WOODARD BAY RESTORATION FEASIBILITY STUDY

Prepared for:

Washington State Department of Natural Resources

In association with:

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Historical Research Associates, Inc.
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Acronyms

ac	acre
BCR	benefit-cost ratio
CRS	cultural resource specialist
CSM	conceptual site model
DOF	Dalton, Olmsted & Fuglevand, Inc.
Ecology	Washington State Department of Ecology
EPA	US Environmental Protection Agency
FS	feasibility study
HEA	Habitat Equivalency Analysis
HRA	Historical Research Associates, Inc.
JARPA	Joint Aquatic Resources Permit Application
MLLW	mean lower low water
NOAA	National Oceanic and Atmospheric Administration
NRCA	Natural Resources Conservation Area
SHPO	State Historic Preservation Officer
Sitts & Hill	Sitts & Hill Engineers, Inc.
SMS	Washington State Sediment Management Standards
SQS	sediment quality standards
THPO	Tribal Historic Preservation Officer
TNC	The Nature Conservancy
TOC	total organic carbon
TVS	total volatile solids
USACE	US Army Corps of Engineers
USFWS	US Fish and Wildlife Service
WAC	Washington Administrative Code
WDFW	Washington State Department of Fish and Wildlife
WDNR	Washington State Department of Natural Resources
Windward	Windward Environmental LLC

1 Introduction

The Washington State Department of Natural Resources (WDNR) manages approximately 800 acres (ac) of upland and 500 ac of nearshore habitat as part of the Woodard Bay Natural Resources Conservation Area (NRCA) and adjoining state-owned aquatic lands in Henderson Inlet, near Olympia, Washington (Map 1-1). NRCAs are managed by WDNR to protect important natural resources, including natural ecosystems; flora and fauna; geological, archaeological, and scenic features; and other environmentally significant sites. NRCAs also provide opportunities for environmental education and other low-impact public uses compatible with the protection of these resource values. The Woodard Bay NRCA was established to protect a variety of natural features, including forested uplands, estuarine and shoreline systems, freshwater wetlands, streams, and a number of priority and sensitive wildlife species. The site also contains important historic and archaeological features and is visited by the public for a variety of activities, including hiking, kayaking, wildlife viewing, and environmental education.

While the site supports these important resources and uses and contains relatively undisturbed areas, portions of it have been heavily altered in the past. The Woodard Bay NRCA is the site of the former South Bay Log Dump operated by the Weyerhaeuser Company between 1928 and 1985. This facility received logs by rail and truck for shipment to Weyerhaeuser's Everett mills; logs were offloaded from a 3,000-ft-long pier, sorted, bundled, and stored nearby in Chapman Bay and Henderson Inlet before being towed to the mills.

WDNR suspected that in-water structures (e.g., piers, anchor pilings, trestles), fill materials, and other site development features from the historic log transfer facility had adversely affected the aquatic habitat through alteration of nearshore processes, accumulation of wood debris, and release of potentially toxic chemicals from the decomposition of submerged wood waste and in-water wooden structures preserved with creosote.

WDNR, in partnership with the US Army Corps of Engineers (USACE), US Environmental Protection Agency (EPA), Washington State Department of Ecology (Ecology), and The Nature Conservancy (TNC) conducted an assessment of the nature of the in-water structures and distribution of wood waste at the site for the purpose of identifying potential wood waste impacts on sediment quality and to support restoration planning. Results of that assessment showed that wood waste was not widespread at the site and the sediment was generally of high quality[1] (SAIC 2008). However, Ecology's review of the sediment characterization results identified potential data gaps for the site, with respect to wood waste impacts on the benthic community.

[1] Most surface sediment chemical results were well below SMS criteria and similar to Puget Sound reference area performance standards (PTI 1991).

0 15 mi
One inch = approximately 9.1 miles

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Map 1-1. Woodard Bay Restoration Project Area - vicinity

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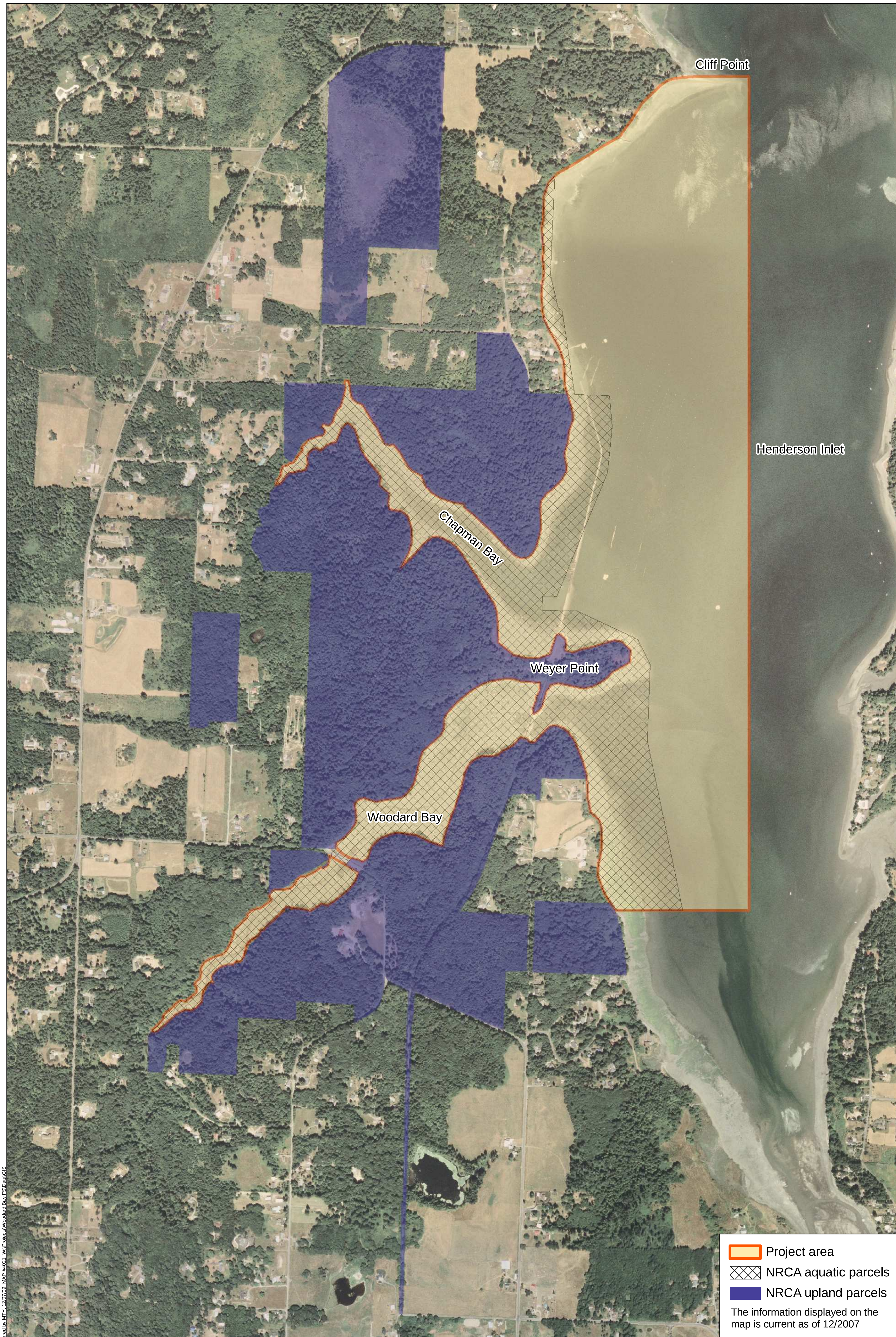
WDNR directed Windward Environmental LLC (Windward) and its team (Dalton, Olmsted & Fuglevand, Inc. [DOF], Sitts & Hill Engineers, Inc. [Sitts & Hill], and Historical Research Associates, Inc. [HRA]) to complete the assessment of wood waste impacts as defined by the Washington State Sediment Management Standards (SMS) and conduct a feasibility study (FS) to evaluate restoration options for the nearshore area of the Woodard Bay site. The project area for the feasibility study (FS) included the Woodard Bay NRCA and adjacent state-owned aquatic lands east of the NRCA that extend approximately to the center of Henderson Inlet (Map 1-2).

The overall goal of the FS is to develop alternatives to restore, enhance, and protect aquatic ecosystem processes and habitats within the project area, as well as the native species and communities they support. This overall goal is consistent with those outlined in the Woodard Bay Natural Resources Conservation Area Management Plan (WDNR 2002), hereafter referred to as the Woodard Bay NRCA Management Plan.[2] Restoration of the nearshore environment will also support the broader watershed restoration planning underway by numerous stakeholders and partnering agencies, including the USACE, National Oceanic and Atmospheric Administration (NOAA) Fisheries Service, US Fish and Wildlife Service (USFWS), Washington State Department of Fish and Wildlife (WDFW), Ecology, Thurston County, TNC, and the Puget Sound Nearshore Partnership.

This FS is intended to inform WDNR of the benefits and impacts of a range of alternatives (groups of selected individual actions) to facilitate the agency's management of the restoration activities at the Woodard Bay NRCA. The FS is organized into the following sections:

- Section 1 – Introduction
- Section 2 – Site History
- Section 3 – Existing Conditions
- Section 4 – Feasibility Study Approach
- Section 5 – Development of the Conceptual Site Model
- Section 6 – Selection of Restoration Targets
- Section 7 – Identification and Evaluation of Potential Restoration Elements
- Section 8 – Development and Evaluation of Alternatives
- Section 9 – Costs
- Section 10 – Selection of Preferred Alternative
- Section 11 – Next Steps
- Section 12 – References

[2] Management goals developed for the site include protection of "outstanding examples of native ecosystems, habitat for endangered, threatened, and sensitive plants and animals and scenic landscapes" (WDNR 2002).



Prepared by MTY, 12/07/09; MAP #4021; W:\Projects\Woodard Bay FS\Data\GIS

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Map 1-2. Woodard Bay NRCA and project area

2 Site History

Woodard Bay and adjacent areas of Henderson Inlet were inhabited by Native Americans for thousands of years, as evidenced by the many prehistoric archaeological sites in the NRCA. By the time European-American settlers arrived in the 1800s, the Native American settlements and encampments were small or had been entirely displaced. The Woodard family was the first of the settlers to establish a claim for the land around Woodard Bay (in the mid-1800s); the land was farmed off and on until about 1878. Just before the turn of the century, the property was sold and logged; adjacent tidelands were sold for oyster farming around the same time (Stilson 1991). Weyerhaeuser constructed the South Bay Log Dump in the mid-1920s for the purpose of supplying logs to its Everett mills (Poultridge 1991). The log dump operated until 1985,[3] when the site was closed. In 1988, Washington State purchased over 450 ac of relatively undeveloped[4] uplands and tidelands in Henderson Inlet from the Weyerhaeuser Foundation and established the Woodard Bay NRCA (WDNR 2002). Prior to the ownership transfer, Weyerhaeuser removed several underground tanks and aboveground structures, including a diesel fuel tank, three-car garage, bunkhouse, and 8,000-gallon wooden water tank (Hart Crowser 2007a). As part of site restoration in 2005, WDNR deconstructed and recycled the onsite residence and other outbuildings, and removed the septic tank and bulkheads from Weyer Point. The riparian zone near the residence on Weyer Point was subsequently restored.

Historic features remain at the site: a 450-piling railroad trestle at the mouth of Woodard Bay, a 3,000-ft-long pier constructed of some 1,500 creosoted pilings across the mouth of Chapman Bay, and roughly 500 individual pilings and 30 dolphins (clusters of pilings bound together) east of the pier and northeast of the trestle in what was the Main Operational Area of the log dump and Southern Operational Area (Map 2-1). These features are listed in the National Register of Historic Places and site is classified as a historic landscape district.

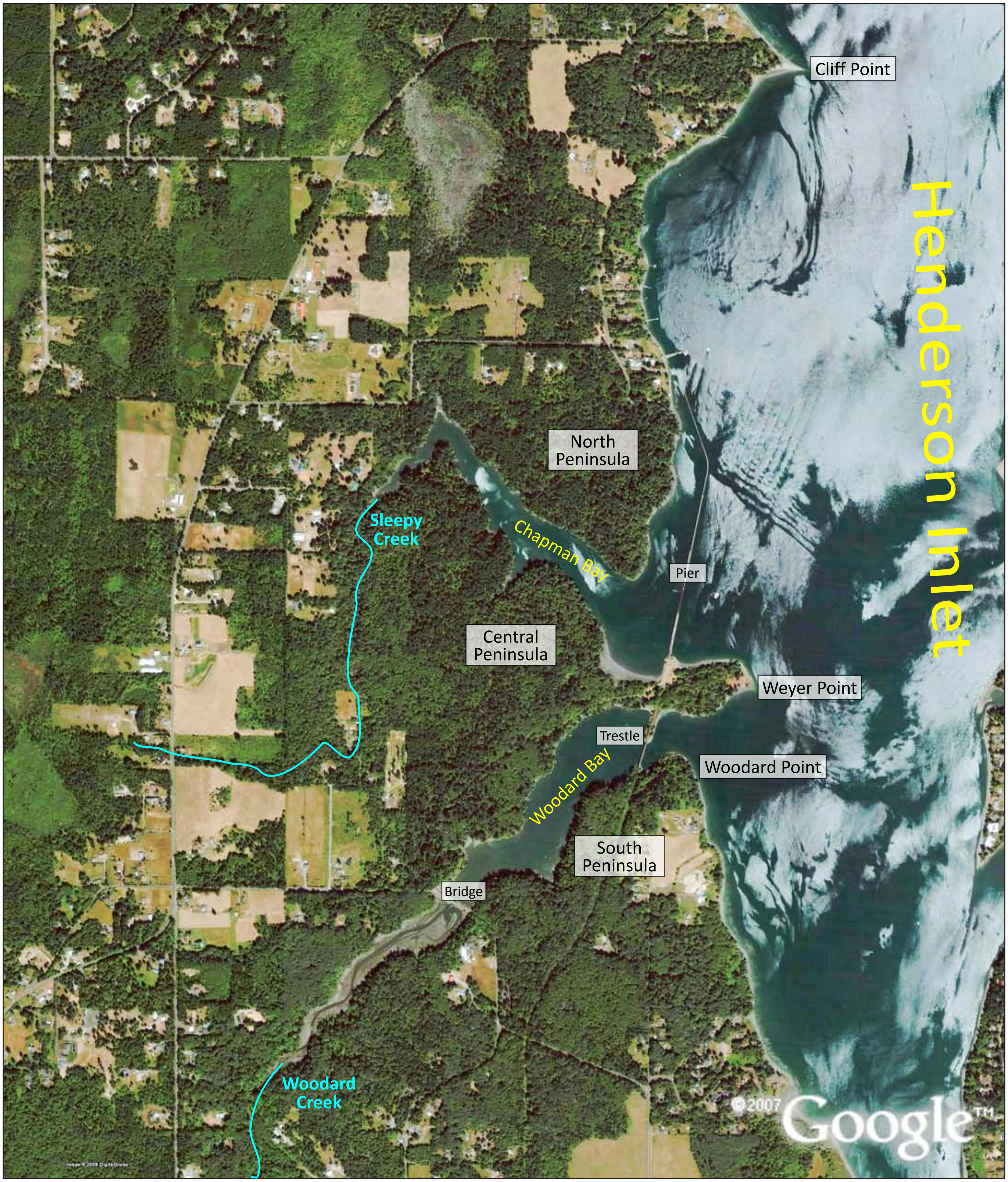
Other current features include a county road and bridge over Woodard Bay, modified shoreline and fill associated with Weyer Point,[5] and minimal upland development (i.e., parking, picnic areas, signage, and an interpretive center in the old foreman's shack near the pier). Additional details regarding site features are available in a historical characterization report (Hart Crowser 2007a).

