Feasibility Study for Sediment Unit and Sawmill Unit

Port Gamble Bay and Mill Site
Port Gamble, WA

FINAL

Prepared by

DEPARTMENT OF
ECOLOGY
State of Washington

Toxics Cleanup Program
Aquatic Lands Cleanup Unit
Washington State Department of Ecology
Lacey, Washington

December 2012

TABLE OF CONTENTS

List of Tables

List of Figures

List of Appendices

LIST OF ACRONYMS AND ABBREVIATIONS

Abbreviation	Definition
µg/kg	micrograms per kilogram
AC	activated carbon
BMP	best management practice
BTV	background threshold value
CAP	Cleanup Action Plan
CFR	Code of Federal Regulations
cm	centimeters
cm/yr	centimeter per year
COC	contaminant of concern
Corps	U.S. Army Corps of Engineers
cPAH	carcinogenic polynuclear aromatic hydrocarbon
CQAP	Construction Quality Assurance Project Plan
CSL	Cleanup Screening Level
CSM	conceptual site model
CWA	Clean Water Act
cy	cubic yards
DAHP	Washington Department of Archaeology and Historic Preservation
DCA	MTCA Disproportionate Cost Analysis
DMMO	Dredged Material Management Office
DMMP	Dredged Material Management Program
DNR	Washington State Department of Natural Resources
Ecology	Washington State Department of Ecology
EMNR	enhanced, monitored natural recovery
EPA	U.S. Environmental Protection Agency
FLA	former lease area
FLTF	former log transfer facility
FS	feasibility study
g/day	grams per day
HPA	Hydraulic Project Approval
ng/kg	nanograms per kilogram

mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MLLW	mean lower low water
MNR	monitored natural recovery
MTCA	Model Toxics Control Act
NHPA	National Historic Preservation Act
NWP	Nationwide Permit
OPG	Olympic Property Group
P&T	Pope & Talbot, Inc.
PCB	polychlorinated biphenyl
ppt	parts per thousand
PQL	practical quantitation limit
PR	Pope Resources LP
PSEP	Puget Sound Estuary Program
RCW	Revised Code of Washington
RI	remedial investigation
SEPA	State Environmental Policy Act
SMA	sediment management area
SMS	Sediment Management Standards
SPI	sediment profile imaging
SQS	Sediment Quality Standard
TEQ	toxicity equivalent quotient
TVS	total volatile solids
WAC	Washington Administrative Code
WSDOT	Washington State Department of Transportation

1 INTRODUCTION

This report presents a feasibility study (FS) assessment of cleanup options for sediments in Port Gamble Bay. This report is a companion to the remedial investigation (RI) report prepared by the Washington State Department of Ecology (Ecology). This FS has been prepared on behalf of Pope Resources LP (PR), the Washington State Department of Natural Resources (DNR), and Ecology. Under Ecology's Toxics Cleanup Program Puget Sound Initiative, Port Gamble Bay (Figure 1-1) is one of seven bays in Puget Sound identified for focused sediment cleanup and integrated habitat restoration actions, as appropriate. This FS evaluates a range of potential sediment remedial actions in Port Gamble Bay to restore and protect ecological receptors at the Site, consistent with current Washington State Model Toxics Control Act (MTCA; Chapter 173-340 Washington Administrative Code [WAC]) and Sediment Management Standards (SMS; Chapter 173-204 WAC) regulatory requirements.

Port Gamble Bay is located in Kitsap County and encompasses more than 2 square miles of subtidal and shallow intertidal habitat just south of the Strait of Juan de Fuca (Figure 1-1). Pope & Talbot, Inc. (P&T) continuously operated a sawmill facility at the mill site for a period of approximately 142 years (1853 to 1995). Over that period, the mill site underwent a variety of changes, including expansion by filling, as well as changes in the location and function of buildings and structures. A detailed history of the Site operations is presented in Parametrix (1999), and is summarized in Section 1.1. P&T leased the 72-acre portion of the former lease area (FLA) from DNR between 1970 to 2001 for log storage and transfer purposes (Parametrix 2002). Log rafting ceased in 1995 when the sawmill closed, and P&T removed pilings from the leased area in 1996. Similarly, log rafting and associated log sort yard activities that began in 1970 at the former log transfer facility (FLTF) ceased after P&T removed the pilings in 1996 (Parametrix 2003). Figure 1-1 also shows several historical landfills along the western shoreline, some of which received mill and municipal waste materials, but were subsequently remediated to MTCA standards.

As discussed in the RI report, chip loading, log rafting, and associated sawmill operations resulted in accumulations of wood waste on the bed of Port Gamble Bay, particularly at locations near the former sawmill facility.

The bay and surrounding areas support diverse aquatic and upland habitats, as well as resources for fishing, shellfish harvesting, and many other aquatic uses. The area surrounding the bay remains largely rural in nature, though more than 100 acres of the basin are currently in commercial land use, largely in the Gamble Creek watershed. The Port Gamble S'Klallam Tribal Reservation is located east of the bay, with extensive use of the bay by the tribe for shellfish harvesting, fishing, and other resources; an upland tribal casino operates in the watershed.

1.1 Site Background

In 1853, the corporate predecessor to P&T established one of the first sawmills on Puget Sound in Port Gamble. At that time, the mill site was a relatively small sand spit projecting east from the base of a bluff that forms the western boundary to the mouth of Port Gamble Bay. The Port Gamble Bay region is known to be archaeologically sensitive. At the time of contact with American settlers, the Port Gamble area was home to a S'Klallam Tribe village, which relocated to the Point Julia ("Little Boston") village site directly across the bay when operations began at the mill site in 1853. Four cultural resource areas have been identified along the shoreline of the mill site, and another four areas of potential historic significance have been identified along the western shoreline of the bay (NWAA 2010).

The mill operated as a forest products manufacturing facility from 1853 to 1995. The mill site underwent several changes over that period including filling activities, which expanded the upland area, moving building locations, and causing changes in functions of buildings and structures. Between 1853 and 1995, operations in Port Gamble included a succession of sawmill buildings, two chip loading facilities, a log transfer facility, and log rafting and storage areas. During the mill's operating period, logs were rafted and stored offshore of the mill site. In the late 1920s, a chip barge loading facility was installed on the north end of the mill site. During the mid-1970s, an additional chip barge loading facility (referred to as the alder mill) was constructed in the southeast portion of the sawmill property.

In 1985, P&T transferred ownership of the uplands and adjacent tidelands portion of the mill site to PR. P&T continued wood products manufacturing until 1995 under a lease with PR. Mill operations ceased in 1995, and the sawmill facility was dismantled and mostly removed in 1997. Since 1997, the uplands portion of the former sawmill facility has been leased to a variety of parties for use as a log sort and wood chipping yard, material handling activities, a marine laboratory, and parking for Washington State Department of Transportation (WSDOT) operations.

In January 1997, Ecology conducted an initial investigation of the former sawmill facility, which consisted of sampling sediment in four catch basins. The results of that investigation indicated that concentrations of petroleum hydrocarbons and metals were present at levels above MTCA and SMS chemical criteria for these compounds. Subsequently, Clean Services Company, Inc. removed accumulated materials from 12 catch basins, four valve vaults, and four sumps on April 23, 1997.

In July 1998, Ecology notified P&T of the potential listing of the former sawmill site on Ecology's Confirmed and Suspected Contaminated Site List. Subsequently, detailed environmental investigations were conducted by P&T and PR to characterize soil, groundwater, surface water, and sediment quality conditions at the Site (Parametrix 2000). The site characterization data confirmed the presence of hazardous substances in soil and groundwater in several mill site uplands areas. The investigations also confirmed the presence of wood waste in nearshore sediments. Based on these data, Ecology added the mill site to the hazardous sites list in 2001.

Between 2002 and 2005, approximately 26,310 tons of contaminated soils were excavated from the former sawmill facility uplands, and in 2003, approximately 13,500 cubic yards (cy) of sediment containing the greatest accumulations of wood waste was dredged from a 2-acre area in the bay. Both the upland soils and the 2003 wood waste dredge material were disposed of at approved upland facilities. In 2004, follow-on surface sediment sampling and sediment profile imaging (SPI) was conducted by P&T to characterize post-dredge sediment quality conditions and to provide a baseline dataset for evaluation of anticipated future natural recovery (Parametrix 2004). In 2006, P&T and Ecology performed additional sediment characterization, including benthic infaunal abundance, sediment bioassays, and SPI across a gradient of wood waste levels.

In early 2007, Ecology dredged an additional 17,500 in situ cy of wood waste in a 1-acre area adjacent to the 2003 dredging action and placed a 6-inch layer of clean sand over a portion of the newly dredged area. In cooperation with this Ecology-led project, P&T took over the day-to-day management of the dredged material once it was transferred from Port Gamble Bay and subsequently removed salt from the material utilizing an on-site upland holding cell and freshwater washing system to allow for upland beneficial reuse of these materials. Unsuitable solid waste materials were segregated and disposed of at an approved off-site landfill facility. All soil segregation, disposal, treatment, and relocation tasks were successfully completed in spring 2009, in accordance with Kitsap County Grading Permit 08-52323.

In November 2007, P&T filed for bankruptcy (Delaware Case No. 07-11738).

As discussed in the RI report, Ecology performed supplemental sediment and tissue sampling in Port Gamble Bay in 2011. This sampling was conducted in response to public comments on the draft bay-wide and Mill Site RI/FS reports, and included collection of additional sediment chemistry and sediment bioassay samples. During this time, the Port Gamble S'Klallam Tribe also collected sediment and tissue samples. The results of these additional investigations were combined with the data previously evaluated, and a revised bay-wide RI was prepared by Ecology reflecting these data and combining the Mill Site RI into a single comprehensive RI document.

1.2 Report Organization

The remainder of this FS is organized as follows:

- Section 2 summarizes the results of the RI, including a summary of the bay-wide environmental conditions, RI sampling, the conceptual site model (CSM), and the contaminants of concern (COCs) identified in the RI
- Section 3 describes the basis for the cleanup action, including a summary of cleanup standards and the locations requiring cleanup action evaluation as identified in the RI
- Section 4 describes the regulatory framework, including the objectives of the cleanup action, the applicable regulatory requirements, and screening of general response action technologies

- Section 5 describes the criteria used to evaluate the cleanup action alternatives
- Section 6 presents the development and evaluation of bay-wide sediment cleanup action alternatives
- Section 7 presents a summary of preferred bay-wide sediment cleanup actions
- Section 8 presents the references used in preparing this FS

The following appendix provides supporting technical evaluations for the FS:

- Appendix A – Detailed Cost Estimates

2 REMEDIAL INVESTIGATION SUMMARY

This section summarizes the findings of the RI report, including the nature and extent of sediment contamination, COCs, and cleanup standards, along with delineation of specific sediment management areas (SMAs) addressed in this FS.

2.1 Site Environmental Conditions

Port Gamble Bay is located in north-central Puget Sound in Kitsap County (Figure 1-1). The bay has water depths ranging from 0 to -65 feet mean lower low water (MLLW) datum, although more typical bottom elevations in the center of the bay range from -30 to -40 feet MLLW.

The bay is oriented with its long axis directed generally north to south, approximately 2.9 miles long and 0.9 miles wide at its maximum dimensions. Due to the long north/south fetch distance, wind-generated waves on the order of 1 to 3 feet are predicted in the bay for storms with recurrence intervals ranging from 50 to 100 years.

Table 2-1 summarizes tidal datum elevations within the bay, based on the MLLW vertical datum.

Table 2-1
Tidal Datum Information – Port Gamble Bay

Reference Plane	Elevation (feet)
Mean Higher High Water	10.3
Mean Tide Level	6.0
North American Vertical Datum of 1988 (NAVD88)	1.85
Mean Lower Low Water	0.0

Note: Based on National Oceanic and Atmospheric Administration Vertical Datum conversion at Latitude 47.85; Longitude -122.58

2.2 Summary of RI Sampling

Ten sampling investigations have been completed in Port Gamble Bay between 2000 and 2011. The results of these studies are described and incorporated in the RI report. Both sediment and tissue samples have been collected bay-wide, with additional focused sampling in the former sawmill area. The work has included surface sampling, sediment core collection, and SPI. In addition to sediment conventional data and chemistry, bioassay, and tissue sampling, work has also included radioisotope dating of sediment cores to characterize overall net sedimentation rates in the bay. Key conclusions from the sampling with respect to COCs are summarized in the sections below.

2.3 Conceptual Site Model

The CSM described in the RI report identified the following current and former sources of contamination to the bay: wood waste, creosoted pilings, wood burning and hog fuel boiler burning, upland mill activities, and shoreline debris.

The transport pathways identified in the CSM presented in the RI report include currents and tidal fluctuations, concentration of clay particles, aerial deposition, and stormwater runoff.

Potential ecological and human health risks were also identified in the CSM. Benthic effects have been studied primarily through a series of bioassay tests conducted during several studies over the last 10 years. The primary conclusion in the RI report is that risks to sensitive benthic invertebrates have been identified adjacent to portions of the former sawmill facility, in the FLA, and also in the south-central portion of the bay. Human health risks were also identified for those who may consume seafood obtained from both Port Gamble Bay and from natural background areas of Puget Sound. Overall concentrations of cadmium and dioxins/furans in Port Gamble Bay sediments were 2 to 3 times higher than Puget Sound natural background levels, and carcinogenic polynuclear aromatic hydrocarbon (cPAH) sediment concentrations were roughly 10 times higher in Port Gamble Bay compared to Puget Sound natural background levels.

Consistent with deposition rates measured throughout Puget Sound (Carpenter et al. 1985; Lavelle et al. 1985), net sedimentation rates throughout Port Gamble Bay average approximately 0.4 ± 0.1 centimeters per year (cm/yr), based on radioisotope dating (as described in the RI report), corrected for wood waste accumulations in the former mill site area (four cores total).

2.4 Contaminants of Concern

The RI report evaluated a series of human health COCs: metals (arsenic, cadmium, copper, and mercury), cPAHs, polychlorinated biphenyls (PCBs), and dioxins/furans. Of this list, cadmium, cPAHs, and dioxin/furans were identified as site-related human health COCs. Cadmium has been identified as a low-level COC for human health, while cPAHs have been identified as a primary COC for human health. Dioxins/furans are a site-related COC for human health in limited areas of Port Gamble Bay.

In addition, addressing biological toxicity observed in the RI will require cleaning up wood waste and its degradation byproducts associated with the observed RI bioassay failures, including wood waste (as measured by total volatile solids; TVS), phenols, resin acids, and total and dissolved sulfides.

3 BASIS FOR CLEANUP ACTION

This section summarizes the need for sediment cleanup actions within certain areas of Port Gamble Bay, hereinafter denoted as the "Site." There are two distinct elements that form the basis for the cleanup action: 1) site-specific cleanup standards; and 2) the locations and media requiring cleanup action evaluation. Each of these elements is described below.

3.1 Cleanup Standards

The RI report provides detailed discussions of cleanup standards for the Site, including both ecological risk-based and human health risk-based standards.

Ecological risk-based cleanup standards were based on SMS biological criteria, using the bioassay results presented in the RI report. The bioassay cleanup standard identified by Ecology for the Site is the Sediment Quality Standard (SQS) criterion, which was used to delineate SMAs as described subsequently in this section.

Human health risk-based standards were developed based on the highest of risk-based concentrations, natural background levels, and practical quantitation limits (PQLs). Standards were developed for cadmium, cPAHs, and dioxins/furans.

3.1.1 Sediment Cleanup Levels

Based on the evaluations described in the RI report, Table 3-1 summarizes the sediment cleanup levels that were identified by Ecology for the Site.

Table 3-1
Sediment Cleanup Levels

Chemical of Concern	Preliminary Cleanup Level
Toxicity due to wood waste breakdown products	SQS numeric biological standards described in WAC 172-204-320(3)
cPAH TEQ	16 µg/kg
Dioxin/furan TEQ	5 ng/kg
Cadmium	3.0 mg/kg

3.1.2 Points of Compliance

Under MTCA, the point of compliance is the point or location on a site where the cleanup levels must be attained. For marine sediments, the point of compliance for protection of the environment is surface sediments within the biologically active zone. The biologically active zone is not specified by rule, but represents the depth in surface sediments within which benthic organisms at the site are found. For most members of the benthic community, a 10-centimeter (cm) biologically active zone is considered appropriate (e.g., for benthic infauna such as polychaete worms). However, for geoducks, which are an important natural resource in Port Gamble Bay, the biologically active zone extends approximately 3 feet below the mudline (Straus et al. 2009).

The biologically active zone can include deeper sediments that could become exposed given conditions or Site uses that may be expected to occur following cleanup (e.g., storm events or propeller wash that contribute to erosional forces).

3.2 Locations Requiring Cleanup Action Evaluation

This section summarizes the RI report conclusions regarding locations at the Site that require cleanup action evaluation.

Based on RI evaluations, SMAs were delineated at the Site. Figure 3-1 presents the location of these SMAs. Briefly, the SMAs are as follows:

- **Mill Site North (SMA-1)**. An approximately 6-acre area located in the embayment north of the former sawmill facility. This SMA is characterized by localized deep deposits of wood debris near the former chip loading area, and was delineated based on bioassay results that exceed SQS criteria, elevated cPAH levels that exceed background, and elevated dioxins/furans that exceed background and the PQL.
- **Mill Site South (SMA-2)**. An approximately 19-acre area located immediately south and east, and adjacent to the former sawmill facility. This SMA is characterized by areas of relatively deep deposits of wood debris, particularly adjacent to the former alder mill chip loading area, and was delineated based on bioassay results that exceed SQS criteria, elevated cPAH levels that exceed background, and elevated dioxins/furans that exceed background and the PQL.

- **Former Lease Area (SMA-3)**. An approximately 19-acre area located along the western shoreline of the south-central portion of the bay. This area was delineated based on bioassay results that exceed SQS criteria and the presence of wood waste breakdown products in sediments.
- **Central Bay (SMA-4)**. An approximately 77-acre area located in the south-central portion of Port Gamble Bay. This area was delineated based on bioassay results that exceed SQS criteria and the presence of wood waste breakdown products in sediments.
- **cPAH Background Area (SMA-5)**. An approximately 602-acre area that encompasses all of the other SMAs and serves as the Site boundary. The boundary of this SMA was developed based on surface sediment cPAH that exceeds natural background levels. It also includes an area of elevated dioxins/furans near the FLA and one station at which cadmium exceeds natural background levels.

The SMAs presented in the RI report are used in this FS to define the horizontal extents for development and evaluation of cleanup action alternatives. Within a given SMA for a particular alternative, multiple response action technologies may be appropriate in various combinations depending on SMA-specific considerations. Details of the alternatives development and further discussion of horizontal and vertical extents are presented subsequently in this FS.

4 REGULATORY FRAMEWORK

This section presents cleanup action objectives, applicable regulatory requirements for the cleanup action, and a screening evaluation of general response actions and remediation technologies that are potentially applicable to the Site.

4.1 Cleanup Action Objectives

Cleanup action objectives consist of chemical- and medium-specific goals for protecting the environment. The cleanup action objectives specify the media and contaminants of interest, potential exposure routes and receptors, and proposed cleanup goals for bay-wide sediments.

The cleanup action objectives for this FS are focused on sediments and the COCs listed in Table 3-1, including:

- Toxicity due to wood waste breakdown products
- Carcinogenic petroleum hydrocarbons toxicity equivalent quotient (TEQ)
- Dioxin/furan TEQ
- Cadmium

Exposure routes addressed in this FS include transport pathways to benthic receptors and humans. Transport pathways described in the RI are: 1) currents and tidal fluctuations; 2) concentrations of clay particles; 3) aerial deposition; and 4) stormwater runoff. Exposure of benthos and humans results from both direct contact with and ingestion of sediments; in the case of human exposure, ingestion primarily occurs indirectly through shellfish consumption and secondarily through incidental ingestion of sediments during shellfish harvesting and other beach uses.

The sediment cleanup action objectives for this FS are summarized as follows:

1. Eliminate, reduce, or otherwise control to the extent practicable risks to benthic organisms through exposure to sediments or porewater containing deleterious wood waste and/or other chemicals that exceed the benthic chemical or biological criteria described in the RI.

2. Eliminate, reduce, or otherwise control to the extent practicable risks to humans from ingestion of seafood containing chemicals that exceed risk-based concentrations and/or natural background concentrations.

4.2 Applicable Regulatory Requirements

In addition to the cleanup standards developed through the SMS process, other regulatory requirements must be considered in the selection and implementation of a cleanup action. SMS and MTCA require cleanup standards to be at least as stringent as all applicable state and federal laws [WAC 173-340-700(6)(a)]. In addition to establishing minimum requirements for cleanup standards, applicable state and federal laws may also impose certain technical and procedural requirements for performing cleanup actions. These requirements are described in WAC 173-340-710. Applicable state and federal laws are discussed below.

While implementation plans are still under development, the cleanup action at the Site will likely be performed pursuant to SMS under the terms of a Consent Decree between Ecology and one or more implementing parties. Accordingly, the anticipated cleanup action will likely meet the permit exemption provisions of MTCA, obviating the need to follow procedural requirements of the various local and state regulations that would otherwise apply to the action. Similarly, the anticipated cleanup action also qualifies for a U.S. Army Corps of Engineers (Corps) Nationwide Permit 38 (NWP 38). Nevertheless, federal consultation under the Endangered Species Act, Section 401 Water Quality Certification, and other substantive requirements must still be met by the cleanup action. Ecology will be responsible for issuing the final approval for the cleanup action, following consultation with other state and local regulators. The Corps will separately be responsible for issuing approval of the project under NWP 38, following Endangered Species Act consultation with the federal Natural Resource Trustees, and also incorporating Ecology's 401 Water Quality Certification.

4.2.1 SMS and MTCA Requirements

The primary law that governs the cleanup of contaminated sites in the state of Washington is MTCA (WAC 173-340), with sediment cleanup sites primarily governed under the state SMS (WAC 173-204). The SMS were developed to establish cleanup standards for marine, low salinity, and freshwater environments for the purpose of reducing and/or eliminating adverse effects on biological resources and significant health threats to humans from surface sediment contamination. Both SMS and MTCA regulations require that cleanup actions must protect human health and the environment, meet environmental standards in other applicable laws, and provide for monitoring to confirm compliance with cleanup levels.

SMS requires that cleanup actions meet the threshold requirements of overall protection of human health and the environment and attainment of cleanup standards, with selection of an appropriate cleanup action considering the following additional factors: short-term effectiveness, long-term effectiveness, implementability, cost, community concerns, the use of recycling, reuse and waste minimization, and environmental impact (WAC 173-204-560). Ecology's recommended time frame for sediment cleanup actions to achieve the cleanup level under SMS is 10 years, as practicable (WAC 173-204-570). For those cases where the 10-year time frame cannot be practicably met, Ecology may authorize a cleanup time frame that exceeds 10 years, requiring a technical impracticability demonstration as part of the FS.

