DRAFT FINAL

Feasibility Study

Maury Island Open Space Property

Maury Island, Washington

King County Parks and Recreation Division
King Street Station
201 South Jackson Street,
M.S. KSC-NR-700
Seattle, Washington 98104-3855

April 17, 2017

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A Report Prepared For:

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Acronyms

µg/kg	micrograms per kilogram
µg/L	micrograms per liter
AESI	Associated Earth Sciences Inc.
ARAR	Applicable, Relevant, and Appropriate Requirements
Aspect	Aspect Consulting
BaP	benzo(a)pyrene
bgs	below ground surface
BMP	best management practices
CDM	Camp Dresser & McKee Inc., now CDM Smith Inc.
COC	contaminants of concern
County	King County
cPAH	carcinogenic polycyclic aromatic hydrocarbons
CWA	Clean Water Act
DCA	Disproportionate Cost Analysis
DCAP	draft cleanup action plan
Ecology	Washington State Department of Ecology
EPA	Environmental Protection Agency
ESA	environmental site assessment
ESL	ecological screening levels
FEIS	final environmental impact statement
FS	feasibility study
ft	feet
IAP	interim action plan
Landau	Landau Associates
MBTA	Migratory Bird Treaty Act
mg/kg	milligrams per kilogram
MNA	monitored natural attenuation
MSL	mean sea level
MTCA	Model Toxics Control Act
NEBA	Net Environmental Benefit Analysis
NPDES	National Pollution Discharge Elimination System
NWA	Northwest Aggregates
NWI	National Wetlands Inventory
OSHA	Occupational Safety and Health Administration
PAH	polycyclic aromatic hydrocarbons
O&M	Operation and Maintenance
Qva	Vashon advance outwash
Qvr	Vashon recessional outwash
Qvt	Vashon glacial till
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act
RI	remedial investigation
RCW	Revised Code of Washington
SCUM II	Sediment User's Cleanup Manual II
SEPA	State Environmental Policy Act

TA	Terra Associates
TEE	terrestrial ecological evaluation
TEF	toxic equivalent factor
TEQ	toxic equivalency
TCLP	toxicity characteristic leaching procedure
TSP	Tacoma Smelter Plume
USACE	United States Army Corps of Engineers
USFS	United States Forest Service
XRF	X-Ray Fluorescence

Executive Summary

This report presents the results of a feasibility study (FS) of the Maury Island Open Space property (referred to as the Cleanup Unit), which is located on the southeast side of Maury Island in unincorporated King County, Washington. The FS was performed to satisfy a portion of the requirements of Agreed Order No. DE 8439 with the Washington State Department of Ecology (Ecology) dated January 31, 2013, which requires King County to complete a remedial investigation (RI), FS, and draft cleanup action plan (DCAP) for the Cleanup Unit.

Project Description

The Cleanup Unit is approximately 266-acres in size and is located on the southeast side of Maury Island situated on a sea bluff above Puget Sound. CalPortland operated a sand and gravel mine within the central portion of the Cleanup Unit, most of which is steeply sloped and all of which is now sparsely vegetated, primarily with Scot's broom and Pacific madrone. The remainder of the Cleanup Unit consists of over-100 year old forests, younger forests, blackberry patches, and sea bluffs covered in blackberries, poison oak and Pacific madrone. The public have created a series of footpaths through the forests and utilize these, as well as former graded dirt roads, as casual walking trails.

It is commonly known that Maury Island lies within the plume fallout area from the former ASARCO Tacoma Smelter. The copper ores used by the ASARCO smelter contained high concentrations of arsenic and other metals. Over the years of operation, metals released from the Tacoma Smelter's smokestack, particularly arsenic and lead, were carried by wind, ultimately settling over a 1,000 square-mile area. As a result of this, surface soils within much of the Tacoma Smelter Plume (TSP) fallout area contain arsenic and lead concentrations that are many times greater than natural background concentrations. The soils on Maury Island are among those most significantly impacted within the TSP and the Cleanup Unit itself lies within an area most greatly impacted by the TSP on Maury Island.

In June 2014, CDM Smith Inc. (CDM Smith) completed a Remedial Investigation (RI) for the Cleanup Unit. The RI determined that metals concentrations in forest duff and surface soil throughout the Cleanup Unit, with the exception of recently mined areas and the beach, consistently exceed Model Toxics Control Act (MTCA) cleanup Levels. Research of the Cleanup Unit's land use history identified one additional source of contamination – an area that had previously been utilized as a private skeet shooting range. The RI confirmed that former skeet shooting activities resulted in an area of relatively greater lead concentrations than found throughout the rest of the Cleanup Unit, as well as an area where surface soils are impacted by polycyclic aromatic hydrocarbons (PAH) from skeet shards.

In May 2014, CDM Smith completed a Net Environmental Benefit Analysis (NEBA) for the Cleanup Unit. The NEBA concluded that the bluffs and much of the upland areas are eligible for the application of NEBA because they contain "especially valuable habitat." Therefore, a cleanup alternative involving removal of soil would result in greater environmental harm than an alternative of leaving the contaminated topsoil in place. Decision units within the Cleanup Unit that did not qualify for the NEBA included three upland areas that are densely vegetated with blackberry bushes. Ecology concurred with the NEBA determination. Therefore, based on the NEBA, remedial alternatives developed for the Cleanup Unit will also need to take into account the protection of the environment for those Units that qualify for the NEBA, regardless of the arsenic and lead concentrations.

Following the 2014 RI and NEBA, King County conducted an additional investigation of the wetland soils/sediments in Unit 5 to document the nature and extent of impacts to indicator species from arsenic, lead, and PAHs. The FS has been revised as needed to include any necessary modifications to the proposed remedial alternatives.

FS Remedial Alternatives

The FS developed and assessed five remedial alternatives for the Cleanup Unit. Because of the sensitive terrestrial ecological conditions throughout much of the Cleanup Unit, there is no remedial alternative that can be implemented that will result in a total cleanup. Therefore, each of the remedial alternatives relies substantially on institutional controls, including but not limited to: signage, hygiene stations, ongoing maintenance, and a land use covenant. Additional elements of each alternative evaluated are as follows:

Alternative 1 – Closure of redundant trail spurs. Capping the entire network of forest footpaths per the US Forest Service guidelines. Excavating soils on the graded road/trail that exceeds 40 milligrams per kilogram (mg/kg) and regrading the road. Excavating contaminated surface soils in all areas that do not pass the NEBA. All excavated soils to be disposed of off-island in a Resource Conservation and Recovery Act (RCRA) Subtitle D landfill.

Alternative 2 – Alternative 2 is the same as Alternative 1, except that soils will be contained below grade in two separate areas (which did not pass the NEBA), one of which will be capped by a visitor parking lot to be constructed in the portion of the former trap range area that does not pass the NEBA.

Alternative 3 - Closure of redundant trail spurs. Capping the entire network of forest footpaths per the US Forest Service guidelines. Conducting soil mixing for soils on the graded road/trail that exceed 20 milligrams per kilogram (mg/kg) and regrade the road. In the portion of the former trap range area that does not pass the NEBA, the organic layer will be stripped off and disposed of at an off-island landfill and capped with gravel for use as an equestrian parking lot. Soils in the other two areas that do not pass the NEBA will remain because both of these areas are heavily vegetated with blackberry bushes and virtually impassible by humans.

Alternative 4 – Alternative 4 is the same as Alternative 3, except that capping of the footpaths will be limited to a main thoroughfare.

Alternative 5 - Modification of Alternative 4 including revegetation of Units 3c and 3e. Graded roads will be capped with a minimum of 3- to 4- inches of compacted gravel and a 3-inch thick layer of mineral soil (or equivalent) to protect horse's hooves and dog's feet. Trails to be eliminated will be decommissioned by the cessation of trail maintenance. Hygiene stations will be placed at all main trail heads. In Unit 5, clearing and grubbing will only be performed for an area large enough to construct a 40 to 50- stall gravel parking lot. The cleared area will be graded and a gravel parking lot and driveway will be constructed by placing a minimum of a 6-inch thick layer of compacted gravel. A 6-foot chain link fence will be placed around the perimeter of the gravel parking lot and driveway to discourage visitors from walking through the former skeet range area. Limited remediation in the adjacent wetland will be done where lead exceeds allowed levels.

Conclusions and Recommendations

Cleanup of the Maury Island Open Space Cleanup Unit is complicated by its natural environment and the extensive nature of contamination. The NEBA completed for the Cleanup Unit demonstrated that, for a majority of the property, extensive cleanup actions would result in greater environmental harm than leaving the contaminated topsoil in place. Therefore, any remedial alternative selected for the Cleanup Unit must rely substantially on institutional controls, as are included in each of the remedial alternatives evaluated for this FS.

Besides institutional controls, the remedial alternatives developed for the Cleanup Unit all include capping of the forest trails to varying degrees and cleanup or capping of the graded road which currently serves a dual purpose as a trail and emergency fire access road. The primary difference between Alternatives 1, 2, and 5 and Alternatives 3-4 is in the cleanup of Units 3c and 3e –two areas which do not pass the NEBA. Although these areas are presently densely covered in blackberry bushes such that the potential for human exposure is low, MTCA requires that decision units not protected by the NEBA designation be addressed as part of the cleanup. The results of the DCA further indicate that Alternatives 3 and 4 do not provide benefits approaching the other, more permanent alternatives. For these reasons, Alternatives 3 and 4 are not recommended.

The main differences between Alternatives 1 and 2 and Alternative 5 include complete removal of contaminated soils from Units 3c and 3e and installation of topsoil and native vegetation. Alternative 5 provides for isolation of these contaminated soils through installation of a 3-inch layer of compost and closely spaced native shrubs and trees. In addition, rather than excavate and remove contaminated soils outside of the NEBA protected area in Unit 5, Alternative 5 limits human exposure in Unit 5 through installation of a 6-foot chain link fence around the proposed gravel lot and warning signs. Alternative 2 scored the same as Alternative 5 in the Disproportionate Coat Analysis (DCA) but its cost is much higher and it was eliminated from further consideration. The much higher costs for Alternative 1 as compared to Alternative 5 are disproportionate to the marginal, if any, increase in benefit for Alternative 1. Therefore Alternative 5 is selected as the preferred alternative.

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Section 1

Introduction

This document presents the results of a feasibility study (FS) for the King County Maury Island Open Space property, hereafter referred to as the "Cleanup Unit," which is located on the southeast side of Maury Island in unincorporated King County, Washington. CDM Smith Inc. (CDM Smith) completed the FS on behalf of King County (the County). This FS was performed to satisfy a portion of the requirements of Agreed Order No. DE 8439 with the Washington State Department of Ecology (Ecology) dated January 31, 2013, which requires King County to complete a remedial investigation (RI), FS, and draft cleanup action plan (DCAP) for the Cleanup Unit. In a letter dated February 25, 2014, Ecology approved the October 14, 2013 draft RI, which was finalized on June 2, 2014. A preliminary draft version of this document was prepared for King County by CDMSmith and submitted on July 6, 2015 (CDM 2015). This draft final FS report incorporates changes made to address Ecology comments to the preliminary draft. The Ecology comments were received by the County on October 15, 2015.

1.1 FS Objectives

The objectives of this FS are summarized below:

- Develop remedial action objectives (RAOs) for the Cleanup Unit.
- Screen potential remedial technologies to attain RAOs for the Cleanup Unit.
- Combine remedial technologies to develop remedial action alternatives that address all of the RAOs.
- Develop conceptual level cost estimates for implementation, operation, and maintenance of the remedial action alternatives.
- Evaluate the remedial action alternatives against the basis of the requirements and criteria established in the Model Toxics Control Act (MTCA).
- Recommend the most appropriate remedial action alternative program for implementation at the Cleanup Unit.

1.2 Definition of the Tacoma Smelter Plume and Relationship to the Cleanup Unit

It is commonly known that Maury Island lies within the plume fallout area from the former ASARCO Tacoma Smelter. The Tacoma Smelter was a 67-acre facility located in the Ruston/North Tacoma area. Beginning in 1890, the Tacoma Smelter was a lead smelter and refinery (EPA, 2010). The American Smelting and Refining Company (ASARCO) purchased the smelter in 1905. In 1912, the facility was converted to a copper smelter and refined copper from copper-bearing ores and concentrates that were shipped in from other locations (EPA, 2010). These copper ores contained high arsenic concentrations (EPA, 2010). The ore that ASARCO used also contained significant concentrations of other metals besides copper and arsenic, including lead, nickel, zinc, cadmium, selenium, antimony, mercury, and silver. ASARCO closed the Tacoma Smelter in 1985 (EPA, 2010).

Over the years of operation, metals released from the Tacoma Smelter's smokestack, particularly arsenic and lead, were carried by wind, ultimately settling over a 1,000 square-mile area (Ecology, 2012a). As a result of this, surface soils within much of the Tacoma Smelter fallout area contain arsenic and lead concentrations that are many times greater than natural background concentrations. This is what is referred to as an area-wide contaminant plume, and for this case specifically, the Tacoma Smelter Plume (TSP).

Ecology defines any area where a hazardous substance has come to be located as the "Site," regardless of property boundaries. For this reason, the Maury Island Open Space property is referred to as the "Cleanup Unit" throughout this FS, and the "Site" refers to the entire area impacted by the TSP.

The soils on Maury Island are among those most significantly impacted within the TSP, with average arsenic concentrations in some areas greater than 100 milligrams per kilogram (mg/kg), and sometimes greater than 200 mg/kg (Ecology, 2004). On Maury Island, the Cleanup Unit lies within an area most greatly impacted by the TSP (Ecology, 2004).

Ecology has completed a Final Interim Action Plan for the Tacoma Smelter Plume (Ecology, 2012b). The document includes a Model Remedies Guidance and Model Remedies Feasibility Study in its appendices. However, the recommendations in these documents are not necessarily feasible or appropriate for natural areas. In natural areas (e.g., forest land) the population at greatest risk is the terrestrial ecological environment, as opposed to humans, due to the relatively greater exposure. Even so, in instances where contamination is widespread but over a relatively thin layer, cleanup actions can be more harmful to the environment than the contaminants. Remedial actions in these circumstances must balance the short and long term risks and benefits for both human health and the environment.

Section 2
Cleanup Unit Description

2.1 Location

The Cleanup Unit is located on the southeast side of Maury Island, which is located in the State of Washington's Puget Sound Area, north of Tacoma, as shown on **Figure 1**. Maury Island is just off the southeast side of Vashon Island and connected to Vashon Island at its north end by an isthmus. The two landmasses together are sometimes referred to as Vashon-Maury Island. The Cleanup Unit is situated in portions of Sections 28 and 29, Township 22 North, Range 3 East, Willamette Meridian.

2.2 Physical Description

The Cleanup Unit consists of the following tax parcels, which have the assigned addresses and the acreage:

- Parcel No. 2822039023, 8215 SW 260th Street (257.38 acres)
- Parcel No. 2822039024, SW 260th Street (2.91 acres)
- Parcel No. 2822039025, SW 260th Street (2.74 acres)
- Parcel No. 2822039057, SW 260th Street (3.09 acres)

The Cleanup Unit is irregularly-shaped and is bordered on the southeast by the Puget Sound. SW 260th Street bisects an approximately 30 acre portion of the property on the north from an approximately 227 acre portion of the property on the south.

Topographically, most of the Cleanup Unit is situated on a sea bluff above the Puget Sound. The upland northern, western, and southern portions of the Cleanup Unit are gently rolling. Slopes range from roughly 5 to 20 percent in these areas. The Cleanup Unit is steeply sloped along the sea bluffs above Puget Sound and previously mined areas with slope gradients of up to approximately 60 percent. Total elevation change across the Cleanup Unit is approximately 363 feet (AESI, 1998). **Figure 2** shows the Cleanup Unit's boundaries with topographic contours projected on an aerial photograph. **Appendix A** contains photographs that show some of the Cleanup Unit's features.

Until 2010 when King County purchased the property, CalPortland[1] operated a sand and gravel mine within the Cleanup Unit. The most recent mining operations had been centrally located within the area referred to as the "South Pit" (**Figure 3**). There currently are some mine-associated above ground and underground conveyor structures existing on the property (**Figure 2**). A partially reconstructed dock is located at the base of the South Pit. To the northeast of the South Pit is another abandoned gravel pit, referred to as the "North Pit," which had operated in the early 1900s (**Figure 3**). Most recently mined areas of the South Pit are sparsely vegetated, typically with Scot's broom (also known as Scotch broom), sparse grasses, seedling Pacific madrone, and blackberry bushes. The North

[1] The Cleanup Unit was owned by Northwest Aggregates' (NWA), a wholly owned subsidiary of Glacier Northwest, Inc. Glacier Northwest is now a wholly owned subsidiary of CalPortland.

Pit is predominantly vegetated with Scot's broom, sparse grass, and a few mature trees (Pacific madrone, maple, and Douglas fir).

The majority of the upland areas are undisturbed by mining and covered by mature and semi-mature forest, which includes Pacific madrone, Douglas fir, Red alder, Black cottonwood, Western hemlock, and maple with an understory that includes salal, various ferns, huckleberry, Oceanspray, and Oregon grape. The exceptions to this are an area north of SW 260th Street that was once used as a private skeet range and an area in the northeast corner of the Cleanup Unit; these areas are predominantly covered by blackberry bushes. Large stands of blackberry bushes and scrubby vegetation, such as poison oak, Himalayan blackberries, and Scot's broom, cover the sea bluffs. A beach extends along the base of the bluff. The portion of property north of SW 260th Street also contains a wetland that is included in the National Wetlands Inventory (NWI). Photographs in **Appendix A** show some of these features.

A network of trails exists throughout the Cleanup Unit. These consist of "footpaths" and "graded roads," which were assessed during the RI. Footpaths consist of the meandering trails throughout the upland forest areas, which were created over time by continued long-term use. The footpaths connect with a larger trail system that extends off the Cleanup Unit. The graded roads are specific to the Cleanup Unit. They were originally constructed for the mine use and later abandoned. Over time, much of the former graded roads located along the bluff have become narrowed by encroaching vegetation, and in some places are completely overgrown. The graded roads located in the upland area have mostly retained a width suitable for vehicle passage and serve a dual purpose as access for emergency fire suppression. For purposes of the RI and FS discussions, the main access road into the site from SW 20th Street, which extends down the South Pit to the beach is not a part of the graded road system.

2.3 Natural Conditions

2.3.1 Geology

The Cleanup Unit is located within the Puget Sound Lowland, a north-south trending structural and topographic depression bordered on the west by the Olympic Mountains and on the east by the Cascade Mountains. The Puget Sound Lowland is underlain primarily by sediments deposited during and between repeated glacial advances and retreats in the Pleistocene Epoch.

The upland areas of the Cleanup Unit are mantled by Vashon till (Qvt) and recessional outwash (Qvr). Vashon till is an unsorted and unstratified, but highly compact, mixture of clay, silt, sand, gravel and boulders deposited by and overridden by the advancing glacier. Recessional outwash is a stratified sand and gravel deposited by meltwater streams from the receding Vashon ice sheet. The Qvt and Qvr are underlain by advance outwash (Qva), which is exposed along the bluffs and within the mine areas.

The Qvt and Qvr range from approximately 3 to 12 feet (ft) thick, where present. The Advance outwash (Qva) layer is approximately 200 to 250 feet thick. Pre-Vashon age deposits occur approximately 290 to 263 feet below the ground surface of the upland areas (approximate elevations of 8 to 90 ft Mean Sea Level [MSL], respectively) (AESI, 1998).

2.3.2 Groundwater

Limited perched water may be present seasonally on a discontinuous basis in areas where till is present. However, this has not been observed.

The first primary aquifer beneath the Cleanup Unit occurs in the Qva unit under unconfined conditions. Despite the large thickness of the Qva, the saturated interval is roughly one quarter of its average thickness (approximately 50 ft). Water table elevations for the Qva aquifer range from 85 ft MSL in the northwest corner of the Cleanup Unit to 20 ft MSL near the Puget Sound (ELS, 2006). Groundwater monitoring conducted across the Cleanup Unit for a decade (1998-2007) consistently shows a southeasterly groundwater flow direction towards the Puget Sound.

2.3.3 Springs

Springs occur at the contact between the Vashon advance outwash and the underlying less pervious silt and clay of the pre-Vashon unit where exposed near sea level along the beach. These seepage zones are considered to be related to groundwater discharge (AESI, 1998). Six "springs" were identified during the RI. These include four of the five springs previously identified by others and two new springs. These "springs" are more like seeps than actual springs. Only two springs actually emanated from the base of the shoreline bluff. The other four seeps appear to emanate from the beach at locations between normal high and low tide elevations. These seeps tend to run parallel to the shoreline, for lengths of as much as 200 ft.

2.3.4 Surface Water

The primary surface water feature is the Puget Sound, which forms the southeastern boundary of the Cleanup Unit, a distance of approximately 4,800 feet.

The only surface water feature within the Cleanup Unit is a wetland within the portion of the Cleanup Unit north of SW 260th Street. This wetland was delineated by King County as a part of the RI and its location is shown on **Figure 2**.

2.4 Natural Ecological Environment

The 2014 RI included surveys of current terrestrial ecological conditions, the wetland, the beach, and nearshore subtidal area adjacent to the North Pit. Assessments of terrestrial ecological conditions and the subtidal area adjacent to the South Pit were also conducted in 2000 during the environmental impact assessment process conducted for the proposed mine expansion.

2.4.1 Terrestrial Ecological

The presence of wildlife and habitat at the Cleanup Unit were documented in a Final Environmental Impact Statement (FEIS) for the gravel mine (King County, 2000) and a field survey was also conducted by a King County biologist in 2013 as a part of the RI. These assessments determined that sixty percent of the area is covered by a mixed Pacific madrone and Douglas fir forest, with one patch of Douglas fir forest (about 35 acres). Approximately 30% of the Cleanup Unit is previously mined area consisting of invasive shrubs and vines (Scot's broom and Himalayan blackberry) with madrone saplings in various stages of succession. Bluffs, densely vegetated with invasive shrubs and madrone, total approximately 10% of the area.

Wildlife observed during the 2013 survey included four species of amphibians, three reptile species, 33 species of birds, and five species of mammals. As documented in the 2000 FEIS, two special-status species, bald eagle and peregrine falcon (both now federally delisted), are likely to be occasional or rare on the Cleanup Unit. Other priority species and species of concern, including pileated woodpecker, great blue heron, red-tailed hawk, and band-tailed pigeons are all likely to occur. Black-tailed deer are common. Observations or signs of flycatchers, woodpeckers, sapsuckers, owls, and chickadees were reported in the FEIS and the 2013 field visit confirmed them.

2.4.2 Wetland

A 2013 survey of the wetland north of SW 260th Street determined it to be a forested/shrub-scrub depressional wetland, approximately 49,657 square feet in size (King County, 2013a). The wetland vegetation is dominated by hardhack (spirea) and willow in its understory, with black cottonwoods and red alders providing the forested canopy. A pocket of birch trees is in the southwest corner. The edge of the wetland supports emergent vegetation, with a band of slough sedge. Additional species observed in the wetland include salmonberry, soft rush, skunk cabbage, smartweed, and mannagrass. The wetland was rated a Category II based on the Washington State Wetland Rating system for Western Washington (Hruby, 2004) and determined to be functioning well.

2.4.3 Beach

The beach contains a variety of construction debris and remnant structures spread throughout. This material ranges from rock placed for historic shoreline armoring to old electrical cables. Concrete blocks and chunks of rusty metal are also quite common. The most significant structures remaining on the beach are associated with shoreline armoring. One of the more prominent structures is a concrete pier which is a remnant of the North Pit. An approximately 80-foot-long bulkhead is located 160 feet east of the existing dock. Numerous residual pilings exist on the beach in the vicinity of the North Pit, most of which protrude only a foot or two from the sand. King County intends to remove debris, shoreline armoring, the old pilings, and the existing dock as a part of the park improvement.

2.4.4 Nearshore Subtidal

A baseline characterization of the nearshore subtidal area adjacent to the proposed mine expansion area in 2000 identified a number of seabed features, including three eelgrass beds, sunken barges, patches of coarse-grained sediment, and a patch of debris (EVS, 2000; **Appendix B**). In 2013, a subtidal survey was conducted to assess additional pilings and deleterious debris associated with the North Pit. The survey identified only additional old pilings (CDM Smith, 2014a).

2.5 Cleanup Unit History

In 2010 CDM Smith (previously Camp Dresser & McKee Inc. [CDM]) conducted research of the history of the Cleanup Unit during completion of a Phase 1 environmental site assessment (ESA), which is summarized in this section. Maury Island and the Cleanup Unit itself were extensively logged during the 1880s-1890s. The first recorded human occupancy was in the late 1800s when the northeastern portion of the Cleanup Unit was homesteaded (see Section 2.6, Unit 3c); however, the homesteading occupants left in 1891. Anthropogenic activities on the Cleanup Unit for the area north of SW 260th Street and the area south of SW 260th Street subsequent to the late 1800s are described separately in the following sections.

2.5.1 North of SW 260th Street

The only known use of this property was as a private skeet shooting range, which operated possibly as early as the 1930s, and certainly by the early 1960s, until the mid-1980s. The former skeet range area rested on a small plateau located at the southwest corner of the property, which drops off to the north, east, and west. The skeet range reportedly had a high tower, low tower, and a shed. Based on the configuration of the former skeet range, shooting would have generally occurred in a northeasterly direction. The approximate configuration of the skeet range is shown on **Figure 2**. The wetland, located off the northeast side of the embankment for the skeet range appears to have been manmade as a result of earthmoving activities to construct the skeet range.

2.5.2 South of SW 260th Street

Shortly after 1902, a gravel mine was established in the northeastern portion of the Cleanup Unit along the bluff, below the former homesteaded area (North Pit; **Figure 3**). Those initial mining operations peaked in 1917 and shut down after 1923 – possibly operating as late as the early to mid-1930s. The owner of the gravel mine also began a dairy farm on the level upland portion of the property adjacent to the mine, approximately at the same location as the homestead. The farm (also known as the Pembroke Farm) included barns, silos, a superintendent's residence, and residences for employees of the mine and farm. Concrete foundations from this dairy farm still exist (**Figure 2**). The farm also shut down around 1923.

Gravel mining did not occur again on the Cleanup Unit until sometime between 1965 and 1969 when mining operations began in the central area (South Pit; **Figure 3**). The amount of and exact location of mining activities varied throughout the years, as indicated by the presence or lack of vegetation on the mine areas. Mining ceased in 2010 when King County purchased the property, but during the last several years before 2010, mining operations were very limited.

The only structures ever indicated on the Cleanup Unit besides the residence/farm related structures were mine related (i.e., aboveground and underground conveyors, current dock at the South Pit, and the former concrete pier at the Northern Pit, bulkheads, and small temporary or portable structures in vicinity of the South Pit).

2.6 Decision Units

The Cleanup Unit is not homogenous and is very complex in that it varies widely in topography, historical use, and vegetation. For purposes of evaluating how these differences affect the nature of contamination from the TSP, the Cleanup Unit was divided into five primary "decision units." Some of these decision units were further subdivided into two or more "sub-decision" units during the RI. The five primary decision units and their associated numbers that are used throughout this FS consist of the following: 1) forest, 2) gravel mines, 3) unmined historic disturbed areas, 4) bluff, and 5) former skeet range property. Within the gravel mine decision unit, sub-decision units are based upon the time of active mining relative to the operation of the Tacoma Smelter. **Figure 3** shows the approximate boundaries of the various primary decision and sub-decision units across the Cleanup Unit. The primary decision units, associated sub-decision units, and the distinctions between each are described below. Throughout this report, decision/sub-decision units are referred to generally as Unit 1, Unit 2, etc., and specifically as Unit 4a, Unit 3b, etc.

Unit 1) Mature Forest

1a) Western Forest - characterized by a predominance of Pacific madrone, maple, and Douglas fir, with understory of salal, bracken fern, sword fern, Oregon grape, and huckleberries. The area was last logged during the 1880s-1890s.

1b) Northern Forest - similar to the Western Forest area but geographically separated. The area was similarly logged during the 1880s-1890s.

Unit 2) Gravel Mines

2a) South Pit - Most actively mined from the mid-1960s through 1980s, and a relatively small amount of mining along the north side in the late 1990s. Scot's broom and Pacific madrone are encroaching in this area.

2b) Southern edge of the South Pit - Mined from the 1980s to 2010. This area is graded level, rather than steeply sloped like the South Pit area. Some Scot's broom and sparse grass are beginning to encroach at the edges of this area.

2c) North Pit – Mined from the early 1900s until the mid-1920s. Vegetated primarily with Scot's broom on the northern slope. A few mature maple, Douglas fir, and Pacific madrone exist on the southwest slope and the northeast slope.

Unit 3) Unmined Historic Disturbed Areas

3a) Presently forested, but with a much higher percentage of young alder than in Unit 1. There is also a substantial amount of nettles and blackberries at the edge of the forest at some locations. In the mid-1970s the unit appeared to have been partially logged/cleared. Roads through this unit have been redirected several times over the years and substantial grading occurred off the east side of the unit during the early 1980s to repair a large slide.

3b) This unit was extensively graded, apparently in association with the North Pit activities, in the 1930s. Since the 1930s grading, Unit 3b has been relatively undisturbed and has grown back into forest. The forest in this unit appears to have a higher percentage of Douglas fir than in Unit 1.

3c) Homesteaded in the late 1800s until 1891, followed by dairy farm from the early 1900s until about 1923. This unit appears to have been relatively undisturbed since the dairy farm except for the dirt road that was graded through it. Presently the area is characterized by thick stands of blackberry bushes, but also contains a few madrone, maple, aspen, and old fruit trees, as well as Scot's broom and ivy.

3d) This unit was identified during the RI Work Plan, but since then, the data for this unit has been merged in with data for adjacent Units 1b and 3e and is no longer used.

3e) Western Edge of the South Pit. This unit presently consists of dense stands of Scot's broom and blackberries that cover soil mounds and level grassy areas. Historical aerial photographs indicate that the area was stripped level then material was mined out of several relatively shallow holes that were later filled in. The source of the fill and stockpiled material was never determined. Upon exploration with a backhoe during the RI it was determined that the fill and stockpiles in this area contain stumps and construction debris, such as concrete, asphalt, brick, and power poles.

Unit 4) Bluff

4a) South bluff – Several landslides have occurred along this bluff over the decades. The area is heavily vegetated and there are no trails or roads.

4b) Middle bluff – Numerous large landslides occurred along this bluff in the 1930s through 1980s. The area is heavily vegetated, primarily with Scot's broom and blackberries.

4c) North bluff – Landslides have not been prevalent along this bluff, but a substantial amount of road grading occurred in 1960s, which in turn generated a substantial amount soils that were side-cast down the hillside. The area is heavily vegetated, primarily with Scot's broom and blackberries, and it also contains a substantial amount of poison oak. Unit 4c also includes what were once three long, narrow residential-zoned parcels at the north end.

Unit 5) Former Skeet Range

Unit 5 is not subdivided into subunits. It consists of the approximately 30 acre forested property located to the north of SW 260th Street, a portion of which was formerly used as a private skeet shooting range. The wetland is located in Unit 5. The plateau where the skeet range was situated is typically covered in blackberry bushes, but were cleared out to allow for sampling during the RI.

2.7 Current and Future Land Use

The Cleanup Unit is currently designated as Open Space by King County and more recently has been referred to as the Maury Island Natural Area by King County. While the main road into the property south of SW 260th Street is currently blocked by a locked gate, this does not discourage access by the general public as several trails lead into the property from various locations. Some trails extend directly from private properties, evidently having been created by the homeowners. Other trails extend in from adjacent roads.

On any given day local island residents can be seen on the property. The locals frequent the property for daily walks and jogs, berry picking, dog walking, bike riding, and equestrians. The usual observed routes have been the main access road down to the beach and the graded fire break road that extends from SW 260th Street to the main access road. These routes provide the most scenic vistas and access to the beach.

The most current plan for the Maury Island Open Space property is outlined in a February 2013 draft document entitled "*Maury Island Natural Area Site Management Plan*" (King County, 2013b). The property will be generally accessible to the public for limited, passive recreational use, such as: hiking, mountain biking, horseback riding, dog walking, jogging, and water-based activities such as canoeing, kayaking, and scuba diving, as it currently is and has been used. Off-road vehicles will not be allowed. Structures that present a safety hazard, impact wildlife movement, restrict natural processes, or restrict access unnecessarily will be removed. Constructed facilities may include paved or unpaved parking lots, small picnic shelters/areas, and primitive toilet facilities.

Specifically, future parking areas may be located near the terminus of the main access road (near the former mine pit) and in the northern parcel, located across SW 260th Street. Picnic areas could be located near the bluff overlook in the northeast area of the cleanup unit and near the terminus of the main access road, near the main pit. At this time, the County is planning only to install a parking area in the northern parcel. Cleanup actions associated with this development are addressed in the FS. Any future development will be assumed to require excavation of soils as needed to achieve Method A cleanup levels in the area developed, unless Ecology were to approve alternative cleanup methods proposed by the County. These provisions would likely be included as a condition of the cleanup decree.

As part of the mine reclamation process, the county will also be grading and re-contouring the main pit area to help prevent slides and to promote revegetation. As discussed in the RI, this area has been stripped of topsoil containing TSP contaminants. Therefore, these actions will not be included as part of the cleanup actions for this unit

No production wells will be installed on the property for a source of potable or irrigation water. Thus, if any water is to be supplied for sanitary facilities it will have to be trucked into the site and stored in holding tanks.

Section 3

RI Summary

3.1 Summary of Investigations

Several environmental studies related to impacts resulting from the TSP and site activities have been conducted on the Cleanup Unit by various consultants prior to the RI. Anchor Environmental (Anchor), Associated Earth Sciences (AESI), EVS Environmental Consultants (EVS), Landau Associates (Landau), Terra Associates (TA), Foster Wheeler, and Aspect Consulting (Aspect) conducted one or more investigations between 1998 and 2008. The purposes of these investigations varied, whether to evaluate the distribution of metals in surface soils, to evaluate remedial alternatives, or to evaluate metals concentrations in mined soils for use in the SeaTac third runway expansion. The RI completed by CDM Smith in 2014 summarized and evaluated the data collected by others; the metals data generated during these investigations which were deemed usable for purposes of the RI (i.e., comparable to the same depth intervals) were used within the context of the RI. CDM Smith followed up with two field investigations in the 2010 and 2013 to complete the RI. In addition, King County Department of Natural Resources completed an investigation of sediments from the wetland located near the Former Skeet Range (Figure 2). The following sections summarize the media and potential contaminants of concern that were investigated.

3.1.1 Forest Duff and Soil

3.1.1.1 Metals

Surficial sampling occurred throughout the Cleanup Unit. The majority of samples were collected from the forest duff (when present) and surface soils at a depth interval of 0-2 inch. Subsurface soil sampling (9-inch, 18-inch, and 24-inch depths) occurred at a subset of the surface soil sample locations. Within the decision units, there were five basic areas in which soil sampling occurred (as present in the individual decision units). These are described below.

- *Property - Wide* – Forest duff and soil samples collected from relatively undisturbed areas off trails and roads (**Figure 4**).
- *Footpaths* – Surface soil samples collected directly from the soft trail system generally created by the public as a result of continued informal use over time, as described in Section 2.2 (**Figure 5**).
- *Graded Roads* – Trails created from graded roads as described in Section 2.2. King County Parks Department has determined that the upland graded roads are necessary to maintain as emergency access roads for fire control (**Figure 5**).
- *Exposed Beach Bluffs* – Both as slough from the bluff faces that has piled on the beach against the face of the bluff and as exposed vertical bluff sidewalls located adjacent to the beach.
- *Small-Scale Variability* - The purpose of the small scale variability study was to evaluate whether the widespread variation in concentrations observed in any given unit was also present at a much smaller scale. Each study area was located where a relatively elevated arsenic concentration had been detected and was situated within an area that appeared relatively homogenous in nature (i.e., similar vegetation, topography).

Samples collected were either analyzed with an X-Ray Fluorescence (XRF) meter or submitted to an analytical laboratory (or both). As a part of the data validation, the data for the XRF-analyzed samples were adjusted using a regression analysis of results obtained by comparing the laboratory (dry weight) and XRF (wet weight) data.

3.1.1.2 Polycyclic Aromatic Hydrocarbons

Polycyclic aromatic hydrocarbons (PAH) from skeet shards were identified as additional potential contaminants of concern associated with skeet shooting activities. Skeet shards were observed near where the clay trap throwers had been located. Therefore, soil and forest duff samples collected from the former skeet range area were also submitted for analysis of PAH. Sample locations are shown on **Figure 6**.

3.1.2 Vegetation

Plant uptake of arsenic, lead, and cadmium was evaluated by collecting composite leaf/needle samples of some of the primary tree and shrub species in the Cleanup Unit.

The following plant species were selected for sampling:

Trees – Douglas fir, Pacific madrone, and Alder
Shrubs – Salal, Blackberry, and Bracken Fern
Berries – Himalayan blackberries (both berries and leaves)

3.1.3 Springs

The locations of springs were identified during a period of very low tide and five spring samples were collected based on this survey. The spring samples were analyzed for total and dissolved arsenic, lead, and cadmium.

3.1.4 Groundwater

Three of seven existing observation wells located throughout the Cleanup Unit were regularly monitored for metals and a variety of other inorganic chemicals between February 1999 and December 2009. CDM Smith conducted an evaluation of this existing groundwater data for the Cleanup Unit and the Vashon-Maury Islands to evaluate whether arsenic in surface soils could adversely affect potable water supply wells or shallow spring systems. The results of this evaluation determined that the first aquifer is not impacted by elevated arsenic and lead concentrations in the overlying surface soils and no further sampling was conducted.

3.1.5 Sediments

Two historical studies were conducted to characterize nearshore marine sediments for impacts originating from the Cleanup Unit (EVS. 2000; King County. 2013). Marine sediments were collected from locations near the former dock and analyzed for grain size, organic carbon content, selected organics and metals for comparison to Washington State Marine Sediment Quality Standards (SQSs). A technical memorandum evaluating the results of these studies is provided in **Appendix B**. Supporting sampling location maps from studies referenced in the memorandum are also provided.

Five surface soil samples were collected from the wetland located near the Former Skeet Range. The term “soil” is used because there are no applicable regulations articulating a definition of “wetland sediments.” All soil samples were analyzed for conventional parameters, arsenic, lead, and polycyclic aromatic hydrocarbons. Bioassays were also conducted on all samples. A sampling and bioassay results report is provided in **Appendix C** (King County. 2016).

3.2 Nature and Extent of Contamination

3.2.1 Metals in Forest Duff and Soil

Arsenic, lead, and cadmium concentrations are consistently elevated in forest duff and surface soil throughout the upland areas and bluffs. The maximum concentrations of arsenic, lead, and cadmium were 477 mg/kg, 2,600 mg/kg, and 9.3 mg/kg, respectively. The MTCA Method A soil cleanup levels are 20 mg/kg, 250 mg/kg, and 2 mg/kg, respectively. Summary statistics for arsenic, lead and cadmium by decision units property-wide (excludes trails and roads), on trails, and on roads are provided in **Tables 1** through **3** and discussed below.

The mean concentration of arsenic in forest duff and surface soils throughout relatively undisturbed areas (referred to as "property-wide" samples) in upland decision units 1a, 1b, 3a, 3b, 5 is 101 mg/kg; on footpaths it is 130 mg/kg, and on graded roads it is 17 mg/kg. For lead, mean concentrations property-wide are 333 mg/kg, but when Unit 5 is dropped from the data set, the mean concentration is only 196 mg/kg (the maximum concentration is 930 mg/kg). A portion of Unit 5 (approximately 4.7 acres) contains overall greater lead concentrations than in any of the other Cleanup Units as a result of the historical presence of a skeet range. On footpaths and graded roads, mean lead concentrations are 277 and 24 mg/kg, respectively. The mean cadmium concentration in Unit 1 (forest duff and surface soil) is 3.3 mg/kg and in Unit 3 (surface soil), it is 1.7 mg/kg.

Soils within recently mined areas, whether surficial or subsurface, are within normal background concentrations for arsenic (7 mg/kg), cadmium (1 mg/kg), and lead (24 mg/kg). Unit 3e is an exception to this. Unit 3e is a recently mined area that is characterized by fill with some construction debris from an unknown source. Arsenic concentrations were found to be elevated in the fill (138 mg/kg maximum, 36 mg/kg mean), albeit lower than in the forest areas. Lead concentrations in Unit 3e fill are also elevated (403 mg/kg maximum, 61 mg/kg mean).

A significant amount of variability in metals concentrations occurs within each of the decision units where contamination is present, most of which is likely as a result of the various natural physical processes referred to as bioturbation. Examples of bioturbation include soil mixing by worms and burrowing animals, and uprooted trees which cause a rootball-sized crater. Small versus large-scale variability studies conducted during the RI indicate that the distribution of metals observed within each decision unit are within the overall variability of each decision unit, meaning there is no way to define "hot spots" beyond the decision units themselves, unless of course there is a source of contamination beyond that of the TSP, such as the former firing range.

Overall, metals concentrations decline rapidly with depth. The data suggests that when subsurface soils (i.e., 9-inches and deeper) contain elevated metals concentrations, it is because of physical transport mechanisms other than leaching, such as fill, inexact sampling practices that may have caused cross contamination from surface soils, and/or bioturbation.

The beach sands themselves are not contaminated – this is because of the low cation exchange capacity of sand (the result is that the metals have very little ability to adsorb to the sand), combined with the constant movement of beach sands. Samples were collected at the bluff face at the edge of the beach and from slough accumulations along the base of the bluff. Arsenic concentrations ranged from 1.8 to 27 mg/kg. Lead concentrations ranged from 1.5 to 31 mg/kg.

3.2.2 PAH in Forest Duff and Soil

Skeet shards were observed near where the clay trap throwers had been located. The PAH concentrations are summarized on **Table 4**. The greatest overall concentrations of PAH occurred in a forest duff sample where the concentration of benzo(a)pyrene (BaP) was 82,600 micrograms per kilogram (μg/kg) and the benzo(b,j,k)fluoranthene concentration was 138,000 μg/kg. The concentrations of PAHs in surface soil samples tend to be lower than in the forest duff, typically by one to two orders of magnitude. PAH are not mobile and will bind to the organic matter. The toxic equivalency (TEQ) of carcinogenic PAH (cPAH) exceeded the MTCA Method A cleanup level of 100 μg/kg for both forest duff and surface soil at sample locations where skeet shards were present. The approximate area where PAH exceed the Method A TEQ concentration of 100 μg/kg is outlined on **Figure 6**. The area of cPAH-contaminated soils generally occurs within the former range area, close to the target throwers, unlike the area of more highly lead-contaminated soils, which occurs further out.

3.2.3 Plant Tissue

Arsenic, lead, and cadmium concentrations were found to be greater in plant tissue samples from the Cleanup Unit as compared to the same plants grown on uncontaminated soils. Even so, metals concentrations are typically less than 1.0 mg/kg. But concentrations between 1 and 3.5 mg/kg for arsenic and lead are not uncommon. Significant arsenic uptake was observed in one type of plant, Douglas fir, with the concentration averaging 47.6 mg/kg for Douglas fir needles collected from Units 1a and 1b. Uptake and shedding of fir needles could result in continued redeposition of arsenic. Arsenic concentrations in the Douglas fir tree trunks was not studied during the RI.

The blackberry fruit was also sampled. This study showed an increased metals uptake in blackberries; however, hyperaccumulation is not occurring and the overall uptake appears to be relatively low.

3.2.4 Spring Water

The data for spring water samples collected during the RI were consistent with the historical groundwater data reviewed, and further demonstrate that groundwater has not been significantly impacted by metals concentrations in surface soils. Dissolved arsenic concentrations ranged from 1.24 micrograms per liter (μg/L) to 4.03 μg/L and total arsenic concentrations ranged from 1.54 to 4.59 μg/L. Dissolved lead concentrations were all less than <0.1 μg/L and total lead was detected in two samples at concentrations of 0.22 and 0.26 μg/L, respectively. Dissolved cadmium was detected in only one sample (0.06 μg/L) and total cadmium was detected in two samples at 0.062 and 0.065 μg/L, respectively.

3.2.5 Sediments

The King County Department of Natural Resources and Parks (DNRP) reviewed the results of two historical marine sediment sampling events to evaluate potential impacts resulting from removal of the former dock at the site. Marine sediments were sampled by Glacier Northwest in 2000 as part of permitting efforts for expansion of the gravel mining operation. Based on their review of the 2000 samples, DNRP concluded that since no chemicals exceeded SQSs, no further evaluation of sediments was required (King County. 2013). DNRP also reviewed results from Glacier Northwest's 2008 sediment sampling in support of the Maury Island Dock Reconstruction Project. A single concentration of 4-methylphenol above the SQS was detected in one of the sediment samples during the study. DNRP concluded that the single detection above the SQS was very localized and not expected to be of concern. The creosote pilings were identified as the only source of the 4-methyphenol and DNRP concluded that the best course of action was removal of the pilings.

In addition, bioassay tests were conducted using five soil samples collected from the wetland in Decision Unit 5. Arsenic and lead in most of these soil samples exceeded cleanup screening levels and toxicity was observed in some of the bioassays. The bioassay toxicity appeared to be primarily related to elevated lead levels, but not related to arsenic.

3.3 Receptors

3.3.1 Human Health Pathways

The potential human exposure pathways at the Cleanup Unit include: direct contact with soil/sediment; ingestion of soil particles; inhalation of soil particles, ingestion of water (groundwater/spring), ingestion of vegetation, and ingestion of marine organisms exposed to contaminants of concern (COC). The primary transport pathways of COCs include: leaching of contaminants from soil to groundwater; discharge of groundwater to surface water; erosion of soil as a result of bluff failures; windblown dust; and via physical transport, such as may occur when soil adheres to pet hair and shoes.

Soil: Because the current and future use of the Cleanup Unit is open space with walking trails, the primary concern for human health is direct exposure to site contaminants. This may include: skin contact, direct ingestion by hand to mouth contact, or inhalation. The COCs have a low risk of being a skin irritant. The primary risk of exposure is through incidental ingestion as a result of hand to mouth contact, such as may occur from soil particles sticking to clothing, body parts, and pet fur. Children (and sometimes adults in instances of pica disorder) frequently ingest soil directly. Inhalation via dust may be significant if motorized off-road vehicles were to use the property. Bikes and horses may also tend to kick up to dust, but to a much lesser extent and the forest footpaths do not tend to be dusty.

Groundwater: The results of spring water sampling conducted for the RI and historical sampling data from seeps and on-site observation wells demonstrate that groundwater and spring water have not been impacted by metals and that ingestion of impacted groundwater is not a potential human exposure pathway. This is consistent with the TSP Interim Action Plan (Ecology 2012b), which noted that area-wide soil levels of arsenic below 200 mg/kg and lead below 1000 mg/kg were unlikely to pose a significant threat to groundwater. This conclusion was developed by the MTCA Science Advisory Board using a conservative leaching model to estimate impacts of area-wide soil contamination. The board's conclusion is based on three main pieces of evidence: 1) soil profile data showed that area-wide arsenic and lead have not migrated significantly over a span of 50 years; 2) drinking water on Vashon-Maury Island do not show impacts to groundwater, and; 3) modeling shows that arsenic and lead from the plume have low mobility except under specific circumstances, which are not applicable to the Cleanup Unit. The specific circumstances referred to in Item 3 consist of soils with high organic content, biodegradable organic compounds like petroleum, and very low pH and waste material. These conditions can cause depleted oxygen through bacterial degradation of organics and geochemically reducing conditions, which may cause metals such as arsenic to become more mobile. None of the cited conditions were observed in site soils during the RI.

Vegetation: The data collected during the RI suggests that plants growing in metals-enriched soils have an uptake of metals that is greater than in areas unimpacted by the TSP. The primary concern of metals in vegetation would be from ingestion. However, blackberries were not found to have elevated levels of arsenic. The greatest degree of metals uptake was that of arsenic in Douglas fir – a plant type that is not likely to be consumed by humans.

Surface Water/Sediment: The RI demonstrated that there is no significant impact to the Puget Sound by metals originating from the Cleanup Unit, whether from seeps or bluff soils. An underwater dive survey conducted as part of the RI did not identify other significant impacts from historical mining activities originating from the Cleanup Unit.

3.3.2 Ecological Exposure Pathways

Arsenic, lead, and several PAHs are present at the Cleanup Unit at concentrations that exceed terrestrial ecological screening levels (ESLs). The primary exposure pathways for ecological receptors at the Cleanup Unit were determined to be:

1. Direct contact with and uptake of soil contaminants by terrestrial plants;
2. Direct contact with and ingestion of soil contaminants primarily by soil-associated terrestrial animals (e.g., earthworms, voles).
3. Ingestion of contaminated plants by herbivorous animals (e.g., black-tailed deer).
4. Ingestion of contaminated prey (e.g., earthworms) by omnivorous animals (e.g., American robin, deer mouse).
5. Bioaccumulation of contaminants in carnivorous animals (e.g., red-tailed hawk) via ingestion of contaminated prey (e.g., vole, deer mouse).

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Section 4

Cleanup Levels and Points of Compliance

4.1 Soil Cleanup Level Development

4.1.1 Soil

4.1.1.1 Human Health

The Final Interim Action Plan (IAP) for the Tacoma Smelter Plume (Ecology, 2012b) established that the MTCA Method A soil cleanup levels for unrestricted land use are applicable within the TSP. As the Cleanup Unit falls within the TSP, MTCA Method A cleanup levels are applicable. Because forest duff is an integral part of the soil matrix, Method A cleanup levels also apply to forest duff. The IAP also determined that arsenic and lead cleanups driven by TSP will also address all other hazardous substances from the smelter emissions. This is because, while other metals sometimes exceed MTCA cleanup levels, the frequency of this is much less. The Method A unrestricted land use soil cleanup levels are: 20 mg/kg for arsenic and 250 mg/kg for lead.

The Method A cleanup level for PAH is based on the toxic equivalency method with the Method A cleanup level for benzo(a)pyrene (0.1 mg/kg) being the basis for comparison. For this method, toxicity equivalency factors (TEF) are used to calculate the toxicity of individual cPAH on an equivalent basis with benzo(a)pyrene. The adjusted concentrations are then summed and compared to the Method A cleanup level for benzo(a)pyrene.

4.1.1.2 Terrestrial Ecological

MTCA requires that existing or potential threats to terrestrial plants or animals exposed to hazardous substances also be evaluated by determining whether the site is: 1) excluded from the terrestrial ecological evaluation (TEE), 2) qualified for a simplified TEE, or 3) must undergo a site-specific TEE in accordance with WAC 173-340-7490. The Cleanup Unit does not qualify for an exclusion from a TEE per WAC 173-340-7491, nor does it qualify for a simplified TEE per WAC 173-340-7492. Under WAC 173-340-7493 sites located in an area where management or land use plans will maintain or restore native or semi-native vegetation (e.g., greenbelts and protected wetlands) require a site-specific TEE. The scope of a site-specific TEE requires consultation with Ecology. The goal of the TEE process is the protection of terrestrial ecological receptors (plants and animals) from exposure to contaminated soil with the potential to cause significant adverse effects.

Ecology's final ecological cleanup levels for the TSP are the same as the Method A cleanup levels (20 mg/kg arsenic, 250 mg/kg lead).

The PAHs detected at the site were also compared against ecological screening levels. Based on this screening evaluation, multiple PAH were determined to be chemicals of ecological concern within the skeet range portion of Unit 5.

4.1.2 Water

There are various drinking water and marine criteria for metals in addition to Method A, including the National Toxics Rule criteria, state groundwater and drinking water standards. The standards are not at all consistent. Under MTCA, the cleanup standards are based on the most stringent of all regulatory standards, or background, whichever is greater. Since the MTCA Method A standard for arsenic is based on background for Washington State, the groundwater cleanup standard defaults to Method A, which is 5 μg/L. For cadmium, the lowest of the groundwater and marine standards is Method A, which is 5 μg/L. For lead, the lowest value is the chronic marine standard for protection of aquatic life, which is 8.1 μg/L. None of these standards were exceeded for groundwater or spring/seep water, so no remedial actions are required for groundwater or spring/seep water.

4.2 Remediation Levels

A remediation level is the concentration (or other method of identification) of a hazardous substance in soil, water, air, or sediment above which a particular cleanup action component will be required as part of a cleanup action at a site. By definition a remediation levels are greater than cleanup levels.

4.2.1 Human Health

Considerable effort was undertaken to develop human health risk-based concentrations for arsenic in soils for the trail system based on the current land use. What this means, is developing a site-specific remediation level that is based on the expected long and short-term exposures to the COCs based on the land use. For example, the potential exposure to COCs within a residential back yard where children frequently play would be much greater than in a natural forest area where the activity is mostly limited to periodic walks; therefore, the remediation level would be greater in areas where potential exposures are lower. While other states have adopted the same type of approach at similar sites.

The TSP Model Remedy established remediation levels for certain cap types. For example, where arsenic concentrations are greater than 100 mg/kg, only a Type 2 cap may be used. A type 2 cap is either a 24-inch-thick soil cap, or a 3-inch-thick (minimum) hard cap (i.e., asphalt). Both of these types of caps are impractical for the Cleanup Unit, particularly in Units 1a and 1b where mean arsenic concentrations exceeded 100 mg/kg. A 2-foot-thick cap constructed on the footpaths would create a dangerous mound. A hard cap would be quickly destroyed by roots.

4.2.2 Terrestrial Ecological

While results of the RI determined that the COCs at the Cleanup Unit may pose a threat to the terrestrial environment, terrestrial ecological evaluation procedures should not create an incentive to cause harm through destruction of habitat. As a result, WAC 173-340-7490(5) states: "The department may require additional measures to evaluate potential threats to terrestrial ecological receptors notwithstanding the provisions in this and the following sections, when based upon a site-specific review, the department determines that such measures are necessary to protect the environment." (Ecology, 2007). The Net Environmental Benefit Analysis (NEBA) is a procedure of weighing the advantages of an active cleanup versus the impact that the cleanup might have on potentially valuable ecological receptor habitat.

In May 2014, CDM Smith completed a NEBA for the Cleanup Unit. The NEBA concluded that Units 1a, 1b, 2c, 3a, 4a, 4b, 4c, and a portion of 5 are eligible for the application of NEBA because they contain "especially valuable habitat." Therefore, a cleanup alternative involving removal of soil would result in greater environmental harm than an alternative of leaving the contaminated topsoil in place. The other units did not qualify for the NEBA. In a memorandum dated November 21, 2014, Ecology concurred with the NEBA determination (Ecology, 2014). Therefore, based on the NEBA, remedial alternatives developed for the Cleanup Unit will also need to take into account the protection of the environment for those Units that qualify for the NEBA, regardless of the arsenic and lead concentrations.

4.2.3 Wetlands

Wetland areas that are inundated for more than six or more consecutive weeks per year are regulated under WAC 173-204 (Sediment Management Standards) and should therefore be assessed for toxicity using the Sediment User's Cleanup Manual II (SCUM II). The bioassay analysis conducted for the wetland in Decision Unit 5 found elevated lead levels as the primary concern in this area. The NEBA already concluded that the non-inundated areas of Decision Unit 5 are applicable for the application of NEBA because they contain "especially valuable habitat". For inundated areas, WAC 173-204-560, establishes initial sediment cleanup levels Sediment Cleanup Objective (SCO) of 360 mg/kg for lead in freshwater. An upward adjustment can be made to the SCO of 360 mg/kg (Pb) if it can be shown that by achieving the SCO there will be a net adverse environmental impact on the aquatic environment. However, the limitation is that the upward adjustment may not exceed the Cleanup Screening Level of (>1300 mg/kg)

For this reason, inundated wetland areas under 1,300 mg/kg would not be proposed for remediation because, similarly to the terrestrial habitat, it would do more harm to the habitat than good. For areas over 1,300 mg/kg some level of remediation would be required. The soil and duff samples taken as part of the RI and bioassay analysis show that only a portion of the inundated wetland area exceeds this threshold for lead, and in those areas that do exceed the threshold, the high lead levels are primarily found in the upper forest duff layer, not in the soil.

4.3 Points of Compliance

Under MTCA, (WAC 173-340-740(6)), the standard point of compliance for protection of human health from direct contact is 15 feet bgs. The regulation states that this represents a reasonable estimate of the depth of soil that could be excavated and distributed to the soil surface as a result of redevelopment activities. The standard point of compliance for protection of ecological receptors is 6 feet below ground surface (bgs).

As determined during the RI, the contaminants in the Cleanup Unit typically were within the top 24 inches, unless they occur in fill. Therefore, the standard point of compliance for the Cleanup Unit is the maximum depth of contamination. However, MTCA regulations allow for a conditional point of compliance in instances where cleanup actions involve containment of contaminants, such as use of soil capping. In these instances the cleanup action may be determined to comply with MTCA standards provided that:

- cleanup actions are permanent, to the extent feasible;
- cleanup actions are protective of human health and terrestrial ecological receptors;
- institutional controls are implemented to protect the integrity of the cleanup actions;
- compliance monitoring and periodic reviews occur; and,
- the types, levels and amount of hazardous substances remaining on-site and the measures that will be used to prevent migration and contact with those substances are specified in the draft cleanup action plan.

4.4 Conclusions

As will be established in Section 6, technologies that remove or degrade arsenic, lead, and PAH in soils under the circumstances in which they exist at the Cleanup Unit are lacking. Because of this and the natural environmental conditions at the site, cleanup levels cannot be practicably achieved throughout the Cleanup Unit. Further, the Model Remedies established for the TSP were intended for developed properties and are not practical for natural areas. Remedies developed for the Cleanup Unit will need to focus on other alternative methods of protection for human health and the environment.

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Section 5
Applicable Laws

5.1 Overview

MTCA (WAC 173-340-710(1)) requires that all cleanup actions comply with applicable state and federal laws (in addition to MTCA). This includes legally applicable requirements and relevant and appropriate requirements. Relevant and appropriate requirements include those cleanup standards, standards of control, and other environmental requirements, criteria, or limitations established under state or federal law that, while not legally applicable to the hazardous substance, cleanup action, location or other circumstance at the site, address problems or situations sufficiently similar to those encountered at the site as that their use is well suited to the site.

Under the Revised Code of Washington (RCW) 70.105D.090 (Hazardous Waste Cleanup – the Model Toxics Control Act), remedial actions conducted under a consent decree, order or agreed order are exempt from the procedural requirements of Chapters 70.94, 70.95, 70.105, 77.55, 90.48, and 90.58 RCW, and the procedural requirements of any laws requiring or authorizing local government permits or approvals for the remedial action. However, remedial actions exempt from the procedural requirements must still comply with the substantive requirements of these laws and provide an opportunity for comment by the public and state and local agencies that would otherwise implement these laws. This section identifies and summarizes potential applicable, relevant, and appropriate requirements (ARARs) considered when evaluating the remedial alternatives presented in Section 7.

5.2 ARARs

Several state and federal laws and local regulations will apply to cleanup actions considered for the Cleanup Unit. ARARs identified for this FS are listed below and summarized briefly in the following sections. Most of the listed ARARs are state laws where there are corresponding federal regulations (e.g., hazardous waste regulations, clean air act). In those instances where the Federal government has delegated authority to the State of Washington, the Federal regulations are considered duplicative and are not listed.

- RCW 43.21C, State Environmental Policy Act (SEPA)
- Executive Order 05-05, Archeological and Cultural Resources
- Chapter 70.94 RCW, Washington Clean Air Act
- Chapter 70.105D RCW, Hazardous Waste Management
- Chapter 70.95 RCW, Solid Waste Management, Reduction, and Recycling
- Chapter 90.48 RCW, Water Pollution Control, 90.54 Water Resources Act of 1971
- 40 CFR 1910.120 Occupational Safety & Administration (OSHA) Hazardous Waste Operations and Emergency Response
- Chapter 296-848 WAC, Inorganic Arsenic Rule, Department of Labor and Industries

- Chapter 296-155-176, Lead, Department of Labor and Industries
- 16 USC 1531–1544, Endangered Species
- 16 USC 703–712, Migratory Bird Treaty Act
- WAC 173-204, Sediment Management Standards
- 33 USC 1251 et seq., Clean Water Act
- Chapter 90.58 RCW, Shoreline Management Act of 1971 (covered under local regulations)

5.2.1 RCW 43.21C, State Environmental Policy Act

Soil cleanup can trigger requirements under SEPA. The cleanup should be coordinated with the local jurisdiction (i.e., King County) to determine what is required to comply with SEPA.

5.2.2 Executive Order 05-05, Archaeological and Cultural Resources

SEPA and the Governor‘s Executive Order No. 05-05 require that state agencies and local governments consider impacts to cultural resources as a result of proposed remedial actions during their public environmental review process.

5.2.3 RCW 70.94, Washington Clean Air Act

Best available control technologies consistent with the requirements of Chapter 70.94 RCW, Washington Clean Air Act, and the regulations that implement this statute shall be applied to releases of hazardous substances to the air resulting from cleanup actions at a site per WAC 173-340-710(7)(b). Fugitive dusts will need to be controlled during all soil handling activities, such as grading and excavation. Typically this is controlled by watering down soils. Vehicle exhaust and greenhouse gas impacts can be reduced by careful planning of the haul routes, trucking during periods when traffic is less, and minimizing unnecessary idling of excavators and other soil moving vehicles.

5.2.4 RCW 70.105D, Hazardous Waste Management

Waste classification of soil depends on the leachability of the metals. Soil failing the Toxicity Characteristic Leaching Procedure (TCLP) test is federally-designated hazardous waste and state dangerous waste under WAC 173-303-070(3). These types of soils are subject to the disposal and tracking requirements of the state and federal laws for dangerous and hazardous wastes. During development of the TSP Model Remedy Ecology tested soils for disposal as part of the Soil Safety Program, and found that soils impacted by the TSP do not fail the TCLP. Therefore, it is unlikely that soils excavated at the Cleanup Unit would designate as dangerous or hazardous wastes.

5.2.5 RCW 70.95, Solid Waste Management - Reduction, and Recycling

If soils are disposed of offsite they will be managed as contaminated soil in accordance with the Solid Waste Handling Standards, Chapter 173-350 WAC. These soils may be disposed of in any Subtitle D landfill (landfills authorized to accept non- hazardous waste).