[3] Weyerhaeuser regularly dredged the dump area and sweep lanes along the Chapman Bay pier as part of its operations.

[4] Weyerhaeuser's facilities were primarily limited to Weyer Point and adjacent tidelands.

[5] As part of site development, Weyerhaeuser excavated the north side of Weyer Point to accommodate a rail spur leading to a fuel dock, filled the area around the base of Chapman Bay pier, and constructed an extensive berm perpendicular to the south side of Weyer Point to support the railroad leading to the pier. Bulkheads were installed along parts of the Weyer Point shoreline to protect the upland facility.

The southeastern-most part of the project area includes a 10-ac aquatic parcel leased by TNC as part of a restoration program for the native Olympia oyster, *Ostrea lurida (=O. conchaphila)*.



0 2,500 5,000 ft
One inch = approximately 3,030 feet

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Map 2-1. Woodard Bay Restoration Project Area - features

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3 Existing Conditions

The description of existing conditions focuses primarily on the nearshore processes, habitats (including water and sediment quality), and biological resources that may have been affected by the former use of the site as a log dump.

3.1 NEARSHORE PROCESSES

In their simplest form, nearshore processes can be defined as the movement or exchange of water, sediment, and nutrients at the boundary between terrestrial and aquatic ecosystems. Many physical and chemical interactions occur to create and maintain aquatic ecosystems. In Puget Sound, these interactions have the greatest influence in the nearshore zone. The nearshore zone covers the aquatic area from the shore or riparian zone (where the land and water meet) out to the depth at which light can penetrate (i.e., the photic zone). At the Woodard Bay NRCA, the nearshore zone is defined by the bathymetric contour 20 ft below mean lower low water (MLLW), or -20 ft MLLW. Intertidal areas are necessarily included, but the nearshore zone also includes tidally influenced portions of local streams, shoreline bluffs, and wetlands.

Past activities have dramatically altered the nearshore environment in Puget Sound. Sediment loads from construction sites and agricultural practices have filled streams with silt, altered tidal wetlands and channels, reduced the depth of shallow bays and estuaries, and changed the characteristics of the bottom sediment. Sediment and surface water runoff from farms, yards, parking lots, and roads is often of degraded quality, sometimes significantly so. At the same time, natural sources of sediment have been restricted through the construction of bulkheads or dredging. The exchange of sediment and water has been further altered by the construction of piers, bulkheads, bridges, and other nearshore structures.

Other than the historical activity noted above, little upland or shoreline development has occurred within the site boundaries; however, the NRCA lies in a watershed that is undergoing rapid urbanization. Woodard Creek originates near Lacey, Washington, and drains approximately 5,500 ac of residential, agricultural, industrial, and commercial land. The creek bed and riparian habitats in the watershed have been altered; and the creek receives stormwater from adjacent roads, parking lots, shopping centers, warehouses, small farms, and homes.

Woodard Creek, which discharges to Woodard Bay, typically does not meet water quality standards and is considered impaired because of high bacteria counts, low dissolved oxygen concentrations, and high temperatures (Thurston County 2007). Degraded water quality persists in Henderson Inlet because of high bacteria counts; the southern end of Henderson Inlet, Woodard Bay, and Chapman Bay are continually closed to shellfish harvest because of pollution,[6] and shellfish harvest in other areas of

[6] No shellfish harvesting is allowed within the NRCA boundary as part of the management of the site.

Henderson Inlet is periodically restricted for the same reason. It is unknown if bacteria (particularly fecal coliform bacteria that are associated with the water quality standard) directly affect the health of aquatic organisms living in Henderson Inlet.

In-water structures at the site affect the local circulation of water (and therefore the exchange of nutrients and movement of sediment). The effect on wave energy at the site is illustrated in Figure 3-1, which shows how the piling field in the Main Operational Area acts as a baffle, retarding the wave buildup in the shallow nearshore areas of the NRCA. As is typical for in-water structures (Johannessen and MacLennan 2007), this baffling effect likely causes increased deposition of sediment within the Main Operational Area piling field and reduced exchange of water and longshore transport of sediment in Chapman Bay. The exchange of water and sediment between Chapman Bay and Henderson Inlet is further slowed by a berm composed of fine-grained sediment and shell debris that has built up over time under the pier.

The trestle across the mouth of Woodard Bay has significantly narrowed the outlet of Woodard Creek, changing flow patterns and tidal exchange in the lower reach of the creek. Similarly, the Woodard Bay Bridge has restricted the exchange of water between the upper and lower bays. The reduction in water exchange may exacerbate water quality issues in this area of Henderson Inlet.

The sediment grain size in Henderson Inlet (and South Puget Sound as a whole) has likely become increasingly fine. Original sediment characteristics were a legacy of the last period of glaciation, over 13,000 years ago. Waves and currents reworked the sands and gravels left by receding ice, forming beaches where there was a sufficient source of unconsolidated sediment. Mud- and sand-flats formed in areas near rivers and where low wave energy or restricted circulation allowed material suspended in currents to settle to the bottom. While Henderson Inlet is relatively protected, archaeological evidence[7] suggests that sediments may have been coarser prior to European-American settlement. Although local rivers (particularly the Nisqually River) seasonally discharge significant loads of sediment to Puget Sound, agricultural and logging practices in the 1800s and early 1900s were likely to have substantially increased erosion and surface water runoff in Puget Sound watersheds, contributing to a shift in bottom habitat characteristics to finer-grained materials. In recent years, changes in farming and forest practices along with shoreline development (including the construction of bulkheads and other shoreline protection) have reduced the amount of sediment entering Puget Sound, which, over time, may have caused a change in bottom elevations.

[7] Hard-shell clams that are typically associated with coarse-grained sediments have been found in middens at Native American encampments and villages in Henderson Inlet.

Imagery date: July 20, 2006

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0 500 1,000 Feet

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Figure 3-1. Wave defraction in Main Operational Area piling field

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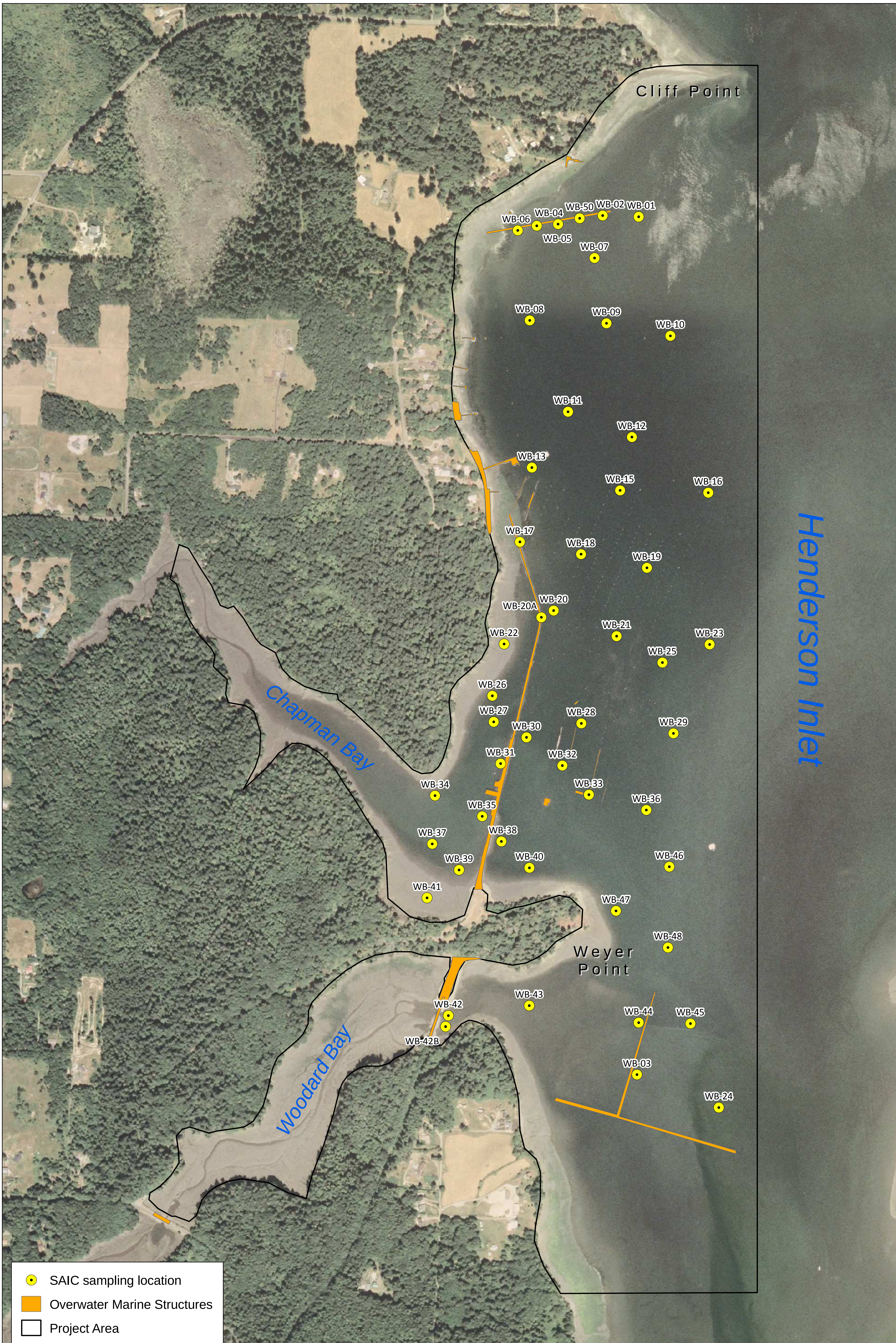
3.2 SEDIMENT QUALITY

Under current state regulation and policies, wood waste is treated as a deleterious substance. If significant impacts to the benthic community can be identified, sediment cleanups are conducted under the SMS (Washington Administrative Code [WAC] 173-204). In absence of significant benthic impacts, various restoration programs, including those supported by the Puget Sound Initiative and subsequent Puget Sound Action Agenda address ecological restoration issues related to wood waste.

WDNR and its partners[8] assessed the potential contribution of in-water creosote-preserved structures to surface sediment contamination as well as the distribution of wood waste at the site. The assessment was conducted to identify potential sediment quality impacts and to support restoration planning. Initial investigations (Hart Crowser 2007a, b, c, d) were qualitative or semi-quantitative: a descriptive intertidal habitat survey, an assessment of the distribution and condition of piling and over-water structures, two underwater observation surveys (one documented by a video mounted on a remotely operated vehicle and one documented by divers using a hand-held camera), and a sub-bottom acoustical profiling survey to examine the distribution of wood waste. The results of these surveys were used to design a field investigation focused on delineating areas likely affected by wood waste or creosoted structures and determining the extent of impacts on sediment quality according to the SMS (WAC 173-204).

Sediment samples were collected in February 2008 from areas with evidence of wood waste in the vicinity of in-water structures built with creosoted pilings and in areas known to have been used for log storage (Map 3-1). Analyses included all chemicals required by SMS in addition to total volatile solids (TVS), total solids, total organic carbon (TOC), grain size, ammonia, and total sulfides.

[8] USACE, EPA, Ecology, and TNC.



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0 250 500 Yards

0 180 360 Meters

Source: SAIC (2008)

Map 3-1. Existing sampling locations for 2008 sediment characterization

The sediment quality assessment (SAIC 2008) showed that wood waste was not widespread at the site[9] and, where present, was composed primarily of bark and small pieces of wood. It is likely that the long-term dredging conducted by Weyerhaeuser to keep log sorting lanes clear may have helped minimize the amount of wood debris at the site. The sediment was generally of high quality.[10] However, Ecology's review of the sediment results revealed that one sediment sample exceeded the cleanup screening level for phenol, and five samples exceeded the sediment quality standard (SQS) for the same chemical. These concentrations were questionable because the exceedances occurred only when the samples had been reanalyzed to achieve better detection limits (the original detected results were below the SQS).

In the absence of biological testing, Ecology was also concerned about impacts at locations where concentrations were elevated for other conventional sediment parameters (but not SMS-regulated chemicals) that might be associated with wood debris. Ecology examined ammonia, total sulfides, TOC, TVS, and total solids, establishing a level of concern by applying a numerical score to each parameter. To make a final determination of compliance with SMS, Ecology recommended that toxicity testing be conducted in samples with scores greater than a defined threshold.

Additional sampling was conducted in January 2009 to complete the assessment of wood waste impacts as recommended by Ecology. This follow-on effort focused on three issues:

- Resolving the quantification of wood waste indicator chemicals (phenol, 2-methyl phenol, 2,4-dimethyl phenol, and other selected semivolatile organic compounds) in previously collected samples by analyzing archived sediment
- Collecting additional sediment for toxicity testing from reference areas and from locations where Ecology's rating was of high, medium, or low-medium concern
- Collecting additional sediment adjacent to in-water structures to assess the scale of potential polycyclic aromatic hydrocarbon releases from creosoted piling

Reanalysis of the archived sediment samples resolved the quantification of wood waste indicator chemicals; no exceedances of the SMS SQS were identified. Chemical concentrations in the newly collected samples did not exceed the SMS, except for two individual creosote-related compounds in one sample. Toxicity test concentrations were similar to those detected in clean reference areas and were not indicative of widespread impacts on the benthic community. From these results, WDNR concluded that wood waste has not had significant adverse effects on sediment quality in the Woodard Bay

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[9] Wood waste was absent in 72% of the surface images; where present, it accounted, on average, for less than 8% of the surface sediment coverage (range was 0 to 20%). This finding was generally confirmed by the video probe images and subsurface cores in which wood debris averaged about 10% by volume within the top 1 ft of sediment.

[10] Most surface sediment chemical results were well below SMS criteria and similar to Puget Sound reference area performance standards (PTI 1991).

NRCA. Complete results of the 2009 sediment sampling program are provided in Appendix A.

3.3 NEARSHORE HABITATS

Aquatic portions of the site are used extensively by species whose natural habitat is shrinking on a regional scale or even more widely. The nearshore environments of Woodard and Chapman Bays and contiguous portions of Henderson Inlet are highly productive, with local populations of shellfish and other invertebrates (e.g., worms, snails, amphipods) that provide food for many species.

Nearshore and estuarine features at the site are extensive: over 5 miles of relatively undeveloped shoreline, three peninsulas (North Peninsula, Central Peninsula/Weyer Point, and South Peninsula/Woodard Point) that form two estuarine embayments (Woodard and Chapman Bays), tidal creeks (Woodard and Sleepy Creeks and several unnamed seasonal creeks and tributaries), and over 500 ac of intertidal and shallow subtidal estuarine habitat.

Habitats in quiescent areas of the site are typically silty muds, often with a seasonal covering of ulvoid or other small algae. Bottom substrates in areas with more wave action or tidal currents (e.g., around Weyer Point) are coarser, composed of sand or gravels. Sediment underneath structures such as the trestle and pier have been further modified by the shell "hash" from the fouling organisms that live on the pilings. Except in two areas, large woody debris is present along the shoreline throughout the site, originating from trees on slumping embankments and bluffs; the steeply sloped and armored trestle berm at the mouth of Woodard Bay is only sparsely vegetated, and the shoreline at the base of the Chapman Bay pier remains clear, having been extensively modified during historical operations.