The key SMS decision-making document for cleanup actions is the RI/FS. In the RI/FS, the nature and extent of contamination and the associated risks at a site are evaluated, and potential alternatives for conducting a site cleanup action are identified. The cleanup action alternatives are then evaluated against SMS remedy selection criteria, and one or more preferred alternatives are selected. After reviewing the RI/FS, and after consideration of public comment, Ecology then selects a cleanup action for the site and documents the selection in a Cleanup Action Plan (CAP). Following public review of the CAP, the site cleanup process typically moves forward into design, permitting, construction, and long-term monitoring.

This FS report was prepared consistent with the requirements of the SMS and MTCA.

4.2.2 Solid and Hazardous Waste Management

The Washington Hazardous Waste Management Act (Revised Code of Washington [RCW] 70.105) and the implementing regulations, the Dangerous Waste Regulations (Chapter 173-303 WAC), would apply if dangerous wastes are generated during the cleanup action. There is no indication of dangerous wastes being generated or disposed of at the Site. Related regulations include state and federal requirements for solid waste handling and disposal facilities (40 Code of Federal Regulations [CFR] 241, 257; Chapter 173-350 and -351 WAC) and land disposal restrictions (40 CFR 268; WAC 173-303-340).

4.2.3 Puget Sound Dredged Material Management Program

In Puget Sound, the open-water disposal of sediments is managed under the Dredged Material Management Program (DMMP). This program is administered jointly by the Corps, the U.S. Environmental Protection Agency (EPA), DNR, and Ecology. The DMMP developed the Puget Sound Dredge Disposal Analysis protocols, which include testing requirements to characterize whether dredged sediments are appropriate for open-water disposal. The results of this characterization are formalized in a written suitability determination from the Dredged Material Management Office (DMMO).

The DMMP has also designated disposal sites throughout Puget Sound. Initial DMMP characterization of sediments has been performed on representative subsurface samples collected from the wood chip deposit in the Mill Site North SMA (including bioassay and dioxin testing), and these data indicated that wood waste material from this part of the Site is likely suitable for unconfined open-water disposal at a non-dispersive location (e.g., at the nearby Port Gardner disposal site). Similar wood waste materials have also been determined to be suitable for open-water disposal at DMMP facilities (e.g., DMMP 2009). However, if this option is selected, additional dredged material characterization would be required to complete the suitability determination. Use of DMMP facilities would need to comply with other DMMP requirements including material approval, disposal requirements, and payment of disposal site fees.

4.2.4 State Environmental Policy Act

The State Environmental Policy Act (SEPA) (RCW 43.21C; WAC 197-11) and the SEPA procedures (WAC 173-802) are intended to ensure that state and local government officials consider environmental values when making decisions. The SEPA process begins when an application for a permit is submitted to an agency, or an agency proposes to take some official action such as implementing a MTCA CAP. 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 Environmental Impact Statement is required. A SEPA checklist would be required prior to initiating remedial construction activities. Because the Site cleanup action will be performed under a Consent Decree, SEPA and MTCA requirements will be coordinated, if possible.

4.2.5 Shoreline Management Act

The Shoreline Management Act (RCW 90.58) and its implementing regulations establish requirements for substantial developments occurring within water areas of the state or within 200 feet of the shoreline. Local shoreline management master programs are adopted under state regulations, creating an enforceable state law. Because the Site cleanup action will likely be performed under a Consent Decree, compliance with substantive requirements would be necessary, but a shoreline permit would not likely be required.

4.2.6 Washington Hydraulics Code

The Washington Hydraulics Code (WAC 220-110) establishes regulations for the construction of any hydraulic project or the performance of any work that will use, divert, obstruct, or change the natural flow or bed of any of the salt or fresh water of the state. The code also creates a program requiring Hydraulic Project Approval (HPA) permits for any activities that could adversely affect fisheries and water resources. Timing restrictions and technical requirements under the hydraulics code are applicable to dredging, construction of sediment caps, and placement of post-dredge residual covers if necessary. For the reasons stated above, the procedural requirements of an HPA permit would not likely be required, though the substantive requirements of an HPA must still be met by the cleanup action.

The FS has been prepared using durations that recognize potential fish closure periods, during which time dredging and any in-water work will not be permitted. Exact in-water closure periods will be determined through agency and tribal consultation.

4.2.7 Water Management

4.2.7.1 Clean Water Act

The Clean Water Act (CWA) is the primary federal law for protecting water quality from pollution. The CWA regulations provide requirements for the discharge of dredged or fill material to waters of the United States and are applicable to any in-water work. The CWA regulations also prescribe permitting requirements for point source and non-point source discharges. Acute marine criteria are relevant and appropriate requirements for discharges to marine surface water during sediment dredging, as well as for return flows (if necessary) to surface waters from dewatering operations.

Section 404 of the CWA requires permits from the Corps for discharges of dredged or fill material into waters of the United States, including wetlands. Section 404 permits depend on suitability determinations (described previously) according to DMMP guidelines.

Section 404(b)(1) requires an alternatives analysis as part of the permitting process. Requirements for all known, available, and reasonable technologies for treating waste water prior to discharge to state waters are applicable to any dewatering of marine sediment prior to upland disposal. Section 401 of the CWA requires the state to certify that federal permits are consistent with water quality standards. The substantive requirements of a certification determination are applicable.

Ecology has promulgated statewide water quality standards under the Washington Water Pollution Control Act (RCW 90.48). Under these standards, all surface waters of the state are divided into classes (Extraordinary, Excellent, Good, and Fair) based on the aquatic life uses of the water bodies. Water quality criteria are defined for different types of pollutants and the characteristic uses for each class of surface water. The standards for marine waters will be applicable to discharges to surface water during sediment dredging, and return flows (if necessary) to surface waters from dewatering operations.

4.2.7.2 Construction Stormwater General Permit

Construction activities that disturb 1 acre or more of land need to comply with the provisions of construction stormwater regulations. Ecology has determined that a construction stormwater general permit is not covered under the permit exemption provisions of MTCA, and thus a project-specific construction stormwater permit would be required if land disturbance greater than 1 acre is necessary. It is anticipated that the construction stormwater general permit would be obtained during the design phase and a Construction Quality Assurance Project Plan (CQAP) would also be prepared as part of the remedial design process, supplemented as appropriate by the remedial contractor.

4.2.8 Other Applicable Regulatory Requirements

The following is a list of other applicable regulations for the cleanup action:

- **Archaeological and Historic Preservation** – The Archaeological and Historic Preservation Act (16 USCA 496a-1) will apply if any subject materials are discovered during Site grading and excavation activities. Previously conducted cultural resource surveys indicate several areas of significant historical interest in the bay. Prior to construction, a more detailed cultural resources survey will be conducted during remedial design and a monitoring and management plan prepared to ensure protection of archaeological and/or historic resources.

- **Health and Safety** – Site cleanup-related construction activities will be performed in accordance with the requirements of the Washington Industrial Safety and Health Act (RCW 49.17) and the federal Occupational Safety and Health Act (29 CFR 1910, 1926). These applicable regulations include requirements that workers are to be protected from exposure to contaminants and that excavations are to be properly shored.

These requirements are not specifically addressed in the detailed analysis of cleanup action alternatives because they apply to any active cleanup alternative.

4.3 Screening of General Response Actions

This section presents a screening evaluation of potentially applicable general response actions and remediation technologies for the cleanup action. Based on the screening evaluation, selected response actions and technologies are carried forward for use in the development of cleanup action alternatives.

4.3.1 No Action

The No Action alternative does not achieve the project objectives of protecting human health and the environment and, thus, has been screened from further evaluation for sediments.

4.3.2 Institutional Controls

For any aquatic construction project (e.g., dredging), environmental reviews are conducted by permitting agencies including the Corps, Ecology, and other resource agencies. These reviews include a review of area files relating to sediment conditions and requirements to address materials management and water quality.

Additional institutional controls may be implemented as appropriate, depending on the preferred cleanup action alternative. Such additional controls could include restrictive covenants for platted tidelands, use authorizations for state-owned aquatic lands, and/or documenting the Site cleanup action in Corps and regulatory agency permit records and records maintained by the State of Washington for state-owned aquatic lands.

Institutional controls can be effective, implementable, and cost-effective provided that the cleanup action for which the institutional controls are implemented is consistent with marine land and navigation uses. In cases where the proposed cleanup action is incompatible with land use and navigation uses, conflicts can result, which can jeopardize the effectiveness of institutional controls or require mitigation. While the use of institutional controls is not carried forward as an independent action for detailed evaluation, the use of institutional controls may be appropriate in combination with other general response actions, and thus would be considered as an additive requirement where appropriate.

4.3.3 Source Control

Wood waste source controls within the Port Gamble Bay area were implemented during and following mill operations. Discontinuation of hog fuel burning eliminated one primary source of dioxins/furans and cPAHs. Cleanup of upland areas of the site and landfills along the shoreline have further reduced sources related to the former mill. Additional source control for cPAHs will occur through removal of creosoted structures and pilings. All piling removal will also be sequenced with follow-on dredging or capping actions to maximize control of piling removal residuals. Piling removal and disposal will target complete removal using equipment preferences and best management practices (BMPs) identified in the statewide Hydraulic Project Approval (HPA) - *Creosote Piling and Structural Removal* (WDFW 2011) and the accompanying DNR Puget Sound Initiative – *Derelict Creosote Piling Removal, BMPs for Pile Removal and Disposal* (DNR 2011). Areas of extensive piling removal not otherwise anticipated to be later capped or dredged will be covered with 6 inches of sand to control anticipated piling removal residuals. This action is compatible with and supports all of the following technologies and will be part of the selected alternative for all SMAs in which creosoted pilings and structures are present.

4.3.4 Monitored Natural Recovery

Natural processes that are fundamental to the recovery of wood waste- or cPAH-impacted sediments following source control include sedimentation and biodegradation. The monitored natural recovery (MNR) remedy relies on these processes to reduce risks to acceptable levels following source control, while monitoring recovery over time to verify remedy success (Magar et al. 2009).

MNR lines of evidence can be developed from rigorous analyses of Site data (e.g., laboratory and field studies, modeling, and other activities) that define the role of natural processes in reducing risk. Key factors for determining whether MNR is an appropriate remedy include the ability to achieve and sustain an acceptable level of risk reduction through natural processes within an acceptable period of time. Predicting future natural recovery rates requires site-specific inputs to numerical models, such as the net sedimentation rate (which averages approximately 0.4 ± 0.1 cm/yr at the Site, as described above), to quantify processes described in the CSM and associated lines of evidence. Numerical models can be used to develop estimates of time to recovery using baseline data to determine likely effectiveness of MNR implementation.

Natural recovery processes operate regardless of the selected remedy. Effective sediment remedies may incorporate MNR in combination with approaches such as engineered containment or removal. Factors particularly favorable to MNR include evidence that natural recovery will effectively reduce risks within an acceptable time period, the ability to manage risks during the recovery period, and (where physical isolation is important) a low potential for exposure of buried contaminants. In SMAs where this technology is potentially promising, MNR was retained as a response action for more detailed evaluation in this FS.

Under SMS, preference is given to remedies providing for timely cleanup, taking into account potential risks posed by a site and practicability of achieving cleanup standards in less than a 10-year time frame. Where natural recovery time frames are expected to be greater than 10 years but there is no practicable cleanup alternative, a technical practicability evaluation is required in the FS.

4.3.5 Enhanced Monitored Natural Recovery

Enhanced monitored natural recovery (EMNR) involves active measures, such as the placement of a thin layer of suitable sand or sediment, to accelerate the natural recovery process. EMNR is often applied in areas where natural recovery may appear to be an appropriate remedy, yet the rate of sedimentation or other natural processes is insufficient to reduce potentially unacceptable risks within an acceptable timeframe (EPA 2005). The acceleration of natural recovery most often occurs due to burial and/or incorporation and mixing of the clean material into the contaminated surface sediments through bioturbation and physical mixing processes. Other recovery processes can also occur such as binding of contaminants to organic carbon in the clean material, particularly if the material is from a clean sediment source with naturally occurring organic carbon. Placement of such EMNR materials is typically different than capping (discussed in Section 4.3.6), because it is not designed to provide long-term isolation of contaminants. Clean sand or sediment can be placed in a relatively uniform thin layer over a contaminated area or it can be placed in berms or windrows, allowing natural sediment transport processes to distribute the clean material over wider areas. As with MNR, EMNR includes both monitoring and contingency plan components to verify that recovery is occurring as expected, and to respond accordingly.

EMNR can be highly effective where natural recovery is occurring, but at a slower rate than desired. In many areas of the Site, the most recent bioassay test results are close to achieving SQS biological criteria. EMNR in these locations is one strategy that can effectively improve surface sediment conditions upon application, and thus the expected recovery in these marginal exceedance areas should occur within the SMS 10-year timeframe, although achieving human health risk-based criteria may take longer. EMNR is also an effective strategy for managing dredge residuals, as discussed below. EMNR has been retained is a general response action for this FS, and would entail placement of a nominal 6-inch-thick layer of clean sediment.

EMNR sediment would be obtained from a clean marine beneficial reuse sediment source to ensure maximum compatibility with and the quickest recovery of the benthic community. A specific source for this material has not been identified for this FS. Prior project experience suggests that the availability of clean material from relatively local beneficial reuse projects changes over time, and thus the availability of sources would need to be more fully understood and evaluated during remedial design. If material is only available on a limited basis each year, this could extend the implementation timeline of those projects that require larger volumes of EMNR sediments.

4.3.6 Engineered Containment

Engineered containment for sediments involves placing a suitable cap to isolate contaminated material for protection of the biological receptors of interest (e.g., benthic infauna, forage fish, and geoduck in Port Gamble Bay) and human routes of exposure. In the aquatic environment, the containment must be designed to withstand erosive forces generated by wave action and propeller wash, and must be thick enough to provide the required isolation of the material contained by the cap. Monitoring results at other sites in the Puget Sound region have shown that containment can provide effective sediment remediation without the risks involved in removing contaminants by dredging (Sumeri 1996). Engineered containment was retained for further evaluation in this FS.

Placing a layer of cap material (12 or 48 inches thick, depending on location-specific biological requirements) can provide isolation of potentially contaminated sediments. Aggregate caps (e.g., with a gravel surface) may potentially be appropriate for consideration in sediment areas with high potential for disturbance (e.g., from propeller wash or wind-generated wave forces) or in intertidal zones where the natural habitat is coarse-grained.

If selected as part of the Site remedy, a sediment cap would be designed to effectively contain and isolate contaminated sediments from the biologically active surface zone in accordance with EPA and Corps cap design criteria (see below). The cap would be designed to be thick enough and of sufficient grain size to maintain its integrity under reasonable worst-case conditions.

Engineered caps at the Site would be designed to ensure that wood waste is effectively confined below the cap and that post-cap sediment porewater sulfide concentrations in the biologically active zone (0 to 10 cm for most receptors, and 0 to 3 feet specifically for geoducks) are maintained below the no effects threshold of 3.4 milligrams per liter (mg/L) cited by the DMMP for *Neanthes* testing (Kendall and Barton 2004).

Cap designs to maintain porewater sulfide exposure below these performance standards would be developed considering surface and subsurface sediment porewater concentrations measured during the RI/FS, and also considering groundwater upwelling, tidally induced transient porewater flow reversal, and geochemical processes at the Site. Tidal reversals can promote sulfide production in wood waste deposits by supplying sulfate-rich seawater to wood chips confined below the cap, and are most pronounced in the near-surface permeable soils of the shallow aquifer at the Site that are adjacent to intertidal and shallow subtidal areas of the Site. During the design phase, hydraulic and/or geochemical modeling may be necessary to assess potential groundwater discharge into a cap to confirm the protectiveness of the cap.

Sediment caps would be constructed of clean silt/sand and/or sand and gravel materials and could be placed by a number of mechanical and hydraulic methods. Cap material would either be provided from a beneficial reuse marine dredging project or from a commercial quarry in cases where beneficial reuse material would not provide the appropriate grain size. The grain size requirements would be determined during remedial design based on consideration of erosive forces (e.g., wind/wave, propeller wash) and habitat compatibility as discussed subsequently, and would likely vary depending on elevation and location.

Table 4-1 provides a general summary of protective cap designs in Puget Sound that have been developed and approved under both EPA and Ecology cleanup programs. Cap designs must meet stringent criteria set forth in EPA and Corps design guidance, including EPA (2005) and Palermo et al. (1998a, 1998b). These guidance documents provide detailed procedures for cap design, cap placement operations, and monitoring of engineered caps, and have been relied upon extensively for successful cap designs at other SMS cleanup sites. Caps designed according to the EPA and Corps guidance have been demonstrated to be protective of human health and the environment (EPA 2005). Design specifications for in situ engineered caps in Port Gamble would be further refined during remedial design based on detailed analyses of the following components:

- Bioturbation/habitat quality
- Habitat compatibility
- Erosion (e.g., propeller wash, tidal currents, waves, wakes, and slope stability)
- Chemical isolation (accounting for tidal advection of porewater/groundwater)
- Consolidation
- Operational considerations (e.g., gas generation and placement inaccuracies)

Table 4-1

Regional Sediment Capping Projects

Water Body	Project	Regulatory Program	Year	Contaminants of Concern	Cap Design(s)
Bellingham Bay	Georgia-Pacific Log Pond	MTCA	2001	Mercury, wood debris, phenols	3-foot-thick sand cap
Eagle Harbor	Eagle Harbor (East Harbor)	CERCLA	1994	PAHs, metals	3-foot-thick cap of dredged material
Elliott Bay	King County – Denny Way CSO	Corps	1990	PCBs, PAHs, metals	2.5-foot-thick cap of dredged material
Elliott Bay	Pier 51 – Coleman Dock	Corps	1989	PCBs, PAHs, metals	1.5-foot-thick cap of dredged material
Elliott Bay	Pier 53 – Washington Street CSO	Corps	1992	PCBs, PAHs, metals	1-foot-thick and 3-foot-thick cap of dredged material
Elliott Bay	Pier 64 – Port of Seattle	MTCA	1994	PCBs, PAHs, metals	1-foot-thick enhanced natural recovery layer of dredged material
Elliott Bay	Pacific Sound Resources	CERCLA	2004	PAHs	6-foot-thick sand and gravel cap, armored in places; 54-inch sand and gravel cap; 42-inch sand cap
Duwamish Waterway	Duwamish/Diagonal CSO	NRDA	2005	PCBs, mercury, phthalates	3-foot-thick sand cap or armored cap; restore grade
Duwamish Waterway	Norfolk CSO	NRDA	1998	PCBs, mercury, BEHP,1,4-dichlorobenzene	3-foot-thick sand cap; restore grade
Duwamish Waterway	West Waterway CAD	Corps	1984	PCBs, metals	2-foot-thick sand cap
Commencement Bay	Thea Foss	CERCLA	2003	Metals, PAHs, PCBs, phenols, phthalates	
Commencement Bay	Middle Waterway	CERCLA	2003	Metals, PCB, phthalates	3-foot-thick sand cap or armored cap
Commencement Bay	Head of Thea Foss	CERCLA	2003	PAHs, NAPLs	HDPE plus 3-foot-thick sand cap
Commencement Bay	Simpson Tacoma Kraft	Corps	1988	PAHs	4-foot-thick sand cap
Budd Inlet	One Tree Island Marina		1987	Metals, PAHs	4-foot-thick sand cap

Notes:
BEHP = bis(2-ethylhexyl)phthalate
CAD = confined aquatic disposal
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
Corps = U.S. Army Corps of Engineers
CSO = combined sewer outfall
MTCA = Model Toxics Control Act
NAPLs = nonaqueous phase liquid
NRDA = Natural Resources Damage Assessment
PAHs = polynuclear aromatic hydrocarbons
PCBs = polychlorinated biphenyls

During remedial design, appropriate cap designs in different areas of the Site would be determined individually for each component based on location-specific design parameters. For the purposes of this FS, conceptual-level cap designs were developed based on a review of engineered caps designed, approved, and successfully constructed and monitored in other areas of Puget Sound, also taking into consideration site-specific habitat conditions within Port Gamble. Based on these factors, this FS developed three different cap designs for development of the alternatives, summarized in Table 4-2.

Table 4-2
Cap Designs Developed for the Feasibility Study

Cap Type	Criteria	Thickness
I	Benthic cap in intertidal areas (above -3 feet mean lower low water [MLLW]) that exceed site-specific cleanup levels or toxic porewater sulfide levels	24 inches of coarse sand and gravel
II	Benthic cap in subtidal areas (below -3 feet MLLW) without substantial wood waste deposits that exceed site-specific cleanup levels but with porewater sulfide below potentially toxic levels	12 inches of silt/sand
III	Benthic cap in geoduck subtidal areas (below -3 feet MLLW) with substantial wood waste deposits or in subtidal areas where porewater sulfide exceeds potentially toxic levels	48 inches of silt/sand

Beneficial reuse of Snohomish River maintenance dredged material or other suitable sediments will be considered during remedial design and is preferred over quarried material. The beneficial reuse of sand is subject to similar considerations for Engineered Containment as described previously for EMNR. Other potential sources of sand include the local quarry owned by PR, which was used as the primary source for the post-dredge sand cover successfully placed during the 2007 interim action. Where the local quarry does not contain sufficient quantity of sand, and for larger sized aggregates, a commercial quarry would be the likely source of cap material. For costing purposes, the cap designs summarized in Table 4-2 are considered to be the final placed thicknesses (i.e., including overplacement allowances).

4.3.7 Removal

Removal of sediments from the aquatic environment is a common approach to addressing materials that require remedial action, and was used during both the 2003 and 2007 interim actions at the mill site when an aggregate total of approximately 30,000 cy of woody sediments were removed. If selected as a part of the final remedy, removal of subtidal sediments would likely be performed from a barge-mounted clamshell dredge, similar to these prior actions, while intertidal sediments could be excavated under lower-tide conditions using upland-based equipment. Removal was retained as a response action for more detailed evaluation in this FS.

A number of site-specific operational conditions influence the effect of environmental dredging of contaminated sediment on aquatic systems. Experience at the site, as well as has been documented on other sediment cleanup projects, shows that resuspension of contaminated sediment and release of contaminants occur during dredging and that contaminated sediment residuals will remain following operations, which can affect the magnitude, distribution, and bioavailability of the contaminants and the exposure and risk to receptors of concern. Dredging residuals have been shown to be particularly problematic at sites with considerable debris (Patmont and Palermo 2007). Even after decades of sediment remediation project experience, there are still substantial uncertainties in our understanding of the cause-effect relationships relating dredging processes to risk reduction (EPA 2005; Bridges et al. 2008; Bridges et al. 2010).

