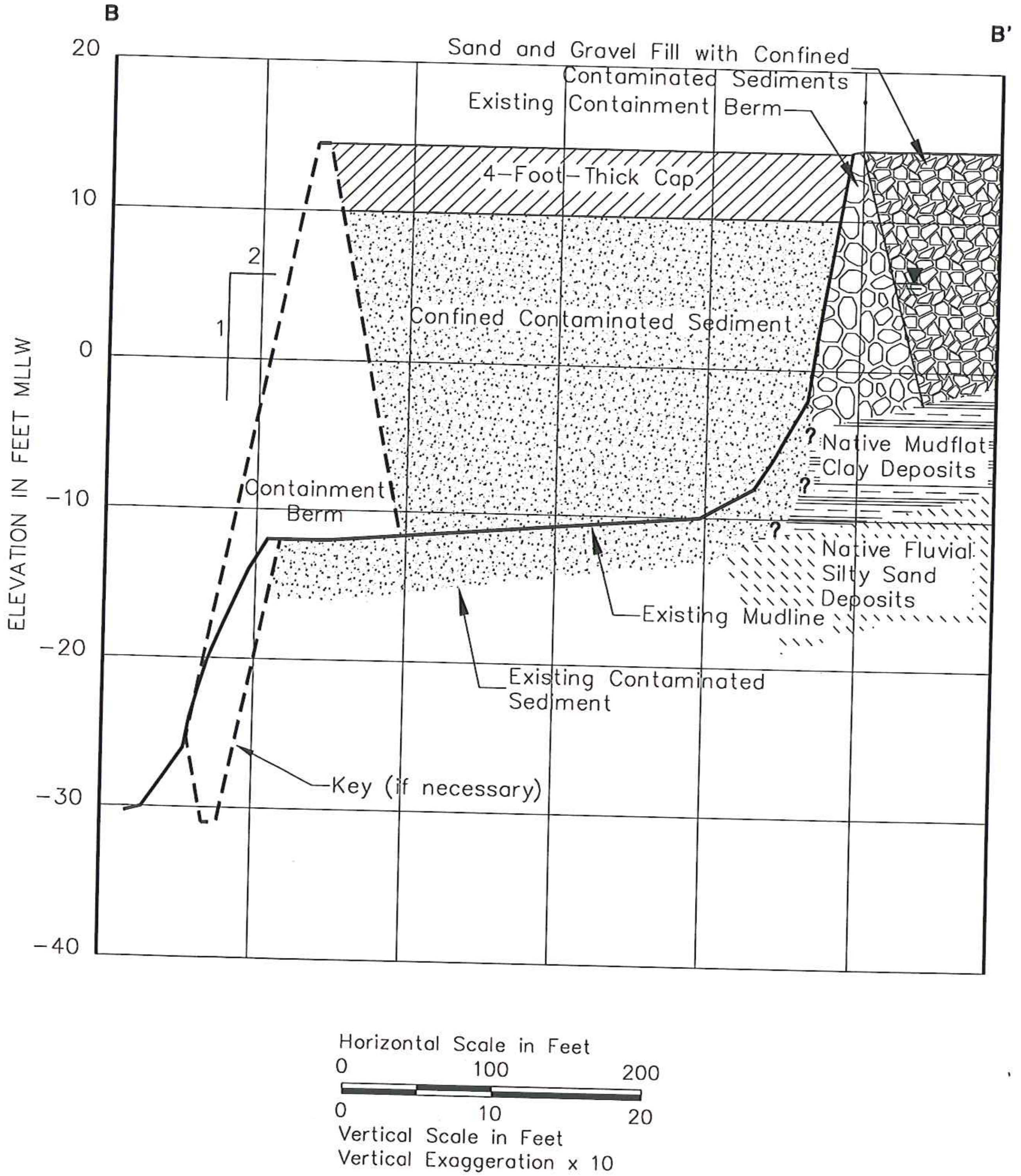


Figure 14-3
Natural Recovery Modeling Results
Whatcom Waterway Site



ANCHOR ENVIRONMENTAL, L.L.C.
07/15/99 ww-su10r2.dwg

Figure 14-4
Typical Cross Section B-B' through the G-P Log Pond Nearshore Fill
Whatcom Waterway Area