The anthropogenic structures themselves provide habitat. Eagles and marine birds such as cormorants perch on the pilings and pier structures, although perches are not limited to these structures at the site. The largest known bat colony, composed of several species (approximately 3,000 individuals), roosts in a section of the Chapman Bay pier where the support timbers create narrow, deep crevices and are currently covered by metal flashing, which keeps the roost dry. The remaining southern portion of the pier serves as a protected flyway when the colony exits the roost to forage; the Woodard Bay trestle may also be used as an alternative roost and flyway for a portion of the colony. A constructed bat house installed adjacent to the pier near the colony is currently unused; this is likely because the structure requires additional maintenance and modification to make it a suitable habitat and the fact that the bats prefer the existing pier. Harbor seals haul out, pup, and molt on floating logs anchored to pilings in the Main Operational Area; these logs are currently maintained by WDNR (and require frequent maintenance and management). Nesting boxes attached to the pilings are used by purple martin (a member of the swallow family that had been extirpated from its historical habitat). The trestle pilings over the Woodard Bay entrance support a large mussel reef that spans the entrance of the bay. This alteration of the Woodard Bay entrance may also contribute to the maintenance of a small subpopulation of Olympia oyster at its mouth. Numerous small invertebrates encrust the pilings throughout the site below the waterline; these organisms are eaten by many others, including larger invertebrates (e.g., starfish and crabs), fish, and aquatic birds. Encrusted pilings have altered the sediment around them through the contribution of shell hash, which supports invertebrate communities more typical of coarse-grained sediments.

3.4 BIOLOGICAL RESOURCES

As described above, the Woodard Bay NRCA supports many different populations of aquatic and aquatic-dependent organisms. Table 3-1 lists key species (including endangered or protected species) that use nearshore habitat at the Woodard Bay site.

Table 3-1. Aquatic or water-dependent species that use Woodard Bay/Chapman Bay habitats

Species	Special Status	Site Use	Habitat	Occurrence
Bald eagle	state sensitive species and federal species of concern	breeding, rearing young, hunting	breed, rear young, and hunt in upland habitats, with some foraging over water	year-round resident
Great blue heron	state priority species[a]	breeding, rearing young, foraging	breed and rear young in upland habitats, with extensive foraging in tideflats	year-round resident
Purple martin and other swallows	state candidate species (purple martin)	breeding, rearing young, foraging	rear young in artificial nests (on pilings), with extensive foraging over water	summer resident
Pigeon guillemot	state priority species[b]	breeding, rearing young, foraging	rear young in burrows in banks; use water column for foraging and other activities	year-round resident
Resident waterfowl	state priority species[c]	refuge, foraging	forage in water column; use protected embayments for refuge	winter or summer residents
Migratory waterfowl	protected by Migratory Bird Treaty Act	refuge, foraging	forage in water column; use protected embayments for refuge	fall/spring migration
Resident shorebirds	state priority species[d]	refuge, foraging	forage over tideflats; use protected embayments for refuge	winter or summer residents
Migratory shorebirds	protected by Migratory Bird Treaty Act	refuge, foraging	forage over tideflats; use protected embayments for refuge	fall/spring migration
Harbor seal	state priority species; protected by Marine Mammal Protection Act	breeding, rearing young, refuge during molting, foraging	pup, rear young, and haul out on floating structures maintained for their use; forage throughout Henderson Inlet	year-round resident

Species	Special Status	Site Use	Habitat	Occurrence
Bats (Yuma myotis, little brown bat, big brown bat)	roosting concentrations of bats are state priority species	breeding, rearing young, roosting	rear young and take refuge in Chapman Bay pier or other structures,[e] may also use snags or other habitat in upland area; forage[f] over fresh water and in uplands	spring through fall
Salmonids (Chinook, chum, coho, steelhead)	Chinook are federally threatened and a state candidate species, coho are a federal species of concern, and steelhead are federally threatened	spawning, rearing, smoltification, refuge, migration, foraging	chum and coho may spawn in Woodard Creek; steelhead and Chinook have been observed, but use unknown; juveniles of several species likely forage and transition to salt water in shoreline and protected embayments; adults use area for migration	various species and life stages present year-round
Forage fish	state priority species	spawning, rearing, foraging	surf smelt spawn on gravelly beach south of Woodard Point; potential habitat exists around Weyer Point for both surf smelt and sand lance	fall/winter
Olympia oyster	state candidate species	entire life cycle	small population of native oysters is located in areas of freshwater influence, most notably the mouth of Woodard Bay; spat from the remnant population in Woodard Bay and surrounding inlet preferentially settle in areas with hard substrate	year-round resident

Source: WDNR (2002); state and federal lists (WDFW 2008)

[a] State priority status specifically addresses nesting colonies, including the colony at Woodard Bay.

[b] All alcids (breeding and non-breeding aggregations) are considered state priority species.

[c] Priority species include cavity-nesting ducks (wood duck, Barrows and common goldeneye, bufflehead, hooded merganser), other waterfowl such as brant and snow geese, swans, and all other concentrations of waterfowl. These species and many others may be seasonal residents at Woodard Bay.

[d] Priority species include plovers, sandpipers, godwit, dowitchers, snipe, curlew, tattlers, turnstones, and phalarope. Killdeer, spotted sandpiper, sanderling, dunlin, long-billed dowitcher, and common snipe may be year-round or seasonal residents at Woodard Bay.

[e] The Woodard Bay trestle is used by individuals within the colony as one of several alternative roosts. Artificial habitat was constructed for bats adjacent to the pier structure but is currently unused (Falxa 2007).

[f] The majority of the bat colony at the Woodard Bay NRCA forages over 12 km away at Capitol Lake in Olympia.

3.5 Archaeological and Historical Resources

In a 1991 archaeological reconnaissance survey, WDNR discovered 21 locations with evidence of long-term Native American use at Woodard Bay NRCA (Stilson 1991). Although the survey was not considered comprehensive, the area represented the densest congregation of archaeological sites in South Puget Sound; additional sites are likely present in other upland and nearshore areas. Investigations by archaeologists and students from Pacific Lutheran University (Huelsbeck 1991) focused on sites along the shoreline that showed evidence of use of the area for shellfish harvest, most notably butter clams, cockles, littleneck clams, mussels, oysters, moon snails, and whelks. Complete site use is unknown and would require additional archaeological investigation.

In 1991, the site was added to the National Register of Historic Places as the Weyerhaeuser South Bay Log Dump Rural Historic Landscape District, the first listing of its kind. The site is considered historically important because it displays the relationship between people and the land (especially the Puget Sound shoreline) over thousands of years. Weyerhaeuser's ownership of the land helped preserve the evidence by limiting development. The site also provides a historical record of the importance of logging in Washington State history. National Register-listed historic structures associated with the log dump include the Chapman Bay pier, dolphins, and individual pilings that were part of the log sorting area; the Woodard Bay trestle; and the foreman's shack (now an educational center for the site). The natural features that drew people to this area still exist, including some of the shellfish beds used by native peoples.

Current site use reflects its historic significance. WDNR manages the NRCA to preserve and enhance the natural features of the site, as well as to offer educational and recreational opportunities focused on its environment and history.

4 Feasibility Study Approach

The FS consists of a series of tasks to identify a preferred alternative for the restoration of the Woodard Bay NRCA:

- Develop a conceptual site model (CSM) to describe the various ecological features of the site and their interactions (Section 5)
- Select restoration targets that represent site attributes and resources to preserve, enhance, or restore (Section 6)
- Identify and evaluate restoration elements that represent discrete actions to benefit one or more targets (Section 7)
- Develop and evaluate restoration alternatives (i.e., combinations of discrete actions) that represent a range of benefits to the ecosystem as a whole (Sections 8) and associated costs (Section 9)
- Select a preferred alternative (Section 10)

The analysis and development of alternatives is limited to the NRCA project area, although it is recognized that regional habitat restoration issues may be affected by site-specific decisions. There are also research needs related to the restoration requirements of specific targets on a landscape scale, which are not addressed here. However, the FS will identify data gaps that may affect the implementation of the preferred alternative, which will be considered in project sequencing.

The preferred alternative will be carried forward to the design phase, which will develop the details of the restoration (including a schedule and phasing of individual components of restoration) and public review process. The design and implementation of site restoration will be subject to consultation with stakeholders and regulatory approval and funding.

5 Development of Conceptual Site Model

To guide restoration planning, a CSM was developed for the nearshore portion of the site. A CSM serves several purposes: it describes general relationships among living organisms and their site-specific environment; it allows resource managers to identify needed restoration; and it provides a framework by which to judge restoration actions via long-term monitoring objectives and metrics. The CSM identifies the ecological attribute (e.g., an ecosystem process or service, population attribute), stressors to that attribute (aspect of the environment that may cause a deleterious impact), indicators of the health of that attribute, and restoration goals.

The Woodard Bay NRCA Management Plan (WDNR 2002) was the primary source used to identify the significant ecological attributes of the site. The description of likely stressors and indicators of the health of and goals for ecological attributes were refined by WDNR and its partners as part of the restoration planning process. Additional consultations with regional experts and tribal staff, a workshop with WDNR[11] and various stakeholders, and two public meetings provided more detail about the site, potential interactions among targets, and restoration goals. Table 5-1 presents a summary of the ecological indicators, stressors, site status, and restoration goals that form the basis of the current CSM.

[11] WDNR sponsored a workshop on January 26, 2009, with Tribes, federal and state agencies, and regional experts to discuss what is known about the use of the site by seals, salmon, and forage fish and interactions among these species.

Table 5-1. Indicators, stressors, current conditions, and restoration goals for ecological resources at the Woodard Bay site

Attribute	Indicator/Measurement	Threats/Stressors	Current Condition	Restoration Goal
Nearshore Processes				
Sediment transport	– quantitative indicators not available	– increased sediment loading within watershed	– altered sediment transport and depositional patterns by structures (bridge, pier and trestle) between sediment source and sink	– enhance natural processes to minimize influence of built structures on sediment transport, accretion, and erosion
Sediment quality	– chemical concentrations in sediment – magnitude of toxicity in laboratory bioassays	– increased chemical contamination in sediment resulting from decomposition of wood debris and leaching from in-water structures	– limited chemical contamination and toxicity present	– maintain sediment chemistry and toxicity below SQS (threshold below which no adverse effects are predicted)
Water quality	– chemical and bacterial concentrations in water column	– degradation of water quality within watershed from stormwater runoff and non-point source discharges	– state standards exceeded for fecal coliform bacteria, dissolved oxygen, and temperature in Woodard Creek; bacterial standard not met in Woodard and Chapman Bays	– meet water quality standards throughout site
Hydrologic regime	– quantitative indicators not available	– change in flushing rate with potential water quality degradation and sediment retention	– circulation and flushing in Woodard Bay disrupted from road bridge and trestle; some modification of Chapman Bay circulation from pier	– enhance natural circulation and flushing, with less influence from anthropogenic structures
Riparian zone interactions with nearshore processes	– structural diversity of plant communities (stratified canopy of understory plants, shrubs, and trees) along shoreline compositional diversity of native riparian plants	– loss of trees (specifically conifers) that contribute large woody debris and shoreline shading – loss of communities that export insects, plant material, etc. to nearshore habitats	– significantly altered riparian vegetation on Weyer Point – limited contribution of large woody debris and export of organic material to the aquatic environment in areas with extensive invasive plant cover near Chapman Bay pier, along south side of Weyer Point and trestle berm.	– restore native riparian forest species composition; increase canopy, including that by conifers, along the shoreline

Table 5-1. Indicators, stressors, current conditions, and restoration goals for ecological resources at the Woodard Bay site (cont.)

Attribute	Indicator/Measurement	Threats/Stressors	Current Condition	Restoration Goal
Benthic Organisms				
Benthic community (including shellfish)	– abundance and diversity of benthic organisms – depth of biological activity in sediment column – thickness and type of wood debris accumulation on sediment surface and within biologically active zone	– sediment chemistry greater than effect levels – sediment toxicity exceeding defined thresholds – smothering by wood debris	– late successional stage/mature benthic community present per sediment profile image evaluation – limited wood debris in biologically active zone – qualitative evidence of large shellfish population – sediment chemistry below effects thresholds except possibly where sediment is in immediate contact with creosote-treated pilings – limited toxicity; similar to reference area	– maintain sediment chemistry below effects thresholds for benthic invertebrates maintain sediment characteristics that will support healthy epifaunal/infaunal communities
Olympia oyster	– abundance – presence of freshwater seeps – silt-free, consolidated substrate – multiple age classes within a population – sediment and water chemistry	– siltation – predation – degraded water and sediment quality	– small subpopulation of Olympia oyster at the mouth of Woodard Bay; may not be contributing to overall recovery of oyster in Henderson Inlet[a]	– enhance Woodard Bay population of native oyster, if possible
Fish				
Forage fish spawning habitat	– sediment grain size characteristics – presence of freshwater seeps[b] – sediment and water chemistry	– loss of habitat through shoreline modification – degraded water and sediment quality	– forage fish spawning south of Woodard Point; unknown if all potential habitats are used – shoreline modification adjacent to privately owned properties; degree of beach alteration unknown – sediment quality meets standards; unlikely to impair spawning – unknown if impaired water quality affects spawning success	– maintain or increase areal extent and quality of habitat to support spawning and development of forage fish

Table 5-1. Indicators, stressors, current conditions, and restoration goals for ecological resources at the Woodard Bay site (cont.)

Attribute	Indicator/Measurement	Threats/Stressors	Current Condition	Restoration Goal
Juvenile salmonid habitat	– sediment and water chemistry – presence of low-salinity transition zones – abundance of prey species	– degraded water and sediment quality – loss of shallow nearshore habitat – loss of quiescent, low-salinity transition zones – low abundance of prey – increase in predator density – contaminated prey	– sediment quality meets standards; unlikely to impair smoltification or migration – unknown if impaired water quality affects smoltification success or migration behavior – shallow, nearshore, low-salinity habitats intact – unknown if impoundment of tidal water behind bridge and trestle on Woodard Bay affects survival	– maintain or increase areal extent and quality of habitat to support juvenile salmonid smoltification, survival, and growth
Mammals				
Seals	– population size – population trends – reproductive success	– loss of haulout habitat for pupping and molting – human disturbance – contaminated prey – reduced prey availability	– population varies between 300 and 600 individuals – current population apparently in decline, although reproductive success is good	– maintain current haulout area[c] for pupping and molting – minimize human disturbance
Bats	– number of species roosting at the site – population size – reproductive success	– loss of roosts – loss of foraging area[d] – loss of protected flyways (tree canopy or structures such as the pier) – contaminated prey – human disturbance	– two or three species roosting in Chapman Bay pier; largest known maternity colony in state – population estimated at 3,000 bats[e] – anthropogenic structures provide current habitat; pier deteriorating in the vicinity of the colony; constructed bat house remains unoccupied	– increase diversity, if possible – maintain or increase roost habitat throughout site (including repair of pier habitat and rehabilitation of existing [unused] bat house) with a long-term goal of shifting use to upland roost areas (if possible) – create/maintain critical flyways – minimize human disturbance
Birds				
Great blue heron	– population size – reproductive success	– loss of roosts – loss of foraging area – contaminated prey – human disturbance	– over 90 nests noted in 2007, with new nests the following year – similar hatching success in 2008, but qualitative observation[f] of possible high chick mortality	– maintain foraging habitat and prey quality – minimize human disturbance

Table 5-1. Indicators, stressors, current conditions, and restoration goals for ecological resources at the Woodard Bay site (cont.)