Where removal is considered, residuals management strategies should be considered. Considerable experience from prior dredging projects shows that the historical approach of using multiple cleanup passes to address residuals is ineffective. More recently, sediment remedies have incorporated a residuals management strategy that entails placement of a post-dredge clean cover. This strategy was effectively demonstrated during the 2007 interim action conducted at the mill site. For alternatives that entail removal, a post-dredge residuals management strategy that includes placement of a nominal 6-inch-thick layer of clean sand has been incorporated as part of this general response action.

To effectively assess potential impacts from removal alternatives, and to properly compare alternatives, the volume of removal associated with each alternative must be estimated. For removal-based alternatives, the horizontal extent of dredging is considered to be either the boundary of the SMA, or an internal sub-area that is specific to a particular alternative, the limits of which are described for that particular alternative. The vertical extents of removal are based on the results of the sediment coring data where available, and supplemented by the surface sample results. For cores, the vertical limit of dredging was estimated considering sediment TVS results, where TVS greater than 15 percent is the criterion for removal of wood waste; for other contaminants, the site-specific cleanup standards or SMS criteria apply. For surface samples where core data are not available, a prospective dredge depth of 2 feet has been incorporated into the volume estimates, and will be refined during remedial design.

Because of the widespread distribution of individual sample points, and due to the uncertainty of the depth of removal in surface sample areas, it is appropriate and consistent with current sediment FS practice to “scale up” estimated dredge volumes from neatline calculations. Based on a review of historical sediment cleanup projects, appropriate scaling factors are considered to be 1.25 to 2 times the neatline estimate of dredge volumes, depending on site understanding at the time of the FS, and the level of engineering that was used in developing the volume estimate. Removal volumes calculated in this FS are based on the horizontal and vertical extents as described above and include a 1-foot overdepth allowance on the neatline dredge volumes. This volume is then further scaled up by an average factor of 1.25 for the mid-range cost estimate to 1.5 for the high-end cost estimate to accommodate potential uncertainty in actual distribution of potential contamination, and considering engineering factors such as side slopes and level cuts that would be implemented during remedial design development, consistent with recent Corps guidance (Palermo et al. 2008).

4.3.7.1 Disposal Options

There are several options for disposal of marine sediments removed through dredging. For those sediments that are determined by the DMMP to be suitable for open-water disposal, such sediments may be transported by bottom-dump barge for disposal at an unconfined open-water disposal site. Based on preliminary DMMP characterization of sediments at the Site, subtidal wood waste within portions of the Mill Site North and South SMAs could be suitable for open-water disposal at the non-dispersive DMMP site in Port Gardner near Everett, Washington. However, additional testing and suitability determinations by the DMMP would be required during design to verify the suitability of these materials for open-water disposal.

For debris and sediments that are not suitable for open-water disposal, beneficial reuse and/or upland disposal at a permitted municipal or private landfill (e.g., construction debris landfill or Subtitle D landfill) may be necessary. Sediments excavated using water-based equipment could be loaded on a barge, and could potentially be shipped directly to a Canadian landfill, or to a barge-truck-rail transloading facility for shipment to a United States landfill with rail access. Alternately, if space permits, an on-site offloading and staging area could be set up to process sediments and debris, and load this material into trucks for off-site transport and disposal. Where chemistry results allow for potential beneficial reuse, additional alternatives for managing dredged material may be available as discussed in Section 4.3.7.2.

4.3.7.2 Reuse Options

While a specific beneficial reuse opportunity for subtidal wood waste material and/or intertidal sediments was not identified for this FS, there may be practicable opportunities to reuse some of these materials beneficially, including topsoil for upland restoration. In this case, debris would need to be screened out, larger pieces chipped, and salt rinsed (i.e., "sparged") from the material prior to upland reuse. Successful sparging of salinity from wood debris was demonstrated as part of the 2007 interim action at the Site, where wood debris sediments were dredged from Port Gamble Bay and placed within a nearshore upland stockpile containment structure (i.e., 4-foot-thick sparging basin). Fresh water was applied through a simple sprinkler system, which successfully reduced porewater salinity within the sparging basin to below secondary drinking water standards (less than 0.5 parts per thousand [ppt]) within a period of approximately 4 months (Anchor QEA and EPI 2010). Leachate from the sparging basin did not exceed discharge criteria, and was passively returned to Port Gamble Bay. Much of the sparged Port Gamble material was successfully reused as an upland soil amendment on property owned by Olympic Property Group (OPG).

At the Site, the practicability of beneficial reuse of wood waste and/or intertidal sediments is limited by the available land to facilitate sparging, and also by logistics and costs associated with transport of sparged materials to prospective beneficial reuse locations. While specific beneficial reuse opportunities were not identified for this FS, if this option were to be selected as part of the final Site remedy, such opportunities would be further explored and evaluated during remedial design.

4.3.8 Ex Situ Treatment

As discussed above, ex situ treatment of wood waste and/or intertidal sediments using relatively low-cost sparging technologies has been demonstrated as a method to remove salt from the material to facilitate beneficial reuse of these materials. However, in order to be cost-effective, ex situ treatment by sparging requires a significant upland space available adjacent to the project site while sparging is performed. While other remedial technologies such as thermal desorption, incineration, and stabilization could potentially be applied to the Site, such technologies are substantially more expensive than off-site landfill disposal, and many of these technologies have limited effectiveness for sediments with a high organic content such as wood waste. Thus, no ex situ treatment technologies, other than sparging to facilitate beneficial reuse of wood waste and/or intertidal materials, are retained as general response actions.

4.3.9 In Situ Treatment

In situ treatment entails the direct application or placement of amendments into the sediment and/or mixing reagents with sediment cap substrate to reduce the bioavailability of certain contaminants. Selection of appropriate in situ treatment requires evaluation of available process options to determine which amendments and distribution methods are likely to be most effective for site sediment and COCs. Typical application involves the placement of activated carbon (AC) or other types of reagents that bind certain organic and/or metal contaminants. In situ treatment has been applied at sediment cleanup sites using one of five process options at the field pilot scale, including:

- Mechanical mixing of amendments into shallow sediment
- Slurry placement of the amendments onto the sediment surface

- Mixing amendments with sand, and placing the blended materials using methods similar to the EMNR or containment technology discussed above
- Sequentially placing amendments under a thin sand cover
- Broadcast application of amendments in a pelletized form to improve settling characteristics (e.g., SediMite™); the pellet matrix subsequently degrades, allowing the AC to slowly mix into surface sediments through bioturbation)

Of the amendments available, AC has received more testing and evaluation than organoclays, particularly with respect to sediment remediation, because the sorption capacities for PAHs, dioxin/furans, and other chemicals in AC are at least an order of magnitude higher than other sorbents.

While application of in situ treatment has been demonstrated to be effective and implementable at other sediment sites, Port Gamble sediments are expected to be less amenable to treatment of wood waste and wood waste degradation byproducts such as porewater sulfide. Application of in situ treatment for such COCs has not been documented and is expected to not be effective. Thus, in situ treatment was screened from further consideration as an applicable general response action.

4.3.10 Summary of Retained Response Actions

Table 4-3 summarizes the screening decisions for the general response actions that were carried forward for detailed evaluation in this FS.

Table 4-3
Remedial Technology and Disposal Screening Summary

General Response Action	Process Option	Screening Decision
Institutional Controls	Access and deed restrictions; informational devices	Retained
Source Control	Creosote piling and structure removal	Retained
Monitored Natural Recovery (MNR)	Natural sedimentation	Retained
Enhanced Monitored Natural Recovery (EMNR)	Place thin layer of clean cover	Retained
Engineered Containment	Capping	Retained
Removal	Soil excavators; mechanical dredging	Retained
In Situ Treatment	Adsorptive amendments; stabilization	Not Retained
Ex Situ Treatment	Stabilization	Not Retained
	Washing (sparging)	Retained
	Incineration	Not Retained
	Thermal desorption	Not Retained
Disposal	Upland beneficial reuse	Retained
	Upland landfill disposal	Retained
	Open-water disposal	Retained

5 EVALUATION BASIS

Remedy selection criteria under the SMS regulations are similar to those required under MTCA. The SMS evaluation criteria are specified in WAC 173-204-560(4)(f) through (k). This section describes the requirements for cleanup action evaluations under the SMS.

5.1 Threshold Criteria

Cleanup actions performed under the SMS must comply with two basic, or "threshold" requirements. Alternatives that do not comply with threshold criteria would typically not be considered suitable cleanup actions under the SMS. The SMS threshold requirements are:

- Overall protection of human health and the environment
- Attainment of cleanup standards

5.1.1 Overall Protection of Human Health and the Environment

The overall protectiveness of a cleanup action alternative is evaluated based on several factors. Primary considerations include the extent to which human health and the environment are protected and the degree to which overall risk at a site is reduced. Both on-site and off-site reductions in risk are considered. Protectiveness also gauges the degree to which the cleanup action may perform above the level of the specific standards presented in the SMS. Finally, protectiveness is a measure of the improvement in the overall environmental quality at the site. This criterion also includes consideration of whether the alternative is likely to achieve site-specific cleanup standards within a 10-year time frame.

5.1.2 Attainment of Cleanup Standards

This threshold criterion evaluates whether the alternative meets the site-specific cleanup standards selected in the RI. In addition, SMS specifies that cleanup actions must comply with federal, state, and local laws. For SMAs where no alternative can attain site-specific cleanup standards within the 10-year time frame specified in SMS, an additional technical practicability evaluation is required as described subsequently in this section.

5.2 Additional SMS Evaluation Criteria

This section describes the specific factors that are considered under each of the SMS criteria when evaluating an alternative, and the parameters that would lead to a relatively lower or higher score. For scoring each alternative, the criteria use a weighting factor to reflect the relative importance of the factor in the overall assessment of the alternative. Each weighting factor is provided in the discussion below.

5.2.1 Short-term Effectiveness

Evaluation of this criterion considers the relative magnitude and complexity of actions required to maintain protection of human health and the environment during implementation of the cleanup action. Cleanup actions carry short-term risks, such as potential mobilization of contaminants during construction (e.g., dredge residuals as discussed in Section 4), or safety risks typical of large construction projects. Other impacts to short-term effectiveness include water quality degradation, noise, vessel and vehicle traffic, and air emissions. Some short-term risks can be managed to some degree through the use of best practices during project design and construction, while other risks are inherent to project alternatives. Those activities that result in unavoidable environmental or safety impacts during construction are considered to have a lower ranking than those activities that result in minimal impact. For similar types of activities (which would typically have similar impacts over the same time period), longer duration actions would rank lower for short-term effectiveness than shorter duration actions.

The short-term effectiveness criterion has been given a weighting factor of 10 percent—i.e., the absolute score described in Section 6 is multiplied by 0.10 when summing the total alternative score. This relatively low weighting factor recognizes that active construction alternatives will all have a short-term impact regardless of the technology used.

5.2.2 Long-term Effectiveness

Long-term effectiveness is a parameter that expresses the degree of certainty that the alternative will be successful in maintaining compliance with cleanup standards over the long-term performance of the cleanup action.

The highest long-term effectiveness ranking is given to those alternatives that remove wastes and toxic sediments from the aquatic environment and effectively treat or contain them in confined disposal facilities. Moderate ranks are assigned to alternatives that effectively cap or contain sediments in place and prevent human and ecological exposures. Lower long-term effectiveness rankings are applied for technologies such as EMNR, MNR, and institutional controls. The regulations recognize that, in most cases, the cleanup alternatives will combine multiple technologies to accomplish the cleanup action objectives.

The long-term effectiveness factor has been given a weighting of 30 percent, the highest of the criteria. This relatively high factor reflects that the long-term outcome is of primary importance when assessing the value of an alternative.

5.2.3 Implementability

Implementability is an overall metric expressing the relative difficulty and uncertainty of implementing the cleanup action. Evaluation of implementability includes consideration of technical factors such as the availability of mature technologies, materials, and experienced contractors to accomplish the cleanup work. Implementability is also related to project duration in that longer construction projects can have significantly more impact on the access to and use of the bay for recreational and tribal fishing and shellfish harvest activities, and thus are more difficult to implement from a coordination standpoint, particularly when construction spans multiple in-water work seasons and must start and stop a number of times before completion. The evaluation of implementability also includes administrative factors associated with the ability and time required to obtain any necessary approvals and permits from other agencies for the cleanup activities.

Implementability has been given a weighting factor of 20 percent in the overall scoring. This weighting factor recognizes the important real-world considerations surrounding implementability in that alternatives with low implementability scores have a very low likelihood of actually being accomplished on the ground.

5.2.4 Cost

The analysis of cleanup action alternative costs includes all costs associated with implementing an alternative, including design, construction, long-term monitoring, and institutional controls. Costs between the different alternatives are compared to assist in the overall analysis of relative costs and benefits of the alternatives. The costs to implement an alternative include the net present value of any long-term costs (e.g., operation and maintenance, monitoring, equipment replacement, and maintaining institutional controls), along with agency oversight costs. Cost estimates for removal and disposal technologies include processing, analytical, labor, and waste management costs.

The FS scoring for cost was based on the overall cost per acre of each alternative. Alternatives that cost less than $250,000 per acre were assigned the highest score, and those that cost more than $1 million per acre were assigned the lowest score according to the scheme presented in Table 5-1.

Table 5-1
Evaluation Scoring for Estimated Cost

Evaluation Score	Estimated Cost Range
1	Greater than $1 million/acre
2	$750,000 to $1 million/acre
3	$500,000 to $750,000/acre
4	$250,000 to $500,000/acre
5	Less than $250,000/acre

Cost has been given a weighting factor of 25 percent. This relatively high factor is a reflection of the reality that cleanup funds, from both a private and public perspective, are limited. The intent of this weighting factor is to balance cost-effectiveness against the benefits associated with the other assessment criteria.

5.2.5 Consideration of Public Concerns

The public involvement process under SMS is used to identify potential public concerns regarding cleanup action alternatives. The extent to which an alternative addresses those concerns is considered as part of the evaluation process. This includes concerns raised by individuals, community groups, local governments, tribes, federal and state agencies, local businesses, and other organizations with an interest in the site. Potential impacts to cultural resources from a given remedy and potential impacts to tribal use of the bay during remedy implementation are considered under this evaluation criterion. Ecology will continue to evaluate public concerns through the public involvement process as the CAP is developed.

Input from members of the community is used to shape the remedial actions with respect to timing, local or cultural considerations, effects from disturbances including noise, light, and traffic that result from implementation methods or transportation routes, etc. It is recognized that different members of the community may have different priorities, and these priorities may or may not be aligned with the goals of the cleanup and/or the specific requirements of SMS.

The weighting factor for community concerns is 5 percent in selecting the preferred alternative. However, substantial input was received during the RI/FS process that has been carefully taken into account in designing the remedial investigations and developing the alternatives. In addition, tribal, federal, state, and local government involvement will occur during planning, design, and implementation of the preferred alternatives to ensure that cultural and community impacts are minimized and that all applicable regulations and guidance are followed.

5.2.6 Use of Recycling, Reuse, and Waste Minimization

The use of recycling, reuse, and waste minimization for a given alternative considers whether materials can effectively be beneficially reused. Opportunities include beneficial use of woody debris and/or intertidal sediments dredged or excavated during cleanup actions, and beneficial reuse of suitable dredged sediments for residuals cover or cap materials that would otherwise be disposed of in a DMMP open-water disposal site. Finally, there may be opportunities to beneficially reuse wooden demolition debris (including wharf structures and/or creosoted piles) as fuel for power generation. Specific beneficial reuse opportunities for sediment or demolition materials have not been identified for this FS, although they have been demonstrated previously as discussed in Section 4. Beneficial reuse of suitable sediments for cover and cap material can result in significant cost efficiency and is desirable from a resource standpoint. Ecology, DNR, and OPG will continue to explore opportunities and sources of beneficial reuse materials in greater detail during remedial design.

A weighting factor of 5 percent was selected for this evaluation criterion. While the use of recycling and waste minimization in the context of a cleanup is an important goal, recycling and waste minimization are inherent to efficient and cost-effective construction projects, and there will be a natural tendency to maximize this element of a project during implementation.

5.2.7 Consideration of Environmental Impacts

Environmental impacts are associated with construction activities during remedy implementation. Per SMS, this evaluation should consider the following:

- Significant short-term environmental impacts
- Significant long-term environmental impacts
- Significant irrevocable commitments of natural resources
- Significant environmental impacts that cannot be mitigated

Short term-impacts to water quality, including turbidity and ammonia or sulfide release associated with dredging and turbidity associated with capping, are considered under this criterion. In addition, emissions related to the construction activity, both on the water and off site (through transloading and shipment of materials) are also considered. Irrevocable commitments of natural resources are also considered, such as the use of aggregates from commercial or other sources for cap material and the use of fossil fuel for construction equipment.

Environmental impacts were given a weighting factor of 5 percent. This relatively low factor reflects the fact that environmental impacts are also considered, to some degree, under the evaluation of short-term effectiveness, implementability, consideration of public concerns, and the use of recycling and waste minimization. In addition, a SEPA evaluation will be conducted along with or prior to the CAP.

5.3 Technical Practicability Evaluation

For a given SMA where no alternative can practicably achieve cleanup standards within a 10-year time frame, the SMS allows for establishment of a sediment recovery zone (WAC 173-205-590) provided that the establishment of the sediment recovery zone "shall not be used as a substitute for active cleanup actions, when such actions are practicable and meet the standards of WAC 173-204-580." Where a sediment recovery zone is proposed, the cleanup study plan shall include a discussion of the following:

- The time period during which a sediment recovery zone is projected to be necessary
- The legal location and landowner(s) of property proposed as a sediment recovery zone
- Operational terms and conditions including, but not limited to, proposed monitoring actions for the sediment recovery zone
- Potential risks posed by the proposed sediment recovery zone to human health and the environment
- The technical practicability of elimination or reduction of the size and/or degree of chemical contamination and/or level of biological effects within the proposed sediment recovery zone
- Current and potential use of the sediment recovery zone, surrounding areas, and associated resources that are, or may be, affected by releases from the zone
- The need for institutional controls or other site use restrictions to reduce site contamination risks to human health

As discussed in Section 6 of this FS, a technical practicability evaluation was performed for SMA-5, in which no alternative can reasonably achieve the site-specific cleanup standards within the 10-year time frame. The practicability evaluation considers environmental effects, technical feasibility, and cost, as defined under SMS (WAC-173-204-200(19)) for construction of either a dredging, capping or EMNR remedy in SMA-5.

6 DEVELOPMENT AND EVALUATION OF CLEANUP ACTION ALTERNATIVES

In this section, the technologies and process options for cleanup technologies retained through the screening evaluation described in Section 4 are used to develop alternatives to address the cleanup action objectives for impacted areas and media at the Site. This section also provides a comparative analysis of the cleanup action alternatives. Each alternative addresses impacted media with a combination of technologies appropriate for Site conditions.

The cleanup action alternatives developed in this section are based on conceptual-level designs for the implementation of individual technologies described in Section 4. The design parameters used to develop the alternatives are based on engineering judgment and current knowledge of Site conditions. The final design for the preferred alternatives may require additional characterization and analysis to refine the scope and costs associated with the selected cleanup action.

This section describes the cleanup action alternatives, an initial screening of appropriate remedial technologies for each SMA, and the evaluation and comparison of the alternatives. A summary of the evaluation is presented in Table 6-1. Estimated costs for the alternatives are summarized in Table 6-2, and estimated volumes and durations for the alternatives are summarized in Table 6-3.