5.2.6 RCW 90.48 and 90.54, Water Pollution Control

Hazardous substances that are directly or indirectly released or proposed to be released to waters of the state shall be provided with all known, available, and reasonable methods of treatment consistent with the requirements of Chapters 90.48 RCW, Water Pollution Control Act, and 90.54 RCW, Water Resources Act, and the regulations that implement those statutes.

Stormwater discharges associated with construction activities must comply with National Pollutant Discharge Elimination System (NPDES) requirements, as implemented through Ecology. Ecology requires that coverage under the Construction Stormwater General Permits obtained for clearing, grading, and excavating activities that disturb one or more acres and which discharge stormwater to surface waters of the state. Operators of regulated construction sites are required to obtain coverage under the permit and meet permit requirements, including the development of a stormwater pollution prevention plan and implementation of best management practices (BMPs) for sediment, erosion and pollution prevention control. Selected BMPs must be consistent with the most recent version of the Stormwater Management Manual for Western Washington (Ecology 2012c). Ecology may add additional requirements including monitoring as the remedial construction activities are occurring.

5.2.7 WAC 296-848, WAC 296-155-176 and OSHA requirements in 40 CFR 1910.120

Health and safety at the site is governed by statutes and regulations implemented by the Washington State Department of Labor & Industries. The Inorganic Arsenic Rule (Chapter 296-848 WAC) governs work at sites impacted by soil arsenic contamination. Chapter 296- 155-176 WAC provides for worker protection for all construction work where an employee may be occupationally exposed to lead. In addition, requirements of OSHA in 40 CFR 1910.120, apply to remediation activities at listed sites containing hazardous substances.

A Health and Safety Plan will be prepared to ensure safety of workers engaged in implementing remedial actions. Workers are required to be trained in accordance with the requirements of 40 CFR 1910.120 for Hazardous Waste Operations and Emergency Response. Safety measures include, but are not limited to, protective clothing and gloves for workers, masks for dusty conditions, and hand-washing facilities. Workers will be educated about health hazards related to soil arsenic and lead.

5.2.8 16 US Code Chapter 35, Endangered Species

The Endangered Species Act provides for the protection of federally-listed species and the ecosystems on which they depend. Section 9 of the federal Endangered Species Act (16 USC 1538) prohibits the "take" of any plant, fish, or wildlife species listed under the federal Endangered Species Act as endangered unless otherwise authorized by federal regulations. Under the federal Endangered Species Act, "take" is to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect or attempt to engage in any such conduct. Actions that would alter the habitats that listed species use are also considered a "take."

The Maury Island Open Space Property was determined to support “valued ecosystem components” that are integral to the proper functioning of nearshore habitats that support several federally listed species.

5.2.9 16 USC 703–712, Migratory Bird Treaty Act

The Migratory Bird Treaty Act of 1918 (MBTA) protects selected species of birds that cross international boundaries (i.e., species that occur in more than one country at some point during their annual life cycle). The law applies to the removal of nests, eggs, and feathers. It defines a native migratory bird as a species present in the United States and its territories as a result of natural biological or ecological processes.

Virtually all of the birds that occur on the Maury Island Open Space Property would be protected under the MBTA as it is not limited to those listed as threatened, endangered, or species of local importance. Activities that would remove trees, shrubs or other vegetation would have the potential to adversely affect migratory birds.

5.2.10 WAC 173-204, Sediment Management Standards

The purpose of WAC 173-204 is to reduce/eliminate adverse effects on biological resources and significant health threats to humans from surface sediment contamination. The Sediment User's Cleanup Manual II (SCUM II), released March 2015, provides guidance for implementing cleanup provisions of the sediment management standards. SCUM II describes ephemeral wetlands, such as the one present in Unit 5, as "unusual aquatic habitats" and provides limited guidance that specifically outlines how unique wetland soils or sediments are to be evaluated under the freshwater sediment management standards.

As discussed in Sections 3.25 and 4.23, even though ephemeral wetlands are atypical of the habitats assessed under sediment management standards, lacking any other best available science, King County elected to investigate the wetland soils/sediments in Unit 5 using standard bioassay methods as described in the SCUM II to document the nature and extent of impacts to indicator species from arsenic and lead.

5.2.11 33 USC 1251 et seq., Clean Water Act

The Clean Water Act (CWA) is the primary federal law protecting the nation's waters, including wetlands. Under Section 404 discharges into wetlands are prohibited unless specifically authorized by a permit. Activities that disturb the soils of wetlands are considered to be a discharge. The primary directive of the CWA is to first avoid impacts to wetlands, followed by minimization of the impact. The U.S. Environmental Protection Agency (EPA) guidelines (40 Code of Federal Regulations [CFR] 230 et seq.) and U.S. Army Corps of Engineers (USACE) regulatory guidelines (33 CFR 320 et seq.) are the substantive environmental criteria used to evaluate permit applications. Remediation of the wetland, if required, will necessitate permitting under the Clean Water Act.

5.3 Local Government Requirements

Local government requirements (i.e., King County) cover grading and controlling drainage at construction sites. The remedial actions considered under this FS are unlikely to extend to within 200 feet of the shoreline and are therefore exempt from shoreline-related permits. King County is working with Ecology to address removal of shoreline debris (i.e., pilings, concrete bulkheads) separate from this FS.

Section 6

Identification and Screening of Remedial Technologies

This section identifies general response actions and screens viable technology types potentially applicable to the Cleanup Unit. Remedial technologies that are carried forward into the detailed description of selected technology alternatives (Section 7) are also summarized.

6.1 General Response Actions

General response actions are broad classes of actions that can be combined to satisfy MTCA requirements for the site. General response action categories are assembled based on the nature and extent of contamination. The seven general response actions identified for the Cleanup Unit include the following:

- No Further Action
- Institutional Controls
- Monitored Natural Attenuation
- Physical Removal
- Containment
- *In-Situ* Treatment
- *Ex-Situ* Treatment

Except for the "No Further Action" general response action, each represents a category of technologies. The specific remedial technologies and associated process options potentially applicable to the Cleanup Unit will vary based on site conditions and the COCs.

6.2 Screening of Technologies

Technology types were identified for each general response action and one or more process options were identified for each technology. Remedial technologies and related process options were identified in consideration of the type, distribution, and volume of arsenic, lead and cPAH found in soil at the Cleanup Unit, the NEBA, and the requirements discussed in Sections 4 and 5. Then each was evaluated with respect to three preliminary criteria: effectiveness, implementability, and relative cost. The results of this screening are summarized in **Table 5**. This subsection further details the screening and evaluation of identified potential technology and process option types for remediating contaminated soil at the Cleanup Unit. The basis of the determination for each of the three criteria used to evaluate individual technology process options is described below.

Effectiveness: This evaluation focused on the potential effectiveness of each process option in remediating the contaminated soil and in meeting the MTCA requirements. Specific information considered included: types and levels of contamination, volume, location, and areal extent of contaminated soil, and time required to achieve remediation goals. Each process option was classified as being effective, moderately effective, of limited effectiveness, or not effective.

Implementability: This evaluation rated the relative degree of technical and administrative feasibility of implementing a technology. Aspects considered included any substantive requirements of potential permits for actions; location of disposal facilities; availability of necessary equipment and skilled workers to implement the technology, and; the level of disturbance that would occur to the natural environment in order to implement the technology. The implementability of each process option was classified as easy, moderately difficult, difficult, or not implementable.

Cost: This evaluation rated the relative cost of each technology, based on engineering judgment and other process options. Both capital and operating costs were considered. The cost of each remedial technology was classified as none, low, moderate, high, very high. In instances where the technology is both not effective or unproven and not implementable the cost was not evaluated.

Most of the process options result in destruction of the natural environment. As determined in the NEBA, throughout much of the Cleanup Unit this will cause more harm than benefit; therefore, the applicability of many of the process options is going to be limited to certain units or areas within units. The analysis in the following subsections typically does not detail applicability by specific areas. Further analysis to specify the areas that the retained process options are applicable to is provided in Section 6.4.

6.2.1 No Further Action

No Further Action implies that no remedial action will be conducted on the Cleanup Unit. The Cleanup Unit is allowed to continue in its current state, and no future actions are conducted to remove or remediate the contamination. No access restrictions are put into place, and no deed restrictions are placed on the Cleanup Unit. The No Further Action response provides a baseline for comparison to other remedial response actions.

Effectiveness: The No Further Action option would not be effective in remediating contaminated soil at the Cleanup Unit or in meeting MTCA requirements.

Implementability: The No Further Action process option is technically easy to implement because it does not require any actions to be taken.

Cost: There are no construction or operation and maintenance costs associated with the No Further Action process option because no actions are taken and no site monitoring is conducted.

Screening Summary: The No Further Action process option will not achieve MTCA requirements and is not acceptable under MTCA, so it is not retained for further evaluation.

6.2.2 Institutional Controls

Institutional controls are non-engineering measures, such as administrative or legal controls, that help minimize the potential for human exposure to contamination and/or protect the integrity of an implemented remedy by limiting land or resource use. MTCA defines institutional controls under WAC 173-340-440 as measures undertaken to limit or prohibit activities that may interfere with the integrity of an interim action or cleanup action or that may result in exposure to hazardous substances at a site. These institutional controls may include:

- Physical measures to limit access to areas of contamination, such as closing off certain trails.
- Restrictions such as limitations on the use of property or resources (e.g., residential, developed park, open space) or requirements that a cleanup action will occur if an existing cap that covers contaminated soil is disturbed or removed (e.g., pavement, building).
- Maintenance requirements for engineered controls, such as inspection and repair of physical barriers, such as fencing and caps.
- Educational programs such as signs, postings, public notices, health advisories, mailings, and similar measures that educate the public about the TSP contamination and ways to limit exposure.
- Provision of hygiene stations to facilitate removal of contaminated soil from shoes and hands. Stations could be established at parking areas and future picnic areas and would include boot brushes and portable water supply to allow for hand and face washing. Signage would also be included to remind site users to utilize the hygiene stations after visiting the cleanup unit.

Effectiveness: Institutional controls can be effective at managing human exposure to contaminated soil; however, they do nothing to reduce existing contaminant concentrations. The effectiveness of institutional controls depends on the mechanisms, the need for human actions to implement and maintain the controls, and the general public's compliance with the institutional controls. For the Cleanup Unit the various institutional controls considered range from limited effectiveness to effective.

Implementability: For the Cleanup Unit, the various institutional controls considered range from easy to moderately difficult to implement.

Cost: Institutional controls are usually low cost, but the institutional controls that require active management, such as maintaining hygiene stations and ongoing maintenance requirements of the engineered systems, do have an associated cost in perpetuity.

Screening Summary: Institutional controls alone will not achieve MTCA requirements; however, when used in conjunction with other remedies, it can improve overall protectiveness. Therefore, institutional controls are retained for further consideration.

6.2.3 Monitored Natural Attenuation

Monitored natural attenuation (MNA) refers to the reliance on natural attenuation processes to achieve site-specific remedial objectives within a timeframe that is reasonable compared with that offered by other more active methods (EPA, 1999). The processes, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil. The primary *in-situ* processes for metals in soils include dispersion and dilution and for cPAH, biological degradation, as well as dispersion and dilution. Ecology expects that natural attenuation of hazardous substances may be appropriate at sites where:

- Source control (including removal and/or treatment of hazardous substances) has been conducted to the maximum extent practicable.
- Leaving contaminants on-site during the restoration time frame does not pose an unacceptable threat to human health or the environment.

- There is evidence that natural attenuation is occurring and will continue to occur at a reasonable rate at the site.
- Appropriate monitoring requirements are conducted to ensure that natural attenuation is taking place and that human health and the environment are protected.

Effectiveness: For soils, MNA of metals and cPAH is essentially not effective. Metals do not degrade and cPAH do not degrade in any reasonable time period. As has been demonstrated in the RI, the metals and cPAH are bound in the upper, organic soil profile and are not migrating, so dilution through migration through the soil profile is not occurring. Nor does it appear that dilution through soil mixing (e.g., bioturbation) has been occurring to any great degree.

Implementability: As MNA is not effective, it is not implementable.

Cost: Because it is not effective or implementable, the cost for MNA is not applicable.

Screening Summary: MNA will not achieve MTCA requirements. It is not retained for consideration.

6.2.4 Containment

Containment serves two functions: 1) to isolate contaminated soil to reduce the possibility of exposure by direct contact, and 2) to control or reduce migration of the contaminated materials into the surrounding environment. Containment may occur offsite (i.e., disposal at a landfill) or onsite, either consolidated in a cell or capped in place by a suitable material. Soil that is contained in an offsite landfill or an onsite cell must first be excavated, therefore, soil excavation is combined with these process options.

6.2.4.1 Soil Excavation and Offsite Landfill Disposal

This action involves excavation of contaminated soil exceeding soil cleanup standards, offsite transport and internment in an appropriate landfill. Ecology has not found that TSP soils exceed dangerous waste limitations for leachable metals; therefore, soil disposal in a RCRA (Resource Conservation and Recovery Act) Subtitle D landfill is assumed (Ecology, 2012b).

Effectiveness: Excavation and off-site disposal of soil exceeding cleanup standards for arsenic and cPAH would be effective in achieving soil cleanup standards for those areas where soil excavation can be utilized.

Implementability: Typically contaminated soil is excavated using conventional earth-moving equipment such as front-end loaders and hydraulic excavators. Any other means (i.e., hand digging) would make this technology not implementable. There is no on island landfill so soil would need to be transported to the mainland. Soil transport to the mainland would either need to be via truck and ferry or barge. The dock on the Cleanup Unit is not currently viable. An economic analysis would need to be conducted in order to evaluate the practicality of completing the dock for use in soil transport via barge, versus trucking the soil. The island ferry system is not an appropriate infrastructure for transporting massive quantities of soil via truck and trailers. For these reasons, implementing soil excavation and offsite disposal would range from easy to difficult, depending upon the volume of soil to be disposed of.

Cost: Excavation and off island disposal will range from moderate to high, depending on the soil volume involved. The overall cost of off island transport would be much higher than soil excavation projects on the mainland.

Screening Summary: Excavation and removal of contaminated soil and disposal at an off-site facility is expected to meet MCTA requirements for soil in those areas where this technology can be implemented. This process option is retained for further consideration.

6.2.4.2 Soil Excavation and Onsite Consolidation

This action involves excavating contaminated soil exceeding soil cleanup standards, the same as described above, only for this remedial technology, the excavated soil would be consolidated and contained onsite. There are different methods of implementing the onsite containment technology. One method is to contain the material in an above-ground cell and another is to consolidate and bury the material at a suitable depth. Either method will prevent future direct human and ecological exposure.

Effectiveness: Excavation and onsite containment of soil exceeding cleanup standards for arsenic and cPAH would be effective in achieving soil cleanup standards for those areas where soil excavation can be utilized. The soil would remain within the Cleanup Unit, but it would be contained in a manner that would eliminate the potential for future human and ecological exposure.

Implementability: The same as for the offsite disposal method, typically contaminated soil would be excavated using conventional earth-moving equipment such as front-end loaders and excavators. The degree of engineering required may vary substantially. Disposal in an engineered cell (e.g., use of an engineered cap, liner system, leachate collection system) would require a much greater level of effort in engineering and construction than it would for a direct burial option. There is a possibility of some public opposition to be overcome for any onsite containment option. Implementability was ranked as ranging from easy to moderately difficult.

Cost: The cost of containment in an engineered cell would be much higher than direct burial due to the initial construction cost and ongoing maintenance and monitoring that would likely be necessary (i.e., control/monitoring of leachate and methane, monitoring of the cap). The cost was ranked as ranging from moderate to high.

Screening Summary: Internment in an engineered cell would likely be more detrimental than simple direct burial, when considering the long-term maintenance issues. Since arsenic, lead, and cPAH are not found to be leaching, the direct burial technology is considered just as effective and therefore more favorable over internment in an engineered cell. The direct burial option is retained for further evaluation as a remedial technology.

6.2.4.3 Cap in Place

This action involves placement of a cap over existing contamination. Capping may occur in many forms. It can be a hard cap, such as pavement, or soft cap, such as gravel, hog fuel, or soil, or a mix thereof.

The TSP Model Remedy has promoted the use of capping in certain circumstances and has developed "Type 1" and "Type 2" cap systems, the use of which depends upon the arsenic and lead concentrations. The Type 1 cap is used when maximum arsenic concentrations are less than 200 mg/kg and lead concentrations are less than 1,000 mg/kg. For the Type 1 cap, average arsenic concentrations would range between 40 and 100 mg/kg and lead between 250 and 500 mg/kg. The Type 2 cap is used when average arsenic concentrations are greater than 100 mg/kg, lead greater than 500 mg/kg. Under the Model Remedy, a Type 1 cap is a minimum of 12 inches thick and consists of a geotextile layer with at least 6 inches of soil and another 6 inches of soil or landscape material. A Type

2 cap is either a 3-inch hard cap (such as asphalt pavement), or a 24-inch soft cap, which consists of a geotextile layer with at least 18 inches of soil and 6 inches of soil or landscape material. Based on the contaminant concentrations, if one were to follow the Model Remedy recommendations, the Type 2 cap would be applicable throughout most areas of the Cleanup Unit.

Effectiveness: A cap is only good as long as it is intact. If the cap does not hold up to the use activity and is not maintained, then its effectiveness is diminished. For example, while pavement would seemly be the most effective cap, it would be ineffective on the footpaths in the long term. This is because such a cap would not hold up to the forest root system for very long. Having to continually repair damaged asphalt would be onerous and not feasible. Also, for forest footpaths, the Model Remedy Type 2, or even the Type 1 soft cap, would create an impractical and dangerous mound and their edges would soon breakdown. It appears that the Model Remedy cap systems were not developed from scientific studies. They were probably based on engineering judgment of how the cap would hold up under scenarios involving little or no ongoing maintenance. However, any physical barrier that prevents contact with the contamination is going to be effective at eliminating contact with the contamination. Therefore, suitable alternatives to the Model Remedy capping system should be considered.

Implementability: Capping is considered a standard construction practice and under many circumstances, readily easily implemented. Equipment and construction methods associated with capping are readily available, and design methods and requirements are well understood. The Model Remedy cap designs were designed for urban properties and highly developed parks, not natural areas. All of them would require significant widening of footpaths for constructability. Construction of a hard cap would require removal of the roots along the path. This would severely damage the vegetative root systems, which is inconsistent with the NEBA. The most difficult and time consuming aspect of capping at the Cleanup Unit would be implementation over miles of remote and narrow trails, particularly if asphalt or massive quantities of fill have to be brought in. For all these reasons, the Model Remedy cap system was ranked as being not implementable for the footpath system throughout the Cleanup Unit and moderately difficult to implement in other areas. Alternative capping systems could be developed which would be much more reasonable to implement.

Cost: The cost of attempting to implement the Model Remedy cap would be high to very high, depending upon to the extent to which it is implemented. Alternative capping systems could be developed whose costs would range from moderate to high.

Screening Summary: Capping provides reduction of human exposure for COCs. As indicated above, the Model Remedy caps were eliminated from further consideration, at least on forest footpaths, because of impracticality to implement, inconsistency with the NEBA, potential physical danger factors, inability to hold up, and high cost. With appropriate maintenance alternative capping systems may be developed for the Cleanup Unit that are just as protective. This alternative capping process option is retained for further evaluation as a remedial technology.

6.2.5 In Situ Treatment

In-situ treatment consists of actions that treat contaminants in place. *In-situ* treatment can include a broad range of technologies ranging from physical to chemical in nature. There are several methods of *in-situ* soil treatment sometimes used for metals remediation that are completely impractical and/or unproven, particularly for the Cleanup Unit because of the widespread surficial nature of the contamination and the fact that leaching is not an issue. These include: stabilization or solidification, which involves physical mixing or pumping of cement, grout, or other reagent into the contaminated vadose zone soil; vitrification to solidify the soil matrix by high temperatures created using electric current; soil flushing or electrokinetic separation to separate contaminants from the soil matrix; therefore, these are not included on **Table 5**. Two methods of in situ treatment considered include soil mixing and phytoremediation.

6.2.5.1 Soil Mixing

This action involves mixing surficial soils with deeper soils containing lesser concentrations of COCs. This is an approved Model Remedy, albeit for soils with arsenic concentrations that are less than 40 mg/kg.

Effectiveness: Soil mixing would be effective in reducing overall COC concentrations where concentrations are relatively low.

Implementability: Soil mixing typically uses conventional equipment, such as rototillers. For this reason, soil mixing is considered easy. However, it cannot be used in areas where it will damage existing root systems in areas that are covered by the NEBA, nor would it be all that effective as the root systems would cause a diminished effectiveness of mixing.

Cost: The cost for soil mixing, given the conventional methods and shallow mixing depth is low.

Screening Summary: Soil mixing is a simple and relatively inexpensive technology that is expected to meet Method A cleanup levels for specific areas where arsenic concentrations are relatively low. This process option is retained for further evaluation as an alternative.

6.2.5.2 Phytoremediation

This action involves the use of plants that have the ability to uptake and bioconcentrate arsenic and/or lead, with the intention of reducing metals concentrations in soil. This involves growing a metal hyperaccumulating plant, such as Chinese brake fern, and harvesting the plants to remove the metal containing biomass.

Effectiveness: This technology is largely unproven. In one study, the authors estimated that it would take 8 years to reduce average soil arsenic concentrations of 87 mg/kg to 40 mg/kg. The presence of other metals, such as lead, may suppress the uptake of arsenic (Koller, et. al. 2008; Kertulis-Tartar, et. al., 2006). Also, much of the arsenic may not be bioavailable to plants, thus, reduced efficacy may occur the longer it is attempted to be implemented (Kertuli-Tartar, et. al., 2006).

Implementability: Not implementable. The most commonly recognized arsenic hyperaccumulator is the Chinese brake fern and other species from the same genus. However, these ferns appear to be adapted to a subtropical climate, therefore would not do well in the Pacific Northwest. While the RI determined that Douglas fir is uptaking arsenic, unless the trees are harvested the arsenic is largely returned to the biomass on the ground when the trees fall or shed their needles. Logging the forest is not consistent with the NEBA determination for the site. Also, whether or not arsenic concentrations in soil have significantly declined as a result of this uptake by Douglas fir trees is not apparent.

Cost: The technology is largely unproven and not implementable, therefore the cost is not applicable.

Screening Summary: This technology is unproven and not implementable. It was not retained for further evaluation.

6.2.6 Ex Situ Treatment

6.2.6.1 Stabilization

This action involves mixing a chemical reagent into soils to stabilize arsenic and lead in order to reduce the potential for leaching. This technology is conducted on soils that have been excavated. Typically it is used when metals concentrations in the soils exceed dangerous waste limits, based on toxicity characteristic leaching testing.

Effectiveness: The technology is very effective in reducing the leachability of metals in soils. However, it does not remove the metals from the soil.

Implementability: Soil stabilization can be implemented using conventional equipment, such as rototillers and excavators. For this reasons, soil mixing is considered easy.

Cost: The comparative cost for stabilization is moderate.

Screening Summary: Soil stabilization is a well-established technology and relatively inexpensive. However, levels of arsenic and lead found in the TSP have not been high enough to cause a failure of the TCLP. Therefore, Ecology assumes that the soils generated during cleanups in the TSP are not state or federal dangerous waste (Ecology, 2012b). Therefore, it is not deemed to be a necessary technology for the Cleanup Unit and this process option is not retained for further evaluation.

6.2.6.2 Solidification

This action involves mixing a cement grout into soils to reduce the potential for metals leaching. This technology is conducted on soils that have been excavated. Typically it is used when metals concentrations in the soils exceed dangerous waste limits based on toxicity characteristic leaching testing.

Effectiveness: This technology is very effective in reducing the leachability of metals in soils. However, it does not remove the metals from the soil.

Implementability: Soil stabilization can be implemented using conventional equipment, such as rototillers and excavators. For this reason, soil mixing is considered easy.

Cost: The comparative cost for solidification is moderate.

Screening Summary: Soil solidification is a well-established technology and relatively inexpensive. However, it is not deemed to be a necessary technology for the Cleanup Unit for the same reason as discussed for stabilization above. Therefore, this process option is not retained for further evaluation.

6.2.6.3 Soil Washing

This action involves either the addition of a chemical (acid, cosolvent, surfactant) to excavated contaminated soil to leach out metals. Alternatively, it can involve physical separation of more contaminated soil particles (i.e., silt, clay) from less contaminated soil particles (i.e., sand, gravel).

Effectiveness: The effectiveness of this technology is variable, depending upon the soil type and contaminants. It is unlikely to be an effective technology for the Cleanup Unit as most of the contaminants occur within the forest duff and the organic soil layer, which would make it very difficult to separate the COCs using either a chemical or a physical process option.

Implementability: Soil washing is typically a very difficult and complex process. It is so seldom utilized that there are very few vendors who offer it.

Cost: Soil washing is typically only seriously considered if the soil volumes are very large because it is costly to implement.

Screening Summary: Soil washing is not a well-established technology. Its effectiveness is marginal, it is difficult to implement, and the cost is very high. This technology is not retained for further evaluation.

6.3 Initial Technology Screening Results

Based on the results of the remediation technologies screening in **Table 5**, the following technologies were retained for assembly into remediation alternatives.

- Institutional Controls
  - Education
  - Access restrictions
  - Maintenance Requirements
  - Land Use Restrictions
  - Hygiene stations
- Excavation with offsite disposal
- Excavation with onsite consolidation
- Cap-in-place
- Soil Mixing

6.4 Screening by Decision Unit and Conceptual Design

Table 6 lists the technologies that were retained based on the initial screening. Due to the distribution of COCs and the NEBA, the retained technologies are limited to certain decision units and sometimes only areas within those decision units and these are also summarized in **Table 6** and described further in the following sections. Also, as applicable, further detail regarding the conceptual design is provided for the individual technologies to substantiate their applicability and provide the basis for evaluation when these technologies are assembled into alternatives and evaluated in Section 7.

6.4.1 Institutional Controls

All of the institutional controls were retained. Based on the screening analysis, no single technology or combination of technologies were identified that will eliminate the presence of arsenic and lead contaminated soils at the Cleanup Unit, short of complete removal of the forest system. This is essentially what would have occurred if the mine expansion were to proceed as was initially proposed by Glacier NW. However, the mining expansion was met with heavy opposition by the public, with the result being King County purchased the property for re-designation as a natural area in perpetuity.

Removal of the forest system is inconsistent with the natural area designation and the NEBA. Therefore, any remedial alternative will require implementation of institutional controls. Institutional controls involving education, access restrictions, land use restrictions, hygiene stations and requirements for maintenance of engineering controls were all deemed applicable under any remedial alternative scenario.

6.4.2 Excavation

Excavation is considered potentially applicable only to areas that do not pass the NEBA. These include Units 3c, 3e and that portion of Unit 5 not passing the NEBA. Excavation may also be implemented on the graded roads that now serve as part of the trail system and as fire access roads. Excavation may not occur within the footpaths in the forested areas. This is because such efforts would cause greater harm to the ecology. Beyond the damage caused by having to widen trails in order to bring in equipment necessary to achieve soil excavation and to load soil out through miles of trails, excavation by machinery would cause extensive damage to root systems. It would also be impossible to excavate soils by hand due to complex root systems and such an attempt would result in incomplete removal.

6.4.3 Offsite Disposal

Any soils removed during the course of excavation may be transported offsite to a RCRA Subtitle D Landfill, assuming that the existing ferry system can accommodate the truck traffic. As indicated in previous sections, Ecology has not found that TSP soils exceed dangerous waste limitations for leachable metals, so Subtitle D landfill disposal is considered appropriate without further testing. One possible exception would be wetland soil/sediment, should this area require excavation as this specific area may have greater lead concentrations due the former skeet range activities.

6.4.4 Onsite Containment

As indicated in **Table 5**, two forms of onsite containment were identified for the Cleanup Unit. The first is internment of excavated soil below ground and the second is capping soils in situ. The following sections further describe both of these technologies.

6.4.4.1 Onsite Consolidation

Any soils removed during the course of excavation may be consolidated and interred onsite in decision units that do not pass the NEBA. Units 3c, 3e, and the portion of Unit 5 not passing the NEBA are all large enough to accommodate an internment cell. Onsite consolidation would involve excavating an internment cell below grade and placing excavated soils within the cell. The interred soil would then be covered over with a suitable thickness of clean fill (i.e., the clean soils that were removed during excavation of the cell). For ecological protection, MTCA considered 6 feet to be adequate. However, since the COCs do not appear to be adversely affecting the ecological environment, as based on the NEBA, any reasonable cap thickness that would preclude exposure and maintain integrity should be protective. If these soils were interred in Units 3c or 3e, the area would be re-vegetated. If they were interred in Unit 5, they would be covered by a gravel parking lot.

6.4.4.2 Alternative Cap Design

As discussed previously, the implementation of the Model Remedy Type 1 and 2 cap designs would cause unacceptable harm to the ecological environment inconsistent with the NEBA and practically speaking, are not implementable. These caps were designed for urban properties and highly developed parks, not natural areas. Since the mid-1990s The King County Parks Department King

County Parks has adopted the standards set by the United States Forest Service (USFS, 2011). The trail construction for the Cleanup Unit using the USFS technique is generally as follows:

1. Any blockages are removed (i.e., fallen trees, stumps that encroach into the trail area)
2. The organic duff layer overlying the mineral soil is removed. (See **Appendix C**, **Photo #1**)
3. Drainage is improved where necessary, such as the construction of side channels and installation of culverts. (See **Appendix C**, **Photos #2** and **#3**)
4. In low and wet areas 2”-4” rock is used as a base fill. This layer can be compacted by using a power carrier (by driving over it). (See **Appendix C**, **Photo #4**)
5. A layer of 5/8”-minus gravel is placed along the entire length of the path, including over areas with the 2”-4” rock, to a depth of 3-4”. This is crowned (allowing for drainage) and compacted by driving a power carrier over it. (See **Appendix C**, **Photos #5** and **#6**).

At similar sites already constructed in this manner, King County Parks Department staff inspect these trails approximately weekly to check for maintenance issues. Annual maintenance of these trails consists of blowing the organics off the trails and brush cutting along the trail edges. Additional drainage and/or gravel are added in limited areas on an as-needed basis. At the Island Center Forest (similar to the Cleanup Unit and located on Vashon Island) at least two miles of trails have successfully been capped using this technique, portions of which have been in place for almost eight years. These trails are used by hikers, joggers, mountain bikers, and equestrians.

6.4.5 Soil Mixing

Soil mixing may be applicable to the graded roads in Units 3a, 3b, and 3c. Elevated metals concentrations on the graded roads occur sporadically and are not all that high. It would be very simple and easy to conduct small field tests to ensure that the process will work. If it does, it would be a very cost effective approach in these areas and ongoing road maintenance through periodic grading could help to ensure that contaminant concentrations remain low.

Soil mixing may also be applicable when used in conjunction with other technologies. For example, the portion of Unit 5 that does not pass the NEBA may be developed into an equestrian truck/trailer parking area. Prior to development, the organic layer will have to be stripped off to a sound subgrade. The organic layer contains the majority of the COCs. With the reduction in COC concentrations, the soils may be mixed, recompacted and surfaced with crushed rock. All of these actions together would provide a permanent, significant reduction of potential exposures to COC in this area.

6.4.6 Summary

Table 7 provides a checklist summary of remedial technologies that are applicable to specific decision units and portions thereof. Based on the results of this screening, there are several areas where institutional controls are the only feasible remedial technologies. These include the steep bluffs and forested areas that pass the NEBA. This does not include the footpaths and graded roads within the areas that pass the NEBA; however, as indicated in the previous sections, the NEBA does restrict the type of remedial technologies that may be used.

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Section 7

Development of Remedial Alternatives

7.1 Remedial Goals and Objectives

The overall goals for the proposed remedies at this site are to:

- Protect human health and the environment.
- Comply with applicable regulations.
- Satisfy all provisions of the Order and receive written notification from Ecology that King County has completed the remedial activity required by the Order.

RAOs provide a general description of what the cleanup is expected to accomplish and help focus alternative development and evaluation. The following RAOs have been developed to meet these overall goals.

Remedial Action Objective #1 – Soil (Human Health): RAO#1 is to reduce to acceptable levels human health risks from park users' exposure to metals resulting from incidental ingestion of and dermal contact with forest duff and soil.

Remedial Action Objective #2 – Soil (Ecological): RAO#2 is protection of the existing terrestrial ecological environment as identified in the NEBA.

Remedial Action Objective #3 – Soil: RAO#3 is to comply with ARARs.

7.2 Remedial Alternatives

The technologies that passed the screening analyses in Section 6 were assembled into four remedial alternatives with the intent of meeting the RAO's described above. These four remedial alternatives are differentiated by the amount of soil that is excavated or capped, and are summarized in **Table 8**. Although additional combinations of technology options are possible, the alternatives presented here are considered to represent a reasonable range of approaches and costs. The proposed remedy of institutional controls, including installation of hygiene stations, is common for all of the remedial action alternatives. The analysis of remedial action alternatives in the following subsections focuses primarily on actions not involving institutional controls.

7.2.1 Remedial Action Alternative 1

Alternative 1 involves closing redundant forest trail spurs in general accordance with Ecology's recommendations in its opinion on the NEBA (Ecology, 2014). Trails that would not be closed are those that are part of a larger loop that extends offsite. The remaining forest trail system throughout the Cleanup Unit would be capped with gravel in accordance with the methodology outlined in Section 6.4.4.2.

On the graded roads, areas with soils exceeding 40 mg/kg arsenic would be excavated. The entire length of the graded roads would then be re-graded. The process of soil mixing through re-grading is likely to reduce residual arsenic throughout the length of the roads to concentrations less than 20 mg/kg.

For the former range area within Unit 5, the portion of which does not qualify for the NEBA, and which includes the area of cPAH-contaminated soils, the contaminated organic layer and surface soils would be excavated. At the conclusion of this, all soils exceeding Method A cleanup levels for arsenic, lead, and cPAH would be removed throughout this specific area. The soil removal area is estimated to be 3.9 acres. The thickness of contaminated materials to be removed is estimated to be 3 inches of duff and 6 inches of soil based in RI sampling. Following excavation, the excavated area would be covered with a 6-inch layer of compacted gravel for use as a future parking lot.

Arsenic and lead contaminated soils would be excavated throughout Units 3c and 3e, which do not pass the NEBA. For Unit 3c, this would involve cutting down the blackberry bushes that predominate throughout this area, as well as all other vegetation, with the exception of the few mature trees that occupy this area. The organic duff layer and contaminated top soil would be excavated. At the conclusion of this, all soils exceeding Method A cleanup levels for arsenic and lead would be removed throughout this specific area. The thickness of the layers to be removed from Unit 3c is estimated to be 3 inches of duff and an average of 6 inches of soil. The soil removal area is estimated to be 12.4 acres. After soil removal, the area would be regraded and an organic topsoil mix would be imported to the site and spread to achieve a 6-inch topsoil layer throughout. The topsoil would be graded to match pre-existing drainage patterns. The area would then be replanted with a mix of evergreen trees and native shrubs. Ongoing maintenance would also be required for at least 8 years to ensure an acceptable survival rate.

Similarly, in Unit 3e, the blackberries would be cut down and composted or removed from the site. In Unit 3e contaminated soils occur in the imported fill which exists as mounds and buried below grade. All soil mounds would be removed and further exploration would occur to locate and remove imported fill soils. The soil removal area is estimated to be 4.1 acres. It is estimated that a contaminated soil layer with an average thickness of 12 inches would be removed. Following this, the area would be re-graded to a level surface shaped to match pre-existing drainage patterns. No imported soil would be placed to cover the graded area. As this area is a part of the former mine site, the area would be hydroseeded and allowed to revegetate naturally after that.

Figure 7 illustrates the remedial actions that would be conducted throughout the Cleanup Unit for Alternative 1.

Under Alternative 1, all contaminated soils excavated would be transported off island to a RCRA Subtitle D landfill for disposal.

7.2.2 Remedial Action Alternative 2

Remedial Alternative 2 differs from Alternative 1 only in that soils excavated would not be transported offsite for disposal in a landfill. Excavated soils would instead be contained within the Cleanup Unit in below grade containment cells. For this alternative, the most appropriate location to contain these soils would be in the remediated areas within Decision Unit 5 and Decision Unit 3e. Soils excavated from Decision Unit 5 and 3e would be temporarily stockpiled. Once contaminated soils have been stripped off, areas of suitable size and depth within the two Units would be excavated to allow for placement of the total amount of excavated soils from Units 5, 3c, 3e, and the graded roads. Once placed, the containment areas would be capped by a minimum of 2 feet of clean material. In Unit 5, the soil containment area would then be used as a visitor parking lot. In order to provide access to the main property a spur trail will need to be constructed beginning at a point across from the lot and ending at the existing trail located in Unit 3b. The spur would be constructed using the same soil excavation and capping techniques applied in Unit 5 (excavation to below Method A cleanup levels then capping with gravel) except that the gravel cap would be based on trail versus parking lot construction specifications. For Unit 3e, contaminated soils within that area would be similarly interred below grade. A geotextile layer would be placed over the top of the interred contaminated soils and a two foot layer of clean soil would be placed over the top level with the existing grade. The area would then be revegetated by hydroseeding. **Figure 7** illustrates the remedial actions that would be conducted throughout the Cleanup Unit for Alternatives 1 and 2.

7.2.3 Remedial Action Alternative 3

Alternative 3 involves closing redundant forest trail spurs and capping the remaining forest trail system throughout the Cleanup Unit, the same as for Alternatives 1 and 2.

On the graded roads, arsenic concentrations in areas exceeding 20 mg/kg would be reduced by a process of soil mixing. The entire length of the graded roads would then be re-graded. These actions will likely reduce residual arsenic throughout the length of the graded roads to concentrations less than 20 mg/kg.

For the former range area within Unit 5, the portion of which that does not qualify for the NEBA, and which includes the area of cPAH-contaminated soils, the organic layer will be stripped off, as well as any soils that are removed with the organics. The difference between Alternatives 1 and 2 and Alternative 3 is that the material removed will be limited to the most highly contaminated, which is the surficial organic layer. This will remove the majority of the contamination. After excavation, soils throughout this area will undergo soil mixing and grading to reduce overall contaminant concentrations to an acceptable level. A portion of this area will be capped with gravel and converted to a visitor parking lot. The remainder of this area will be re-vegetated. The spur trail would be similar to Alternative 2 except that only enough soil/organic matter would be excavated to construct the trail and gravel cap, and achievement of Method A cleanup levels below the trail cap will not be a criterion.

Units 3c and 3e would remain as they currently are – covered in blackberry bushes. As it currently exists, the blackberry bushes create an effective barrier between park users and the underlying soils. The County may gradually replace these invasive species with native vegetation over time, which could eventually improve habitat in this area to the degree that it may qualify under the NEBA. These areas also do not contain features that would encourage off-trail excursion, even in the absence of blackberry bushes.

Figure 8 illustrates the remedial actions that would be conducted throughout the Cleanup Unit for Alternative 3.

Under Alternative 3, the material stripped from Unit 5 and the spur trail would be transported off island to a RCRA Subtitle D landfill for disposal.

7.2.4 Remedial Action Alternative 4

Alternative 4 is the same as Alternative 3, with the exception that the forest trail system capping will be limited to a main northeast-southwest thoroughfare from one end of the Cleanup Unit to the next, along with the connection to the proposed parking lot in Unit 5 (former skeet range). **Figure 9** illustrates the remedial actions that would be conducted throughout the Cleanup Unit for Alternative

4. Signage and the improved conditions on capped trails will encourage use of the capped trails over the uncapped trails, further minimizing arsenic and lead exposures.

7.2.5 Remedial Action Alternative 5

Alternative 5 is a modification of Alternative 4 that includes several additional measures that increase the protectiveness of the cleanup. Specifically, Units 3c and 3e will be cleared of invasive plants, covered with 3 inches of compost, and revegetated with native plants in phases every 2 to 3 years. Mature native plantings will provide a physical barrier that will discourage foot traffic through these units. In addition, the compost layer will provide a physical barrier that will reduce the potential for direct contact with underlying soils. In addition, once the mature, the combination of native trees and shrubs will meet the definition of especially valuable habitat.

The work will include removal of non-historic obstructions including chain link fence along SW 260th Street. Other structures, such as the old mining apparatus, may be completely or partially removed if it is deemed necessary for safety reasons. Any removal of structures will only be done after an appropriate health and safety plan is developed and after required data is gathered for historical documentation of the structure.

For graded roads and existing trails, instead of using soil mixing to reduce concentrations, they will be capped with a minimum of 3- to 4- inches of compacted gravel. A 3-inch thick layer of mineral soil (or equivalent) will be placed on the gravel to protect horse's hooves and dog's feet. Temporary erosion control methods may be added over the soil, on an as needed basis, until it is compact enough to be erosion resistant.

Some existing trails will be decommissioned by by the cessation of trail maintenance. Trail closed signs will be placed at the entrance to each closed trail section to discourage their use and encourage use of the capped main trails. The trails chosen for decommissioning are ones that are redundant to other trails in the vicinity or that do not connect directly to other trails on adjacent King County property. The number of proposed decommissioned trails has been kept to the absolute minimum necessary to keep trail capping costs and ongoing operations costs within the project budget.

Benches, picnic tables, picnic shelters, signage, and kiosks will be located adjacent to the capped trails at several locations. Some data recovery activities will likely be required before the revegetation occurs in the vicinity of the old historical farm foundations. Historical markers or signage may be added in this area to document the farm. These amenities will be located on pads constructed of 3-to 4- inches of the same compacted gravel used for the trail cap.

In Unit 5, clearing and grubbing will only be performed for an area large enough to construct a 40 to 50 stall gravel parking lot which will accommodate both cars and equestrian trailers. Vegetation, duff, and organic topsoil removed during this operation will be disposed of at an off-site landfill. The cleared area will be graded and a gravel parking lot and driveway will be constructed by placing a minimum of a 6-inch thick layer of compacted gravel. A 6-foot chain link fence will be placed around the perimeter of the gravel parking lot and driveway to discourage visitors from walking through the former skeet range area. Additional planting will be done to create a vegetated buffer for stormwater management. Some additional trails may be constructed to connect the parking lot to the existing trail network. New trails would be constructed using the same treatment described above for the capped trails. Existing trails to be maintained in Unit 5 will also receive the same cap treatment.

Additional testing will be done in the inundated areas of the Area 5 wetland to determine where lead levels exceed the Cleanup Screening Level of (>1,300 mg/kg). Remediation would be done in these areas to bring lead levels below 1,300 mg/kg. Based on existing data, this remediation can likely be achieved by removing the duff layer and surface soil in select locations only. Any remediation performed would be the minimum necessary to meet cleanup requirements while protecting the existing habitat. This remediation would be coordinated with the phased revegetation of Units 3C and 3E.

Hygiene stations will be placed at all main trail heads and at the entrance to the parking lot. Each station will contain a boot brush with metal walk off grate, rental "Porta Potty" style hand washing station and waste receptacle. The station near the parking lot may also include a sanican and dog washing station.

Additional reclamation activities specific to the gravel mining may be required by King County Department of Permitting and Environmental Review; however, because this activities would be required in areas actively worked as part of the gravel mining operation, it is not expected that contamination levels in these areas would exceed cleanup standards. The old mining apparatus may be completely or partially removed for safety reasons, but that work would also be outside the contaminated area.Additional shoreline or planting restoration activities also may occur on the property, but these activities are also not expected to occur in areas where contamination levels would exceed cleanup standards.

7.3 Cost Estimates

CDM Smith completed conceptual cost estimates for the four alternatives, the details of which are provided in **Appendix E**. **Table E-1** in **Appendix E** provides a summary of assumptions used in preparing the cost estimates. **Tables E-2** through **E-6** in **Appendix E** provide detailed capital cost breakdowns of the five remedial action alternatives. **Tables E-7** through **E-11** provide the long-term operation and maintenance (O&M) costs of the five remedial action alternatives. These cost estimates are based on the conceptual remediation approaches described in this section and were prepared for the purposes of this FS. An engineer's cost estimate will need to be developed for the selected remedial action alternative and based on the remedial design.

General assumptions for the conceptual level cost estimates are as follows:

- Future O&M costs are presented in net present value terms with a 4 percent discount rate.
- All construction costs include a markup (15%), insurance (1.5%) B&O tax (0.65%), and bonding (2%).
- All construction items include 8.6 percent sales tax.
- Since the design is still preliminary, all costs include a contingency of 25 percent.
- The long-term operation and maintenance cost for each alternative was estimated for a 30 year period.

Appendix E should be consulted for further details. The estimated total costs for each alternative are summarized in the following table.

Alternative	Capital Cost	O & M Costs	Total Costs
Alternative 1	$8,422,304	$1,012,053	$9,434,357
Alternative 2	$5,552,168	$1,012,053	$6,564,221
Alternative 3	$2,137,495	$187,607	$2,325,102
Alternative 4	$1,600,844	$149,835	$1,750,679
Alternative 5	$4,324,182	$1,244,767	$5,568,949

Section 8

Evaluation of Remedial Action Alternatives

This section evaluates the remedial action alternatives according to the process described in WAC 173-340-360.

8.1 Threshold Requirements

MTCA's threshold requirements for cleanup actions are described in WAC 173-340-360, which states that all cleanup actions shall:

- protect human health and the environment
- comply with cleanup standards
- comply with applicable state and federal laws
- provide for compliance monitoring
- use permanent solutions to the maximum extent practical
- provide for a reasonable restoration time frame
- consider public concerns

8.1.1 Protection of Human Health and the Environment

Overall protectiveness of human health and the environment includes the degree to which existing risks are reduced, time required to reduce risk at the site and attain cleanup standards, and improvement of the overall environmental quality. Each of the remedial alternatives was developed to strike a balance between protection of human health and the environment. Currently, there are no viable technologies that will remove the metals that exist in surface soil and duff layer (which is the most biologically active zone in the soil profile) without causing irreparable harm to the existing forest biological system. However, the NEBA demonstrated that, in spite of the high concentrations of metals in the surface soil and duff layer, the site ecology is functioning well with no apparent adverse effects. The following provides an evaluation of the alternatives by the various Cleanup Unit features addressed.

Forest Footpaths – Alternatives 4 and 5 differ from Alternatives 1 through 3 (which are the same) in that a main thoroughfare is capped as opposed to the entire trail system. Having a main thoroughfare tends to encourage the majority of trail users to utilize a specific trail system. The main thoroughfare will be particularly appealing to users with young children (the most sensitive population) for its ease of use. People who frequent a site routinely (e.g., daily jogs or dog walks) tend to be habitual and will follow the same route – the main thoroughfare makes it convenient. With one main thoroughfare, the Parks personnel can focus their maintenance efforts more effectively. Between a capped main thoroughfare for the forest footpath system and the remediation of the graded roads, the additional protectiveness afforded by capping all the forest footpaths versus a main thoroughfare is minimal.

Graded Roads – All of the alternatives will ultimately provide the same level of protection. The only differences are in how the cleanup levels are achieved. In our estimation, the relatively minor and sporadic cleanup level exceedances found on the graded roads are likely mainly caused by contaminated soil being conveyed onto the roads from adjacent areas. Since these cleanup level exceedances are sporadic and fairly minor, this does not appear to be occurring on a significant scale. For Alternatives 1 through 4, continued maintenance of these roads through regrading should keep arsenic concentrations below the cleanup level. For Alternative 5, protectiveness is maintained by long-term maintenance of the gravel cap.

Former Range Area – Alternatives 1 through 4 ultimately provide the same level of protection by ultimately achieving Method A cleanup levels at the ground surface where there is a potential for exposure. Alternative 5 provides a similar level of protection by providing a physical barrier (the 6-foot chain link fence) between the gravel capped parking lot and the remainder of the former skeet range area.

Units 3c and 3e - While Alternatives 1 and 2 provide for the removal of contaminants and provide for offsite disposal or onsite containment, these units are already covered by blackberry bushes, which provide an effective deterrent for human encroachment. People may pick the blackberries (which were determined not to uptake arsenic and lead to any significant degree), but they do so from the edges of the graded roads. The brambles are much too dense for people to forage into. In addition, the institutional controls imposed on the Cleanup Unit would ensure that these areas are not disturbed in the future for purposes other than long-term restoration of natural habitat (Alternative 5), which could eventually transform these areas into more productive wildlife habitat and inclusion under the NEBA. Finally, these areas do not contain features that would encourage off-trail excursion, even in the absence of blackberry bushes. For this reason, removal of contaminants in these areas is not, in all practicality, any more protective than simply leaving it as is (Alternatives 3 and 4) or revegetating the units with native plants (Alternative 5). Alternative 2 is the only one that provides for onsite containment of excavated soil. The plan to inter this soil below grade virtually eliminates any potential human health and environmental exposure.For the reasons described above, none of the alternatives afford a strongly greater or lesser overall protection of human health and the environment.

8.1.2 Compliance with Cleanup Standards

There is only one type of remedial action that would result in full compliance with cleanup levels across the Cleanup Unit, and that would be to remove all vegetation and scrape off the forest duff and surface soil layer and dispose of it. Obviously, this is not only impractical, it is also inconsistent with the NEBA. Therefore, the primary objective of the remedial alternatives is to reduce park user's exposures to metals to acceptable risk levels.

Each of the alternatives includes actions that will reduce the potential for human exposures in areas that are frequented by park users (i.e., the trail system of footpaths, graded roads, the former trap range area) either by capping or soil mixing (with or without some soil removal). These methods are all consistent with the TSP Model Remedy. Where proposed, soil mixing is used only minimally, in that it applies only to small sections of the graded roads where it is likely that the layer of contaminated soil is very thin, and in the former trap range area to further reduce contaminant concentrations following removal of the bulk of contaminated material, which is the organic zone.

Alternatives 1 and 2 result in the greatest amount of land that will meet Method A cleanup levels because these two remedial alternatives include cleanup of all areas that do not pass the NEBA. However, for Units 3c and 3e, practically speaking, there is no significant reduction in potential human exposure by the removal of surface soils in these areas as they are presently covered in thick blackberry brambles, which effectively discourages human trespass, particularly when there is nothing in these blackberry-covered areas that would cause people to wander off trail.

8.1.3 Compliance with State and Federal Laws

All of the laws discussed in Section 5 that need to be satisfied during implementation (e.g., grading permits, dust control, stormwater discharge BMPs during construction, soil profiling before offsite disposal) can and will be satisfied for all of the remedial alternatives.

8.1.4 Compliance Monitoring

Compliance monitoring must be performed such that protection of human health and the environment can be confirmed during implementation of the remedial alternative and that cleanup levels or remediation levels have been attained at completion of the cleanup action, as may be applicable, and that the engineering design specifications are being met. All of the Alternatives will include several forms of compliance monitoring appropriate to the individual technologies being applied. Confirmation sampling will be conducted as a part of any of the remedial actions that involve excavation and/or soil mixing to ensure that cleanup levels are being met. Health and safety compliance monitoring includes monitoring during excavation activities to ensure that any necessary actions to control discharges of dust are taken before it poses a potential health/environmental issue. Finally, compliance monitoring will be conducted to ensure that the constructed portions of the remedial alternatives will meet design specifications (e.g., gravel caps)

Compliance monitoring will not end with the completion of construction activities. It will also include regular inspections to assess the condition of institutional controls. For example, signage that is vandalized will be repaired/replaced. Hygiene stations will be maintained in good working order and all consumable supplies replenished as necessary. Trails will be inspected to ensure that trail blockages remain in place and no new trails are being forged or other land clearing is taking place. On a regular basis, organics will be blown off the trail cap regularly and its condition inspected. All necessary repairs to the trail cap will be made promptly.

8.1.5 Permanence

None of the remedial alternatives can offer a full cleanup and contaminants will remain throughout much of the upland areas and bluffs for every alternative. Soil excavation and disposal, while it is the only permanent method of cleaning up metals in any given area of the Cleanup Unit, does not in any way reduce toxicity, mobility or volume of the hazardous substance. It simply moves the contaminant from one place to another, but to an area where the potential for human health and ecological exposure is no longer a consideration. Even so, there is no guarantee that, once any individual area has been cleaned up to Method A cleanup levels, whether by capping or excavation, it will remain completely free of contaminants. Natural processes, including the shedding of foliage (i.e., Douglas fir needles), burrowing and migratory animals, human traffic, and windblown dust, will tend to move top soils. Some soils containing high concentrations of metals, are likely to end up in areas that have been previously excavated and capped.

8.1.6 Restoration Time Frame

Alternative 4 will require the least amount of time to implement, with Alternatives 3, 5, 2, and 1 requiring successively greater amounts of time to implement. The construction phase of Alternative 1 is estimated to require 10 months to complete due to the inefficiency of trucking soil off island for disposal. Alternatives 1, 2, and 5 will require many years in order to re-establish vegetation in Units 3c and 3e.

8.1.7 Consideration of Public Concerns

This criterion includes concerns from individuals, community groups, local governments, tribes, federal and state agencies, or any other organization that may have an interest in or knowledge of the site. While the potential public concerns are difficult to predict, we know that the public have a strong interest in maintaining this property as a natural park. The public have been using the Cleanup Unit as a park for decades – well before King County purchased the property – and have been educated regarding the presence of arsenic and lead in surface soils as a result of the TSP. It was due to the vehement objections of the public over the proposed mine expansion that King County ultimately decided to purchase the property. Based on this, it is evident that: a) the public is not overly concerned about possible adverse health impacts, and b) would object vehemently about any actions that would interrupt their continued enjoyment of the property.

8.2 Disproportionate Cost Analysis

MTCA specifies that preference be given to cleanup actions that use permanent solutions to the maximum extent practicable. Identifying an alternative that is permanent to the maximum extent practicable requires weighing the costs and benefits of each, which under MTCA, is known as a disproportionate cost analysis (DCA). According to MTCA, "costs are disproportionate to benefits if the incremental costs of the alternative over that of a lower cost alternative exceed the incremental degree of benefits achieved by the alternative over that of the other lower cost alternative" (WAC 173-340-360(3)(e)(i)). The following criteria (which overlap some of the first seven requirements already discussed above) are used in the disproportionate cost analysis.

- protectiveness
- permanence
- long-term effectiveness
- management of short-term risks
- technical and administrative implementability
- consideration of public concerns
- cost

Table 9 lists the evaluation criteria described above and provides a numeric ranking from 1 to 6 for each criterion for each alternative. Scores range from 1 to 6. In general, a score of 1 represents poor performance and a score of 6 represents optimal performance for that metric. The alternatives do not necessarily cover the full range of numbers. The scoring of the benefit of each metric for each remedial alternative is somewhat subjective and based on best professional judgment. . Each of the criteria were also weighted using percentages between 5% and 30% to emphasize the core purpose of protecting human health and the environment. The weighted values applied are the same as those used in the Final Feasibility Study completed for the Lower Duwamish Waterway (AECOM, 2012). The justification provided for each of the weighting values are as follows.

"Protectiveness" represents the ultimate objective of implementing the remedial alternative, so it was weighted relatively high at 25%

"Permanence" was weighted as 20%. MTCA focuses on the degree of that the toxicity, mobility, or volume of hazardous substances is reduced and considers the extent to which contamination is removed, rather than leaving it in place.

"Effectiveness over the long term" addresses how well the remedy reduces risk, for example, whether the contamination is removed or left in place to be managed over the long term, and whether controls are adequate to maintain protection against exposures to contamination left in place. Because of its importance this criterion was weighted at 30%.

"Management of short-term risks" considers risks incurred during the implementation of the remedial action. For most sites, this is a finite period. However, for the Cleanup Unit short-term risks are, in reality, in perpetuity due to the ongoing maintenance of the trail caps. A weighting factor of 15% was assigned for this criterion.

"Technical and administrative implementability" was assigned a weighting of 5% to reflect the fact that implementability is less associated with environmental concerns than with the relative difficulty and uncertainty of implementing the project.

"Consideration of public concerns" was assigned a weighting of 5% to reflect that most public concerns are embodied by the other criteria.

Cost was not weighted, but was used in the DCA to evaluate the benefit of each alternative relative to its cost.

8.2.1 Benefit Analysis

Protectiveness: This criterion considers the overall protectiveness of human health and the environment, degree to which the risk is reduced, time required to reduce the risk, on and offsite risks resulting from implementation of the alternative, and overall improvement of environmental quality. As described in Section 8.1.1., none of the alternatives have a strongly greater or lesser overall protection of human health and the environment. Alternatives 1, 2, and 5 do provide for mass excavation and/or revegetation in Units 3c and 3e, which is not included in Alternatives 3 and 4. However, besides that Units 3c and 3e are already covered by blackberry bushes, which effectively limits human contact, the total area of these two units is less than 7% of the total area of the Cleanup Unit. Regardless, Alternatives 1, 2, and 5 were ranked slightly higher than for Alternatives 3 and 4 to account for the additional soil removal and/or revegetation of Units 3c and 3e. Alternative 4 requires that less of the trail and dirt road system be capped than the other alternatives, so it was ranked slightly less than Alternative 3.

Permanence: This criterion considers the degree to which the alternative permanently reduces toxicity, mobility, and volume of the substance, including adequacy of the alternative in destroying the hazardous substance, reduction or elimination of the hazardous substance, and degree of irreversibility of the waste treatment process. For the alternatives, permanence is not straightforward because none of the remedial alternatives destroys contaminants and none can offer a full cleanup —contaminants will remain throughout much of the upland areas and bluffs. For those areas that are cleaned up, this is achieved by one of the following: 1) removing it to a landfill, 2) containing it on the property, or 3) capping. To some extent, residual contamination can re-contaminate other areas by soil movement and uptake and shedding of foliage (i.e., Douglas fir). For these reasons none of the alternatives were rated strongly favorable over the others, but Alternative 1 was ranked the highest because the excavated soil would be transported offsite for disposal and Alternative 2 over Alternatives 3, 4, and 5 because excavated soil would be interred in cells onsite. Alternative 5 was ranked similarly to Alternative 2 because contaminated soils in Units 3c and 3e will be contained on site under a 3-inch layer of compost.

Long-term effectiveness: The long-term effectiveness for the remedial alternatives considers the reliability in perpetuity, magnitude of residual risk, and effectiveness of the institutional controls. For any of the remedial alternatives, the primary concern regarding long-term effectiveness is maintenance of the caps and institutional controls. The first three alternatives involve maintenance of 100 percent of the forest trails, as opposed to one main thoroughfare. While King County is committed to the trail maintenance, having to maintain every sidebar trail will be less efficient than maintaining a single main line, particularly if these efforts extend to requiring King County to cap all trails in all adjacent forest lands impacted by the TSP. At the same time, the not having all the trails capped affords somewhat less protectiveness. Onsite containment versus offsite disposal are considered essentially equal under this criterion, given the long-term land use as a natural area. For these reasons, Alternatives 1 and 2 were ranked the same and greater than Alternatives 3 and 4. Alternative 5 was given a higher score than Alternatives 3 and 4 to account for a greater degree of on-site containment in Units 3c and 3e.

Management of short-term risks: This criterion includes the protection of human health and the environment during the implementation/construction phase. Each of the alternatives will include conditions to manage short-term risks, such as implementation of a health and safety plan and best management practices for dust control; however, alternatives with a greater level of construction will, inherently have greater short-term risks. Alternative 1 with the greater the amount of soil to be transported offsite has a much greater risk for vehicular accidents, especially considering the volume of soil that will need to be moved. Trail capping requires a considerable amount of hand labor and heavy lifting; thus, alternatives that require a greater amount of trail capping inherently have much greater short-term risks. Given this, Alternative 4 carries the least inherent short-term risk with Alternative 5 posing a slightly higher inherent short term risk. Alternative 1 is the most unfavorable for short-term risk management as it calls for excavation and offsite disposal of a large amount of excavated soils. Alternative 2 is has a slightly lesser short-term risk than Alternative 1 because, while it still involves a large volume of soil excavation, it is contained onsite, as opposed to being trucked offsite.

Technical and administrative implementability: This criterion includes an evaluation of whether the alternative is technically possible; the availability of offsite facilities, services, and materials; the administrative and regulatory requirements; the alternative's schedule, size, complexity, and monitoring requirements; access for construction, monitoring, and operations; and integration with existing facility operations. Alternative 2 received the least favorable rating primarily due to the probable additional permitting requirements for onsite containment of the material, as well as the difficulties that will be encountered in successfully re-vegetating Unit 3c/3e. Alternative 1 received the second to least favorable rating due to the added burden on the ferry system with the large amount of soil that would need to be transported offsite for disposal, as well as the anticipated difficulty in revegetating Unit 3c/3e. Alternative 5 received a higher favorability rating that Alternatives 1 and 2 because the alternative does not involve mass on-site containment of material or the same burden to the ferry system. With that said Alternative 4 received the most favorable rating over Alternatives 3 and 5 because it does not involve the extensive capping of the entire trail system or revegetation of Units 3c and 3e.

Consideration of public concerns: This criterion includes concerns from individuals, community groups, local governments, tribes, federal and state agencies, or any other organization that may have an interest in or knowledge of the site. It is King County's impression based on public comment received that the residents in the area do not perceive a significant risk as they have been using the Cleanup Unit for decades, in spite of mining operations, and continue to use the Cleanup Unit as it presently is. Rather, the residents are likely to be more concerned about disturbances that will impact their use and enjoyment of the park. Any activity that results in prolonged construction activity, noise and other inconveniences in the public's use of the property is going to be met with some opposition, at least for the short term. For this reason, Alternatives 1 and 2 were ranked lower than Alternatives 3, 4, and 5. In addition, Alternative 2 was also ranked lower than Alternative 1 as some of the public may perceive an inherent risk in containing material onsite.

It should also be considered that some people favor "unimproved" trails over "improved" trails. Alternative 3, which involves capping of all trails does not provide the public with a choice, so some individuals may be more likely to start forging new trails if their choices become limited. For this reason, Alternatives 3 and 4 were ranked the same.