Attribute	Indicator/Measurement	Threats/Stressors	Current Condition	Restoration Goal
Pigeon guillemot	– population size – reproductive success	– loss of nesting sites – loss of foraging area – contaminated prey – human disturbance	– may nest in sand bluffs along south side of Weyer Point – population size and reproductive success unknown	– maintain foraging habitat and prey quality – minimize human disturbance – maintain or increase potential nesting habitat
Purple martin	– population size – reproductive success	– loss of nesting sites (including displacement by invasive species) – loss of foraging area – human disturbance	– nest in artificial boxes attached to pilings in the Main Operational Area – population size and reproductive success unknown	– maintain nesting sites – minimize impact of invasive species (e.g., starlings) – minimize human disturbance
Bald eagle	– population size – reproductive success	– loss of nesting and perching sites – loss of foraging area – contaminated prey – human disturbance	– nest at several upland locations within the NRCA[g] – pier and dolphins used as perches for loafing and locating prey – population size and reproductive success unknown	– maintain perches – maintain prey diversity and quality
Vegetation				
Aquatic vegetation	– abundance (percent cover) of algae or aquatic grasses – sediment and water chemistry	– excessive sedimentation – degraded water and sediment quality – competition from and replacement by invasive species	– species composition, abundance, and distribution as expected for this area	– maintain existing conditions
Riparian vegetation	– structure and composition of native species	– reduction in structural diversity of forest stand – competition from and replacement by invasive species	– high proportion of native shoreline vegetation, except on Weyer Point – non-natives limiting native vegetation around Weyer Point	– restore native plant species; reduce percent cover of non-native species in riparian zone

[a] Allen (2009).
[b] Surf smelt spawning on intertidal beaches is thought to be associated with freshwater seeps;(WDFW 2009)
[c] Current haulout area composed of 600 linear ft of bundled logs approximately 3 ft wide (1,800 sq ft)
[d] Bats from the Woodard Bay colony forage primarily at Capitol Lake in Olympia, rather than within the NRCA.
[e] Bat count per Greg Falxa (2009).
[f] Debuse (2009).
[g] Restoration actions within aquatic portions of the site will not affect eagle nests.
NRCA – Natural Resources Conservation Area
SQS – sediment quality standards

Historic and archaeological attributes of the site (and impacts to them) are included in the CSM. The majority of known historic and archaeological resources occur either along or close to the shoreline (i.e., within intertidal or nearshore zone); several are accessible to visitors because of proximity to trails or beaches. Restoration actions could harm these sensitive sites, both in the short term (e.g., through disturbance of soils or sediments containing artifacts) and long term (e.g., by changing shoreline erosion rates). To control these potential impacts, WDNR will consult with the State Historic Preservation Officer (SHPO) and the Tribal Historic Preservation Officer (THPO) or cultural resource specialist (CRS) regarding the performance of an archaeological assessment and monitoring of shoreline erosion, as needed. An archaeological data recovery plan to address the adverse effects of erosion may be developed. This consultation may also involve modifications to the project design or development of other procedures to avoid or minimize any impacts to archaeological sites. An inadvertent discovery plan (prepared by WDNR staff) specifies procedures to be followed should archaeological materials or human remains be encountered at the site.

Woodard Bay became a National Register of Historic Places historic district because of the significant role that logging, specifically Weyerhaeuser's operations, played in the region's history. Since Weyerhaeuser ceased operations in 1984, the log unloader (on the pier), the caretaker's house, various outbuildings, the fuel pier, water and fuel tanks, and rails have been removed. The features that remain include the pier, the trestle,[12] the in-water structures described above, and the boom foreman's shack, which is now used as an educational resource. The foreman's shack has been restored. The pier, trestle, and pilings that supported the log sorting pens have not been maintained. Pilings, decking, and stringers on the pier and trestle structures have deteriorated over time; a fire in 1999 damaged a middle section of the pier. Even with deterioration, the main support structures (e.g., the major pilings and cross beams) of the pier and trestle are likely to remain intact for some time to come, inasmuch as the structures had been built to accommodate very heavy loads.

As an NCRA, the Woodard Bay site provides educational and recreational opportunities. School groups often visit, and students from local universities and colleges have undertaken various research projects onsite. Signs explaining the site history and significant natural resources are posted; additional educational resources are available to groups touring the foreman's shack. A system of trails and open areas allows for passive recreation, including bird watching and other wildlife viewing. Boaters and kayakers also visit. Recent riparian habitat restoration near the east end of Weyer Point (former caretaker's house) provides additional educational opportunities.

[12] Although the trestle was not included in the historic district, its omission might have been inadvertent, and the resource likely qualifies for inclusion.

6 Selection of Restoration Targets

Restoration targets and their specific uses or functions, as listed in Table 6-1, were selected from information compiled for the CSM. These targets reflect the management goals identified in the Woodard Bay NRCA Management Plan (WDNR 2002) and the ecological, educational, cultural, and recreational services valued by the public and other stakeholders. The restoration targets are located within the aquatic portion of the Woodard Bay NRCA. Historic, cultural, educational, and recreational values were evaluated qualitatively.

Table 6-1. Ecological restoration targets

Nearshore Processes − Sediment processes − Circulation − Water quality − Sediment quality − Riparian functions **Bat Habitat** − Roosting/pupping − Protected flyways **Seal Habitat** − Molting, pupping − Foraging **Olympia Oyster Habitat** − Feeding/spawning **Forage Fish Habitat** − Spawning − Foraging	**Juvenile Salmonid Habitat** − Foraging − Smolting **Waterfowl Habitat** − Foraging/loafing − Nesting (specifically pigeon guillemots) **Purple Martin Habitat** − Nesting **Shorebird Habitat** − Foraging/loafing **Heron Habitat** − Foraging **Bald Eagle Habitat** − Feeding/perching **Riparian Vegetation** − Structure/cover

7 Identification and Evaluation of Potential Restoration Elements

Individual restoration elements (discrete actions) and their possible effects on restoration targets had been identified in the FS work plan (Windward et al. 2008). Potential restoration actions relied primarily upon the removal of anthropogenic structures or other features (e.g., shoreline fill). Three levels of effort—none, partial, and all—were defined for each possible action, as identified in Table 7-1.

Table 7-1. Individual actions considered in the development of alternatives

Action	Alternative		
	None/ No Action	Partial	All
Chapman Bay fill removal	X	ne	X[a]
Chapman Bay pier removal	X	X	ne
Piling removal	X	X	X
Seal haulout maintenance and enhancement	X[b]	X[c]	X[d]
Bat roost maintenance	X	ne	X
Woodard Bay trestle fill removal	X	X[e]	X[f]
Woodard Bay trestle removal	X	ne	X
Woodard Bay bridge removal and reconstruction	X	X	X
Riparian habitat restoration	X	X[g]	X[g]

[a] Area associated with base of pier and adjacent fill.
[b] No initial change in haulout surface area; assumes no long-term maintenance.
[c] No change in haulout surface area; assumes incremental replacement over time, with long-term maintenance.
[d] No change in haulout surface area; assumes initial replacement of all haulout structures, with long-term maintenance.
[e] Fill associated with south side of trestle.
[f] Fill associated with south side of trestle and trestle berm.
[g] Limited to Weyer Point.
ne – not evaluated

The Habitat Equivalency Analysis (HEA) model developed by NOAA (2000) was used to compare individual restoration actions and alternatives. The HEA is a semi-quantitative tool used to evaluate the net natural resource benefits of different site-specific restoration actions. For each proposed restoration element, the HEA results in a composite score that integrates the benefits and impacts to all of the restoration targets at the site. These composite scores allow the net environmental benefit of each action to be ranked and compared with those of other actions according to their relative impact. The process is repeated to compare restoration alternatives, each of which is a combination of discrete restoration actions.

The higher the score, the greater the benefits. Higher scores are a function of the area and duration of the benefit as well as the ecological value assigned to a given action (within the model, some actions are valued higher than others based on restoration goals for the site).

Inputs into the HEA model include area of effect (in acres), an estimated present-day value of the resource based on current ecological function, an estimated value after a particular action is taken (or the "recovered" habitat value), a timeframe for the target to reach full ecological function, and a discount factor[13] that allows the final credit to be

[13] The discount factor assumes that a future benefit is worth less than a present benefit.

expressed in net present-day value. Additional information on the HEA model and results are provided in Appendix B. HEA model inputs were developed from information from the CSM; direction provided by WDNR; and discussions with their partners, Tribes, and resource experts.

The following sections provide the assumptions used as inputs to the model and results for individual restoration components. Individual components were combined to configure four alternatives for further evaluation.

7.1 MODEL ASSUMPTIONS AND INPUTS

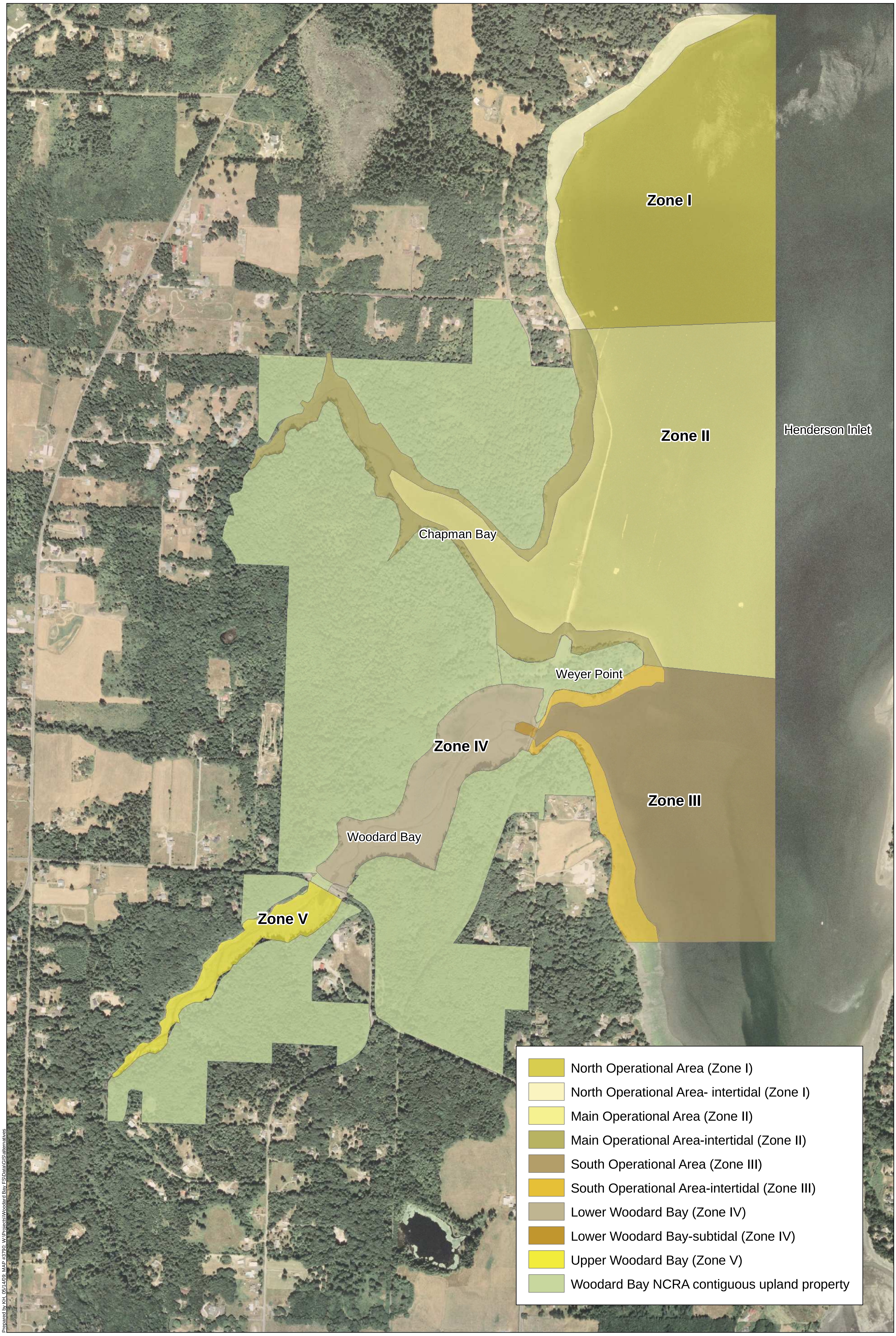
In the HEA model, each individual element is associated with an area (in acres) affected by the action and a habitat value that are then used to generate an estimate of the effect (positive or negative) on a restoration target.

Within the Woodard Bay NRCA, seven zones were defined for the purpose of evaluating the areal extent of impacts and benefits of individual restoration elements (Map 7-1):

1. Zone 1 – North Operational Area
2. Zone 2 – Main Operational Area
3. Zone 3 – South Operational Area
4. Zone 4 – Lower Woodard Bay (between road bridge and trestle)
5. Zone 5 – Upper Woodard Bay (above road bridge)
6. Riparian zone on Weyer Point
7. All contiguous upland areas that are part of the Woodard Bay NRCA

The three operational areas were subdivided into two depth zones—intertidal and subtidal. A third, intermediate zone of intertidal and shallow subtidal (< -20 ft MLLW) areas—the nearshore—was created to evaluate impacts and benefits to the primary habitat for Olympia oyster and juvenile salmonids.

The area associated with potential impacts varied by restoration target. The maximum impact area is the entire project area, including contiguous upland NRCA property; locations beyond the project boundaries were not included in the evaluation. The presence of each restoration target within each zone and habitat is indicated by an “X” in Table 7-2. An “na” (not applicable) means either a target is not expected to use resources in that zone or the habitat does not exist in that zone (e.g., there is no subtidal habitat in the upper or lower portion of Woodard Bay).



Prepared by KH, 05/14/09; MAP #3790; W:\Projects\Woodard Bay FS\Data\GIS\alternatives

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Map 7-1. Woodard Bay assessment areas

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Table 7-2. Potential impact areas for restoration targets

Restoration Target	Habitat/Zone																
	1 – North Operational Area			2 – Main Operational Area			3 – South Operational Area			4 – Lower Woodard Bay			5 – Upper Woodard Bay			6 – Riparian	7 – Upland
	I	S	N	I	S	N	I	S	N	I	S	N	I	S	N		
Sediment processes	X	X	incl	X	X	incl	X	X	incl	X	na	incl	X	na	incl	X	na
Circulation	X	X	incl	X	X	incl	X	X	incl	X	na	incl	X	na	incl	X	na
Water quality	X	X	incl	X	X	incl	X	X	incl	X	na	incl	X	na	incl	na	na
Sediment quality	X	X	incl	X	X	incl	X	X	incl	X	na	incl	X	na	incl	na	na
Riparian functions	incl	na	X	incl	na	X	incl	na	X	incl	na	X	incl	na	X	X	na
Bats (nursery)	na	na	na	X	X	incl	na	na	na	X	na	na	na	na	na	na	na
Seals (pupping, molting)	na	na	na	na	X	na	na	na	na	na	na	na	na	na	na	na	na
Seals (foraging)	X	X	incl	X	X	incl	X	X	incl	X	na	incl	X	na	incl	na	na
Olympia oyster	na	na	X	na	na	X	na	na	X	na	na	X	na	na	X	na	na
Heron	X	na	na	X	na	na	X	na	na	X	na	na	X	na	na	na	X
Purple martin	na	na	na	X	X	incl	na	na	na	na	na	na	na	na	na	na	na
Forage fish (spawning)	X	na	na	X	na	na	X	na	na	X	na	na	X	na	na	na	na
Forage fish (foraging)	X	X	incl	X	X	incl	X	X	incl	X	na	incl	X	na	incl	na	na
Juvenile salmonids	na	na	X	na	na	X	na	na	X	na	na	X	na	na	X	na	na
Shorebirds	X	na	na	X	na	na	X	na	na	X	na	na	X	na	na	na	na

Table 7-2. Potential impact areas for restoration targets (cont.)