Table 6-1
Alternative Scoring Summary

		Protection of Human Health and the Environment[a]			Attainment of Cleanup Standards and Compliance with Laws[b]		Short-term Effectiveness[c]			Long-term Effectiveness[d]					Ability to be Implemented[e]				Cost[f]	Community Concerns[g]	Recycling, Reuse, Waste Min.[h]	Environmental Impacts[i]	
SMA	Alternative	Human Health	Environment	Time to Achieve Standards	Cleanup Standards	Applicable laws	Human Health	Environment	Score	Environment	Human Health	Certainty and Reliability	Residual Risks	Score	Technical Feasibility	Availability of Materials, Land, etc.	Permitting and Regulatory	Score	Estimated Average Cost Score	Score	Score	Score	Total Score
Mill Site North	1 - Dredge	Y	Y	Y	Y	Y	3	4	**3.5**	5	5	4	4	**4.5**	4	5	5	**4.7**	**1**	5	**2**	**4**	**69**
	2 - Dredge and Cap	Y	Y	Y	Y	Y	4	4	**4.0**	5	5	4	3	**4.3**	4	5	5	**4.7**	**2**	3	**3**	**4**	**72**
	3 - Cap	Y	Y	Y	Y	Y	5	4	**4.5**	4	5	3	3	**3.8**	5	5	5	**5.0**	**3**	1	**3**	**4**	**75**
	4 - Cap and EMNR	Y	Y	Y	Y	Y	5	5	**5.0**	3	5	2	2	**3.0**	5	5	5	**5.0**	**3**	1	**3**	**4**	**71**
Mill Site South	1 - Dredge	Y	Y	Y	Y	N	1	1	**1.0**	5	5	4	4	**4.5**	3	2	4	**3.0**	**1**	5	**2**	**1**	**54**
	2 - Dredge and Cap	Y	Y	Y	Y	Y	2	1	**1.5**	5	5	4	3	**4.3**	3	3	5	**3.7**	**1**	4	**3**	**3**	**58**
	3 - Dredge and Cap II	Y	Y	Y	Y	Y	3	2	**2.5**	4	5	4	3	**4.0**	4	4	5	**4.3**	**2**	3	**4**	**3**	**66**
	4 - Dredge, Cap, and EMNR	Y	Y	Y	Y	Y	4	4	**4.0**	4	5	4	3	**4.0**	4	4	5	**4.3**	**3**	2	**4**	**4**	**74**
	5 - Cap	Y	Y	Y	Y	Y	5	5	**5.0**	4	5	3	3	**3.8**	5	4	5	**4.7**	**4**	1	**5**	**3**	**80**
	6 - Cap and EMNR	Y	Y	Y	Y	Y	5	5	**5.0**	3	5	2	1	**2.8**	5	4	5	**4.7**	**4**	1	**5**	**4**	**75**
Central Bay	1 - Dredge	Y	Y	Y	Y	N	1	1	**1.0**	5	5	2	4	**4.0**	2	1	2	**1.7**	**2**	2	**2**	**1**	**48**
	2 - Cap	Y	Y	Y	Y	Y	5	3	**4.0**	4	5	4	3	**4.0**	4	3	5	**4.0**	**5**	3	**5**	**2**	**83**
	3 - EMNR	Y	Y	Y	Y	Y	5	5	**5.0**	3	5	4	2	**3.5**	5	4	5	**4.7**	**5**	4	**5**	**3**	**87**
	4 - MNR	N	N	N	N	N	1	1	**1.0**	2	1	1	1	**1.3**	5	5	5	**5.0**	**5**	1	**1**	**5**	**62**
FLA	1 - Dredge	Y	Y	Y	Y	Y	1	1	**1.0**	5	5	5	4	**4.8**	3	3	5	**3.7**	**2**	4	**2**	**3**	**64**
	2 - Cap	Y	Y	Y	Y	Y	5	4	**4.5**	4	5	5	3	**4.3**	4	5	5	**4.7**	**5**	4	**5**	**4**	**91**
	3 - EMNR	Y	Y	Y	Y	Y	5	5	**5.0**	4	5	4	3	**4.0**	5	5	5	**5.0**	**5**	3	**5**	**4**	**91**
	4 - MNR	N	N	N	N	N	1	1	**1.0**	2	1	1	1	**1.3**	5	5	5	**5.0**	**5**	1	**1**	**5**	**62**
Background	1 - Dredge and MNR	N	Y	N	N	N	1	1	**1.0**	3	2	2	4	**2.8**	2	1	2	**1.7**	**2**	1	**2**	**1**	**39**
	2 - Cap and MNR	N	Y	N	N	N	2	2	**2.0**	3	2	3	3	**2.8**	3	2	4	**3.0**	**5**	2	**5**	**2**	**67**
	3 - EMNR and MNR	N	Y	N	N	N	2	3	**2.5**	4	2	2	2	**2.5**	4	3	5	**4.0**	**5**	2	**5**	**3**	**71**
	4 - MNR	N	Y	N	N	N	1	5	**3.0**	5	1	1	1	**2.0**	5	5	5	**5.0**	**5**	1	**1**	**5**	**70**

Notes:

Does not meet threshold criteria
Highest scoring alternatives (within a few points)
Draft preferred alternative

EMNR = enhanced, monitored natural recovery
FLA = former lease area
MNR = monitored natural recovery
SMA = Sediment Management Area

1 = Low
2 = Low-medium
3 = Medium
4 = Medium-high
5 = High

a = Overall protection of human health and the environment, time required to attain the cleanup standard(s), and on-site and off-site environmental impacts and risks to human health resuling from implementing the cleanup alternatives.
b = Attainment of the cleanup standard(s) and compliance with applicable federal, state, and local laws.
c = Short-term effectiveness, including protection of human health and the environment during construction and implementation of the alternative.
d = Long-term effectiveness, including degree of certainty that the alternative will be successful, long-term reliability, magnitude of residual biological and human health risk, and effectiveness of controls for ongoing discharges and/or controls required to manage treatment residues or remaining waste cleanup and/or disposal site risks.
e = Ability to be implemented, including the potential for landowner cooperation, consideration of technical feasibility, availability of needed off-site facilities, services and materials, administrative and regulatory requirements, scheduling, monitoring requirements, access for construction, operations and monitoring, and integration with existing facility operations and other current or potential cleanup actions.
f = Cost, including consideration of present and future direct and indirect capital, operation, and maintenance costs and other foreseeable costs.
g = The degree to which community concerns are addressed.
h = The degree to which recycling, reuse, and waste minimization are employed.
i = Environmental impact. Sufficient information shall be provided to fulfill the requirements of the State Environmental Policy Act. Discussions of significant short-term and long-term environmental impacts, significant irrevocable commitments of natural resources, significant alternatives including mitigation measures, and significant environmental impacts which cannot be mitigated shall be included.

Feasibility Study
Port Gamble Bay
1 of 1
December 2012
080388-01.01

Table 6-2
Estimated Cost Summary

	Estimated Total Cost	Estimated Cost/Acre
Mill Site North - SMA-1 (6 acres)		
Alt 1 - Dredge	$6,600,000	$1,100,000
Alt 2 - Dredge and Engineered Cap	$5,300,000	$880,000
Alt 3 - Engineered Cap	$4,300,000	$720,000
Alt 4 - Engineered Cap and EMNR	$4,200,000	$700,000
Mill Site South - SMA-2 (19 acres)		
Alt 1 - Dredge	$30,700,000	$1,620,000
Alt 2 - Dredge and Engineered Cap I	$21,400,000	$1,130,000
Alt 3 - Dredge and Engineered Cap II	$16,300,000	$860,000
Alt 4 - Dredge, Engineered Cap, and EMNR	$9,600,000	$510,000
Alt 5 - Engineered Cap	$7,100,000	$400,000
Alt 6 - Engineered Cap and EMNR	$7,000,000	$370,000
Central Bay - SMA-3 (77 acres)		
Alt 1 - Dredge	$60,500,000	$790,000
Alt 2 - Engineered Cap	$4,900,000	$60,000
Alt 3 - EMNR	$2,800,000	$40,000
Alt 4 - Monitored Natural Recovery	$300,000	$4,000
Former Lease Area - SMA-4 (19 acres)		
Alt 1 - Dredge	$15,700,000	$830,000
Alt 2 - Engineered Cap	$1,800,000	$90,000
Alt 3 - EMNR	$1,300,000	$70,000
Alt 4 - Monitored Natural Recovery	$150,000	$8,000
Background - SMA-5 (cPAH Area - 196 acres)		
Alt 1 - Dredge	$152,400,000	$780,000
Alt 2 - Engineered Cap	$11,600,000	$60,000
Alt 3 - EMNR	$6,100,000	$30,000
Alt 4 - Monitored Natural Recovery	$400,000	$2,000

Notes:
1. Costs include engineering, design, permitting, and construction management, which range from 25% to 35% of overall total.
2. Estimated costs assume some open-water disposal for dredge material (80% for Mill Site North, 25% for Mill Site South, 50% for all other SMAs), mining of cap and EMNR cover sand from an open-water or beneficial reuse site, and 1.25x scaling factor on preliminary dredge volumes, consistent with recent sediment FS guidance.

Table 6-3
Estimated Volume and Duration Summary

	Dredge Vol (cy)	Cap Vol (ton)	Duration (days)	Duration (seasons)
Mill Site North - SMA 1 (6 acres)				
Alt 1 - Dredge	41,000	6,900	58	0.7
Alt 2 - Dredge and Engineered Cap	18,425	16,400	33	0.4
Alt 3 - Engineered Cap	5,300	26,100	20	0.3
Alt 4 - Engineered Cap and EMNR	5,300	22,500	18	0.2
Mill Site South - SMA 2 (19 acres)				
Alt 1 - Dredge	170,700	23,200	239	3.0
Alt 2 - Dredge and Engineered Cap I	109,000	40,600	166	2.1
Alt 3 - Dredge and Engineered Cap II	71,900	77,000	134	1.7
Alt 4 - Dredge, Engineered Cap, and EMNR	33,200	91,800	90	1.1
Alt 5 - Engineered Cap	9,100	116,400	70	0.9
Alt 6 - Engineered Cap and EMNR	9,100	112,300	68	0.9
Central Bay - SMA 3 (77 acres)				
Alt 1 - Dredge	466,000	93,200	668	8.5
Alt 2 - Engineered Cap	-	186,300	93	1.2
Alt 3 - EMNR	-	93,200	47	0.6
Alt 4 - Monitored Natural Recovery	-	-	-	-
Former Lease Area - SMA 4 (19 acres)				
Alt 1 - Dredge	116,000	23,100	166	2.1
Alt 2 - Engineered Cap	-	46,200	23	0.3
Alt 3 - EMNR	-	23,100	12	0.2
Alt 4 - Monitored Natural Recovery	-	-	-	
Background - SMA-5 (cPAH Area - 196 acres)				
Alt 1 - Dredge	1,190,000	237,900	912	11.5
Alt 2 - Engineered Cap	-	475,900	238	3.0
Alt 3 - EMNR	-	237,900	119	1.5
Alt 4 - Monitored Natural Recovery	-	-	-	-

Notes:
1. Cap production rate assumed to be 2,000 tons/day; fish window assumed to be Nov. 15 to Feb. 15; work week assumed to be 6 days.
2. For SMA-1 through SMA-4, dredge production rate assumed to be 750 cy/day.
3. For SMA-5, dredge production rate assumed to be 1,500 cy/day.
4. Volumes based on "Mid-Range Estimate" scenario from each detail spreadsheet.

6.1 Initial Screening of Technologies for SMAs

While Section 4 provided a general screening for all remedial technologies that would be considered for sediments, the retained technologies were further screened for application to specific SMAs based on SMA-specific considerations. This section provides an initial screening of alternatives relative to the SMAs, and summarizes the alternatives that were carried forward for detailed evaluation.

6.1.1 Mill Site North (SMA-1)

Located in the northern embayment, the Mill Site North SMA (SMA-1) contains a buried deposit of wood chips extending approximately 6 feet below mudline, identified by the existing core data to be primarily located in the shallow subtidal zone (between 4 and 15 feet below MLLW). This SMA is characterized by relatively high surface sediment porewater sulfide concentrations, as well as CSL-level amphipod and SQS-level larval bioassay exceedances (Ecology 2012). The Mill Site North area is also characterized by elevated cPAH in surface sediments, with values ranging from 2 to 6 times above background in this area.

Existing structures in this SMA are supported by creosoted piles. As part of the remedy and for cPAH source control, all creosoted pilings and structures will be removed.

A range of remedial technologies including dredging, dredging combined with engineered containment (dredge and cap), capping, and capping combined with EMNR were evaluated as potentially appropriate remedial alternatives to address wood waste and associated biological impacts in SMA-1.

The engineered cap in SMA-1 would need to be able to attenuate porewater sulfide generated by the biochemical reaction of sulfate in marine water with underlying decomposing wood waste. Based on detailed cap performance modeling conducted for similar projects in the Puget Sound region, an engineered cap in the absence of dredging (which would remove sulfide source material) may need to provide an approximate 5- to 10-foot-long flow path of clean sand to attenuate sulfide, which can often be achieved with a 1- to 4-foot-thick cap (e.g., Anchor and Aspect 2004). The protectiveness of the 1- to 4-foot-thick caps as they relate to site-specific flow paths and tidal flux would be confirmed during remedial design.

EMNR and MNR do not address the sulfide impacts from the wood waste area of the Mill Site North. Thus, both of these technologies will only be considered protective outside of the footprint of the chip deposit in SMA-1.

6.1.1.1 Dredge Alternative Description

Geophysical survey and sediment coring work performed in the northern embayment identified a concentrated shallow subtidal deposit of wood chips within the footprint of the former chip loading facility. This deposit is located directly below surface sediments containing elevated porewater sulfide concentrations. Removal of this wood chip deposit, as well as removal of sediments that exceed site-specific cleanup levels in the biologically active zone, is the goal of the SMA-1 dredging alternative. Dredging in SMA-1 entails the following major elements:

- Demolition and removal of the existing creosoted structures and piles as practicable, or cut off to a depth of 2 feet below the sediment surface in SMA-1.
- Dredging of approximately 10,000 to 15,000 cy (including overdredge allowances) of wood chips and associated shallow subtidal (and possibly intertidal) sediments located in the vicinity of the former chip loading dock. Based on the combined sediment coring and sub-bottom profiling data, which delineated the extent of wood chips in SMA-1, dredging would extend over an area of approximately 0.9 acres.
- Dredging of 22,000 to 35,000 cy (including overdredge allowances) of sediments outside the footprint of the chip deposit throughout the remainder of the SMA. The FS assumes a target depth of 2 feet, with a 1-foot allowable overdepth for volume estimates.
- Screening and removal of debris for upland disposal.
- Transport and disposal of suitable dredge material at a non-dispersive DMMP open-water disposal site—presumed to be Port Gardner in Everett. While early DMMP screening performed on the approximately 10,000 to 15,000 cy of wood chips and associated shallow subtidal sediments located in the vicinity of the former chip loading dock indicates that these materials are likely suitable for open-water disposal,

sediments outside of the chip footprint have not been tested relative to DMMP criteria. In addition, although SMA-1 surface sediment cPAH levels are above human health risk levels, wood chips and associated shallow subtidal sediments near the former chip loading dock are below DMMP screening criteria. The percentage of SMA-1 dredge material considered "suitable" for open-water disposal is a partial data gap, due in part to evolving agency guidance on appropriate dioxin/furan levels. This FS assumes that roughly 80 percent of SMA-1 dredge material would be suitable for open-water disposal, with the remaining unsuitable material disposed of off-site in an upland landfill. The suitability of material for disposal at a DMMP open-water site requires evaluation for protection of the benthic community and may differ from levels established based on protection of human health at the reasonable maximum exposure scenario.

- Placing a nominal 6-inch-thick post-dredge residuals cover over the dredge footprint.
- Performing compliance monitoring to assess the effectiveness of this remedy.

The estimated construction duration of this remedial alternative is approximately 3 months (Table 6-3). Figure 6-1 presents the Dredge alternative in SMA-1.

6.1.1.2 Dredge and Cap Alternative Description

Focused removal of the wood chip deposit is the goal of the SMA-1 dredge and cap alternative. The geophysical survey delineated the general limits of the wood chip deposit; coring data collected in this area verified the accuracy of this delineation within SMA-1. Dredging and capping in SMA-1 entails the following major elements:

- Demolition and removal of creosoted structures and piling in SMA-1.
- Intertidal excavation and upland reuse and/or disposal of sediments. Depending on the distributions of chemical concentrations within the intertidal area, up to approximately 5,000 cy of material may need to be excavated (likely using upland-based equipment operating during relatively low tidal conditions) to a depth of 2 feet below the existing sediment surface. This material may either be reused as appropriate in upland areas near the Site, or disposed of off-site in an upland landfill. Screening-level sampling and testing in the intertidal sediments from SMA-1 conducted by OPG/PR suggests that dioxin and/or cPAH concentrations in these materials may exceed MTCA soil cleanup levels for unrestricted residential use, but

are likely within protective levels for potential park, open-space, commercial, or other non-ground-floor residential uses if appropriately confined and subjected to institutional controls.

- Dredging of approximately 10,000 to 15,000 cy (including overdredge allowances) of wood chips and associated sediments located in the vicinity of the former chip loading dock.
- Screening and removal of debris for upland disposal.
- Transport and disposal of suitable dredge material at a non-dispersive DMMP open-water disposal site, if suitable.
- Placing a nominal 6-inch-thick post-dredge residuals cover over the dredge footprint.
- Placing a nominal 2-foot-thick post-excavation backfill over the intertidal excavation footprint.
- Placing a nominal 1-foot-thick benthic cap over the remainder of the SMA to manage sediments that exceed cleanup levels.
- Implementing institutional controls for the area where caps are used. Institutional controls would, at a minimum, include a site use and deed restriction.
- Performing long-term monitoring to assess the effectiveness of this remedy.

The estimated construction duration of this remedial alternative is approximately 2 months (Table 6-3). Figure 6-2 presents the Dredge and Cap alternative in SMA-1.

6.1.1.3 Cap Alternative Description

A cap-only alternative in SMA-1 will require consideration of a thicker cap over the shallow subtidal chip deposit due to tidal pumping in this zone, which will need to be attenuated to reduce porewater sulfide levels to below the DMMP screening criterion of 3.4 mg/L. The capping alternative in SMA-1 entails the following major elements:

- Demolition and removal of creosoted structures and piles as practicable, or cut off to a depth of 2 feet below the sediment surface, in SMA-1.
- Intertidal excavation and upland reuse and/or disposal (as appropriate) of an estimated 5,000 cy of sediments.

- Placing a nominal 4-foot-thick benthic cap over the chip deposit to separate sediments containing elevated porewater sulfide levels, prevent tidal inundation into this deposit, and attenuate the generation of porewater sulfide within the cap.
- Placing a nominal 2-foot-thick post-excavation backfill over the intertidal excavation footprint.
- Placing a nominal 1-foot-thick benthic cap over the remainder of the SMA to manage sediments that exceed cleanup levels.
- Implementing institutional controls for the area where caps are used. Institutional controls would, at a minimum, include a site use and deed restriction.
- Performing long-term monitoring to assess the effectiveness of this remedy.

The estimated construction duration of this remedial alternative is approximately 1 to 2 months (Table 6-3) provided that a sufficient supply of sand can be procured over this time frame (see Section 4). Figure 6-3 presents the Cap alternative in SMA-1.

6.1.1.4 Cap and EMNR Alternative Description

A cap and EMNR alternative in SMA-1 makes use of EMNR outside of the footprint of the chip deposit with the intent of accelerating recovery of those areas where bioassay results indicate exceedance of cleanup levels. This alternative includes:

- Demolition and removal of creosoted structures and piles as practicable, or cut off to a depth of 2 feet below the sediment surface, in SMA-1.
- Intertidal excavation and upland beneficial reuse and/or disposal (as appropriate) of an estimated 5,000 cy of sediments.
- Placing a nominal 4-foot-thick benthic cap over the chip deposit to separate sediments containing elevated porewater sulfide levels, prevent tidal inundation into this deposit, and attenuate the generation of porewater sulfide within the cap.
- Placing a nominal 2-foot-thick post-excavation backfill over the intertidal excavation footprint.
- Placing a nominal 6-inch-thick EMNR cover over the remainder of the SMA to accelerate recovery of sediments that exceed cleanup levels.
- Implementing institutional controls for the area where caps are used. Institutional controls would, at a minimum, include a site use and deed restriction.
- Performing long-term monitoring to assess the effectiveness of this remedy.

The estimated construction duration of this remedial alternative is approximately 1 month (Table 6-3) provided that a sufficient supply of sand can be procured over this time frame. Figure 6-4 presents the Cap and EMNR alternative in SMA-1.

6.1.2 Mill Site South (SMA-2)

Located in the southern embayment, the Mill Site South SMA (SMA-2) also contains a buried deposit of wood chips in shallow subtidal and deeper subtidal zones that averages approximately 5 to 10 feet thick depending on location. Unlike SMA-1, the thicker portion of the deposit is located in deeper water (more than 20 feet below MLLW). Porewater sulfide has not been detected in samples collected from deeper areas of this SMA (below -20 feet MLLW), but evidence for the presence of sulfides (e.g., *Beggiatoa* colonies) was evident at shallower depths (above -20 feet MLLW) in underwater videos obtained during the 2007 dredging event. While lower surface sediment porewater sulfide concentrations were reported throughout SMA-2 (Ecology 2012), the presence of subsurface *Beggiatoa* mats in the wood waste in this area indicates similar dynamics to SMA-1, particularly within the shallow subtidal zone (between -4 and -20 feet MLLW).

A range of remedial technologies including dredging, dredge and cap (three different dredge footprints), capping, and capping combined with EMNR were identified as potentially appropriate remedial alternatives to address wood waste and associated biological impacts in SMA-2.

6.1.2.1 Dredge Alternative Description

This alternative targets full removal of potentially impacted sediments within the footprint of SMA-2. Dredging to the maximum extent practicable in SMA-2 entails the following major elements:

- Demolition and removal of creosoted structures and existing creosoted piles as practicable, or cut off to a depth of 2 feet below the sediment surface, in SMA-2.
- Dredging an estimated 90,000 to 130,000 cy (including overdredge allowances) of wood chips, sawdust, bark, and associated sediments with TVS exceeding 15 percent.

- Dredging an estimated 50,000 to 70,000 cy of additional sediments that exceed cleanup levels over the remainder of the SMA footprint.
- Screening and removal of debris for upland disposal.
- Transport and disposal of suitable dredge material at a non-dispersive DMMP open-water disposal site. The percentage of SMA-2 dredge material potentially "suitable" for open-water disposal is currently not well characterized. However, preliminary screening of SMA-2 sediments conducted by OPG/PR suggests that only roughly 25 percent of the entire SMA-2 sediment dredge prism under this alternative would likely be suitable for open-water disposal due to elevated PAH and/or dioxin/furan concentrations. Thus, the FS assumes that 25 percent of SMA-2 dredge material would be suitable for open-water disposal, with the remaining unsuitable material disposed of off-site in an upland landfill.
- Placing a nominal 6-inch-thick post-dredge residuals cover over the dredge footprint.
- Performing compliance monitoring to assess the effectiveness of this remedy.

The estimated construction duration of this remedial alternative is approximately 3 years (Table 6-3), considering the anticipated in-water construction windows that are typically required for marine construction projects, which would require significant stretches of time (February 15 to November 15, based on past experience in this area) when in-water construction would not be allowed. Figure 6-5 presents the conceptual Dredge alternative for SMA-2.

6.1.2.2 Dredge and Cap Alternative Description

The Dredge and Cap alternative considers a reduced dredge footprint that is focused on the estimated area of sediments exceeding the 15 percent TVS criterion in SMA-2, with the additional overlay that the area of the 2007 Interim Action would be re-visited by placing a nominal 6-inch-thick cover of clean EMNR sediment. Areas outside of the 15 percent TVS footprint are addressed either with an intertidal dredge and cap action, or a cap action. The Dredge and Cap alternative in SMA-2 entails the following major elements:

- Demolition and removal of creosoted structures and all creosoted piles as practicable, or cut off to a depth of 2 feet below the sediment surface, in SMA-2.

- Intertidal excavation and upland reuse and/or disposal of sediments. Based on screening-level sampling conducted by OPG/PR within the intertidal area, up to 9,000 cy of material may need to be excavated (likely using upland-based equipment operating during relatively low tidal conditions) to a depth of 2 feet below mudline. This material may either be reused as appropriate in upland areas near the Site, or disposed off-site in an upland landfill.
- Dredging an estimated 80,000 to 120,000 cy (including overdredge allowances) of wood chips and sediments with TVS exceeding 15 percent.
- Screening and removal of debris for upland disposal.
- Transport and disposal of suitable dredge material at a non-dispersive DMMP open-water disposal site, and upland beneficial reuse or disposal for material that is not suitable.
- Placing a nominal 6-inch-thick post-dredge residuals cover over the dredge footprint and the previously dredged area.
- Placing a nominal 2-foot-thick post-excavation backfill over the intertidal and shallow subtidal excavation footprint.
- Placing a nominal 1-foot-thick benthic cap over the remainder of the SMA to manage sediments that exceed cleanup levels.
- Implementing institutional controls for the area where caps are used. Institutional controls would, at a minimum include a site use and deed restriction.
- Performing long-term monitoring to assess the effectiveness of this remedy.