8.2.2 Benefit/Cost Analysis

Table 9, presents weighted benefit scores for the five alternatives ranging from 3.4 (Alternative 4) to 4.3 (Alternative 1). Alternatives 2 and 5 received the same score of 4.1. In accordance with the MTCA DCA procedure, the weighted benefit scores were used to rank the alternatives from most permanent (Alternative 1) to least permanent (Alternative 4). As most permanent, Alternative 1 was the baseline against which the other alternatives were compared. Alternatives 3 and 4 are the least permanent alternatives, do not provide a similar benefit as the other alternatives, and were not considered further in the DCA. Alternative 2 scored the same as Alternative 5 but its cost is much higher and it was eliminated from further consideration under the DCA. A benefit versus cost comparison for alternatives 1 and 5 and selection of the preferred alternative is provided below.

Alternative 1 received a slightly higher score than Alternative 5 in the evaluation of benefits shown in Table 9. However, protection of human health and reduction in health risks under each alternative are essentially the same. The much higher costs for Alternative 1 ($9,434,357) as compared to Alternative 5 ($5,568,949) are disproportionate to the marginal, if any, increase in benefit. Therefore Alternative 5 is selected as the preferred alternative.

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Section 9

Conclusions and Recommendations

Cleanup of the Maury Island Open Space Cleanup Unit is complicated by its natural environment and the extensive nature of contamination. The NEBA completed for the Cleanup Unit demonstrated that, for a majority of the property, extensive cleanup actions would result in greater environmental harm than leaving the contaminated topsoil in place. Therefore, any remedial alternative selected for the Cleanup Unit must rely substantially on institutional controls, as are included in each of the remedial alternatives evaluated for this FS.

Besides institutional controls, the remedial alternatives developed for the Cleanup Unit all include capping of the forest trails to varying degrees and cleanup or capping of the graded road which currently serves a dual purpose as a trail and emergency fire access road. The primary difference between Alternatives 1, 2, and 5 and Alternatives 3-4 is in the cleanup of Units 3c and 3e –two areas which do not pass the NEBA. Although these areas are presently densely covered in blackberry bushes such that the potential for human exposure is low, MTCA requires that decision units not protected by the NEBA designation be addressed as part of the cleanup. The results of the DCA further indicate that Alternatives 3 and 4 do not provide benefits approaching the other, more permanent alternatives. For these reasons, Alternatives 3 and 4 are not recommended.

The main differences between Alternatives 1 and 2 and Alternative 5 include complete removal of contaminated soils from Units 3c and 3e and installation of topsoil and native vegetation. Alternative 5 provides for isolation of these contaminated soils through installation of a 3-inch layer of compost and closely spaced native shrubs and trees. In addition, rather than excavate and remove contaminated soils outside of the NEBA protected area in Unit 5, Alternative 5 limits human exposure in Unit 5 through installation of a 6-foot chain link fence around the proposed gravel lot and warning signs. Alternative 2 scored the same as Alternative 5 in the DCA but its cost is much higher and it was eliminated from further consideration. The much higher costs for Alternative 1 as compared to Alternative 5 are disproportionate to the marginal, if any, increase in benefit for Alternative 1. Therefore Alternative 5 is selected as the preferred alternative.

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Section 10
References

AECOM. 2012. Final Feasibility Study, Lower Duwamish Waterway, Seattle, Washington Volume 1 – Main Text, Tables, Figures, Sections 11, 12, 13. Lower Duwamish Waterway Group. October 31.

AESI (Associated Earth Sciences, Inc.). 1998. Soils, Geology, Geologic Hazards and Ground Water Report, Existing Conditions, Impacts, and Mitigations. Maury Island Pit, King County, Washington. Prepared for Lone Star Northwest, Inc. Revised April 27, 1998.

CDM (Camp Dresser & McKee Inc.). 2010. Phase 1 Environmental Site Assessment, Maury Island Glacier Pit, Maury Island, Washington. Project No. 19897-79767. December 23.

CDM Smith. 2015. Preliminary Draft, Feasibility Study, Maury Island Open Space Property, Maury Island, Washington. July 6.

CDM Smith. 2014a. Final, Remedial Investigation, Maury Island Open Space Property, Maury Island, Washington. Project No. 19897-99064. June 2.

CDM Smith. 2014b. Draft Net Environmental Benefit Analysis, Maury Island Open Space Property, Maury Island, Washington. Project No. 19897-99064. May 29.

Ecology. 2004. Tacoma Smelter Plume (Dirt Alert) Extended Footprint Study, December 2004 Update. http://www.ecy.wa.gov/programs/tcp/sites/tacoma_smelter/Extended_footprint_Dec_2004.html#Footprint%20Studies

Ecology. 2007. Model Toxics Control Act Cleanup Regulation, Chapter 173-340 WAC. October 12.

Ecology. 2012a. Tacoma Smelter Plume 2012 Annual Report. Publication No. 12-09-088.

Ecology. 2012b. Final Interim Action Plan for the Tacoma Smelter Plume, Asarco Tacoma Smelter Site. Publication No. 12-09-086-A. June.

Ecology 2012c. Stormwater Management Manual for Western Washington. Publication No. 12-10-030. August 2012.

Ecology. 2014. Memorandum. Comments on the Maury Island Net Environmental Benefit Analysis. November 21.

ELS (Ecological Land Services, Inc.). 2006. Maury Island Sand and Gravel Mine Reclamation Plan. Prepared for Northwest Aggregates and Glacier Northwest. February 20.

EPA. 1999. Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action and Underground Storage Tank Sites. OWER Directive 9200.17P. April 21.

EPA. 2010. Commencement Bay, Nearshore/Tideflats, Washington. http://yosemite.epa.gov/r10/nplpad.nsf/e144fa5b179a8a0388256365007ef6eb/06e1c0cda0d11fc285256594007559fd?OpenDocument

EVS. 2000. Maury Island Impact Study: Nearshore Impact Assessment. Prepared for Pacific Groundwater Group. March.

Hruby, T. 2004. Washington State Wetland Rating System for Western Washington – Revised. Washington State Department of Ecology. Publication No. 04-06-025.

King County. 2000. Final Environmental Impact Statement (FEIS) for Maury Island Glacier Northwest Gravel Mine. June.

King County. 2013. Technical Memorandum, Assessment of Maury Island Sediment Data. King County Department of Natural Resources and Parks, Parks and Recreation Division, Seattle, Washington. August 22

King County. 2013a. Maury Island Site Wetland Delineation Study. Prepared by Tina Miller, King County Parks and Recreation Division. August 2.

King County. 2013b. Draft Maury Island Natural Areas Site Management Plan. King County Department of Natural Resources and Parks, Parks and Recreation Division, Seattle, Washington. February.

King County. 2016. 2015 Maury Island Open Space Area 5 Wetland Soil Sampling and Sediment Bioassay Results. King County Department of Natural Resources and Parks, Parks and Recreation Division, Seattle, Washington. February

Kertulis-Tartar, G. M.; Lena Q Ma, Cont Tu; and T. Chirenje. 2006. Phytoremediation of an Arsenic-Contaminated Site Using Pteris vittata L: A Two Year Study. In International Journal of Phytoremediation. January 1.

Koller, C.E.; Patrick, J.W.; Rose, R.J.; Offler, C.E.; and MacFarlane. G.R. 2008. Arsenic and Heavy Metal Accumulation by *Pteris vittata* L. and *P. umbrosa* R. Br. In: Bulletin of Environmental Contamination and Toxicology. Vol 80, Issue 2, p. 128-133.

USFS. 2011. Trail Fundamentals and Trail Management Objectives. Training Reference Package. Updated May 1, 2011. See: http://www.fs.fed.us/recreation/programs/trail-management/documents/trailfundamentals/Fundamentals_Trng_Pkg_05_01_2011.pdf

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Tables

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Table 1
Summary Statistics for Arsenic in Forest Duff and Soil
Maury Island Open Space Property FS
Maury Island, Washington

	Unit and Media (Forest Duff or Soil at Specified Depth)											
	1a				1b				2a/2b	Unit 2c/4b/4c		
	Forest Duff	0-2"	9"	18"	Forest Duff	0-2"	9"	18"	0-2"	0-2"	9"	18"
Count (n)	20	32	19	16	10	30	9	9	35	21	5	5
Count (nd)	0	0	0	0	0	0	1	2	2	0	0	0
Min	10	11	5.8	4.5	13	19	<0.8	<0.8	<0.8	1.8	6.2	5.7
Max	170	477	119	19	163	379	48	43	19	148	111	29
Mean	84	164	34	8	73	105	26	11	5.9	37	43	14
Median	93	151	19	8	65	88	22	7	6.0	18	19	13
Standard Dev	50	95	34	4	45	85	15	13	3.6	44	45	10
UCL95	112	203	53	10	111	142	40	23	7.4	61	114	29

	Unit and Media (Forest Duff or Soil at Specified Depth)														
	3a				3b			3c					3e	5	
	Forest Duff	0-2"	9"	18"	Forest Duff	0-2"	9&18"	Forest Duff	0-2"	9"	18"	24"	All Depths	Forest Duff	0-2"
Count (n)	13	22	9	5	5	9	6	5	20	10	9	4	40	31	37
Count (nd)	0	0	1	1	0	0	0	0	1	1	1	1	1	0	0
Min	9	1.9	<0.8	<0.8	23	53	4.5	70	<0.8	<0.8	<0.8	<0.8	<0.8	11	12
Max	154	280	75	22	82	190	19	148	199	19	10	4.5	138	310	200
Mean	40	63	22	9.9	43	123	9.2	97	70	8.3	5.1	2.7	36	123	87
Median	26	57	8.7	4.5	34	111	8.0	82	69	6.0	4.6	2.8	29	110	90
Standard Dev	41	58	27	9.6	24	54	5.1	31	55	5.7	2.7	1.5	30	75	52
UCL95	69	92	47	25	80	173	16	146	100	13	7.6	5.9	47	155	107

	Location/Unit and Media (Forest Duff or Soil at Specified Depth)						
	Trails					Roads	Units 1a,1b,3a, 3b, 5
	All Trail	1a	1b/3b	5	9" (all)		Property-Wide
	0-2"	0-2"	0-2"	0-2"	9"	0-2"	Forest Duff and 0-2"
Count (n)	31	16	7	8	12	22	209
Count (nd)	0	0	0	0	0	0	0
Min	10	10	36	76	2.8	3.1	1.9
Max	394	297	394	182	26	67	477
Mean	130	117	165	125	8.5	17	101
Median	114	102	122	121	6.7	10	82
Standard Dev	85	88	114	40	6.7	17	76
UCL95	166	171	293	165	13	26	113

Notes:
Concentrations are in milligrams per kilogram.
Count (n) - number of samples
County (nd) - number of samples nondetect for arsenic
UCL95 - Upper 95% confidence limit

Table 2
Summary Statistics for Lead in Forest Duff and Soil
Maury Island Open Space Property FS
Maury Island, Washington

	Unit and Media (Forest Duff or Soil at Specified Depth)										
	1a				**1b**				**2a/2b**	**Unit 2c/4b/4c**	
	Forest Duff	0-2"	9"	18"	Forest Duff	0-2"	9"	18"	0-2"	0-2"	9"
Count (n)	20	27	19	16	10	20	9	9	35	20	5
Count (nd)	0	0	1	1	0	0	0	1	6	0	1
Min	33	7.1	<0.5	<0.5	9.6	1.0	8.3	<0.5	<0.5	2.0	<0.5
Max	817	710	102	12	576	930	87.4	23	17	423	112
Mean	364	220	19	6.6	220	195	26	11	5.8	55	42
Median	377	167	11	7.1	230	54	19	9.6	5.8	13	18
Standard Dev	218	185	23	2.7	158	268	25	6.3	3.9	98	48
UCL95	483	305	31	8.3	354	341	48	17	7.4	108	117

	Unit and Media (Forest Duff or Soil at Specified Depth)												
	3a				**3b**			**3c**					**3e**
	Forest Duff	0-2"	9"	18"	Forest Duff	0-2"	9&18"	Forest Duff	0-2"	9"	18"	24"	All Depths
Count (n)	13	21	9	5	5	6	6	5	15	10	9	4	40
Count (nd)	0	1	1	1	0	0	0	0	0	0	1	1	0
Min	11	<0.5	<0.5	<0.5	67	83	7.1	161	9.0	4.6	<0.5	<0.5	3.0
Max	636	330	110	45	196	224	25	487	450	40	37	8	403
Mean	119	68	35	18	102	173	11	309	118	14	9	5	61
Median	51	45	7.1	12	89	201	8.3	323	90	10	5	5	38
Standard Dev	182	68	45	18	54	60	7.1	127	123	11	11	3	81
UCL95	249	104	77	45	186	251	20	507	198	24	19	12	90

	Location/Unit and Media (Forest Duff or Soil at Specified Depth)									
	Unit 5		**Trails 0-2"**				**Trails 9"**	**On Road**	**Units 1a,1b,3a, 3b, 5**	**Units 1a,1b,3a, 3b**
									Property-Wide	**Property-Wide**
	Forest Duff	0-2"	All Trail	1a	1b and 3b	5			Forest Duff and 0-2"	Forest Duff and 0-2"
Count (n)	31	37	31	16	7	8	12	22	190	122
Count (nd)	0	0	0	0	0	0	0	0	1	1
Min	48	13	11	11	135	36	2.7	3.4	0.5	0.5
Max	2,600	2,520	1,590	776	510	1,590	17	130	2,600	930
Mean	898	312	277	208	275	415	7.8	24	333	196
Median	620	150	193	142	215	271	7.1	13	186	103
Standard Dev	762	472	304	206	148	503	4.3	33	475	202
UCL95	1,221	493	405	336	442	921	11	41	411	237

Notes:
Concentrations in milligrams per kilogram.
Count (n) - number of samples
County (nd) - number of samples nondetect for lead
UCL95 - Upper 95% confidence limit

Table 3
Summary Statistics for Cadmium in Forest Duff and Soil
Maury Island Open Space Property FS
Maury Island, Washington

	Unit and Media (Forest Duff or Soil at Specified Depth)						
	Unit 1a, 1b, 2c, 3a	**Unit 1a, 1b**	**Unit 3a,3b,3c**	**Unit 3e**	**Unit 2a, 4b,4c**	**All (1a, 1b, 2a, 2c, 3a, 3c, 3e, 4b)**	**All (1a, 1b, 2a, 2c, 3a, 3b, 3c, 3e, 4b)**
	Forest Duff	0-2"	0-2"	(all)	0-2"	9"	18"
Count (n)	9	26	14	29	13	16	22
Count (nd)	0	7	5	16	12	7	14
Min	1.2	<0.281	<0.281	<0.281	<0.2	<0.281	<0.19
Max	5.4	11	9.3	7.9	0.28	2.2	1.5
Mean	3.3	3.3	1.7	1.7	0.27	0.80	0.52
Median	3.6	2.3	0.89	0.93	0.28	0.78	0.28
Standard Dev	1.4	3.1	2.5	1.7	0.02	0.58	0.37
UCL95	4.6	4.8	3.4	2.4	0.29	1.2	0.71

Notes:
Concentrations in milligrams per kilogram.
Count (n) - number of samples
County (nd) - number of samples nondetect for cadmium
UCL95 - Upper 95% confidence limit

Table 4
PAH in Soil - Unit 5
Maury Island Open Space Property FS
Maury Island, Washington

		Sample Location, Media, Sample ID, and Units							
		#172	#173	#174	#177	#178		#179	
		Soil, 0-2"	Soil, 0-2"	Soil, 0-2"	Soil, 0-2"	Forest Duff	Soil, 0-2"	Forest Duff	Soil, 0-2"
		5-S-172-0[a]	5-S-173-0[a]	5-S-174-0[a]	5-S-177-0[a]	5-FD-178-0[a]	5-S-178-0[a]	5-FD-179-0[a]	5-S-179-0[a]
Compound	**PEF**	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg
1-Methylnaphthalene		<7.3	<7.3	<8.9	<6.4	<8.4	<7.2	<12	<7.2
2-Methylnaphthalene		<7.3	<7.3	<8.9	<6.4	<8.4	<7.2	<12	<7.2
Acenaphthene		<7.3	<7.3	<8.9	<6.4	<8.4	<7.2	<12	<7.2
Acenaphthylene		<7.3	<7.3	<8.9	<6.4	<8.4	<7.2	<12	<7.2
Anthracene		<7.3	<7.3	<8.9	<6.4	<8.4	<7.2	<12	<7.2
Benzo(a)anthracene*	0.1	<7.3	<7.3	<8.9	<6.4	<8.4	7.4	<12	<7.2
Benzo(a)pyrene*	1	<7.3	<7.3	<8.9	<6.4	<8.4	<7.2	<12	<7.2
Benzo(b,j,k)fluoranthene*	0.1	26.2	59.1	69.5	12	<8.4	36.4	<12	70.4
Benzo(g,h,i)perylene		<7.3	<7.3	<8.9	<6.4	<8.4	<7.2	<12	<7.2
Chrysene*	0.01	<7.3	<7.3	<8.9	<6.4	<8.4	16.8	<12	<7.2
Dibenzo(a,h)anthracene*	0.4	<7.3	<7.3	<8.9	<6.4	<8.4	<7.2	<12	<7.2
Fluoranthene		17.7	27.7	36.7	<6.4	22	19.2	19	24.6
Fluorene		<7.3	<7.3	<8.9	<6.4	<8.4	<7.2	<12	<7.2
Indeno(1,2,3-cd)Pyrene*	0.1	<7.3	<7.3	<8.9	<6.4	<8.4	<7.2	<12	<7.2
Naphthalene		<7.3	<7.3	<8.9	<6.4	<8.4	<7.2	<12	<7.2
Phenanthrene		<7.3	10	15	<6.4	13	7.5	<12	8.4
Pyrene		11	16.5	18.5	<6.4	20	15	<12	16.2
TEQ cPAH		**2.62**	**5.91**	**6.95**	**1.20**	**N/A**	**4.55**	**N/A**	**7.04**

Table 4
PAH in Soil - Unit 5
Maury Island Open Space Property FS
Maury Island, Washington

		Sample Location, Media, Sample ID, and Units						
		#179		#180			#181	
		Forest Duff	Soil, 0-2"	Forest Duff	Soil, 0-2"	Soil, 0-2"	Forest Duff	Soil, 0-2"
		5-FD-179-0[a]	5-S-179-0[a]	5-FD-180-0[a]	5-S-180-0[a]	5-S-180-D6[a,b]	5-FD-181-0[a]	5-S-181-0[a]
Compound	**PEF**	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg
1-Methylnaphthalene		<12	<7.2	<11	<6.8	<6.7	<9.8	<6.6
2-Methylnaphthalene		<12	<7.2	<11	<6.8	<6.7	<9.8	<6.6
Acenaphthene		<12	<7.2	<11	<6.8	<6.7	<9.8	<6.6
Acenaphthylene		<12	<7.2	<11	<6.8	<6.7	<9.8	<6.6
Anthracene		<12	<7.2	<11	<6.8	<6.7	<9.8	<6.6
Benzo(a)anthracene*	0.1	<12	<7.2	<11	<6.8	<6.7	<9.8	<6.6
Benzo(a)pyrene*	1	<12	<7.2	<11	<6.8	<6.7	<9.8	<6.6
Benzo(b,j,k)fluoranthene*	0.1	<12	70.4	<11	17.9	17.8	39.1	17.5
Benzo(g,h,i)perylene		<12	<7.2	<11	<6.8	<6.7	<9.8	<6.6
Chrysene*	0.01	<12	<7.2	<11	<6.8	<6.7	33.6	7.9
Dibenzo(a,h)anthracene*	0.4	<12	<7.2	<11	<6.8	<6.7	<9.8	<6.6
Fluoranthene		19	24.6	16	<6.8	<6.7	19	8.5
Fluorene		<12	<7.2	<11	<6.8	<6.7	<9.8	<6.6
Indeno(1,2,3-cd)Pyrene*	0.1	<12	<7.2	<11	<6.8	<6.7	<9.8	<6.6
Naphthalene		<12	<7.2	<11	<6.8	<6.7	<9.8	<6.6
Phenanthrene		<12	8.4	<11	<6.8	<6.7	<9.8	<6.6
Pyrene		<12	16.2	11	<6.8	<6.7	13	7.1
TEQ cPAH		**N/A**	**7.04**	**N/A**	**1.79**	**1.78**	**3.91**	**1.83**

Table 4
PAH in Soil - Unit 5
Maury Island Open Space Property FS
Maury Island, Washington

		Sample Location, Media, Sample ID, and Units					
		#182		#183		#184	
		Forest Duff	Soil, 0-2"	Forest Duff	Soil, 0-2"	Forest Duff	Soil, 0-2"
		5-FD-182-0[a]	5-S-182-0[a]	5-FD-183-0[a]	5-S-183-0[a]	5-FD-184-0	5-S-184-0
Compound	**PEF**	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg
1-Methylnaphthalene		<18	<12	<12	<7.7	<7.6	<6.7
2-Methylnaphthalene		<18	<12	<12	<7.7	9.6 J	<6.7
Acenaphthene		<18	<12	<12	<7.7	64.9	6.8 J
Acenaphthylene		<18	<12	<12	<7.7	<7.6	<6.7
Anthracene		<18	<12	<12	<7.7	125	12 J
Benzo(a)anthracene*	0.1	<18	<12	<12	<7.7	1,410	160
Benzo(a)pyrene*	1	<18	<12	<12	<7.7	2,210	252
Benzo(b,j,k)fluoranthene*	0.1	<18	127	<12	12	4,050	488
Benzo(g,h,i)perylene		<18	<12	<12	<7.7	1,270	137
Chrysene*	0.01	<18	<12	<12	<7.7	1,820	209
Dibenzo(a,h)anthracene*	0.4	<18	<12	<12	<7.7	328	33.2
Fluoranthene		<18	28.7	<12	<7.7	2,000	232
Fluorene		<18	<12	<12	<7.7	80.9	7.5 J
Indeno(1,2,3-cd)Pyrene*	0.1	<18	<12	<12	<7.7	1,520	166
Naphthalene		<18	<12	<12	<7.7	26.6	<6.7
Phenanthrene		<18	<12	<12	<7.7	694	74.7
Pyrene		<18	24.5	<12	<7.7	2,180	240
TEQ cPAH		**N/A**	**12.70**	**N/A**	**1.20**	**3,057**	**349**

Table 4
PAH in Soil - Unit 5
Maury Island Open Space Property FS
Maury Island, Washington

		Sample Location, Media, Sample ID, and Units						
		#185		#186			#187	
		Forest Duff	Soil, 0-2"	Forest Duff	Soil, 0-2"	Soil, 0-2"	Forest Duff	Soil, 0-2"
		5-FD-185-0	5-S-185-0	5-FD-186-0	5-S-186-0	5-S-186-D7[b]	5-FD-187-0	5-S-187-0
Compound	**PEF**	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg
1-Methylnaphthalene		15 J	<6.7	100 J	<7.6	<7.6	269	<7.4
2-Methylnaphthalene		23.9	8.1 J	170 J	9 J	9 J	271	10 J
Acenaphthene		116	62.1	639	44.1	41.9	1,990	126 J
Acenaphthylene		<7.8	<6.7	<90	<7.6	<7.6	<93	<7.4
Anthracene		845	192	954	70.5	66.9	3,710	64.3
Benzo(a)anthracene*	0.1	3,240	1,390	18,500	1,810	1,970	62,700	889
Benzo(a)pyrene*	1	3,120	2,300	24,100	2,920	3,240	82,600	2,020
Benzo(b,j,k)fluoranthene*	0.1	5,940	4,240	41,800	5,500	6,430	138,000	3,200
Benzo(g,h,i)perylene		1,360	374	10,500	801	836	37,400	358
Chrysene*	0.01	3,590	1,630	22,100	2,190	2,380	75,700	1,220
Dibenzo(a,h)anthracene*	0.4	478	153	3,010	248	260	10,900	129
Fluoranthene		6,990	2,210	26,900	2,250	2,440	104,000	1,180
Fluorene		194	46.9	439	27.8	27.1	743	28.7 J
Indeno(1,2,3-cd)Pyrene*	0.1	1,760	546	14,000	1,120	1,190	48,300	510
Naphthalene		57.9	15	253	13 J	12 J	286	9.7 J
Phenanthrene		3,720	865	5,120	384	371	22,500	334 J
Pyrene		5,540	2,150	27,700	2,490	2,710	105,000	1,430
TEQ cPAH		**4,441**	**2,995**	**32,955**	**3,884**	**4,327**	**112,617**	**2,544**

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Table 4
PAH in Soil - Unit 5
Maury Island Open Space Property FS
Maury Island, Washington

Compound	PEF	Sample Location, Media, Sample ID, and Units	
		#188	
		Forest Duff 5-FD-188-0 µg/kg	**Soil, 0-2"** 5-S-188-0 µg/kg
1-Methylnaphthalene		<6.6	<6.3
2-Methylnaphthalene		<6.6	<6.3
Acenaphthene		<6.6	11 J
Acenaphthylene		<6.6	<6.3
Anthracene		<6.6	16.7
Benzo(a)anthracene*	0.1	52.7	138
Benzo(a)pyrene*	1	97.8	223
Benzo(b,j,k)fluoranthene*	0.1	165	353
Benzo(g,h,i)perylene		29.3	99
Chrysene*	0.01	78.3	179
Dibenzo(a,h)anthracene*	0.4	6.7 J	29.5
Fluoranthene		77.8	211
Fluorene		<6.6	<6.3
Indeno(1,2,3-cd)Pyrene*	0.1	39.9	130
Naphthalene		<6.6	<6.3
Phenanthrene		21.5	82.5
Pyrene		88.1	233
TEQ cPAH		**127**	**299**

Notes:
* Carcinogenic PAHs
Shaded value exceeds the Model Toxics Control Act Method A Cleanup Level of 100 µg/kg.
Sample Locations shown on Figure 30.
a) sample extracted out of holding time
b) duplicate sample
J - estimated concentration
PAHs - polycyclic aromatic hydrocarbons
PEF - potency equivency factor
TEQ - toxic equivalency
cPAH - carcinogenic PAHs
N/A - not applicable - no cPAH detected
µg/kg - micrograms per kilogram
< - analyte not detected at or greater than listed concentration

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Table 5
Identification and Screening of Potential Remedial Technologies
Maury Island Open Space Property FS
Maury Island, Washington

General Response Action	Remedial Technology	Process Option	Issue Primarily Addressed	Effectiveness	Implementability	Relative Cost	Screening Result
No Further Action	None	Conduct no action	None	Not Effective	Easy	None	Not Retained
Institutional Controls	Education	Signage, public notices, health advisories, mailings, public meetings, hygiene stations	Reduction in human exposure by educating exposed populations of risks of exposure and methods of minimizing exposure.	Limited Effectiveness.	Easy	Low	Retained
	Access Restrictions	Maintenance of existing trails to encourage use to defined trail system. Discourage additional trail forging by the public. Blocking off unnecessary/duplicative trails.	Reduction in human exposure by channelling site users to uncontaminated areas. Access to contaminated areas is not stopped, however.	Limited Effectiveness.	Easy	Low	Retained
	Maintenance Requirements	Requirements to maintain engineered controls.	Ensures that engineered controls are properly monitored and maintained.	Effective	Moderately Difficult	Moderate	Retained
	Land Use Restrictions	Environmental covenant, zoning, etc. to impose limitations on the use of the property. Imposition of requirements that additional cleanup will occur if and as additional development occurs (i.e., development of picnic areas in areas having contamination).	Minimizing human exposure by ensuring that the property cannot be used for another land use with a greater exposure risk (such as residential development). But not expected to change the exposures associated with the current land use.	Moderately Effective	Easy	Low	Retained
Monitored Natural Attenuation (MNA)	MNA	Degradation via natural biological and/or chemical processes. Concentration reduction through natural physical processes such as dispersion, mixing, capping (by continued deposition of forest duff)	Reduction in human/ecological exposure.	Not Effective. Metals are not destroyed and contaminant reduction by physical processes over recent decades is not apparent.	Not Implementable	N/A	Not Retained
Physical Removal	Excavation	Physical removal of contaminated soil and organics with disposal by one of several methods.	Reduction in human/ecological exposure.	Effective	Easily implemented in open areas.	Low-High	Retained
Containment	Offsite Landfill Disposal	Dispose of excavated contaminated soil in an appropriate RCRA landfill.	Reduction/elimination of human/ecological exposure.	Effective	Easy to Difficult, depending upon the soil volume.	High	Retained
	Onsite Consolidation	Onsite containment of excavated soil in an engineered cell.	Reduction/elimination of human/ecological exposure.	Effective	Moderately Difficult.	High	Not Retained
		Internment of excavated soil below ground surface with a suitable depth of fill cover and cap design.	Reduction/elimination of human/ecological exposure.	Effective	Easy	Moderate	Retained

Table 5
Identification and Screening of Potential Remedial Technologies
Maury Island Open Space Property FS
Maury Island, Washington

General Response Action	Remedial Technology	Process Option	Issue Primarily Addressed	Effectiveness	Implementability	Relative Cost	Screening Result
Containment (cont.)	Cap in Place	Model Remedy - For the Type 2 cap - Emplacement of either 2 ft of soil over geotextile or installation of a 3 inch hard cap (Practically speaking this would consist of a 3-inch asphalt layer over a minimum of 6 inches of gravel base course). For the Type 1 cap - Emplacement of 1 ft soil over geotextile.	Reduction of human exposure.	Effective - with maintenance.	Not Implementable on trails. A 1 or 2 ft cap would create an impractical and dangerous "mound" and would also require widening the trails. In addition, construction of a hard cap would cause disturbance of the habitat inconsistent with the NEBA; it would not hold up to equestrian use or the forest root system. Moderately difficult in other areas.	High - Very High	Not Retained
		Alternative Cap Design - Design of a cap system specific to the Cleanup Unit.	Reduction of human exposure.	Effective - With routine maintenance this alternative would be just as protective of human health as the Model Remedy type caps.	Moderately Difficult - Difficult	Moderate to High	Retained
In Situ Treatment	Soil Mixing	Reduce concentrations of contaminants by mixing with less contaminated soils	Reduction of human/ecological exposure by reducing concentrations.	Effective where metal concentrations are not particularly high.	Easy, except where subsurface obstructions, such as tree roots, reduce the effectiveness of soil mixing.	Low	Retained
	Phytoremediation	Use of plants that have the ability to uptake and "bioconcentrate" arsenic and/or lead to reduce soil concentrations.	Reduction of metals concentrations	Not Effective. Largely unproven technology.	Not Implementable. Hyperaccumulators identified are not adapted to this area.	N/A	Not Retained
ExSitu Treatment	Stabilization	Use of a chemical reagent to stabilize arsenic and lead in excavated soils and reduce potential for leaching	Eliminates potential for leaching, but leaching is not a concern for metals and PAH at the Cleanup Unit, unless the material is excavated for offsite disposal and waste profiling analysis determines contaminant concentrations in the material exceeds dangerous waste limits.	Effective, but not an applicable technology for the Cleanup Unit unless waste profiling analyses conclude dangerous waste limits are exceeded.	Easy	Moderate	Not Retained
	Solidification	Solidification of excavated soil by mixing with a cement grout to reduce leaching.	Eliminates potential for leaching, but leaching is not a concern for metals and PAH at the Cleanup Unit, unless the material is excavated for offsite disposal and waste profiling analysis determines contaminant concentrations in the material exceeds dangerous waste limits.	Effective, but not an applicable technology for the Cleanup Unit unless waste profiling analyses conclude dangerous waste limits are exceeded.	Easy	Moderate	Not Retained
	Soil Washing	Addition of an acid/cosolvent/surfactant mixture to excavated contaminated soil to leach out metals. Alternatively, physical separation of more contaminated soil particles from less contaminated soil particles (size separation).	Reduction/elimination of human/ecological exposure.	Effectiveness is variable. Unlikely to be effective for the Cleanup Unit as the contaminants are primarily sorbed to the organics and limited to the topsoil layer where the organics are concentrated.	Difficult	Very high	Not Retained

Table 6
Identification of Remedial Technologies Applicable to the Cleanup Unit Subunits
Maury Island Open Space Property FS
Maury Island, Washington

Remedial Technology	Process Option	Applicable Units - Portion Thereof	Reason
Education	Signage, public notices, health advisories, mailings, public meetings, hygiene stations	All, except Decision Units 2a and 2b, which are free of contamination.	Regardless of the level of effort and money expended, no combination of remedial technologies short of removing all vegetation and the contaminated forest duff and top soil layer, will eliminate the risk of exposure to soil containing arsenic/lead concentrations exceeding Method A cleanup levels.
Access Restrictions	Maintenance of existing trails to encourage use to defined trail system. Discourage additional trail forging by the public. Blocking off unnecessary/duplicative trails.	All, except Decision Units 2a and 2b, which are free of contamination.	While the property is to remain a Natural Area open to the public, unfettered access cannot be allowed as long as a primary goal is to minimize human exposure to metals containing soils.
Maintenance Requirements	Requirements to maintain engineered controls.	All, except Decision Units 2a and 2b, which are free of contamination.	In order for engineering controls to be effective, there need to be assurances that they are routinely maintained in perpetuity.
Land Use Restrictions	Environmental covenant, zoning, etc. to impose limitations on the use of the property. Imposition of requirements that additional cleanup will occur if and as additional development occurs (i.e., development of picnic areas in areas having contamination).	All Decision Units	Keeps the land use for the entire property as a Natural Area. Assures appropriate handling of soil if development occurs in specific areas.
Excavation	Physical removal of contaminated soil and organics with disposal by one of several methods.	Decision Units 3c, 3e Decision Unit 5 - wetland & portion not passing NEBA. Decision Units 3a, 3b, 3c - graded roads	Excavation in other areas is not consistent with the NEBA. Even excavation of contaminated soils along footpaths would harm tree roots and cause damage beyond the existing narrow footpaths.
Offsite Disposal	Dispose of excavated contaminated soil in an appropriate RCRA landfill.	Decision Units 3c, 3e Decision Unit 5 - wetland & portion not passing NEBA. Decision Units 3a, 3b, 3c - graded roads	A final and conclusive disposal alternative that requires no long-term monitoring or maintenance.
Onsite Containment	Internment of soil below ground surface with a suitable depth of fill cover and cap design.	Internment of excavated soil from any unit could occur in Decision Units 3c, 3e, and/or Decision Unit 5 - wetland & portion not passing NEBA.	These areas are large enough to accommodate excavated soils and do not pass the NEBA.
	Alternative Cap Design - Design of a cap system specific to the Cleanup Unit.	Footpaths throughout the Cleanup Unit.	This is the only viable technology for the footpaths that exist throughout the area passing the NEBA. The Model Remedy capping options are not praticably implemented and would cause greater than acceptable destruction to habitat.
Soil Mixing	Reduce concentrations of contaminants by mixing with less contaminated soils	Decision Unit 5 - portion not passing NEBA Decision Units 3a, 3b, 3c - graded roads	Metals concentrations on the graded roads are not all that high. In Decision Unit 5 (portion passing the NEBA), soil mixing may be combined with excavation.

Table 7
Summary of Remedial Technologies Applicable to the Cleanup Unit Subunits
Maury Island Open Space Property FS
Maury Island, Washington

		Viable Remedial Technologies								
		Institutional Controls				Removal	Containment			In Situ Treatment
Decision Units	Description	Education	Access Restrictions	Maintenance Requirements	Land Use Restrictions	Excavation	Offsite Disposal	Onsite Containment	Cap in situ	Soil Mixing
2a/2b										
	Recently Mined Areas									
2c/4a/4b/4c										
	Steep Bluffs	✓	✓	✓	✓					
	Graded Roads	✓	✓	✓	✓					
1a/1b/3a/3b										
	Forested Area	✓	✓	✓	✓					
	Footpaths	✓	✓	✓	✓				✓	
	Graded Roads	✓	✓	✓	✓	✓	✓	✓	✓	✓
3c/3e										
	Previously disturbed areas primarily covered in blackberries	✓	✓	✓	✓	✓	✓	✓		
	Graded Roads	✓	✓	✓	✓	✓	✓	✓	✓	✓
5										
	Forested Area	✓	✓	✓	✓					
	Footpaths	✓	✓	✓	✓				✓	
	Former Range Area	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Wetland	✓	✓	✓	✓	✓	✓	✓	✓	

Table 8
Remedial Alternatives
Maury Island Open Space Property FS
Maury Island, Washington

Applicable Decision Units	Area Addressed	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
All	Cleanup Unit in General	Signage, public notices, public meetings, hygiene stations, ongoing maintenance of trail system, land use covenant	Signage, public notices, public meetings, hygiene stations, ongoing maintenance of trail system, land use covenant	Signage, public notices, public meetings, hygiene stations, ongoing maintenance of trail system, land use covenant	Signage, public notices, public meetings, hygiene stations, ongoing maintenance of trail system, land use covenant	Signage, public notices, public meetings, hygiene stations, ongoing maintenance of trail system, land use covenant
1a, 1b, 3a, 3b, 5	Forest Footpaths	Close redundant trail spurs in Unit 1a. Cap remaining trail system with the U.S. Forest Service-type cap.	Close redundant trail spurs in Unit 1a. Cap remaining trail system with the U.S. Forest Service-type cap. Construct short spur of trail to connect the visitor parking lot with the trail in Unit 3b (contaminated soils to be excavated prior to placement of gravel cap).	Close redundant trail spurs in Unit 1a. Cap remaining trail system with the U.S. Forest Service-type cap. Construct short spur of trail to connect the visitor parking lot with the trail in Unit 3b (trail to be capped the same as the extisting trail system, no soil excavation prior to capping).	Close redundant trail spurs. Cap a main thoroughfare with a U.S. Forest Service-type cap. Construct short spur of trail to connect the visitor parking lot with the trail in Unit 3b (trail to be capped with gravel, no soil excavation prior to capping).	Decommision side trails. Cap a main thoroughfare with a U.S. Forest Service-type cap. Construct short spur of trail to connect the visitor parking lot with the trail in Unit 3b (trail to be capped with gravel, no soil excavation prior to capping).
3a, 3b, 3c	Graded Roads	Excavate soils exceeding 40 mg/kg arsenic and regrade the road. (Note - the graded road in Unit 3c will already fall within the area of excavation described below)	Excavate soils exceeding 40 mg/kg arsenic and regrade the road. (Note - the graded road in Unit 3c will already fall within the area of excavation described below)	Conduct soil mixing in areas exceeding 20 mg/kg arsenic and regrade.	Conduct soil mixing in areas exceeding 20 mg/kg arsenic and regrade.	Cap with gravel and mineral soil similar to trails.
5	Former Range Area - portion that fails NEBA. Wetland	Excavate contaminated soils to meet MTCA Method A cleanup levels for arsenic, lead and cPAH.	Excavate contaminated soils to meet MTCA Method A cleanup levels for arsenic, lead and cPAH. Contain excavated soils from Units 5 and 3c and the graded road in a below grade cell. Cap with gravel for future use as a parking area.	Strip off organics. Conduct soil mixing and regrading. Cap a portion o f the area with crushed gravel for future use as a parking area. Revegetate the remainder of the area.	Strip off organics. Conduct soil mixing and regrading. Cap a portion o f the area with crushed gravel for future use as a parking area. Revegetate the remainder of the area.	Strip off organics in a limited area for a new parking lot. Cap parking lot area with crushed gravel. Place a 6-foot chain link fence between parking lot and remainder of Unit 5. Remediate wetland areas with lead concentrations >1,300 mg/kg.
3c, 3e	Formerly disturbed areas, primarly covered in blackberries - failing NEBA	Excavate contaminated soils to meet MTCA Method A cleanup levels for arsenic and lead. Unit 3c to be reforested. Unit 3e to be hydroseeded.	Excavate contaminated soils to meet MTCA Method A cleanup levels for arsenic and lead. Unit 3c to be reforested. Unit 3e to be hydroseeded.	Area to remain covered in blackberries.	Area to remain covered in blackberries.	Clear and grub, place 3-inches of compost and revegetate with native species.
Soil Disposal ⟶		Offsite Landfill	Contain soils in a below grade cell, covered with geotextile and a 2 foot soil cap.	Offsite Landfill	Offsite Landfill	Offsite Landfill

Notes
Cells with the same colors are the same technology

Table 9
Evaluation of Remedial Action Alternatives for Disproportionate Cost Analysis
Maury Island Open Space Property FS
Maury Island, Washington

Alternative	Description	Disproportionate Cost Analysis Criteria	Protectiveness	Permanence	Long-term Effectiveness	Management of Short-Term Risks	Technical and Administrative Implementability	Consideration of Public Concerns	Total Weighted Benefit	Cost (in millions)	Ranking (1 = most permanent, 4 = least permanent)	Overall Recommendation
	Weighting Criteria		25%	20%	30%	15%	5%	5%				
1	Close redundant trail spurs in Unit 1a. Cap remaining trails per USFS guidelines. Excavate soils exceeding 40 mg/kg arsenic on dirt roads and regrade. In the area that fails the NEBA in Unit 5 excavate contaminated soils to Meet MTCA Method A cleanup levels for arsenic, lead and cPAH. In Units 3c and 3e excavate soil to meet MTCA Method A cleanup levels for arsenic and lead. Revegetate the area. Implement institutional controls.		5	4	5	2.5	3	4	4.3	8.8	1	No
2	The same as Alternative 1, except that all excavated soils would be contained by direct burial in a subsurface cell onsite.		4.5	3.5	5	3.5	2	3	4.1	5.9	2	No
3	Close redundant trail spurs in Unit 1a. Cap remaining trails per USFS guidelines. Conduct soil mixing in areas on dirt roads that exceed 20 mg/kg and regrade. In the area that fails the NEBA in Unit 5 strip off organics. Conduct soil mixing and regrading. Cap a portion of the area with crushed gravel for future use as a parking area. Revegetate the remainder of the area. Leave Units 3 an 3e as is, as contaminated soils are covered in blackberry bushes, which act as a barrier for direct human exposure. All excavated soils to be disposed of at an offsite landfill. Implement institutional controls.		3	3	4	4	4	5	3.6	2.3	3	No
4	Close redundant trail spurs in Unit 1a. Cap a main thoroughfare per USFS guidelines. Conduct soil mixing in areas on dirt roads that exceed 20 mg/kg and regrade. In the area that fails the NEBA in Unit 5 strip off organics. Conduct soil mixing and regrading. Cap a portion of the area with crushed gravel for future use as a parking area. Revegetate the remainder of the area. Leave Units 3 an 3e as is, as contaminated soils are covered in blackberry bushes, which act as a barrier for direct human exposure. All excavated soils to be disposed of at an offsite landfill. Implement institutional controls.		2	3	3	6	5	5	3.4	1.8	4	No
5	Decommission side trails and install warning signs and hygiene stations. Cap main thoroughfare trails per USFS guidelines. Cap dirt roads that exceed 20 mg/kg with gravel. In a portion of the area that fails the NEBA in Unit 5, strip off duff and organic soils and cap the area with crushed gravel for use as a parking area. Install 6-foot chain lnk fence between parking area and remainder of Unit 5. Remediate wetland. Remove chain link fence along SW 260th Street. Revegetate Units 3c and 3e with 3-inches of compost and native vegetation. All excavated soils to be disposed of at an offsite landfill. Implement institutional controls.		4	3.5	4.5	4	3.5	4.5	4.1	4.4	2	Yes

Disproportionate Cost Analysis Scoring Criteria

6	Ideal/excellent favorability
5	High benefit/very favorable
4	Reasonable benefit/favorable
3	Some benefit/moderate favorability
2	Slight benefit/low favorability
1	Virtually no benefit/not favorable

Figures

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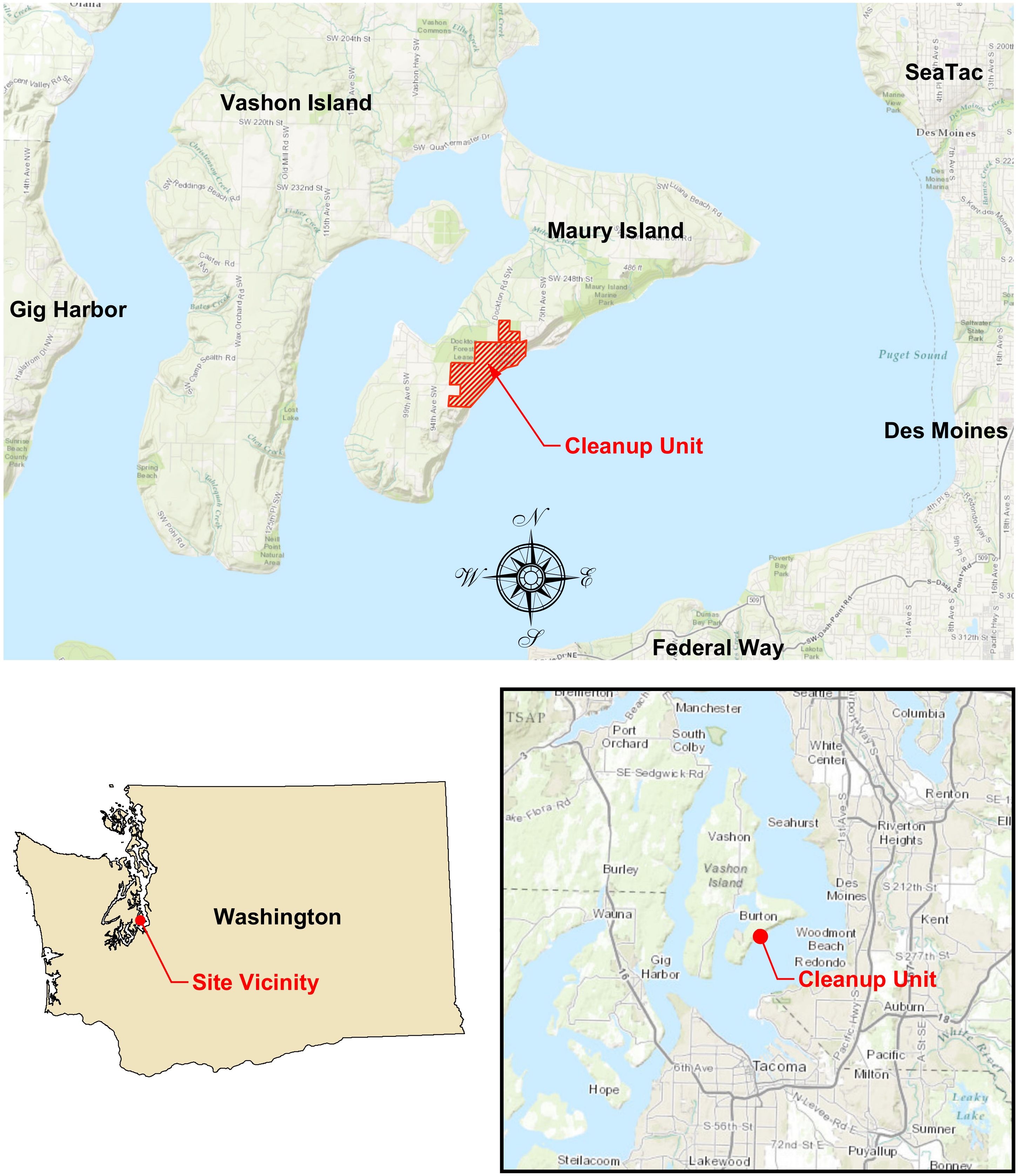

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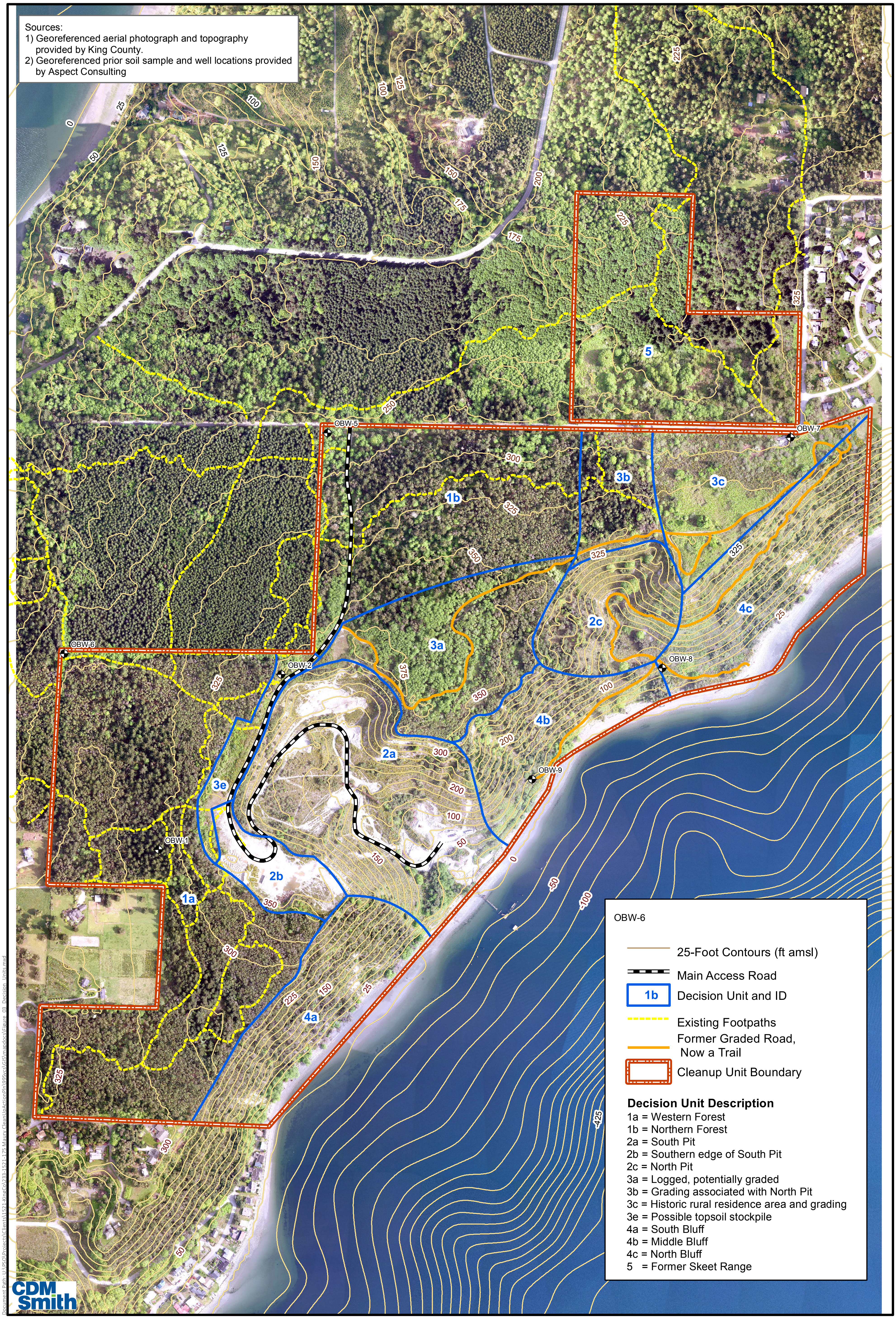
Parametrix

FIGURE 1
VICINITY AND LOCATION MAP
Maury Island Open Space Property FS

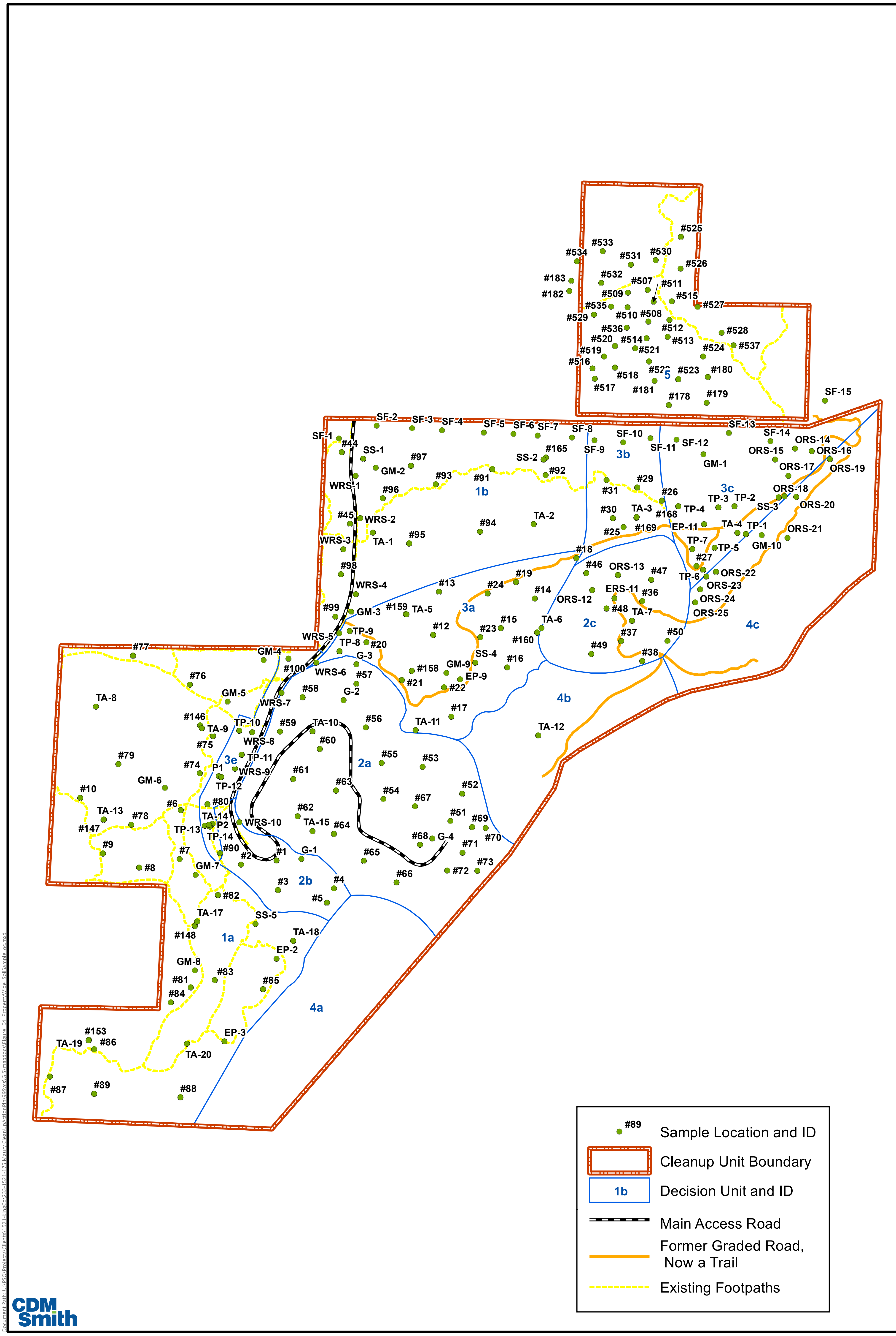
FIGURE 2
CLEANUP UNIT AND VICINITY FEATURES
Maury Island Open Space Property FS



Parametrix

0 250 500 1,000 Feet

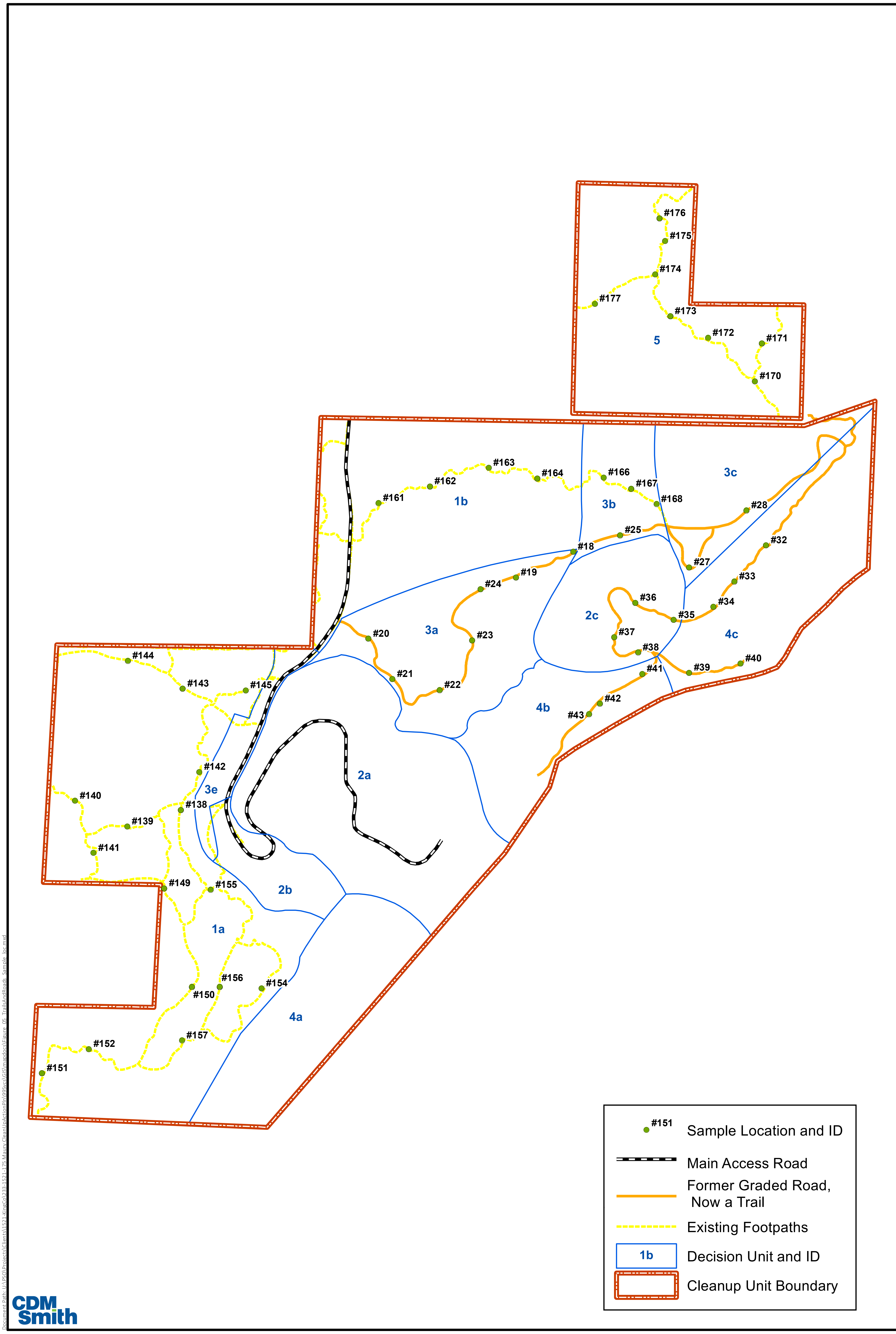
FIGURE 3
DECISION UNITS AND MONITORING WELL LOCATIONS
Maury Island Open Space Property FS



Parametrix

0 250 500 1,000 Feet

FIGURE 4
PROPERTY-WIDE SOIL SAMPLE LOCATIONS
Maury Island Open Space Property FS



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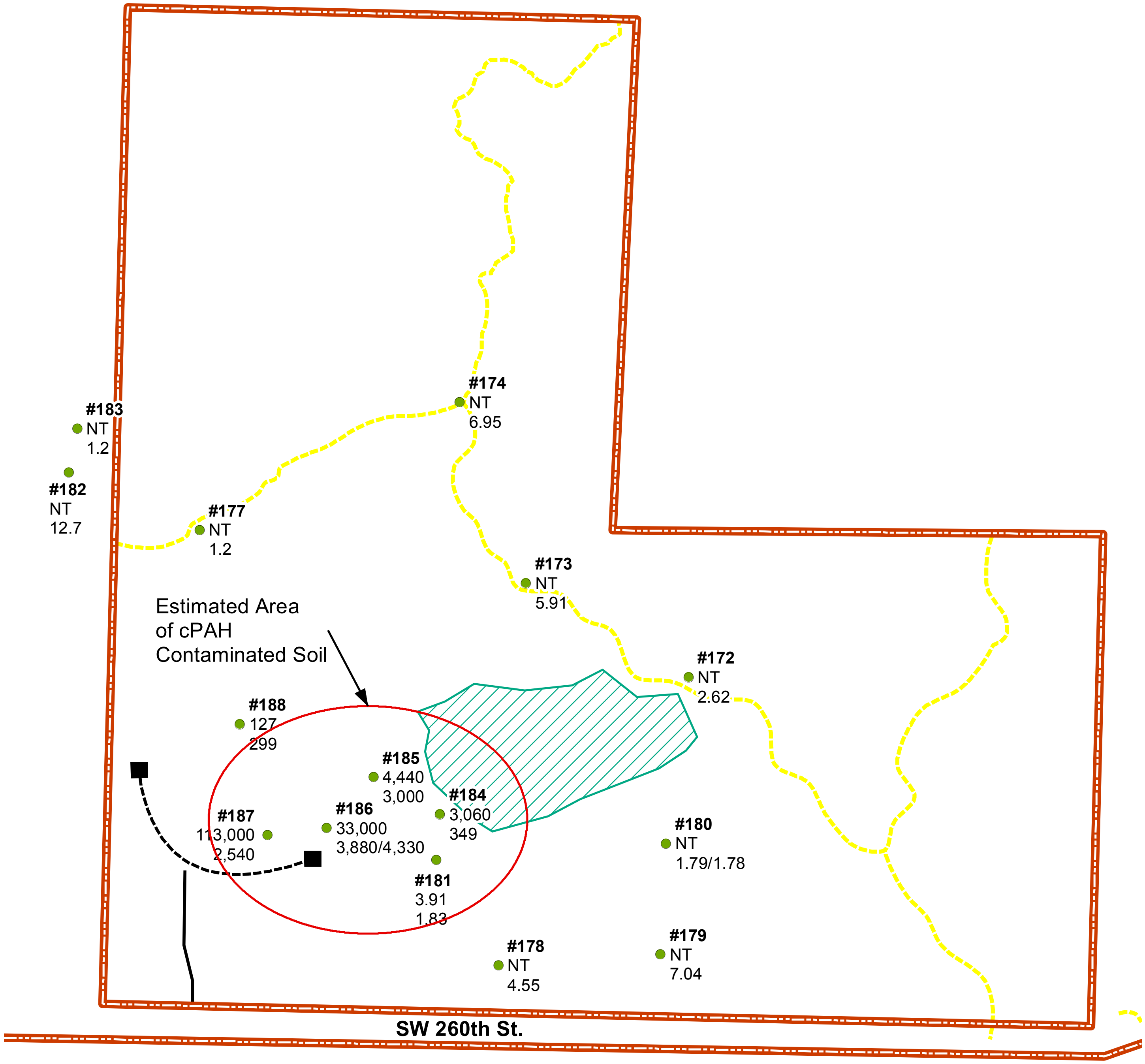
Parametrix

Feet
0 250 500 1,000

FIGURE 5
SAMPLE LOCATIONS ON TRAIL AND ROADS
Maury Island Open Space Propoerty FS



Sample Key:
#186 Sample ID
33,000 cPAH TEQ concentration in forest duff
3,880 cPAH TEQ concentration in soil at 0-2" depth

Notes:
1) Data presented below sample ID number is in descending order of depth. Only sampled depths shown unless a preceding depth was not sampled; then NT (Not Tested) was used as a place holder.
2) Concentration in micrograms per kilogram adjusted for dry weight basis and TEQ.
3) Concentrations may differ slightly from the summary tables due to rounding.