Restoration Target	Habitat/Zone																
	1 – North Operational Area			2 – Main Operational Area			3 – South Operational Area			4 – Lower Woodard Bay			5 – Upper Woodard Bay			6 – Riparian	7 – Upland
	I	S	N	I	S	N	I	S	N	I	S	N	I	S	N		
Waterfowl (foraging, loafing)	X	X	incl	X	X	incl	X	X	incl	X	X	incl	X	X	incl	na	na
Pigeon guillemot (nesting)	X	na	na	X	na	na	X	na	na	X	na	na	X	na	na	na	X
Bald eagle	X	X	incl	X	X	incl	X	X	incl	X	X	incl	X	X	incl	na	X

I – intertidal
S – subtidal
N – nearshore (intertidal + subtidal to -20 ft MLLW)
MLLW – mean lower low water
na – not applicable
incl – included in related category (e.g., when both intertidal and subtidal habitat areas are specified, nearshore is included by definition)

7.1.1 Model assumptions

Key assumptions regarding natural resource impacts and benefits of restoration elements are summarized in the Table 7-3. These assumptions were developed in consultation with WDNR, TNC, WDFW, NOAA Fisheries Service, USACE, the Squaxin and Nisqually Tribes, marine mammal and bat experts at Cascadia Research, and best professional judgment of Windward Environmental LLC (Windward) biologists and ecologists. Assumptions regarding the effects of restoration on seals and salmonids were developed as part of a workshop with the Tribes, resources agencies, and other experts held in January 2009. Effects on oysters were developed through consultation with Brian Allen of the Puget Sound Restoration Fund and Betsy Lyons of TNC, who are involved in restoration of the Olympia oyster. Information about bats was derived from a 2007 status report prepared by Greg Falxa of Cascadia Research (Falxa 2007). WDNR staff provided additional input on assumptions for multiple resources based on their site-specific knowledge and programmatic goals for the Woodard Bay NRCA.

Table 7-3. Key assumptions

Action[a]	Ecological Benefit	Ecological Impact
Chapman Bay fill removal	– increased intertidal/aquatic area – After removal of small area of armored bank, possible coarsening of intertidal sediment from bank erosion – improved exchange of water and sediment between inner and outer Chapman Bay. – Improved sediment transport processes	– slight decrease in shoreline-water interface. – short-term decrease in water quality during removal (primarily from resuspension of soil/sediment)
Chapman Bay pier removal (bat colony segment retained under all alternatives)	– decreased shading – Improved sediment quality over the long term from removal of treated pilings – improved intertidal foraging habitat – increased flushing at mouth of Chapman Bay – possible increase in sediment transport and erosion on north-facing shoreline and points due to exposure to northeast fetch – improved sediment transport processes and water circulation	– decrease of sediment quality within piling halo, but with longer-term recovery – short-term impact to water quality within 300 ft of action – reduction of foraging habitat for waterfowl with removal of biofouled piling – possible smothering of benthic infauna in localized areas due to redeposition of sediments disturbed during removal – under maximum removal alternative, possible impact to raptors and aquatic birds using pier as perch – maximum removal alternative adversely affects critical flyway (pier south of roost)
Piling removal Zone 1 – North Operational Area	– improved sediment quality over the long term – limited overall benefit to other targets	– decrease of sediment quality within piling halo, but with recovery – short-term impact to water quality within 300 ft of action
Piling removal Zone 2 – Main Operational Area	– improved sediment quality over the long term – increased flushing of Chapman Bay with removal of the majority of the piling field – possible increased transport and erosion of sediment on north-facing shoreline and points due to increased exposure to NE fetch – improved sediment transport processes and water circulation	– decrease of sediment quality within piling halo, but with recovery – short-term impact to water quality within 300 ft of action – no loss of habitat for purple martin or anchorage for seal haulout because of retention (and eventual replacement) of some piling
Piling removal Zone 3 – South Operational Area	– improved sediment quality over the long term – limited overall benefit to other targets	– decrease of sediment quality within piling halo, but with recovery – short-term impact to water quality within 300 ft of action

Table 7-3. Key assumptions (cont.)

Action[a]	Ecological Benefit	Ecological Impact
Seal haulout status quo without any further maintenance	– no initial change from existing condition of relatively protected, undisturbed site for pupping, nursing, and molting for individuals from South Puget Sound seal population – possible seal relocation and local reduction in fish predation with eventual degradation of unmaintained haulout	– location of primary feeding areas will likely shift, when seals relocate. Increased seal density at other locations (e.g., Nisqually Delta) may adversely impact populations of forage fish and migratory salmonids at those locations possible increase in competition among seals due to higher densities and greater disturbance among pupping or molting seals at other locations, with possible increased pup mortality
Seal haulout with incremental replacement and long-term maintenance	– no change from existing condition of relatively protected, undisturbed site for pupping, nursing, and molting for individuals from South Puget Sound seal population.	– no change from existing condition – predation on local populations of forage fish and migratory salmon at existing levels
Seal haulout with initial complete replacement and long-term maintenance	– no change from existing condition of relatively protected, undisturbed site for pupping, nursing, and molting for individuals from South Puget Sound seal population – benefit primarily related to management costs	– no change from existing condition
Woodard Bay trestle fill removal[b]	– increased tidal exchange in Lower Woodard Bay due to removal of intertidal fill – reduced ponding and potential entrapment of juvenile salmonids at low tides – increased intertidal foraging areas – improved long-term sediment transport processes and water circulation – Improved linkage with riparian zone	– remobilization of sediment deposited in Lower Woodard Bay from runoff in upper watershed, with possible smothering of Olympia oysters and benthic invertebrates at the mouth of Woodard Bay (but with eventual recovery) – altered recovery of Olympia oyster due to changed water circulation after removal of berm fill (Allen 2009).
Woodard Bay trestle removal	– slight increase in tidal exchange in Lower Woodard Bay – possible reduction in ponding and fish entrapment at low tides	– possible destabilization or loss of mussel reef – possible remobilization of sediment deposited in Lower Woodard Bay, with possible smothering of Olympia oysters and benthic invertebrates (less so than with trestle fill removal, and with eventual recovery) – loss of alternative bat roost and flyway
Woodard Bay bridge removal and reconstruction	– increased tidal exchange in Lower Woodard Bay – reduced ponding and fish entrapment at low tides	– decrease in shoreline-water interface – increase in intertidal transport of sediment deposited in Upper Woodard Bay, with possible smothering of benthic invertebrates (including oysters) in Lower Woodard Bay and at mouth (with eventual recovery) – possible change in fringing estuarine wetland community characteristics with increased transport of sediment

Table 7-3. Key assumptions (cont.)

Action [a]	Ecological Benefit	Ecological Impact
Riparian habitat restoration on Weyer Point	– increased transfer of organic material to nearshore environment – increased habitat for birds, mammals, invertebrates, and others – improved shade to beach and water	– higher erosion potential while plants are getting established.

Note: Key assumptions do not currently address impacts/benefits to historic, archaeological, educational, or recreational resources nor do they include costs.

[a] Evaluation of individual actions does not currently account for possible mitigation (e.g., reseeding of oysters).

[b] There are two components to the fill. The north fill area is the main berm that supported the railroad. The south fill area is an intertidal depositional area under the existing trestle that has further constricted the outlet from Lower Woodard Bay.

The following additional assumptions were incorporated into the HEA model:

- Sediment processes include accretion, erosion, and excess sediment loading from human activity. Each action is evaluated for both its positive and negative effects on the overall target.
- The bat roost on the Chapman Bay pier will be repaired and maintained.
- Riparian habitat is defined as shoreline and upland areas that most directly influence or are influenced by nearshore environments (contributions can include the export of large woody debris or coarse organic material, shading, and cooling of water). Its restoration is evaluated as a separate action within the HEA model, and the maximum action area is the Weyer Point riparian habitat.
- All single pilings will eventually be removed; a subset will be replaced with steel pilings for seal float anchors and purple martin nest boxes.
- Water quality and sediment quality are judged relative to existing Washington State standards for those media.
- Surface sediment within the Woodard Bay NRCA currently meets SMS criteria and does not require remediation.
- Fill material that may be removed from the site is assumed to be "clean" under the Dredged Material Management Program open-water or Washington State upland disposal criteria.
- The railroad berm on the north side of the Woodard Bay trestle has been compacted over time and is armored; therefore, minimal erosion or loss of this feature is expected. Other shoreline areas are more subject to erosion.
- Pigeon guillemots nest primarily in sand and clay bluffs or boulder fields adjacent to the intertidal zone but may also nest in tree roots, disused burrows of rabbits or other seabirds, driftwood pilings, rotten logs, vegetation, wharfs, bridges, navigation aids, walls, disused buildings, spent tire casings, pipes, or wooden nest boxes. At the site, guillemots are known to nest in the banks along the south side of Weyer Point.

The following assumptions about timeframe were also made:

- Construction will be completed within 1 year (sequencing and duration developed during the design phase of the project may alter this timeline).
- Construction will occur during non-breeding seasons for bat and seals and during non-migratory periods for juvenile salmonids.
- Subsurface sediment that is in direct contact with creosoted pilings may currently be degraded relative to the SMS. When pilings are removed, this sediment may be released. Sediment quality in the vicinity of the removed

pilings will require 10 years to recover naturally, assuming the depth of affected sediment is at least 10 cm and the rate of natural sedimentation is 1 cm/year.

- Farfield sediment degraded from resuspension during piling removal will require 2 years to recover naturally based on the need for a layer of new material that is 2 cm thick to reduce water quality impacts and a natural sedimentation rate of 1 cm/year.
- The natural sedimentation rate of clean sediment is assumed to be 1 cm/year.
- Sediment processes will require 30 years to reach equilibrium.
- The benthic community, including the Olympia oyster,[14] will take 5 years to recover following disturbance (affects benthic invertebrates, juvenile salmonids, forage fish, and heron).

7.1.2 Model uncertainties

The model relied on the best professional judgment of resource managers and scientists to establish the relative effect or benefit of a given restoration action. Necessary scientific information on the detailed ecological requirements of all target species and communities, carrying capacities of the Woodard Bay ecosystem, interactions among target species, or the relationship of site conditions in the context of a larger landscape, is not currently available. In addition, the scale and duration of any effects represented by available scientific information were based on generalizations from other projects in Puget Sound and thus may not be accurate for Woodard Bay. However, these uncertainties had a similar effect across restoration actions and were unlikely to alter the relative rankings of restoration options. Although the HEA model scores fluctuated with the use of different assumptions, the management priorities and restoration goals would have had to change dramatically in order to substantially affect the numerical scoring and reorder the relative ranking of the restoration options considered.

In order to refine the long-term management of the site, a data gaps for the site will need to be addressed through additional research. The seals that haul out at Woodard Bay are part of the South Puget Sound population. Changes in conditions at Woodard Bay may affect the dynamics among seals in this region and their reproductive success, but the overall outcome is not known. Shifting the distribution of seals in South Puget Sound (if Woodard Bay were no longer available as a haul out and pupping site) would likely alter the seals' interactions with prey and humans. Natural resource managers from state, federal, and Tribal agencies are discussing research needs and priorities to address data gaps regarding the South Puget Sound seals and their interactions within economically important fisheries such as salmon. Because the effect of displacing the

[14] Conservative recovery times were used in the model. The duration may be mitigated by direct actions during restoration (e.g., collection and relocation of oyster stocks) or natural processes (e.g., higher rates of recruitment).

Woodard Bay seals is unknown, maintenance of existing conditions was considered to be the goal for the site.

A long-term goal of migrating the bat colony from the pier to other artificial habitats constructed in upland areas of the NRCA has been identified by regional experts and stakeholders. However, additional research is needed to address the habitat requirements of the bat maternity colony, including factors affecting the selection of a roost and the role of protective flyways in roost selection. Because this information is not currently available, the existing bat habitat and flyway associated with Chapman Bay pier were considered within the HEA model to be critical to the success of the bat maternity colony.

7.2 MODEL RESULTS

The model results for individual restoration components were used as the basis for configuring four alternatives to be considered in the FS. A summary of the cumulative HEA results for the individual actions is provided in Table 7-4. In general, restoration actions provide some benefit to at least one or more targets, and No Action alternative is detrimental to many because of the long-term deterioration of ecosystem processes, including sediment transport, water quality and circulation, and habitats (including anthropogenic structures). Results for individual restoration actions (i.e., HEA scores) are summarized below.

Table 7-4. Summary of HEA results for individual restoration elements

Restoration Action	HEA Results by Restoration Target																			
	Bald Eagle	Forage Fish – Foraging	Forage Fish – Spawning	Heron	Juvenile Salmonids	Oyster	Purple Martin	Shorebirds	Seal – Foraging	Seal – Haulout	Bat – Foraging/Flyway	Bat – Roosting	Waterfowl – Foraging	Waterfowl – Nesting	Benthic	Riparian	Sediment Quality	Water Quality	Sediment Transport	Grand Total
Chapman fill removal	**4.4**	**0.7**	**9.8**	**18.0**	**21.6**	**21.9**	0.0	**14.8**	**0.4**	0.0	0.0	0.0	**7.4**	0.0	**7.0**	**-0.1**	0.0	**-0.2**	**4.6**	**110.1**
Chapman fill removal – no action	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pier removal 1 – 76%[b, c]	**11.1**	0.0	**4.8**	**8.1**	**4.1**	0.0	0.0	**2.4**	**0.1**	0.0	**-2.1**	**-1.3**	**-1.7**	0.0	**6.3**	**-0.3**	**1.3**	**-0.4**	**44.0**	**76.5**
Pier removal 2 – 49% [b, c]	**7.2**	0.0	**2.4**	**5.2**	**2.6**	0.0	0.0	**1.5**	**0.1**	0.0	**-2.1**	**-1.3**	**-1.4**	0.0	**3.8**	**-0.2**	**0.8**	**-0.1**	**38.0**	**56.5**
Pier removal 3 – 38% [b, c]	**5.6**	0.0	**1.8**	**4.1**	**2.0**	0.0	0.0	**1.2**	**0.1**	0.0	**-1.1**	**-1.3**	**-1.2**	0.0	**2.8**	**-0.2**	**0.6**	**-0.1**	**9.0**	**23.2**
Pier removal – no action[a]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**-0.8**	0.0	0.0	**-0.5**	0.0	**-0.1**	**-1.2**	**-2.7**	**-5.3**
Piling removal (Zone 1) – 100%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**-0.4**	0.0	0.0	0.0	0.0	**-0.2**	**0.5**	**-0.1**
Piling removal (Zone 1) – no action	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**-0.6**	**-0.1**	**-0.6**
Piling removal (Zone 2) – 90%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**-0.5**	0.0	**-0.1**	0.0	**0.4**	**-0.4**	**3.5**	**2.8**
Piling removal (Zone 2) – no action	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**-1.2**	**-0.7**	**-2.0**
Piling removal (Zone 3) – 100%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**-0.4**	0.0	0.0	0.0	0.1	**-0.3**	**0.6**	**-0.1**
Piling removal (Zone 3) – no action	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**-1.4**	**-0.1**	**-1.5**
Riparian restoration – Weyer Point (all)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**9.7**	0.0	0.0	0.0	**9.7**
Riparian restoration – Weyer (partial)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**5.2**	0.0	0.0	0.0	**5.2**
Riparian restoration – no action	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**-3.9**	0.0	0.0	0.0	**-3.9**

Table 7-4. Summary of HEA results for individual restoration elements (cont.)