The estimated construction duration of this remedial alternative is approximately 2 years (Table 6-3), with consideration of anticipated in-water work windows as described previously, and provided that a sufficient supply of sand can be procured over this time frame. Figure 6-6 presents the conceptual Dredge and Cap alternative in SMA-2.

6.1.2.3 Dredge and Cap II Alternative Description

The Dredge and Cap II alternative considers a smaller dredge footprint than the Dredge and Cap alternative for SMA-2. Dredging in this alternative is focused on the estimated area of sediments exceeding TVS criteria in the north area of SMA-2, where chip deposits are thicker and potentially more affected by tidal pumping, particularly within the shallow subtidal zone. This alternative also includes the additional overlay of the 2007 Interim Action being addressed with a nominal 6-inch-thick cover of clean EMNR sediment. TVS areas that are not dredged in the Dredge and Cap II Alternative would receive a 4-foot-thick benthic cap due to the potential presence of geoducks in this area and the remaining wood waste deposits in the sediments. Areas outside of the TVS footprint are addressed either with an intertidal dredge and backfill action, or a 1-foot-thick benthic cap. The Dredge and Cap II alternative in SMA-2 entails the following major elements:

- Demolition and removal of creosoted structures and all creosoted piles as practicable, or cut off to a depth of 2 feet below the sediment surface, in SMA-2.
- Intertidal excavation and upland beneficial reuse and/or disposal (as appropriate) of an estimated 9,000 cy of sediments.
- Dredging an estimated 50,000 to 75,000 cy (including overdredge allowances) of wood chips and sediments from the northern area of the SMA where TVS exceeds 15 percent.
- Screening and removal of debris for upland disposal.
- Transport and disposal of suitable dredge material at a non-dispersive DMMP open-water disposal site.
- Beneficial reuse and/or upland disposal for materials determined unsuitable for DMMP open-water disposal.
- Placing a nominal 6-inch-thick post-dredge residuals cover over the dredge footprint and previously dredged area.
- Placing a nominal 2-foot-thick post-excavation backfill over the intertidal and shallow subtidal excavation footprint.
- Placing a nominal 4-foot-thick cap over areas exceeding 15 percent TVS that are not dredged.
- Placing a nominal 1-foot-thick benthic cap over the remainder of the SMA to manage sediments that exceed cleanup levels.
- Implementing institutional controls for the area where caps are used. Institutional controls would, at a minimum, include a site use and deed restriction.
- Performing long-term monitoring to assess the effectiveness of this remedy.

The estimated construction duration of this remedial alternative is approximately 1.5 to 2 years (Table 6-3), with consideration of anticipated in-water work windows as described previously, and provided that a sufficient supply of sand can be procured over this time frame. Figure 6-7 presents the conceptual Dredge and Cap II alternative in SMA-2.

6.1.2.4 Dredge, Cap, and EMNR Alternative Description

The Dredge, Cap, and EMNR alternative in SMA-2 considers a smaller dredge footprint than the Dredge and Cap II alternative. Dredging in this alternative is focused on the estimated area of sediments exceeding TVS criteria in the north area of SMA-2, at elevations shallower than -20 feet MLLW (Figure 6-8), to focus dredging within the more productive photic zone and also to target the zone of elevated sulfide concentrations, while concurrently minimizing dredging of relatively deeply buried sediments that are likely unsuitable for open-water disposal due to elevated cPAH and dioxin/furan levels. Based on preliminary screening-level sampling conducted by OPG/PR, approximately 50 percent of SMA-2 dredge material under this alternative could potentially be suitable for open-water disposal, with the remaining unsuitable material either beneficially reused near the site or disposed off-site in an upland landfill. This alternative also includes the additional overlay of the 2007 Interim Action being addressed with a nominal 6-inch-thick cover of clean EMNR sediment. Areas with TVS concentrations above 15 percent that are not dredged in the Dredge, Cap, and EMNR Alternative would receive a 4-foot-thick benthic cap due to the potential presence of geoducks in this area and the remaining wood waste deposits in the sediments. Areas outside of the TVS footprint are treated either with an intertidal dredge and cap action, or a 6-inch-thick EMNR cover. The Dredge, Cap, and EMNR alternative in SMA-2 entails the following major elements:

- Demolition and removal of creosoted structures and all creosoted piles as practicable, or cut off to a depth of 2 feet below the sediment surface, in SMA-2.
- Intertidal excavation and upland beneficial reuse and/or disposal (as appropriate) of an estimated 9,000 cy of sediments.
- Dredging an estimated 20,000 to 30,000 cy (including overdredge allowances) of wood chips and sediments from the northern area of the SMA where TVS exceeds 15 percent and sediments are inshore of -20 feet MLLW.
- Screening and removal of debris for upland disposal.
- Transport and disposal of suitable dredge material at a non-dispersive DMMP open-water disposal site.

- Beneficial reuse and/or upland disposal for material determined unsuitable for DMMP open-water disposal.
- Placing a nominal 6-inch-thick post-dredge residuals cover over the dredge footprint and previously dredged area.
- Placing a nominal 2-foot-thick post-excavation backfill over the intertidal excavation footprint.
- Placing a nominal 4-foot-thick cap over areas exceeding 15 percent TVS that are not dredged, (i.e., areas offshore of -20 feet MLLW).
- Placing a nominal 6-inch-thick clean cover for EMNR over the remainder of the SMA.
- Implementing institutional controls for the area where caps are used. Institutional controls would, at a minimum, include a site use and deed restriction.
- Performing long-term monitoring to assess the effectiveness of this remedy.

The estimated construction duration of this remedial alternative is approximately 1 year (3 months of in-water work, Table 6-3) provided that a sufficient supply of sand can be procured over this time frame. Figure 6-8 presents the conceptual Dredge, Cap, and EMNR alternative in SMA-2.

6.1.2.5 Cap Alternative Description

The Cap alternative focuses on containment of sediments in SMA-2. Limited excavation of the intertidal area is assumed so as to accommodate a cap in this area without modifying the location of the ordinary high water line. As with the Dredge and Cap alternatives, this alternative includes the additional overlay of the 2007 Interim Action being addressed with a nominal 6-inch-thick cover of clean EMNR sediment. The Cap alternative in SMA-2 entails the following major elements:

- Demolition and removal of creosoted structures and all creosoted piles as practicable, or cut off to a depth of 2 feet below the sediment surface, in SMA-2.
- Intertidal excavation and upland beneficial reuse and/or disposal (as appropriate) of an estimated 9,000 cy of sediments.
- Placing a nominal 2-foot-thick post-excavation backfill over the intertidal excavation footprint.

- Placing a nominal 4-foot-thick cap over areas that exceed TVS criteria.
- Placing a nominal 6-inch-thick clean cover for EMNR over the 2007 Interim Action footprint.
- Placing a nominal 1-foot-thick cap over the remainder of the SMA.
- Implementing institutional controls for the area where caps are used. Institutional controls would, at a minimum, include a site use and deed restriction.
- Performing long-term monitoring to assess the effectiveness of this remedy.

The estimated construction duration of this remedial alternative is approximately 3 months (Table 6-3) provided that a sufficient supply of sand can be procured over this time frame. Figure 6-9 presents the conceptual Cap alternative in SMA-2.

6.1.2.6 Cap and EMNR Alternative Description

The Cap and EMNR alternative provides focused containment in TVS exceedance areas, and supplements this action with EMNR to accelerate recovery in the remaining area of the SMA, as well as the 2007 Interim Action area. The Cap and EMNR alternative in SMA-2 entails the following specific elements:

- Demolition and removal of creosoted structures and all creosoted piles as practicable, or cut off to a depth of 2 feet below the sediment surface, in SMA-2.
- Intertidal excavation and upland beneficial reuse and/or disposal (as appropriate) of an estimated 9,000 cy of sediments.
- Placing a nominal 2-foot-thick post-excavation backfill over the intertidal excavation footprint.
- Placing a nominal 4-foot-thick cap over areas that exceed 15 percent TVS.
- Placing a nominal 6-inch-thick clean cover for EMNR over the remainder of the SMA, including the 2007 Interim Action footprint.
- Implementing institutional controls for the area where caps are used. Institutional controls would, at a minimum, include a site use and deed restriction.
- Performing long-term monitoring to assess the effectiveness of this remedy.

The estimated construction duration of this remedial alternative is approximately 3 months (Table 6-3) provided that a sufficient supply of sand can be procured over this time frame. Figure 6-10 presents the conceptual Cap and EMNR alternative in SMA-2.

6.1.3 Central Bay (SMA-3)

The Central Bay SMA (SMA-3) is a 77-acre area in the south-central bay that is characterized by surface sediment samples that exceed SQS criteria based on bioassay testing, contains somewhat elevated concentrations of wood waste breakdown products, and also exceeds criteria for protection of human health. A range of alternatives, including dredging, capping, EMNR, and MNR were evaluated for this SMA.

6.1.3.1 Dredge Alternative Description

Dredging in SMA-3 entails removal of an assumed 2-foot-thick surface layer of sediment, with a 1-foot allowable overdepth. The specific activities included in the FS for this alternative include:

- Dredging an estimated 375,000 to 560,000 cy (including overdredge allowances) of surface sediment across the SMA.
- Screening and removal of debris for upland disposal.
- Transport and disposal of suitable dredge material at a non-dispersive DMMP open-water disposal site. The percentage of SMA-3 dredge material potentially “suitable” for open-water disposal is not known, as this material has not been screened against DMMP criteria. However, the FS assumes that 50 percent of SMA-3 dredge material could potentially be suitable for open-water disposal, with the remaining unsuitable material disposed off-site in an upland landfill.
- Placing a nominal 6-inch-thick post-dredge residuals cover over the dredge footprint.
- Performing compliance monitoring to assess the effectiveness of this remedy.

The estimated construction duration of this remedial alternative is approximately 4 to 5 years (Table 6-3), considering the anticipated in-water construction windows that are typically required for marine construction projects, which would require significant stretches of time (February 15 to November 15, based on past experience in this area) when in-water construction would not be allowed. This equates to dredging approximately 100,000 cy of material per season, which is within the range of demonstrated production on other large-scale Puget Sound remedial dredging projects. Figure 6-11 presents the conceptual Dredge alternative for SMA-3.

6.1.3.2 Cap Alternative Description

Capping in SMA-3 entails placement of an assumed 1-foot-thick surface layer of clean sand to contain sediments within the 77-acre footprint. The specific activities included in the FS for this alternative include:

- Procuring and placing 180,000 to 200,000 tons of clean beneficial reuse sand to cap the SMA footprint.
- Implementing institutional controls for the cap area. Institutional controls would, at a minimum, include a site use and deed restriction.
- Performing long-term monitoring to assess the effectiveness of this remedy.

The estimated construction duration of this remedial alternative is approximately 1 year (3 months of in-water construction, Table 6-3) provided that a sufficient supply of sand can be procured over this time frame. Figure 6-12 presents the conceptual Cap alternative footprint for SMA-3.

6.1.3.3 EMNR Alternative Description

The EMNR alternative in SMA-3 entails placement of a nominal 6-inch-thick surface layer of clean sand to accelerate the recovery of sediments within the 77-acre SMA footprint. The specific activities included in the FS for this alternative include:

- Procuring and placing 90,000 to 100,000 tons of clean beneficial reuse sand for EMNR cover within the SMA.
- Performing long-term monitoring to assess the effectiveness of this remedy.

The estimated construction duration of this remedial alternative is approximately 2 months (Table 6-3) provided that a sufficient supply of sand can be procured over this time frame. Figure 6-13 presents the conceptual EMNR alternative footprint for SMA-3.

6.1.3.4 MNR Alternative Description

The MNR remedy in SMA-3 does not entail active construction. Rather, MNR would consist of a series of sediment monitoring events at a scope and frequency defined in the CAP to verify the anticipated continued recovery of the benthic community and reduction of concentrations of bioaccumulative chemicals of concern to the site-specific cleanup standards due to natural processes (sedimentation, bioturbation, and biodegradation). Similar to the EMNR alternative, long-term monitoring would be performed at 5- to 10-year intervals over a 20- to 30-year period (with more extensive sampling and analysis at approximately $50,000 per event), and would be defined in more detail in the CAP. If the MNR alternative were selected, the CAP would include clear endpoints and timeframes for measuring success and triggers for initiating more active alternatives if recovery is not occurring in a reasonable timeframe.

6.1.4 Former Lease Area (SMA-4)

The FLA (SMA-4) includes approximately 19.1 acres of Port Gamble Bay adjacent to the western shoreline near the south end of the Site. This area is characterized by SQS bioassay exceedances, elevated levels of wood waste breakdown products, and bioaccumulative contaminants above human health-based cleanup standards (Ecology 2012). A range of alternatives, including dredging, capping, EMNR, and MNR were evaluated for this SMA.

6.1.4.1 Dredge Alternative Description

Dredging in SMA-4 entails removal of an assumed 2-foot-thick surface layer of sediment, with a 1-foot allowable overdepth. The specific activities included in the FS for this alternative include:

- Removal of creosoted pilings throughout the entire SMA.
- Dredging an estimated 90,000 to 140,000 cy (including overdredge allowances) of surface sediment across the SMA.
- Screening and removal of debris for upland disposal.
- Transport and disposal of suitable dredge material at a non-dispersive DMMP open-water disposal site. The percentage of SMA-4 dredge material potentially “suitable” for open-water disposal is not known, as this material has not been screened against DMMP criteria. However, the FS assumes that 50 percent of SMA-4 dredge material

would potentially be suitable for open-water disposal, with the remaining unsuitable material disposed off-site in an upland landfill.

- Placing a nominal 6-inch-thick post-dredge residuals cover over the dredge footprint.
- Performing compliance monitoring to assess the effectiveness of this remedy.

The estimated construction duration of this remedial alternative is approximately 2 years (Table 6-3), considering the anticipated in-water construction windows that are typically required for marine construction projects, which would require significant stretches of time (February 15 to November 15, based on past experience in this area) when in-water construction would not be allowed. Figure 6-14 presents the conceptual Dredge alternative for SMA-4.

6.1.4.2 Cap Alternative Description

Capping in SMA-4 entails placement of an assumed 1-foot-thick surface layer of clean sand to contain sediments within the 19-acre footprint. The specific activities included in the FS for this alternative include:

- Removal of creosoted pilings throughout the entire SMA.
- Procuring and placing 45,000 to 50,000 tons of clean beneficial reuse sand to cap the SMA footprint.
- Implementing institutional controls for the cap area. Institutional controls would, at a minimum, include a site use and deed restriction.
- Performing long-term monitoring to assess the effectiveness of this remedy.

The estimated construction duration of this remedial alternative is approximately 1 month (Table 6-3) provided that a sufficient supply of sand can be procured over this time frame. Figure 6-15 presents the conceptual Cap alternative footprint for SMA-4.

6.1.4.3 EMNR Alternative Description

The EMNR alternative in SMA-4 entails placement of a nominal 6-inch-thick surface layer of clean sand to accelerate the recovery of sediments within the 19-acre SMA footprint. The specific activities included in the FS for this alternative include:

- Removal of creosoted pilings throughout the entire SMA.
- Procuring and placing 20,000 to 25,000 tons of clean beneficial reuse sand for EMNR cover within the SMA.
- Performing long-term monitoring to assess the effectiveness of this remedy.

The estimated construction duration of this remedial alternative is approximately 1 month (Table 6-3). Figure 6-16 presents the conceptual EMNR alternative footprint for SMA-4.

6.1.4.4 MNR Alternative Description

As in the Central Bay SMA (SMA-3), the MNR remedy in SMA-4 does not entail active construction beyond removal of creosoted pilings throughout the entire SMA, but consists of a series of sediment monitoring events at a scope and frequency defined in the CAP, as described above. The MNR alternative would include clear endpoints and timeframes for measuring success and triggers for initiating more active alternatives if recovery is not occurring in a reasonable timeframe.

6.1.5 cPAH Background Area (SMA-5)

The cPAH Background Area (SMA-5) includes sediments exceeding site-specific cleanup standards based on natural background or PQLs for cPAHs, dioxins/furans, and cadmium in the bay. This SMA surrounds and includes all of the other SMAs, and thus also serves as the Site boundary for sediments. SMA-5 has a total area of 602 acres, not including the areas associated with SMA-1 through SMA-4.

Because the evidence of current biological impacts in SMA-5 is relatively limited, widespread use of technologies such as dredging or engineered containment, which would remove or place a thick sequence of sand over recovering sediments and functioning habitat, respectively, would lead to unnecessary disruptions of the biological communities present in SMA-5. Thus, the Dredge, Cap, and EMNR alternatives were retained for a subset of this SMA: those areas of the SMA where surface sediment concentrations exceed site-specific cleanup levels by at least a factor of 3. The surface area of this portion of SMA-5 is approximately 196 acres. However, as a source control measure for protection of human health, the creosoted pilings that remain throughout the entire SMA will be removed under each of the alternatives below.

6.1.5.1 Dredge Alternative Description

Dredging in SMA-5 entails removal of an assumed 2-foot-thick surface layer of sediment, with a 1-foot allowable overdepth in the 196-acre area described above. The specific activities included in the FS for this alternative include:

- Removal of creosoted pilings and structures throughout the entire SMA. The majority of piles in this SMA are associated with the FLTF dock, and the log rafting piles offshore of this dock.
- Dredging an estimated 900,000 to 1,400,000 cy (including overdredge allowances) of surface sediment across a subset of the SMA.
- Screening and removal of debris for upland disposal.
- Transport and disposal of suitable dredge material at a non-dispersive DMMP open-water disposal site. The percentage of SMA-5 dredge material potentially "suitable" for open-water disposal is not known, as this material has not been screened against DMMP criteria. However, the FS assumes that 50 percent of SMA-5 dredge material would potentially be suitable for open-water disposal, with the remaining unsuitable material disposed off-site in an upland landfill.
- Placing a nominal 6-inch-thick post-dredge residuals cover over the dredge footprint.
- Performing long-term monitoring to assess the effectiveness of this remedy and recovery of the impacted benthic community.

The estimated construction duration of this remedial alternative is approximately 10 to 15 years (Table 6-3), considering the anticipated in-water construction windows that are typically required for marine construction projects, which would require significant stretches of time (February 15 to November 15, based on past experience in this area) when in-water construction would not be allowed. Figure 6-17 presents the conceptual Dredge alternative for SMA-5.

6.1.5.2 Cap Alternative Description

Capping in SMA-5 entails placement of an assumed 1-foot-thick surface layer of clean sand to contain sediments within the 196-acre footprint. The specific activities included in the FS for this alternative include:

- Removal of creosoted pilings and structures throughout the entire SMA.
- Procuring and placing 475,000 to 500,000 tons of clean beneficial reuse sand to cap the subset of the SMA footprint identified.
- Implementing institutional controls for the cap area. Institutional controls would, at a minimum, include a site use and deed restriction.
- Performing long-term monitoring to assess the effectiveness of this remedy and recovery of the impacted benthic community.

The estimated construction duration of this remedial alternative is approximately 3 years (Table 6-3) provided that a sufficient supply of sand can be procured over this time frame. Figure 6-18 presents the conceptual Cap alternative footprint for SMA-5.

6.1.5.3 EMNR Alternative Description

The EMNR alternative in SMA-5 entails placement of a nominal 6-inch-thick surface layer of clean sand to accelerate the recovery of sediments within the 196-acre SMA footprint. The specific activities included in the FS for this alternative include:

- Removal of creosoted pilings and structures throughout the entire SMA.
- Procuring and placing 225,000 to 250,000 tons of clean beneficial reuse sand for EMNR cover within the SMA.
- Performing long-term monitoring to assess the effectiveness of this remedy.

The estimated construction duration of this remedial alternative is approximately 1 to 2 years (Table 6-3) provided that a sufficient supply of sand can be procured over this time frame. Figure 6-19 presents the conceptual EMNR alternative footprint for SMA-5.

6.1.5.4 MNR Alternative Description

As in the Central Bay (SMA-3) and FLA (SMA-4) SMAs, the MNR remedy in SMA-5 does not entail active construction beyond removal of creosoted pilings throughout the entire SMA, but consists of a series of sediment monitoring events at a scope and frequency defined in the CAP. The MNR alternative would include clear endpoints and timeframes for measuring success and triggers for initiating more active alternatives if recovery is not occurring in a reasonable timeframe.

6.2 Detailed Evaluation and Comparison of Marine Alternatives

This section provides a narrative description of the evaluation and comparison of these alternatives for each SMA. In each description, an absolute numeric ranking is provided ranging from 1 to 5, where 1 is the lowest (least favorable) ranking and 5 is the highest (most favorable) ranking. These absolute rankings are ultimately modified by weighting factors (discussed in Section 5.2) when summed to the total score for each alternative. Table 6-1 summarizes the evaluation and tabulates the overall score for each alternative. Table 6-2 provides a summary of estimated costs, and Table 6-3 summarizes estimated volumes and durations associated with each alternative.

6.2.1 Mill Site North (SMA-1) Detailed Evaluation

6.2.1.1 Threshold Evaluation

All of the alternatives evaluated for SMA-1 meet the SMS threshold criteria of protection of human health and the environment, and attainment of cleanup standards. Each alternative has been configured to meet the required cleanup standards, and all alternatives will meet the cleanup standard within a 10-year time frame. Finally, cleanup will be achieved in compliance with applicable laws.

6.2.1.2 Short-term Effectiveness

For the Dredge alternative, short-term effectiveness was given a score of 3 for human health and 4 for environment, for an average score of 3.5. This scoring reflects the relatively large volume of material that needs to be handled in this alternative and potential risks to human health associated with this work, as well as generated dredge residuals.

For the Dredge and Cap alternative, less material is removed, with less attendant human health risk during implementation. At the same time, dredge residuals will still result in environmental impact. Thus, this alternative was given a score of 4 for human health, and 4 for environment, for an average score of 4.0.

The Cap alternative does not require upland management of dredge material and debris, and thus represents the lowest potential risk to human health. However, there are water quality impacts associated with placing a large volume of capping material, which represents a short-term environmental risk. Thus, this alternative ranks 5 for human health, and 4 for environment, for an overall average of 4.5.

The Cap and EMNR alternative entails handling the lowest volume of material, and thus has the lowest attendant risks to both human health and the environment. This alternative scored 5 for both human health and the environment, for an overall average score of 5.0.

6.2.1.3 Long-term Effectiveness

The long-term effectiveness of the Dredge alternative ranks high for protection of human health and the environment because source material is removed to the maximum extent practicable. Because of generated dredge residuals, this alternative ranks marginally lower for certainty and reliability, and residual risks. This alternative was scored 5 for human health, 5 for environment, 4 for certainty/reliability, and 4 for residual risks, for an average score of 4.5.