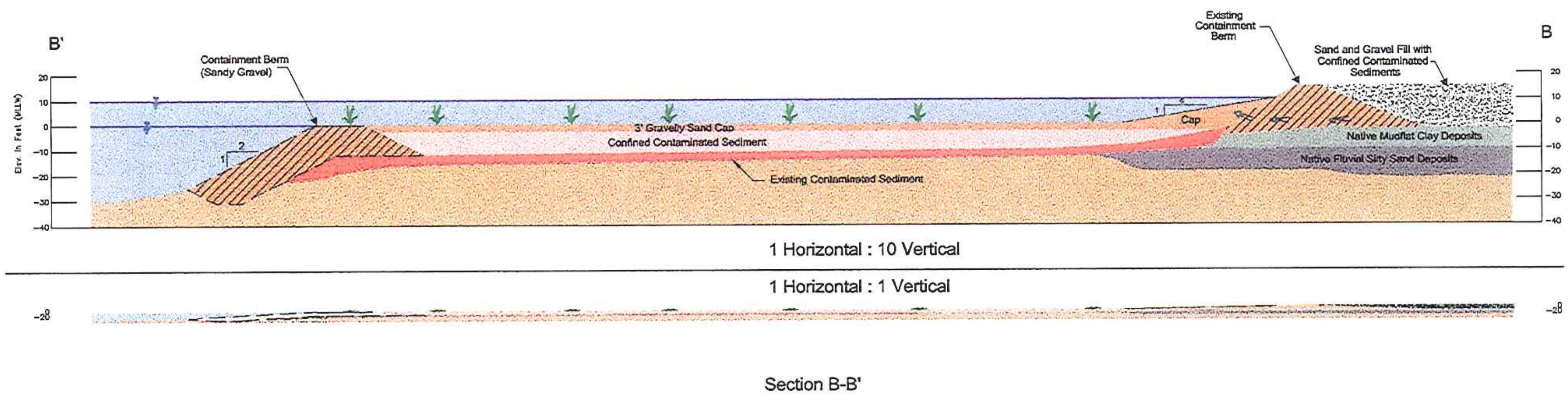


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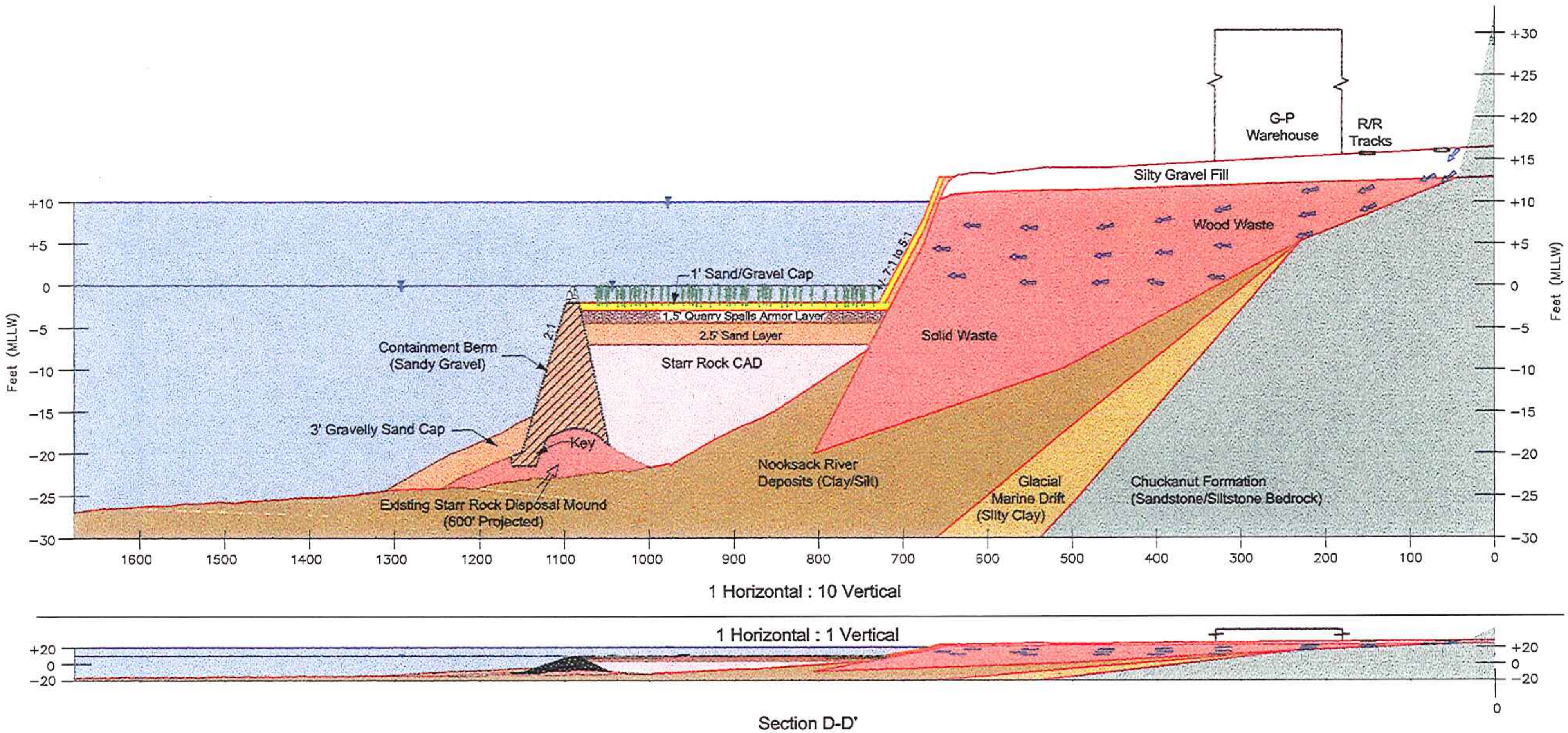
Figure 14-5
B'-B Typical Cross Section
G-P Log Pond CAD