Restoration Action	HEA Results by Restoration Target																			
	Bald Eagle	Forage Fish – Foraging	Forage Fish – Spawning	Heron	Juvenile Salmonids	Oyster	Purple Martin	Shorebirds	Seal – Foraging	Seal – Haulout	Bat – Foraging/Flyway	Bat – Roosting	Waterfowl – Foraging	Waterfowl – Nesting	Benthic	Riparian	Sediment Quality	Water Quality	Sediment Transport	Grand Total
Seal haulout – status quo with enhancement	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**1.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**1.0**
Seal haulout – no action[d]	0.0	**4.0**	**13.0**	0.0	**6.3**	0.0	0.0	0.0	**-7.9**	**-22**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**-6.9**
Trestle and fill removal (south and north side)	0.0	**0.8**	**11.1**	0.0	**54.9**	**-37.2**	0.0	**14.3**	**1.1**	0.0	0.0	**-0.2**	**17.1**	0.0	**5.7**	**-0.3**	0.0	0.0	**1.7**	**68.9**
Trestle and fill removal (south side only)	0.0	**0.4**	**5.5**	0.0	**27.5**	**-18.6**	0.0	**10.3**	**0.6**	0.0	0.0	**-0.2**	**15.1**	0.0	**2.8**	**-0.3**	0.0	0.0	**0.9**	**44.0**
Trestle removal only – no fill removal	0.0	0.0	0.0	0.0	0.0	**14.9**	0.0	**12.4**	0.0	0.0	0.0	**-0.2**	0.0	0.0	0.0	**-0.3**	**1.9**	**-0.3**	**0.1**	**28.5**
Trestle and fill removal – no action	0.0	0.0	0.0	0.0	**-13.1**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**-0.2**	**-13.3**
Woodard bridge partial removal/reconstruction	0.0	0.0	0.0	0.0	**-1.0**	**-0.5**	0.0	**-0.7**	0.0	0.0	0.0	0.0	**0.3**	0.0	**-1.5**	0.0	0.0	0.0	**0.6**	**-1.4**
Woodard bridge complete removal/reconstruction	0.0	0.0	0.0	0.0	**-0.1**	**0.4**	0.0	**1.3**	0.0	0.0	0.0	0.0	**0.7**	0.0	**-1.2**	0.0	0.0	0.0	**1.2**	**2.4**
Woodard bridge – no action	0.0	0.0	0.0	0.0	**-26.3**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**-26.3**

Note: Positive numbers reflect a positive impact; negative numbers reflect an adverse impact.

[a] There is an assumed loss in bat roost quality and sediment and water quality over time as the pier structure deteriorates under the No Action alternative.

[b] Some impacts to bats (based on reductions in pier flyway length) and waterfowl foraging are anticipated with the removal of any pier sections.

[c] Bat habitat is repaired and maintained under all action alternatives.

[d] The No Action alternative for seal haulout assumes the deterioration of haulout areas over time.

The removal of fill in Chapman Bay increases the intertidal and nearshore area available as habitat for benthic organisms, including oysters and other shellfish; a foraging area for heron and shorebirds; potential spawning habitat for forage fish (assuming substrate is appropriate); and a migratory corridor for juvenile salmonids. The aquatic portion of the site increases slightly with the removal of fill, which increases the foraging area for diving ducks and other waterfowl. The removal of fill in this area improves water circulation and longshore sediment transport. This action also has the effect of smoothing the shoreline, which may serve to dissipate wave energy that impinges on the north shoreline of Weyer Point and thus slow erosion.[15]

The removal of portions of the pier has the overall effect of improving the circulation and longshore sediment transport in Chapman Bay. Water and sediment quality are improved over the long-term because creosote-treated pilings are removed from the marine environment (although there are short-term impacts during removal). Animals assumed to forage in the water column benefit from the increased aquatic area; benthic organisms (including shellfish) benefit from the improved chemical quality of their habitat. Although the area of the pier currently used as a bat roost remains undisturbed, a portion of the pier used as a flyway is removed; the effects of flyway changes on bat behavior are unknown but are assumed to be detrimental within the context of the HEA scoring. Removing portions of the pier reduces the habitat available for fouling organisms (e.g., mussels, barnacles), slightly reducing the foraging opportunities for waterfowl.

The removal of individual pilings throughout the site has similar benefits: improved sediment transport, water circulation, water quality, and sediment quality (with localized, short-term impacts to sediment and water quality during removal). Waterfowl foraging habitat (fouling organisms on pilings) and bird perching and loafing opportunities are reduced. Purple martin artificial nest density remains the same because some pilings are replaced.

Trestle removal at the mouth of Woodard Bay yields benefits to sediment transport, water circulation, water quality, and sediment quality similar to those of pier and piling removal. The small population of Olympia oysters at the mouth of Woodard Bay may benefit from the eventual improvement in water and sediment quality resulting from the removal of the trestle's creosote-treated pilings. Shorebirds may benefit from the slight increase in intertidal habitat resulting from piling removal. A small fraction (< 7%) of bats roosts on the trestle some of the time (Falxa 2007); removal would impact this portion of the bat population.

The removal of the fill associated with the trestle has mixed benefits, depending on the target. Fill removal opens up additional intertidal habitat for animals that forage (e.g., heron, shorebirds, other waterfowl, juvenile salmonids) or spawn (forage fish) in this

[15] Shoreline features that extend into the water tend to focus wave energy as the waves bend around the feature, increasing the potential for erosion (Downing 1983).

zone. The shoreline along the north side of the trestle berm can be recontoured to provide a more natural slope (and greater intertidal area), enhancing the value of riparian restoration in this area. However, the fine-grained sediment that has accumulated on the upstream side of the opening of Woodard Bay (which was significantly restricted by the trestle fill) will likely be remobilized when the fill and trestle berm are removed, and transported either into the cove at the mouth of Woodard Bay or farther out into Henderson Inlet. The initial effect may be to smother the existing population of Olympia oyster and other clams in this area, although most species would likely recover over time. It is unclear why Olympia oysters have successfully colonized the mouth of Woodard Bay but not elsewhere at the site (it is possible site-specific conditions result in less dessication and temperature stress). If the berm and fill areas have created a unique environment that supports their survival, then the removal of these features may negatively impact their recovery; this action was conservatively considered to be a detriment to Olympia oysters in the HEA model. This impact could be mitigated through the creation of oyster reefs or other features following removal; however, the potential benefit from mitigation was not included in the model.

Reconstruction of the Woodard Bay road bridge generates benefits and impacts (except for impacts associated with creosote pilings because the bridge has none) such as those of removing the trestle, berm, and fill at the mouth of the bay. In addition, the action may cause the remobilization and transport of fine-grained sediment that has accreted in upper Woodard Bay, altering the physical processes by which the fringing marsh has developed. The areal extent of the marsh community may be reduced over time.

Benefits associated with reconfiguration of the seal haulout are related primarily to management and maintenance costs because there is no change in the overall surface area available for use. A small incremental benefit will accrue to sediment and water quality after the replacement of the creosoted pilings that anchor the floats.

Any degree of riparian restoration is considered a benefit to ecosystem processes at the site.

The absence of restoration actions has long-term consequences for ecosystem processes and restoration targets. If the pier is not reduced in size, water circulation and longshore sediment transport will remain restricted; contaminant (including bacteria) transport from the watersheds that drain to Woodard and Chapman Bays will exacerbate water and sediment quality issues in Henderson Inlet. Without maintenance, the pier will continue to degrade, and its large bat populations will likely be displaced or lost. Although the long-term goal is to build and encourage use of upland artificial habitats (with eventual removal of the pier), the success of such action is uncertain and requires additional research regarding bat behavior and roost requirements. Until that time, the pier provides critical habitat for bats.

If other in-water structures are not removed, there will be a long-term impact on sediment and water quality as the creosote pilings eventually fall apart and release the chemical preservative into the environment. Purple martin nest sites will be reduced once the pilings have fallen apart. In addition, leaving creosote pilings in place does not meet WDNR's internal policy. Without replacement and maintenance, the seal haulout will deteriorate, and the current population will disperse to other areas of South Puget Sound, creating greater pressure on the other seals and their prey, with possible increased pup mortality. If no restoration were to occur at the site, no nearshore fill would be removed. While leaving fill in place does not cause significant long-term impacts, the benefits of removal (primarily the creation of new aquatic habitat) would never be realized.

8 Development and Evaluation of Alternatives

Based on the cumulative results, four alternatives were compiled to represent a range of ecological benefits; a No Action alternative is included for comparison (Table 8-1). These alternatives integrate benefits to multiple resources and restoration targets through various combinations of elements. The elements associated with each of the alternatives are summarized below. Potential impacts to historic, archaeological, educational, and recreational resources at the site are also described.

Table 8-1. Summary of proposed alternatives

Action	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Remove sections of Chapman Bay pier	no action	X	X	X
Repair and maintain bat habitat on pier	no action	X	X	X
Remove fill at base of Chapman Bay pier	no action	no action	X	X
Remove 100% of pilings in North and South Operational Areas	no action	X	X	X
Remove 90% of pilings in Main Operational Area	no action	X	X	X
Maintain seal haulout	no action	X	no action	no action
Improve and maintain seal haulout	no action	no action	X	X
Remove berm on north side of Woodard Bay trestle	no action	no action	no action	X
Remove fill on south side of Woodard Bay trestle	no action	no action	X	X
Remove trestle over Woodard Bay	no action	X	X	X
Remove and reconstruct Woodard Bay bridge[a]	no action	no action	no action	X
Restore riparian zone	no action	X	X	X

[a] `Three options for Woodard Bay bridge management were considered under Alternative 4: Alternative 4a leaves the bridge in place, Alternative 4b modifies the bridge, and Alternative 4c reconstructs the bridge as an open-span structure.

Costs are provided as planning estimates (see Section 9)[16] to allow comparison among alternatives and are expected to be accurate within -10% to +30% based on current market conditions.

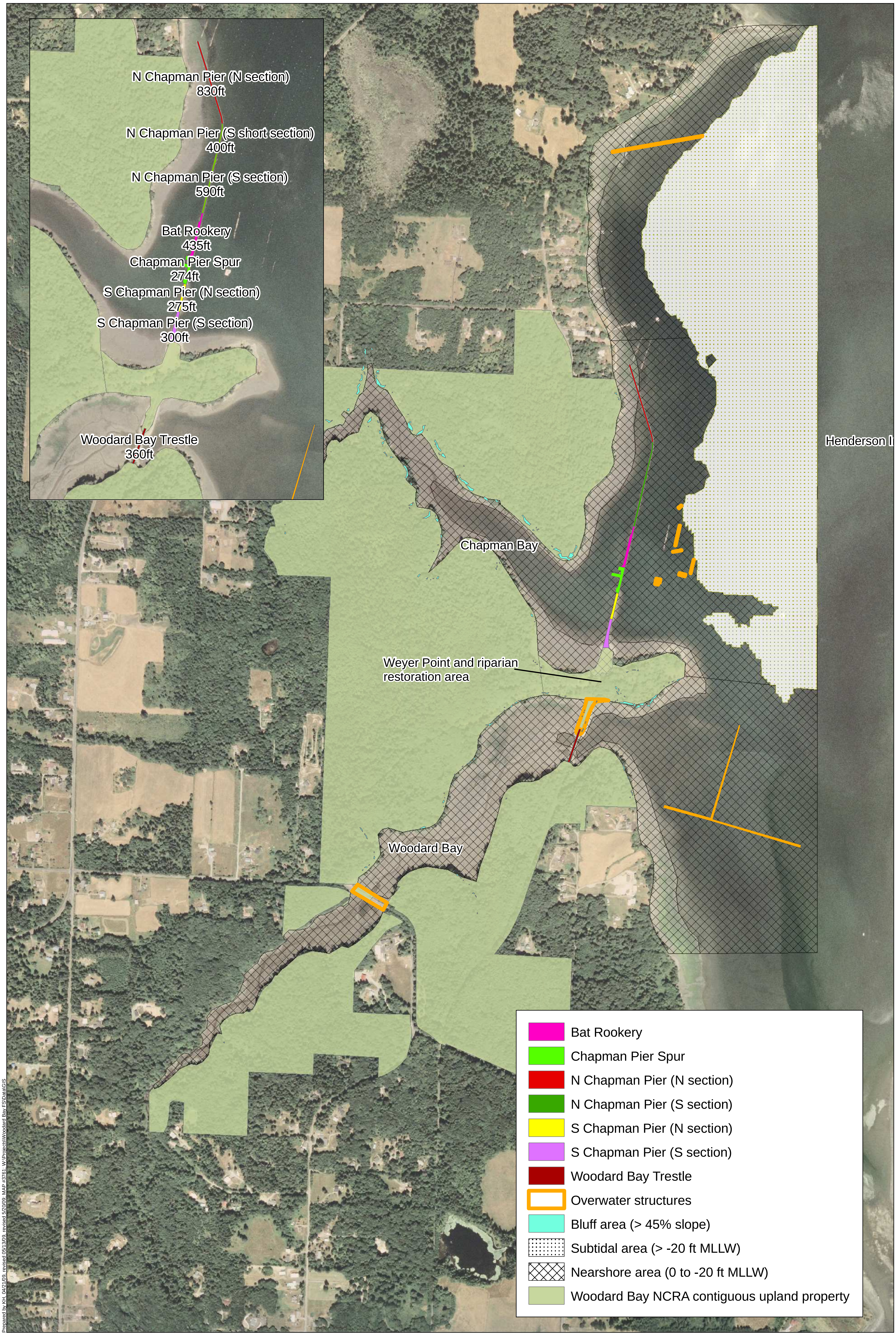
[16] Costs do not include restoration contractor overhead, or profit.

Certain restoration actions are included in all alternatives (not including Alternative 1, the No Action alternative):

- Retention and maintenance of the bat roost in the middle section of Chapman Bay pier
- Retention and maintenance of the seal haulout
- Removal of the northernmost (560 ft) and southernmost (320 ft) sections of Chapman Bay pier
- Removal of all of the pilings in the North and South Operational Areas
- Removal of 90% of pilings in the Main Operational Area (with removal and replacement of remaining pilings in 10 years)
- Removal of the Woodard Bay trestle
- Restoration of the riparian zone

In all action alternatives, some section of the Chapman Bay pier is removed, although the specific sections removed vary among alternatives. The section of the pier that contains the bat roost is not removed in any alternative; although varying portions of the southern underpier flyway are removed in the alternatives. Pier section references are shown in Map 8-1. The seal haulout is kept in all the action alternatives with no additional increase in haulout area; however, the degree of maintenance or improvement varies. In most cases, the floats are replaced with an engineered structure to increase the longevity and reduce maintenance costs (see Appendix C for description). Maps 8-2, 8-3, and 8-4 illustrate components of Alternatives 2, 3, and 4, respectively.

All in-water and shoreline restoration activities have the potential to disturb archaeological resources at the site. Such disturbance will be addressed through archaeological assessment, in consultation with SHPO and the THPO/CRS, and implementation of resulting recommendations. WDNR will implement their inadvertent discovery plan as needed.



WindWard environmental LLC

N

0 200 400 Yards

0 100 200 Meters

Map 8-1. Woodard Bay overwater structures and features

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Prepared by KH, 03/13/09, 4/21/09, 5/13/09; MAP #3699; W:\Projects\Woodard Bay FS\Data\GIS\alternatives

Windward environmental LLC

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Map 8-2. Alternative 2: Minimal removal of anthropogenic features

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WindWard LLC environmental

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Map 8-3. Alternative 3: Mid-range removal of anthropogenic features

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WindWard environmental LLC

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Map 8-4. Alternative 4: Maximum removal of anthropogenic features

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The elements of each alternative are further outlined below; a brief description of the impacts and benefits are provided for each element.

8.1 Alternative 1 – No Action

Relative cost—low (~$1 million)

All anthropogenic and ecological features will remain, with no further improvements. The seal haulout and bat roost will be allowed to degrade, with the ultimate loss of the habitat. The assumed baseline cost is $35,000 per year over 30 years for maintaining the site, including public safety (fencing, signage, gates, monitoring and patrolling), based on current annual costs. The site will continue to be used for environmental education and passive recreation such as hiking and bird-watching.