The Dredge and Cap alternative has a similar ranking to the Dredge alternative; however, the residual risk category ranks lower because of the reliance on caps to prevent exposure to material that remains in the environment. Thus, the scoring is 5, 5, 4, 3 for human health, environment, certainty/reliability, and residual risk, respectively, for an overall average of 4.3.

The Cap alternative is protective of human health because the exposure pathway to sediments is removed; a score of 5 was assigned. Because the benthic community will reside within the cap matrix and there remains a lower risk of toxicity due to sulfides from decomposing wood waste (though the caps would be designed to address this risk), environment ranks slightly lower compared to human health, and was scored 4. Because institutional controls are required, capping has lower certainty/reliability compared to removal, and was scored 3. Similar to the Dredge and Cap alternative, residual risk was also scored 3, for an overall average score of 3.8 for long-term effectiveness.

The Cap and EMNR alternative is similar to the Cap alternative and ranks 5 for protection of human health. However, the reliance on EMNR in parts of the SMA results in a lower score of 3 for environment because of the potential for benthic exposure before natural recovery processes have reduced concentrations below criteria. EMNR presumes ongoing natural recovery following placement of clean sand, and thus is less certain (until a demonstration is made through long-term monitoring) than capping, so certainty has been scored 2. Similarly, residual risk ranks 2 because of the reliance on EMNR in portions of the SMA. The overall average score for long-term protectiveness is 3.0 for the Cap and EMNR alternative.

6.2.1.4 Implementability

The technical feasibility of the Dredge alternative was given a score of 4 in consideration of the amount of material handled, and the need to process debris and unsuitable dredge material in an available upland location. Materials and equipment for dredging are commonly available, and this criterion was scored 5. Finally, dredging projects are routinely permitted in Puget Sound and have the support of regulatory agencies when performed in conjunction with cleanup, and thus this criterion scored 5. The overall average implementability score for the Dredge alternative is 4.8.

The Dredge and Cap alternative is the same as the Dredge alternative from an implementability standpoint, and the same considerations and scoring are applied. The implementability average score for this alternative is also 4.8.

Capping ranks higher for technical feasibility compared to dredging because there would be less need for upland sorting or processing of excavated material. Thus, the Cap alternative was scored 5 for technical feasibility. Capping materials and equipment are commonly available, and thus this criterion was also scored 5. Finally, as with dredging, there is regulatory and permitting support for capping performed during environmental cleanup, and this criterion scored 5 as well, for an overall average score of 5.0 for implementability.

The Cap and EMNR alternative has the same considerations as the Cap alternative and was thus scored the same, with an overall average score of 5.0.

6.2.1.5 Cost

The Dredge alternative in SMA-1 has the highest estimated cost ($1.1 million/acre) and the lowest rank, scoring 1. The Dredge and Cap alternative is estimated to cost $900,000/acre and has a score of 2. The Cap and Cap and EMNR alternatives are estimated to cost $700,000/acre, and have been given a score of 3 for cost. Table 6-2 provides a summary of the estimated costs for all of the alternatives. Appendix A provides details for the cost estimates.

6.2.1.6 Community Concerns

As this is one of the smaller SMAs with relatively few existing shellfish beds that would be impacted by the cleanup, a stronger preference has been expressed for removal (dredging) of as much material as possible. Removal of contaminated sediments also provides the greatest flexibility for future land uses in this area. This preference is reflected in a score of 5 for the Dredge alternative, a score of 3 for the Dredge and Cap alternative, and scores of 1 for the Cap and EMNR alternatives.

6.2.1.7 Recycling and Waste Minimization

The ability for a sediment cleanup project to use recycling and waste minimization is limited to a few key opportunities discussed in Section 5. The Dredge alternative has limited opportunity for recycling or reuse, while at the same time generating waste during excavation, and was thus scored 2. The Dredge and Cap, Cap, and Cap and EMNR alternatives have the potential to beneficially reuse navigationally dredged sand for cap material, and thus all of these alternatives were scored 3 for this evaluation criterion.

6.2.1.8 Environmental Impacts

The potential environmental impacts associated with all alternatives rank equally considering that the scale and scope of each project is similar. The environmental impacts associated with dredge residuals are relatively low due to the relatively low volume of material excavated. The environmental (water quality) impacts associated with cap material placement are also relatively low considering the relatively low volume of material used. Thus, all alternatives were scored 4 for consideration of environmental impacts.

6.2.1.9 Preferred Alternative

Based on this evaluation, the Dredge and Cap, Cap, and Cap and EMNR total scores rank highest. The Dredge and Cap alternative was identified by Ecology as the preferred alternative among these three due to Ecology's preference for removal of dense wood waste deposits as part of the remedy, particularly in areas with identified sulfide toxicity.

The restoration timeframe for the Dredge and Cap alternative is approximately 2 to 3 years for design, permitting, and implementation.

6.2.2 Mill Site South (SMA-2) Detailed Evaluation

6.2.2.1 Threshold Evaluation

The Dredge alternative meets the threshold criteria for protection of human health and the environment, and achieves cleanup standards within a 10-year time frame. However, a Dredge alternative over this large area is likely to have significant water quality impacts that would be difficult to control. There are also concerns about resuspension and distribution of wood debris and contaminated sediments to other areas of the bay. For these reasons, this alternative may be more difficult to obtain permits for, and it may also be more difficult to remain in compliance with water quality limits during implementation.

The remaining alternatives evaluated for SMA-2 meet the SMS threshold criteria of protection of human health and the environment, and attainment of cleanup standards. Each of these alternatives has been configured to meet the required cleanup standards, and all of the remaining alternatives will meet the cleanup standard within the required 10-year time frame. Finally, cleanup will be achieved in compliance with applicable laws.

6.2.2.2 Short-term Effectiveness

For the Dredge alternative, short-term effectiveness was given a score of 1 for human health and 1 for environment, for an average score of 1.0. This scoring reflects the significant volume of material that needs to be handled in this alternative, resulting in significant potential risks to human health associated with this work based on documented health and safety issues that show measurable increased worker safety risk for marine construction compared to upland construction. The large volume of dredge material would also result in significant generated dredge residuals and unknown residual distribution and impacts on the rest of the bay.

For the Dredge and Cap alternative, less material is removed than the Dredge alternative, with less attendant human health risk during implementation. However, the overall volume of removal is still significant. Further, significant generated dredge residuals will result in environmental impact. Thus, this alternative was given a score of 2 for human health, and 1 for environment, for an average score of 1.5.

The Dredge and Cap II alternative removes less volume than the Dredge and Cap alternative. Considerations about human health and the environment are similar, but scoring is higher to reflect the lower removal volume, with a value of 3 selected for human health, and 2 for environment, for an overall average score of 2.5.

The Dredge, Cap, and EMNR alternative balances removal and capping such that the dredging is focused on the highest concentration of woody debris in the area most susceptible to porewater sulfide generation. The result is a lower volume of removal compared to the Dredge and Cap II alternative, and a greater percentage of the dredged material would be suitable for open-water disposal. The dredge prism is also located in an area that is less subject to strong currents. Because of the lower risks associated with the lower volume of removal, human health and environment both score 4, with an overall average of 4.0 for this alternative.

The Cap alternative requires limited upland management of dredge material and debris (from the intertidal excavation area), and thus represents the lowest potential risk to human health. While there may be water quality impacts associated with placing a large volume of capping material, this represents a short-term environmental risk that is lower than the risk of water quality impacts and residuals generation associated with removal. Thus, this alternative ranks 5 for human health, and 5 for environment, for an overall average of 5.0.

The Cap and EMNR alternative entails handling the lowest volume of material, and thus has the lowest attendant risks to both human health and the environment. This alternative scored 5 for both human health and the environment, for an overall average score of 5.0.

6.2.2.3 Long-term Effectiveness

The long-term effectiveness of the Dredge alternative ranks high for protection of human health and the environment because source material is removed to the maximum extent practicable. Because of generated dredge residuals, this alternative ranks marginally lower for certainty and reliability, and residual risks. This alternative was scored 5 for human health, 5 for environment, 4 for certainty/reliability, and 4 for residual risks, for an average score of 4.5.

The Dredge and Cap alternative has a similar ranking to the Dredge alternative; however, the residual risk category ranks lower because of the reliance on caps to maintain protectiveness. Thus, the scoring is 5, 5, 4, 3 for human health, environment, certainty/reliability, and residual risk, respectively, for an overall average of 4.3.

The Dredge and Cap II alternative has a similar ranking to the Dredge and Cap alternative; however, the environment category ranks slightly lower because less removal is accomplished. Thus, the scoring is 5, 4, 4, 3 for human health, environment, certainty/reliability, and residual risk, respectively, for an overall average of 4.0.

The Dredge, Cap, and EMNR alternative shares the same considerations and scoring as the Dredge and Cap II alternative, and thus has an overall average score of 4.0 for long-term effectiveness.

The Cap alternative is protective of human health because the exposure pathway to sediments is removed; a score of 5 was assigned. Because the benthic community (and in particular, geoducks) will reside within the cap matrix, environment ranks slightly lower compared to human health, and was scored 4. Because institutional controls are required and there may be a lower risk of continuing sulfides impacts (though the caps would be designed to address this risk), capping has lower certainty/reliability compared to removal, and was scored 3. Similar to the Dredge, Cap, and EMNR alternative, residual risk was also scored 3, for an overall average score of 3.8 for long-term effectiveness.

The Cap and EMNR alternative is similar to the Cap alternative and ranks 5 for protection of human health. However, the reliance on EMNR in parts of the SMA results in a lower score of 3 for environment because of the potential for benthic exposure before natural recovery processes have reduced concentrations below criteria. EMNR presumes ongoing natural recovery following placement of clean sand, and thus is less certain (until a demonstration is made through long-term monitoring) than capping, and thus certainty/reliability has been scored 2. Finally, residual risk ranks 1 because of the reliance on EMNR in portions of the SMA, and because of the risk posed by the relatively large volume of woody debris that remains under this alternative. The overall average score for long-term protectiveness is 2.8 for the Cap and EMNR alternative.

6.2.2.4 Implementability

The technical feasibility of the Dredge alternative was given a score of 3 in consideration of the relatively large amount of material handled, and the need to process debris and unsuitable dredge material in an available upland location. While materials and equipment for dredging are commonly available, the upland space required for processing up to 100,000 to 150,000 cy (representing the 75 percent of SMA-2 material assumed to be unsuitable for DMMP open-water disposal) of dredge material is significant and the ability to manage this volume upland is questionable; thus this criterion was scored 2. The permitting and regulatory criterion was scored 4 because the large volume of dredging could trigger regulatory concerns. The overall average implementability score for the Dredge alternative is 3.0.

The Dredge and Cap alternative is similar to the Dredge alternative from an implementability standpoint, and the same considerations and scoring (3) are applied for technical feasibility. Because the volume of dredge material is lower, the scores for availability of materials and space, as well as the score for regulatory and permitting is slightly higher than the dredge alternative, with scores of 3 and 5, respectively. The implementability average score for the Dredge and Cap alternative is 3.8.

The Dredge and Cap II alternative entails a lower volume of material handled on the upland compared to the Dredge and Cap alternative, and thus has been assigned a higher score of 4 for technical feasibility. Considerations for availability of materials/space, and permitting/regulatory are reduced, and thus a score of 4 was assigned. Finally, a score of 5 was assigned for regulatory/permitting (similar to other small- to medium-scale dredging alternatives) for an overall average score of 4.3.

The Dredge, Cap, and EMNR alternative is similar in scope and scale to the Dredge and Cap alternative, and the scoring for implementability reflects this, with an overall average of 4.3 for this alternative.

Capping ranks higher for technical feasibility compared to dredging because there would be less need for upland sorting/processing of excavated material. Thus, the Cap alternative was scored 5 for technical feasibility. Capping materials and equipment are commonly available; however, a relatively large volume of cap material would be required under this alternative (over 100,000 tons), and thus this criterion was scored 4. Finally, as with dredging, there is regulatory and permitting support for capping performed during environmental cleanup, and this criterion scored 5 as well, for an overall average score of 4.8 for implementability.

The Cap and EMNR alternative has the same considerations as the Cap alternative and similar cap material volume requirements and was thus scored the same, with an overall average score of 4.8.

6.2.2.5 Cost

The Dredge alternative in SMA-2 has the highest estimated cost ($1.6 million/acre) and the lowest rank, scoring 1. The Dredge and Cap alternative is estimated to cost $1.1 million/acre and has also been assigned a score of 1. The Dredge and Cap II alternative is estimated to cost $900,000/acre and has been assigned a score of 2. The Dredge, Cap, and EMNR alternative has an estimated cost of $510,000/acre and has been assigned a score of 3. The Cap and Cap and EMNR alternatives are estimated to cost $370,000/acre, and have been given a score of 4 for cost, as summarized in Table 6-2.

6.2.2.6 Community Concerns

This SMA represents the area most heavily impacted by mill operations over time, and where it has been reported by divers that geoducks have been heavily impacted by wood wastes in sediments. While dredging large volumes of wood waste and impacted sediments may present some challenges and short-term risks to human health and the environment, the long-term gains over multiple generations from cleaning up this area have been stated by community and tribal members as being worth the risks. Therefore, like at SMA-1, alternatives that result in greater long-term removal (dredging) of contaminated sediments were scored higher. The Dredge alternative received a score of 5; the Dredge and Cap alternative a score of 4; Dredge and Cap II (which dredges lower quantities of sediments) a score of 3; Dredge, Cap, and EMNR a score of 2; and both the Cap and Cap and EMNR alternatives a score of 1.

6.2.2.7 Recycling and Waste Minimization

The ability for a sediment cleanup project to use recycling and waste minimization is limited to a few key opportunities discussed in Section 5. As with SMA-1, the Dredge alternative in SMA-2 has limited opportunity for recycling or reuse, while at the same time generating waste during excavation, and was thus scored 2.

The Dredge and Cap alternative has the potential to beneficially reuse sand for cap material, and thus this alternative was scored 3 for this evaluation criterion.

The Dredge and Cap II and Dredge, Cap, and EMNR alternatives are similar to the Dredge and Cap alternative, with the key difference that they would generate less waste from the removal process, and thus these alternatives were scored 4.

Finally, the Cap and Cap and EMNR alternatives produce the least waste and have the highest potential for recycling through the beneficial reuse of maintenance dredge material in the cap, and thus these alternatives both score 5 for this evaluation criterion.

6.2.2.8 Environmental Impacts

The potential environmental impacts associated the Dredge alternative are significant. The large volume of material removed (140,000 to 200,000 cy) and associated water quality and dredge residuals impacts would be substantial. Because open-water disposal would only be applicable to a small portion of the dredge material, upland rehandling would result in significant noise, traffic, and local air emissions at the offloading facility and during transloading to the landfill. Marine traffic associated with dredging would interfere with local fishing and shellfish harvest activities for at least 3 years, and noise and light associated with this long-term construction project would cause notable impacts on the local communities that surround Port Gamble Bay. As a result, the Dredge alternative was given a score of 1 for the environmental impacts criterion.

The Dredge and Cap and Dredge and Cap II alternatives have lower overall dredge volumes and lower impacts associated with dredging. There are additional potential water quality impacts (specifically turbidity) associated with cap material placement that are not associated with dredging, because the volume of material placed is higher under these alternatives than under the Dredge alternative. Thus, these two alternatives were both assigned a score of 3 for environmental impacts.

The Dredge, Cap, and EMNR alternative provides a balanced approach that minimizes impacts associated with dredging, and reduces impacts associated with capping compared to the Cap alternative. Thus, this alternative was assigned a score of 4.

The Cap alternative does not result in dredge-related impacts; however, this alternative does require placement of significant volumes of material for cap construction, and thus has been assigned a score of 3 for environmental impacts.

The Cap and EMNR alternative requires less cap material placement than the Cap alternative and, therefore, scores comparatively higher at 4 for environmental impacts.

6.2.2.9 Preferred Alternative

Based on this evaluation, the Dredge, Cap, and EMNR alternative and the Cap alternative total scores rank highest. The Dredge, Cap, and EMNR alternative was identified by Ecology as the preferred alternative due to Ecology's preference for removal of large deposits of wood waste as part of the remedy, particularly in areas with identified sulfide toxicity. However, the overall cost of the Dredge, Cap, and EMNR alternative presumes the use of open-water disposal for 50 percent of the dredge material, consistent with OPG/PR's preliminary screening-level sampling.

The restoration timeframe for the Dredge, Cap, and EMNR alternative is approximately 3 years for design, permitting, and implementation.

6.2.3 Central Bay (SMA-3) Detailed Evaluation

6.2.3.1 Threshold Evaluation

The Dredge alternative meets the threshold criteria for protection of human health and the environment, and achieves cleanup standards within a 10-year time frame. However, dredging over this large area is likely to have significant water quality impacts that would be difficult to control. There are also concerns about resuspension and distribution of wood debris and contaminated sediments to other areas of the bay. For these reasons, this alternative may be more difficult to obtain permits for, and it may also be more difficult to remain in compliance with water quality limits during implementation.

The Cap and EMNR alternatives for SMA-3 meet the SMS threshold criteria of protection of human health and the environment, and attainment of cleanup standards. Each of these alternatives has been configured to meet the required cleanup standards, and these alternatives will meet the cleanup standard within a 10-year time frame. Finally, cleanup will be achieved in compliance with applicable laws for the Cap and EMNR alternatives.

The MNR alternative does not meet the threshold criteria for protection of human health and the environment or attainment of cleanup standards/compliance with laws. Bioassay results currently exceed SQS, and cPAH levels are on the order of 2 to 4 times the cleanup level. Because ongoing natural recovery has not been documented in this SMA and sedimentation rates in the area are very low, this alternative is not expected to meet the cleanup standards within 10 years.

6.2.3.2 Short-term Effectiveness

For the Dredge alternative, short-term effectiveness was given a score of 1 for human health and 1 for environment, for an average score of 1.0. This scoring reflects the substantial volume of dredge material that needs to be managed in this alternative (with approximately twice the volume compared to the Mill Site South Dredge alternative—and similar effectiveness considerations on a larger scale), as well as generated dredge residuals, which will result in a significant environmental impact in the Central Bay.

The Cap alternative does not require upland management of dredge material and debris, and thus represents the lowest potential risk to human health. However, there are water quality impacts associated with placing a large volume of capping material, which represents a short-term environmental risk. Thus, this alternative ranks 5 for human health and 3 for environment, for an overall average of 4.0.

The EMNR alternative entails handling the lowest volume of material, and thus has the lowest attendant risks to both human health and the environment. This alternative scored 5 for both human health and the environment, for an overall average score of 5.0.

Because MNR does not take active measures to improve human health and the environment in the short term, it was scored 1 for both of these criteria, for an overall average of 1.0 for short-term effectiveness.

6.2.3.3 Long-term Effectiveness

The long-term effectiveness of the Dredge alternative ranks high for protection of human health and the environment because source material is removed to the maximum extent practicable. However, the scale of the removal would require more than eight construction seasons to complete, which significantly impacts the certainty that the dredging remedy can be completed. Finally, due to generated dredge residuals, this alternative ranks marginally lower for residual risks. This alternative was scored 5 for human health, 5 for environment, 2 for certainty/reliability, and 4 for residual risks, for an average score of 4.0.

The Cap alternative is protective of human health because the exposure pathway to sediments is removed; a score of 5 was assigned. Because the benthic community will reside within the cap matrix, environment ranks lower compared to human health, and was scored 4. Because institutional controls are required, capping has lower certainty/reliability compared to removal, and was scored 4. Similar to the Cap alternatives in the other SMAs, residual risk was also scored 3, for an overall average score of 4.0 for long-term effectiveness.

The EMNR alternative is similar to the Cap alternative and ranks 5 for protection of human health. However, the reliance on EMNR in parts of the SMA results in a lower score of 3 for environment because of the potential for benthic exposure before natural recovery processes have reduced concentrations below criteria. EMNR presumes ongoing natural recovery following placement of clean sand, and thus is less certain than capping; however, bioassay exceedances are very close to the SQS and so it is reasonable to assume EMNR can be reliable in reducing toxicity to the benthic community. Thus certainty/reliability has been scored 4. Residual risk ranks 2 because of the reliance on natural recovery processes and the fact that material is not removed under this alternative. The overall average score for long-term protectiveness is 3.5 for the EMNR alternative.

The FS presumes that natural recovery is occurring very slowly in SMA-3, and thus MNR has been assigned a score of 1 for protection of human health and 2 for protection of the environment because the predominant issue in the Central Bay is exceedance of cPAH levels. Further, MNR is scored 1 for certainty/reliability and 1 for residual risks because active measures are not taken under this alternative. The overall average score for long-term effectiveness of MNR in SMA-3 is 1.3.

6.2.3.4 Implementability

The technical feasibility of the Dredge alternative was given a score of 2 in consideration of the significant amount of material handled, and the need to process debris and unsuitable dredge material in an available upland location. Materials and equipment for dredging are commonly available; however, the space required to manage 200,000 to 250,000 cy of dredge material would likely be difficult, if not impossible to find, and thus this criterion was scored 1. Finally, while dredging projects in Puget Sound typically have the support of regulatory agencies when performed in conjunction with cleanup, it is expected that dredging on the scale necessary in SMA-3 for this alternative would create significant concerns, and thus this criterion scored 2. The overall average implementability score for the Dredge alternative is 1.8.

Capping ranks higher for technical feasibility compared to dredging because there would be less need for upland sorting/processing of excavated material. Thus, the Cap alternative was scored 4 for technical feasibility. While capping equipment is commonly available, procuring more than 180,000 tons of cap material for this alternative could be difficult, and thus this criterion was scored 3. Finally, there is typically regulatory and permitting support for capping performed during environmental cleanup, and this criterion was scored 5, for an overall average score of 4.0 for implementability.

The EMNR alternative has similar considerations to the Cap alternative but ranks higher for technical feasibility and availability of materials because only one-half of the cap material is required under this alternative. Thus, scores were 5, 4, and 5 for technical feasibility, availability of materials and equipment, and permitting/regulatory considerations, respectively, for an overall average score of 4.8.

MNR does not entail active construction. Implementability is related to periodic sampling during each monitoring event. Because it does not trigger any of the technical feasibility, materials availability, or permitting/regulatory issues that occur with active construction, all factors were assigned a score of 5, for an overall average score of 5.0 for implementability.