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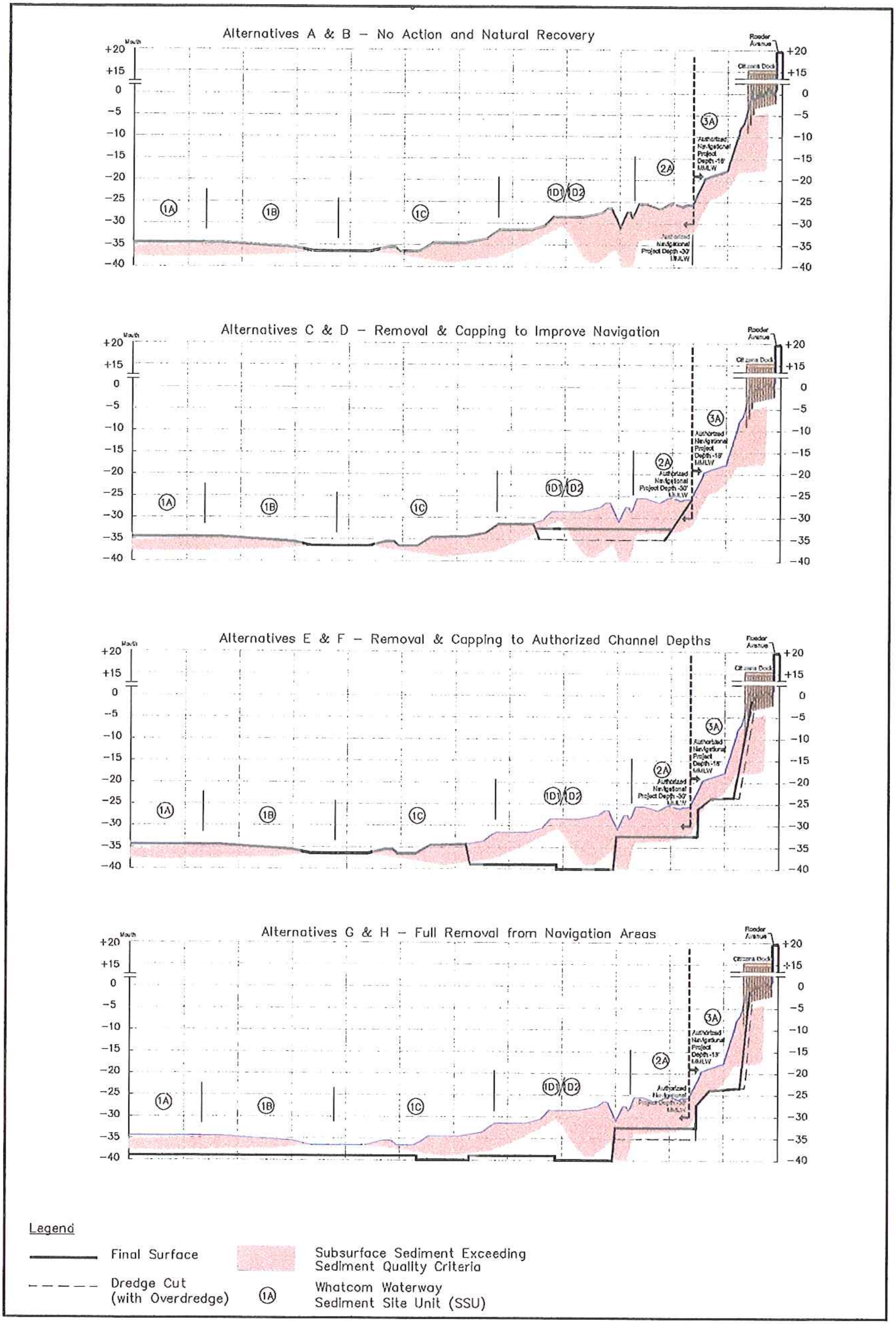
07/15/99 BBY016-04.dwg 98-007-04