/ # - Results of duplicate analyses
TEQ - Toxic equivalency
cPAH - Carcinogenic polycyclic aromatic hydrocarbons

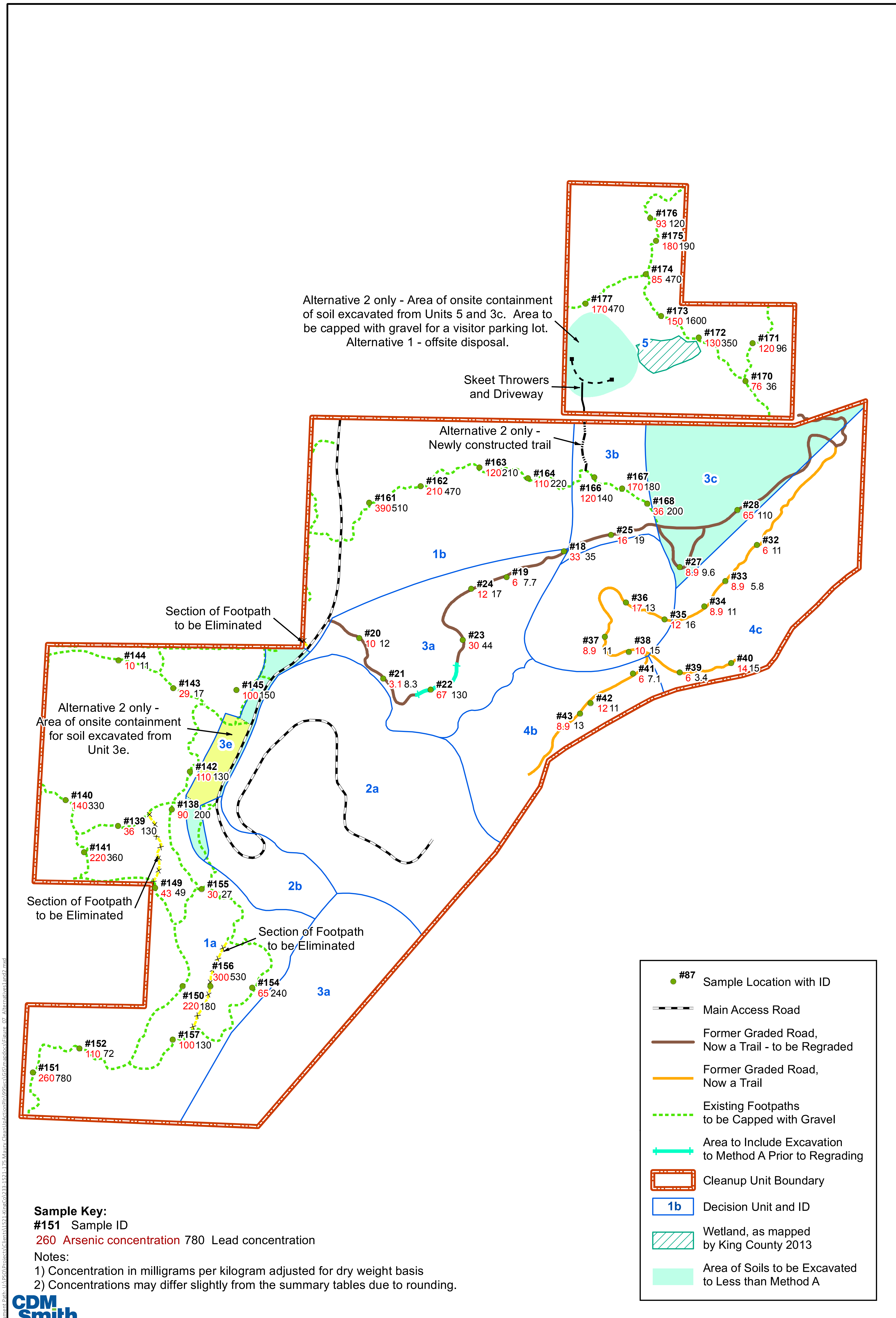
#186 Sample Location and ID
Existing Footpaths
Cleanup Unit Boundary
Wetland, as mapped by King County 2013

CDM Smith
Parametrix

Feet
0 50 100 200

FIGURE 6
CPAH IN FOREST DUFF AND SOIL
Maury Island Open Space Property FS

Document Path: U:\PSO\Projects\Clients\1521-KingCo\233-1521-175 Maury CleanUpActionPln\99Svcs\GIS\mapdocs\Figure_06_PAH_skeet.mxd

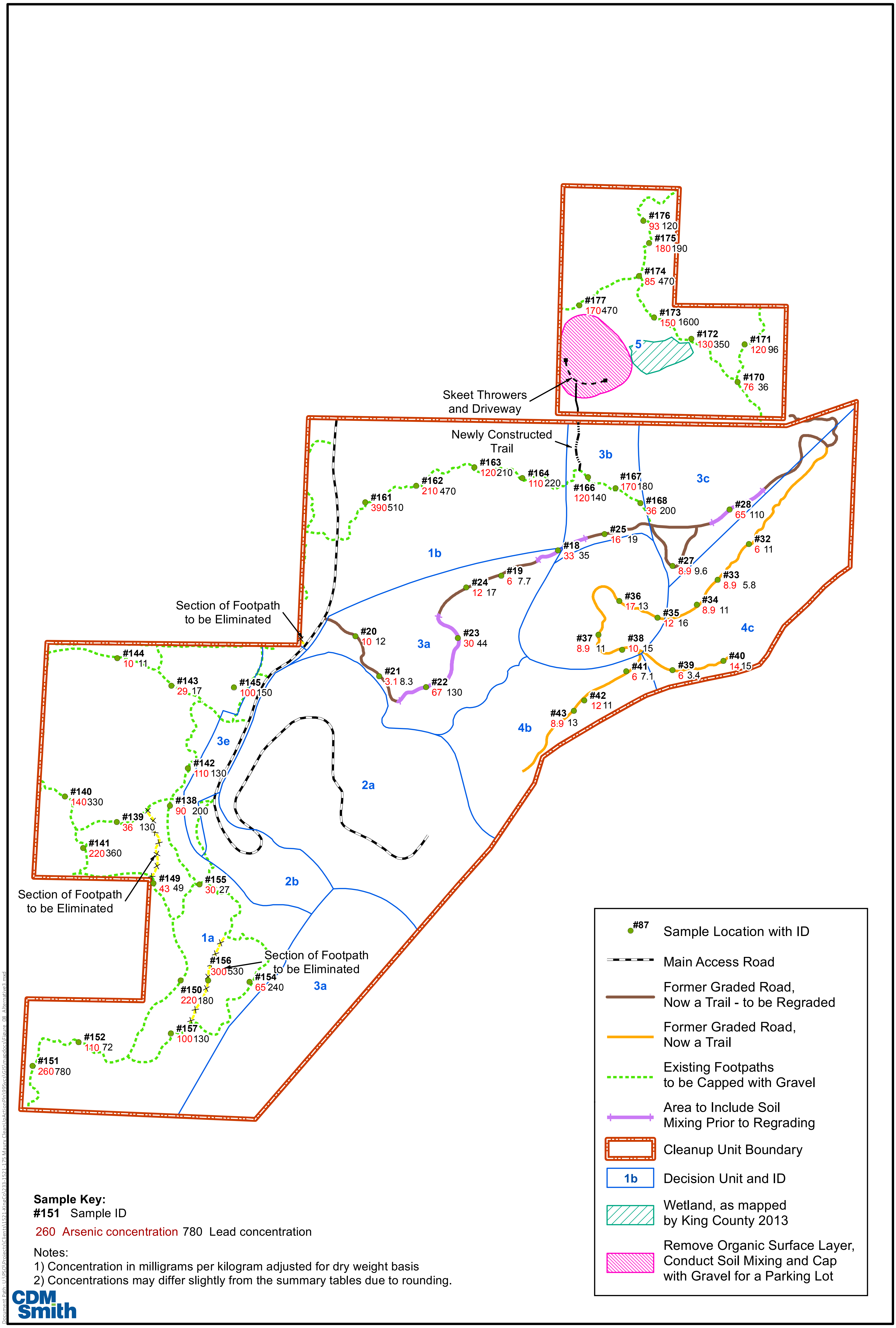


Parametrix

0 250 500 1,000 Feet

FIGURE 7
REMEDIAL ALTERNATIVES 1 AND 2

Maury Island Open Space Property FS



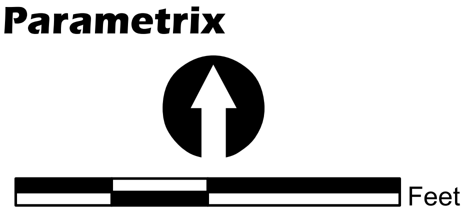
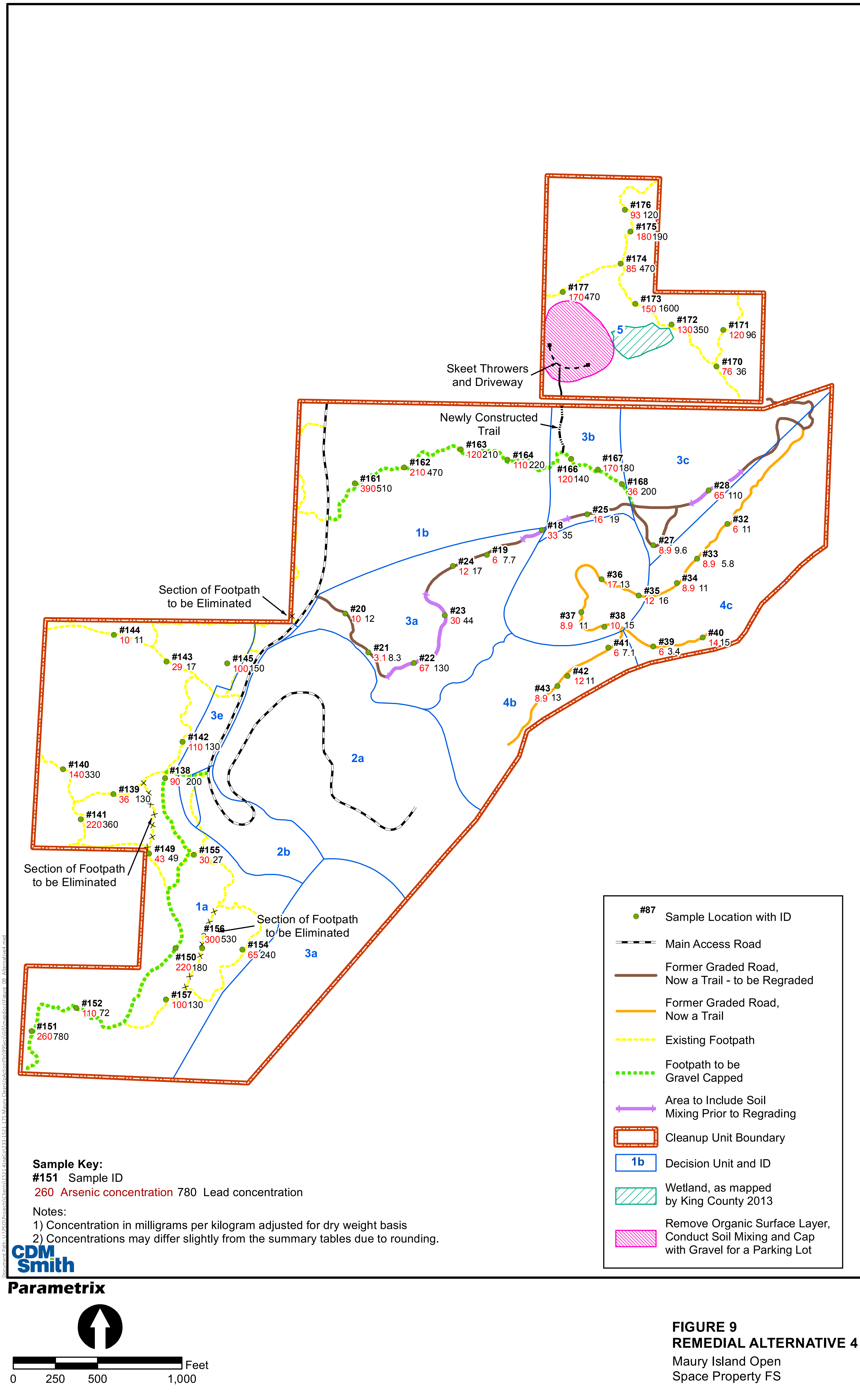


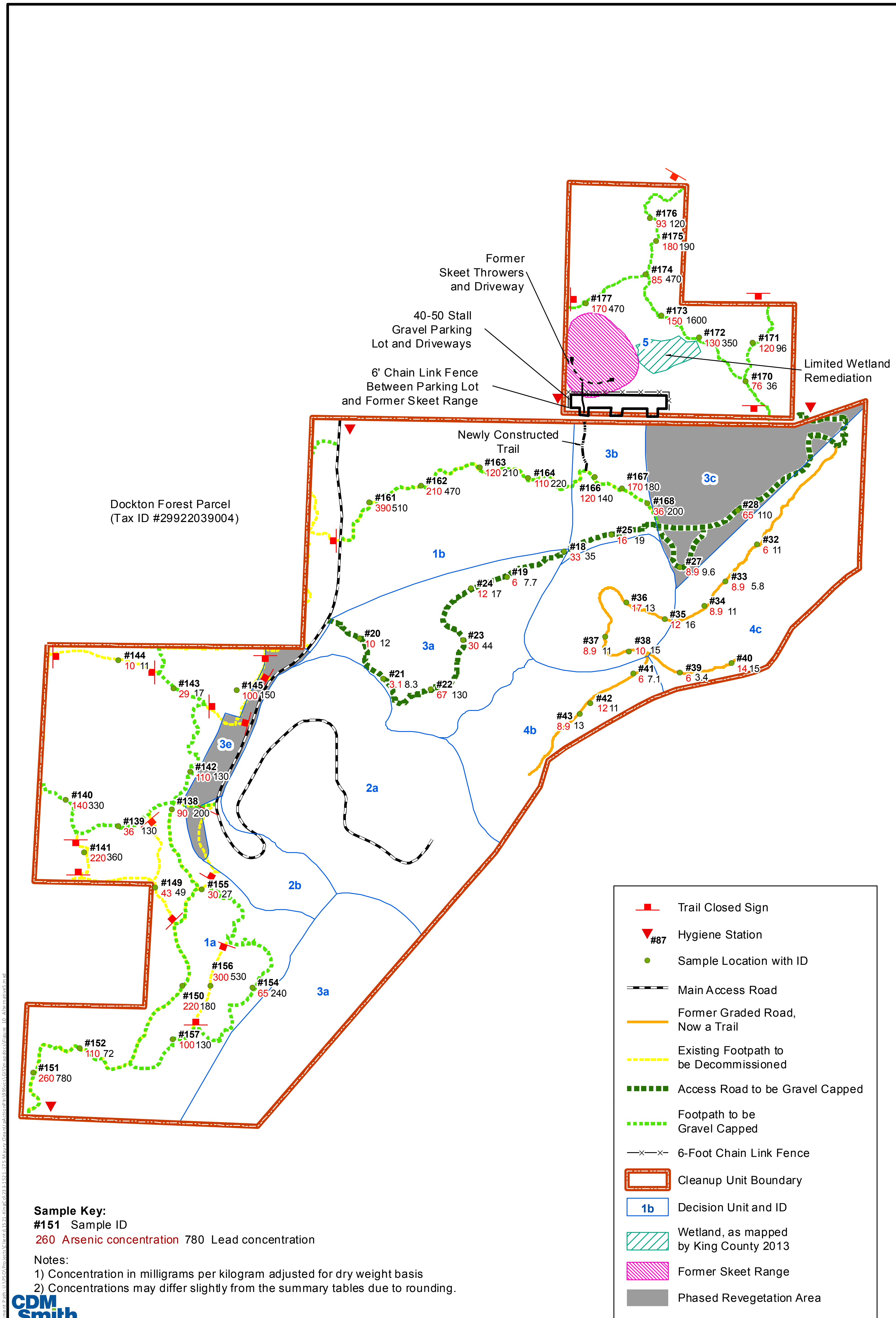
FIGURE 8
REMEDIAL ALTERNATIVE 3
Maury Island Open
Space Property FS



Sample Key:
#151 Sample ID
260 Arsenic concentration 780 Lead concentration

Notes:
1) Concentration in milligrams per kilogram adjusted for dry weight basis
2) Concentrations may differ slightly from the summary tables due to rounding.

FIGURE 9
REMEDIAL ALTERNATIVE 4
Maury Island Open Space Property FS



Parametrix

Feet
0 250 500 1,000

FIGURE 10
REMEDIAL ALTERNATIVE 5
Maury Island Open Space Property FS

Appendix A

Site Photographs

Maury Island Open Space Property
Maury Island, WA

Photograph No. 1

Description:
View of Unit 2a (South Pit from the beach. Remnant of mining conveyor structures and the road down to the beach shown.

Photograph No. 2

Description:
Partially reconstructed dock at the base of the South Pit.

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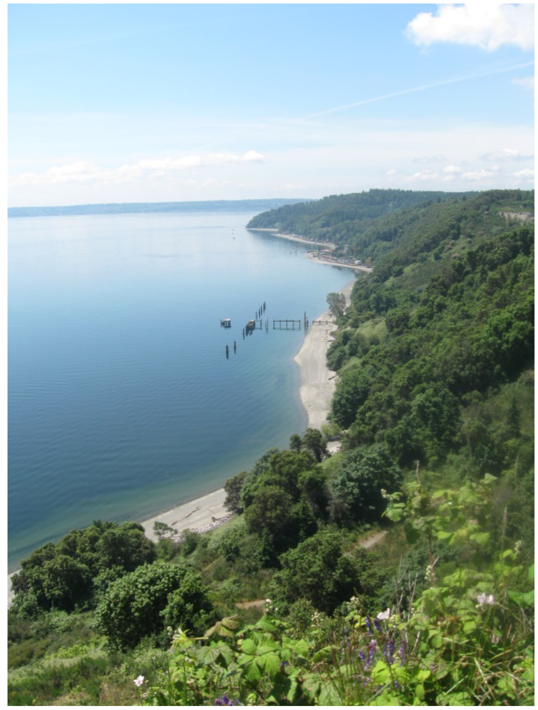
Photograph No. 3

Description:
View of bluffs from Unit 3c.



Photograph No. 4

Description:
View of bluff from the beach.

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Photograph No. 5

Description:
The trail (formerly a graded road) on Unit 4c now becoming overgrown with Scot's broom, blackberries, and poison oak.

Photograph No. 6

Description:
Typical forest footpath.

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Photograph No. 7

Description:
Remnant pilings near the old North Pit concrete pier.

Photograph No. 8

Description:
Sand and mud intertidal terrace.

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Photograph No. 9

Description:
Douglas fir forest in Unit 1a showing understory of salal.

Photograph No. 10

Description:
Douglas fir forest in Unit 1b showing understory of evergreen huckleberry.

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Photograph No. 11

Description:
Previously mined area in Unit 2a beginning to recolonize, primarily with invasive Scot's broom.

Photograph No. 12

Description:
Scot's broom scrub habitat in Unit 2b.

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Photograph No. 13

Description:
Unit 2c showing early succession of Pacific madrone with Scot's broom scrub habitat.

Photograph No. 14

Description:
Himalayan blackberries in Unit 3c.

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Photograph No. 15

Description:
Wetland in Unit 5.

Photograph No. 16

Description:
Mixed deciduous forest in Unit 5.

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Photograph No. 17

Description:
Blackberries in former trap shooting range of Unit 5 before they were cleared to allow for sampling.

Photograph No. 18

Description:
Former trap shooting range a year after removal of the blackberries.

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Appendix B

Marine Sediment Sampling Evaluation and Reports

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King County
Water and Land Resources Division
Department of Natural Resources and Parks
King Street Center
201 South Jackson Street, Suite 600
Seattle, WA 98104-3855
206-296-6519 Fax 206-296-0192
TTY Relay: 711

August 22, 2013

TO: Ron Timm, Toxic Cleanup Program, Northwest Regional Office, Washington Department of Ecology

FM: Debra Williston, Science and Technical Support Section, Water and Land Resources Division, Department of Natural Resources and Parks (DNRP)

RE: Assessment of Maury Island Sediment Data

King County has reviewed the March 2000 Maury Island Gravel Mine Impact Study: Nearshore Impact Assessment (EVS 2000). The evaluation of the sediment data from this study indicates no further evaluation is required. The low total organic carbon of sample MI-SED-05 (TOC of 0.33%) results in comparisons to Lowest Apparent Effects Threshold (LAET) dry weight values for the PAH data. When organic carbon is less than 0.5% in sediments, dry weight concentrations are compared to LAET and 2LAET concentrations rather than the organic carbon normalized sediment quality standards (SQS) and cleanup screening levels (CSL). The dry weight PAH concentrations do not exceed any LAET values. No chemicals exceed sediment quality standards based on the 2000 sediment data.

Additional sediment data for the site was found in Ecology's EIM Database. Sediment samples were collected in 2008 by Glacier Northwest, Inc. as part of the Maury Island Dock Reconstruction project. In this study, five surface sediment samples (0-10 cm) were collected in November 2008 along the dock structure and analyzed for semi-volatile organic compounds, metals, mercury, PCBs, total solids, and total organic carbon. These data were compared to the SQS and CSL of the Sediment Management Standards (WAC 173-204). Two of the samples had low total organic carbon (0.148% and 0.371%) and therefore chemicals that have organic-carbon normalized numeric criteria were compared to LAET and 2LAET values for these two samples. All sample results were below SQS with the following exceptions: Station MI-02 for fluoranthene; MI-04 for phenol; and MI-05 for phenol and 4-methylphenol (p-Cresol). The concentrations of phenol and 4-methylphenol at Station MI-05 exceeded the CSL, whereas fluoranthene at MI-02 and phenol at MI-04 exceeded the SQS but not the CSL (Table 1).

Based on this finding, the three highest concentrations from the five stations were averaged to determine if there were station clusters of concern (i.e., does the average concentration exceed the CSL). For both fluoranthene and phenol, averaging the three highest concentrations did not result in exceedances of their respective CSL. When the three highest concentrations of 4-methylphenol were averaged, the CSL was exceeded (note the SQS and CSL are the same value for this chemical). However, three of the five samples were not detected at 19, 19 and 20 micrograms per kilogram on a dry weight basis (µg/kg dw) and one was below the reporting detection limit at 13 µg/kg dw (J); only one station had a detection of 4-methylphenol above the reporting detection limit that exceeded the SQS/CSL. Therefore, this one detection above numeric criteria of 4-methylphenol is not expected to be of concern for the site; there is only a very localized potential for adverse effects based on these data.

Based this analysis, no further evaluation is needed at this site and the Washington Department of Natural Resources should proceed with the removal of the dock structure and associated pilings. The creosote pilings would be the only potential source of the fluoranthene and phenolic compounds and therefore the best course of action is the removal of the pilings. With the high energy environment and removal of potential point sources to the sediments, no further action beyond dock and piling removal is necessary.

Please let me know if you have questions concerning this analysis of the sediment data for the site. I can provide you with an Excel file of the EIM download of the 2008 data if needed.

Table 1. 2008 Chemistry Data Exceeding Sediment Management Standards

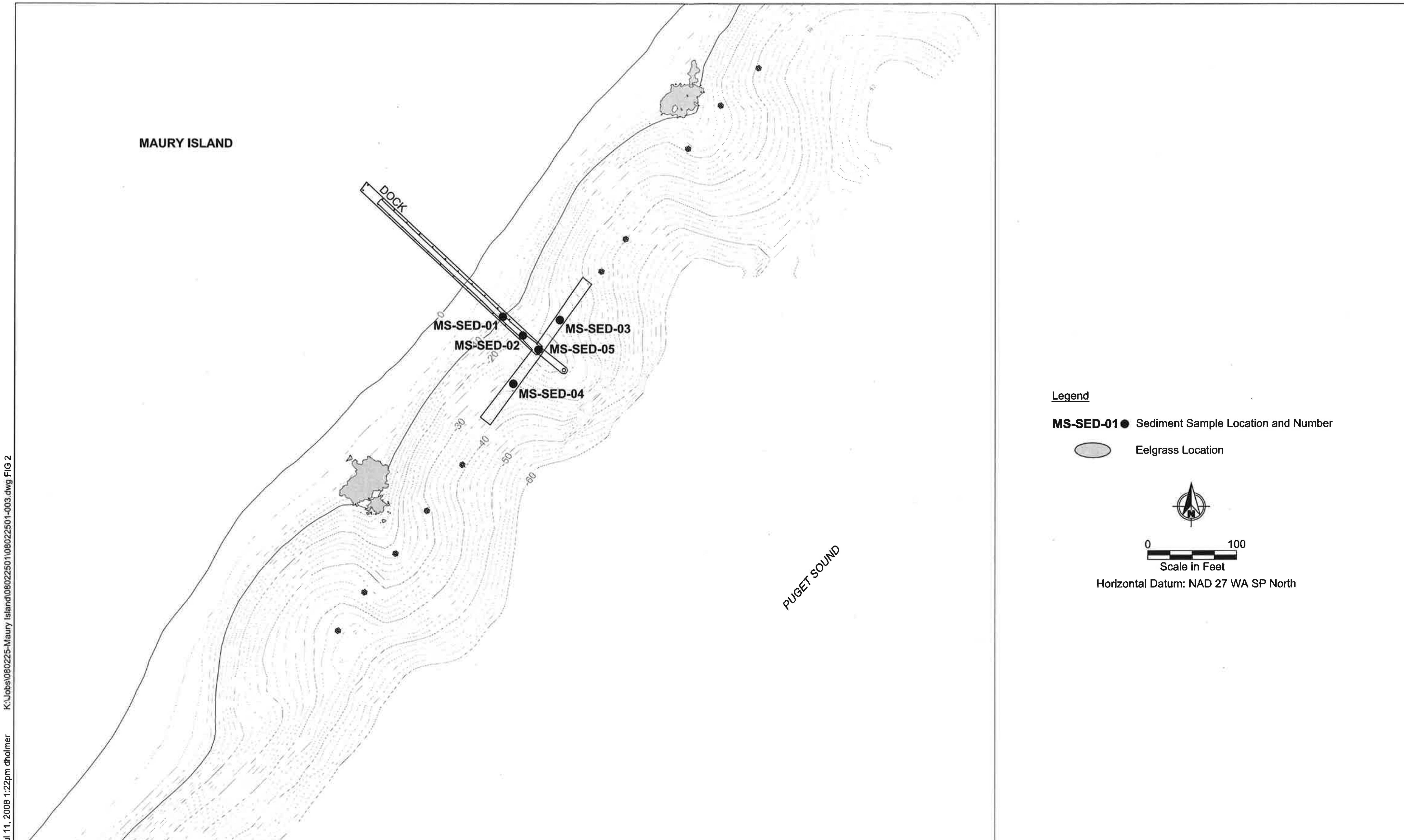
Parameter	SQS/LAET	CSL/2LAET	Station				
			MI-01	MI-02	MI-03	MI-04	MI-05
Total Organic Carbon (%)	n/a	n/a	0.148 J	0.371 J	2.26 J	1.9 J	1.81 J
Fluoranthene (µg/kg dw)	1,700	2,500	17 J	1,900	n/a	n/a	n/a
Fluoranthene (mg/kg OC)	160	1,200	n/a	n/a	40	63	77
Phenol (µg/kg dw)	420	1,200	19 U	19 U	87	500	1,400
4-methyl Phenol (µg/kg dw)	670	670	19 U	19 U	20 U	13 J	2,500

n/a = not applicable
J = estimated value
U = not detected
Yellow shading indicates exceedance of Sediment Management Standard

References:

EVS. 2000. Maury Island Gravel Mine Impact Study: Nearshore Impact Assessment. Prepared for Pacific Groundwater Group. Prepared by EVS Environmental Consultants, Inc., Seattle, WA.

cc: James Neely, Recycling and Environmental Services, Solid Waste Division, DNRP



Jul 11, 2008 1:22pm dholmer K:\Jobs\080225-Maury Island\08022501\08022501-003.dwg FIG 2

ANCHOR ENVIRONMENTAL, L.L.C.

Figure 2
Existing Dock Structures and Proposed Sample Locations
Maury Island Sediment Characterization

EVS Environment Consultants

March 2000

Maury Island Gravel Mine Impact Study:

Nearshore Impact Assessment

Prepared for:

Pacific Groundwater Group
2377 Eastlake Avenue East
Seattle, WA 98102

Prepared by:

EVS Environment Consultants
200 West Mercer Street, Suite 403
Seattle, WA 98119

Maury Island Gravel Mine Impact Study

NEARSHORE IMPACT ASSESSMENT

Prepared for

Pacific Groundwater Group
2377 Eastlake Avenue East
Seattle, WA 98102

Prepared by

EVS Environment Consultants, Inc.
200 West Mercer Street, Suite 403
Seattle, WA 98119

EVS Project No.
2/527-02

MARCH 2000

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LIST OF ACRONYMS

ACOE	U.S. Army Corps of Engineers
ADDAMS	Automated Dredging and Disposal Alternatives Modeling System
AES	Associated Earth Sciences
ARI	Analytical Resources Incorporated
DEIS	Draft Environmental Impact Statement
DGPS	differential global positioning system
ESA	Endangered Species Act
MLLW	mean lower low water
NOAA	National Oceanographic and Atmospheric Administration
OLLD	Ocean and Lake Levels Division
PAH	polycyclic aromatic hydrocarbon
PAR	photosynthetically active radiation
PCB	polychlorinated biphenyl
PSEP	Puget Sound Estuary Program
QA	quality assurance
SPI	sediment profile imaging
USCG	U.S. Coast Guard
USEPA	U.S. Environmental Protection Agency
WDFW	Washington Department of Fish and Wildlife

ACKNOWLEDGMENTS

This report was prepared by EVS Environment Consultants (EVS) under subcontract to Pacific Groundwater Group (PGG) for their contract with the Washington Department of Ecology. Ms. Janet Knox served as PGG's Project Manager for this project. EVS's Project Manager was Dr. Steve Ellis. The authors of this report were Dr. Steve Ellis, Dr. Joe Germano, Ms. Julie Haddad, Dr. Dennis Hanzlick , Ms. Sally Lawrence, Dr. Susan McGroddy, and Mr. Jim Starkes. Report graphics were prepared by Mr. Brad Alleman, Mr. Rick Dailey, Ms. Kimberly Galimanis, and Ms. Peggy Myre. Technical review was provided by Dr. Robert Dexter, Dr. Steve Ellis, and Dr. Joe Germano. Editing was performed by Ms. Linda Cognato of Techne. Word processing was conducted by Ms. Kay Hessemer and Ms. Carol Pearsall.

Precision bathymetric and side scan surveys were conducted on the vessel *Surveyor* by Mr. Tony Petrillo of Blue Water Engineering. Mr. Garrett Gray and Mr. Tim Hammermeister of EVS collected the sediment samples and deployed the Sediment Profile Imaging camera from the vessel *Kittiwake*, which is owned and operated by Mr. Charles Eaton of Bio-Marine Enterprises. Sediment chemistry analyses were conducted by Analytical Resources Inc.

The following individuals provided comments on an earlier draft of this report:

Mr. Dave Garland	Washington Department of Ecology
Ms. Pamela Erstad	Washington Department of Fish and Wildlife

1.0 INTRODUCTION

Glacier Northwest, a subsidiary of Lone Star Northwest, Inc., and referred to herein as Lone Star, has applied for a permit to increase its rate of gravel extraction from an existing mine located on the eastern shore of Maury Island in Puget Sound, Washington. The legislation commissioning the Maury Island mine impact studies specified that the study consider impacts to the nearshore environment. For this reason, the Washington Department of Ecology included a nearshore study element in the mine impact study.

This document provides an assessment of potential impacts of the proposed mine project on critical nearshore marine resources. The assessment uses the following methods:

- A field study was conducted to establish baseline benthic habitat types and conditions
- Reports from Washington Department of Fish and Wildlife (WDFW) fisheries specialists were reviewed to assess the use of the nearshore area by listed and candidate fish species
- Published scientific studies on the effects of similar impacts on the nearshore species of concern were reviewed

This document consists of the following sections:

Section 2.0 Baseline Nearshore Assessment

Section 3.0 Impact Assessment

Section 4.0 Conclusions

Section 5.0 References

Appendices

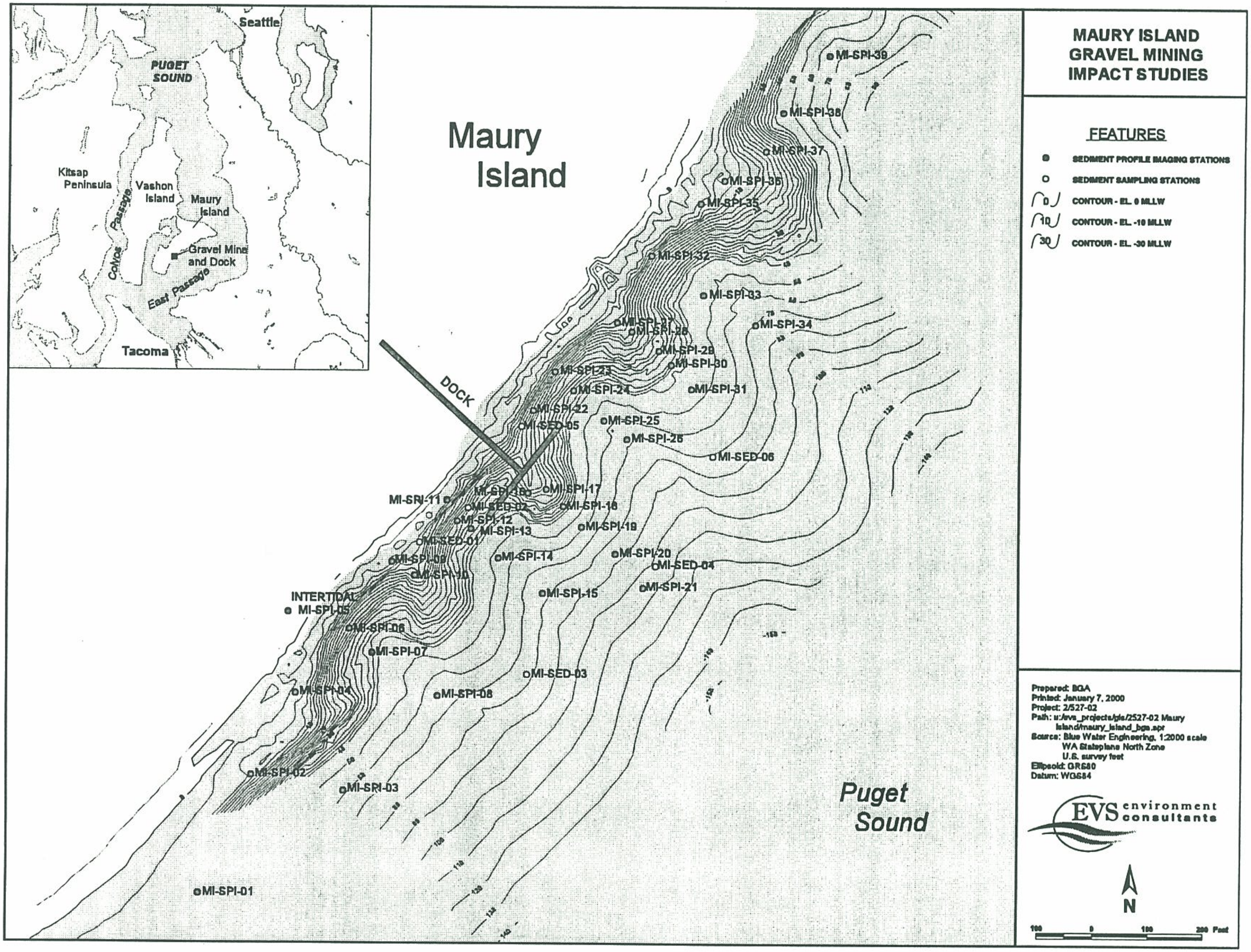


Figure 2-1. Map showing bathymetry (depths in ft) and locations of SPI and sediment sampling stations for nearshore survey of Maury Island

2.0 BASELINE NEARSHORE ASSESSMENT

This baseline nearshore assessment characterizes the sediment condition, benthic habitats, and likely use by fisheries resources of the Maury Island nearshore area. EVS Environment Consultants (EVS) conducted a field study in the fall of 1999 to characterize the sediments and benthic condition. The characterization of the use of this area by fish and marine mammal species was developed through information gained from fisheries specialists, WDFW stock assessment reports, and scientific literature.

2.1 STUDY AREA

Maury Island is an extension of Vashon Island in south central Puget Sound, Washington (Figure 2-1). Lone Star has proposed to expand mining activities on a roughly 95-ha (235-ac) site located on the eastern edge of Maury Island and along the East Passage of Puget Sound. The nearshore study area, referred to as the nearshore area in this document, is delineated by approximately 975 m (3,200 ft) of shoreline, the Glacier Northwest property boundary, from mean lower low water (MLLW) to about –9 m (-30 ft) MLLW. In addition, the approximately 366 m (1,200 ft) of the central section of shoreline out to a greater depth of approximately -40 m (-130 ft) MLLW were included in the baseline benthic assessment.

The nearshore subtidal habitat adjacent to the Lone Star mine has been characterized as a sand and silt substratum with a gradually sloping bottom from the shoreline to the seaward edge of the Lone Star dock (Jones & Stokes et al. 1999). Results from diver transects have indicated that a diverse habitat with bare sand areas, patchy eelgrass beds, and areas with kelp and green algae is present in the vicinity (Jones & Stokes and AR 1999). The Puget Sound Environmental Atlas (Evans-Hamilton and D.R. Systems 1987; Puget Sound Estuary Program [PSEP] 1992) reports the existence of eelgrass beds along most of the southeastern shoreline of Maury Island, from the mean low water mark down to a depth of approximately -7 m (-22 ft) MLLW. Geoduck (*Panope abrupta*) beds are also found along the entire southeastern shoreline of Maury Island within 183 m (200 yd) of the shore (Sizemore et al. 1998). Both piddock and geoduck clams were reported in the barge loading area (Jones & Stokes and AR 1999).

2.2 BENTHIC HABITATS WITHIN STUDY AREA

To obtain more detailed information about bottom type and habitat conditions in the project area, EVS used a combination of acoustic and photographic survey techniques, along with sediment sampling, to document baseline conditions in the fall of 1999. Approximately 16 ha (39 acres) in the nearshore environment were characterized using a precision bathymetric survey, a side-scan sonar survey, a series of sediment profile images, and the results of the chemical analysis of sediment samples collected from six locations in the immediate vicinity of the Lone Star dock.

2.2.1 Materials and Methods

2.2.1.1 Bathymetry and Side-Scan Sonar Survey

Blue Water Engineering precision conducted bathymetric and side-scan sonar surveys using the vessel *Surveyor* by on October 12, 1999. Bathymetric survey lanes were centered around the Lone Star dock and oriented perpendicular to shore; 975 m (3,200 ft) of shoreline were surveyed. Survey lanes were spaced 6 m (20 ft) apart for the nearshore profile and 18 m (60 ft) apart for the portion of survey that extended out into deep water. Bathymetric data were collected with a narrow-beam, 208 kHz transducer Odom survey fathometer. Observed tidal data were obtained through the National Oceanographic and Atmospheric Administration (NOAA) Ocean and Lake Levels Division's (OLLD) National Water Level Observation Network. These stations are equipped with the Next Generation Water Level Measurement System tide gauges and satellite transmitters that have collected and transmitted tide data to the central NOAA facility every six minutes since January 1, 1994.

Observed tidal data are available 1 to 6 hours after the time of collection in station datum or referenced to MLLW and based on Coordinated Universal Time. For the October 12, 1999, survey of Maury Island, data from the NOAA tide stations 9446484, located at Pier 7 at the Port of Tacoma, Tacoma, Washington, and 9447130, located at the Washington State Ferry Building, Seattle, Washington, were used for tidal calculations. The NOAA tide data were downloaded in the MLLW datum, interpolated for spatial correction, corrected to local time, and applied to the collected data at 30-minute intervals. Bathymetric data were analyzed using Coastal Oceanographic HYPACK® software and corrected to MLLW using the NOAA observed tides. The bathymetric data were then used to construct depth models of the surveyed area.

To characterize sediment type, the location of eelgrass beds, and the location of underwater targets, a side-scan sonar survey was conducted with a Dowty 3050 Wide-Scan towfish. Acoustic signals at a frequency of 500 kHz were emitted from the two transducers mounted in the 3050 towfish, and the returns were relayed to an EPC 1086 graphic recorder. The side-scan sonar lanes were run parallel to shore at a spacing of 9 m (30 ft); bathymetric data were also collected during the side-scan sonar survey.

Navigation data for both side-scan and bathymetric surveys were collected with a Trimble AG132 differential global positioning system (DGPS).

2.2.1.2 Sediment Profile Imaging and Sediment Sampling Survey

The sediment profile imaging (SPI) and sediment sampling were conducted on the research vessel *Kittiwake* owned and operated by Charles Eaton, Bio-Marine Enterprises, on November 4 and 5, 1999. The *Kittiwake* utilized a Trimble NT300D DGPS with internal receiver for processing the differential signal to provide navigation and positioning support for the project. The coordinates were recorded for each sampling station occupied. During this project, the differential corrections applied were those generated and transmitted by U.S. Coast Guard installations. Accuracy of the system is rated to be within ±2 m (±7 ft).

Sampling Locations—Sampling locations for the sediment profile images and sediment samples were predetermined based on the preliminary results from the side-scan and bathymetric surveys. Figure 2-1 presents the locations for both the SPI survey and 6 sediment sampling stations.

Sediment Profile Imaging Survey—Photographs of the benthic sediment profile were taken at 39 offshore stations. Two replicate images were taken with Kodak Ektachrome® color slide film (ISO 100) at each station, identified as MI-SPI-01 through MI-SPI-39 in Table 2-1; each SPI replicate is identified by the time recorded on the film and corresponding entries in the field and navigation logbooks. Even though duplicate images were taken at each location, each image was assigned a unique frame number by the data logger and cross-checked with both the hand-entered sample logs kept by the field crew and the sampling station electronic file.

On deck test exposures were made using the Kodak® Color Separation Guide (Publication No. Q-13) at the beginning and end of each roll of film to verify that all internal electronic systems were working to design specifications and to provide a color standard against which the final film emulsion could be checked for proper color balance. After deployment of the camera at each station, the frame counter was checked to make sure that the requisite number of replicates had been taken. In addition, a prism penetration depth indicator on the camera frame was checked to verify that the optical prism had actually penetrated the bottom to a sufficient depth to acquire a profile image. Because of the paucity of fine-grained sediments in the study area, all available prism weights (total of 113 kg [250 lbs]) were kept in the camera for the entire survey to maximize the camera's prism penetration.

Table 2-1. Station locations for sediment profile imaging survey

STATION ID	LATITUDE	LONGITUDE
MI-SPI-01	47 21.6654	122 26.5124
MI-SPI-02	47 21.7002	122 26.4906
MI-SPI-03	47 21.6962	122 26.4501
MI-SPI-04	47 21.7246	122 26.4720
MI-SPI-05	47 21.7484	122 26.4762
MI-SPI-06	47 21.7438	122 26.4493
MI-SPI-07	47 21.7369	122 26.4391
MI-SPI-08	47 21.7246	122 26.4103
MI-SPI-09	47 21.7637	122 26.4316
MI-SPI-10	47 21.7598	122 26.4215
MI-SPI-11	47 21.7821	122 26.4084
MI-SPI-12	47 21.7760	122 26.4037
MI-SPI-13	47 21.7738	122 26.3975
MI-SPI-14	47 21.7655	122 26.3853
MI-SPI-15	47 21.7554	122 26.3657
MI-SPI-16	47 21.7847	122 26.3731
MI-SPI-17	47 21.7860	122 26.3652
MI-SPI-18	47 21.7810	122 26.3577
MI-SPI-19	47 21.7751	122 26.3495
MI-SPI-20	47 21.7674	122 26.3345
MI-SPI-21	47 21.7577	122 26.3221
MI-SPI-22	47 21.8092	122 26.3718
MI-SPI-23	47 21.8206	122 26.3628
MI-SPI-24	47 21.8152	122 26.3545
MI-SPI-25	47 21.8066	122 26.3411
MI-SPI-26	47 21.8013	122 26.3307
MI-SPI-27	47 21.8355	122 26.3364
MI-SPI-28	47 21.8328	122 26.3299
MI-SPI-29	47 21.8274	122 26.3179
MI-SPI-30	47 21.8234	122 26.3124
MI-SPI-31	47 21.8164	122 26.3035
MI-SPI-32	47 21.8554	122 26.3221
MI-SPI-33	47 21.8441	122 26.2995
MI-SPI-34	47 21.8357	122 26.2767
MI-SPI-35	47 21.8709	122 26.3016
MI-SPI-36	47 21.8778	122 26.2918
MI-SPI-37	47 21.8868	122 26.2742
MI-SPI-38	47 21.8982	122 26.2671
MI-SPI-39	47 21.9153	122 26.2478

Sediment Sampling—Six locations near the Lone Star dock were established to collect sediment for chemical and benthic analyses. The sampling stations are identified as MI-SED-01 through MI-SED-06, as shown in Figure 2-1. Samples were intentionally located around the perimeter of the dock, with three locations on the inshore side of the dock, and three locations on the open-water side of the dock. The three stations on the open-water side of the dock, MI-SED-03, MI-SED-04, and MI-SED-06, were located at the nearest position to the dock that an acceptable sediment sample could be collected. Because of the proliferation of cobble and gravel on the sediment surface near the dock, the sampling vessel was repositioned at increments of approximately 4 m (13 ft) along a radial transect until sediment could be retrieved. Table 2-2 lists the coordinates for the locations where acceptable samples were retrieved.

Table 2-2. Station locations for sediment sampling

ID	Latitude	Longitude
MI-SED-01	47 21.7696	122 26.4197
MI-SED-02	47 21.7801	122 26.3989
MI-SED-03	47 21.7315	122 26.3716
MI-SED-04	47 21.7641	122 26.3169
MI-SED-05	47 21.8038	122 26.3762
MI-SED-06	47 21.7969	122 26.2934

Sediment Collection—Surface sediment samples for all locations were collected using a double 0.1 m^2 (1.1 ft^2) van Veen grab sampler (total area sampled 0.2 m^2 [2.2 ft^2]). The grab sampler was deployed and retrieved from the stern of the boat using a hydraulic main winch equipped with 5/16-in. stainless steel wire. Upon retrieval, the sample was examined to determine acceptability based on the following sediment acceptance criteria:

- The sample does not contain foreign objects
- The sampler is not over-filled with sediment so that the sediment surface presses against the top of the sampler
- No significant leakage has occurred, as indicated by overlying water on the sediment surface
- No sample disturbance has occurred, as indicated by limited turbidity in the overlying water
- No winnowing has occurred, as indicated by a relatively flat, undisturbed surface

Once a sample was deemed acceptable, one chamber of the double van Veen was used to carefully siphon any overlying water in order to avoid disturbing the sediment surface. The upper 10 cm (4 in.) of sediment were extracted from the sampler and placed into clean stainless steel containers. Once a sufficient amount of sediment for analysis had been collected at a location, the sample was thoroughly homogenized by hand using a stainless steel spoon in order to achieve consistent color and texture. Aliquots of the homogenized mixture were carefully placed into glass sample jars. Subsamples collected for total sulfides analysis were collected prior to the homogenization of the sediment sample.

The other chamber of the double van Veen grab sample was designated for benthic community analysis. All of the sediment and overlying water from the designated chamber was extracted from the grab sample and placed in a 7-L (2-gal) plastic bucket for processing at the completion of the field effort. The processing of these samples is discussed in Section 2.2.1.3.

After the containers were filled and the outsides cleaned, each container received a label with a unique sample ID number that was sealed and affixed with clear tape. The following information was recorded on the sample labels and in the logbooks:

- Project number
- Unique sample ID number
- Date and time of collection
- Required analyses
- Sampler's initials
- Preservation type (if any)
- Any other pertinent comments (e.g., duplicate)

The quality assurance (QA) officer was present during all homogenization, container filling, labeling, document processing, and sample packing.

In addition to the field notes taken during sample collection and the sample labels affixed to the containers, additional documentation recorded during processing included a sample log and chain-of-custody forms. An individual record of each filled container was maintained in the sample log; each sample was identified by the unique sample ID number affixed to the container and included information such as the station ID, time collected, the analysis required, and the corresponding analytical laboratory to which the sample was to be shipped. Chain-of-custody forms accompanied all samples during storage and shipment to the laboratory. Samples were kept on ice and kept in proper custody (either in the presence of the sample custodian or locked up) after processing until they could be shipped. All sediment samples were personally delivered by a member of the EVS field crew to Analytical Resources Incorporated (ARI), Seattle, Washington, for chemical analysis.

2.2.1.3 Benthic Community Samples

When an acceptable sample was obtained, the sediment from the designated chamber was emptied into a high-density polyethylene bucket for temporary storage. The benthic community samples were processed at the completion of the survey, after all sediment samples had been collected. The sediment was sieved through a 1-mm (0.04-in) mesh screen using a saltwater rinse aboard the *Kittiwake*. Sieving was performed until the water draining through the bottom of the sieve buckets ran relatively clear. Visible foreign objects were carefully removed from the retained material. The remaining material was then placed into plastic jars, covered with 10 percent formalin, and labeled appropriately. Sample jar lids were wrapped with electrical tape to prevent any leaking during storage or transport. Samples were archived at EVS in Seattle, Washington. No benthic taxonomic analysis was performed.

2.2.2 Results

2.2.2.1 Bathymetry

A two-dimensional contour map of the bathymetric results is presented as Figure 2-2. Water depths along the face of the dock ranged from approximately 6 m (18 ft) at their shallowest, along the center portion of the dock, to between 11 and 12 m (35 and 38 ft) at the ends of the dock. Depth increased at a fairly uniform rate as one heads offshore, reaching depths of over 31 m (100 ft) within 84 m (275 ft) straight out from the middle of the dock. The most notable distinction was the series of rhythmic shoreline features, or submerged beach cusps, that were perpendicular to the shoreline (see Figure 2-2). The crests of these cusps are regularly spaced at approximately 91-m (300-ft) intervals; the middle of the Lone Star dock happened to be located on one of these crests.

These shoreline cuspate deposits, which typically occur on sand and gravel bottoms, have attracted a great deal of interest in the field of coastal geomorphology. However, for practically every theory that has been put forth by one author as to the origin of these rhythmic formations, a different, contradicting theory has been offered by another author. As a result, a great deal of controversy still exists among geomorphologists regarding which processes of wave motion and sediment transport control their rhythmic spacings (Komar 1998). The strongest evidence to date has been advanced by Guza and Inman (1975). Their studies show that standing edge waves play a prominent role in the formation of nearshore beach cusps; when conditions are such that the edge waves have a period that is twice that of the normal incident waves, then cusps are formed. However, it is not possible to identify with absolute certainty the process that caused the submerged cuspate formation found offshore Maury Island.

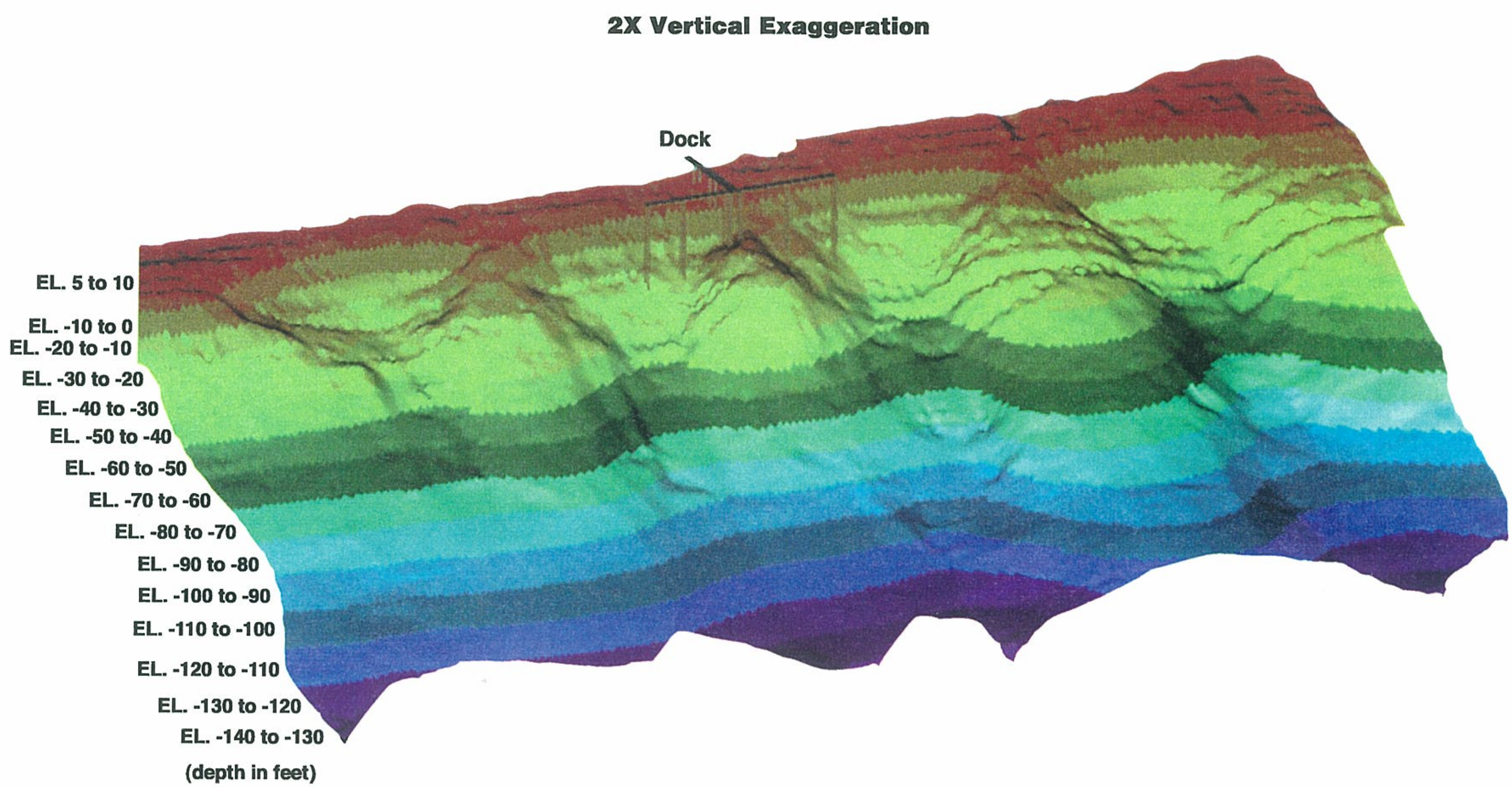


Figure 2-2. Three-dimensional representation of nearshore Maury Island bathymetry showing the "hill and valley" topography of the submerged beach cusp formations

2.2.2.2 Side-Scan Sonar

Side-scan sonar transmits a specially shaped acoustic beam 90 degrees from either side of the survey vessel and records the sound energy that reflects back to the towfish. The results are recorded as a gray-scale image depicting the varied strengths of the returning beam; strong reflectors are displayed as dark areas on the image, and a total lack of returning energy as white. From a photographic analysis, this gives an image that appears to be a negative. In the side-scan sonar image, shadows are often the most important interpretive tool. In many cases, shadows can indicate more about the makeup of a reflector than the acoustic returns from the reflector itself because they provide a three-dimensional quality to the two-dimensional sonar record. They are produced by objects projecting above or depressed into the sea floor.

For the Maury Island survey, the side-scan sonar survey was used to characterize sediment type, target locations, and provide a more accurate delineation of eelgrass beds. If the density of eelgrass plants was sufficiently high, the plants reflected the side-scan signal. A variety of seabed features were readily apparent from an examination of the side-scan image. These included two sunken barges and a small vessel off the southern end of the dock (Figure 2-3), patches of coarse-grained sediment (Figure 2-4), and the presence of eelgrass (Figure 2-5). In combination with the bathymetric and sediment profile data (Section 2.2.2.3), an overall interpretive map was compiled to show the prominent features of the nearshore habitat (Figure 2-6).

The acoustic information from both the side-scan sonar survey and the bathymetric records confirmed that the sediments off Maury Island were primarily sands (fine to coarse) with some concentrated patches of coarser-grained sediment from gravel, cobble, or rocks on the bottom (Figure 2-6). There were two major eelgrass beds to the northeast and southwest of the Lone Star dock in water depths shallower than 6 m (20 ft) (Figure 2-6), as well as two smaller patches on either side of the dock on the crests of the submerged cusps. While other isolated patches of eelgrass at densities too low to reflect sound waves were identified in the sediment profile images (see Section 2.2.2.3), the side-scan sonar mapped an approximate total of 1.0 ha (2.5 ac) of bottom covered by eelgrass, or a little over 6 percent of the total area surveyed.

Other nearshore features included patches of coarse sediment along the shore and rough bottom. One larger debris pile, consisting of logs and rocks, started at approximately 15 m (50 ft) SE of the dock and extended downslope roughly 46 m (150 ft). A few isolated logs or planks on the seabed are indicated on the map, as is the line of dolphins, five to the northeast and five to the southwest of the existing dock; these are proposed to be repaired for use in tugboat and barge operations at the dock.