6.2.3.5 Cost

The Dredge alternative in SMA-3 has the highest estimated cost ($800,000/acre) and the lowest rank, scoring 2. The Cap alternative is estimated to cost $60,000/acre and has been assigned a score of 5. The EMNR alternative is estimated to cost $40,000/acre and has been given a score of 5 for cost. MNR is estimated to cost $5,000/acre in the Central Bay and has been assigned a score of 5. Table 6-2 provides a summary of the estimated cost for all of the alternatives in SMA-3, with details provided in Appendix A.

6.2.3.6 Community Concerns

The Central Bay is a much larger area than those at the mill site, and contains thriving geoduck beds that serve as a recruitment area for the commercial beds to the north. This SMA is also in the center of the bay and both dredging and capping actions will interfere with fishing over the short-term. Balancing these considerations is the need to clean up an area of the bay in which breakdown products of wood waste have settled and formed flocculant sediments that are undesirable habitat for shellfish, fish, crab, and other biota. Therefore, alternatives received a higher score that would have the potential to improve sediment conditions for biota and remediate contamination while still allowing survival of the existing benthic community and interfering with fishing activities as little as possible.

Based on these considerations, the Dredge alternative received a score of 2. This alternative would require 7 years of dredging operations in the center of the bay, and would likely resuspend a great deal of flocculant sediments that would settle elsewhere in the bay. In addition, dredging would destroy the existing geoduck beds and benthic community throughout this area. The Cap alternative received a score of 3. This alternative would have fewer impacts than the Dredge alternative and would require only two capping seasons to carry out. However, the full 1-foot cap envisioned under this alternative would likely kill the existing benthic community, including the geoduck bed, which would require a substantial period of time to become reestablished. The EMNR alternative is similar, but uses a 6-inch layer of sediments, which would likely be enough to improve the physical and chemical conditions in sediments without completely eliminating the shellfish and benthic communities. The MNR alternative received a score of 1, because it does not result in any immediate benefit to this area and public comments were received expressing clear dissatisfaction with this approach in the bay.

6.2.3.7 Recycling and Waste Minimization

Similar to SMA-1 and SMA-2, the Dredge alternative in SMA-3 has limited opportunity for recycling or reuse, while at the same time generating waste during excavation, and was thus scored 2 for recycling/waste minimization.

The Cap alternative and the EMNR alternative produce the least waste and have the highest potential for recycling through the beneficial reuse of maintenance dredge material in the cap, and thus these alternatives both score 5 for this evaluation criterion.

MNR does not entail active construction. There is no opportunity for recycling or waste minimization with this alternative. MNR has been assigned a score of 1 for this criterion.

6.2.3.8 Environmental Impacts

The potential environmental impacts associated the Dredge alternative are significant. Dredging over 4 to 8 years would have substantial community impact, with noise, air, and light issues affecting the Port Gamble Bay community, disruption of access to fishing and shellfish harvesting, and significant potential air emissions associated with the marine equipment and offloading/transloading activity for the estimated more than 200,000 cy of material that would not be suitable for DMMP open-water disposal. The large volume of material removed, associated water quality and dredge residuals impacts, and community impacts described above result in a score of 1 for this criterion. In addition, dredging would eliminate the benthic community and any shellfish resources in the area remediated.

The Cap alternative does not result in dredge-related impacts; however, this alternative does require placement of significant volumes of material for cap construction, with associated potential for water quality impacts. This alternative also buries the benthic community. Although most elements of the benthic community recover within 2 to 3 years, larger organisms such as geoduck may require long timeframes for recovery. Thus, this alternative has been assigned a score of 2 for environmental impacts.

The EMNR alternative requires less and thinner cap material placement than the Cap alternative and, therefore, scores comparatively higher at 3 for environmental impacts.

Because MNR does not entail construction activities, there are no environmental impacts associated with this alternative. MNR has been assigned a score of 5 for environmental impacts.

6.2.3.9 Preferred Alternative

Based on this evaluation, the Cap alternative and EMNR alternative total scores rank similarly, with EMNR ranking highest of the alternatives. Thus, EMNR is the preferred alternative for SMA-3.

The restoration timeframe for the EMNR alternative is approximately 2 to 3 years for design, permitting, and implementation.

6.2.4 Former Lease Area (SMA-4) Detailed Evaluation

6.2.4.1 Threshold Evaluation

The Dredge, Cap, and EMNR alternatives for SMA-4 meet the SMS threshold criteria of protection of human health and the environment, and attainment of cleanup standards. Each of these alternatives has been configured to meet the required cleanup standards, and these alternatives will meet the cleanup standard within a 10-year time frame. Finally, cleanup will be achieved in compliance with applicable laws for the Dredge, Cap, and EMNR alternatives.

The MNR alternative does not meet the threshold criteria for protection of human health and the environment or attainment of cleanup standards/compliance with laws. Bioassay results currently exceed SQS, and cPAH levels are on the order of 2 times the cleanup level. Because ongoing natural recovery has not been documented in this SMA, and sedimentation rates in the area are very low, this alternative is not expected to meet the cleanup standards within 10 years.

6.2.4.2 Short-term Effectiveness

For the Dredge alternative, short-term effectiveness was given a score of 1 for human health and 1 for environment, for an average score of 1.0. This scoring reflects the large volume of dredge material that needs to be managed in this alternative and potential risks to human health associated with this work, as well as generated dredge residuals in a more nearshore shellfish-rich environment, which may result in a significant environmental impact in the FLA.

The Cap alternative does not require upland management of dredge material and debris, and thus represents the lowest potential risk to human health. However, there are water quality impacts associated with placing the capping material, which represents a short-term environmental risk. Thus, this alternative ranks 5 for human health and 4 for environment, for an overall average of 4.5.

The EMNR alternative entails handling the lowest volume of material, and thus has the lowest attendant risks to both human health and the environment. This alternative scored 5 for both human health and the environment, for an overall average score of 5.0.

Because MNR does not take active measures to improve human health and the environment in the short term, it was scored 1 for both of these criteria, for an overall average of 1.0 for short-term effectiveness.

6.2.4.3 Long-term Effectiveness

The long-term effectiveness of the Dredge alternative ranks high for protection of human health and the environment because source material is removed to the maximum extent practicable. The ability to dredge a site of this size has been demonstrated on other projects, and the overall duration is reasonable, making dredging rank high for certainty/reliability. Finally, due to generated dredge residuals, this alternative ranks marginally lower for residual risks. This alternative was scored 5 for human health, 5 for environment, 5 for certainty/reliability, and 4 for residual risks, for an average score of 4.8.

The Cap alternative is protective of human health because the exposure pathway to sediments is removed; a score of 5 was assigned. Because the benthic community will reside within the cap matrix, environment ranks lower compared to human health, and was scored 4. Although institutional controls are required, capping can be completed in a reasonable time frame, and thus certainty/reliability was scored 5. Similar to the Cap alternatives in the other SMAs, residual risk was also scored 3, for an overall average score of 4.3 for long-term effectiveness.

The EMNR alternative is similar to the Cap alternative and ranks 5 for protection of human health. However, the reliance on EMNR in parts of the SMA results in a lower score of 4 for environment because of the potential for benthic exposure before natural recovery processes have reduced concentrations below criteria. EMNR presumes ongoing natural recovery following placement of clean sand, and thus is less certain than capping. Thus, certainty/reliability has been scored 4. Residual risk ranks 3 because of the reliance on natural recovery processes and the fact that material is not removed under this alternative. The overall average score for long-term protectiveness is 4.0 for the EMNR alternative.

Similar to the Central Bay SMA, the FS presumes that natural recovery is occurring very slowly in SMA-4, and thus MNR has been assigned a score of 1 for protection of human health and 2 for protection of the environment. Further, MNR is scored 1 for certainty/reliability and 1 for residual risks because active measures are not taken under this alternative. The overall average score for long-term effectiveness of MNR in SMA-4 is 1.3.

6.2.4.4 Implementability

The technical feasibility of the Dredge alternative was given a score of 3 in consideration of the large volume of material handled, and the need to process debris and unsuitable dredge material in an available upland location. Materials and equipment for dredging are commonly available; however, the space required to manage 50,000 to 60,000 cy of dredge material would be significant, and thus this criterion was scored 3. Finally, as with other alternatives, dredging cleanup projects of this scale in Puget Sound typically have the support of regulatory agencies, and thus this criterion scored 5. The overall average implementability score for the Dredge alternative is 3.8.

Capping ranks higher for technical feasibility compared to dredging because there would be less need for upland sorting/processing of excavated material. Thus, the Cap alternative was scored 4 for technical feasibility. Capping equipment is commonly available, and procuring the required volume of cap material for this alternative is feasible, and thus this criterion was scored 5. Finally, there is typically regulatory and permitting support for capping performed during environmental cleanup, and this criterion was scored 5, for an overall average score of 4.8 for implementability.

The EMNR alternative has similar considerations to the Cap alternative but ranks higher for technical feasibility and availability of materials because only one-half of the cap material is required under this alternative. Thus, scores were 5, 5, and 5 for technical feasibility, availability of materials and equipment, and permitting/regulatory considerations, respectively, for an overall average score of 5.0.

MNR does not entail active construction. Implementability is related to periodic sampling during each monitoring event. Because it does not trigger any of the technical feasibility, materials availability, or permitting/regulatory issues that occur with active construction, all factors were assigned a score of 5, for an overall average score of 5.0 for implementability.

6.2.4.5 Cost

The Dredge alternative in SMA-4 has the highest estimated cost ($800,000/acre) and the lowest rank, scoring 2. The Cap alternative is estimated to cost $100,000/acre and has been assigned a score of 5. The EMNR alternative is estimated to cost $70,000/acre and has been given a score of 5 for cost. MNR is estimated to cost $10,000/acre in the FLA and has been assigned a score of 5. Table 6-2 provides a summary of the estimated cost for all of the alternatives in SMA-4, with details provided in Appendix A.

6.2.4.6 Community Concerns

This SMA is also relatively small, and is located along a sloped area where neither substantial intertidal shellfish beds nor major geoduck beds are likely to be impacted by cleanup operations. It is also out of the way of most fishing activities in the bay. Therefore, based on preferences expressed by the community, alternatives that actively remove or remediate sediments in this SMA received higher scores. The Dredge and Cap alternatives both received a score of 4, the EMNR alternative received a score of 3, and the MNR alternative received a score of 1.

6.2.4.7 Recycling and Waste Minimization

Similar to the other SMAs, the Dredge alternative in SMA-4 has limited opportunity for recycling or reuse, while at the same time generating waste during excavation, and was thus scored 2 for recycling/waste minimization.

The Cap alternative and the EMNR alternative produce the least waste and have the highest potential for recycling through the beneficial reuse of maintenance dredge material in the cap, and thus these alternatives both score 5 for this evaluation criterion.

MNR does not entail active construction. There is no opportunity for recycling or waste minimization with this alternative. MNR has been assigned a score of 1 for this criterion.

6.2.4.8 Environmental Impacts

The potential environmental impacts associated the Dredge alternative are greater than for capping alternatives. The relatively large volume of material removed and associated water quality and dredge residuals impacts result in a score of 3 for this criterion.

The Cap and EMNR alternatives do not result in dredge-related impacts; however, these alternatives do require placement of relatively large volumes of material during construction, with associated potential for water quality impacts, and thus both of these alternatives have been assigned a score of 4 for environmental impacts.

Because MNR does not entail construction activities, there are no environmental impacts associated with this alternative. MNR has been assigned a score of 5 for environmental impacts.

6.2.4.9 Preferred Alternative

Based on this evaluation, the Cap alternative and EMNR alternative total scores rank similarly, with EMNR ranking highest of the alternatives. Thus, EMNR is the preferred alternative for SMA-4.

The restoration timeframe for the EMNR alternative is approximately 2 years for design, permitting, and implementation.

6.2.5 cPAH Background Area (SMA-5) Detailed Evaluation

6.2.5.1 Threshold Evaluation

None of the alternatives for SMA-5 meet the SMS threshold criteria of protection of human health and, therefore, none meet the requirement for attainment of cleanup standards. Consistent with SMS, because no practicable alternative exists to achieve cleanup levels, a technical practicability evaluation is necessary for SMA-5. This evaluation is described in Section 6.4.

Although active measures cannot achieve risk-based cleanup levels, four alternatives were carried through the SMS detailed evaluation as described subsequently: Dredge and MNR, Cap and MNR, EMNR and MNR, and MNR. The active remedies focus on a subset of the SMA where concentrations exceed 3 times cleanup levels. Thus, each of the alternatives also has an MNR component for those areas of the SMA between 1 and 3 times the cleanup level.

6.2.5.2 Short-term Effectiveness

For the Dredge and MNR alternative, short-term effectiveness was given a score of 1 for human health and 1 for environment, for an average score of 1.0. This scoring reflects the substantially large volume of dredge material (an estimated 1.0 to 1.4 million cy) that needs to be managed in this alternative and potential risks to human health associated with this work, as well as generated dredge residuals, which will result in a significant environmental impact in the bay. In addition, the benthic community and existing geoduck beds would be impacted over 196 acres of the bay, which is a substantial percentage of the resources present. Only some of these resources would be expected to recover within a few years.

The Cap and MNR alternative does not require upland management of dredge material and debris, and thus represents a lower potential risk to human health compared to dredging. However, there are water quality impacts associated with placing the capping material, and potential bay-wide concerns with the scale of material placement (approximately 500,000 tons of cap material) under this alternative, which represent a short-term human health and environmental risk. As above, the benthic community and existing geoduck beds would be impacted over 196 acres of the bay, which is a substantial percentage of the resources present. Thus, this alternative ranks 2 for human health and 2 for environment, for an overall average of 2.0.

The EMNR and MNR alternative entails handling the lowest volume of material, and thus has the lowest attendant risks to both human health and the environment. However, the scale of material placement is still significant, with more than 200,000 tons of material needed. This alternative scored 2 for both human health and 3 for environment (indicating the possibility that some of the benthic community may survive a thinner layer placement), for an overall average score of 2.5.

Because MNR does not take active measures to improve human health in the short term, it was scored 1 for this criterion. On the other hand, the concentrations of chemicals in SMA-5 do not present a risk to the benthic community, and so this MNR is scored 5 for short-term environmental impact, for an overall average of 3.0 for short-term effectiveness.

6.2.5.3 Long-term Effectiveness

The long-term effectiveness of the Dredge and MNR alternative ranks low for protection of human health because much of the bay remains unaddressed even after implementing the remedial action. Dredging ranks medium for long-term environment effectiveness; while the SMA-5 primary COC, cPAH, is not a benthic risk driver, the Dredge and MNR alternative would still disrupt significant portions of the benthic community, and long-term geoduck impacts could be expected. Dredging on this scale has not been demonstrated locally, and the overall duration is significant, making dredging rank low for certainty/reliability. Finally, due to generated dredge residuals, this alternative ranks marginally lower for residual risks. This alternative was scored 2 for human health, 3 for environment, 2 for certainty/reliability, and 4 for residual risks, for an average score of 2.8.

The Cap and MNR alternative ranks low for protection of human health because much of the SMA is not remediated under this alternative; a score of 2 was assigned. Although cPAH are not a benthic risk driver, placement of approximately 500,000 tons of sand for capping under this alternative could significantly disrupt the geoduck community; thus long-term effectiveness for the environment was scored 3. Institutional controls would be required, and capping would require more than 3 years to complete; thus, certainty/reliability was scored 3. Similar to the Cap alternatives in the other SMAs, residual risk was also scored 3, for an overall average score of 2.8 for long-term effectiveness.

The EMNR and MNR alternative is similar to the Cap alternative and ranks 2 for protection of human health. However, because this alternative entails placement of a nominal 6-inch-thick cover, the benthic community would be expected to be only marginally disrupted and thus a score of 4 was used for protection of the environment. EMNR presumes ongoing natural recovery following placement of clean sand, and thus is less certain than capping. Thus certainty/reliability has been scored 2. Residual risk ranks 2 because of the reliance on natural recovery processes and the fact that material is not removed under this alternative. The overall average score for long-term protectiveness is 2.5 for the EMNR and MNR alternative.

Similar to the Central Bay SMA, the FS presumes that natural recovery is occurring very slowly in SMA-5, and thus MNR has been assigned a score of 1 for protection of human health and 5 for protection of the environment. Further, MNR is scored 1 for certainty/reliability and 1 for residual risks because active measures are not taken under this alternative. The overall average score for long-term effectiveness of MNR in SMA-5 is 2.0.

6.2.5.4 Implementability

The technical feasibility of the Dredge and MNR alternative was given a score of 2 in consideration of the substantially large volume of material handled, and the need to process debris and unsuitable dredge material in an available upland location, which would present a logistical challenge for a project of this scale. Materials and equipment for dredging are commonly available; however, the space required to manage 500,000 to 700,000 cy of dredge material (the 50 percent of dredge material assumed unsuitable for DMMP open-water disposal) would be significant, if not impossible to find, and thus this criterion was scored 1. Finally, while dredging projects in Puget Sound typically have the support of regulatory agencies when performed in conjunction with cleanup, it is expected that dredging on the scale necessary in SMA-5 for this alternative would create significant concerns, and thus this criterion scored 2. The overall average implementability score for the Dredge and MNR alternative is 1.8.

Capping ranks higher for technical feasibility compared to dredging because there would be less need for upland sorting/processing of excavated material. Thus, the Cap and MNR alternative was scored 3 for technical feasibility. Capping equipment is commonly available; however, procuring almost 500,000 tons of cap material for this alternative could be very difficult, and thus this criterion was scored 2. Finally, there is typically regulatory and permitting support for capping performed during environmental cleanup; however, the volume of material and logistics required to obtain this material are significant and thus this criterion was scored 4, for an overall average score of 3.0 for implementability.

The EMNR and MNR alternative has similar considerations to the Cap alternative but ranks higher for technical feasibility and availability of materials because only one-half of the cap material is required under this alternative. Thus, scores were 4, 3, and 5 for technical feasibility, availability of materials and equipment, and permitting/regulatory considerations, respectively, for an overall average score of 4.0.

MNR does not entail active construction. Implementability is related to periodic sampling during each monitoring event. Because it does not trigger any of the technical feasibility, materials availability, or permitting/regulatory issues that occur with active construction, all factors were assigned a score of 5, for an overall average score of 5.0 for implementability.

6.2.5.5 Cost

The Dredge and MNR alternative in SMA-5 has the highest estimated cost ($800,000/acre) and the lowest rank, scoring 2. The Cap and MNR alternative is estimated to cost $60,000/acre and has been assigned a score of 5. The EMNR and MNR alternative is estimated to cost $30,000/acre and has been given a score of 5 for cost. MNR is estimated to cost $2,000/acre in SMA-5 and has been assigned a score of 5. Table 6-2 provides a summary of the estimated cost for all of the alternatives in SMA-5, with details provided in Appendix A.

6.2.5.6 Community Concerns

For this SMA, there are few practicable alternatives, and it was not considered likely that any of them would fully address community concerns for the larger bay. Active cleanup alternatives such as dredging and capping would have major impacts on the ecological health of the bay, as well as fisheries activities, and dredging would also create a great deal of resuspension throughout the bay that could temporarily increase contaminant concentrations in seafood as well as impact a variety of biological resources due to turbidity. On the other hand, allowing the bay to naturally recover will be a lengthy process.

Reflecting these issues, all of the scores for this SMA were low. The Dredge and MNR alternative was given a score of 1 due to its major detrimental ecological impacts on the bay, as well as interference with fisheries operations over a period of 18 years. The Cap and MNR and the EMNR and MNR alternatives would also have significant impacts on the bay and interference with fisheries, and were given a score of 2. MNR was given a score of 1, as it does not provide immediate improvements in the bay in areas that are not included in other SMAs.

6.2.5.7 Recycling and Waste Minimization

Similar to the other SMAs, the Dredge and MNR alternative in SMA-5 has limited opportunity for recycling or reuse, while at the same time generating waste during excavation, and was thus scored 2 for recycling/waste minimization.

The Cap and MNR alternative and the EMNR and MNR alternative produce the least waste and have the highest potential for recycling through the beneficial reuse of maintenance dredge material in the cap, and thus these alternatives both score 5 for this evaluation criterion.

MNR does not entail active construction. There is no opportunity for recycling or waste minimization with this alternative. MNR has been assigned a score of 1 for this criterion.

6.2.5.8 Environmental Impacts

The potential environmental impacts associated the Dredge and MNR alternative are significant. As with the Mill Site South and Central Bay dredging alternatives, community impacts during construction of a cPAH Background Dredge and MNR remedy (air quality, noise, light, and traffic) would be substantial and over a long duration. Impacts to bay users (tribal and recreational fishing, shellfish harvesting, etc.) would mean significant disruption and interference in the use of this resource for 10 or more years. The substantially large volume of material removed and associated water quality and dredge residuals impacts, as well as the community impacts result in a score of 1 for this criterion.

The Cap and MNR alternative does not result in dredge-related impacts; however, this alternative does require placement of significant volumes of material for cap construction, with associated potential for water quality impacts, and related interference with the use of Port Gamble Bay for fishing and shellfish harvest during construction, and thus has been assigned a score of 2 for environmental impacts.

The EMNR and MNR alternative requires less cap material placement than the Cap alternative and, therefore, scores comparatively higher at 3 for environmental impacts.

Because MNR does not entail construction activities, there are no environmental impacts associated with this alternative. MNR has been assigned a score of 5 for environmental impacts.

6.2.5.9 Preferred Alternative

Although none of the alternatives meet threshold requirements, based on this evaluation, the Cap and MNR alternative, EMNR and MNR alternative, and MNR alternative total scores rank similarly. Because of the substantially higher costs associated with capping and EMNR compared to MNR, the minimal additional benefit provided, and the possibility for harm to resources in the bay, the MNR alternative was identified by Ecology as the preferred alternative for SMA-5.

The restoration timeframe for the MNR alternative is unknown, but expected to be greater than 10 years.

6.3 Data Gaps Evaluation

During development of the FS alternatives, several data gaps were identified. This section describes those data gaps and provides a preliminary plan for addressing these data gaps during development of the CAP, and/or during remedial design as appropriate.

6.3.1 Mill Site Open-water Disposal Suitability

A portion of the dredge sediments generated from Mill Site North and Mill Site South are prospectively considered suitable for open-water disposal at a non-dispersive, unconfined DMMP open-water disposal site. Provided that large wood debris is appropriately screened, chemistry levels (including dioxin/furan) pass suitability criteria, and DMMP bioassays also pass suitability criteria, it is expected that the DMMP agencies would permit some or all of the SMA-1 and/or SMA-2 wood debris to be disposed in a suitable open-water disposal location.