Figure 14-6
Typical Cross Section
Starr Rock Cornwall CAD



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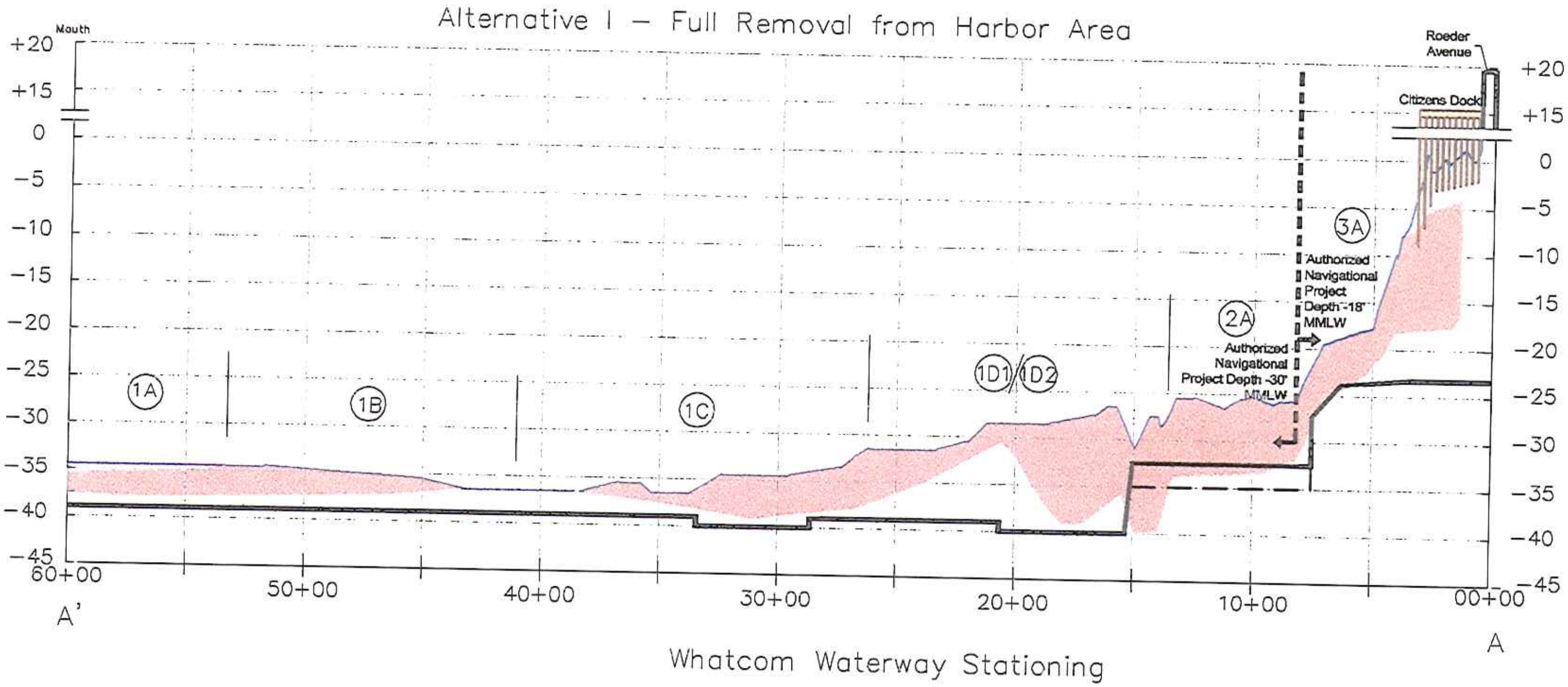
Horizontal Scale in Feet: 0, 400, 800

Vertical Scale in Feet: 0, 10, 20

Vertical Exaggeration x 40

Figure 14-7a

Typical Cross Sections Through Whatcom Waterway Centerline



Legend

——— Final Surface	Subsurface Sediment Exceeding Sediment Quality Criteria
– – – Dredge Cut (with Overdredge)	(1A) Whatcom Waterway Sediment Site Unit (SSU)

Horizontal Scale in Feet: 0, 400, 800
Vertical Scale in Feet: 0, 10, 20
Vertical Exaggeration x 40

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07/15/99 bby020c-03.dwg 98-007-04

Figure 14-7b
Typical Cross Sections Through Whatcom Waterway Centerline

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