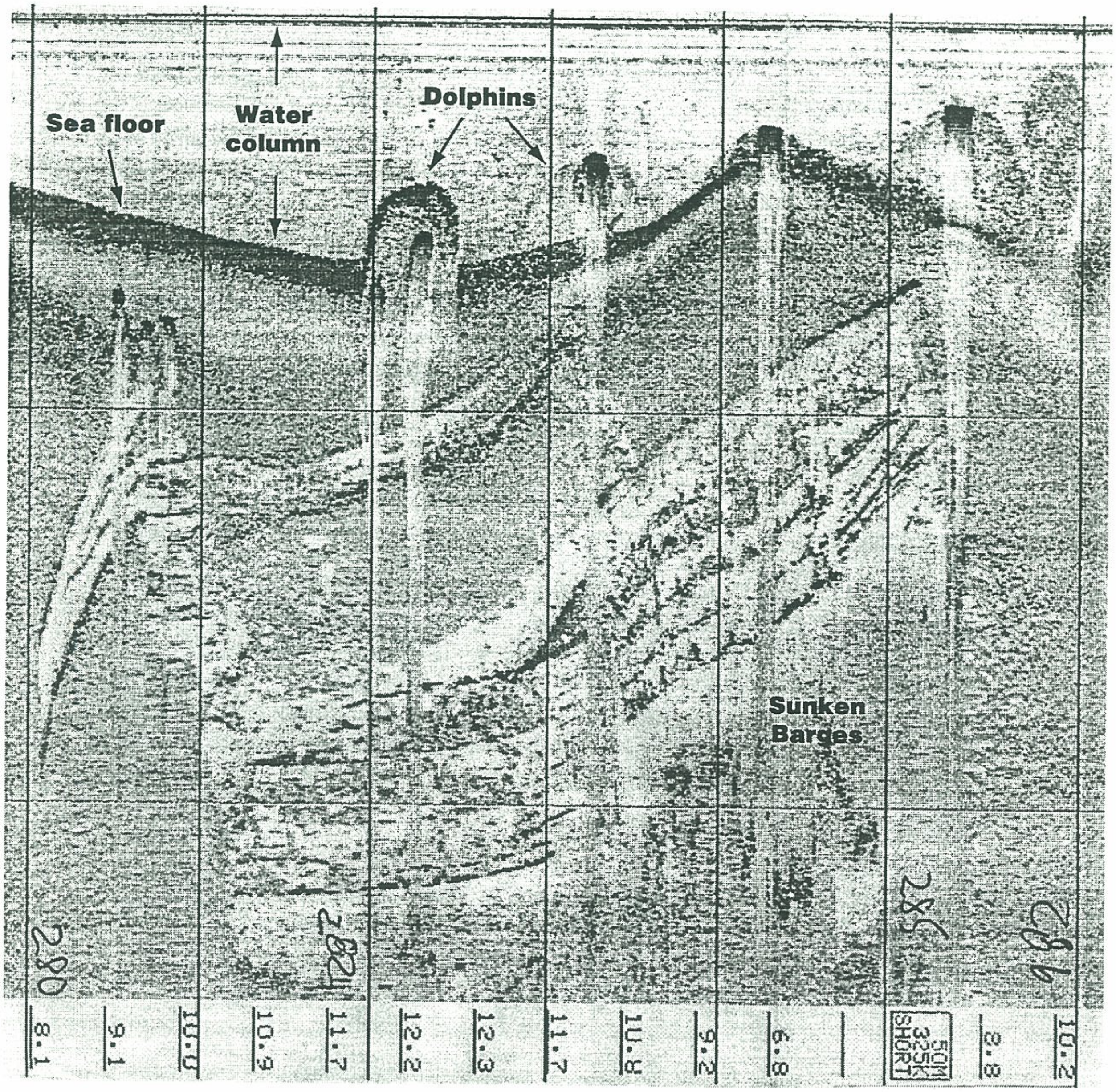


Figure 2-3. Side-scan sonar image of the two sunken barges located off the southern end of the Lone Star dock

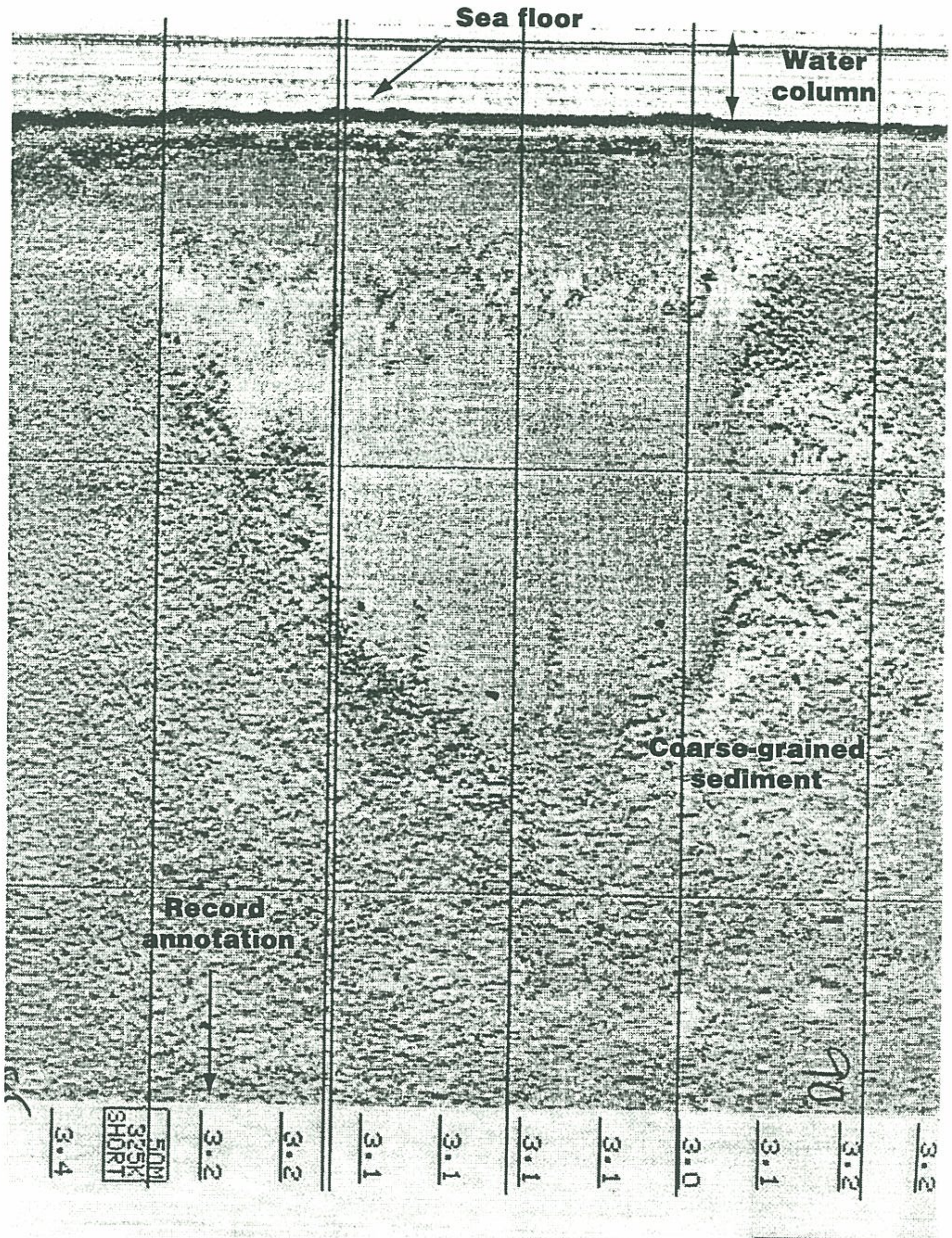


Figure 2-4. Side-scan sonar image of a patch of coarse-grained sediment distinct from the surrounding sandy bottom

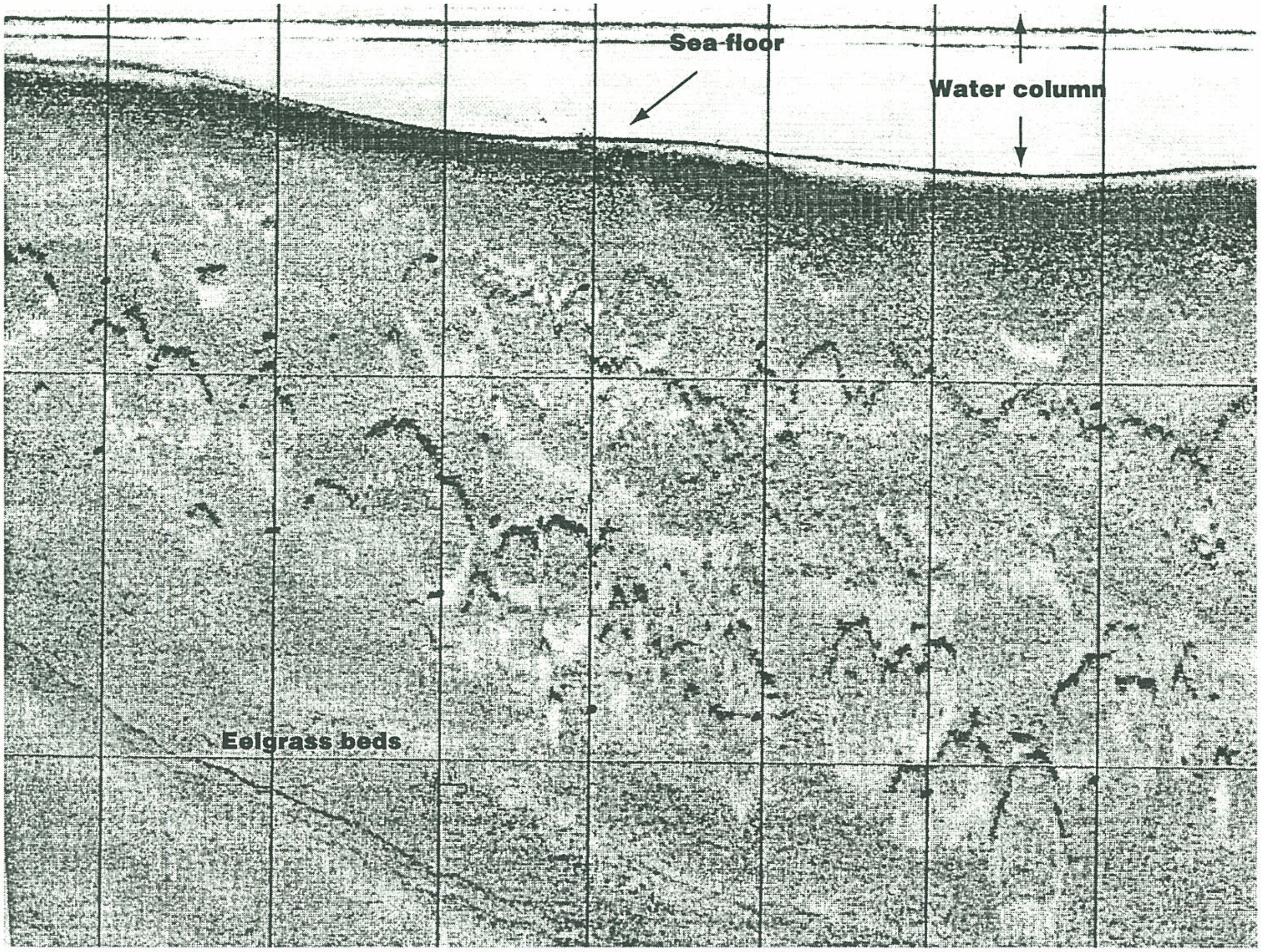


Figure 2-5. Side-scan sonar image of eelgrass patches

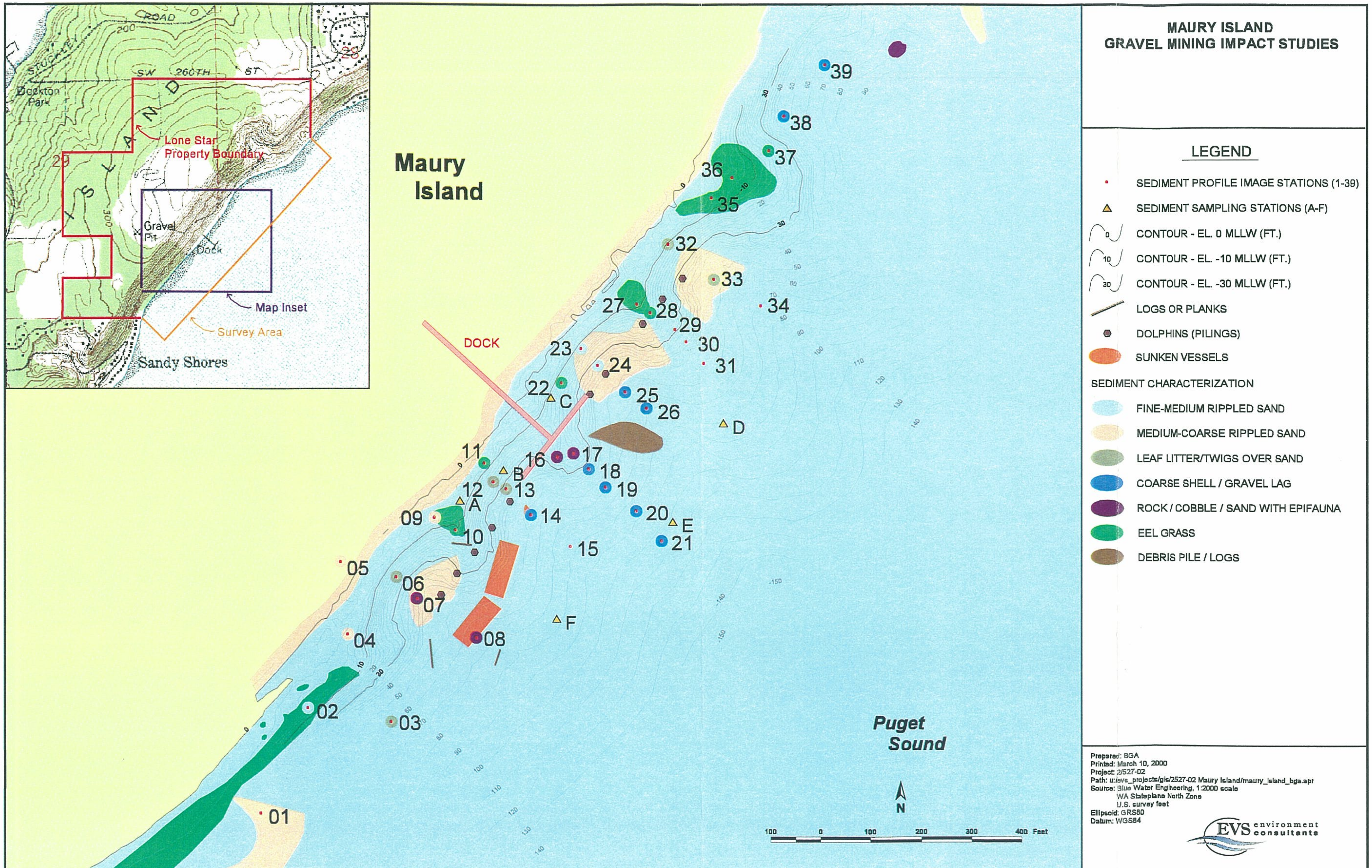


Figure 2-6. Characterization of sediment type and seabed features of the nearshore environment from side-scan sonar interpretation combined with bathymetric results

2.2.2.3 Sediment Profile Images

The results from the sediment profile images confirmed and, in some cases, enhanced the sediment characteristics mapped by the side-scan sonar (see Appendix A for detailed results from all images). The majority of the bottom surveyed was rippled medium sand; a typical profile image from the area is shown in Figure 2-7. Several of the shallower stations near the shore showed evidence of leaf litter and wood twigs on the bottom, not an unusual pattern for nearshore areas that receive runoff from land (Figure 2-8). The presence of leaf and twig debris may have contributed to the patches of rough bottom noted in side-scan data. While images from stations within the eelgrass patches delineated by the side-scan sonar confirmed the presence of plants (Figure 2-9), eelgrass was also found at Stations 11 and 22 where plant densities were low enough or the bottom slope steep enough to avoid detection by the side-scan sonar (Figure 2-10).

Prism penetration was fairly shallow at most stations (less than 10 cm [4 in.]), reflecting the higher shear strength of sandy sediments; however, a few isolated stations had sands with lower shear strength, most likely due to dilation caused by burrowing organisms (Figure 2-11). Surface layers of gravel were found at Stations 17, 19, 20, 21, 26, 33, 38, and 39, and an area of hard bottom with large rocks was found at Station 16. While the source of this gravel could easily be inferred as having originated from past gravel mining operations because of the proximity of the stations to the dock (Stations 16, 17, 19, 20, 21, and 26), there were also stations far away from the dock with surface gravel layers (Stations 33, 38, and 39; see Figure 2-12). Similarly, there were stations close to the dock without continuous gravel layers (Stations 11, 12, 13, 14, and 15). In any event, the presence of gravel increases the habitat diversity, providing a substratum for colonial epifauna, including barnacles and bryozoans (Figure 2-13), macrophytes (Figure 2-14), and suspension-feeding bivalves such as mussels (Figure 2-15). Many stations showed armored surface layers of shell or gravel lag deposits, typical of areas experiencing strong bottom currents (Figure 2-16).

Habitat conditions were typical of a nearshore, sandy bottom; there was no evidence of an accumulation of fine-grained sediments or organic loading at any of the locations sampled. A wide variety of fauna and flora were detected in the images, from worm tubes and eelgrass projecting above the sediment-water interface to starfish, mussels, hermit crabs, and invertebrate egg clusters found on both the sand and gravel bottoms (Figure 2-17). The community in this area and in the shallower depths is obviously adapted to high-energy regimes and frequent disturbances.

Figure 2-7. Sediment profile image from Station 5; note the well-sorted, medium sand with surface ripples and evidence of emerging eelgrass fronds at the sediment-water interface. Width of image = 15 cm

Figure 2-8. Sediment profile image from Station 6; wood twigs and leaf litter are very common in nearshore areas. Width of image = 15 cm

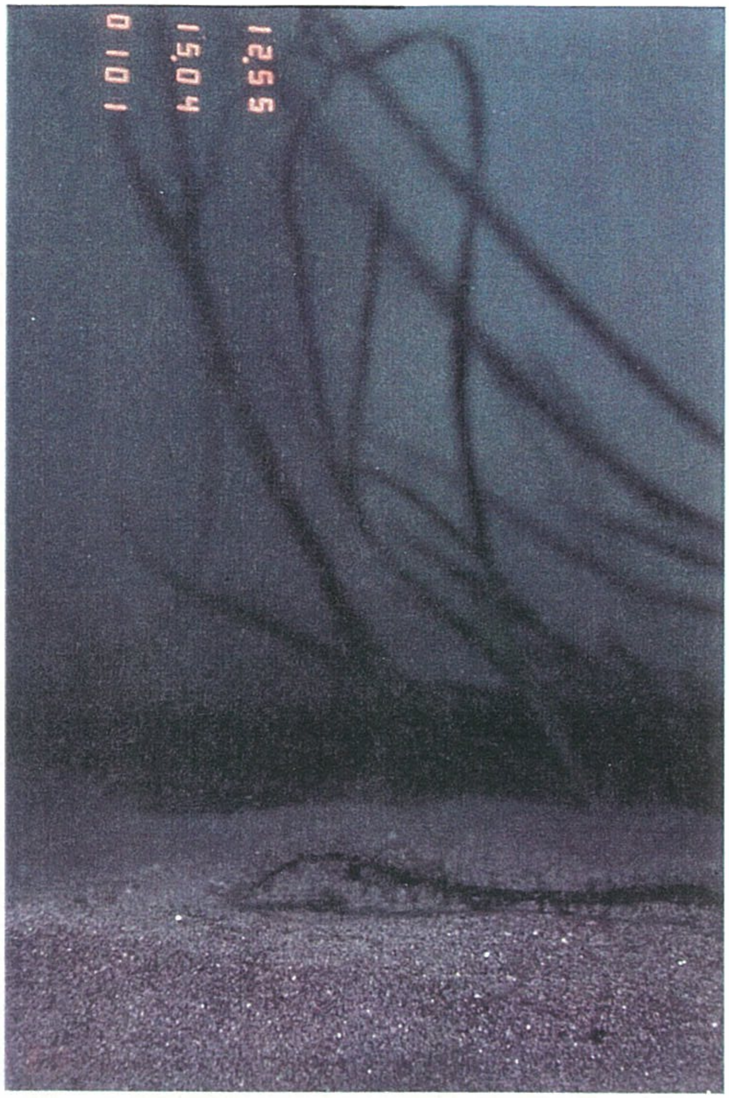


Figure 2-9. Sediment profile image from Station 10; eelgrass fronds are readily apparent projecting above the sediment-water interface. Width of image = 15 cm

Figure 2-10. Sediment profile image from Station 11; both eelgrass and sea lettuce (*Ulva sp.*) can be seen bent over from the current at this shallow station (5 ft water depth). Width of image = 15 cm

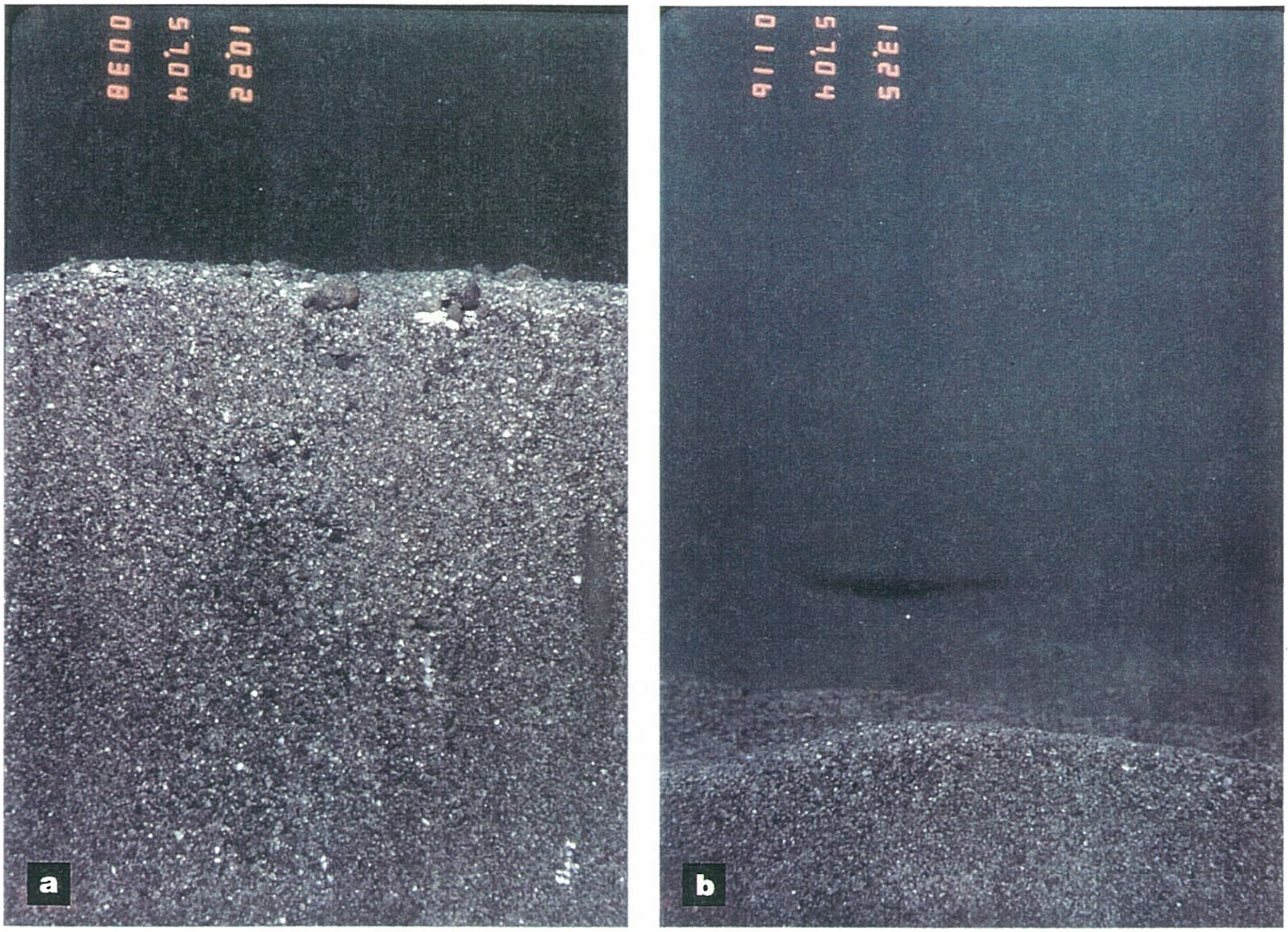


Figure 2-11. Sediment profile images from Station 18 (a) and Station 4 (b). Note the uniform cross section of well-sorted sand in each image; the greater SPI prism penetration at Station 18 is likely due to increased bioturbation activity. Width of image = 15 cm

Figure 2-12. Sediment profile image from Station 39; note the uniform surface layer of gravel that was most likely deposited due to natural physical transport mechanisms. Width of image = 15 cm

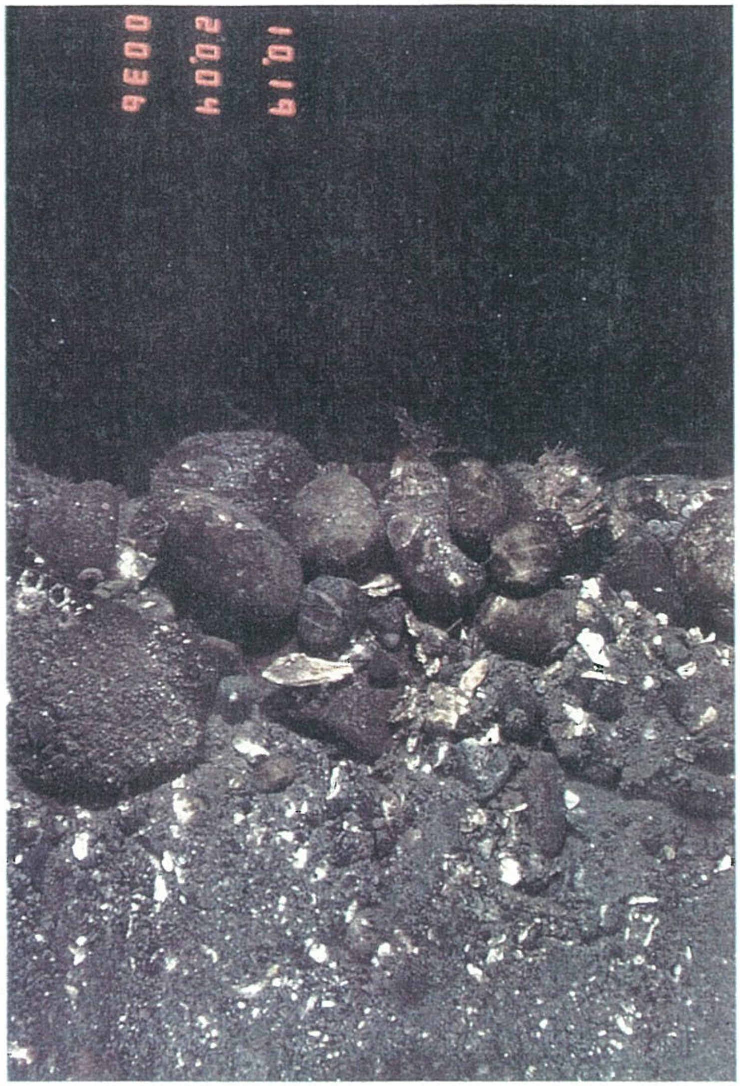


Figure 2-13. Sediment profile image from Station 19 showing a layer of gravel on the sand surface; note the colonial epifauna growing on the surface of the gravel. Width of image = 15 cm

Figure 2-14. Sediment profile image from Station 17; both barnacles and kelp are utilizing the surface gravel layer as a substratum for growth. Width of image = 15 cm

Figure 2-15. Sediment profile image from Station 21; the mussels on the gravel surface provide a food source for larger foraging predators. Note the tip of a starfish arm at the right edge of the image. Width of image = 15 cm

Figure 2-16. Sediment profile image from Station 25; the thick layer of shells from dead bivalves prevented any substantial penetration by the sediment profile camera prism. Width of image = 15 cm

Figure 2-17. Sediment profile image from Station 23; note the hermit crab and the cluster of what are most likely squid eggs on the sediment surface. Width of image = 15 cm

2.2.2.4 *Sediment Chemistry*

Sediment chemistry data were collected at six stations (Figure 2-1). The sediment samples were analyzed for grain size, organic carbon content, and selected organic concentrations and trace element contaminants. The measured contaminant concentrations were compared to Washington State Marine Sediment Quality Standards.

The sediment organic carbon content and grain size data are presented in Table 2-3. The samples were all coarse-grained, sandy sediments with relatively low organic carbon content, ranging from 0.14 to 1.9 percent organic carbon.

Table 2-3. Sediment organic carbon content and grain size[a]

	MI-SED-01 A[b]	MI-SED-02 B[b]	MI-SED-03 F[b]	MI-SED-04 E[b]	MI-SED-05 C[b]	MI-SED-06 D[b]
Percent organic carbon	0.24	1.9	0.25	0.32	0.33	0.14
Total Solids	77.3	76.8	78	75.1	77.5	78
Gravel	1.3	14.9	8.3	3.7	6.8	2.2
Sand	96.3	81.1	89.3	91.5	88.6	94.7
Silt	1.2	2.7	0.9	2.8	3.2	1.8
Clay	1.2	1.4	1.5	2.1	1.2	1.3

[a] All units are percent.
[b] Letters correspond to sediment sample locations on Figure 2-6.

Sediment polycyclic aromatic hydrocarbon (PAH) concentrations are presented in Table 2-4. In general, very low concentrations were measured, with the highest concentrations measured in sample MI-SED-5. The sediment pesticide and polychlorinated biphenyl (PCB) concentrations are presented in Table 2-5. All pesticide and PCB concentrations were reported as not detected. In order to compare the PAH, pesticide, and PCB concentrations to marine sediment quality standards, organic-carbon normalized sediment concentrations were calculated, and they are presented in Table 2-6. The only concentration that exceeded the corresponding criterion was that of one individual PAH compound, fluoranthene, in MI-SED-05. It should be noted that the magnitude of the organic-carbon normalized values is driven, in large part, by the low organic carbon content of these sediments.

Sediment trace element concentrations are presented in Table 2-7. There were no detected concentrations of arsenic, cadmium, or silver. The measured concentrations of all trace elements were less than the corresponding marine sediment criteria.

Table 2-4. Sediment PAH concentrations[a]

	MI-SED-01	MI-SED-02	MI-SED-03	MI-SED-04	MI-SED-05	MI-SED-06
Naphthalene	8 U	8.2 U	8 U	8 U	8.2 U	8 U
2-Methylnaphthalene	8 U	8.2 U	8 U	8 U	8.2 U	8 U
Acenaphthylene	8 U	8.2 U	8 U	8 U	11	8 U
Acenaphthene	8 U	8.2 U	8 U	8 U	8.2 U	8 U
Fluorene	8 U	8.2 U	8 U	8 U	8.2 U	8 U
Phenanthrene	8 U	29	8 U	8 U	54	8 U
Anthracene	8 U	24	8 U	8 U	22	8 U
Fluoranthene	12	140	8 U	4.8 J	790	8 U
Pyrene	6.4 J	75	6.4 J	5.6 J	450	8 U
Benzo(a)anthracene	8 U	24	8 U	8 U	110	8 U
Chrysene	8 U	39	8 U	8 U	240	8 U
Benzo(b)fluoranthene	8 U	28	8 U	8 U	170	8 U
Benzo(k)fluoranthene	8 U	22	8 U	8 U	130	8 U
Benzo(a)pyrene	8 U	18	8 U	8 U	86	8 U
Indeno(1,2,3-cd)pyrene	8 U	9.8	8 U	8 U	48	8 U
Dibenzo(a,h)anthracene	8 U	8.2 U	8 U	8 U	9.9	8 U
Benzo(g,h,i)perylene	8 U	7.3 J	8 U	8 U	38	8 U
Dibenzofuran	8 U	8.2 U	8 U	8 U	8.2 U	8 U

NOTE: U – chemical was not detected; the value shown is the detection limit
J – value reported as an estimate

[a] All units are μg/kg dry weight.

Table 2-5. Sediment pesticide and PCB concentrations

	MI-SED-01	MI-SED-02	MI-SED-03	MI-SED-04	MI-SED-05	MI-SED-06
alpha-BHC	0.86U	0.88U	0.86U	0.86U	0.89U	0.86U
beta-BHC	0.86U	0.88U	0.86U	0.86U	0.89U	0.86U
delta-BHC	0.86U	0.88U	0.86U	0.86U	0.89U	0.86U
gamma-BHC (Lindane)	0.86U	0.88U	0.86U	0.86U	0.89U	0.86U
Heptachlor	0.86U	0.88U	0.86U	0.86U	0.89U	0.86U
Aldrin	0.86U	0.88U	0.86U	0.86U	0.89U	0.86U
Heptachlor Epoxide	0.86U	0.88U	0.86U	0.86U	0.89U	0.86U
Endosulfan I	0.86U	0.88U	0.86U	0.86U	0.89U	0.86U
Dieldrin	1.7U	1.8U	1.7U	1.7U	1.8U	1.7U
4,4'-DDE	1.7U	1.8U	1.7U	1.7U	1.8U	1.7U
Endrin	1.7U	1.8U	1.7U	1.7U	1.8U	1.7U
Endosulfan II	1.7U	1.8U	1.7U	1.7U	1.8U	1.7U
4,4'-DDD	1.7U	1.8U	1.7U	1.7U	1.8U	1.7U
Endosulfan Sulfate	1.7U	1.8U	1.7U	1.7U	1.8U	1.7U
4,4'-DDT	1.7U	1.8U	1.7U	1.7U	1.8U	1.7U
Methoxychlor	8.6U	8.8U	8.6U	8.6U	8.9U	8.6U
Endrin Ketone	1.7U	1.8U	1.7U	1.7U	1.8U	1.7U
Endrin Aldehyde	1.7U	1.8U	1.7U	1.7U	1.8U	1.7U
gamma Chlordane	0.86U	0.88U	0.86U	0.86U	0.89U	0.86U
alpha Chlordane	0.86U	0.88U	0.86U	0.86U	0.89U	0.86U
Toxaphene	86U	88U	86U	86U	89U	86U
Aroclor 1016	17U	18U	17U	17U	18U	17U
Aroclor 1242	17U	18U	17U	17U	18U	17U
Aroclor 1248	17U	18U	17U	17U	18U	17U
Aroclor 1254	17U	18U	17U	17U	18U	17U
Aroclor 1260	17U	18U	17U	17U	18U	17U
Aroclor 1221	35U	35U	35U	35U	35U	34U
Aroclor 1232	17U	18U	17U	17U	18U	17U

NOTE: U – chemical was not detected; the value shown is the detection limit

[a] All units are μg/kg dry weight.

Table 2-6. Organic carbon normalized PAH and pesticide concentrations

	SMS Criteria	MI-SED-01	MI-SED-02	MI-SED-03	MI-SED-04	MI-SED-05	MI-SED-06
Naphthalene	99	3.33 U	0.43 U	3.20 U	2.50 U	2.48 U	5.71 U
2-Methylnaphthalene	38	3.33 U	0.43 U	3.20 U	2.50 U	2.48 U	5.71 U
Acenaphthylene	66	3.33 U	0.43 U	3.20 U	2.50 U	3.33	5.71 U
Acenaphthene	16	3.33 U	0.43 U	3.20 U	2.50 U	2.48 U	5.71 U
Fluorene	23	3.33 U	0.43 U	3.20 U	2.50 U	2.48 U	5.71 U
Phenanthrene	100	3.33 U	1.53	3.20 U	2.50 U	16.36	5.71 U
Anthracene	220	3.33 U	1.26	3.20 U	2.50 U	6.67	5.71 U
Fluoranthene	160	5.00	7.37	3.20 U	1.50 J	239.39	5.71 U
Pyrene	1000	2.67 J	3.95	2.56 J	1.75 J	136.36	5.71 U
Benzo(a)anthracene	110	3.33 U	1.26	3.20 U	2.50 U	33.33	5.71 U
Chrysene	110	3.33 U	2.05	3.20 U	2.50 U	72.73	5.71 U
Benzo(b)fluoranthene	na	3.33 U	1.47	3.20 U	2.50 U	51.52	5.71 U
Benzo(k)fluoranthene	na	3.33 U	1.16	3.20 U	2.50 U	39.39	5.71 U
Benzo(a)pyrene	99	3.33 U	0.95	3.20 U	2.50 U	26.06	5.71 U
Indeno(1,2,3-cd)pyrene	34	3.33 U	0.52	3.20 U	2.50 U	14.55	5.71 U
Dibenzo(a,h)anthracene	12	3.33 U	0.43 U	3.20 U	2.50 U	3.00	5.71 U
Benzo(g,h,i)perylene	31	3.33 U	0.38 J	3.20 U	2.50 U	11.52	5.71 U
Dibenzofuran	15	3.33 U	0.43 U	3.20 U	2.50 U	2.48 U	5.71 U
LPAH	370	20.00	4.52	19.20	15.00	33.82	34.29
HPAH	960	34.33	19.54	31.36	23.25	627.85	57.14
Total benzofluoranthenes	230	6.67	2.63	6.40	5.00	90.91	11.43
alpha-BHC	–	0.36 U	0.05 U	0.34 U	0.27 U	0.27 U	0.61 U
beta-BHC	–	0.36 U	0.05 U	0.34 U	0.27 U	0.27 U	0.61 U
delta-BHC	–	0.36 U	0.05 U	0.34 U	0.27 U	0.27 U	0.61 U
gamma-BHC (Lindane)	–	0.36 U	0.05 U	0.34 U	0.27 U	0.27 U	0.61 U
Heptachlor	–	0.36 U	0.05 U	0.34 U	0.27 U	0.27 U	0.61 U
Aldrin	–	0.36 U	0.05 U	0.34 U	0.27 U	0.27 U	0.61 U
Heptachlor Epoxide	–	0.36 U	0.05 U	0.34 U	0.27 U	0.27 U	0.61 U
Endosulfan I	–	0.36 U	0.05 U	0.34 U	0.27 U	0.27 U	0.61 U
Dieldrin	–	0.71 U	0.09 U	0.68 U	0.53 U	0.55 U	1.21 U
4,4'-DDE	–	0.71 U	0.09 U	0.68 U	0.53 U	0.55 U	1.21 U
Endrin	–	0.71 U	0.09 U	0.68 U	0.53 U	0.55 U	1.21 U
Endosulfan II	–	0.71 U	0.09 U	0.68 U	0.53 U	0.55 U	1.21 U
4,4'-DDD	–	0.71 U	0.09 U	0.68 U	0.53 U	0.55 U	1.21 U
Endosulfan Sulfate	–	0.71 U	0.09 U	0.68 U	0.53 U	0.55 U	1.21 U
4,4'-DDT	–	0.71 U	0.09 U	0.68 U	0.53 U	0.55 U	1.21 U
Methoxychlor	–	3.58 U	0.46 U	3.44 U	2.69 U	2.70 U	6.14 U
Endrin Ketone	–	0.71 U	0.09 U	0.68 U	0.53 U	0.55 U	1.21 U
Endrin Aldehyde	–	0.71 U	0.09 U	0.68 U	0.53 U	0.55 U	1.21 U
gamma Chlordane	–	0.36 U	0.05 U	0.34 U	0.27 U	0.27 U	0.61 U

Table 2-6, continued

	SMS Criteria	MI-SED-01	MI-SED-02	MI-SED-03	MI-SED-04	MI-SED-05	MI-SED-06
alpha Chlordane	–	0.36 U	0.05 U	0.34 U	0.27 U	0.27 U	0.61 U
Toxaphene	–	35.83 U	4.63 U	34.40 U	26.88 U	26.97 U	61.43 U
Aroclor 1016	–	7.08 U	0.95 U	6.80 U	5.31 U	5.45 U	12.14 U
Aroclor 1242	–	7.08 U	0.95 U	6.80 U	5.31 U	5.45 U	12.14 U
Aroclor 1248	–	7.08 U	0.95 U	6.80 U	5.31 U	5.45 U	12.14 U
Aroclor 1254	–	7.08 U	0.95 U	6.80 U	5.31 U	5.45 U	12.14 U
Aroclor 1260	–	7.08 U	0.95 U	6.80 U	5.31 U	5.45 U	12.14 U
Aroclor 1221	–	14.58 U	1.84 U	14.00 U	10.94 U	10.61 U	24.29 U
Aroclor 1232	–	7.08 U	0.95 U	6.80 U	5.31 U	5.45 U	12.14 U

NOTE: U – chemical was not detected; the value shown is the detection limit
J – value reported as an estimate

a All units are mg/kg percent organic carbon

Table 2-7. Sediment trace element concentrations[a]

	SMS criteria	MI-SED-01	MI-SED-02	MI-SED-03	MI-SED-04	MI-SED-05	MI-SED-06
Arsenic	57	3 U	3 U	3 U	3 U	3 U	3 U
Cadmium	5.1	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Copper	390	9.5	11.1	6.9	8.9	11.4	7
Lead	540	3	4	6	6	4	5
Mercury	0.41	0.01 U	0.01 U	0.02	0.02	0.02	0.01
Nickel	na	31.2	29.3	25	34	33.3	25.5
Silver	3.3	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Zinc	410	26.9	27.4	27.8	29.8	28.6	27.5

NOTE: U – chemical was not detected; the value shown is the detection limit
na – not applicable

a All units are mg/kg dry weight

2.2.3 Conclusions

The nearshore environment off the southeastern portion of Maury Island in the vicinity of the Lone Star dock was typical of nearshore, sandy bottoms in Puget Sound. One of the most interesting features discovered through this survey was the submerged cusp formation of the bottom topography. While it is impossible to state definitively what caused this submarine topography, it does have implications for sediment deposition and transport in the nearshore area. If source or current conditions were such that any fine-grained material were to settle on the bottom, it would be more likely to do so on the crests where the kinetic regime is at its lowest as opposed to in the valleys of these rhythmic formations.

Eelgrass beds were found in water depths shallower than 6 m (20 ft). The presence of eelgrass has been mapped in two previous studies (Jones & Stokes et al. 1999; Jones & Stokes and AR 1999) in the immediate vicinity of the dock. This survey provides a much more comprehensive overview and shows the locations of major eelgrass patches over a larger area. However, it is important to keep in mind that seagrass beds move over time and shrink and expand seasonally (Fonseca et al. 1998); one-time surveys are inadequate as a means of providing a thorough characterization of seagrass habitats. Bed form migration, the presence of seed banks, annual population cycles, recent nonpoint source anthropogenic impacts, as well as natural disturbance events can all affect the presence and size of eelgrass patches. Given all of these caveats, the one consistent finding from the three surveys in the immediate area of the dock is that there are no major eelgrass beds directly at the dock face where the barges would be loading. The edge of the closest large patch is 46 m (150 ft) southwest of the southern end of the dock.

The biological community, as interpreted from the SPI, is typical for a nearshore, sandy bottom. This area appears to be a relatively high-energy environment, as evidenced by the lack of accumulation of fine sediments in the area surveyed; frequent disturbance from land runoff, as evidenced by leaf litter and twigs; gravel deposits, both anthropogenic and storm-generated; and currents. A wide variety of fauna and flora was present both on the sand and gravel areas of the bottom, and there appeared to be no substantial adverse affects to any bottom communities from past commercial activities. The sunken barges and vessel off the southern end of the dock, while definitely an anthropogenic disturbance, appeared to have had the same long-term effect as that of the gravel deposits off the end of the dock: increasing habitat niche diversity by providing increased surface area upon which new organisms can grow.

2.3 NEARSHORE FISHERIES RESOURCES

2.3.1 Expected Fish Community

The aquatic habitats in the study area are fairly typical of the nearshore, non-estuarine environments that are present in many areas of south central Puget Sound (Evans-Hamilton and D.R. Systems1987; PSEP 1992). Most nearshore species that reside in Puget Sound can be expected to occur in the study area at some time. Table 2-8 presents a list of fish species that have been identified in the study area (Associated Earth Sciences [AES] 1998; Jones & Stokes and AR 1999) or are species managed by the State of Washington and likely to reside in the study area (Lemberg et al. 1997; Palsson et al. 1997).

Table 2-8. Managed fish species that have been identified in the study area or are likely present

Common Name	Scientific Name	Species Status[a]	Identified in Study Area	Habitat Use: Spawning Area	Habitat Use: Juvenile Rearing	Habitat Use: Adult Resident
Salmonids						
Chinook salmon	*Oncorhynchus tshawytscha*	Declining/ Threatened[b]	◆		◆[c]	
Coho salmon	*Oncorhynchus kisutch*	Declining			◆[c]	
Pink salmon	*Oncorhynchus gorbuscha*	Stable			◆[c]	
Chum salmon	*Oncorhynchus keta*	Stable			◆[c]	
Steelhead trout	*Oncorhynchus mykiss*	Declining			◆[c]	
Cutthroat trout	*Oncorhynchus clarki*	Declining			◆[c]	
Sea Perch						
Pile perch	*Rhacocheilus vacca*	Below Average	◆	◆	◆	◆
Striped sea perch	*Embiotoca lateralis*	Unknown	◆	◆	◆	◆
Shiner perch	*Cymatogaster aggregata*	Unknown	◆	◆	◆	◆
Cods						
Pacific cod	*Gadus macrocephalus*	Critical/Candidate[b]			◆	
Pacific hake	*Merluccius productus*	Critical/Candidate[b]			◆	
Walleye pollock	*Theragra chalcogramma*	Critical/Candidate[b]			◆	
Greenlings						
Painted greenling	*Oxylebius pictus*	Very Poor	◆	◆	◆	◆
Whitespot greenling	*Hexagrammos stelleri*	Very Poor	◆	◆	◆	◆
Kelp greenling	*Hexagrammos decagrammus*	Very Poor		◆	◆	◆
Lingcod	*Ophiodon elongatus*	Below Average	◆	◆	◆	◆
Rockfish						
Copper rockfish	*Sebastes caurinus*	Below Average/ Candidate[b]	◆		◆	
Brown rockfish	*Sebastes auriculatus*	Below Average/ Candidate[b]	◆		◆	
Sculpins						
Cabezon	*Scorpaenichthys marmoratus*	Above Average	◆	◆	◆	◆
Buffalo sculpin	*Enophrys bison*	Above Average	◆	◆	◆	◆
Great sculpin	*Myoxocephalus polyacanthocephalus*	Above Average		◆	◆	◆
Other sculpins	Cottidae	Above Average	◆	◆	◆	◆
Flatfish						
English sole	*Pleuronectes vetulus*	Unknown	◆		◆	◆
C-O sole	*Pleuronectes coenosus*	Unknown	◆		◆	◆
Starry flounder	*Platichthys stellatus*	Unknown	◆		◆	◆
Sanddab	*Citharichthys* spp.	Unknown	◆		◆	◆
Dover sole	*Microstomus pacificus*	Unknown			◆	◆
Rock sole	*Pleuronectes bilineatus*	Unknown			◆	◆
Sand sole	*Psettichthys melanostictus*	Unknown			◆	◆

Table 2-8, continued

COMMON NAME	SCIENTIFIC NAME	SPECIES STATUS[a]	IDENTIFIED IN STUDY AREA	HABITAT USE: SPAWNING AREA	HABITAT USE: JUVENILE REARING	HABITAT USE: ADULT RESIDENT
Forage Fish						
Pacific herring	*Clupea harengus*	Healthy/ Candidate[b]	◆	◆	◆	◆
Sand lance	*Ammodytes hexapterus*	Unknown	◆	◆	◆	◆
Surf smelt	*Hypomesus pretiosus*	Unknown		◆	◆	◆
Tube snout	*Aulorhynchus flavidus*	Unknown	◆	◆	◆	◆
Crescent gunnel	*Pholis laeta*	Unknown	◆	◆	◆	◆
Snake prickleback	*Lumpenus sagitta*	Unknown	◆	◆	◆	◆
Cartilaginous Fish						
Spiny dogfish	*Squalus acanthias*	Above Average	◆			◆
Ratfish	*Hydrolagus colliei*	Unknown	◆			◆
Skates	*Raja* spp.	Unknown				◆
Other Fish						
Sablefish	*Anaplopoma fimbria*	Critical			◆	

[a] WDFW stock status
[b] Federal ESA listing
[c] Although limited rearing may occur, the area is likely used primarily as a migratory corridor

Six anadromous salmonid species are expected to be present in south central Puget Sound (Table 2-8). The four Pacific salmon and steelhead spawn in natal streams of the central Sound and use the study area as a migratory corridor during juvenile outmigration to the ocean and adult spawning migration to natal streams. No natal streams for Pacific salmon and steelhead are known to exist on Maury Island. Three small streams on Vashon Island contain runs of coho salmon—an unnamed stream which drains to Tramp Harbor, Judd Creek which drains to Quartermaster Harbor, and Needle Creek which drains to Fern Cove. These streams are 11, 12, and 24 km (7, 7.5, and 15 mi) from the study area (Schneider 2000). Jones & Stokes and AR (1999) documented juvenile chinook salmon in the study area at low densities. The low densities observed by Jones & Stokes and AR (1999) are consistent with other studies that indicate that the greatest use of nearshore habitats occurs in estuaries proximal to natal stream mouths. In these latter areas, juveniles complete the smoltification process to adult stage before entering freshwater (Miyamoto et al. 1980; Meyer et al. 1980; Shepard 1981). Both juvenile and adult Pacific salmon and steelhead likely use the study area only transitionally.

Mileta Creek, which drains to Quartermaster Harbor approximately 10 km (6 mi) from the study area, is the only stream on Maury Island that contains populations of resident and sea-run cutthroat trout. Several other streams on Vashon Island including Jod Creek, Needle Creek, Fisher Creek, Judd Creek, Beals Creek, and several unnamed streams contain populations of resident and sea-run cutthroat trout. Several of these streams are located between 6 to 8 km (4 to 5 mi) from the study area (Schneider 2000). Anadromous cutthroat trout do not migrate to the open ocean, rather, most remain in shallow nearshore beach environments of less than 3 m (9 ft) in depth (Johnston 1982). Jones (1976) found that the species preferred shorelines and were reluctant to cross bodies of water between 3 and 8 km (2 and 5 mi) in width. Although sea-run cutthroat trout were not observed in the study area, island spawning populations could use the study area as both a migratory corridor and forage area.

The sea perch listed in Table 2-8 are shallow water residents of Puget Sound and reside in bays and estuaries (Hart 1973), likely using the study area for spawning, juvenile rearing, and adult residence. Jones & Stokes and AR (1999) and AES (1998) documented three species of sea perch in the study area that are usually associated with pilings and seagrass. The latter study qualitatively classified shiner and pile perch as "common" in abundance. These findings are consistent with the known behavior and habitat requirements of the fish. All of the species are associated with docks, piers, jetties, and other nearshore structures in Puget Sound (Palsson et al. 1997). Although some offshore movement may occur during the winter, the three species listed on Table 2-8 are not known to migrate and so are likely year-round residents of the study area (Hart 1973).

Lingcod and greenlings are common demersal fish of Puget Sound, occupying rocky shores, reefs, pilings, and eelgrass beds from the intertidal zone up to -50 m (-164 ft) for greenlings and from the intertidal zone to -400 m (-1,313 ft) for lingcod (Hart 1973; Eschmeyer et al. 1983). The pilings, sunken barges, and eelgrass beds present within the study area likely provide suitable habitat for spawning, juvenile rearing, and adult residence. Jones & Stokes and AR (1999) observed two white-spot greenlings and one painted greenling in the study area, while AES (1998) reported lingcod (number not specified). None of the species are known to migrate extensively and so are likely year-round residents in the study area (Hart 1973).

About 20 species of rockfish are present in Puget Sound, but the copper and brown rockfish are among the most common in the south Sound (Palsson et al. 1997; Bargmann 1984). Copper and brown rockfish are common to shallow bays and rocky areas from the intertidal zone to -130 m (-427 ft) (Eschmeyer et al. 1983). The pilings and sunken barges present within the study area likely provide suitable juvenile rearing and adult habitat.

Jones & Stokes and AR (1999) qualitatively classified the abundance of brown rockfish as "common" and the copper rockfish as "occasional" in the study area, both associated with the pilings. AES (1998) reported rockfish near the sunken barges. Tagging studies suggest that older fish may move to offshore waters but do not move far from chosen locations (Mathews and Barker 1983). Overall, studies suggest that, at the least, juvenile and subadult rockfish would utilize the study area year-round. Spawning likely occurs in offshore waters outside of the study area.

Pacific cod, walleye pollock, and Pacific hake are three cod-like species that were once common in Puget Sound, but have undergone drastic declines over the past 20 years. Although the three species have not been observed in the study area, they have been documented in nearshore areas with similar habitats. Pacific cod and walleye pollock are known to spawn in Dalco Passage, located approximately 5 km (3 mi) southwest of the study area. Pacific cod have also been observed by Washington Department of Fish and Wildlife (WDFW) biologists to spawn in waters 18 m (60 ft) deep off of Rosehilla, located 2 km (1.2 mi) southwest of the study area. Pacific hake are known to spawn primarily in Port Susan located approximately 80 km (50 mi) north of the study area, but juvenile and adult hake have been documented in nearshore and offshore areas throughout south Puget Sound (Palsson 2000).

Sculpins are demersal fish species common to Puget Sound and several occupy nearshore areas (Hart 1973). Buffalo sculpin and cabezon are two of the largest species and are found from the intertidal zone to about -75 m (-246 ft). Both are known to spawn in very shallow water; migratory movements are not known to occur (Hart 1973; Eschmeyer et al. 1983). Jones & Stokes and AR (1999) reported the abundance of buffalo sculpin as occasional and reported one cabezon. Other unidentified sculpins were classified as common in abundance. The habitat requirements of the various sculpin species found in Puget Sound indicate that spawning, juvenile rearing, and adult residence is likely to occur in the study area.

Many flatfish species are present in Puget Sound, and several occupy soft to sandy environments in very shallow water, particularly as juveniles. English, rock, and Dover sole show this behavior of young fish residing in the nearshore with larger adults moving offshore. Offshore movement in the winter is apparent for English and Dover sole (Hart 1973). Jones & Stokes and AR (1999) found four flatfish species in the study area; English sole were classified as common, and C-O sole, starry flounder, and sanddabs were classified as occasional. Studies indicate that except for possible offshore movement during spawning periods and the winter, flatfish species likely use the study area for juvenile rearing and adult residence year-round.

Pelagic forage fish, such as the Pacific herring, sand lance, and surf smelt, spawn in distinct nearshore areas year after year. All three species are known to spawn in the vicinity of the study area. The Quartermaster Harbor herring stock, one of 18 distinct herring populations in Puget Sound with distinct spawning periods, spawns in Quartermaster Harbor between January and mid-April (Lemberg et al. 1997). Normally, spawning is limited to the harbor, but during large year classes, spawning extends around the harbor mouth to near the study area. Since 1975, herring spawn has been documented in the study area on two occasions—1975 and 1995 (WDFW). During 1995, the spawning biomass of herring was estimated to be 2,001 tons, the highest on record. The spawning biomass was not available for 1975 (Lemberg et al. 1997). During several other large spawning year classes, spawning herring have been documented to extend around Piner Point but not up to the study area (Schreffler and Moursund 1999).

Similar to herring, surf smelt and sand lance spawn in or near the study area, although it is not known if discrete spawning stocks exist. Jones & Stokes and AR (1999) observed large schools of sand lance in the study area.

Demersal forage fish species such as tube snout, crescent gunnel, and snake prickleback are year-round intertidal and nearshore subtidal residents likely using the study area for spawning, juvenile rearing and adult residence. Tube snout and gunnel are often associated with marine macroalgae (Hart 1973). Jones & Stokes and AR (1999) reported the tube snout and gunnels as common in abundance, while one prickleback was observed.

Dogfish, rays, and ratfish are not associated with nearshore habitats but occasionally can be found in shallow water, probably associated with feeding (Hart 1973; Eschmeyer et al. 1983). This observation is consistent with Jones & Stokes and AR (1999), which reported one dogfish and one ratfish in the study area. Similarly, sablefish are an open-water coastal fish, but migratory juveniles are found in Puget Sound. The species has occasionally been observed to occupy nearshore areas of the Sound, although none have been observed in the study area (Palsson et al. 1997).

As shown in Table 2-8, the status of many of the species potentially present in the nearshore area is not known. Very little stock assessment data are available to analyze populations, particularly with the decline of commercial and recreational catches, which provide major sources of data. Of those species for which sufficient data are available, ten fish species have below average or declining populations, and only five species have stable to healthy populations. Of the salmonids that use central Puget Sound streams, only pink and chum stocks are stable. Chinook stocks have declined such that they were recently federally listed as Threatened. Several Puget Sound coho salmon and steelhead trout stocks are in decline. Overfishing and stream habitat degradation are the most often cited causes for declines (Spence et al. 1996).

Similarly, rockfish and greenling populations are considered to be in very poor condition, while lingcod populations in the south Sound are considered stable. It is not known why these populations have declined, and stock assessment data quality is considered poor. Sculpin populations appear to be increasing. Sablefish populations in the south Sound are critically low; but this is a coastal stock of migratory juveniles, and it may be affected by regional oceanic variables (Palsson et al. 1997). The Quartermaster Harbor herring stock is considered healthy, although Sound-wide populations are declining. The stock status of surf smelt and sand lance is not known because of poor assessment data (Lemberg et al. 1997).

2.3.2 Marine Mammals

Marine mammals that can be present off Maury Island include harbor seals (*Phoca vitulina*); California and Steller sea lions (*Zaloplus californianus* and *Eumetopia jubatus*); killer (*Orcinus orca*), gray (*Eschrichtus robustus*), minke (*Balaenoptera acutorostrata*), and humpback whales (*Megaptera novaengliae*); and Dall's (*Phocoenoides dalli*) and harbor porpoise (*Phocoena phocoena*) (Jones & Stokes and AR 1999; Calambokidis pers. comm. 1999).

Harbor seals are common in the vicinity of Maury Island. However, there are no harbor seal haulout areas near the Lone Star dock; the nearest is on Gertrude Island several miles away (Jones & Stokes and AR 1999; Calambokidis pers. comm. 1999). Harbor porpoises and killer, gray, minke, and humpback whales are rare in south central Puget Sound (Calambokidis pers. comm. 1999). Because of its benthic habitat and fish resources, it is likely that the Maury Island nearshore area provides feeding habitat for marine mammals, but this area is not critical or unique in providing such habitat (Evans Hamilton 1987; PSEP 1992).

2.3.3 Critical Habitat

Sections 2.2 and 2.3.1 provide descriptions of the nearshore habitats, fish presence, and likely fish usage in the study area. The assessment indicates that the study area is composed of aquatic habitats and a fish community that are fairly typical of many nearshore areas of Puget Sound. In order to determine whether project-related activities affect fish populations, it must be ascertained whether the study area provides critical habitats necessary for the survival and maintenance of a fish population or discrete geographical stocks as they currently exist. According to Washington Administrative Code (WAC) 220-110-285: "Critical food fish and shellfish habitats...are those habitats that serve an essential function in the developmental life history of fish or shellfish. These habitats include but are not limited to the following:

(a) Pacific herring, surf smelt, Pacific sand lance, and rock sole spawning beds;
(b) Intertidal wetland vascular plants (except noxious weeds);
(c) Eelgrass (*Zostera* spp.);
(d) Kelp (Order Laminariales);
(e) Lingcod settlement and nursery areas;
(f) Rockfish settlement and nursery areas;
(g) Juvenile salmonid migration corridors and rearing and feeding areas."

By the definition provided in the Washington Administrative Code, the study area contains critical habitat for fish species of Puget Sound. As reported, eelgrass beds; spawning grounds for herring, sand lance, and smelt; salmonid migratory corridors; and lingcod and rockfish nurseries have been documented in the study area. However, the task undertaken by this Nearshore Impact Assessment is to assess the potential for impacts to the nearshore area from proposed dock and shipping operations associated with gravel mine expansion. This assessment evaluates impacts in terms of their potential to disrupt the maintenance of fish populations or the population of discrete geographical stocks as they currently exist. This definition is essentially the same as that used under the Endangered Species Act of 1973, as amended:

> The term "critical habitat" for a threatened or endangered species means (i) the specific areas within the geographical area occupied by the species, at the time it is listed in accordance with the provisions of section 4 of this Act, on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection; and (ii) specific areas outside the geographical area occupied by the species at the time it is listed in accordance with the provisions of section 4 of this Act, upon a determination by the Secretary that such areas are essential for the conservation of the species. (B) Critical habitat may be established for those species now listed as threatened or endangered species for which no critical habitat has heretofore been established as set forth in subparagraph (A) of this paragraph. (C) Except in those circumstances determined by the Secretary, critical habitat shall not include the entire geographical area which can be occupied by the threatened or endangered species.

Using the ESA definition of critical habitat, while the nearshore area of this project does provide habitat that supports a variety of marine biological resources, including listed and candidate fish species, it is not essential to the conservation of species or maintenance of existing populations.

The geographic distribution of habitats and species in Puget Sound, such as forage fish spawning beaches, groundfish areas, salmonid migratory corridors, and eelgrass and kelp beds, indicates that habitats found in the study area are widely available throughout Puget Sound (Evans Hamilton 1987; PSEP 1992). Overall, the fish surveys conducted in the study area, known habitat requirements, and stock assessment studies indicate that the study area does not provide habitats essential for the conservation of fish populations or discrete geographical stocks in Puget Sound.

For the salmonids, critical rearing habitats are in estuaries of natal streams, which are not present in the study area (Shepard 1981). For Vashon and Maury Island sea-run cutthroat trout populations, the likely critical habitat would be the nearshore, shallow beach environments around the two islands (Schneider 2000). This area totals about 70 km (44 mi) of nearshore environment, while the study area totals less than 1 km (0.6 mi).

For Pacific herring, spawning has been documented in the study area in only 2 years between 1975 and 1997, likely the result of large year classes (WDFW). The critical spawning habitats where the bulk of annual spawning occurs is in Quartermaster Harbor (Lemberg et al. 1997).

Surf smelt and sandlance, both of which spawn near or in the study area, have spawning areas that are distributed throughout Puget Sound. Surveys have documented 193 km (120 mi) of spawning habitat for sand lance and 314 km (195 mi) for surf smelt in Puget Sound (Lemberg et al. 1997). As reported, the study area occupies less than 1 km (0.6 mi) of beach environment that may be used by spawning surf smelt and sandlance.

Rockfish appear to be common inhabitants associated with the structures within the study area. However, demersal habitats with natural or artificial structures are found throughout Puget Sound (Evans Hamilton 1987; PSEP 1992) and spawning is not expected to occur within the study area.

The cod-like species, which have not been documented in the study area, have been observed in both nearshore and offshore habitats within Puget Sound. Nearshore habitats are not critical to the survival of these species. In addition, major spawning areas are not associated with the study area (Palsson 2000).

The demersal forage species, sea perch, and sculpins inhabit and reproduce in nearshore areas throughout Puget Sound and do not have specific geographical spawning areas or estuarine requirements (Evans Hamilton 1987; PSEP 1992).

2.3.4 Federally Listed Fish Species

On March 24, 1999, the Puget Sound chinook salmon was listed under the Endangered Species Act (ESA) as Threatened. On June 23, 1999, seven additional species were listed as candidate species for listing. These species are the Pacific herring, Pacific cod, Pacific hake, walleye pollock, brown rockfish, copper rockfish, and quillback rockfish. Species listed as candidates are not afforded protected status under ESA but will be further evaluated to determine if listing and federal protection are necessary. Because of the federally protected status of listed species and the concern associated with candidate species, an extended biological profile is provided, including a determination of whether a species is present in the study area. Tables 2-9 through 2-14 present stock status, habitat requirements, study area habitats, and the likelihood that the species inhabits the study area.

The following summarizes the ESA evaluation regarding the potential presence of these species in study area:

Puget Sound chinook salmon (threatened)

- Juvenile chinook salmon is the lifestage most likely present in the study area and has been documented in small numbers. Juveniles and adults use the area primarily as a migratory corridor.
- Natal streams are not known to occur on Vashon or Maury Island. Estuaries of natal streams hold the highest densities of both juvenile and adult fish in Puget Sound.
- The nearest natal stream and estuary is 10 km (6 mi) to the south of the study area.

Pacific herring (candidate)

- Nearby Quartermaster Harbor is a spawning area for a discrete stock of Pacific herring.
- Spawning in the study area occurs infrequently. Spawning has been documented on nearshore vegetation in the study area during 2 separate years between 1975 and 1997.
- Juvenile and adult herring likely reside in the study area on a regular basis.

Brown, copper, and quillback rockfish (candidates)

- Brown and copper rockfish are the most common species in south central Puget Sound and have been documented in the study area.
- The sunken barges and dolphins likely provide attractive habitat. Large juveniles or adults are likely year-round residents while spawning occurs offshore.

Pacific cod (candidate)

- Pacific cod have not been documented at the site, but have been documented in nearby nearshore areas with similar habitat features.
- Adults are associated with both nearshore and offshore areas.
- Cod spawn in Dalco Passage and have been observed off Rosehilla about 5 to 8 km (3 to 5 mi) from the study area. The bulk of spawning in Puget Sound

occurs in Agate Passage and Port Townsend Bay, located about 45 and 85 km (28 and 53 mi), respectively, north of the study area.

- Spawning adults, larvae, and juveniles appear associated with embayments and nearshore areas.

Pacific hake (candidate)

- Pacific hake have not been documented in the study area, but have been documented in nearshore areas with similar habitat features.