8.2 Alternative 2 – Minimal Removal of Anthropogenic Features

Relative cost—low (~$4.6 million)

Remove southernmost (320 ft) and northernmost (560 ft) sections of the Chapman Bay pier (38% of pier)

- Maintains core bat roost habitat, including majority of under-pier flyway from roost to shore
- Contributes to long-term sediment and water quality restoration goals for Puget Sound through removal of creosote piling
- Improves flow into and circulation of Chapman Bay
- Causes minimal impact to resources using pier as habitat and foraging area (bats, waterfowl, raptors)
- Increases boat access to inner Chapman Bay, with possible increase in disturbance to waterfowl
- Improves public safety by preventing access to pier decking
- Maintains majority of historic site features

Remove 100% of pilings in North and South Operational Areas

- Meets long-term sediment and water quality restoration goals for Puget Sound through removal of creosote pilings
- Reduces foraging habitat for waterfowl and fish and perching habitat for waterfowl and raptors

Remove 90% of piling field in Main Operational Area

- Contributes to long-term sediment and water quality restoration goals for Puget Sound through removal of creosote pilings
- Improves circulation in outer Chapman Bay

- Improves sediment transport processes
- Improves long-term sediment and water quality
- Maintains opportunities for seal haulout anchorage and purple martin nesting habitat; may increase incidence of human disturbance of seals
- Reduces foraging habitat for waterfowl and fish and perching habitat for waterfowl and raptors
- Removes historic site features, affecting visual landscape and reducing educational opportunity

Maintain seal haulout with periodic opportunistic replacement of logs with engineered floats

- No change in haulout area
- Initially replaces 30% of log rafts with floats; additional incremental replacements at year 5 and year 10

Remove trestle over Woodard Bay

- Meets long-term sediment and water quality restoration goals for Puget Sound through removal of creosote pilings
- Improves water exchange between mouth and Lower Woodard Bay
- Decreases potential fish entrapment in Lower Woodard Bay
- Improves public safety
- Removes historic site features, affecting visual landscape and reducing educational opportunity

Restore riparian zone by removing invasive species and replanting native species in only the main public use areas between the Chapman Bay pier and Woodard Bay trestle

- Provides greater potential export of organic carbon to aquatic habitats by increasing canopy diversity
- Contributes large woody debris to intertidal habitat
- Increases potential shading in area with limited overstory
- Provides environmental educational opportunities
- May disturb archaeological sites

8.3 Alternative 3 – Moderate Removal of Anthropogenic Features

Relative cost—moderate (~$7.1 million)

Remove the southernmost section (320 ft) and the two sections (1,180 ft) north of the bat roost (49% of pier)

- Maintains core bat roost habitat, including majority of under-pier flyway from roost to shore (same as in Alternative 2)
- Contributes to long-term sediment and water quality restoration goals for Puget Sound through removal of creosote pilings
- Increases flow into and circulation of Chapman Bay
- Removes half of the pier habitat and foraging area for waterfowl and raptors
- Increases boat access to inner Chapman Bay, with potential for increase in incidence of wildlife disturbance
- Improves public safety by preventing access to pier decking
- Maintains a portion of historic resources, preserving limited educational opportunity

Remove nearshore fill at base of pier

- Improves circulation of Chapman Bay
- Improves sediment transport processes by creating greater connection between inner and outer bay
- Increases intertidal habitat area
- Decreases upland area available for recreation and education, potentially mitigated by enhancement of Woodard Bay trestle berm as a viewing platform; may require relocation of foreman's shack interpretive facility
- Poses short-term impacts to water quality during removal
- Creates potential impacts to archaeological resources in Chapman Bay fill area

Remove 100% of pilings in North and South Operational Areas

- Meets long-term sediment and water quality restoration goals for Puget Sound through removal of creosote pilings
- Reduces foraging habitat for waterfowl and fish and perching habitat for waterfowl and raptors

Remove 90% of piling field in Main Operational Area

- Contributes to long-term sediment and water quality restoration goals for Puget Sound through removal of creosote pilings
- Increases circulation in outer Chapman Bay
- Increases sediment transport processes

- Maintains opportunities for seal haulout anchorage and purple martin nesting habitat, with potential for increase in incidence of human disturbance of seals
- Reduces foraging habitat for waterfowl and fish and perching habitat for waterfowl and raptors
- Removes historic resources, affecting visual landscape and reducing educational opportunity

Replace all seal haulout logs with engineered floats

- Maintains haulout area
- Facilitates maintenance and increases life of float structures
- Replaces creosoted anchor piling with steel piling

Remove trestle over Woodard Bay and intertidal fill on south side of trestle

- Meets long-term sediment and water quality restoration goals for Puget Sound through removal of creosote pilings
- Increases water exchange between mouth and Lower Woodard Bay
- Improves sediment transport processes between mouth and Lower Woodard Bay
- Decreases potential fish entrapment in Lower Woodard Bay
- Improves public safety
- Removes historic site features, affecting visual landscape and reducing educational opportunity
- Retains northern fill area (i.e., berm) for use as a public viewing platform
- Retains northern fill area that appears to be focusing water flow to existing oysters
- May disturb archaeological resources along shoreline where fill is removed

Restore riparian zone by removing invasive species and replanting native species in all areas of Weyer Point

- Provides greater potential export of organic carbon to aquatic habitats
- Contributes large woody debris to intertidal habitat
- Increases potential shading in area with limited overstory
- Creates larger landscape of restored riparian habitat
- Provides environmental educational opportunities
- Restoration of trestle berm (currently inaccessible) may provide opportunity for additional passive recreation by providing views into Woodard Bay

- May disturb archaeological sites

8.4 Alternative 4 – Maximum Removal of Anthropogenic Features

Relative cost—high ($18.4 million)

Remove all of Chapman Bay pier except a ~450-ft section that includes the bat rookery and the adjacent pier section to the south (76% removal)

- Maintains core bat habitat and the adjacent section of pier
- Preserves a portion of flyway
- Provides a buffer adjacent to the bat habitat
- Increases flow into and circulation of Chapman Bay
- Removes almost all restrictions to sediment transport between inner and outer Chapman Bay
- Creates opportunity for large woody debris contribution from inner bay to outer bay
- Contributes to long-term sediment and water quality restoration goals for Puget Sound through removal of creosote pilings
- Poses large-scale impacts to water and sediment quality during removal, with possible mitigation via engineering controls
- Removes the majority of the immediate foraging and perching habitat, but neither habitat type limited at the site
- Significantly increases boat access to inner Chapman Bay, with potential for increased incidence of wildlife disturbance
- Improves public safety by preventing access to pier decking
- Removes almost all of historic resources, affecting visual landscape and reducing educational opportunity

Remove nearshore fill at base of pier

- Improves circulation of Chapman Bay
- Improves sediment transport processes by creating greater connection between inner and outer bay
- Increases intertidal habitat area
- Decreases upland area available for recreation and education, potentially mitigated by enhancement of Woodard Bay trestle berm as a viewing platform; may require relocation of foreman's shack interpretive facility
- Poses short-term impacts to water quality during removal

- Creates potential impacts to archaeological resources in Chapman Bay fill area

Remove 100% of pilings in North and South Operational Areas

- Meets long-term sediment and water quality restoration goals for Puget Sound through removal of creosote piling
- Reduces foraging habitat for waterfowl and fish and perching habitat for waterfowl and raptors

Remove 90% of piling field in Main Operational Area

- Contributes to long-term sediment and water quality restoration goals for Puget Sound through removal of creosote pilings
- Increases circulation in outer Chapman Bay
- Increases sediment transport processes
- Maintains opportunities for seal haulout anchorage and purple martin nesting habitat, but potentially increases incidence of disturbance
- Reduces foraging habitat for waterfowl and fish and perching habitat for waterfowl and raptors
- Removes historic resources, affecting visual landscape and reducing educational opportunity

Replace all seal haulout logs with engineered floats

- Maintains haulout area
- Facilitates maintenance and increases life of float structures
- Replaces creosoted anchor piling with steel piling

Remove trestle over Woodard Bay and all fill on both sides of the trestle

- Meets long-term sediment and water quality restoration goals for Puget Sound through removal of creosote piling
- Increases water exchange between mouth and Lower Woodard Bay
- Improves sediment transport processes between mouth and Lower Woodard Bay
- Decreases potential fish entrapment in Lower Woodard Bay
- Improves public safety
- Removes historic resources, affecting visual landscape and reducing educational opportunity
- May disturb archaeological resources along shoreline where fill is removed (north fill adjacent to historical landfill)

Remove and reconstruct Woodard Bay Road bridge

- Increases water exchange between upper and Lower Woodard Bay
- Improves sediment transport processes between upper and Lower Woodard Bay, with possible increase in sediment loading to lower bay and mouth; could be mitigated by limited dredging adjacent to and upstream of bridge
- Decreases potential fish entrapment in upper Woodard Bay
- Poses unknown impact to wetlands and riparian habitat in upper bay
- Could cause elevation change in freshwater-saltwater lens with increased flushing and drainage of upper bay
- Requires inventory and evaluation of historical resources

Restore riparian zone by removing invasive species and replanting native species in all areas of Weyer Point

- Provides greater potential export of organic carbon to aquatic habitats
- Contributes large woody debris to intertidal habitat
- Increases potential shading in area with limited overstory
- Creates larger landscape of restored riparian habitat
- Provides environmental educational opportunities
- May provide opportunity for additional passive recreation by providing views into Woodard Bay
- May disturb archaeological resources

Two modifications to Alternative 4 as described above (full replacement of bridge; Alternative 4c in the HEA model) were also evaluated. In one version, the bridge is retained without any reconstruction (Alternative 4a in the HEA model); in another version, the channel opening under the bridge is widened without significant removal of the existing bridge (Alternative 4b).

A summary of the HEA results for these alternatives is provided in Tables 8-2 and 8-3.

Table 8-2. HEA model results for four alternatives

Restoration Action	Sum of HEA Scores (from Table 7-4)	Alternative 1 No Action	Alternative 2 Minimal Action	Alternative 3 Moderate Action	Alternative 4a Max Action without Bridge Replacement	Alternative 4b Max Action with Partial Replacement	Alternative 4c Max Action with Complete Replacement
Chapman fill removal	110.1			110.1	110.1	110.1	110.1
Chapman fill removal – no action	0.0						
Pier removal 1 – 76%	74.4				74.4	74.4	74.4
Pier removal 2 – 49%	54.4			54.4			
Pier removal 3 – 38%	22.1		22.1				
Pier removal – no action	-5.3	-5.3					
Piling removal (Zone 1) – 100%[a]	-0.1			-0.1	-0.1	-0.1	-0.1
Piling removal (Zone 1) – no action	-0.6	-0.6					
Piling removal (Zone 2) – 90%	2.8		2.8	2.8	2.8	2.8	2.8
Piling removal (Zone 2) – no action	-2.0	-2.0					
Piling removal (Zone 3) – 100%[a]	-0.1			-0.1	-0.1	-0.1	-0.1
Piling removal (Zone 3) – no action	-1.5	-1.5					
Riparian restoration – Weyer Point (all)	9.7			9.7	9.7	9.7	9.7
Riparian restoration – Weyer Point (partial)	5.2		5.2				
Riparian restoration – no action	-3.9	-3.9					
Seal haulout – status quo with enhancement[c]	1.0		1.0	1.0	1.0	1.0	1.0
Seal haulout – no action	-6.9	-6.9					
Trestle and fill removal (south and north sides)	68.9				68.9	68.9	68.9
Trestle and fill removal (south side only)	44.0			44.0			
Trestle (only) removal	28.5		28.5				

Table 8-2. HEA model results for four alternatives (cont.)

Restoration Action	Sum of HEA Scores (from Table 7-4)	Alternative 1 No Action	Alternative 2 Minimal Action	Alternative 3 Moderate Action	Alternative 4a Max Action without Bridge Replacement	Alternative 4b Max Action with Partial Replacement	Alternative 4c Max Action with Complete Replacement
Trestle and fill removal – no action	-13.3	-13.3					
Woodard bridge partial removal/reconstruction	-1.4					-1.4	
Woodard bridge complete removal/reconstruction	2.4						2.4
Woodard bridge – no action	-26.3	-26.3	-26.3	-26.3	-26.3		
Grand Total		**-59.9**	**33.3**	**195.5**	**240.4**	**265.3**	**269.1**

Note: Positive numbers reflect positive impacts; negative numbers reflect negative impacts.

[a] Removing all anchor pilings and dolphins reduces waterfowl foraging areas and perching areas.

[b] Other resources (primarily fish) benefit from loss of seal haulout under the No Action alternative.

[c] Because there are no proposed changes to the seal haulout area, there is no change from existing condition, and hence, limited credit.

Each alternative, except Alternative 1, the No Action alternative (which poses long-term consequences for most ecological restoration targets), represents an incremental increase in overall benefits to the ecosystem at the Woodard Bay site—the greater the number of anthropogenic features removed from the site, the greater the benefit to restoration targets. The primary contribution to benefits derived from any action alternative is the restoration of nearshore processes and removal of pilings that are a potential source of creosote. Furthermore, the removal of shoreline fill contributes to the overall benefits by increasing the intertidal areas that are used by numerous restoration targets (e.g., Olympia oyster and other shellfish, juvenile salmonids, forage fish, shorebirds, and other water fowl). In contrast, the greater the number of anthropogenic structures removed from the site, the greater the adverse affect on the historic resources of the Woodard Bay NRCA. Actions that modify nearshore processes or shoreline features may also adversely affect archaeological resources.

9 Costs

A cost estimate was developed for each alternative for the purpose of performing a comparison and benefit-cost evaluation. Rather than reflecting actual costs, which cannot be developed until a project is designed, the estimates represent a reasonable price that a construction contractor might charge for the work under the anticipated construction conditions. A 30% contingency fee is included to account for uncertainty at this stage of the project.

Costs for engineering and design, permitting, and WDNR's administration and oversight of a construction contract are not included. Oversight typically runs around 10% of the construction costs; permitting costs are unknown but could range from 20% of construction costs for one of the more costly alternatives to 30% for one of the less costly alternatives.

Additional assumptions were applied to the costs based on the likely time of year (winter) that restoration would take place (see Section 9.3). It was assumed that work would be conducted only during daylight hours but for 7 days a week during the available work window. An overtime pay surcharge of 15% is reflected in the cost estimates. Winter work necessitates greater overhead because it takes longer to deploy personnel, and the weather hampers productivity. The extra time for this overhead has been included as a "winter surcharge" of 20% of the cost of each alternative.

9.1 Costing Methodology

The costing methodology consisted of two parts. First, data related to the site were compiled from existing information (e.g., WDNR drawings, site inventory reports by Hart Crowser (2007c, b) and others, scientific investigations of the bat habitat and seal haulouts, and Thurston County geographic information system data). Next, this information was distilled and costs were estimated based on the actions and assumptions identified in this document for a given alternative. Costs included in the estimate were derived from many sources, including national cost estimating guides and Sitts & Hill historical records of previous projects with similar elements. The costs were adjusted when, in the professional judgment of Sitts & Hill, recent experience or job-specific information indicated such modifications were warranted. The estimated costs, in aggregate, are based on 3% escalation above 2008 prices. The volatility of the construction industry may contribute to greater or lesser price differentials should the restoration actions occur several years in the future.

9.2 Cost Estimate Summary

A summary of costs for each alternative is provided in Table 9-1. Table 9-2 presents the estimated costs for each major element of the alternatives. Costs for the alternatives evaluated ranged from $1 million to $18 million, with Alternative 1 (the No Action alternative) the least expensive and Alternative 4c (maximum removal of anthropogenic structures, including Woodard Bay bridge replacement) the most costly. Additional details are provided in the Sitts & Hill cost estimate report in Appendix C.