The use of open-water disposal for dredge material is evaluated on a case-by-case basis, and future suitability determinations can be subject to evolving policy issues related to sediment chemistry. Prior to the FS, Mill Site North sediments underwent a preliminary screening that suggests these sediments would pass the open-water disposal suitability determination, including for dioxins/furans. Mill Site South sediments were screened against DMMP criteria as part of preliminary sampling recently performed by OPG/PR. Thus, in developing alternatives and associated costs, it has been assumed that 80 percent of Mill Site North and

25 percent of most of the Mill Site South sediments would be suitable for open-water disposal. Under the preferred SMA-2 Dredge, Cap, and EMNR alternative, approximately 50 percent of the sediments dredged from this SMA would be suitable for open-water disposal.

Additional characterization of these sediments would be required to confirm the use of open-water disposal. Sampling and characterization in accordance with DMMP protocols would need to formally occur for specific areas identified in SMA-1 and SMA-2 depending on the proposed dredge area. Formal DMMP suitability would be assessed during detailed design.

6.3.2 Vertical Extent of Wood Waste in Mill Site South (SMA-2)

The current understanding of the vertical extent of wood waste in the Mill Site South SMA is limited to key core locations where the contact between wood waste and native sediments was directly observed. In contrast to Mill Site North, prior geophysical data collection in Mill Site South was not as clearly consistent with the coring observations of the contact with wood waste. Thus, the required bottom elevation of a proposed dredge prism in SMA-2 is less certain, and additional data collection through coring during remedial design will allow the horizontal and vertical extents of dredging to be refined for SMA-2. Because the preferred SMA-2 Dredge, Cap, and EMNR alternative focuses dredging inshore of -20 feet MLLW, less data collection would be necessary to design this remedy, compared to the other SMA-2 alternatives that include a dredging component.

6.3.3 Natural Recovery Trends

There is a limited bioassay dataset for documenting natural recovery trends. In the absence of sufficient bioassay data to demonstrate a trend in recovery, an approach using multiple lines of evidence (for example, net sedimentation measurements, hydrodynamic modeling, bioassay and chemical concentration trends, etc.) has been used for other regional sediment feasibility studies. While a similar approach could be useful for addressing this data gap, ultimately the long-term trend in bioassay test results will be used for monitoring and cleanup decision-making.

Ideally, additional bioassay data and chemistry data for bioaccumulative chemicals would be collected in the future to compare to the most recent dataset provided in the RI, and trends in natural recovery assessed using these new data. For cleanup projects that require multiple years to implement, there may be an opportunity to collect future data, depending on when EMNR material becomes available for this area, to evaluate natural recovery trends and facilitate adaptive management decisions. Additional discussion of adaptive management opportunities is provided in Section 7.

6.4 Technical Practicability Evaluation for Background Area (SMA-5)

6.4.1 Introduction

The Background Area (SMA-5) is characterized by sediments and tissue cPAH concentrations that exceed human health risk criteria. As discussed in the RI, the natural background sediment and tissue cPAH concentrations also exceed MTCA risk criteria for protection of human health under the exposure scenarios modeled. However, cPAH concentrations in Site sediments exceed natural background by an order of magnitude.

Ecology selected a cleanup level for cPAHs based on the sediment background threshold value (BTV). BTVs are higher than natural background because they represent a 90 percent confidence interval on the 90th percentile background value. The cleanup level for cPAH was thus selected to be 16 μg/kg.

SMS defines the term "practicable" as "able to be completed in consideration of environmental effects, technical feasibility and cost." (WAC 173-204-200(19)). The general response actions of dredging, capping, and EMNR are technically impracticable in SMA-5. Given the scope and size of the SMA, environmental impacts from in-water construction on this scale (dredge residuals, water quality impacts during removal and material placement, impacts to shellfish beds, vessel and vehicle traffic, interference with fisheries, construction noise and light, and air emissions) would be substantial as discussed below, and Site use would be restricted for long periods of time during remedy implementation. More importantly, however, is that the best outcome that could be anticipated from an active remedy is that only about 30 percent of this SMA could be cleaned up to a natural background surface sediment concentration, which itself is higher than risk-based concentrations. Further, upon completion of a dredge, cap, or EMNR action in SMA-5, it is not clear that changes in tissue concentrations would be observable, and they would likely be very small compared to the overall risk.

The following details describe the environmental and community impacts that render dredging, capping, and EMNR impracticable for SMA-5.

6.4.2 Dredging Resuspension and Residuals Impacts

As previously discussed, dredging resuspension and residuals releases have been well-documented and would be expected to result in significant impacts to Port Gamble Bay if a dredging remedy were to be implemented in SMA-5. Based on bottom conditions in the bay, residuals loss on the order of 2 to 5 percent of the contaminant mass dredged would be expected (Bridges et al. 2008). For the 500,000 to 700,000 cy of dredging that would be conducted in SMA-5, this translates to a residual loss on the order of 15,000 to 50,000 tons of material. Dredging also unavoidably destroys the existing benthic community within the dredge footprint.

Potential risks posed by resuspension are discussed in Bridges et al. (2008). Short-term risks from resuspension occur due to increased water column exposure of contaminants, and include direct toxicity to benthos, as well as potential increases in bioaccumulation. Long-term risks to benthos from resuspension occur due to a redistribution of the exposure field of contaminants to the benthic community following completion of dredging.

6.4.3 Capping and EMNR Turbidity Impacts

As has been well-documented on other sediment remediation projects, placement of silt, sand, and gravel under water results in a turbidity plume, even for materials with very low fines content. The magnitude of the turbidity plume is a function of the percent fines, the volume of material placed, and the settling velocity of the cap material. The spread of the plume will vary depending on the settling velocity of the material, as well as prevailing currents and wind during cap/EMNR placement. Because of the number of variables involved, predicting the spread of a turbidity plume during cap/EMNR requires a complicated modeling process.

Widespread turbidity can cause a variety of environmental impacts, including a reduction in light penetration (and reduced photosynthesis), and impacts to adult fish, as well as affecting normal development of bivalve eggs and larva. Although not directly quantifiable, these impacts could potentially be significant, and span a long duration for a capping or EMNR remedial action in SMA-5, which would require placement on the order of 250,000 to 500,000 tons of cap/cover material over a period of 1 to 3 years.

6.4.4 Community Impacts

Under any construction scenario for SMA-5, community impacts from noise, light, air emissions, and truck traffic would be significant. Off-site transport and disposal of the 500,000 to 700,000 cy of dredge material would require 50,000 to 70,000 dump truck trips through the Port Gamble community, or wherever else an offloading site would be located. Import of 250,000 to 500,000 tons of cover or cap material from a beneficial reuse source would entail, at a minimum, 100 large barge trips into the bay, but more likely on the order of 200 to 500 barge trips based on typical equipment available for a project of this nature, which would inhibit the use of the bay for fishing and/or shellfish harvesting for anywhere from 1 to 3 years during the construction season. Where an upland quarry is required for cap/cover material, 20,000 to 40,000 truck trips would be needed to deliver the material.

Besides the direct community impacts during construction, related indirect impacts such as infrastructure wear and tear (e.g., pavement damage) would require additional mitigation upon completion of the SMA-5 remedial action.

6.4.5 Technical Practicability Conclusions

Based on the environmental and community impacts, logistical considerations, and overall feasibility of conducting a large-scale remedy in the Port Gamble Bay community, dredging, capping, and EMNR remedies are technically impracticable in SMA-5. Environmental impacts from dredging resuspension/residuals and turbidity from capping and EMNR would be significant. Community impacts such as air emissions, noise, light, and general community disruption would also be substantial.

As with active remedial measures, natural recovery processes are expected to result in a reduction in Site-wide cPAH concentrations over time, particularly after cPAH sources such as creosoted piles are removed during the remedial action. Recovery of SMA-5 will be monitored over time under the MNR alternative.

7 ADDITIONAL CLEANUP CONSIDERATIONS

7.1 Modifications to the Recommended Cleanup Action Alternative

The preferred cleanup action alternatives for the Site are described in Section 6, pending resolution of data gaps for SMA-1 and SMA-2. Depending on the timing of data gap resolution and the results of some of the key screening evaluations (e.g., open-water disposal suitability), the CAP may incorporate modifications to the preferred alternatives identified in the FS, as appropriate.

7.2 Protection of Cultural Resources

A bay-wide cultural resources overview was developed for Port Gamble Bay to identify and map areas of known or possible historical, archaeological, and cultural resources within the project area. The overview was developed by a professional archaeologist for OPG, DNR, and the Port Gamble S'Klallam Tribe and provided specific steps to complete identification, evaluation, and protection of cultural resources that may be affected by the Site cleanup action. Information from the overview was considered in developing the recommended cleanup action alternative for the Site. Significantly, none of the alternatives evaluated in this FS were eliminated based on cultural resource considerations, because the actions that are proposed will occur in locations and at elevations (i.e., recent fill) that are not expected to coincide with the presence of cultural resources.

During the follow-on remedial design and permitting phase of the cleanup action, the implementing parties, in consultation with the Washington Department of Archaeology and Historic Preservation (DAHP) and the Port Gamble S'Klallam Tribe, will identify areas that may be affected by the cleanup action. These areas will include locations where cleanup-related disturbance may occur, including dredging areas, staging areas, transport routes, and mooring areas, as appropriate. More detailed cultural resource evaluations will be integrated with studies for the engineering design phase of the project.

The cleanup action selected by Ecology for the Site will also include appropriate compliance monitoring provisions during implementation of the action, consistent with Section 106 requirements of the National Historic Preservation Act (NHPA) and Washington State laws. Detailed compliance monitoring plans will be developed during the remedial design and permitting phase, consistent with regulatory requirements. Appropriate cultural resource work plans, including a cultural resources treatment plan and an inadvertent discovery plan, will be included in the engineering design reports.

7.3 Habitat Restoration Opportunities

Cleanup of Port Gamble Bay provides an opportunity to integrate habitat restoration. Ecology, in concert with various stakeholders, has identified several priority habitat restoration opportunities in the bay. To the extent that restoration can be combined with cleanup, a cost-effective, integrated project can achieve combined benefits for habitat.

Restoration projects agreed to by Ecology, OPG, and DNR include the following:

- **Riparian Enhancement.** The Mill Site currently does not provide a riparian corridor along the shoreline. Adding riparian planting in the shoreline buffer zone will provide restoration benefits and is compatible with all of the cleanup alternatives considered, provided that the riparian improvement occurs after the need for shoreline access during cleanup has ended.
- **Over-water Structure Removal.** Over-water structures, including derelict and active docks, provide undesirable shading. Creosoted structures will be removed as part of the cleanup, but credit for removing shading will be provided as part of the restoration package as appropriate, based on whether structure removal is permanent.
- **Eastern Wharf and Southeastern Mill Site Fill Removal.** Ecology performed a coastal geomorphological evaluation of the Mill Site and determined that the natural sediment supply to the bay is effectively diverted by the presence of Mill Site fill placed historically during site development. Restoration will include removal of fill along the eastern and southeastern shorelines of the Mill Site uplands to create a more naturally contoured and sloping beach that will support forage fish habitat and shellfish restoration. Removal of fill is compatible with cleanup and can serve to restore sediment transport processes more similar to historic conditions. Removal of upland fill can occur during the same construction phase as intertidal excavation (following demolition activities), and is expected to require similar equipment to that which would be used for intertidal work, for an integrated approach to remediation and restoration in these areas.

- **Debris Removal.** Scattered intertidal debris has been documented along the western shoreline of the bay, particularly adjacent to the former landfills. Removal of this debris, and general cleanup and riparian improvements at the landfill sites, provide a habitat restoration opportunity and are expected to improve conditions for eelgrass in this area. Because the area of restoration identified by Ecology is outside of the SMA areas where active remediation will occur, this restoration opportunity is compatible with all of the alternatives considered.
- **Former Log Transfer Facility Dock and Derelict Vessel Removal.** Removal of the FLTF dock will reduce overwater shading on the western shoreline of Port Gamble Bay, and removal of the derelict sunken vessel in this area will restore the shoreline in this area. The FLTF dock and derelict vessel are located north of the FLA SMA; thus this removal work can be accomplished without impact to the remedial action in the FLA.
- **Olympia Oyster Bed and/or Eelgrass Restoration.** Scattered debris is present along the western shoreline of Port Gamble Bay, south of the Mill Site. Removal of this debris will function to restore oyster beds and/or eelgrass in these areas. As all of these locations are outside of the Mill Site South SMA, this work can be accomplished independently or in concert with cleanup work, with negligible expected impact to the cleanup.

Ultimately, habitat restoration will be determined by Ecology, DNR, and OPG and integrated into cleanup design and implementation as appropriate. Restoration projects will be presented in greater detail in a separate Restoration Plan.

7.4 Adaptive Management Opportunities

The FS assumes that cap, cover, and residuals management materials will largely be sourced from a beneficial reuse maintenance event when the appropriate grain size is available. Based on the historical availability of such materials, it is only on a periodic basis that large volumes of this type of material are dredged in Puget Sound. Alternatively, smaller volumes from local maintenance dredge projects (marinas, etc.) may be available in any given year. Thus, large-scale capping and EMNR may require several years to generate sufficient volume to complete the remedy.

There can be an advantage associated with phasing the project implementation, as it allows for an adaptive management strategy to be used during the cleanup process. Because implementation is expected to take several years, the opportunity exists to collect interim data to gauge the rate and success of natural recovery processes. At the same time, it is desirable to use any capping material that becomes available (whether small or large volumes), to avoid missing opportunities. Phasing can be accomplished in several ways:

1. Discrete cap or EMNR areas can be selected for completion in any given year, and all of the available beneficial reuse material generated during that year would be dedicated to the identified area. The advantage of this approach is that an entire area could be considered effectively "finished" and long-term monitoring could be initiated. The disadvantage of this approach is that other areas that cannot be completed in a given year would remain unaddressed until a future construction season.
2. Wide areas could be addressed, with a thinner placement of material in a series of lifts that are completed as material comes available. This approach would allow interim monitoring to occur to gauge the effectiveness of the remedy as it is implemented. It could be determined that the initial thinner lifts (similar to EMNR) within an area that may have been proposed for capping have sufficiently addressed benthic and human health risk, and the adaptive management approach could ultimately result in a different final remedy for that area. This approach would also cover a wider area with the available material, at least partially addressing exposure over a greater footprint. Finally, this approach would cause less benthic disturbance and short-term environmental impact, as the benthic community is less likely to be damaged with thinner lifts of material, which would allow the community time to adapt before the next placement of material. The disadvantage of this approach is that larger areas of the site would remain "unfinished" until adaptive management endpoints are met and/or full placement of the design thickness of material is achieved.

The use of phasing and adaptive management will be further addressed in the forthcoming CAP.

8 REFERENCES

Anchor and Aspect (Anchor Environmental, L.L.C. and Aspect Consulting, LLC), 2004. Final (100 Percent) Design, Holly Street Landfill Cleanup/Whatcom Creek Estuary Restoration Project. Report prepared for City of Bellingham. April 2004.

Anchor and EPI (Environmental Partners, Inc.), 2008. Final Remedial Investigation/Feasibility Study Work Plan and Sampling and Analysis Plan. Former Pope & Talbot Inc. Sawmill Site, Port Gamble, Washington. Prepared for Pope Resources LP, Olympic Property Group L.L.C., and the Washington State Department of Ecology. October 2008.

Anchor QEA (Anchor QEA, LLC) and EPI, 2010. Remedial Investigation Report: Former Pope & Talbot Sawmill Site, Port Gamble, Washington. Prepared for Pope Resources LP, Olympic Property Group L.L.C., and the Washington State Department of Ecology. October 2010.

Brenner, R.C., V.S. Magar, J.A. Ickes, J.E. Abbott, S.A. Stout, E.A. Crecelius, and L.S. Bingler, 2002. Characterization and Fate of PAH-Contaminated Sediments at the Wyckoff/Eagle Harbor Superfund Site. Environ. Sci. Technol., 36 (12): 2605-2613.

Bridges T., S. Ells, D. Hayes, D. Mount, S. Nadeau, M. Palermo, C. Patmont, and P. Schroeder, 2008. U.S. Army Engineer Research and Development Center. The four Rs of environmental dredging: Resuspension, release, residual, and risk. U.S. Army Engineer Research and Development Center, Vicksburg, MS. ERDC/EL TR-08-4. January 2008.

Bridges, T., K. Gustavson, P. Schroeder, S. Ells, D. Hayes, S. Nadeau, M. Palermo, and C. Patmont., 2010. Dredging Processes and Remedy Effectiveness: Relationship to the 4 Rs of Environmental Dredging. February 10, 2010.

Brooks, K.M., 2003. Creosote-Treated Wood in Aquatic Environments: Technical Review and Use Recommendations. Aquatic Environmental Sciences, Port Townsend, WA.

Caldwell, R.S., 2005. Sulfide as a Marine Sediment Toxicant. Presentation to SMARM 2005 by Northwestern Aquatic Sciences, Newport, OR. May 2005. http://www.nws.usace.army.mil/PublicMenu/.

Carpenter, R., M.L. Peterson, and J.T. Bennett, 1985. ^{210}Pb derived sediment accumulation and mixing rates for the greater Puget Sound region. *Marine Geology* 64:291-312.

DMMP (Dredged Material Management Program), 2009. Determination on the Suitability of Proposed Dredged Material Tested for the Former Scott Mill Site, Anacortes, Washington. Project NWS-2009-203 Evaluated Under Section 404 of the Clean Water Act for Open-Water Disposal at the Port Gardner Non-Dispersive Site. June 2009.

DNR (Washington Department of Natural Resources), 2011. Puget Sound Initiative – Derelict Creosote Piling Removal, Best Management Practices for Pile Removal and Disposal. Appendix to WDFW (2011) HPA 125073-1 (see below). Updated August 26, 2011.

Ecology (Washington State Department of Ecology), 2012. Cleanup and Restoration of Port Gamble Bay, Remedial Investigation Report.

EPA (U.S. Environmental Protection Agency), 2005. Contaminated Sediment Remediation Guidance for Hazardous Waste Sites. EPA-540-R-05-012. December 2005.

Kendall, D., and Barton, J. Ammonium and Sulfide Guidance Relative to *Neanthes* Growth Bioassay. DMMP Clarification Paper, June 15, 2004. http://www.nws.usace.army.mil/publicmenu/DOCUMENTS/dmmo/Ammonia-Neanthes-04-final1.pdf

Lavelle, J.W., G.J. Massoth, and E.A. Crecelius, 1985. Sedimentation rates in Puget Sound from ^{210}Pb measurements. NOAA Technical Memorandum ERL PMEL-61. Pacific Marine Environmental Laboratory, Sequim, WA.

Magar, V.S., D.B. Chadwick, T.S Bridges, P.C. Fuchsman, J.M. Conder, T.J. Dekker, J.A. Steevens, K.E. Gustavson, and M.A. Mills, 2009. Monitored Natural Recovery at Contaminated Sediment Sites. Technical Guide ESTCP Project ER-0622. May 2009.

NewFields (NewFields Northwest), 2007. Port Gamble Baseline Investigations: Marine Natural Resources. Prepared for Olympic Property Group by NewFields Northwest, Port Gamble, WA. February 2007.

NWAA (Northwest Archaeological Associates Inc.), 2010. Cultural Resources Overview for the Port Gamble Bay Cleanup and Restoration Project, Kitsap County, Washington. March 1, 2010.

Palermo, M.R, S. Maynord, J. Miller, and D. Reible, 1998a. Assessment and Remediation of Contaminated Sediments (ARCS) Program Guidance for In Situ Subaqueous Capping of Contaminated Sediments. EPA 905-B96-004, Great Lakes National Program Office, Chicago, IL.

Palermo, M.R., R.E. Randall, R. Fredette, J. Clausner, T. Myers, M. Rollings, and G. Williams, 1998b. Technical Guidance for Subaqueous Dredged Material Capping. United States Army Corps of Engineers. Waterways Experiment Station, Vicksburg, MS.

Palermo et al., 2008. Technical Guidelines for Environmental Dredging of Contaminated Sediments. U.S. Army Corps of Engineers, Engineer Research and Development Center. ERDC/EL TR-08-29. September 2008.

Parametrix, 1999. Pope & Talbot Port Gamble Mill Site, Phase I Groundwater and Surface Water Investigation, Sampling and Analysis Plan. Prepared for Pope & Talbot, Port Gamble, Washington. January 1999.

Parametrix, 2000. Preliminary Oceanographic Report. Prepared for Pope & Talbot, Port Gamble, Washington. May 2000.

Parametrix, 2002. Sediment Data Summary and Cleanup Study Plan, Former Pope & Talbot, Inc. Site, Port Gamble Bay, Washington. Prepared for Pope & Talbot by Parametrix, Seattle, WA.

Parametrix, 2003. Sediment Characterization Report, Former Pope & Talbot, Inc. Department of Natural Resources Aquatic Land Lease No. 20-012795. Prepared for Pope & Talbot by Parametrix, Seattle, WA.

Parametrix, 2004. Final Report, Baseline Natural Recovery Sediment Monitoring Report – Former Port Gamble Mill Site. October 2004.

Patmont C.R., and M.R. Palermo, 2007. Case studies of environmental dredging residuals and management implications. In: Proceedings Remediation of Contaminated Sediments-2007. Savannah, Georgia. Columbus (OH): Battelle Press.

Stout, S.A., and T.P. Graan, 2010. Quantitative Source Apportionment of PAHs in Sediments of Little Menomonee River, Wisconsin: Weathered Creosote versus Urban Background. Environ. Sci. Technol., 44 (8): 2932–2939.

Straus, K.M., L.M. Crosson, and B. Vadopalas, 2009. Effects of Geoduck Aquaculture on the Environment: A Synthesis of Current Knowledge. Washington Sea Grant Technical Report WSG-TR 08-01. School of Aquatic and Fishery Sciences, University of Washington. October 2009.

Sumeri, A., 1996. Dredged Material is Not Spoil: A Report on the Use of Dredged Material in Puget Sound to Isolate Contaminated Sediments. Western Dredging Association Seventeenth Annual Meeting. June 1996.

WDFW (Washington Department of Fish and Wildlife), 2011. Hydraulic Project Approval (HPA) 125073-1: Creosote Piling and Structural Removal. December 15, 2011.http://www.google.com/url?sa=t&rct=j&q=derelict%20piling%20removal%20hpa&source=web&cd=1&cad=rja&ved=0CDAQFjAA&url=http%3A%2F%2Fwww.rco.wa.gov%2Fprism%2FProjectSnapshotAttachmentData.aspx%3Fid%3D140875&ei=YOnHUJHWH8TAigKvqoCQDw&usg=AFQjCNExd2H8s4NgcEE-mBodrCkKWi1P6Q&bvm=bv.1355272958,d.cGE.

FIGURES

APPENDIX A
DETAILED COST ESTIMATES