- The study area is not near known hake spawning areas, but juvenile and adult fish have been documented in both nearshore and offshore waters.

- No information was found regarding the early life stages of hake in Puget Sound.

Walleye pollock (candidate)

- Pollock have not been documented in the study area, but juvenile and adult fish have been documented in both nearshore and offshore waters.

- Dalco Passage has been identified as a spawning area for pollock.

- Although little information is available, Puget Sound populations of walleye pollock are associated with both nearshore and offshore habitats.

Table 2-9. Endangered species evaluation – Puget Sound chinook salmon

1. Species listing	**Type of listing, date** Listed as Threatened under the Endangered Species Act – March 24, 1999
2. Current stock	**South Puget Sound** Separate stocks of Puget Sound chinook salmon spawn in the Puyallup River basin located 10 km (6 miles) south of the study area and the Nisqually Basin, located about 35 km (22 miles) south of the study area. A small stock is present in the Deschutes River, located an additional 15 km (9 miles) southeast of the Nisqually Basin. Very small stocks are present in Goldborough Creek, which discharges to Hammersley Inlet, and Kennedy Creek, which discharges to Totten Inlet, both in southeastern Puget Sound. **Study area** No natal streams for Puget Sound chinook salmon are known to occur on Vashon or Maury Island. The closest natal stream is the Puyallup River, 10 km (6 miles) south of the study area.
3. Study area habitat types	Side-scan sonar and sediment profile imaging studies conducted in 1999 indicate the following physical characteristics: • The study area substrate is primarily medium- to fine-grained sands with areas of coarse-grained sands. Coarser sediments are present in the intertidal zone and three separate subtidal areas between -3 m and -15 m (-10 and -50 ft) MLLW. • From the beach (0 m MLLW), the nearshore slopes gradually for 46 m to 61m (150 to 200 ft) to about -5 m (-17 ft) MLLW. From the -5 m (-17 ft) mark, water depth drops rapidly. Areas near the edge of the existing pier and pilings ranged from 6 m to 12 m (20 to 40 ft) deep. • Four areas of eelgrass were observed between -0.6 m to -6 m (-2 and -20 ft) MLLW. The largest area is approximately 152 m (500 ft) long and is situated in the southwest corner of the study area about 152 m (500 ft) southwest of the existing pier. Two smaller patches of about 5 m^2 (54 ft^2) are present on either side of the pier, and one other area of about 61 m (200 ft) long is present in the northeast corner of the study area. • A debris pile of logs and rocks is situated immediately south of the pier. • Two sunken vessels are located immediately southwest of the pier. • A habitat survey using divers that was conducted in 1999 documented four juvenile chinook salmon at three different transects.

Table 2-9, continued

4. Spawning	**Spawning habitat** No chinook salmon spawning habitats occur in the vicinity of proposed project activities. Large natal chinook streams within the migratory pathway include the Puyallup River and Nisqually River Basins. Streams with smaller populations of chinook salmon in south Puget Sound include the Deschutes River, Goldsborough Creek, Kennedy Creek, and several other smaller stream basins. No salmon streams occur on Maury or Vashon Island. **Spawning season** Spring and fall varieties of chinook salmon use natal streams in south Puget Sound. These adult fish pass the site on the way to spawning streams from May through September. **Adult use of nearshore area** Use of the study area by adult fish has not been documented. Since no natal streams are known to occur on Vashon or Maury Island, the study area would only be used as migratory corridor by adult fish.
5. Juvenile requirements	**Habitat** Studies have shown that juvenile chinook use shoreline areas extensively in waters of a few centimeters to over a meter with substrates of gravel, sand, or mud. Preferences for soft, packed substrates have also been documented. There is evidence to indicate that smaller juveniles use inshore areas, while larger juveniles move progressively to deeper waters. The largest aggregations of juvenile chinook salmon are found in estuarine embayments at the mouths of natal streams. During estuarine rearing, chinook salmon exhibit significant growth. **Timing** Outmigration of fall chinook juveniles generally occurs from mid-February to mid-July, depending upon the estuary, with the average residence time per estuary of 12 weeks.

Table 2-9, continued

6. Likelihood of study area use	The nearshore orientation of juvenile chinook salmon indicates that this is the lifestage most likely present in the study area. Preferred habitats of juvenile salmon appear to be present in the study area, and the latest diving surveys documented juvenile salmon in low densities. Local habitat studies appear consistent with the regional juvenile salmonid studies conducted in Puget Sound. Juvenile salmon likely use the study area in small numbers year-round. Although good habitat exists, the study area is not expected to be used as a major rearing area during the outmigration of juvenile salmon. These heavy-use areas occur in estuarine waters at the mouths of natal streams.

SOURCES: Healey 1980, 1982; Meyer et al. 1980; Miller et al. 1977, 1980; Miyamoto et al. 1980; Shepard 1981

Table 2-10. Endangered species evaluation – Pacific herring

1. Species listing	**Type of listing, date** Listed as a Candidate species under the Endangered Species Act – June 23, 1999
2. Current stock	**Puget Sound** • 18 discrete herring stocks are present in Puget Sound; stocks are defined by the location of annual spawning areas: – 7 are considered healthy (2-yr abundance within 10 percent of the 20-year mean). – 3 are considered moderately healthy (2-yr abundance within 30 percent of the 20-year mean). – 5 are considered depressed (recent abundance well below long-term mean but not so low that permanent damage to the stock is likely). – 2 are considered critical (recent abundance so low that permanent damage to the stock is likely or has already occurred). – 1 is unknown (insufficient assessment data to identify stock status with confidence). **Study area** • Quartermaster Harbor herring population is a discrete stock that spawns in Quartermaster Harbor and around southern Maury Island to the edge of the study area. • Between 1977 and 1997, population biomass ranged from 667 to 2001 tons. • Quartermaster Harbor herring stock is fifth largest in Puget Sound over the past 20 years; third largest over the past 5 years. • Quartermaster Harbor herring stock is considered healthy by WDFW; from 1977 to 1997, no long-term declines are evident: – 21-year mean biomass: 1238 tons. – 5-year mean biomass (1993-1997): 1360 tons.
3. Study area habitat types	Side-scan sonar and sediment profile imaging studies conducted in 1999 indicate the following physical characteristics: • The study area substrate is primarily medium- to fine-grained sands with areas of coarse-grained sands. Coarser sediments are present in the intertidal zone and three separate subtidal areas between -3 and -15 m (-10 and -50 ft) MLLW.

Table 2-10, continued

3. Study area habitat types, cont.	• From the beach (0 m MLLW), the nearshore slopes gradually for 46 m to 61 m (150 to 200 ft) to about -5 m (-17 ft) MLLW. From the -5 m (-17 ft) mark, water depth drops rapidly. Areas near the edge of the existing pier and pilings ranged from 6 to 12 m (20 to 40 ft) deep. • Four areas of eelgrass were observed between -0.6 m to -6 m (-2 and -20 ft) MLLW. The largest area is approximately 152 m (500 ft) long situated in the southwest corner of the study area about 170 m (500 ft) southwest of the existing pier. Two smaller patches of about 5 m^2 (54 sq ft) are present on either side of the pier, and one other area of about 61 m (200 ft) long is present in the northeast corner of the study area. A debris pile of logs and rocks is situated immediately south of the pier. • Two sunken vessels are located immediately southwest of the pier. • WDFW has documented spawning herring in the study area in two different years between 1975 and 1995. • Habitat surveys conducted in 1999 and 1998 did not document herring in the study area.
4. Spawning	**Spawning habitat** Pacific herring spawn primarily on vegetation and substrates in intertidal or shallow subtidal waters. Herring eggs are deposited between the upper limits of high tide to a depth of -12 m (-40 ft) MLLW, but most spawning takes place between 0 and -3 m (0 and -10 ft). Studies in Puget Sound have found that eelgrass, the brown macro alga *Desmarestia* spp. and the red alga *Odonthalia* spp may be preferred substrates of herring eggs. Other macroalgae where herring spawn has been found include *Laminaria, Alaria, Iridaea*, kelp, and *Ulva.* **Spawning season** The Quartermaster Harbor herring stock spawns during late winter and early spring between January and mid-April. Most spawning occurs in Quartermaster Harbor, but during larger year classes, spawning extends out of the bay to the edge of the study area. In 1975 and 1995, spawning was documented in the study area, and spawning extended around Piner Point to near the study area during several other years. **Adult use of nearshore area** Prior to spawning, prespawning adults congregate along the mouth of the harbor and offshore areas around southern Maury Island. Prespawning fish are associated with deep water, generally residing between 27 m and 37 m (90 and 120 ft). During non-spawning periods, the Quartermaster Harbor herring stock is considered resident, but movement patterns are largely unknown. WDFW speculates that they move widely throughout Puget Sound. Given the proximity, it is likely that herring from several Puget Sound stocks may mingle with Quartermaster Harbor herring or be found in the study area.

Table 2-10, continued

5. Larval/Juvenile requirements	**Habitat** Eggs hatch in about 14 days producing yolk-sac larvae. The yolk-sac supplies nutrients for about a week, after which independent feeding begins. Larvae are largely distributed by local current patterns. No larval retention studies have been conducted in the study area. Larvae metamorphose into juveniles 2 to 3 months after hatching. After metamorphosis, juveniles do not appear to have substantial affinity for spawning areas. Young juvenile herring are often found near spawning areas in June, shortly after metamorphosis, but by August, they are usually shore to shore in south Puget Sound.
6. Likelihood of study area use	As reported, herring movements outside of spawning and prespawning adults are not well known in Puget Sound. It is likely that the Quartermaster Harbor herring stock spawns within the study area during larger year classes between January and mid-April. Pre-spawning herring have generally been found offshore in deep water residing between 27 to 37 m (90 and 120 ft). Site area affinity prior to or after spawning by Quartermaster Harbor adults does not appear to be high; however, the study area provides suitable habitat for both adult and juvenile herring. Comprehensive baseline studies conducted in north Puget Sound found that herring was the most abundant species (number and biomass) observed in nearshore beach seine samples. The study area is likely used to a degree similar to other suitable habitats in Puget Sound by several co-mingling herring stocks.

SOURCES: Lemberg et al. 1998; Miller et al. 1977; O'Toole pers. comm. 1999; Stick pers. comm. 1999; Stick 1995; Thornton 1995; WDFW Field Reports

Table 2-11. Endangered species evaluation – Pacific cod

1. Species listing	**Type of listing, date** Listed as a Candidate species under the Endangered Species Act – June 23, 1999
2. Current stock	**Puget Sound** • Three stocks of Pacific cod are present in Puget Sound: – North Puget Sound-Gulf/Bellingham/San Juan Islands. – West Puget Sound-Strait of Juan de Fuca/Port Townsend Bay. – South Puget Sound-South of Admiralty Inlet. **Study area** • The Study Area is within the range of the south Puget Sound cod stock. Cod production exceeded one million pounds per year in the 1970s. Recent surveys indicate that the stock is at a critical or near-extinct level. Critical stock conditions may be the result of warm water conditions in Puget Sound.
3. Study area habitat types	Side-scan sonar and sediment profile imaging studies conducted in 1999 indicate the following physical characteristics: • The study area substrate is primarily medium- to fine-grained sands with areas of coarse-grained sands. Coarser sediments are present in the intertidal zone and three separate subtidal areas between -3 and -15 m (-10 and -50 ft) MLLW. • From the beach (0 m MLLW), the nearshore slopes gradually for 46 to 61 m (150 to 200 ft) to about -5 m (-17 ft) MLLW. From the -5 m (-17 ft) mark, water depth drops rapidly. Areas near the edge of the existing pier and pilings ranged from 6 to 12 m (20 to 40 ft) deep. • Four areas of eelgrass were observed between -0.6 m to -6 m (-2 and -20 ft) MLLW. The largest area is approximately 500 ft long situated in the southwest corner of the study area about 500 ft southwest of the existing pier. Two smaller patches of about 5 m^2 (54 ft^2) are present on either side of the pier, and one other area of about 61 m (200 ft) long is present in the northeast corner of the study area. • A debris pile of logs and rocks is situated immediately south of the pier. • Two sunken vessels are located immediately southwest of the pier. Pacific cod have not been documented in the study area.

Table 2-11, continued

4. Spawning	**Spawning habitat** Pacific cod in Puget Sound have been documented to spawn in Agate Passage, located at the northwestern tip of Bainbridge Island and Port Townsend Bay. Other probable spawning locations within the Sound include Dalco Passage, located off the southern tip of Vashon Island, just south of the study area; and Eliza Island, off Bellingham. WDFW has observed spawning cod off the southern tip of Maury Island, near Rosehilla. Pacific cod are demersal spawners where bottom substrates consist of coarse sand and cobble. Eggs hatch from 8 to 17 days at temperatures between 5 and 11 degrees C (41 and 52 degrees F). Cod larvae in Port Townsend Bay orient toward the bottom in shallow water, moving to deeper water in early juvenile stages. **Spawning season** Pacific cod spawn during the winter in cool waters between 6 and 7 degrees C (43 and 45 degrees F). **Adult use of nearshore area** Adult cod use specific shallow areas and embayments during the winter spawning periods. During non-spawning periods, cod have been known to occupy deep offshore waters and nearshore areas.
5. Larval/Juvenile requirements	**Habitat** Cod larvae in Port Townsend Bay orient toward the bottom in shallow water during the winter and spring moving to deeper water in early juvenile stages by summer. No investigations have been conducted in or near the study area.
6. Likelihood of study area use	Adult Pacific cod can be associated with nearshore or offshore areas; they could occur near the study area. Specific spawning grounds are present in Puget Sound, the closest within Dalco Passage off the southern tip of Vashon and Maury Islands, between 3 and 8 km (2 and 5 mi) from the study area. Spawning adults, larvae, and juveniles appear associated with embayments and nearshore areas.

SOURCES: Palsson 1990; Palsson et al. 1997.

Table 2-12. Endangered species evaluation – Pacific hake

1. **Species listing**	**Type of listing, date** Listed as a Candidate species under the Endangered Species Act – June 23, 1999
2. **Current stock**	**Puget Sound** Separate stocks of hake are found on the Pacific coast, north Puget Sound, and south Puget Sound. **Study Area** The Pacific hake stock in south Puget Sound is probably distinct from the north Sound stock according to WDFW. The adult biomass was estimated at 40 million pounds during the 1970s, but declined to barely one million pounds in 1994. The stock status is considered critical. WDFW reported that high predation by marine mammals may be preventing recovery of the population.
3. **Study area habitat types**	Side-scan sonar and sediment profile imaging studies conducted in 1999 indicate the following physical characteristics: • The study area substrate is primarily medium to fine grained sands with areas of coarse-grained sands. Coarser sediments are present in the intertidal zone and three separate subtidal areas between -3 and -15 m (-10 and -50 ft) MLLW. • From the beach (0 m MLLW), the nearshore slopes gradually for 46 to 61 m (150 to 200 ft) to about -5 m (-17 ft) MLLW. From the -5 m (-17 ft) mark, water depth drops rapidly. Areas near the edge of the existing pier and pilings ranged from 6 to 12 m (20 to 40 ft) deep. • Four areas of eelgrass were observed between -0.6 m to -6 m (-2 and -20 ft) MLLW. The largest area is approximately 152 m (500 ft) long situated in the southwest corner of the study area about 152 m (500 ft) southwest of the existing pier. Two smaller patches of about 5 m^2 (54 ft^2) are present on either side of the pier, and one other area of about 61 m (200 ft) long is present in the northeast corner of the study area. • A debris pile of logs and rocks is situated immediately south of the pier. • Two sunken vessels are located immediately southwest of the pier. Pacific hake have not been documented in the study area.

Table 2-12, continued

4. Spawning	**Spawning habitat and season** The south Puget Sound stock spawns in Port Susan during the spring (the embayment formed by Camano Island). Eggs and larvae are pelagic. **Adult use of nearshore area** Adults are associated with both offshore and nearshore waters of South Puget Sound.
5. Larval/Juvenile requirements	**Habitat** No information was found regarding the larval and juvenile lifestages of hake.
6. Likelihood of study area use	Hake are at critically low levels in south Puget Sound, and high predation by marine mammals may be preventing their recovery. Adult lifestages can be associated with the nearshore so may be found near the study area.

SOURCES: Palsson et al. 1997.

Table 2-13. Endangered species evaluation – Walleye pollock

1. Species listing	**Type of listing, date** Listed as a Candidate species under the Endangered Species Act – June 23, 1999
2. Current stock	**Puget Sound** Walleye pollock are a subarctic cod species that is on the extreme southern end of its Pacific coast distribution in Puget Sound. **Study Area** Growth and other biological data indicate the south Puget Sound pollock are a different biological stock than those in north Puget Sound. The south Puget Sound pollock stock was abundant in the late 1970s but then declined until the fishery collapsed in the late 1980s. Trawl surveys conducted in 1993 and 1994 (latest years of available data) indicate that the population is at a critical, possibly extinct status.
3. Study area habitat types	Side-scan sonar and sediment profile imaging studies conducted in 1999 indicate the following physical characteristics: • The study area substrate is primarily medium- to fine-grained sands with areas of coarse-grained sands. Coarser sediments are present in the intertidal zone and three separate subtidal areas between -3 and -15 m (-10 and -50 ft) MLLW. • From the beach (0 m MLLW), the nearshore slopes gradually for 46 to 61 m (150 to 200 ft) to about -5 m (-17 ft) MLLW. From the -5 m (-17 ft) mark, water depth drops rapidly. Areas near the edge of the existing pier and pilings ranged from 6 to 12 m (20 to 40 ft) deep. • Four areas of eelgrass were observed between -0.6 m to -6 m (-2 and -20 ft) MLLW. The largest area is approximately 152 m (500 ft) long situated in the southwest corner of the study area about 152 m (500 ft) southwest of the existing pier. Two smaller patches of about 5 m^2 (54 ft^2) are present on either side of the pier, and one other area of about 61 m (200 ft) long is present in the northeast corner of the study area. • A debris pile of logs and rocks is situated immediately south of the pier. • Two sunken vessels are located immediately southwest of the pier. Walleye pollock have not been documented in the study area.

Table 2-13, continued

4. Spawning	**Spawning habitat and season** Little information is available on Puget Sound populations. WDFW reported that spawning has been observed in Dalco Passage, south of Maury and Vashon Island. **Adult use of nearshore area** Adults in Puget Sound have been observed in both nearshore and offshore waters.
5. Larval/Juvenile requirements	**Habitat** No information was found regarding the larval and juvenile lifestages of walleye pollock.
6. Likelihood of study area use	Little information on the life history of walleye pollock is available for Puget Sound populations. The species is at critically low levels in the south Sound and may be extinct. Adult lifestages are associated with both nearshore and offshore areas so may be found near the study area.

SOURCES: Palsson et al. 1997

Table 2-14. Endangered species evaluation – Brown rockfish, copper rockfish, quillback rockfish

1. Species listing	**Type of listing, date** Listed as a Candidate species under the Endangered Species Act – June 23, 1999
2. Current stock	**Puget Sound** Separate stocks of rockfish have not been delineated in Puget Sound. Rockfish populations in south Puget Sound have undergone long-term declines in abundance since 1977.
3. Study area habitat types	Side-scan sonar and sediment profile imaging studies conducted in 1999 indicate the following physical characteristics: • The study area substrate is primarily medium to fine grained sands with areas of coarse-grained sands. Coarser sediments are present in the intertidal zone and three separate subtidal areas between -3 and -15 m (-10 and -50 ft) MLLW. • From the beach (0 m MLLW), the nearshore slopes gradually for 150 to 200 ft to about -5 m (-17 ft) MLLW. From the -5 m (-17 ft) mark, water depth drops rapidly. Areas near the edge of the existing pier and pilings ranged from 6 to 12 m (20 to 40 ft) deep. • Four areas of eelgrass were observed between -0.6 m to -6 m (-2 and -20 ft) MLLW. The largest area is approximately 152 m (500 ft) long situated in the southwest corner of the study area about 152 m (500 ft) southwest of the existing pier. Two smaller patches of about 5 m^2 (50 ft^2) are present on either side of the pier, and one other area about 61 m (200 ft) long is present in the northeast corner of the study area. • A debris pile of logs and rocks is situated immediately south of the pier. • Two sunken vessels are located immediately southwest of the pier. Habitat surveys conducted in 1998 and 1999 documented copper and brown rockfish in the study area. Both species were observed around the dolphins. Brown rockfish were classified as common in abundance.
4. Spawning	**Spawning season and habitat** All rockfish species have internal fertilization and bear live young. Little is known of the spawning habits and early life history of individual species because the larvae and juveniles are difficult to distinguish. In Puget Sound, brown rockfish spawn once a year; embryos are released from April to July. Copper rockfish appear to release young in April. No information was found on the quillback rockfish.

Table 2-14, continued

4. Spawning, cont.	**Adult use of nearshore area** All three rockfish species are known to occur in fairly shallow bays as well as deeper offshore areas. Rockfish generally associate with rocky areas, crevices, and reefs. Large juvenile or adult rockfish have been observed by divers to occupy areas around the sunken barges near the existing pier facility in the study area (species unknown). Older fish may move to deeper offshore waters. Tagging studies of copper rockfish in northern Puget Sound suggest that mature fish do not move far from chosen locations.
5. Larval/Juvenile requirements	**Habitat** Larvae are pelagic for periods of several months to a year, drifting with currents. Juvenile brown and copper rockfish occur in shallow nearshore waters, often around piers, other natural and artificial structures, and in bays.
6. Likelihood of study area use	The habitat requirements of large juvenile and young adult rockfish reported in the scientific literature are consistent with habitats present in the study area and the observations of rockfish near the sunken barges. The sunken structures, rockpiles, and the pier facility likely provide attractive cover for juvenile and adult rockfish. The larval stages are not likely present in the area for other than very transient periods. Larger adults and spawning may occur in offshore areas.

SOURCES: Delacy et al. 1964; Hitz and Delacy 1965; Mathews and Barker 1983; Palsson et al. 1997; Stein and Hassler 1989

2.3.5 Conclusions

The habitats and fish community observed or expected in the study area are typical of those found in south central Puget Sound. The study area is nearshore and thus has a preponderance of fish species, such as sea perch, greenlings, rockfish, sculpins, and demersal forage species, that characterize nearshore areas. Preponderantly offshore species such as the cods, sharks, and rays have not been documented or are rare in the study area. The sunken barges and dolphins, while anthropogenic in origin, attract structure-oriented demersal species such as rockfish, lingcod, and cabezon.

The study area does not provide critical habitat as defined under the Endangered Species Act for fish in Puget Sound. The study area is not associated with an estuary of a natal salmonid stream where high densities of juvenile salmonids are found. The study area is outside of the preferred Quartermaster Harbor herring spawning area in all but the largest year classes. Other species that rely heavily on nearshore areas do not have specific habitat requirements, and the study area is typical of those found in south central Puget Sound.

A number of marine mammal species may occur in south central Puget Sound, and these could potentially feed on occasion in the Maury Island nearshore area. The most common marine mammal is the harbor seal, which may use the area for feeding but does not have any haulouts in the vicinity of the nearshore area. Dall's porpoises are also seen frequently in this part of Puget Sound.

One fish species listed as threatened by the federal government and seven candidates for federal listing under ESA are present in Puget Sound. The study area is not likely to provide a critical habitat for ESA species. The study area is not associated with a natal stream and so Puget Sound chinook salmon, listed as threatened, would not be expected to use it as an extensive juvenile nursery or adult staging area. The area is primarily a migratory corridor for juvenile out-migrants and adults on spawning runs to natal streams. The study area lies adjacent to the spawning grounds of the Quartermaster Harbor Pacific herring stock. Annual spawning has been documented within the study area on two occasions and in areas just south of the study area on several occasions since 1975, generally in association with the largest populations of spawning fish. Spawning herring would likely use the study area only during the largest year classes. The brown and copper rockfish likely use the study area, possibly associating with structures such as the sunken barges and dolphins. However, these habitats are not unique in Puget Sound. The cod species—Pacific cod, walleye pollock, and Pacific hake—are associated with both nearshore and offshore areas. Major spawning areas for the three species are offshore and not nearby, but secondary spawning areas for cod and pollock have been documented at Dalco Passage, just south of the study area.

3.0
IMPACT ASSESSMENT

An impact assessment was conducted to identify the various potential environmental impacts to marine mammals and fish that would result from the proposed project. These potential impacts include noise (generated by both dock reconstruction and barge operations); turbidity; habitat loss due to dock reconstruction; chemical contaminants (primarily petroleum input in the form of spills, leaks, or as exhaust); propeller wash; light shading and night lighting; sand and gravel spills at the dock; and the effect on longshore sediment transport. Also discussed are the levels of marine mammal and fish sensitivity to each impact. The level of discussion presented in this assessment is proportional to the potential significance of each environmental impact.

3.1 NOISE

The proposed project will increase noise levels during the short-term while construction activities are underway and have longer-term impacts resulting from vessel traffic and loading operations. A brief description of sound is presented below followed by discussions of the noise characteristics generated by three dock-related operations (pile driving, vessel traffic, and barge loading), the sensitivity of animals to noise, and the impacts of increased noise levels on species.

Sound is a wave of energy traveling through a medium and is described by its pressure and frequency. Pressure is measured in micropascals (μPa), and frequency is measured in hertz (Hz). Frequency can be reported as either a pure tone or as sound spectra (bandwidth) (Richardson et al. 1995). In order to compare sounds, a log scale was developed, and this scale is reported in decibels (dB)(Richardson et al. 1995). An increase of 20 dBs results in a 10-fold increase in sound pressure (Feist 1991). The distance from a sound source affects sound levels; as distance increases, sound level decreases due to transmission loss.

3.1.1 Noise Generated from Project Activities

3.1.1.1 Pile Driving

Description of Project—Reconstruction activities are proposed for the existing Lone Star dock prior to its reuse. Repairs will include (Jones & Stokes and AR 1999):

- Reinstallation of the conveyor loading system
- Replacement of approximately 30 pilings

- Replacement of 25 percent of the existing dock's decking, stringers, and supports

The installation of the conveyor is expected to occur within a 15-day period, and piling replacement will take between 14 and 28 days. Pilings will be replaced using a pile-driving rig secured aboard a 36 m by 18 m (120 ft by 60 ft) barge-like vessel.

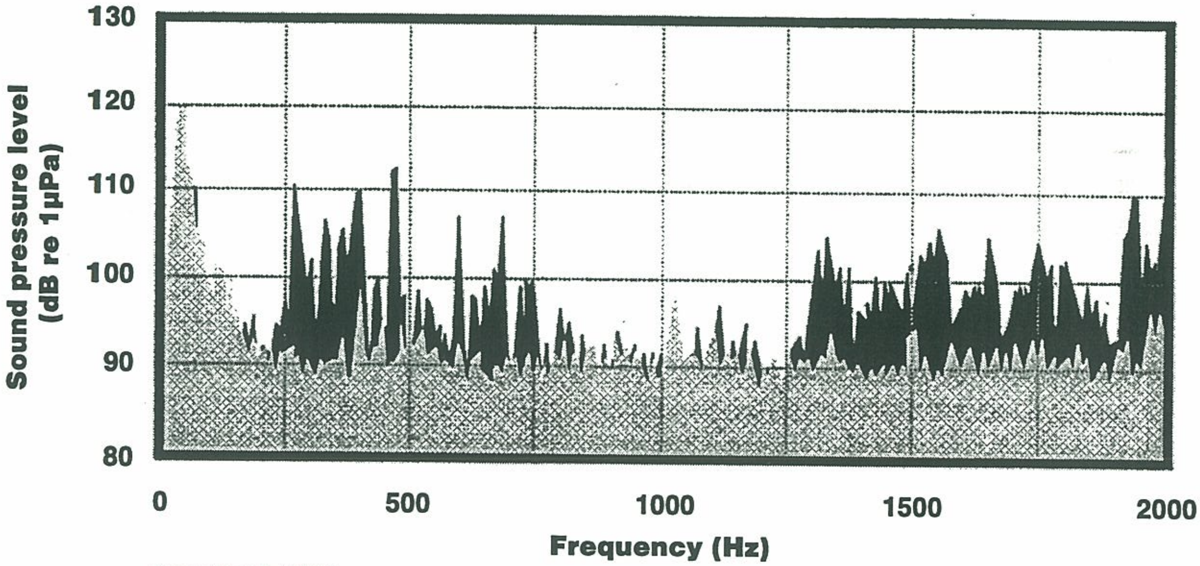
Timber piles will be installed using an air hammer. One existing dolphin of 10 pilings will be replaced, and two to three pilings will be added to each of the remaining nine dolphins (18 to 27 total pilings) for a sum total of 28 to 37 piles. Old piles will be left in place or cut at the sediment line. In addition, 10 fender pilings will be repaired by cutting away damaged wood. The fender pilings will be lifted 1 to 1.5 m (3 to 5 ft) so that the damaged portions can be removed.

Description of Noise—In air, the sound level of a pile driver has been measured at 101 dBA at a distance of 15 m (49 ft) (USEPA 1975). Based on limited underwater acoustical data, pile-driving sound levels have been recorded up to 25 dB (re 1 μPa) above ambient conditions at a distance of 593 m (approximately 0.5 mi) from the pile-driving rig (Feist 1991). In underwater acoustics, a reference (re) pressure is always associated with the dB so that comparisons between sound measurements may be made. the present standard for underwater measurements is 1 μPa (micropascal) at 1 m. If sound is measured at a different distance from the sound source, this distance should be reported. In this report, the reference distance is 1 m and the reference pressure is 1 μPa, unless otherwise noted. Peak sound pressure levels from pile driving have been recorded at frequencies of approximately 250 Hz to 750 Hz and again at 1250 to 2000 Hz; levels were not measured above 2000 Hz. Peak sound pressure levels generally ranged from 95 to 110 dB (re 1 μPa at 593 m) (see Figure 3-1) (Feist 1991).

3.1.1.2 Vessel Traffic

Description of Project—Vessel traffic will increase as tugs bring in empty barges for mining product and depart with full barges. Maximum daily mine production is estimated at 40,000 tons per day (Jones & Stokes and AR 1999). Though a range of barge sizes could be used, the most common would be the 10,000-ton-capacity barge (Table 3-1). Therefore, tugs would need to maneuver 10,000-ton barges eight times per day (to dock and undock). If 4,000- or 2,000-ton capacity barges were used, tugs would be docking and undocking 20 and 40 times per day, respectively. A combination of barge sizes could also be used. At lower production rates, the use of tugs is expected to decrease unless smaller barges are used.

This rate of activity would not be sustained for 365 days a year because the annual capacity of the mine is set at 7.5 million tons. Therefore, at the peak daily production rate of 40,000 tons per day, barging activities would be limited to 183 days per year.



Prepared from Feist 1991

Figure 3-1. Sound pressure level (dB re μPa) and frequency (Hz) of underwater environment 593 from pile driving activities. Black is pile driving noise and gray is ambient conditions

Table 3-1. Dimensions of barges to be used for shipping sand and gravel

BARGE CAPACITY (tons)	LENGTH (ft)	BREADTH (ft)	DEPTH (ft)	LIGHT BARGE DRAFT (ft)	LOADED BARGE DRAFT (ft)
10,000	330	80	19-20	4.5	16-17
4,000	240	62	16	4	12-14
2,000	200	54	11.5	1.5-2	9.5

SOURCE: Summers 1999a

Description of Noise—Table 3-2 shows the sound levels of barges and tugs recorded at a variety of frequencies. Vessel noise tends to dominate the 20 to 500 Hz frequency bandwidth and often reaches 1 kHz (Wenz 1962). Sound levels generated by a tug and barge combination range from 150 dB to 170 dB (re 1 μPa at 1 m) across a range of frequencies (37 to 12,500 Hz). Loaded barges were 6 to 16 dB louder than empty barges.

Table 3-2. Recorded or estimated sound levels and frequencies of various tugboat and barge scenarios

SOURCE	SOURCE LEVEL (dB re 1 μPa at 1 m)	FREQUENCY (Hz)
Supply barge	171	100-12,500
Small barge	168[a]	315-16,000[a]
Tug pulling empty barge[b]	166	37
Tug pulling empty barge[c]	164	1000[d]
Tug pulling empty barge[c]	145	5000[d]
Tug pulling loaded barge[c]	170	1000[d]
Tug pulling loaded barge[c]	161	5000[d]
Tug and barge	143	50[d]
Tug and barge	157	100[d]
Tug and barge	157	200[d]
Tug and barge	161	500[d]
Tug and barge	156	1000[d]
Tug and barge	157	2000[d]

SOURCE: Malme et al. 1989, except where noted

[a] Estimated.
[b] Buck and Chalfant 1972.
[c] Miles et al. 1987.
[d] 1/3 octave band center frequencies.

A tug and barge travelling at a constant speed will have a signature different from that of a tug maneuvering a barge at the dock. Both activities are likely to overlap in frequency and pressure levels. However, the sound levels of maneuvering activities at the dock are expected to be erratic, pulsed noise signatures with rapid changes in frequency and pressure because of abrupt changes in tug speed and direction.

3.1.1.3 Loading Operations

Description of Project—Most of the mine product will be loaded onto barges with a conveyor and transported to market. Two motor drives will run the conveyor: one will be positioned 15 m (50 ft) from the seaward end of dock, and the other will be 23 m (75 ft) landward of the high water mark. To distribute gravel and sand in the barge, a tug will move the barge back and forth while material is being loaded from the conveyor. Alternatively, the conveyor may be moved (Summers 1999b).

Description of Noise—The underwater noise levels associated with barge filling have not been measured. It is likely that sound will be transmitted through the hull into the surrounding aquatic environment. Tugboat noise levels generated by moving a barge for loading are predicted to be similar to those levels generated by docking activities. Low-frequency, pulsed noise signatures will be generated as a result of the tug's abrupt changes in speed and direction.

3.1.2 Sensitivity of Species to Noise

3.1.2.1 Importance of Sound to Aquatic Life

Aquatic organisms have adapted to use sound for a variety of functions. Fish and marine mammals may rely on sound for schooling orientation and predator avoidance (Blaxter and Batty 1985b; FAO 1970), prey location (FAO 1970), competitive interactions and courtship (Hawkins 1993), homing mechanisms (Nikolaev 1982), and echolocation and long-distance communication (Malme et al. 1989).

Unwanted noise can 1) interfere with acoustic communication, 2) produce unpleasant sounds, and 3) damage hearing (Malme et al. 1989). In response to noise stimuli, an organism may avoid an area. While this decreases exposure to acoustic interference, the animal may also be excluded from important feeding, mating, or spawning grounds.

3.1.2.2 Potential Receptors

Twenty fish species were recently observed in the vicinity of the dock, including threatened and candidate species (Jones & Stokes and AR 1999). In addition, several other fish species are likely to utilize this nearshore habitat (Table 2-8). Marine mammals may also be exposed to noise from dock-area activities. Species that may be found in waters off Maury Island include harbor seals (*Phoca vitulina*); California and Steller sea lions (*Zaloplus californianus* and *Eumetopia jubatus*); killer (*Orcinus orca*), gray (*Eschrichtus robustus*), minke (*Balaenoptera acutorostrata*), and humpback whales

(*Megaptera novaengliae*); and Dall's (*Phocoenoides dalli*) and harbor porpoise (*Phocoena phocoena*) (Jones & Stokes and AR 1999; Calambokidis 1999).

3.1.2.3 Sensitivity of Species

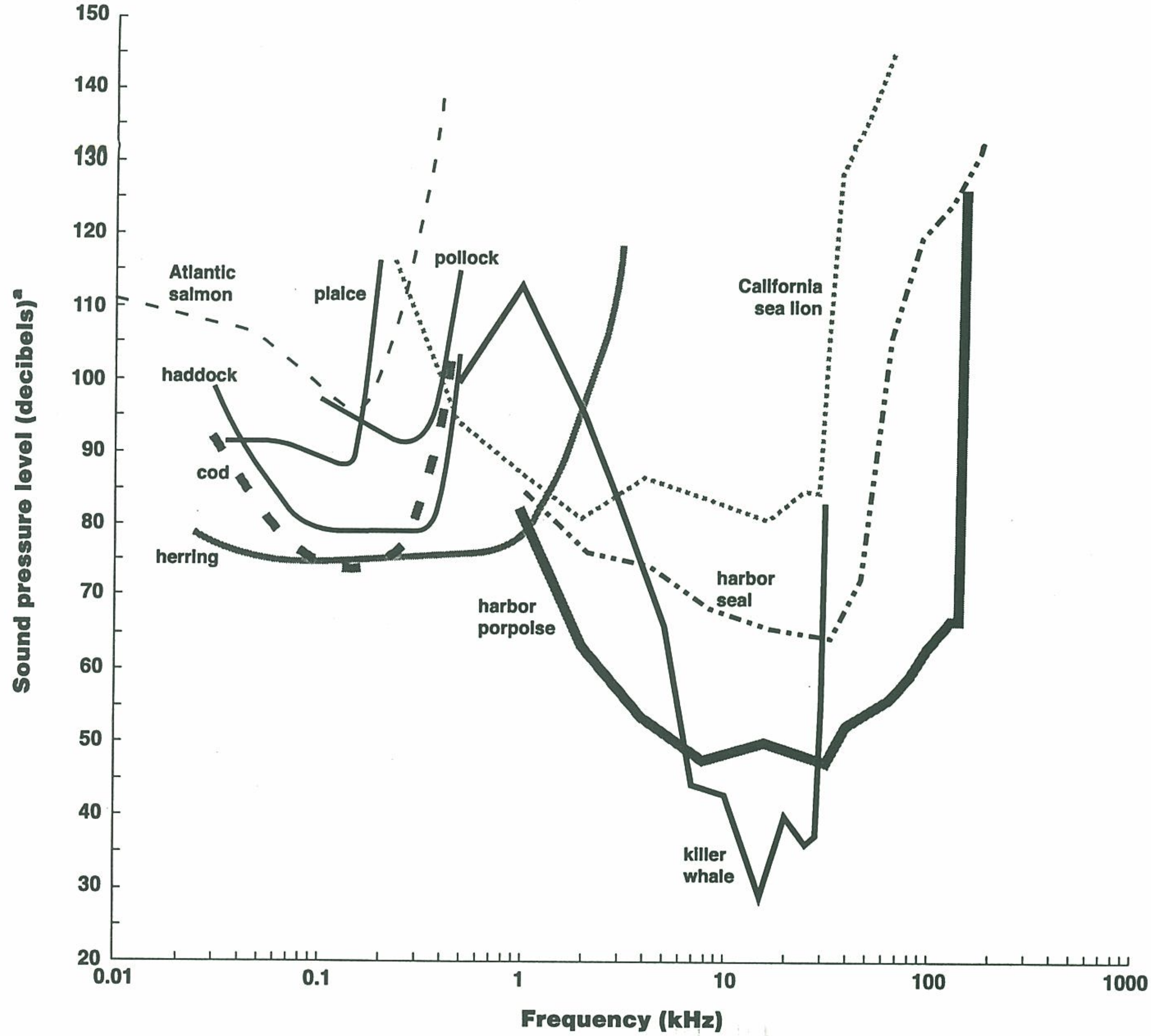
The hearing sensitivity of an animal is represented by an audiogram. An audiogram graphically shows the relationship between pressure and frequency and depicts hearing threshold levels under conditions of low ambient noise. Figure 3-2 shows the audiograms for several fish species and marine mammals. Tables 3-3 and 3-4 present noise levels and behavioral responses of fish and marine mammals to various sounds. For marine mammals, it was assumed that vocalization frequencies translate into frequencies of sensitivity.

Table 3-3. Frequency of greatest sensitivity and vocalization characteristics of several marine mammals that may be found in south central Puget Sound

RECEIVER	$\text{FREQUENCY}_{\text{greatest sensitivity}}$ (kHz)	FREQUENCY RANGE OF VOCALIZATIONS (kHz)	DOMINANT FREQUENCY OF VOCALIZATIONS (kHz)
Gray whale *Eschrichtius robustus*	0.7[a]	20-2,000 (up to 20,000 for calves)	20-800 (up to 4,000 for calves)
Harbor seal *Phoca vitulina*	33	0.5-16	12
Harbor porpoise *Phocoena phocoena*	15	100-160	130
Steller sea lion *Eumetopias jubata*	15[a,b]	–	–
Killer whale *Orcinus orca*	15	0.1-35	1-25
Humpback whale *Megaptera novaeangliae*	–	10-4,000	144-192
Dall's porpoise *Phocoenoides dalli*	–	0.04-12	–

SOURCE: Malme et al. (1989)
NOTE: – - data not available

[a] Value is estimated.
[b] Hearing characteristics of California sea lion used to estimate Steller sea lion.



Note: Threshold stated as sound pressure (decibels with reference to 1μPa) for a frequency range of 0.02 – 1.2 kHz

a Relative to 1μPa

Figure 3-2. Audiograms of several fish and marine mammal species

Table 3-4. Sound levels and behavioral responses of several fish and marine mammal species

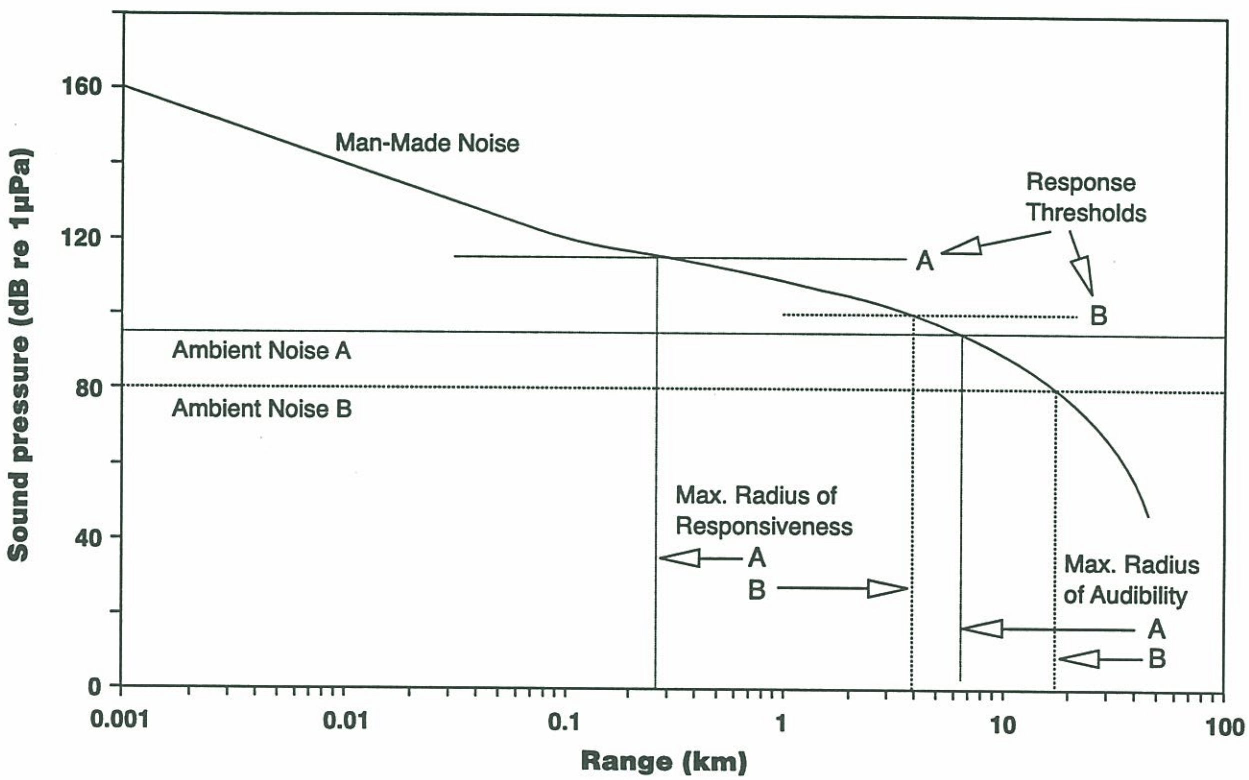
SPECIES	SOUND LEVEL	RESPONSE	REFERENCE
Herring	Approx. 28-34 dB above hearing threshold at 40-250 Hz at ranges between 100 and 200 m	Herring 60-95 feet below echo sounder transducer moved from area	Olsen et al. 1983
	75 dB between 20 Hz and 1.2 kHz	Peak sensitivity of hearing	Mitson 1995
Juvenile spring chinook salmon	10 Hz (5 second duration)	Flight (startle response away from sound) or avoidance No habituation after 20 trials	Knudsen et al. 1997
	30, 60, 180 Hz	Loss of equilibrium, erratic swimming, fish run into one another	VanDerwalker 1967
	70-88 Hz	Escape action, rapid swimming around tank until exhausted	VanDerwalker 1967
	5-280 Hz (strongest response at 35-170 Hz)	Avoidance response; most fish resumed normal distribution after 5 seconds	VanDerwalker 1967
	281-500 Hz	No response	VanDerwalker 1967
Silver salmon (3-5 inches long)	5-20,000 Hz	Initial startle response or quick swimming; reaction more pronounced at lower frequencies	VanDerwalker 1967
	50 Hz-20,000 Hz at intensity levels up to 7200 ubar	No attraction or repulsion to sound; fish elicited startle responses; more pronounced at lower frequencies	Moore and Newman 1956
Atlantic salmon	4dB (125 Hz) and 16 dB (250 Hz) louder than control	In one of three strains of salmon, significantly greater fork length and percent smolting occurred	Terhune et al. 1990
	150-380 Hz	Upper limit of hearing frequencies	Hawkins and Johnstone 1978 as cited in Knudsen et al. 1994
Juvenile Atlantic salmon	5-10 Hz	Most efficient at producing an awareness reaction and avoidance response; may be related to low frequencies often produced by swimming predators	Knudsen et al. 1994
	150 Hz	No repelling effect	
Rockfish	154 dB	Change in movement behavior	Pearson et al. 1992
	168 dB	Change from directed movement to milling	Pearson et al. 1992
	178-207 dB	Alarm behavior; pre-exposure behavior returned within minutes after sound exposure ceased	Pearson et al. 1992
	180 dB	Threshold for avoidance	Pearson et al. 1992
	200-205 dB	Threshold for startle responses	Pearson et al. 1992
	186-191 dB	Elicited changes in swimming and schooling behavior	Skalski et al. 1992
	Fishing vessel	Avoidance reaction by fish 207-265 m deep	Kieser et al. 1992

Table 3-4, continued

SPECIES	SOUND LEVEL	RESPONSE	REFERENCE
	180-191 dB at 6 pulses per min. from an air gun	Significant decline (52.4 percent) in catch-per-unit-effort of rockfish, decrease in aggregation height; assumed behavioral changes caused results	Skalski et al. 1992
Jack mackerel	Research vessel	Reaction distance ranged from 84 m to 341 m at different locations; large schools tended to break in two and pass either side of vessel	Mitson 1995
Sardine	Research vessel, 6.5-8.5 knots	Reaction distance 150-300 m	Diner and Masse 1987 as cited in Mitson 1995
Mackerel	Research vessel, 7 knots	Reaction distance 300-400 m	Diner and Masse 1987 as cited in Mitson 1995
Cod	20 Hz to 300 Hz	Critical frequency band of high sensitivity hearing; peak sensitivity is 75 dB at 100-300 Hz	Mitson 1995
	Threshold exceeded by 30 dB or more	Fish show avoidance reaction at distances 100-200 m up to 400 m	Mitson 1995
California sea lion	Most anthropogenic sounds in ocean	Best adapted to hear in air	Kastak and Schusterman 1998
	Peak sensitivity of 80 dB at about 2 and 16 kHz		Schusterman et al. 1972 as cited in Malme et al. 1989
Harbor seal	100 Hz	About 20 dB more sensitive to 100 Hz signals than California sea lion; more likely to hear low frequency sounds of ships	Kastak and Schusterman 1998
	Low frequency anthropogenic sounds	Potential for masking of intraspecific mating calls, which occur at low frequencies	Hanggi and Schusterman 1994 as cited in Kastak and Schusterman 1998

Effects of Ambient Noise on Sensitivity—Ambient noise represents the portion of the noise spectrum that is present as background levels. Ambient noise is important because it can influence hearing sensitivity to additional noise sources. Three types of underwater noise sources have been classified by Mitson (1995): physical, e.g., breaking waves; biological; and anthropogenic. Figure 3-3 illustrates how a 15-dB increase in ambient noise levels hypothetically decreases the range of responsiveness and audibility (detection) of an animal to anthropogenic noise stimuli. In general, as ambient noise levels increase, the maximum radius of audibility decreases.

Ambient noise conditions off Maury Island have not been measured. The nearshore habitat is a relatively high-energy zone, as indicated by the sandy substrate and open shoreline. Ambient conditions in this area may be estimated from the data presented in



Prepared from Richardson et al. 1995

Figure 3-3. Schematic illustration of a 15 dB change in ambient noise levels on maximum radius of responsiveness and audibility assuming a response occurs when man-made noise levels are at least 20 dB above ambient noise level

Table 3-5, which shows recorded noise levels from tidal action in sandy substrate. Similarly, Stober (1969) measured lake surf beats caused by wave action shifting coarse shore materials, small, loose "rubble," and sand. Frequencies above 5 kHz were attributed to surf beats, and frequencies below 4 kHz were generated by flow noise (from an outlet stream) and bubbles from surface waves. As distance from the shoreline increased, ambient noise levels decreased. Ambient noise levels also depend on propagation and absorption conditions (Mitson 1995). Greater levels of ambient noise are generated in shallow, hard-bottom substrates as compared to fine, silty substrates. Figure 3-4 combines hearing thresholds, ambient conditions, and noise from tugboat and barge combinations. It shows that tugboats and barges will be detected by fish and marine mammals, and noise levels will increase approximately 35 dB (almost 60 times).

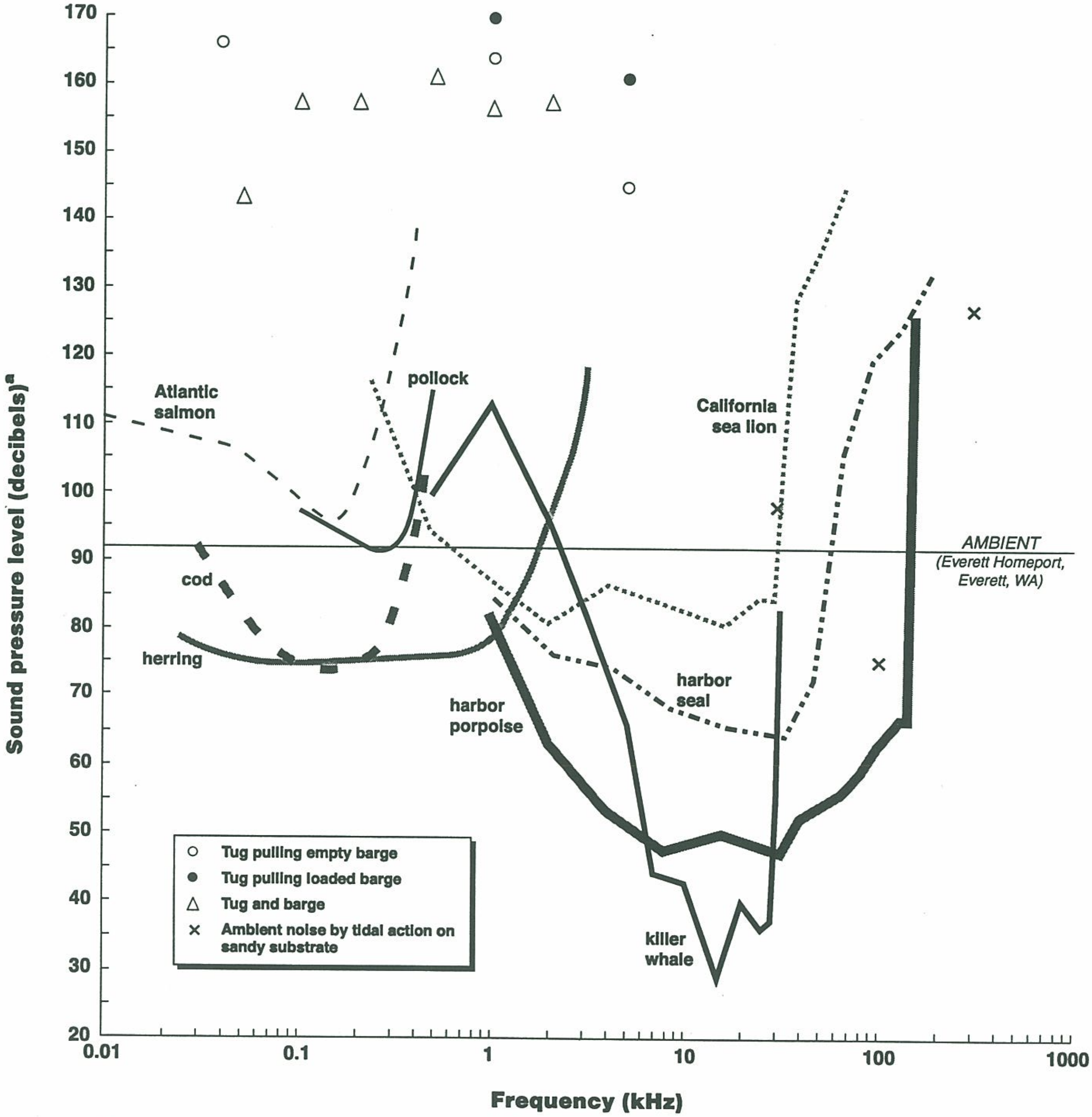
Table 3-5. Noise levels from tidal action on sand ridges

FREQUENCY (kHz)	SOUND PRESSURE (dB re 1μPa at 1 m)
30	98
100	75
300	127

SOURCE: Mitson 1995

Sensitivity of Fish—Industrial activities generate low-frequency noise (<1 kHz) (Malme et al. 1989), and this is within the hearing range of fish (Figure 3-2). In general, salmon are less sensitive to noise than clupeids, which have excellent hearing (Blaxter et al. 1981; Schwarz and Greer 1984; Feist 1991). Audiograms are not available for every fish species that inhabits the site. However, most commercially fished species respond to noise levels exceeding 30 dB (re 1 μPa) above hearing thresholds (Mitson 1995). In addition, fish with swimbladders tend to have better hearing because the organ functions as an amplifier (Mitson 1995). As the size of the swimbladder increases with age, hearing capabilities may also increase because amplification is proportional to the cube of the swimbladder's volume (Mitson 1995). Therefore, audiograms are different between species and possibly between various life stages or ages.

Sensitivity of Marine Mammals—The estimated auditory thresholds for marine mammals (Figure 3-2) in the low-frequency range (< 1 kHz) should be viewed with caution because of the potential interference of holding tanks during measurement (Malme et al. 1989). Frequencies below 1 kHz have not been tested in phocid seals, e.g., harbor seal (Malme et al. 1989). Within the range of frequencies tested, marine mammals are most sensitive above 1 kHz.



[a] Relative to 1μPa

Figure 3-4. Sound pressure level and frequency associated with hearing thresholds of fish and marine mammals, ambient noise levels, and tug and barge combinations.

3.1.3 Effects of Noise

3.1.3.1 Pile-Driving Activities

Hearing thresholds and responses to various noise stimuli are given in Figure 3-2 and Tables 3-4 and 3-5. Noise from pile driving encompasses a range of frequencies detectable by both fish and marine mammals, and broadband, pulsed sounds (such as pile driving) have been shown to be more effective at eliciting a response in fish as compared to continuous, pure tone sounds (reviewed by Feist 1991). Pile driving increased noise levels by 25 dB (re 1 μPa at 593 m [~.5 mi]) above ambient noise levels (Feist 1991). Because every 20 dB increase in sound pressure level increases actual sound pressure tenfold (Feist 1991), the pressure 593 m (1,946 ft)away from pile-driving activities is greater than 10 times the ambient condition. Noise levels closer to the activities are expected to be even greater. This suggests that pile-driving activities would affect fish, especially those with higher sensitivity such as herring.

Feist (1991) investigated the effects of pile driving on juvenile chum and pink salmon at the Everett Homeport, Everett, Washington. Based on behavioral observations, schools of juvenile pink and chum salmon did not show significant changes in behavior with or without pile driving, although fish tended to move toward an acoustically isolated cove. Feist predicted that pile driving would be audible to juvenile salmon more than 300 m (984 ft) from the source, although biological impacts were unclear. Based on salmon hearing thresholds, however, this response may not be indicative of other fish species utilizing the area, which are more sensitive (Figure 3-2). For example, herring spawning activities may be affected by pier reconstruction activities. The Quartermaster Harbor herring stock is one of 18 distinct herring populations in Puget Sound and spawns in Quartermaster Harbor in January through mid-April (Lemberg et al. 1997). A pre-spawning holding area is located approximately 4 km (2.5 mi) south of the mine site. Some research suggests that herring may be most sensitive to noise during the pre-spawning stage and alter their behavior in response to noise (Olsen 1981; Mohr 1964). If noise reaches sufficient levels in the pre-spawning holding area to cause disturbance or avoidance, the spawning success of the stock may decrease. In contrast, some evidence suggests post-spawners are most sensitive (Schwarz and Greer 1984). Post-spawning herring focus their efforts on feeding (O'Toole pers. comm. 1999). In areas with high noise levels, fitness may be decreased because of disruption in feeding activities. Rockfish are expected to avoid the area during pile-driving activities. Pearson et al. (1992) measured avoidance behavior by rockfish aggregated over 200 m (656 ft) deep from sound generated by air guns measured at 180 dB (re 1μPa). Other fish species also would be expected to avoid the area during pile driving.

Although marine mammals would be able to detect pile-driving noise, it is not expected that they would be affected by the temporary increase in noise. Pile-driving activities would likely affect harbor seals if haulout areas were located nearby (Calambokidis 1999). However, there are no harbor seal haulout areas near the Lone Star dock; the nearest haulout is on Gertrude Island several miles away (Jones & Stokes and AR 1999, Calambokidis pers. comm. 1999). Although low frequency sounds may mask intraspecific mating calls (Hanggi and Schusterman 1994), the pulsed short-term nature of pile-driving noise may not be sufficient for this to occur. Also, mating is not known to occur in the vicinity of Maury Island.

Harbor porpoises and killer, gray, minke, and humpback whales are rare in south central Puget Sound (Calambokidis 1999). Therefore, the probability that these marine mammals would be exposed to the pile-driving activity in the 2-to-4-week construction period is low. Even if they were to be exposed, the peak sensitivity and range of vocalization of marine mammals tend to be in the high-frequency range (>10 kHz) (see Table 3-4); and therefore, impacts are expected to be negligible based on available information. Unfortunately, pile-driving sound levels were not recorded in the high-frequency range; the upper limit of recorded frequency was 2 kHz.

Both Dall's porpoise and California sea lions frequent Puget Sound. However, they are not likely to be affected because of the short-term nature of the piling driving and the adaptability of these animals to anthropogenic sounds (Jones & Stokes and AR 1999; Calambokidis 1999).

3.1.3.2 Vessel Traffic and Loading Operations

Vessel activity has been shown to cause a variety of effects in fish and marine mammals, including altered embryonic development (Banner and Hyatt 1973), avoidance (Mohr 1964; FAO 1970; Olsen et al. 1983; Malme et al. 1989), changes in schooling behavior (Schwarz and Greer 1984), and varied respiratory patterns (Malme et al. 1989) (Table 3-4). Vessel noise dominates the 20- to 500-Hz frequency bandwidth and often reaches 1 kHz (Wenz 1962). This is within the hearing range of most fish but not necessarily within the range of marine mammals (Figure 3-2). Therefore, tugboat and barge operations are predicted to affect fish species more than marine mammals.

Docking and barge-loading activities are predicted to have a greater impact on fish and marine mammals as compared to a barge traveling through Puget Sound at a constant speed. This is because the noise from a vessel approaching at constant speed increases in amplitude while frequency remains constant; altering vessel speed changes frequencies (Schwarz and Greer 1984). It is usually abrupt changes in sound frequency or intensity, such as that associated with abrupt changes in vessel speed and direction, that elicit stronger behavioral responses (Schwarz and Greer 1984; Blaxter et al. 1981, Blaxter and Batty 1985). Abrupt changes in tugboat speed and direction are likely to occur during docking activities and possibly during loading. Docking could occur 8 to 40 times per day (see Section 3.1.1.2).

Species sensitivity to tugboat and barge traffic is expected to be ranked in a manner similar to their response to pile driving. For example, juvenile salmon in the area would be less likely than herring to react to the pulsed, changing noise signatures created by tugs maneuvering barges. Increased vessel traffic would increase noise levels at the pre-spawning holding area. It is possible that noise levels may be sufficient to cause disturbance or avoidance by herring and affect spawning success. Rockfish are found in industrial areas throughout Puget Sound. Whether these fish are not sensitive to vessel traffic or habituate to conditions is not clear. Tugboats and barges arriving or departing at constant speeds would be less likely to elicit a behavioral response.

A potential indirect effect of increased vessel traffic on fish and marine mammals is its effect on ambient conditions in Puget Sound. Increases in tugboat and barge traffic would likely increase ambient noise levels. At maximum production rates, 8 to 40 tugboat and barge trips could occur each day. It is not clear at what point ambient noise levels, comprised of natural and anthropogenic sources, reach an intensity that masks auditory functions. For example, vessel noise can mask vocal communication between harbor seal mothers and pups over the ocean surface and limit separation distances, thereby affecting feeding ability (Reiman and Terhune 1993), and the detection of low-frequency sounds is important for predator avoidance in fish (Knudsen et al. 1994).

3.1.4 Conclusions

Noise from pile driving, vessel traffic, and barge-loading activities are expected to be detected by both fish and marine mammals. Various levels of noise have been shown to alter embryonic development (Banner and Hyatt 1973), cause avoidance (Mohr 1964; FAO 1970; Olsen et al. 1983; Malme et al. 1989), change schooling behavior (Schwarz and Greer 1984), and vary respiratory patterns (Malme et al. 1989) (Table 3-2). Pile driving has been recorded at 200 to 2000 Hz, and vessel noise dominates at 20 to 500 Hz, often reaching up to 16 kHz (Wenz 1962). These frequencies are within the hearing range of fish but perhaps less so for marine mammals (Figure 3-2). Marine mammals are not expected to be affected by noise because peak sensitivity is in the high-frequency range (>1kHz). In addition, their presence is more rare in south central Puget Sound. Common species such as harbor seals have no sensitive haulout areas near the dock and, therefore, should not be affected.

Fish species, however, tend to have the greatest sensitivity at low frequencies. Noise generated by dock operations is likely to be detected by fish in the region with varying degrees of sensitivity. For example, herring are much more sensitive to noise than salmon. In addition, herring spawning grounds are located south of the nearshore area of Maury Island. Increased vessel traffic may cause herring to temporarily avoid areas with noisy vessels during pre- or post-spawning activities (Olsen 1981; Mohr 1964; Schwarz and Greer 1984). Pulsed, abrupt noise signatures from changes in vessel speed and direction have been shown to have greater impacts on fish than continuous noise that might be generated by a tugboat and barge moving at constant speed. Docking activities are expected to generate pulsed signatures. Therefore, fish in the immediate vicinity of the dock will be affected by both pile driving and tugboat operations. The underwater sound level of a barge being filled has not been measured. However, this may represent a chronic exposure to noise and cause fish to leave the barge-loading area. The effect on population or ecological dynamics that may result from an individual animal avoiding an area is expected to be negligible. However, fitness of an individual fish is expected to decrease as startle responses and changes in normal activities, such as feeding, increase in association with noise levels from dock activities.

3.2 TURBIDITY

Replacement of dock and dolphin pilings could potentially generate turbidity if bottom sediments were resuspended during sediment disturbance. Driving new pilings into the bottom using an air hammer would disturb sediments in a small area around the piling, while fresh-heading, which involves pulling an existing piling up about 1 to 2 m (3 to 5 ft) and cutting away damaged wood, would also disturb bottom sediments immediately around the piling.

Based on grain sizes for the three sediment samples collected closest to the existing dock (SED-01, -02, and -05; Figure 2-6), sediments in the area are fairly coarse-grained, with some gravel (1 to 15 percent); high percentages of sand (80 to 96 percent); and very low silt and clay fractions (1 to 3 percent, and 1 to 2 percent, respectively). Based on the very low silt and clay content of these sediments, little fine material is available to be resuspended during pile driving and piling removal. As a result, turbidity generation would not be expected to be an adverse impact associated with dock reconstruction.

3.3 HABITAT LOSS

Because the plan for dock and dolphin reconstruction does not involve installation of any additional pilings, no permanent habitat loss would occur. However, positioning of the pile-driver vessel involves the use of two to four anchors. Anchoring in consolidated fine substrates can result in anchor scarring which may persist for several years, depending on resuspension and deposition rates. The sediments near the existing dock and dolphins are generally fine- to coarse-grained sands in which anchor scars would be less likely to persist.

The potential for anchoring to disturb eelgrass beds would depend on which pilings were replaced, and on how far away from the pile-driving vessel the anchors would be placed. Based on Figure 2-6, two eelgrass patches approximately 5 m^2 (54 ft^2) are located within 15 m (50 ft) of a dolphin.

3.4 OIL SPILLS AND LEAKS

No fueling activity would occur at the dock, so the potential for local sea water contamination by petroleum hydrocarbons is limited to spills and leaks of fuel, lubricating oil, or hydraulic oil. The tugboats proposed for use for the Lone Star project would be either 2,000 or 3,000 hp. The 3,000-hp tugboat has a fuel capacity of 80,000 gal, a lubricating oil capacity of 1,000 gal, and a hydraulic oil capacity of 200 gal (R. Summers 1999a).

A worst-case scenario, resulting in a full release of fuel (80,000 gal) as well as other engine fluids, might occur if a tugboat were to collide with the dock. It is beyond the scope of this assessment to provide a full review of the impacts of oil spills in the marine environment, which has been fully reviewed elsewhere (Jewett and Dean 1997; Wells et al. 1995; Rice et al. 1996; U.S. Coast Guard [USCG] et al. 1993). The impacts of oil spills include direct mortality and sublethal effects to fish, invertebrates, birds, and marine mammals.

3.4.1 Description of Tugboat and Barge Operation Impact

Barges would be towed to and from the dock by tugboats equipped with diesel engines of 2,000 or 3,000 hp. A maximum of 40 tugboat movements (20 incoming and 20 departing) would occur daily. Because this activity is not currently occurring at the dock, there are no site-specific measurements of petroleum hydrocarbons, which include PAHs, for marine waters in the project area. Our review of Puget Sound water quality monitoring studies did not produce appropriate measurements of total petroleum hydrocarbons or PAHs in seawater associated with commercial marine traffic. Nor were we able to find measurements of other contaminants, such as hydraulic fluids or lubricants, associated with tugboat operation.

It is likely that in the nearshore project area, which is open and exposed to wave action, longshore currents, and tidal advection, small inputs of petroleum hydrocarbons would be quickly advected from the site, and petroleum hydrocarbons would not be detectable in the water column. The validity of this assumption could be determined easily once project operations were underway by monitoring water quality at the dock. A critical issue related to the potential for adverse impacts to the local biological community would be the concentration and persistence (exposure period) of any contaminant inputs. That is, if petroleum hydrocarbons in project waters were not at high concentrations and remained only for short periods of time, then impacts to the biological community would be unlikely.

3.4.2 Potential Receptors

Potential receptors are benthic organisms listed in Section 2.1 and fish species listed in Section 2.3.1.

3.4.3 Sensitivity of Receptors

Rice et al. (1979) examined the sensitivity of 39 Alaska marine species to crude oil (measured as total aromatics) and determined that Pacific herring was the most sensitive of the species tested, with a 96-hour LC50 of 1 mg/L for herring adults and a 12-day LC50 of 1.5 mg/L for herring eggs. More recently, Carls et al. (1999) determined that herring eggs, exposed during a 16-day incubation period, showed a lowest-observed-effects level of 9.1 μg/L (total aqueous PAHs) for artificially weathered oil. In a study of the sensitivity of pink salmon embryos to weathered crude oil (Heintz et al. 1999), lethal effects were reported for exposure to total aqueous PAHs at 18 μg/L; this result was for a long-term exposure (during a several-month egg incubation period).

Although both studies suggest high sensitivity of salmon and herring embryos to aqueous PAHs, relating these results to marine traffic inputs of petroleum hydrocarbons would require the consideration of both the concentration and the persistence of such inputs in a high-energy environment. Also important would be the type of fuel used in the experiments and the degree of weathering, which may vary from potential fuel inputs resulting from the Lone Star mining operation. Both the Heintz study (Heintz et al. 1999) and the Carls study (Carls et al. 1999) showed that more-weathered oil had different PAH composition than less-weathered oil, resulting in higher toxicity. At the Lone Star dock, petroleum hydrocarbon inputs would likely be unweathered.

Constant water movement at the Lone Star dock would disperse any small inputs of petroleum hydrocarbons, and none would be expected to reach the sediments. Water quality measurements at the dock during operations could be made to confirm this assumption. Unless such measurements indicated that tugboat-related hydrocarbons were persistent at this location, effects due to μg/L concentrations of aqueous PAHs such as those reported by Carls et al. (1999) for herring and by Heintz et al. (1999) for pink salmon would not be expected at this site.

3.5 Propeller Wash Effects

Approaching and departing tugboat and barge combinations will follow an arc-like path relative to the pier face. The depth at the pier face is approximately 7 m (24 ft) MLLW and increases offshore at a ratio of approximately 1 to 5. When lashed to the outer side of a barge at the pier, a tugboat would be in water 9 m (30 ft) deep.

A tugboat's propellers have the potential to resuspend bottom sediments as a result of the generation of propeller jets that locally increase the speed of the water near the bottom.

Maynard (1998) presents a relation between the maximum velocity of a propeller jet and the maximum bottom velocity:

$$V = \frac{CV_oD_p}{Hp}$$

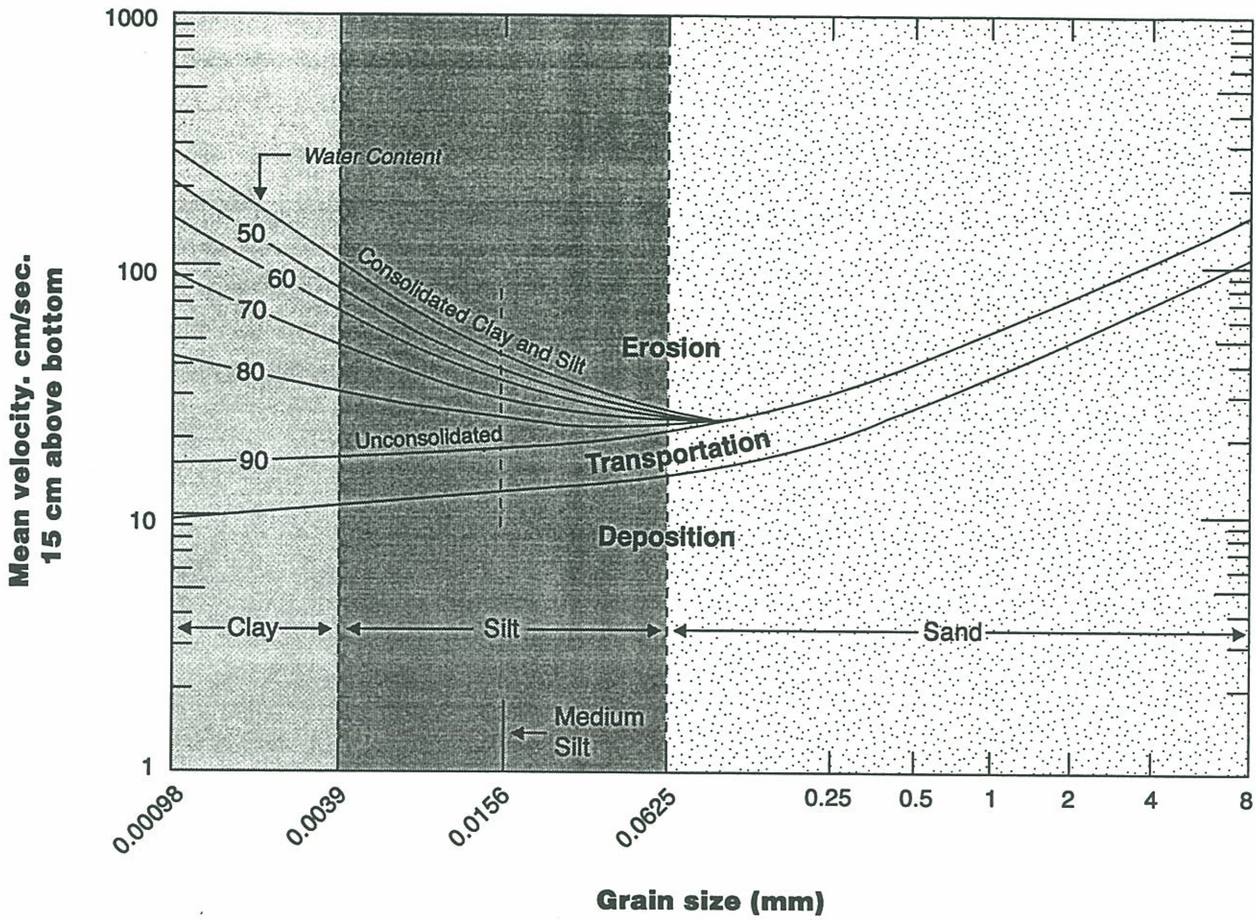
where:

V = maximum induced bottom velocity
C = constant depending upon the propeller/rudder configuration (0.22 for open propeller and single rudder)
V_o = maximum speed of the propeller jet
D_p = diameter of the propeller
H_p = distance from the propeller shaft to the bottom.

Assuming a value of V_o equal to 3 m/s (10 ft/s) relative to the current, a propeller diameter (D_p) of 2 m (7 ft), and a distance (H_p) of 6 m (20 ft) between the propeller shaft and the bottom, the predicted (albeit approximate) maximum bottom velocity would be 26 cm/sec (10 in/sec). Typically, an average speed of approximately 20 to 30 cm/sec (8 to 12 in/sec) near the bottom is necessary to resuspend unconsolidated particles of a size between fine sand and silt (Figure 3-5). According to this rough estimate, bottom velocities induced by the propeller jet would be capable of resuspending bottom sediments in waters immediately adjacent to the loading pier. The potential for propwash to resuspend sediments in deeper waters diminishes in proportion to the increase in depth.

Grain size data obtained from sediment samples obtained near the dock during a recent field survey show that a representative grain size distribution is 3 percent clay and silt, 89 percent sand, and 8 percent gravel and larger (Table 2-3). Bottom sediments near the dock do not contain much fine-fraction material, so little impact would result from its being resuspended by propwash. Once in the water column, the settling velocity of the fine-fraction material is so slow that advection would likely transport it and disperse it away from the resuspension site before any appreciable amount redeposited. Medium sand (settling velocity of approximately 3 cm/sec [0.1 ft/sec]) would likely fall out of the water column within a minute of being resuspended and would not contribute to any long-term turbidity. Fine sand would persist in the water column longer before settling out and would more likely be transported farther than the coarser sand fractions. Coarse sand and larger particles might be moved very locally as bedload along the bottom but would not be resuspended into the water column.

The existing pier lies on a bottom gradient of approximately 1 to 5. Currents tend to be along isobaths, which means that there is very little cross-isobath advection of water, and therefore of any water-borne properties such as suspended sediment. Therefore, even if sediment were resuspended by propeller jets, it would be transported primarily along shore rather than inshore.



Adapted from Paquegnat 1990

Figure 3-5. Current velocities required to transport particulate material

The frequency of tugboat and barge passages to the pier would be at least one barge per day, so there would not be enough time between passages for any additional unconsolidated sediment to accumulate and be available for resuspension. In short, vessel passage would keep the approach and departure corridor cleared of sediment down to the level of consolidated sediments not amenable to resuspension.

In addition to fine sediments, surface organic matter may be resuspended. This could influence the distribution of benthic organisms because it may provide a food source. However, it is assumed that benthos would relocate to areas of sufficient organic matter. A maximum increase in current speed of 26 cm/s (10 in/s) is not predicted to dislodge vegetation. The buffering capacity of vegetation was not included in the model and is likely to reduce resuspension. Eelgrass has been found in currents 1.5 to 2 m/s (10 to 13 ft/s) (Phillips 1994; Fonseca et al. 1983). This speed is two orders of magnitude greater than the predicted bottom current speed generated by a tugboat (26 cm/s or 10 in/s). Macroalgae are also predicted to withstand a bottom current of 26 cm/s.

Fish and marine mammals are not expected to be affected by propeller wash because they can move from the area and the area is not considered critical habitat.

3.6 SHADING AND NIGHT LIGHTING

Ambient light conditions around the dock may be altered by dock operations in two ways: 1) shading by barges, and 2) artificial night lighting and safety lighting. The ecological impact of shading produced by docks and piers on the nearshore community has only recently been investigated. Such structures have been shown to reduce light levels underneath and in the vicinity of the dock. After the light was reduced, alterations in the vegetative community were noted (Fresh et al. 1995; Burdick and Short 1998; Simenstad et al. 1997, 1999).

For this analysis, a barge docked at the Lone Star dock is assumed to function as a modified pier because barge loading may occur 24 hours a day, 7 days a week (Jones & Stokes et al. 1999). Alternatively, loading may occur only 12 hours a day, 5 days a week. However, the barge will still be docked when not being actively loaded; and upon departure, another barge may take its place (Summers 1999b). Table 3-1 shows the dimensions of barges over a range of barge load capacities.

The shade footprint created by a structure (the amount of area with reduced light levels) is important in determining the structure's impact on natural resources. Several parameters have been shown to affect the extent of the footprint: dock height, length, width, and orientation; the spacing between pilings; whether the dock has a floating or fixed structural design; tidal regime; and sun angle (Burdick and Short 1998; Fresh et al. 1995). Barge draft and depth (height above the water line) are characteristics of a barge not found in a dock model, but they are likely to be positively correlated with shading effects.

A light-shading model generated for the Clinton ferry terminal in Clinton, Washington, (Olson et al. 1997) showed shading effects primarily on the northern edges of the pier. The time of year affected the extent of the footprint such that a larger shade footprint was created in December as compared to March or June. In December, the shadow extended approximately 30 m (100 ft), nearly the width of the dock.

By comparison, a 10,000-ton-capacity barge docked at Lone Star has approximately the same width (24 m [80 ft]) and is also oriented in a similar direction. Based on these similarities, a shade footprint is predicted to occur along the northern edge of the barge. This northern edge encompasses nearshore habitat at approximately -6 m (-20 ft) MLLW.

3.6.1 Shading Effects on Eelgrass

Diver surveys (Jones & Stokes et al. 1999; Jones & Stokes and AR 1999) and side-scan sonar data (as detailed in Section 2.0) showed no eelgrass beds immediately below the area where a barge would be docked. Patchy eelgrass at the site was primarily located in depths of -1.5 to -4.5 m (-5 to -15 ft) MLLW, with the deepest eelgrass patch at approximately -5 m (-16 ft) MLLW. During a survey in July and August of 1999, eelgrass density ranged from single plants to 23 shoots per 0.25 sq m (3 sq ft) (Jones & Stokes and AR 1999). The closest eelgrass patches that would be affected by barge shading are two patches underneath the dock (<25 sq ft), surveyed in January 1998, and one patch located alongside the pier in -2 to -3 m (-7 to -10 ft) MLLW surveyed in July and August of 1999 (Jones & Stokes et al. 1999, and Jones & Stokes 1999). It is not clear whether all three patches occur concurrently or if they represent spatial variability over time. Individual shoots were also located just north of the dock in water approximately -20 ft MLLW and the SPI camera recorded the presence of eelgrass shoots at Stations 11 and 22 (Figure 2-6).

The extent of the shade footprint will determine the effect on existing eelgrass beds and individual shoots. The lack of eelgrass beds directly underneath a docked barge decreases the probability of lost eelgrass resources. However, the shadow may extend to the smaller patches of eelgrass plants previously mentioned (Jones & Stokes et al. 1999; Jones & Stokes and AR, 1999). Assuming the shade footprint extends several meters north of the barge, the shading effects produced by a barge may be large enough to alter photosynthetically active radiation (PAR) levels reaching the individual shoots or eelgrass patches located near the docked barge (see Figure 6-2 in Jones & Stokes et al. 1999; Figure 2 in Jones & Stokes and AR 1999; Figure 2-6). If shading to these plants were to be at levels below 300 micromoles per square meter per second ($\mu M/m^2/sec$), the eelgrass would likely become light limited and not survive (Thom and Shreffler 1996). Survivorship may also decrease if the presence of barges results in light levels that are chronically lower but still above the 300 $\mu M/m^2/sec$ threshold. Under these conditions, plants may not be able to accumulate sufficient reserves during summer to use throughout the low-light conditions of winter (Olson et al. 1997; in Simenstad et al. 1997).

Shading effects are predicted to alter light conditions in the vicinity of a barge. Altered light regimes may affect the small eelgrass patches or individual shoots currently established. Shading may also prevent colonization of habitat that could be suitable for larger beds if the presence of eelgrass shoots is indicative of recolonization processes.

3.6.2 Shading Effects on Macroalgae

Although eelgrass was not present at the end of the dock, macroalgae have colonized the area. A diver survey recorded 6 algal taxa, 22 invertebrate species, and 20 fish species along transects in the dock vicinity (Jones & Stokes and AR 1999). At depths of -8 to -9 m (-25 ft to -30 ft) MLLW, *Laminaria, Ulva*, and red algae dominated. *Laminaria saccharina* was common from about -3 to -9 m (-10 to -30 ft) MLLW (the lower limit of the survey). The algal community in the barge loading area was also recorded with the SPI camera at Stations 16 and 17. These stations would be located underneath any of the barges used for loading. Light levels required for *Laminaria saccharina* have been recorded at 0.5 to 1 percent of surface irradiance in coastal water systems (Lüning 1981, in Lee 1989). A barge is predicted to lower light levels in the area and possibly limit the growth of currently distributed macroalgae. If light levels are sufficiently decreased, changes in species richness could occur by creating low-light conditions that would favor deep-water species adapted to these conditions (EVS 1999a).

Macroalgae provide habitat for nearshore organisms. Several species of fish were found to be abundant in *Laminaria*, including flatfish, rockfish, and pile perch (Jones & Stokes and AR 1999). In addition, zones of macroalgae may provide prey resources and refuge to juvenile salmon as they migrate to eelgrass patches in the vicinity. While no eelgrass was present under the barge area, it has been hypothesized that if sufficient prey resources were available under a dock, juvenile salmon might traverse the area between eelgrass beds (Simenstad et al. 1999). A 10,000-ton-capacity barge will cover approximately 2,450 sq m (26,400 sq ft); alteration of light levels is predicted in this area. Impacts to the macroalgal community may indirectly affect the functioning capacity of eelgrass beds by isolating the beds and removing the refuge and prey resources associated with the current habitat. A fundamental basis of landscape ecology is the role of spatial patterns, or proximity of habitat types, to an overall functioning system (Forman and Godron 1986).

3.6.3 Night Lighting Effects on Vegetation

At this time, the effects of artificial light on submerged vegetation cannot be analyzed without further information on the light intensity, placement, and duration of use.

3.6.4 Shading and Night Lighting Effects on Fish

In addition to vegetative impacts, changes in ambient light conditions may influence fish around the dock. Shading produced by barges could affect fish by changing the amount of light available for vision, creating shadow effects in the environment, and altering primary and secondary productivity.

Juvenile salmon have been shown to migrate along dock shadows and natural shadows such as edges of eelgrass beds (Simenstad et al. 1999). Feist (1991) observed juvenile pink and chum salmon swimming near the edges of docks but not going underneath. In a recent study investigating the affects of ferry terminals on salmon migration, chinook fry were released near a ferry dock and their movement was recorded. The migration pattern of the released school did not appear to be disrupted by the dock's shadow line. Fish were observed following the shadow line as it progressed over the course of the day and observed moving from the shadows into lighter areas to feed. Over time, the shadow essentially moved under the dock and the fish were assumed to have moved through to the other side with the shadow (Shreffler and Moursund 1999). It should be noted that this study was limited because of low replication and that general conclusions about the impacts of structures on chinook migration may be premature.

Based on limited information, it appears that for salmon migrating along the coast, the barge could provide a preferred migratory route by creating a shade contrast in the environment. It is not clear whether other species react to shade in the same manner. Marine mammals are not predicted to be influenced by shade, either directly or indirectly, because of the small area affected relative to their distribution.

Barge loading could also generate artificial night lighting through the use of work or safety lights. Little is known about the effects of night lighting on the nearshore community, and this has been identified as an area requiring future research (Simenstad et al. 1999). Chinook salmon typically show nocturnal activity and are negatively phototactic (Simenstad et al. 1999), and rockfish have been shown to be disturbed by artificial light at night (Kieser et al. 1992). Night lighting may deter chinook salmon and rockfish from using the area at night. Effects on other species are uncertain.

A fish's response to changes in light or dark conditions depends on numerous factors, including ambient light conditions, fish species, and fish age. Abrupt changes in light patterns, such as turning on lights in a dark setting or turning off lights abruptly, have greater impacts than do gradual light changes. For example, physiological adaptations in the eyes of chum and pink fry have been timed at 30 to 40 minutes when exposed to a change from light to dark, while for dark-adapted fry, adaptation to increased light requires 20 to 25 minutes (Brett and Ali 1958; Protasov 1970; Simenstad et al. 1999).

The age of a fish can also influence the amount of time required for adaptation to changing light levels. In adult fish, the time to adapt to brighter light stimuli decreases, whereas the time to adapt to darkness increases with age (Simenstad et al. 1999). Therefore, if night lighting were used for barge loading, which is a high probability because loading is proposed to occur 24 hours a day, it could affect fish in the immediate area around the Lone Star dock, especially if light conditions were changed quickly. Abrupt changes in lighting could temporarily hinder the ability of fish to avoid predation or locate prey.

3.7 SAND AND GRAVEL SPILLS AT THE DOCK

A meeting with Washington Department of Ecology, Pacific Groundwater Group, and EVS was held in December 1999 to determine the spill scenarios to be evaluated for the nearshore impact assessment. It was agreed that evaluating the following two scenarios would provide regulators with information about a range of potential impacts from loading operations:

1. A worst-case single event spill, with spillage of an entire load of the maximum size barge at the dock

2. A scenario in which minor spillage (approximately 1 percent) of each load would occur during loading; the evaluation of this scenario would provide insight into potential harm to the benthos of recurring spillage, which could prevent recolonization

3.7.1 Worst-Case Single Event Spill

The area of bottom sediment that potentially would be covered by mine product, primarily coarse sand and gravel, in the event of a spill of a fully loaded, maximum-size barge at the dock is presented in Figure 3-6. The stippled area shown in the figure represents a rough estimate of the spill footprint; this estimate was developed through the application of a computer model combined with best professional judgment (because of limitations associated with the model).

An initial analysis used the computer model STFATE to predict the mounding and spreading of material that would be released if a barge load of material spilled. STFATE is one of the models in the Automated Dredging and Disposal Alternatives Modeling System (ADDAMS) suite of computer programs for investigating impacts of dredging and dredged material disposal (see Appendix C of USEPA and ACOE 1998). STFATE accounts for factors such as current speed, depth to the seabed, and density of seawater at the location of dredge disposal in order to predict the dispersal of dredged material.

However, some limitations exist in the applicability of STFATE to a scenario in which relatively dry material is spilled into seawater from a barge. These limitations include the following:

- STFATE was designed for dredged material, which has a high water content and tends to act as a fluid when released into the sea
- STFATE does not model the larger-sized material, such as cobble, that may be included as part of a sand and gravel shipment from the Lone Star mine
- STFATE uses a single-point source of disposal (in this case, a single-point source of the spill)
- Because of the additional effort required to model the fate of material spilled onto a sloping seabed, the STFATE model was set up for a spill onto a level seabed

Details of the STFATE model as it was set up to predict the footprint of a potential Lone Star sand and gravel spill are provided in Appendix B. The appendix also provides a figure showing the results of the model's output. Briefly, the model predicts that the spill would cover an area of seabed approximately 90 m long by 90 m wide (300 ft long by 300 ft wide) to a depth of 15 cm (6 in.). The spill would be mounded in the center, with an area approximately 26 m (75 ft) in diameter covered to a height of 1 m (3.5 ft).

Best professional judgment was used in translating the STFATE model results to the footprint of the spill, as shown in Figure 3-6. The footprint is roughly oblong-shaped, approximately 122 m long by 91 m wide (400 ft long by 300 ft wide). Because STFATE did not include some of the larger-sized material, we cannot predict the height of the mound. However, it should be noted that, were a spill to result in a very high mound, Lone Star would need to consider recovering much of the material, at a minimum to prevent navigation hazards but also for the economic value of the material itself.

The footprint of the spill is longer (in the direction parallel to the dock and shoreline) than it is wide, corresponding to the shape and size of the barge. Because of the large particle size of most of the load, much of the material would rest immediately beneath the barge. The effect of the nearshore seabed slope would be to minimize the footprint shoreward of the dock, and the center of the footprint would be offset downslope to the southeast. Very little of the barge load is expected to be fine silt or clay (less than 7 percent of the load) which could generate turbidity in the event of a spill; any fine material released from the barge would be advected away.

The footprint of the spill, as shown in Figure 3-6, does not overlay any identified critical marine resources. It would not cover any of the areas of eelgrass that were mapped in

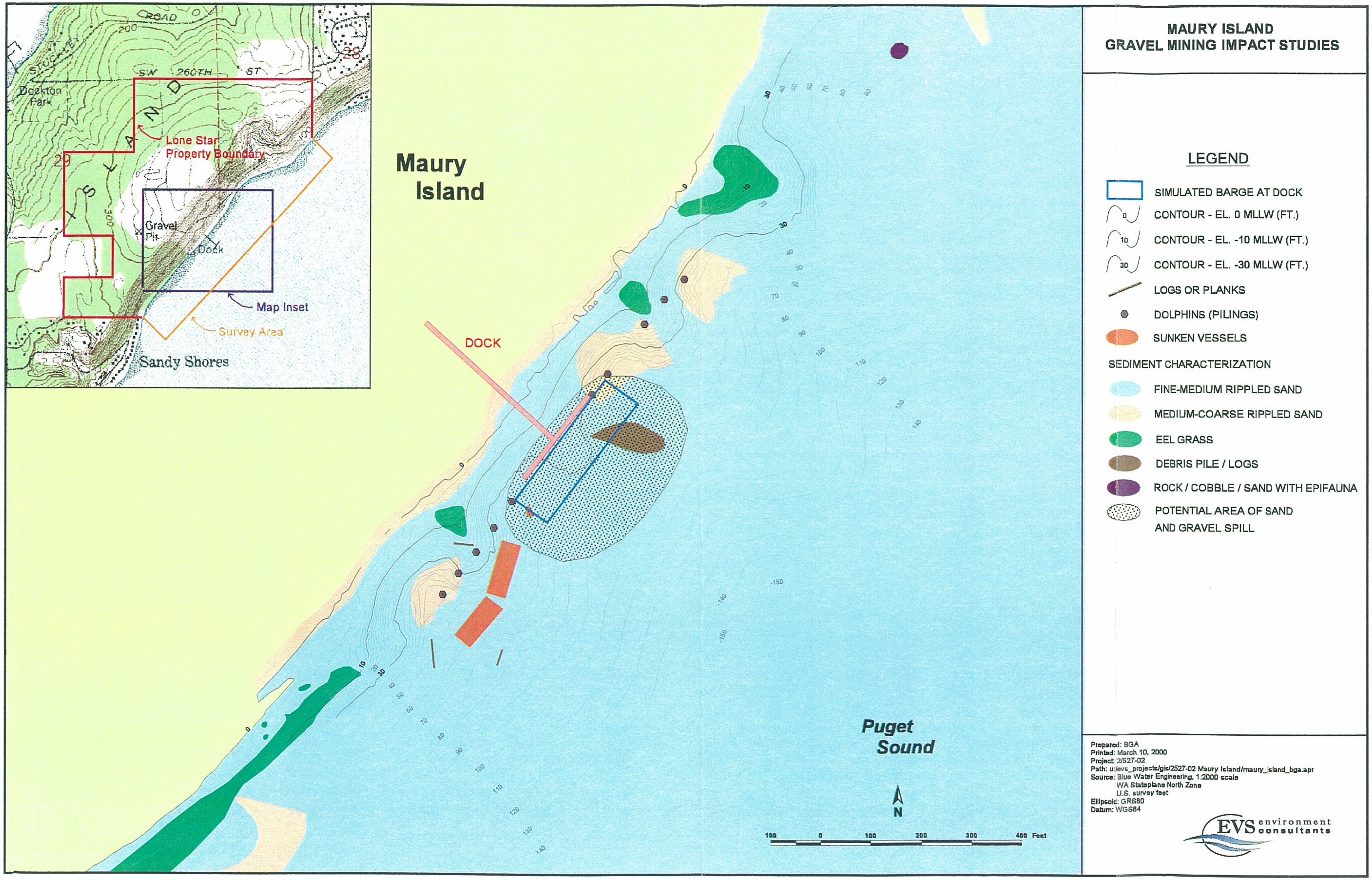


Figure 3-6. Potential area of bottom covered by coarse sand and gravel (worst case spill scenario). See text for explanation.

October 1999. It would cover the entire log and rock debris pile, a small corner of a patch of coarse-grained sediment and the small sunken boat.

The short-term effect of such a spill would be to eliminate the benthic community fish and vegetation in the spill footprint. The benthic organisms occupying this area represent prey for the fish community; therefore, some loss of prey organisms would occur. Because this type of habitat is not expected to be unique among Maury Island nearshore habitats (and it is not unique in the area surveyed), it is not likely that such a loss of prey organisms would have adverse effects on the fish community or even cause them to move away from the nearshore area.

The long-term impact of such a spill would be to shift the type of benthic community occupying this area in the direction of recolonizers appropriate to the grain size of the spill and possibly change vegetation from eelgrass to algae. Table 3-6 provides a comparison of the distribution of grain sizes that were found in the sediments collected near the dock versus the expected grain size distribution of a typical barge load of mine material. Although the size categories are not identical, the overall difference is that greater percentages of coarse sand, gravel, and cobble exist in the barge load than currently exist in the sediments at the dock; the sediments in the nearshore area are generally dominated by fine sand (see also comments in Appendix A, SPI photographs). Following a spill of a full barge load, there would be an overall change in substrate to an area of larger-sized material with more numerous and larger void spaces than currently exists near the dock. Such material could be expected to support a different benthic community, most likely one with greater diversity as a result of the additional cobble substrate. This new substrate could support an epifaunal community as well as small organisms that can hide in or inhabit void spaces. Recolonization of the spill by eelgrass is probably not likely because of the change from sand to coarse sediments. In sum, the long-term effect of a large spill of sand and gravel would likely be adverse for eelgrass but could be slightly beneficial for benthos by providing greater habitat diversity.

Table 3-6. Comparison of sediment grain sizes of nearshore sediments near dock versus gravel mine product

	Near-Dock Sediment Size Distribution		Gravel Mine Product[b] Grain Size Distribution		
Particle Type	Size Range	Percent[a]	Size Range	Screen	Percent
Gravel	2 mm – 256 mm	8	4.75 – 101 mm	#4- 4"	20
Coarse Sand			0.4 – 4.75 mm	<#4	57
Sand/Fine Sand	0.06 – 2 mm	89	0.07 – 0.4 mmg	<#40	23
Silt	0.004 – 0.06	2	<0.07 mm	<#200	7
Clay	< 0.004 mm	1			

[a] Based on mean of SED-01,SED-02, SED-05 (sediment samples collected near dock).
[b] Mine product would be sorted according to customer specifications. This set of specifications is Washington State Dept. of Transportation #9-03.14 (gravel borrow) (R. Summers 1999b).

3.7.2 Small Spills During Loading

Lone Star (Summers 1999b) considers the amount of material lost due to spillage at the dock so minor that they do not attempt to measure it. Windblown material is considered to be the main potential loss of product at the dock. Because such losses represent an economic loss, preventive measures have been taken. These include designing the conveyor so that the product is conveyed to the center of the barge and using barges with walls. In addition, a dock worker is stationed to observe loading, as is the tugboat crew, and personnel are trained to watch for situations in which the barge and conveyor are misaligned.

If small spills were to occur repeatedly during loading at the dock, the effect would be cumulative because the coarse fractions would remain where they fell. The bottom mound would increase in thickness as material accumulated and in breadth as the additional material rolled laterally away from the center of the mound until static stability was reached. If small spills were to occur frequently, finer material that reached the bottom could accumulate before being transported away by the influence of waves and currents. Conversely, infrequent spills would result in little accumulation because there would be sufficient time to transport material away. Whether or not there would be a net accumulation would depend on frequency, volume, and material grain size.

3.8 Piling Installation Effects on Longshore Transport Processes

According to Lone Star (R. Summers 1999a), the basic parameters (configuration) of the dock pilings and dolphins are not expected to change. Therefore, no changes should occur in the longshore transport of sediment as a result of the project.

4.0
CONCLUSIONS

This report provides a baseline characterization of benthic habitat conditions and sediment chemistry in the nearshore subtidal environment adjacent to the Lone Star mine located along the eastern edge of Maury Island. In addition, potential impacts to aquatic resources arising from Lone Star's proposed increase in gravel mining operations have been assessed. The major conclusions reached in this study are summarized below.

4.1 BASELINE CHARACTERIZATION

Several field studies were instigated in the fall of 1999 in order to characterize approximately 16 ha (39 acres) of nearshore environment along the shoreline of Maury Island. Characterizations were accomplished using a precision bathymetric survey, a side-scan sonar survey, a series of sediment profile images (SPI), and the results of chemical analyses from sediment samples.

Bathymetric results indicated that depth increased at a fairly steady rate from the shoreline and reached over 31 m (100 ft) at a distance of 84 m (275 ft) seaward from the center of the dock. A series of submerged beach cusps running perpendicular to the shoreline were detected. These represent a rhythmic shoreline feature common in sand and gravel substrates. The crests of these cusps are regularly spaced, and the Lone Star dock is situated upon a crest.

The side-scan sonar survey characterized a variety of seabed features in the area: several eelgrass beds, sunken barges, patches of coarse-grained sediment, and a patch of debris. Sediments off Maury Island are primarily fine- to coarse-grained sands with some concentrated patches of gravel and cobble or rocky bottom. Approximately 1.0 ha (2.5 ac) of eelgrass was observed. Two major eelgrass beds were located in water depths shallower than 6 m (20 ft), and smaller eelgrass patches were located on either side of the dock.

A total of 39 SPI stations were surveyed. The majority of bottom substrate was rippled medium sand. Penetration into the substrate was fairly shallow (less than 10 cm [4 in.]) because of the high shear strength of sandy sediments. A few isolated stations had deeper penetration, most likely due to bioturbation. Two SPI stations detected eelgrass not detected by side-scan sonar because of low shoot density. Six stations in the vicinity of the dock had surface layers of gravel, possibly indicative of historic gravel mining spills or bluff erosion. However, three stations located away from the dock also had a surface gravel layer.

Analysis of sediment samples revealed coarse-grained, sandy sediments with low organic carbon content (0.14 to 1.9 percent organic carbon). All pesticides, polychlorinated biphenyls (PCB), and three trace metals (arsenic, cadmium, and silver) had chemical concentrations reported as not detected. Concentrations of the remaining trace elements were below corresponding criteria in the Washington State Marine Sediment Quality Standards. Sediment polycyclic aromatic hydrocarbon (PAH) concentrations were low, except at one station where fluoranthene exceeded the marine sediment criterion.

4.2 Assessment of Potential Impacts

Lone Star's proposal to expand the operations at the Maury Island gravel mine would involve reconstructing the existing dock and initiating shipping operations at the dock. Both types of activity could result in environmental impacts to the nearshore area.

The overall assessment of potential impacts to aquatic resources is summarized in Table 4-1. This table summarizes two types of information: first, a subjective assessment of the amount of information (denoted as limited, moderate, or sufficient) that was available for assessing potential impacts; and second, an assessment of potential population impacts (denoted as negligible, moderate, or substantial) to categories of aquatic resources within the study area. Both types of assessments were made for the stressors associated with pier reconstruction activities and barge operations.

The confidence with which potential impacts can be assessed is dependent upon the quantity and quality of information available. The determination of information sufficiency was a subjective decision that considered: 1) the specificity with which the changes in the nearshore environment associated with the proposed nearshore mining operations could be characterized, 2) the amount of site-specific information available to characterize the presence of aquatic species and their use of the habitat, and 3) the amount of information available in the scientific literature on threshold responses to stressors associated with dock and shipping operations. The information evaluated for assessing potential impacts included: 1) baseline habitat and sediment chemistry data collected during this study; 2) descriptions of proposed dock and shipping operations described in the draft environmental impact statement (DEIS) for Maury Island Lone Star Gravel Mine (Jones & Stokes et al. 1999) and provided by Lone Star representatives, 3) an eelgrass and macroalgae survey (Jones & Stokes and AR 1999), 4) information obtained through interviews with state and federal agency staff, and 5) a review of relevant scientific literature (EVS 1999b).

Table 4-1 shows that, for most stressors and aquatic resource categories, the amount of information for assessing impacts was deemed to be moderate or sufficient. The stressor categories for which limited information was available for assessing impacts were light shading and exposure to night lights. For both of these latter stressor categories, some uncertainty exists regarding exposure concentrations that would result from the dock and shipping operations, and, more importantly, very little scientific data exist on how populations of natural resources would react to these stressors.

Table 4-1. Assessment of potential impacts to aquatic resources

Activity/Stressor	Benthic Community Info	Benthic Community Impact	Vegetation Info	Vegetation Impact	Salmonids (threatened/ endangered) Info	Salmonids (threatened/ endangered) Impact	Herring (candidate species) Info	Herring (candidate species) Impact	Rockfish (candidate species) Info	Rockfish (candidate species) Impact	Cod-like Fish (candidate species) Info	Cod-like Fish (candidate species) Impact	Other Fish Species Info	Other Fish Species Impact	Marine Mammals Info	Marine Mammals Impact
Pier Reconstruction																
Noise	—	—	—	—	◍	△	◍	△–▲	◍	△	◍	△	○	△	◍	△
Turbidity	●	△	◍	△	●	△	●	△	●	△	●	△	●	△	◍	△
Habitat Loss	●	△	●	△	●	△	●	△	●	△	●	△	●	△	●	△
Barge Operations																
Noise	—	—	—	—	◍	△	◍	△–▲	◍	△	◍	△	◍	△	◍	△
Chemicals-chronic	◍	△	—	—	◍	△	◍	△	◍	△	◍	△	◍	△	◍	△
Propeller wash	◍	△	○	△	◍	△	◍	△	◍	△	◍	△	◍	△	●	△
Light shading	—	—	◍	◬	○	△	○	△	○	△	○	△	○	△	○	△
Gravel spills	●	◬	●	◬	◍	△	◍	△	◍	△	◍	△	◍	△	◍	△
Night lighting	—	—	—	—	○	△	○	△	○	△	○	△	○	△	—	—

Information available to support decision:

○ limited information

◍ moderate information

● sufficient information

— out of scope

Estimated population impact:

△ negligible impact

◬ moderate impact

▲ substantial impact

Table 4-1 (actually a figure; see Kimberly)

Three categories have been used to denote potential impacts to populations or communities of aquatic resources. A designation of negligible impact indicates that, based on the available information, it was the judgment of the authors that no long-term measurable change in the viability of the population resulting from exposure to a stressor would occur. A designation of moderate impact is provided where it is believed that measurable changes to the population may occur and that these changes may reduce the long-term abundance or spatial distribution, but not the population viability, of the aquatic resource in the study area adjacent to Maury Island. A designation of substantial impact is reserved for impacts that may threaten the viability of the aquatic resource in the study area. The permanent avoidance of the study area or elimination of a type of habitat are examples of impacts that would be classified as substantial.

4.2.1 Pier Reconstruction

The existing Lone Star dock would require repairs to support the proposed expansion of gravel mining and barge transport of product. These repairs would include:
1) reinstallation of the conveyor loading equipment; 2) replacement of approximately 30 pilings; and 3) replacement of approximately 25 percent of the existing dock's decking, stringers, and supports (Jones & Stokes 1999b). The installation of the conveyor equipment is estimated to take 15 days, while the replacement of pilings and decking is estimated to take between 14 and 28 days. Reconstruction activities would require use of a pile-driving vessel, which would be positioned with anchors. Timber pilings would be installed with an air hammer. These short-term reconstruction activities could result in impacts to nearshore marine resources due to:

- Increased noise associated with use of the air hammer
- Increased turbidity resulting from resuspension of sediments during installation and removal of piling
- Bottom habitat loss resulting from the installation of new pilings or associated with anchor scarring

Table 4-1 shows that, with the possible exception of impacts to the Quartermaster Harbor herring stock, the impacts resulting from these activities are not expected to result in any long-term measurable change in aquatic resources within the study area. The increased noise and activity during construction may result in some avoidance by marine species; however, the overall impact to aquatic populations is expected to be negligible.

Impacts to the herring population from noise associated with pier reconstruction were classified as negligible to substantial because the likelihood of construction impacts is dependant on the time of year. Herring are sensitive to noise, and evidence suggests that pre-spawning and post-spawning life history stages are most sensitive (Mohr 1964; Olsen 1981; Schwarz and Greer 1984). The Quartermaster Harbor herring stock, one of the

18 distinct herring populations in Puget Sound, spawns in Quartermaster Harbor between January and mid-April (Lemberg et al. 1997). Prior to the onset of spawning, adults congregate in holding areas off the mouth of Quartermaster Harbor to the southeastern portion of Maury Island. The distance from the mine site to the holding area is approximately 4 km (2.5 miles). If noise were to reach sufficient levels in the pre-spawning holding area to cause disturbance or avoidance, herring spawning success could decrease substantially. Although pier reconstruction represents a relatively short time frame, it could encompass approximately 30 percent of the spawning season for herring. Potential impacts to the Quartermaster Harbor herring stock could be mitigated by scheduling reconstruction activities to occur prior to or after the spawning season. If reconstruction activities did not occur during January through April, the impacts to this population would be judged to be negligible.

4.2.2 Barge Operations

The proposed expansion of gravel mining and the transport of product by barge would result in increased vessel traffic as tugboats brought in empty barges and departed with full barges. Shipping operations at the dock could potentially occur 365 days a year, 24 hours a day. Vessel traffic would include up to 40 docking and undocking movements of a tugboat and barge combination per day if small barges were used and up to 8 docking and undocking movements per day if large barges were used. Vessel and gravel loading operations could affect nearshore marine resources due to:

- Increased noise from vessels and dock loading operations
- Potential contamination of the water column resulting from spills or leaks of marine engine fuels, hydraulic fluids, or lubricants
- Propeller wash effects on bottom sediments
- Increased shading of the water column and bottom substrate by barges
- Use of dock lights at night
- Spills of sand and gravel

4.2.2.1 Noise

With the exception of herring, long-term impacts from noise that would occur with increased vessel traffic and dock loading operations are assumed to be negligible. Other species of fish and mammals are expected to be able to detect the noise generated from increased vessel traffic and dock-loading operations because the dominant frequencies of sound generated by vessels, 20 to 500 Hz, are within the hearing range of fish and mammals. Pulsed, abrupt noise signatures from abrupt changes in vessel speed and direction have been shown to have greater impacts on fish than continuous noise levels.

Docking activities are expected to generate pulsed signatures that could result in avoidance responses by fish and mammals in the vicinity of the dock. The effect of these responses on the long-term viability of fish and mammal populations along eastern Maury Island cannot be predicted with certainty; however, it is assumed that it would be negligible.

Herring are sensitive to noise, and evidence suggests that pre-spawning and post-spawning life history stages are most sensitive. The expansion of mining operations would substantially increase vessel traffic in the vicinity of Maury Island. Depending on the travel route and destination of the barges, noise levels could increase within the pre-spawning holding area or post-spawning feeding grounds, affecting spawning success and feeding success, respectively. Tugboat maneuvers at the dock would generate noise signatures with abrupt changes in frequency and intensity that are more likely to disrupt fish than continuous noise. Therefore, if herring spawn in the study area, noise levels could disrupt spawning activities. If spawning were limited to Quartermaster Harbor, noise levels could still affect herring in the northeast portion of the pre-spawning holding area.

4.2.2.2 Chronic Exposure to Chemical Contaminants

Occasional accidental spills and leaks of fuel, lubricating oil, and hydraulic oil in the vicinity of the dock could release petroleum hydrocarbons into receiving waters. It is likely that in the nearshore study area, which is open and exposed to wave action, longshore currents, and tidal advection, small inputs of petroleum hydrocarbons would be quickly advected from the site and diluted. Impacts on aquatic resources resulting from occasional small quantity releases of petroleum hydrocarbons are assumed to be negligible.

4.2.2.3 Propeller Wash

The maximum bottom current speed generated by a tugboat propeller in 6 m (20 ft) of water was estimated at 26 cm/s (10 in/s). While this velocity can resuspend fine sand and silt fractions, it is not likely to resuspend the coarser grain sizes dominating the study area. The organic matter within the upper boundary of substrate could also be resuspended. This is often a food source for benthic organisms. However, the impact of propeller wash on the benthic population within the study area was estimated as negligible because benthic organisms are assumed to relocate to areas with sufficient organic matter for food. Additionally, the influence of overlying vegetation, mucus tubes, etc. may decrease the actual amount of resuspension by protecting the benthic boundary layer and by consolidating grains. The impact on the vegetative community was also estimated as negligible. Eelgrass has been shown to survive in current speeds from 1.5 to 2 m/s (10-13 ft/s) (Phillips 1984; Fonseca et al. 1983). This is approximately two orders of magnitude greater than the current speed generated by the propeller. Macroalgae are also predicted to withstand currents of 26 cm/s (10 in/s), even if the velocity accelerated rapidly, which would be characteristic of propeller wash. Fish and marine mammals are predicted to avoid the propeller area, and therefore, impact to these populations is also estimated as negligible.

4.2.2.4 Light Shading

The estimated population impact of light shading by barges on eelgrass and macroalgae was predicted to be moderate. The extent of the shade footprint could reach currently distributed eelgrass patches as well as the macroalgae within the barge vicinity. Dock shading has been shown to change the vegetative community by favoring deeper-water species more tolerant of low-light conditions (EVS 1999a; Simenstad et al. 1997). Shading could also prevent colonization of sandy substrate by eelgrass. Individual shoots have been identified in the region estimated to be shaded by the barge. If the shoots are indicative of colonization processes, decreased light conditions may prevent further colonization. Overall, the spatial distribution of vegetation types around the barge-loading area could be altered, and, therefore, a moderate impact is estimated. Impacts on fish and marine mammals are estimated as negligible because the shaded area is not considered critical habitat and because the mobility of these organisms enables them to find other vegetated patches and avoid shaded environments.

4.2.2.5 Night Lighting

The estimated population impact on various fish species from night lighting is estimated as negligible. Because the area around the dock is not considered critical habitat for any fish species, fish that would be disturbed by artificial night lighting are predicted to leave the area. Abrupt changes in lighting conditions (turning lights on and off during the night) would be more likely to disturb local fish as compared to gradual changes in light levels. This is because ambient conditions influence lighting effects (Simenstad et al. 1999). Mitigation for localized impacts could include a gradual artificial lighting schedule and possibly low-lighting conditions when barges were not being loaded at night.

4.2.2.6 Gravel Spills

Gravel spills are estimated to moderately affect both the benthic and vegetative communities. A large, catastrophic spill comprised primarily of gravel and sand would smother benthos and vegetation within the spill footprint. Although the benthic community could recolonize the area, the short-term effect would be the mortality of benthos. If the spill were to occur over a vegetated patch, it would likely affect the spatial distribution of vegetation in the study area. Eelgrass is found in sandy substrate but is less likely to colonize a gravel area. A gravel spill could change the area from an eelgrass bed to one dominated by periphyton and algae.

Recolonization of a gravel spill area by benthic organisms would be expected to occur. Therefore, fish should be able to feed in the area, and the diversity of prey organisms could even increase because of increased substrate diversity. Marine mammals do not feed exclusively in the region and do not feed on benthos. Therefore, both fish and marine mammal populations would be expected to experience negligible impacts from gravel spills.

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REFERENCES

AES. 1998. Existing conditions, impacts, and mitigations for marine fisheries. Maury Island pit barge loading facility, King County, Washington. Prepared for Lone Star Northwest, Inc. Prepared by Associated Earth Sciences, Inc., Kirkland, WA.

Banner, A. and M. Hyatt. 1973. Effects of noise on eggs and larvae of two estuarine fishes. Trans. Amer. Fish. Soc. 1:134-136.

Bargmann, G.G. 1984. Recreational diving in the State of Washington and the associated harvest of food fish and shellfish. Technical Report No. 82. Washington Department of Fisheries, Olympia, WA.

Blaxter, J.S., J.B. Gray, and E.J. Denton. 1981. Sound and startle responses in herring shoals. J. Mar. Biol. Ass. U.K. 61:851-869.

Blaxter, J.S. and R.S. Batty. 1985. The development of startle responses in herring larvae. J. Mar. Biol. Ass. U.K. 65:737-750.

Brett, J.R. and M.A. Ali. 1958. Some observations on the structure and photomechanical responses of the Pacific salmon retina. J. Fish. Res. Board Can. 15:815-829. In: Impacts of ferry terminals on juvenile salmon migrating along Puget Sound shorelines, Phase I: Synthesis of State of Knowledge. C.A. Simenstad, B.J. Nightingale, R.M. Thom, and D.K. Shreffler (eds). Research Report WA-RD 472.1. prepared for Washington State Transportation Commission, Department of Transportation, Olympia, Washington, June 1999.

Buck, B.M. and D.A. Chalfant. 1972. Deep water narrowband radiated noise measurement of merchant ships. Delco TR72-28. Report From Delco Electronics Santa Barbara, CA, for U.S. Navy Office of Naval Research., Arlington, VA. 30 pp. In: Marine mammals and noise. W.J. Richardson, C.R. Greene Jr., C.I Malme, and D.H. Thomson (eds). Academic Press, San Diego, CA.

Burdick, D.M. and F.T. Short. 1998. Dock design with the environment in mind: minimizing dock impacts to eelgrass habitats. An interactive CD-ROM published by the University of New Hampshire, Durham, NH.

Calambokidis, J. 1999. Personal communication (telephone conversation with J. Haddad, EVS Environment Consultants, Seattle, WA, on November 11, 1999, regarding marine mammals in lower Puget Sound). Senior Research Biologist, Cascadia Research, Olympia, WA.

Carls, M.G., S.D. Rice, and J.E. Hose. 1999. Sensitivity of fish embryos to weathered crude oil: Part I. Low-level exposure during incubation causes malformations, genetic damage, and mortality in larval Pacific herring *(Clupea pallasi).* Environ. Toxicol. Chem. 18 (3):481-493.

Diner, K. and J. Masse. 1987. Fish school behavior during echo survey observed by acoustic devices. ICES C.M. 1987/B:30, 41 pp.

Eschmeyer, W.N., E.S. Herald, and H. Hammann. 1983. A field guide to Pacific coast fishes of North America from the Gulf of Alaska to Baja California. Houghton Mifflin Co, Boston, MA.

Evans-Hamilton and D.R. Systems, Inc. 1987. Puget Sound Environmental Atlas. Prepared for U.S. Environmental Protection Agency, 1987-1992. Evans-Hamilton, Seattle, WA.

EVS. 1999a. Cherry Point screening level ecological risk assessment. Prepared for the State of Washington Department of Natural Resources, Olympia, WA. EVS Environment Consultants, Inc., Seattle, WA.

EVS. 1999b. Maury Island gravel mining project technical memorandum: Literature review for nearshore impact assessment. Prepared for Pacific Groundwater Group, Seattle, WA. EVS Environment Consultants, Inc., Seattle WA.

FAO. 1970. Report on a meeting for consultations on underwater noise. Rome, Italy, 17-19 Dec. 1968. FAO Fish. Rep 76. 32 pp.

Feist, B.E. 1991. Potential impacts of pile driving on juvenile pink (*Oncorhynchus gorbuscha*) and chum (*O. keta*) salmon behavior and distribution. Master of Science Thesis. University of Washington, Seattle, WA.

Fonseca, M.S., W.J. Kenworth, and G. W. Thayer. 1998. Guidelines for the conservation and restoration of seagrasses in the United States and adjacent waters. NOAA Coastal Ocean Program Decision Analysis Series No. 12. NOAA Coastal Ocean Office, Silver Spring, MD. 222 pp.

Fonseca, M.S., J.C. Zieman, G.W. Thayer, and J.S. Fisher. 1983. The role of current velocity in structuring eelgrass (*Zostera marina* L.) meadows. Est. Coastal Shelf Sci. 17:367-380.

Forman, R.T.T. and M. Godron. 1986. Landscape ecology. John Wiley and Sons, New York, NY. 430 pp.

Fresh, K.L., B. Williams and D. Pentilla. 1995. Overwater structures and impacts on eelgrass (*Zostera marina*) in Puget Sound. pp 537-543. In: Puget Sound Water

Quality Authority, Puget Sound Research '95: Proceedings of conference held from January 12-14, 1995, in Bellevue, WA. Puget Sound Water Quality Authority, Olympia, WA.

Guza, R.T. and D.L. Inman. 1975. Edge waves and beach cusps. Journal of Geophysical Research 80: 2997-3012.

Hanggi, E.B., and R.J. Schusterman. 1994. Underwater acoustic displays and individual variation in male harbour seals, *Phoca vitulina*. Animal Beh. 48:1275-1283.

Hart, J.L. 1973. Pacific fishes of Canada. Fisheries Research Board of Canada, Ottawa, Ontario.

Hawkins, A.D. 1993. Underwater sound and fish behavior. P. 126-16. In: T.J. Pitcher (ed.), Behavior of teleost fishes. 2nd edition. Chapman and Hall.

Hawkins, A.D. and A.D.F. Johnstone. 1978. The hearing of the Atlantic salmon, *Salmo salar*. J. Fish Biol. 13:655-673.

Heintz, R.A., J.W. Short, and S.D. Rice. 1999. Sensitivity of fish embryos to weathered crude oil: Part II. Increased mortality of pink salmon *(Oncorhynchus gorbuscha)* embryos incubating downstream from weathered Exxon Valdez crude oil. Environ. Toxicol. Chem. 18(3):494-503.

Jewett, S.C. and T.A. Dean. 1997. Exxon Valdez oil spill restoration project final report: The effects of the Exxon Valdez oil spill on eelgrass communities in Prince William Sound, Alaska, 1990-1995. Restoration project 95106, final report, May 1997. Alaska Department of Fish and Game, Habitat and Restoration Division, Anchorage, AK.

Jones & Stokes and AR. 1999. Eelgrass/macroalgae survey report. Lone Star Gravel Mine. Maury Island, Washington. August 31. (JSA 98-306-001). Prepared for King County Department of Development and Environmental Services, Renton, WA. Prepared by Jones & Stokes Associates, Inc. in association with Aquatic Research, Olympia, WA.

Jones & Stokes, Terra Associates, and M.R. Stearns. 1999. Draft environmental impact statement (DEIS). Maury Island Lone Star Gravel Mine. Prepared for King County Department of Development and Environmental Services, Renton, WA. Jones & Stokes Associates, Inc., Terra Associates, Inc., and M.R. Stearns Planning and Design, Bellevue, WA.

Kastak, D. and R.J. Schesterman. 1998. Low-frequency amphibious hearing in pinnipeds: Methods, measurements, noise, and ecology. J. Acoust. Soc. Am. 103(4):2216-2228.

Kieser, R., B.M. Leaman, P.K. Withler, and R.D. Stanley. 1992. W.E. RICKER and EASTWARD HO cruise to study the effect of trawling on rockfish behavior, October 15-27, 1990. Can. Manuscr. Rep. Fish. Aquat. Sci. 1261. 84 pp.

Knudsen, F.R., P.S. Enger, and O. Sand. 1994. Avoidance responses to low frequency sound in downstream migrating Atlantic salmon smolt, *Salmo salar*. J. Fish Biol. 45:227-233.

Knudsen, F.R., C.B. Schreck, S.M. Knapp, P.S. Enger, and O. Sand. 1997. Infrasound produces flight and avoidance responses in Pacific juvenile salmon. J. Fish Biol. 51:824-829.

Komar, P.D. 1998. Beach processes and sedimentation. 2nd edition. Prentice-Hall, Inc., Upper Saddle River, NJ.

Lee, R.E. 1989. Phycology. 2nd edition. Cambridge University Press, New York, NY.

Lemberg, N.A., M.F. O'Toole, D.E. Penttila, and K.C. Stick. 1997. Washington Department of Fish and Wildlife, 1996 forage fish stock status report. Stock Status Report No. 98-1. Washington Department of Fish and Wildlife. Olympia, WA.

Lüning, K. 1981. Light. In: The biology of seaweeds. (C.S. Lobban and M.J. Wynne, eds). pp 326-355. University of California Press, Berkeley, CA.

Malme, C.I., P.R. Miles, G.S. Miller, W.J. Richardson, and D.G. Roseneau. 1989. Analysis and ranking of the acoustic disturbance potential of petroleum industry activities and other sources of noise in the environment of marine mammals in Alaska. OCS/MMS-89/0006. 307 pp.

Mathews, S.B., and M.W. Barker. 1983. Movements of rockfish tagged in northern Puget Sound. Fish. Bull. 81(4):916-922.

Maynard, S.T. 1998. Bottom shear stress from propeller jets. Conference proceedings - Ports '98, Long Beach California, M.A. Kraman (ed.), American Society of Civil Engineers.

Meyer, J.H., T.A. Pierce, and S.B. Pathan. 1980. Distribution and food habits of juvenile salmonids in the Duwamish estuary, Washington. FAO Report. U.S. Fish and Wildlife Service, Olympia, WA.

Miles, P.R., C.I. Malme, and W.J. Richardson. 1987. Prediction of drilling site-specific interaction of industrial acoustic stimuli and endangered whales in the Alaskan Beaufort Sea. BBN Rep. 6509; OCS Study MMS 87-0084. Report from BBN Labs Inc., Cambridge, MA, and LGL Ltd., King City, Ont., for U.S. Minerals

Manage. Service, Anchorage, AK. pp. 341. In: Marine mammals and noise. W.J. Richardson, C.R. Greene Jr., C.I Malme, and D.H. Thomson (eds). NTIS PB88-158498. Academic Press, San Diego, CA.

Mitson, R.B. (ed). 1995. Underwater Noise of Research Vessels: Review and Recommendations. Cooperative Research Report No. 209. International Council for the Exploration of the Sea, Copenhagen, Denmark.

Miyamoto, J., T. Deming, and D. Thayer. 1980. Estuarine residency and habitat utilization by juvenile anadromous salmonids within Commencement Bay, Tacoma, Washington. Technical Report No. 80-1. Puyallup Tribal Fisheries Division, Tacoma, WA.

Mohr, H. 1964. Reactions of herring to fishing gear reveled by echo-sounding. In: Modern Fishing Gear of the World. H. Kristjonsson (ed.). Fishing News (Books) Ltd. 2:253-257.

Moore, H.L. and H.W. Newman. 1956. Effects of sound waves on young salmon. U.S. Fish and Wildlife Service, Spec. Sci Rep. Fish. 172:1-19.

Nikolaev, A.S. 1982. Migration of adult pink salmon in Debroe Nacholo Bay. J. Ichthyol. 22(5):143-152.

Oliver, J.S. and P.N. Slattery. 1976. Effects of dredging and disposal on some benthos at Monterey Bay, California. Prepared for U.S. Army, Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir VA. 83 pp.

Olsen, K. 1981. The significance of fish behavior in the evaluation of hydroacoustic survey data. Coun. Meet. Int. Coun. Explor. Sea (B:22):1-25. (Mimeo.)

Olsen, K., et al. 1983. Observed fish reactions to a surveying vessel with special reference to herring, cod, capelin and polar fish. In: O. Nakken and S.C. Venema. Symp. on Fisheries Acoustics, Bergen, Norway. FAO Fish Rep 300:131-138.

Olson, A.M., S. Visconty, B. Witherspoon III, K. Sweeny, R.M. Thom, and D.K. Shreffler. 1997. Light environment and eelgrass shading around three WSDOT ferry terminals. pp 71-101. In: Simenstad, C.A., R.M. Thom, and A.M. Olsen (eds). Mitigation between regional transportation needs and preservation of eelgrass beds, Volume. 1. Research Report WA-RD 421.1. Prepared for Washington State Transportation Commission, Department of Transportation, Olympia, WA.

O'Toole, M. 1999. Personal communication (telephone conversation with J. Starkes, EVS Environment Consultants, Inc., Seattle, WA, on April 6, 1999). Fisheries biologist, Washington State Department of Fish and Wildlife, Marine Resources Division, LaConner, WA.

Palsson, W.A. 1990. Pacific cod (*Gadus macrocephalus*) in Puget Sound and adjacent waters: biology and stock assessment. Technical Report No. 112 Washington Department of Fisheries, Olympia, WA.

Palsson, W.A., J.C. Hoeman, G.G. Bargmann, and D.E. Day. 1997. State of Washington, 1995 status of Puget Sound bottomfish stocks (revised). Report No. MRD97-03. Washington Department of Fish and Wildlife, Olympia, WA.

Pearson, W.H., J.R. Skalski, and C.I. Malme. 1992. Effects of sound from a geophysical survey device on behavior of captive rockfish (*Sebastes* spp.). Can. J. Fish Aquat. Sci 49:1343-1356.

Protasov, V.R. 1970. Vision and near orientation of fish. Israel program for scientific translations, Jerusalem. pp.175. In: Impacts of ferry terminals on juvenile salmon migrating along Puget Sound shorelines, Phase I: Synthesis of state of knowledge. Simenstad, C.A., B.J. Nightingale, R.M. Thom, and D.K. Shreffler. (eds). Research Report WA-RD 472.1. Prepared for Washington State Transportation Commission, Department of Transportation, Olympia, WA, June 1999.

Puget Sound Estuary Program. 1992. The 1992 Puget Sound environmental atlas update. Prepared for Puget Sound Estuary Program by Puget Sound Water Quality Authority and Department of Natural Resources, Division of Aquatic Lands, Seattle, WA

Reiman, A.J., and J.M. Terhune. 1993. The maximum range of vocal communication in air between a harbor seal (*Phoca vitulina*) pup and its mother. Mar. Mamm. Sci 9(2):182-189.

Rice, S.D., A. Moles, and J.F. Karinen. 1979. Sensitivity of 19 Alaska marine species to Cook Inlet crude oil and No. 2 fuel oil. In: Proceedings of the 1979 Oil Spill Conference (Prevention, Behavior, Control, Cleanup), March 19-21, 1979, Los Angeles, CA. American Petroleum Institute, Washington, DC. pp. 549-554.

Rice, S.D., R.B. Spies, D.A. Wolfe, and B.A. Wright. 1996. Proceedings of the Exxon Valdez oil spill symposium. American Fisheries Society Symposium 18, held at Anchorage Alaska, 2-5 February 1993. American Fisheries Society, Bethesda, MD.

Richardson, J.W., C.R. Green, Jr., C.I. Malme, and D.H. Thomson. 1995. Marine mammals and noise. Academic Press, New York, NY.

Schreffler, D.K. and R.A. Moursund. 1999. Impacts of ferry terminals on juvenile salmon migrating along Puget Sound shorelines. Phase II: Field studies at Port Townsend Ferry Terminal. Washington State Transportation Commission, Department of Transportation, Olympia, WA.

Schusterman, R.J., R.F. Balliet, and J. Nixon. 1972. Underwater audiogram of the California sea lion by the conditioned vocalization technique. J. Exp. Anal. Behav. 17:339-350.

Schwarz, A.L. and G.L. Greer. 1984. Responses of Pacific herring, *Clupea harengus pallasi*, to some underwater sounds. Can. J. Fish. Aquat. Sci. 41:1183-1192.

Shepard, M.F. 1981. Status and review of the knowledge pertaining to the estuarine habitat requirements and life history of chum and chinook salmon juveniles in Puget Sound. Final report. Washington Cooperative Fisheries Unit, University of Washington, Seattle, WA.

Simenstad, C.A., R.M. Thom, and A.M. Olson. 1997. Mitigation between regional transportation needs and preservation of eelgrass beds (Volume I). Final report prepared for Washington State Transportation Commission, Department of Transportation. WA-RD 421.1.

Simenstad, C.A., B.J. Nightingale, R.M. Thom, and D.K. Shreffler. 1999. Impacts of ferry terminals on juvenile salmon migrating along Puget Sound shorelines, Phase I: Synthesis of state of knowledge. Research Report WA-RD 472.1. Prepared for Washington State Transportation Commission, Department of Transportation, Olympia, WA.

Sizemore, B., A. Bradbury, and L. MacGregor. 1998. State of Washington 1998 geoduck atlas. Atlas of major geoduck tracts of Puget Sound. Washington Department of Fish and Wildlife. Olympia, WA.

Skalski, J.R., W.H. Pearson, and C.I. Malme. 1992. Effects of sounds from a geophysical survey device on catch-per-unit-effort in a hook-and-line fishery for rockfish (*Sebastes* spp.). Can. J. Fish. Aquat. Sci 49:1357-1365.

Stober, Q.T. 1969. Underwater noise spectra, fish sounds and response to low frequencies of cutthroat trout (*Salmo clarki*) with reference to orientation and homing in Yellowstone Lake. Trans. Am. Fish Soc. 4:652-663.

Summers, R. 1999a. Personal communication (facsimile from Ronald E. Summers, General Manager Aggregates, to D. Garland, Department of Ecology, Bellevue, WA, Oct. 19, 1999, regarding changes in basic dock parameters; tugboat specifications; and barge specifications). Lone Star Northwest, Inc., Seattle, WA

Summers, R. 1999b. Personal communication (telephone call from Ronald E. Summers, General Manager Aggregates, to J. Haddad, environmental scientist, EVS Consultants, November 29, 1999, regarding potential for spillage of full loads of gravel and potential for small continuous spillage at the dock). Lone Star Northwest, Inc., Seattle, WA

Thom, R.M., and D.K. Shreffler. 1996. Eelgrass meadows near ferry terminals in Puget Sound. Characterization of assemblages and mitigation impacts. Battelle Marine Science Laboratory, Sequim, WA. In: Impacts of ferry terminals on juvenile salmon migrating along Puget Sound shorelines, Phase I: Synthesis of state of knowledge. Simenstad, C.A., B.J. Nightingale, R.M. Thom, and D.K. Shreffler. (eds). Research Report WA-RD 472.1. Prepared for Washington State Transportation Commission, Department of Transportation, Olympia, WA, June 1999.

Terhune, J.M., G.W. Friars, J.K. Bailey, and F.M. O'Flynn. 1990. Noise levels may influence Atlantic salmon smolting rates in tanks. Brief Communications. J. Fish Biol. 37:185-187.

USCG, API, and USEPA. 1993. Proceedings. 1993 International oil spill conference (prevention, preparedness, response). March 29-April 1, 1993, Tampa, FL. Sponsored by U.S. Coast Guard, American Petroleum Institute, and U.S. Environmental Protection Agency. American Petroleum Institute publication No. 4580. Port City Press, Baltimore, MD. 898 pp.

USEPA. 1975. Noise emission standards for construction equipment, background document for portable air compressors. EPA 550/9-76-004. U.S. Environmental Protection Agency, Washington, DC.

USEPA and ACOE. 1998. Evaluation of dredged material proposed for discharge in waters of the U.S. - testing manual. Inland Testing Manual. EPA-823-B-98-004 U.S. Environmental Protection Agency, Office of Water, Washington, DC, and U.S. Army Corps of Engineers, Washington, DC.

VanDerwalker, J.G. 1967. Response of salmonids to low frequency sound. pp. 45-58. Im: Marine Bio-Acoustics, Volume 2 (W.N. Tavolga, ed. Pergamon Press, Oxford.

WDFW. 2000. Personal communication (letter to D. Garland, Washington Department of Ecology dated February 15, 2000, comment letter regarding the Maury Island Gravel Mining Project; draft February 2000 impact assessment report prepared by EVS Environment Consultants). P. Erstad, Washington Department of Fish and Wildlife, Region 4 Office, Mill Creek, WA.

WDFW. WDFW Field Reports. Unpublished annual field reports. Herring spawn surveys, Quartermaster Harbor, WA.

Wells, P.G., J.N. Butler, and J.S. Hughes (eds). 1995. Exxon Valdez oil spill: Fate and effects in Alaskan waters. STP 1219. ASTM Publication Code No. 04-012190-16. American Society for Testing and Materials, Philadelphia, PA.

Wenz, G.M. 1962. Acoustic ambient noise in the ocean: spectra and sources. J. Acoust. Soc. Am. 34(12):1936-1956.

APPENDIX A

Interpretation of Maury Island Sediment Profile Images

Table A-1. Maury Island SPI

STATION	GRAIN SIZE MAJOR MODE	EELGRASS?	COMMENT
1	Medium Sand	no	Well-sorted medium to fine sands with low shear strength
2	Fine Sand	no	Small sand ripples present
3	Fine Sand	no	1 cm penetration, small twigs/debris on sed. surface
4	Medium Sand	no	Rippled sand bottom
5	Medium Sand	no	Rippled sand bottom, shallow water, biogenic BR
6	Fine Sand	no	8-10 cm layer of wood chips, twigs; sea lettuce present
7	Very Fine Sand	no	Shallow penetration, large starfish, some rocks, brittle star
8	Very Fine Sand	no	Large starfish, poorly sorted, fine sand, shell hash & pebbles, twigs, land-based debris
9	Fine Sand	no	Some evidence of fine-grained (silt-clay) present as minor mode
10	Very Fine Sand	YES	Errant macrofaunal burrow at depth
11	Fine Sand	YES	Eelgrass & sea lettuce present, high zooplankton density above boundary layer
12	Fine Sand	no	Sea lettuce & twigs on surface, and leaf litter mixed in sand at depth
13	Fine Sand	no	Shallow penetration, sea lettuce, twigs on surface
14	Very Fine Sand	no	Armored shell lag surface with twigs and some gravel pieces
15	Very Fine Sand	no	Large pieces of wood on sediment surface
16	IND	no	Hard bottom - large rock, macrophytes
17	Pebble/cobble	no	Hard bottom - gravel, barnacles & kelp
18	Medium Sand	no	15 cm penetration - dilated sands -- probably bivalve bed
19	Gravel layer over Very Fine Sand	no	Gravel layer on top of fine sands, barnacles/bryozoans on rocks
20	Gravel layer over Very Fine Sand	no	Pea gravel layer on top of fine sands
21	IND	no	Gravel, mussels, & shell lag with starfish feeding on bivalves
22	Fine Sand	YES	Sea lettuce present
23	Very Fine Sand	no	Hermit crab, squid eggs, Ulva, dead eelgrass in sand
24	Fine Sand	no	Ornamented tubes projecting out of surface (Diopatra?)
25	IND	no	Thick shell layer on surface
26	IND	no	Poorly sorted gravel, wood, & fine sand -- no

Table A-1, continued

STATION	GRAIN SIZE MAJOR MODE	EELGRASS?	COMMENT
			penetration
27	Very Fine Sand	YES	Well-sorted fine sand with dense eelgrass
28	Very Fine Sand	YES	Piece of rusting metal on surface, sparse eelgrass in background
29	Fine Sand	no	Well-sorted fine sand
30	Fine Sand	no	Well-sorted fine sand
31	Fine Sand	no	Well-sorted fine sand
32	Medium Sand	no	Medium sand, leaf litter & Ulva on surface, sands dilated
33	Gravel layer over Very Fine Sand	no	Gravel & twigs on surface
34	Very Fine Sand	no	Low penetration; tubes projecting above S/W interface
35	Very Fine Sand	YES	Dense eelgrass
36	IND	YES	Dense eelgrass, sea lettuce & leaf litter
37	Very Fine Sand	possibly	Dilated sands, sparse eelgrass possibly in background
38	Very Fine Sand	no	Some gravel with shells & sea lettuce on surface
39	Very Fine Sand	no	Mono-layer of gravel and shell valves - gravel looks like fairly recent deposit

APPENDIX B

STFATE Modeling of Sand and Gravel Spill

STFATE MODELING OF SAND AND GRAVEL SPILL

A computer program, STFATE, was used to model the mounding and spreading of material that would be released if a barge load of material spilled. STFATE is one of the models in the Automated Dredging and Disposal Alternatives Modeling System (ADDAMS) suite of computer programs for investigating impacts of dredging and dredged material disposal (Appendix C of USEPA/ACOE 1998). For this application, the event was modeled as a disposal event lasting 5 seconds for release of the entire barge load of material. As discussed elsewhere, there are some limitations in the applicability of STFATE to modeling a spill of dry sand and gravel into a nearshore area. These limitations are:

- STFATE was designed to be applied to dredged material, which because of its water content acts as a fluid when released from a barge into the sea; in contrast, a spill of dry sand and gravel has a lower water content

- STFATE does not model the larger-size (cobble) material that may be included in a load of sand and gravel

- Because of additional effort that would be required to model the fate of material onto a sloping seabed, the STFATE model was set up for a spill onto a level seabed

The model grid was a rectangle 550 m (1,800 ft) long and 180 m (600 ft) wide, and the grid cells were 15 m (50 ft) long and 6 m (20 ft) wide. For simplification in applying the model, the depth was assumed a constant 9 m (30 ft) over the entire grid.

STFATE incorporates site-specific oceanographic data into its simulation of movement and dispersion of discharged material. Because no direct current measurements were available for the area of operations, current speed over the majority of the water column was taken as approximately the maximum estimated tidal current obtained from a monitoring station in Colvos Passage on the west side of Vashon Island. The direction of the current was chosen to be aligned with the longer dimension of the model grid. Speed near the bottom was reduced by a factor of 6 to address bottom boundary layer effects. Choosing the maximum speed yields a scenario in which movement and dispersion can be expected to be greatest. A two-layer density profile reflecting typical values was also chosen, although this particular application of STFATE is not sensitive to the magnitude of the vertical density profile. Table B-1 lists depth, current speed, water column density, and bottom roughness height used for the modeling.

Table B-1. Input data for STFATE application to a gravel barge spill scenario

PARAMETER (Units)	VALUE	SOURCE
Water depth (ft)	30	Bathymetric survey
Roughness height (ft)	0.005	STFATE guidance manual[a]
Slope (degrees)	0	default
Density profile (g/cc)	1.014 at 0 ft 1.018 at 30 ft	representative values for the area
Current profile (fps)	3 at 0 ft 3 at 25 ft 0.5 at 29 ft	Max. tidal current, bottom boundary reduction
Length of barge (ft)	330	R. Summers, pers. comm. 1999a
Width of barge (ft)	80	R. Summers, pers. comm. 1999a
Pre-disposal draft of barge (ft)	16.5	R. Summers, pers. comm. 1999a
Post-disposal draft of barge (ft)	4.5	R. Summers, pers. comm. 1999a
Time required for dumping (s)	5	Assumption for modeling
Vessel velocity (fps)	1	R. Summers, pers. comm. 1999a
Volume of dredged material (cy)	7,500	R. Summers, pers. comm. 1999a
Types of material	silt, med. sand, gravel, void[b]	
Volume fraction for each type	0.04, 0.14, 0.42, 0.40	R. Summers, pers. comm.

[a] USEPA/ACOE 1998

[b] In the formulation of STFATE, void space is assumed to be filled by water.

Three different sizes of barges may be used to transport material: 2,000 ton, 4,000 ton, and 10,000 ton. To address a maximum-impact scenario, the largest barge size was chosen. Table B-1 also lists details of the barge and the discharge operation used in the model.

To address the differences between using STFATE to simulate the discharge of dry terrestrial material rather than wet, dredged material, several assumptions were made in characterizing the material. The typical size composition of the dry material is 7 percent material finer than 62.5 microns in size, 23 percent fine to medium sand, 50 percent medium sand to gravel, and 20 percent greater than approximately 5 mm in size (R. Summers, pers. comm. 1999b). The moisture content of the dry material, typically 5 percent, was ignored. STFATE requires grain-size information in terms of volume fraction rather than weight percent. The size fractions chosen to represent the material in STFATE for modeling purposes were silt, medium sand, and gravel. Particle settling speeds were chosen from the range offered by STFATE for each size class.

The estimated bulk density of the material is approximately 1,600 kg/cu m (2,700 lb per cubic yard [cy]), which translates into approximately 1.6 gm/cm^3 (Summers pers. comm.

1999b). The approximate density of the solid material is 2.7 gm/cm^3. As a rough approximation, the volume fraction of each model size category was assumed equal to the weight percent. To adjust the volume fraction of the combined size categories to yield a bulk density of 1.6 gm/cm^3 (i.e. 2,700 lb/cy), the weight percent of each was multiplied by 1.6/2.7. Void space in the combined material was then assumed to provide the additional volume necessary for 2,700 lb of combined material to occupy a total volume of 1 cy. Table B-1 lists the volume fractions of the material determined in this way.

MODEL RESULTS

Figure B-1 shows the thickness contours predicted by the model. The shape of the contours reflects an inherent feature of STFATE, namely that the program assumes discharge from a point source. Thus, the contours near the specified discharge point are nearly circular and concentric. If STFATE accounted for the shape of the barge, the contours near the discharge point would be elongated and oriented similar to the barge. For reference, if the barge were circular and had the same area as a 100 m × 24 m (330 ft × 80-ft) shape, the outer edge would nearly coincide with the 0.6-m (2.0-ft) thickness contour.

The model predicted a maximum thickness of 2 m (3.5 ft) of material at the discharge point specified in the simulation. The gravel fraction accounted for approximately 80 percent of this thickness. The maximum contribution of silt to total thickness is less than 0.02 ft over the entire simulation grid. In the downstream (along flow) direction, the thickness decreases to approximately 21 cm (0.7 ft) at a distance of 61 m (200 ft) and 6 cm (0.2 ft) at a distance of 91 m (300 ft) from the discharge point. Sand provides the largest contribution to thickness farther than approximately 61 m (200 ft) downstream of the discharge point, which is a reflection of the influence of advection. In the direction perpendicular to the flow, the thickness decreases to approximately 0.3 ft at a distance of 200 ft from the discharge point.

It is likely that the actual footprint from a spill would be smaller than predicted by STFATE. One reason is that predictions by STFATE incorporate a dynamic spreading algorithm that assumes gravitational forcing of sediment that is already fluidized in the barge. Discharged dry material would not be expected to spread in the same way because the frictional resistance of the dry material is greater than that of the discharged dense sediment and water mixture. Dry material would likely spread less upon encountering the bottom. It is also likely that much of the material contained in a barge that sank would remain confined by the barge rather than all being released to the water column.

After a spill event, natural processes will continue to redistribute the sand and finer material fractions just as those same processes work the existing bottom sediments of

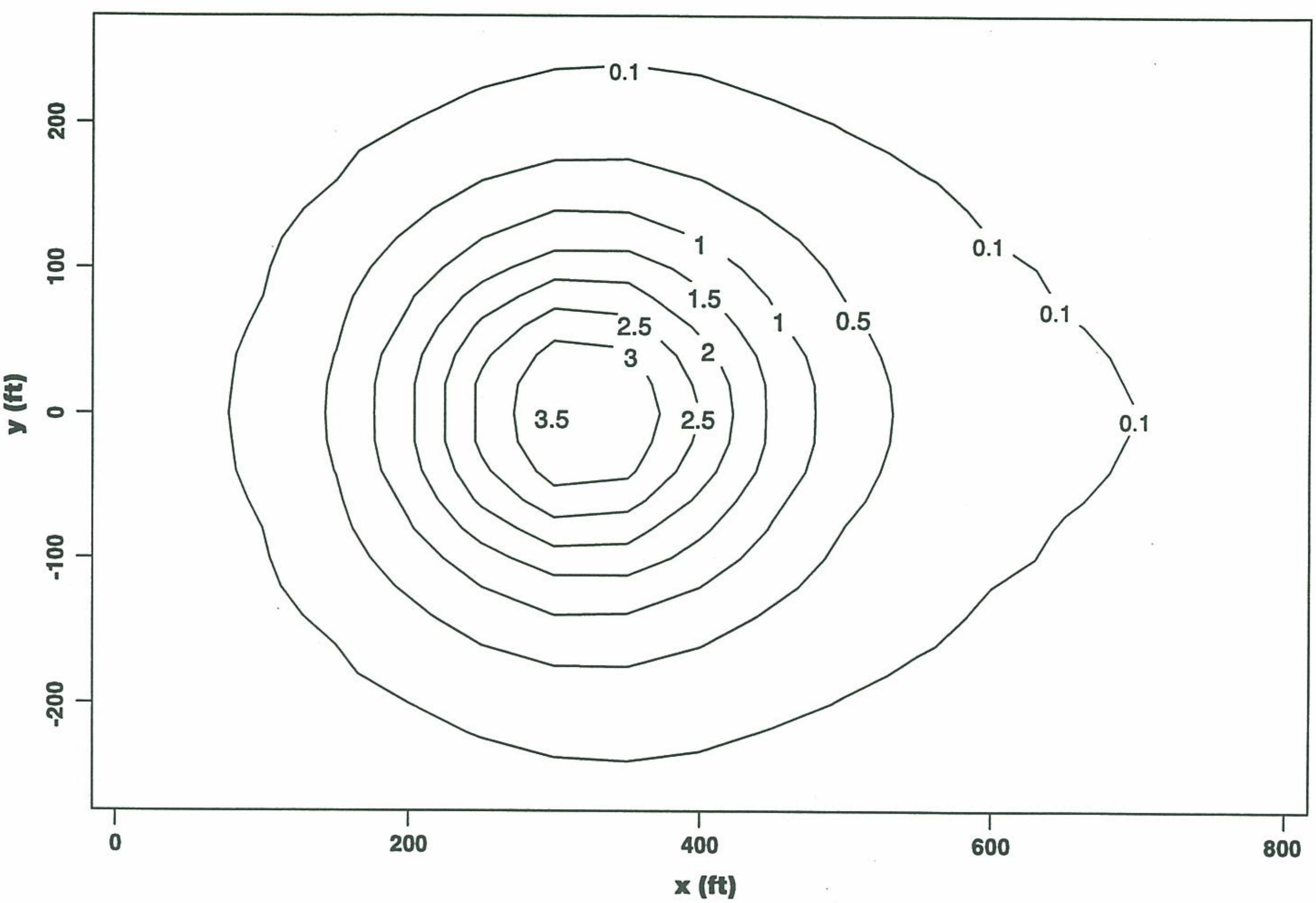

Figure B-1. Predicted footprint area and height of spill (units in feet) of coarse sand and gravel from full loaded, 10,0000-ton barge

comparable size. The coarser fractions that include granules, pebbles, cobbles and larger rocks will remain mounded at the spill site and may facilitate the retention of finer-grain material in the voids. Thus, little likelihood exists of the mound of coarse material dissipating after it has settled onto the bottom.

To maintain a simple scenario, the effects of sloping bottom were not modeled. Inserting a bottom slope greatly increases the amount of time to set up the model. The effect of a sloping bottom would be to direct spreading preferentially downhill, and the thickness distribution of spilled material would thus be skewed toward thicker values downhill of the discharge point.

According to model results, the most likely source of impact away from the immediate location of the spill will be the fine-to-medium sands that can be advected along in the water column before settling out downstream or be transported along the bottom as bedload. The coarser fractions remain near the discharge point, and the finer fractions (silt, clay) have insufficient volumes to have much effect.

Appendix C
Wetland Sampling Report

Appendix D
Photographs of Trails Being Capped Per USFS Guidelines

Appendix D

Photographs of Trails Being Capped Per USFS Guidelines

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EXAMPLE OF TRAIL CAP CONSTRUCTION

April 24, 2015

Photograph No. 1

Photograph Location:
Island Center Forest

Description: Typical forested footpath.

April 24, 2015

Photograph No. 2

Photograph Location:
Island Center Forest

Description: Typical forested footpath ready for gravel cap. Note the large tree roots.

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EXAMPLE OF TRAIL CAP CONSTRUCTION

Undated

Photograph No. 3

Photographed Location:
Island Center Forest

Description:
Hauling in 2-4 inch rock

Undated

Photograph No. 4

Photographed Location:
Island Center Forest

Description:
Placement of 2-4 inch rock

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EXAMPLE OF TRAIL CAP CONSTRUCTION

Undated

Photograph No. 5

Photograph Location:
Island Center Forest

Description: Trail under construction. The 2-4 inch rock used as the base with the 5/8-inch minus gravel surfacing. Gravel brought in using the power carrier shown.

April 24, 2015

Photograph No. 6

Photograph Location:
Island Center Forest

Description: Completed trail showing the crown.

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EXAMPLE OF TRAIL CAP CONSTRUCTION

April 24, 2015

Photograph No. 7

Photograph Location:
Island Center Forest

Description: Completed capped trail.

April 24, 2015

Photograph No. 8

Photograph Location:
Island Center Forest

Description: Completed capped trail showing a small water diversion.

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Appendix E

Alternatives 1 through 5 Conceptual Cost Estimates

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Table E-1

Assumptions and Clarifications Used to Develop Cost Estimates

Maury Island Open Space Property FS

Maury Island, Washington

General

1) Construction Estimate is in current dollars and does not account for cost escalation
2) Unit costs are based on local rates as of June 2015
3) Costs exclude the additional costs of a new Ecology Agreed Order (estimated Ecology costs are similar to what would be expected under a VCP cleanup)
4) Field labor at $100/hr, 10-hr days, $125 per diem while overseeing earthmoving; $50/day travel expense when overseeing work 2/week
5) Existing concrete slabs that may be encountered will remain (will not be broken up and/or removed).
6) Vegetation is sufficiently small in size that is can be tracked over with a bulldozer or excavator (no logging)
7) No additional surface water management is needed; incident precipitation will be allowed to infiltrate in place
8) Decontamination for onsite disposal option, because of limited water, will consist of "dry brushing" and limited pressure washing using water trailer
9) A 25% contingency is added to all options

Soil Excavation and Handling

11) Waste soil transport must use Washington Ferry (Vashon/Fauntleroy assumed)
12) Earthwork is based on deploying earthmoving equipment to the site
13) The durations are based on general production rates
14) The duration of the off-site disposal option is driven by limitations on the number of trucks that can reasonably transport waste soil to Seattle
15) A water truck will be deployed for the months required for excavation for dust control
16) Site earth work is assumed to occur in late Spring through early autumn

Trail Construction

17) Options are based on varying degrees of trail work, including soil removal, soil mixing, gravel capping, and new trail construction
18) Gravel trail costs estimated based on King County Parks experience
19) Trails are assumed to be 4 feet wide

Operation and Maintenance

20) To maintain revegetated areas, 3 years of maintenance is priced
21) Trail/parking lot maintenance (beyond routine for any non-cleanup site) is priced to occur every 5 years and is roughly proportional to the trail area
22) Reports to Ecology every 5 years

Table E-2

Alternative 1 - Construction Estimate

Maury Island Open Space Property FS

Maury Island, Washington

Estimated field duration:	3 months active site; 7 months hauling and trails
Project Name:	Maury Island Cleanup - Engineers Estimate
Location:	Maury Island, Washington
Date:	4/10/2017
Contractor:	
Prepared By:	David Dinkuhn, P.E.
Approved By:	

Rev: 2

Item #	Item Description	Quantity	Unit	Unit Price	Total
	Engineering				
1	Work Plans	1	LS	$ 100,000	$ 100,000
2	Design Engineering for KC and Ecology Review, Stamped	1	LS	$ 125,000	$ 125,000
3	Engineering and oversight during Construction	1	LS	$ 126,300	$ 126,300
4	Project management support	1	LS	$ 50,000	$ 50,000
	Engineering Subtotal				$ 401,300
	General				
5	General Conditions/Permits	1	EA	$ 150,000	$ 150,000
6	Mobilization/Demobilization	1	LS	$ 25,000	$ 25,000
7	Decontamination Facilities, Equipment	1	EA	$ 15,000	$ 15,000
8	Decontamination Facilities, Personnel	1	EA	$ 8,000	$ 8,000
9	Surveying	1	EA	$ 25,000	$ 25,000
10	TESC	1	EA	$ 35,000	$ 35,000
11	Hazwoper Training/Medical Monitoring	4	staff	$ 2,500	$ 10,000
	General Subtotal				$ 268,000
	Trail Work				
12	Close redundant spurs	3	ea	$ 1,000.00	$ 3,000
13	Gravel trails	151,811	sf	$ 2.39	$ 362,829
14	Excavate soil from one section	39	ton	$ 20.00	$ 770
15	Grade section of trail	12,721	sf	$ 0.82	$ 10,415
	Trail Subtotal				$ 377,015
	Units 3c, 3e and 5				
16	Clear and grub 3c and 3e	16.5	Acre	$ 1,000	$ 16,480
17	Clear 5 - light vegetation	3.9	Acre	$ 500	$ 1,950
18	Soil excavation, stockpile, and load Units 3c, 3e, 5	28,831	CY	$ 12	$ 345,972
19	Off-site Transport of affected soil	40,617	Ton	$ 32	$ 1,294,660
20	Off-site Disposal of affected soil at Subtitle D	40,617	Ton	$ 42	$ 1,705,905
21	Place 6-in layer of topsoil at Unit 3c	10,003	CY	$ 40	$ 400,107
22	Gravel at Unit 5	7,786	Ton	$ 15	$ 116,795
23	Place and compact gravel at Unit 5	5,191	CY	$ 5	$ 25,955
24	Regrade Units 3c and 3e	16.5	Acre	$ 1,000	$ 16,480
25	Water truck for dust control, operator and truck	6.0	month	$ 15,000	$ 90,000
26	Revegetate 3c	12.4	Acre	$ 10,000	$ 124,000
27	Hydroseed 3e	4.1	AC	$ 2,000	$ 8,160
				$ -	$ -
	Subtotal, Unit 3c, 3e and Unit 5				$ 4,146,464
	Testing				
28	Total Metals	200	EA	$ 60	$ 12,000
29	TCLP Metals	20	EA	$ 160	$ 3,200
30	XRF Field Testing	1	LS	$ 30,000	$ 30,000
	Subtotal Testing				$ 45,200

Table E-2

Alternative 1 - Construction Estimate

Maury Island Open Space Property FS

Maury Island, Washington

Estimated field duration:	3 months active site; 7 months hauling and trails
Project Name:	Maury Island Cleanup - Engineers Estimate
Location:	Maury Island, Washington
Date:	4/10/2017
Contractor:	
Prepared By:	David Dinkuhn, P.E.
Approved By:	

Rev: 2

Item #	Item Description	Quantity	Unit	Unit Price	Total
	Reports				
31	Closure report	1	LS	$ 30,000	$ 30,000
	Subtotal, Reports				$ 30,000
	Subtotal				$ 5,267,979
32	Contingency 25%	1	LS	$ 1,316,995	$ 1,316,995
	Subtotal, with contingency	1	LS		$ 6,584,973
	Misc				
33	Contractor markup 15%	1	LS	$ 987,746	$ 987,746
34	*Insurance 1.5%*	1	LS	$ 98,775	$ 98,775
35	*B&O Tax .65%*	1	LS	$ 42,802	$ 42,802
36	*Ecology Costs*	1	LS	$ 10,000	$ 10,000
37	*Bond 2%*	1	LS	$ 131,699	$ 131,699
38	*Tax 8.6%*	1	LS	$ 566,308	$ 566,308
	Grand Total				**$ 8,422,304**

Table E-3
Alternative 2 - Construction Estimate
Maury Island Open Space Property FS
Maury Island, Washington

Estimated field duration: 6 months - 4 months active at site for cell construction, hauling; extra 2 mo for concurrent trails and restoration

Project Name:	Maury Island Cleanup - Engineers Estimate		
Location:	Maury Island, Washington	Rev:	2
Date:	4/10/2017		
Contractor:			
Prepared By:	David Dinkuhn, P.E.		
Approved By:			

Item #	Item Description	Quantity	Unit	Unit Price	Total
	Engineering				
1	Work Plans	1	LS	$ 100,000	$ 100,000
2	Design Engineering for KC and Ecology Review, Stamped	1	LS	$ 125,000	$ 125,000
3	Engineering and oversight during Construction	1	LS	$ 132,000	$ 132,000
4	Project management support	1	LS	$ 50,000	$ 50,000
	Engineering Subtotal				$ 407,000
	General				
5	General Conditions/Permits	1	EA	$ 150,000	$ 150,000
6	Mobilization/Demobilization	1	LS	$ 25,000	$ 25,000
7	Decontamination Facilities, Equipment	1	EA	$ 15,000	$ 15,000
8	Decontamination Facilities, Personnel	1	EA	$ 8,000	$ 8,000
9	Surveying	1	EA	$ 30,000	$ 30,000
10	TESC	1	EA	$ 35,000	$ 35,000
11	Hazwoper Training/Medical Monitoring	4	staff	$ 2,500	$ 10,000
	General Subtotal				$ 273,000
	Trail Work				
12	Close redundant spurs	3	ea	$ 1,000.00	$ 3,000
13	Gravel trails	151,811	sf	$ 2.39	$ 362,829
14	Excavate soil from one section	39	ton	$ 20.00	$ 770
15	Grade section of trail	12,721	sf	$ 0.82	$ 10,415
16	New trail construction	1,443	sf	$ 7.36	$ 10,623
	Trail Subtotal				$ 387,637
	Units 3c and 5				
17	Clear and grub 3c	12.4	Acre	$ 1,000	$ 12,400
18	Clear 5 - light vegetation	3.9	Acre	$ 500	$ 1,950
19	Soil excavation and stockpile affected soil at Unit 5	4,719	CY	$ 5	$ 23,595
20	Create containment cell at Unit 5 location (cover soil and volume for 3c soil)	28,846	CY	$ 10	$ 288,464
21	Soil excavation from Unit 3c, haul to Unit 5, bury and compact at Unit 5	15,004	CY	$ 16	$ 240,064
22	Fill/compact Unit 5 cell with affected soil from 5 (stockpile built earlier)	4,719	CY	$ 10	$ 47,190
23	Geofabric Unit 5 cell	186,872	sf	$ 0.10	$ 18,687
24	Cover Unit 5 cell with clean soil	13,842	CY	$ 10	$ 138,424
25	Gravel at Unit 5	7786	Ton	$ 15	$ 116,795
26	Place and compact gravel at Unit 5	5,190.9	CY	$ 5	$ 25,955
27	Backfill Unit 3c with clean spoils from Unit 5 (load, haul, place/compact)	15,004	CY	$ 16	$ 240,064
28	Place 6-in layer of topsoil at Unit 3c	10,003	CY	$ 40	$ 400,107
29	Water truck for dust control, operator and truck	4.0	month	$ 15,000	$ 60,000
30	Revegetation/restoration Unit 3c	12.4	AC	$ 10,000	$ 124,000

Table E-3
Alternative 2 - Construction Estimate
Maury Island Open Space Property FS
Maury Island, Washington

Estimated field duration: 6 months - 4 months active at site for cell construction, hauling; extra 2 mo for concurrent trails and restoration

Project Name:	Maury Island Cleanup - Engineers Estimate		
Location:	Maury Island, Washington	Rev:	2
Date:	4/10/2017		
Contractor:			
Prepared By:	David Dinkuhn, P.E.		
Approved By:			

Item #	Item Description	Quantity	Unit	Unit Price	Total
	Unit 3e				
31	Clear and grub 3e (blackberries)	4.1	Acre	$ 500	$ 2,040
32	Excavate, stockpile, and cover mound material	2,500.0	CY	$ 15	$ 37,500
33	Manage presumed debris	400.0	Ton	$ 100	$ 40,000
34	Test and excavate additional affected soil	6,582	CY	$ 11	$ 72,406
35	Create containment cell at Unit 3e location (cover soil)	14,481	CY	$ 10	$ 144,811
36	Fill/compact Unit 3e cell with affected soil from 3e and mounds (stockpile built earlier)	9,082	CY	$ 10	$ 90,823
37	Geofabric Unit 3e cell	195,495	sf	$ 0.10	$ 19,550
38	Cover Unit 3e cell with clean soil	14,481	CY	$ 10	$ 144,811
39	Water truck for dust control, operator and truck	2.0	month	$ 15,000	$ 30,000
40	Hydroseed Unit 3e	4.1	AC	$ 2,000	$ 8,160
				$ -	$ -
	Subtotal, Unit 3c and Unit 5				$ 2,327,796
	Testing				
41	Total Metals	200	EA	$ 60	$ 12,000
42	TCLP Metals	20	EA	$ 160	$ 3,200
43	XRF Field Testing	1	LS	$ 30,000	$ 30,000
	Subtotal Testing				$ 45,200
	Reports				
44	Closure report	1	LS	$ 30,000	$ 30,000
	Subtotal, Reports				$ 30,000
	Subtotal				$ 3,470,634
45	Contingency 25%	1	LS	$ 867,658	$ 867,658
	Subtotal, with contingency	1	LS		$ 4,338,292
	Misc				
46	Contractor markup 15%	1	LS	$ 650,744	$ 650,744
47	*Insurance 1.5%*	1	LS	$ 65,074	$ 65,074
48	*B&O Tax .65%*	1	LS	$ 28,199	$ 28,199
49	*Ecology Costs*	1	LS	$ 10,000	$ 10,000
50	*Bond 2%*	1	LS	$ 86,766	$ 86,766
51	*Tax 8.6%*	1	LS	$ 373,093	$ 373,093
	Grand Total				**$ 5,552,168**

Table E-4

Alternative 3 - Construction Estimate

Maury Island Open Space Property FS

Maury Island, Washington

Estimated field duration:	2 months for soil excavation and disposal; 4 more months for trail work
Project Name:	Maury Island Cleanup - Engineers Estimate
Location:	Maury Island, Washington
Date:	4/10/2017
Contractor:	
Prepared By:	David Dinkuhn, P.E.
Approved By:	

Rev: 2

Item #	Item Description	Quantity	Unit	Unit Price	Total
	Engineering				
1	Work Plans	1	LS	$ 75,000	$ 75,000
2	Design Engineering for KC and Ecology Review, Stamped	1	LS	$ 75,000	$ 75,000
3	Engineering and oversight during Construction	1	LS	$ 78,600	$ 78,600
4	Project management support	1	LS	$ 40,000	$ 40,000
	Engineering Subtotal				$ 268,600
	General				
5	General Conditions/Permits	1	EA	$ 100,000	$ 100,000
6	Mobilization/Demobilization	1	LS	$ 15,000	$ 15,000
7	Decontamination Facilities, Equipment	1	EA	$ 10,000	$ 10,000
8	Decontamination Facilities, Personnel	1	EA	$ 4,000	$ 4,000
9	Surveying	1	EA	$ 15,000	$ 15,000
10	TESC	1	EA	$ 15,000	$ 15,000
11	Hazwoper Training/Medical Monitoring	4	staff	$ 2,500	$ 10,000
	General Subtotal				$ 169,000
	Trail Work				
12	Close redundant spurs	3	ea	$ 1,000.00	$ 3,000
13	Gravel trails	155,479	sf	$ 2.39	$ 371,595
14	Soil Mix section of trail	6,008	sf	$ 1.31	$ 7,870
15	Grade section of trail	14,771	sf	$ 0.33	$ 4,838
16	New Trail	1,443	sf	$ 7.36	$ 10,623
	Subtotal, Trails				$ 397,926
	Unit 5				
17	Clear 5 - light vegetation	3.9	Acre	$ 500	$ 1,950
18	Soil excavation and stockpile, and stockpile top 6 inches of Unit 5	3,135	CY	$ 12	$ 37,618
19	Off-site Transport of affected soil	3,448	Ton	$ 32	$ 109,916
20	Off-site Disposal of affected soil at Subtitle D	3,448	Ton	$ 42	$ 144,831
21	Gravel at Unit 5	7759	Ton	$ 15	$ 116,382
22	Place and compact gravel at Unit 5	5,172.5	CY	$ 5	$ 25,863
23	Water truck for dust control, operator and truck	2.0	month	$ 15,000	$ 30,000
				$ -	$ -
	Subtotal, Unit 5				$ 466,561
	Testing				
24	Total Metals	50	EA	$ 60	$ 3,000
25	TCLP Metals	20	EA	$ 160	$ 3,200
26	XRF Field Testing	1	LS	$ 4,000	$ 4,000
	Subtotal Testing				$ 10,200

Table E-4
Alternative 3 - Construction Estimate
Maury Island Open Space Property FS
Maury Island, Washington

Estimated field duration:	2 months for soil excavation and disposal; 4 more months for trail work	
Project Name:	Maury Island Cleanup - Engineers Estimate	
Location:	Maury Island, Washington	Rev: 2
Date:	4/10/2017	
Contractor:		
Prepared By:	David Dinkuhn, P.E.	
Approved By:		

Item #	Item Description	Quantity	Unit	Unit Price	Total
	Reports				
27	Closure report	1	LS	$ 20,000	$ 20,000
	Subtotal, Reports				$ 20,000
	Subtotal				$ 1,332,286
28	Contingency 25%	1	LS	$ 333,072	$ 333,072
	Subtotal, with contingency	1	LS		$ 1,665,358
	Misc				
29	Contractor markup 15%	1	LS	$ 249,804	$ 249,804
30	*Insurance 1.5%*	1	LS	$ 24,980	$ 24,980
31	*B&O Tax .65%*	1	LS	$ 10,825	$ 10,825
32	*Ecology Costs*	1	LS	$ 10,000	$ 10,000
33	*Bond 2%*	1	LS	$ 33,307	$ 33,307
34	*Tax 8.6%*	1	LS	$ 143,221	$ 143,221
	Grand Total				**$ 2,137,495**

Table E-5
Alternative 4 - Construction Estimate
Maury Island Open Space Property FS
Maury Island, Washington

Estimated field duration:	2 months excavation and disposal; 2 months for trail work
Project Name:	Maury Island Cleanup - Engineers Estimate
Location:	Maury Island, Washington
Date:	4/10/2017
Contractor:	
Prepared By:	Matthew Schultz
Approved By:	

Rev: 2

Item #	Item Description	Quantity	Unit	Unit Price	Total
	Engineering				
1	Work Plans	1	LS	$ 75,000	$ 75,000
2	Design Engineering for KC and Ecology Review, Stamped	1	LS	$ 75,000	$ 75,000
3	Engineering and oversight during Construction	1	LS	$ 61,800	$ 61,800
4	Project management support	1	LS	$ 40,000	$ 40,000
	Engineering Subtotal				$ 251,800
	General				
5	General Conditions/Permits	1	EA	$ 100,000	$ 100,000
6	Mobilization/Demobilization	1	LS	$ 15,000	$ 15,000
7	Decontamination Facilities, Equipment	1	EA	$ 10,000	$ 10,000
8	Decontamination Facilities, Personnel	1	EA	$ 4,000	$ 4,000
9	Surveying	1	EA	$ 15,000	$ 15,000
10	TESC	1	EA	$ 15,000	$ 15,000
11	Hazwoper Training/Medical Monitoring	4	staff	$ 2,500	$ 10,000
	General Subtotal				$ 169,000
	Trail Work				
12	Close redundant spurs	3	ea	$ 1,000	$ 3,000
13	Gravel trails	21,896	sf	$ 2.39	$ 52,332
14	Soil Mix section of trail	6,008	sf	$ 1.31	$ 7,870
15	Grade section of trail	14,771	sf	$ 0.33	$ 4,838
16	New Trail	1,443	sf	$ 7.36	$ 10,623
17					
	Subtotal, Trails				$ 78,662
	Unit 5				
18	Clear 5 - light vegetation	3.9	Acre	$ 500	$ 1,950
19	Soil excavation and stockpile top 6 inches of Unit 5	3,135	CY	$ 12	$ 37,618
20	Off-site Transport of affected soil	3,448	Ton	$ 32	$ 109,916
21	Off-site Disposal of affected soil at Subtitle D	3,448	Ton	$ 42	$ 144,831
22	Gravel at Unit 5	7759	Ton	$ 15	$ 116,382
23	Place and compact gravel at Unit 5	5,173	CY	$ 5	$ 25,863
24	Water truck for dust control, operator and truck	2.0	month	$ 15,000	$ 30,000
				$ -	$ -
	Subtotal, Unit 5				$ 466,561
	Testing				
25	Total Metals	50	EA	$ 60	$ 3,000
26	TCLP Metals	20	EA	$ 160	$ 3,200
27	XRF Field Testing	1	LS	$ 4,000	$ 4,000
	Subtotal Testing				$ 10,200

Table E-5
Alternative 4 - Construction Estimate
Maury Island Open Space Property FS
Maury Island, Washington

Estimated field duration:	2 months excavation and disposal; 2 months for trail work
Project Name:	Maury Island Cleanup - Engineers Estimate
Location:	Maury Island, Washington
Date:	4/10/2017
Contractor:	
Prepared By:	Matthew Schultz
Approved By:	

Rev: 2

Item #	Item Description	Quantity	Unit	Unit Price	Total
	Reports				
28	Closure report	1	LS	$ 20,000	$ 20,000
	Subtotal, Reports				$ 20,000
	Subtotal				$ 996,223
29	Contingency 25%	1	LS	$ 249,056	$ 249,056
	Subtotal, with contingency	1	LS		$ 1,245,279
	Misc				
30	Contractor markup 15%	1	LS	$ 186,792	$ 186,792
31	*Insurance 1.5%*	1	LS	$ 18,679	$ 18,679
32	*B&O Tax .65%*	1	LS	$ 8,094	$ 8,094
33	*Ecology Costs*	1	LS	$ 10,000	$ 10,000
34	*Bond 2%*	1	LS	$ 24,906	$ 24,906
35	*Tax 8.6%*	1	LS	$ 107,094	$ 107,094
	Grand Total				**$ 1,600,844**

Table E-6
Alternative 5 - Construction Estimate
Maury Island Open Space Property FS
Maury Island, Washington

Estimated field duration:	8 months	
Project Name:	Maury Island Cleanup - Engineers Estimate	
Location:	Maury Island, Washington	Rev: 1
Date:	4/6/2017	
Contractor:		
Prepared By:	David Dinkuhn	
Approved By:		

Item #	Item Description	Quantity	Unit	Unit Price	Total
	Engineering				
1	Work Plans	1	LS	$ 75,000	$ 75,000
2	Design Engineering for KC and Ecology Review, Stamped	1	LS	$ 75,000	$ 75,000
3	Engineering and oversight during Construction	1	LS	$ 100,000	$ 100,000
4	Project management support	1	LS	$ 45,000	$ 45,000
	Engineering Subtotal				$ 295,000
	General				
5	General Conditions/Permits	1	EA	$ 100,000	$ 100,000
6	Mobilization/Demobilization	1	LS	$ 15,000	$ 15,000
7	Decontamination Facilities, Equipment	1	EA	$ 10,000	$ 10,000
8	Decontamination Facilities, Personnel	1	EA	$ 4,000	$ 4,000
9	Surveying	1	EA	$ 15,000	$ 15,000
10	TESC	1	EA	$ 15,000	$ 15,000
11	Hazwoper Training/Medical Monitoring	4	staff	$ 2,500	$ 10,000
	General Subtotal				$ 169,000
	Trail and Graded Road Work				
12	Signs and hygiene stations	1	LS	$ 10,000	$ 10,000
13	Gravel trails	23,500	sf	$ 2.39	$ 56,165
14	Gravel graded road	52,000	sf	$ 0.55	$ 28,600
15	3-inches mineral soil trails and graded road	75,500	sf	$ 1.00	$ 75,500
16	New Trail	1,443	sf	$ 7.36	$ 10,620
	Subtotal, Trails and Graded Road				$ 180,885
	Units 3c, 3e, and 5				
17	Clear and grub 3c and 3e	16.5	Acre	$ 1,000	$ 16,500
18	Area 3c remove obstructions including chain link fence	1	LS	$ 10,000	$ 10,000
19	Clear 5 - light vegetation	1.0	Acre	$ 5,000	$ 5,000
20	Removed Cont. Soil/Duff Wetland	200	Ton	$ 200	$ 40,000
21	Off-site transport of mixed vegetation/soil (17 Acre)	3,400	Ton	$ 32	$ 108,375
22	Off-site disposal of mixed vegatation/soil (17 Acre)	3,400	Ton	$ 42	$ 142,800
23	Gravel for parking lot and driveway	5810	Ton	$ 15	$ 87,150
24	6-foot chain link fence	725	lf	$ 50.00	$ 36,250
25	Place and compact gravel at Unit 5	3,140	CY	$ 5	$ 15,700
26	Regrade Units 3c and 3e	16.5	Acre	$ 1,000	$ 16,480
27	3-inches compost 3c and 3e	6,655	CY	$ 60	$ 399,300
28	Revegetate 3c and 3e	16.5	Acre	$ 66,000	$ 1,089,000
29	Water truck for dust control, operator and truck	4.0	month	$ 15,000	$ 60,000
	Subtotal, Units 3c, 3e, and 5				$ 2,026,555
	Testing				
30	Total Metals	50	EA	$ 60	$ 3,000
31	TCLP Metals	20	EA	$ 160	$ 3,200
32	XRF Field Testing	1	LS	$ 4,000	$ 4,000

Table E-6
Alternative 5 - Construction Estimate
Maury Island Open Space Property FS
Maury Island, Washington

Estimated field duration:	8 months
Project Name:	Maury Island Cleanup - Engineers Estimate
Location:	Maury Island, Washington
Date:	4/6/2017
Contractor:	
Prepared By:	David Dinkuhn
Approved By:	

Rev: 1

Item #	Item Description	Quantity	Unit	Unit Price	Total
	Subtotal Testing				$ 10,200
	Reports				
33	Closure report	1	LS	$ 20,000	$ 20,000
	Subtotal, Reports				$ 20,000
	Subtotal				$ 2,701,640
34	Contingency 25%	1	LS	$ 675,410	$ 675,410
	Subtotal, with contingency	1	LS		$ 3,377,051
	Misc				
35	Contractor markup 15%	1	LS	$ 506,558	$ 506,558
36	*Insurance 1.5%*	1	LS	$ 50,656	$ 50,656
37	*B&O Tax .65%*	1	LS	$ 21,951	$ 21,951
38	*Ecology Costs*	1	LS	$ 10,000	$ 10,000
39	*Bond 2%*	1	LS	$ 67,541	$ 67,541
40	*Tax 8.6%*	1	LS	$ 290,426	$ 290,426
	Grand Total				**$ 4,324,182**

Table E-7
Alternative 1 - O&M Estimate
Maury Island Open Space Property FS
Maury Island, Washington

Project Name:	Maury Island Cleanup - Engineers Estimate	
Location:	Maury Island, Washington	Rev: 2
Date:	4/10/2017	
Contractor:		
Prepared By:	David Dinkuhn, P.E.	
Approved By:		

Item #	Item Description	Quantity	Unit	Unit Price	Total
	Engineering				
1	Work Plans	1	LS	$ 2,000	$ 2,000
2	Project management support & field inspection	1	LS	$ 10,000	$ 10,000
	Engineering Subtotal				$ 12,000
	Trail Work				
3	Trail/parking lot repair	14,000	sf	$ 2.39	$ 33,460
	Subtotal, Trails				$ 33,460
	Planting Maintenance				
4	Watering, weeding, plant replacement; Unit 3c	12.4	Acres	$ 12,800	$ 158,720
	Subtotal, Planting				$ 158,720
	Reports				
5	Monitoring report	1	LS	$ 10,000	$ 10,000
6	Ecology reporting	1	LS	$ 5,000	$ 5,000
	Subtotal, Reports				$ 15,000
	Subtotal				$ 219,180
7	Contingency 25%	1	LS	$ 54,795	$ 54,795
	Subtotal, with contingency	1	LS		$ 273,975
	Misc				
8	Contractor markup 15%	1	LS	$ 41,096	$ 41,096
9	*Insurance 1.5%*	1	LS	$ 4,110	$ 4,110
10	*B&O Tax .65%*	1	LS	$ 1,781	$ 1,781
11	*Bond 2%*	1	LS	$ 5,480	$ 5,480
12	*Tax 8.6%*	1	LS	$ 23,562	$ 23,562
					$ 350,003
	Grand Total				**$ 350,003**

Present worth analysis at 4% interest rate

Costs every 5 years (total minus planting maintenance)	$ 97,638
Yearly costs for years 1-3 for plant maintenance	$ 252,365

Net present worth over 30 years

	Type	Rate	Years	PV
PV Plant Maintenance Years 1-3	Payment	4%	3	($700,335.29)
PV Costs at Year 5	FV Cost	4%	5	($80,251.53)
PV Costs at Year 10	FV Cost	4%	10	($65,960.91)
PV Costs at Year 15	FV Cost	4%	15	($54,215.06)
PV Costs at Year 20	FV Cost	4%	20	($44,560.83)
PV Costs at Year 25	FV Cost	4%	25	($36,625.75)
PV Costs at Year 30	FV Cost	4%	30	($30,103.70)
			Total PV	**($1,012,053)**

Table E-8
Alternative 2 - O&M Estimate
Maury Island Open Space Property FS
Maury Island, Washington

Project Name:	Maury Island Cleanup - Engineers Estimate
Location:	Maury Island, Washington
Date:	4/10/2017
Contractor:	
Prepared By:	David Dinkuhn, P.E.
Approved By:	

Rev: 2

Item #	Item Description	Quantity	Unit	Unit Price	Total
	Engineering				
1	Work Plans	1	LS	$ 2,000	$ 2,000
2	Project management support & field inspection	1	LS	$ 10,000	$ 10,000
	Engineering Subtotal				$ 12,000
	Trail Work				
3	Trail/parking lot repair	14,000	sf	$ 2.39	$ 33,460
	Subtotal, Trails				$ 33,460
	Planting Maintenance				
4	Watering, weeding, plant replacement; Unit 3c	12.4	Acres	$ 12,800	$ 158,720
	Subtotal, Planting				$ 158,720
	Reports				
5	Monitoring report	1	LS	$ 10,000	$ 10,000
6	Ecology reporting	1	LS	$ 5,000	$ 5,000
	Subtotal, Reports				$ 15,000
	Subtotal				$ 219,180
7	Contingency 25%	1	LS	$ 54,795	$ 54,795
	Subtotal, with contingency	1	LS		$ 273,975
	Misc				
8	Contractor markup 15%	1	LS	$ 41,096	$ 41,096
9	*Insurance 1.5%*	1	LS	$ 4,110	$ 4,110
10	*B&O Tax .65%*	1	LS	$ 1,781	$ 1,781
11	*Bond 2%*	1	LS	$ 5,480	$ 5,480
12	*Tax 8.6%*	1	LS	$ 23,562	$ 23,562
	Grand Total				**$ 350,003**

Present worth analysis at 4% interest rate

Costs every 5 years (total minus planting maintenance)	$ 97,638
Annual costs for years 1-3 for plant maintenance	$ 252,365

Net present worth over 30 years

	Type	Rate	Years	PV
PV Plant Maintenance Years 1-3	Payment	4%	3	($700,335.29)
PV Costs at Year 5	FV Cost	4%	5	($80,251.53)
PV Costs at Year 10	FV Cost	4%	10	($65,960.91)
PV Costs at Year 15	FV Cost	4%	15	($54,215.06)
PV Costs at Year 20	FV Cost	4%	20	($44,560.83)
PV Costs at Year 25	FV Cost	4%	25	($36,625.75)
PV Costs at Year 30	FV Cost	4%	30	($30,103.70)
			Total PV	**($1,012,053)**

Table E-9
Alternative 3- O&M Estimate
Maury Island Open Space Property FS
Maury Island, Washington

Project Name:	Maury Island Cleanup - Engineers Estimate	
Location:	Maury Island, Washington	Rev: 2
Date:	4/10/2017	
Contractor:		
Prepared By:	Matthew Schultz	
Approved By:		

Item #	Item Description	Quantity	Unit	Unit Price	Total
	Engineering				
1	Work Plans	1	LS	$ 2,000	$ 2,000
2	Project management support & field inspection	1	LS	$ 10,000	$ 10,000
	Engineering Subtotal				$ 12,000
	Trail Work				
3	Trail repair	4,100	sf	$ 2.39	$ 9,799
	Subtotal, Trails				$ 9,799
	Reports				
4	Monitoring report	1	LS	$ 10,000	$ 10,000
5	Ecology reporting	1	LS	$ 5,000	$ 5,000
	Subtotal, Reports				$ 15,000
	Subtotal				$ 36,799
6	Contingency 25%	1	LS	$ 9,200	$ 9,200
	Subtotal, with contingency	1	LS		$ 45,999
	Misc				
7	Contractor markup 15%	1	LS	$ 6,900	$ 6,900
8	*Insurance 1.5%*	1	LS	$ 690	$ 690
9	*B&O Tax .65%*	1	LS	$ 299	$ 299
10	*Bond 2%*	1	LS	$ 920	$ 920
11	*Tax 8.6%*	1	LS	$ 3,956	$ 3,956
	Grand Total				**$ 58,763**

Present worth analysis at 4% interest rate

Costs every 5 years $ 58,763

Net present worth over 30 years

	Type	Rate	Years	PV
PV Costs at Year 5	FV Cost	4%	5	($48,299.23)
PV Costs at Year 10	FV Cost	4%	10	($39,698.45)
PV Costs at Year 15	FV Cost	4%	15	($32,629.23)
PV Costs at Year 20	FV Cost	4%	20	($26,818.85)
PV Costs at Year 25	FV Cost	4%	25	($22,043.14)
PV Costs at Year 30	FV Cost	4%	30	($18,117.85)
			Total PV	**($187,607)**

Table E-10
Alternative 4 - O&M Estimate
Maury Island Open Space Property FS
Maury Island, Washington

Project Name:	Maury Island Cleanup - Engineers Estimate
Location:	Maury Island, Washington
Date:	4/10/2017
Contractor:	
Prepared By:	David Dinkuhn, P.E.
Approved By:	

Rev: 2

Item #	Item Description	Quantity	Unit	Unit Price	Total
	Engineering				
1	Work Plans	1	LS	$ 2,000	$ 2,000
2	Project management support & field inspection	1	LS	$ 10,000	$ 10,000
	Engineering Subtotal				$ 12,000
	Trail Work				
3	Trail repair	1,000	sf	$ 2.39	$ 2,390
	Subtotal, Trails				$ 2,390
	Reports				
4	Monitoring report	1	LS	$ 10,000	$ 10,000
5	Ecology reporting	1	LS	$ 5,000	$ 5,000
	Subtotal, Reports				$ 15,000
	Subtotal				$ 29,390
6	Contingency 25%	1	LS	$ 7,348	$ 7,348
	Subtotal, with contingency	1	LS		$ 36,738
	Misc				
7	Contractor markup 15%	1	LS	$ 5,511	$ 5,511
8	*Insurance 1.5%*	1	LS	$ 551	$ 551
9	*B&O Tax .65%*	1	LS	$ 239	$ 239
10	*Bond 2%*	1	LS	$ 735	$ 735
11	*Tax 8.6%*	1	LS	$ 3,159	$ 3,159
	Grand Total				**$ 46,932**

Present worth analysis at 4% interest rate
Costs every 5 years $ 46,932

Net present worth over 30 years

	Type	Rate	Years	PV
PV Costs at Year 5	FV Cost	4%	5	($38,574.81)
PV Costs at Year 10	FV Cost	4%	10	($31,705.68)
PV Costs at Year 15	FV Cost	4%	15	($26,059.76)
PV Costs at Year 20	FV Cost	4%	20	($21,419.22)
PV Costs at Year 25	FV Cost	4%	25	($17,605.04)
PV Costs at Year 30	FV Cost	4%	30	($14,470.06)
			Total PV	**($149,835)**

Table E-11
Alternative 5 - O&M Estimate
Maury Island Open Space Property FS
Maury Island, Washington

Project Name:	Maury Island Cleanup - Engineers Estimate	
Location:	Maury Island, Washington	Rev: 1
Date:	4/10/2017	
Contractor:		
Prepared By:	David Dinkuhn, PE	
Approved By:		

Item #	Item Description	Quantity	Unit	Unit Price	Total
	Engineering				
1	Work Plans	1	LS	$ 2,000	$ 2,000
2	Project management support & field inspection	1	LS	$ 10,000	$ 10,000
	Engineering Subtotal				$ 12,000
	Maintenance Work				
3	Trail/parking lot repair	14,000	sf	$ 2.39	$ 33,460
	Subtotal, Maintenance				$ 33,460
	Planting Maintenance				
4	Watering, weeding, plant replacement units 3c and 3e	16.5	Acres	$ 12,800.00	$ 211,200
	Subtotal, Planting				$ 211,200
	Reports				
5	Monitoring report	1	LS	$ 10,000	$ 10,000
6	Ecology reporting	1	LS	$ 5,000	$ 5,000
	Subtotal, Reports				$ 15,000
	Subtotal				$ 271,660
7	Contingency 25%	1	LS	$ 67,915	$ 67,915
	Subtotal, with contingency	1	LS		$ 339,575
	Misc				
8	Contractor markup 15%	1	LS	$ 50,936	$ 50,936
9	*Insurance 1.5%*	1	LS	$ 5,094	$ 5,094
10	*B&O Tax .65%*	1	LS	$ 2,207	$ 2,207
11	*Bond 2%*	1	LS	$ 6,792	$ 6,792
12	*Tax 8.6%*	1	LS	$ 29,203	$ 29,203
	Grand Total				**$ 433,807**

Present worth analysis at 4% interest rate

Costs every 5 years	$ 97,999
Yearly costs for years 1-3 for plant maintenance	$ 335,808

Net present worth over 30 years

	Type	Rate	Years	PV
PV Plant Maintenance Years 1-3	Payment	4%	3	($931,897.77)
PV Costs at Year 5	FV Cost	4%	5	($80,548.09)
PV Costs at Year 10	FV Cost	4%	10	($66,204.66)
PV Costs at Year 15	FV Cost	4%	15	($54,415.40)
PV Costs at Year 20	FV Cost	4%	20	($44,725.49)
PV Costs at Year 25	FV Cost	4%	25	($36,761.09)
PV Costs at Year 30	FV Cost	4%	30	($30,214.94)
			Total PV	**($1,244,767)**