Table 9-1. Cost estimate summary for Woodard Bay aquatic restoration alternatives

Alternative	Description	Cost Estimate ($ millions)
1	No action: 30 years of yearly maintenance[a]	$1.1
2	Minimal removal of anthropogenic structures	$4.6
3	Moderate removal of anthropogenic structures	$7.1
4a	Maximum removal of anthropogenic structures	$10.2
4b	Alternative 4a plus Woodard Bay Bridge modification	$10.6
4c	Alternative 4a plus Woodard Bay Bridge replacement	$18.4

[a] The costs associated with Alternative 1, the No Action alternative, are related to operation and maintenance of the site and do not entail any restoration activities.

Table 9-2. Estimated costs for Woodard Bay restoration alternatives

Task	Estimated Costs ($ millions)				
	Alternative 2	Alternative 3	Alternative 4a	Alternative 4b	Alternative 4c
Chapman Bay pier removal	$2.0	$2.5	$4.1	$4.1	$4.1
Chapman Bay fill[a] removal	na	$0.9	$0.9	$0.9	$0.9
Woodard Bay trestle removal	$0.8	$0.8	$0.8	$0.8	$0.8
Woodard Bay south trestle fill[a] removal	na	$0.4	$0.4	$0.4	$0.4
Woodard Bay north trestle fill removal	na	na	$1.3	$1.3	$1.3
Anchor piling removal	$0.8	$1.0	$1.0	$1.0	$1.0

Task	Estimated Costs ($ millions)				
	Alternative 2	Alternative 3	Alternative 4a	Alternative 4b	Alternative 4c
Seal haulout and maintenance	$0.4	$0.4	$0.4	$0.4	$0.4
Bat habitat repair and maintenance	$0.1	$0.1	$0.1	$0.1	$0.1
Modify Woodard Bay bridge	na	na	na	$0.4	$0
Replace Woodard Bay bridge	na	na	na	na	$8.2
Riparian zone restoration	$0.2	$0.4	$0.4	$0.4	$0.4
Other (mobilization, etc.)	$0.3	$0.6	$0.8	$0.8	$0.8
TOTAL ESTIMATE	**$4.6**	**$7.1**	**$10.2**	**$10.6**	**$18.4**

Note: The No Action alternative provides no restoration, so no comparable costs can be provide here. See Table 9-1 for an estimate of the costs associated with general management of the site and Section 8.1 for a description of those activities.

na not part of alternative

9.3 PROJECT SCHEDULE

All cost estimates assume that the alternative could be completed in a single work season, despite the fact that it is more likely that work will be phased over multiple work seasons for reasons of funding and in-water work restrictions. Mobilization and other costs are provided for each work element in Appendix C, allowing the derivation of costs for a longer work period.

WDNR currently has a programmatic permit for the removal of pilings associated with derelict structures—it is likely that piling removal will represent a first phase of work. Other work restrictions will affect subsequent phasing. Currently, in-water activities are restricted as follows:

- **Fish Disturbance Periods—**the USACE, NOAA Fisheries Service, and WDFW restrict in-water work between March 15 and June 14 for the protection of migrating juvenile salmonids. This restriction applies primarily to nearshore areas at the site.
- **Seal Disturbance Periods—**WDFW and USFWS restrict activities around pupping and molting seals from April through June and again from September through October. This restriction affects primarily the Main Operational Area and pier in Chapman Bay.
- **Bat Disturbance Periods—**Bats are present from April through September. This restriction affects work on or use of the Chapman Bay pier.

Sensitive periods for other species that use the site (e.g., nesting bald eagles and herons) are captured within the restrictions for juvenile salmonids, seals, and bats. Given the above restrictions, the construction schedule with the least impact would be November through February (approximately 120 days).

Work duration varies by alternative, but exceeds the 120-day work window in all cases. Completion of Alternative 2 is estimated to require 220 days, and completion of Alternative 4c is estimated to require 644 days. The duration of the in-water work will be affected by the contractor's choice of equipment, availability of crew and equipment, and access to the site. Estimates of durations assume that the contractor will be unable to work 15% of the time because of weather. A line item for "contractor hold-over" has been included in the "time to complete" estimate to account for missed days. Actual work phasing and schedule will be identified as part of the design specifications of the selected alternative.

9.4 COST EFFECTIVENESS EVALUATION

9.4.1 Financial approach

Traditional benefit-cost analysis is a planning and decision tool that compares the financial cost of an action to its financial benefits to identify the most cost-effective alternative. The benefit-cost ratio (BCR) is calculated by dividing the dollar value of the benefit derived from the facility or action by the cost for construction and maintenance. Typically, only alternatives with a BCR of 1.0 or more are selected, indicating that the benefit is worth at least as much as the cost. The alternative with highest BCR is considered the most cost-effective as it provides the most "bang for the buck."

9.4.2 Ecological services approach

A major shortcoming of BCRs is that they do not account for non-financial benefits or costs. This weakness is particularly significant for environmental restoration projects for which the benefits are not readily monetized. The Woodard Bay aquatic restoration alternatives were evaluated, instead, on an ecological services approach. Under this method, the HEA model results were used to calculate ecological service benefits and conventional cost estimating was used to prepare the associated construction costs. The alternatives were then evaluated in terms of the cost to provide the service.

Section 7 presents the HEA ecological service values for individual restoration elements (Table 7-4), and Section 8 presents service values for the four alternatives (i.e., combinations of restoration elements) (Table 8-2). Costs are summarized in Tables 9-1 and 9-2, with details provided in Appendix C. Table 9-3 presents the ecological services score for each restoration alternative, the cost, and the habitat output per $1 million in costs (HEA score divided by cost in millions of dollars).

Table 9-3. Ecological service and cost for aquatic restoration alternatives

Alternative[a]	Ecological Service (HEA score)	Cost ($ million)	Ecological Service per $1 Million of Cost
2 – Minimal action	34	$4.6	7
3 – Moderate action	198	$7.1	28

Alternative[a]	Ecological Service (HEA score)	Cost ($ million)	Ecological Service per $1 Million of Cost
4a – Maximum action without bridge replacement	242	$10.2	24
4b – Maximum action with bridge modification	267	$10.6	25
4c – Maximum action with bridge reconstruction/replacement	271	$18.4	15

a Alternative 1, the No Action alternative, does not result in restoration of the site and is not included in this table. Actual ecological service is estimated to be detrimental over the long term (i.e., having a negative HEA score).

HEA – Habitat Equivalency Analysis

Figure 9-1 plots the total cost vs. HEA score from Table 9-1 for each aquatic restoration alternative. Costs and scores are provided only for the restoration actions; Alternative 1, the No Action alternative, has an estimated long-term cost of about $1.1 million over 30 years. Because of the deterioration of structures over time and the loss of the artificial habitat they provide, along with continued effects on nearshore processes, the No Action alternative results in the degradation of the ecological functions of the Woodard Bay ecosystem.

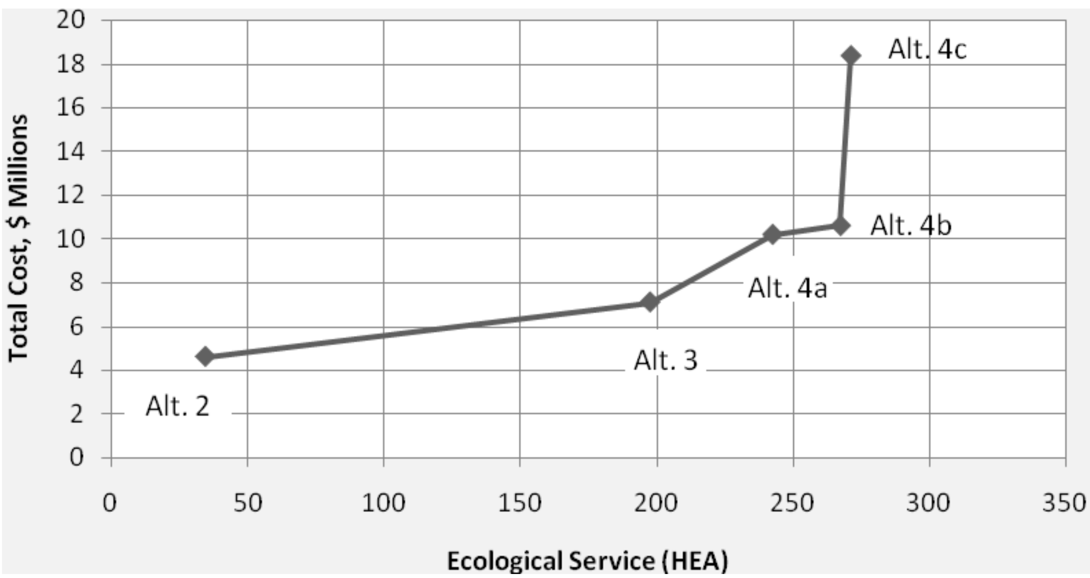

Figure 9-1. Cost and ecological service for aquatic restoration alternatives

As shown on Figure 9-1, the cost increases for each subsequent alternative, while at the same time, the ecological service also increases. Alternative 2 has the lowest cost and lowest ecological service, while Alternative 4c has the highest cost and the highest ecological service. Figure 9-2 presents an indication of the cost effectiveness of each alternative by plotting the ecological service generated per $1 million spent for each aquatic restoration alternative.

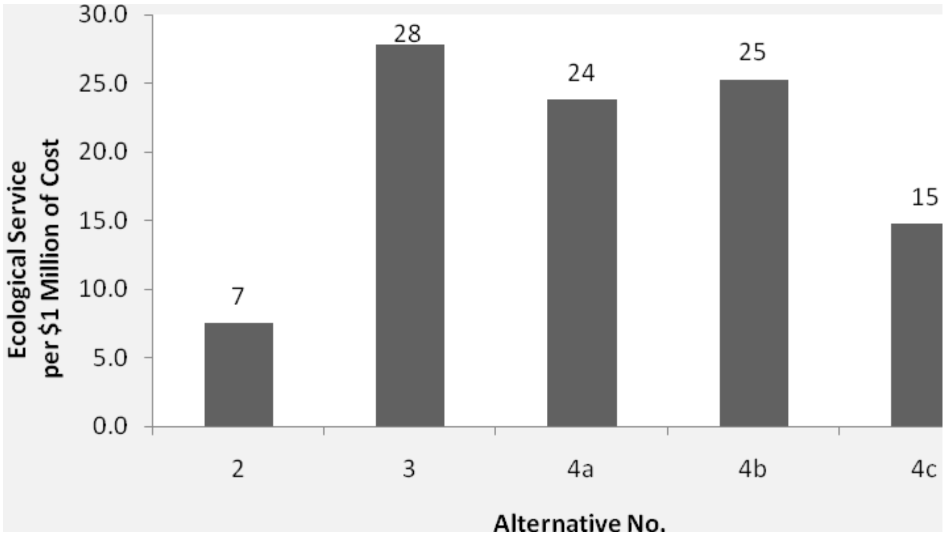

Figure 9-2. Ecological service per $1 million of cost for each aquatic habitat restoration alternative

As shown on Figure 9-2, Alternative 2 produces the least ecological service per $1 million of costs (7), and Alternative 3 produces the highest ecological service (28) closely followed by Alternatives 4b (25) and 4a (24). Alternative3 is the most cost-effective alternative for restoring ecological services.

9.5 CONSIDERATION OF CONSTRUCTION SEQUENCING

WDNR may phase the implementation of the restoration program. Phasing will include consideration of new information regarding seal and bat restoration targets, differing lead times to design and permit specific tasks, available program funding for a given task and year, applicability of existing permits for various tasks, needed maintenance and repair actions, and the ecological service generated per dollars spent for different tasks. Phasing may also be based on the packaging of tasks into scopes of work that are compatible with the capability of regional contractors so as to improve competitive bidding for the work. Some examples of how these considerations may affect phasing are described below.

- **Research Results –** New information regarding bat roost requirements and seal population dynamics and prey interactions may trigger additional actions related to the Chapman Bay pier or seal haulout structures. Any additional actions could be incorporated as an additional phase of the project.
- **Maintenance Considerations –** Items needing maintenance, such as the bat habitat in Chapman Bay Pier and the seal haulout structures, could be scheduled as one of the early actions to limit loss of these resources.

- **Creosote Piling Removal –** WDNR could take advantage of existing authorities and funding to remove portions of the anchor pilings and possibly portions of Chapman Bay pier and Woodard Bay trestle.
- **Ecological Service Value –** The tasks that provide the greatest ecological service (HEA) per dollar spent could be completed first, followed by the tasks that provide less ecologic service per dollar spent. For Alternative 3, that would mean first completing the Chapman Bay fill removal (122 HEA score/million dollars), the Woodard Bay south berm removal (39 HEA score/million dollars), the Woodard Bay trestle removal (36 HEA score/million dollars), and the riparian zone restoration (24 HEA score/million dollars), followed later by the Chapman Bay pier removal (23 HEA score/million dollars) and anchor piling removal (3 HEA score/million dollars).
- **Construction Packages –** The marine work could be phased in packages that could readily be completed by regional contractors during the shortened construction schedule of 120 days between November and February. That might mean that each major marine task, such as the anchor piling removal, the Chapman Bay pier removal (Alternative 3), or the Woodard Bay trestle removal might be packaged in a separate contract so that contractors with one major set of marine plans and crew could compete for the work. If desired, each contract could also be phased in a separate construction season.

10 Selection of Preferred Alternative

The preferred alternative was selected after weighing and balancing a multitude of factors, including the effectiveness at achieving restoration goals, cost-effectiveness, public acceptance, impacts on historic and archaeological resources, and funding. The overall goal was to select an alternative that could provide sustainable benefits to the Woodard Bay ecosystem.

10.1 Effectiveness of Achieving Restoration Goals

The habitat output for each alternative is a measure of its effectiveness in achieving the restoration goals for Woodard Bay. All action alternatives provide an increase in ecological services at the site compared to existing conditions. The difference in ecological services among alternatives was most strongly influenced by the degree of nearshore process restoration and creation of intertidal habitat because of the number of species that benefit from these actions. As shown on Figure 9-1, Alternative 4 (all three versions) provides the highest ecological service.

10.2 Cost-Effectiveness

Total costs ranged from $1 million for the No Action alternative (Alternative 1) to $18.4 million for the most expensive alternative (Alternative 4c). The ecological service generated per each million dollars spent on the alternative is a measure of cost effectiveness. The alternative with the highest service per unit cost is considered the most cost effective. As shown on Figure 9-2, **Alternative 3 provides the highest ecological service per unit cost (28)**, followed by Alternatives 4b, 4a, and 4c (25, 24, and 15, respectively), and then Alternative 2 (7).

10.3 Public Acceptance

Initial public acceptance of restoration alternatives for the site has been gauged through an informal public process that has included comments during public meetings, responses to articles published in local and regional newspapers, conversations with neighbors, and e-mails or phone calls from interested public. Three main elements were raised by the public: maintenance and improvement of bat habitat, maintenance and improvement of the seal haulouts, and removal of creosote-treated pilings and timbers from the inlet. The alternatives developed for this FS included components identified by the public as being important or valued, and many were included in every alternative; however, **Alternative 4 implements those components to the greatest degree** because of the greatest removal of creosoted pilings.

Public use of the site for either recreation or education will be minimally affected by restoration actions, except during actual construction periods. Removal of fill near the Chapman Bay pier has the greatest potential impact because of the removal of some of the shoreline fill in an area currently used for viewing and picnicking. Educational value of the site may increase as a result of the restoration efforts, including riparian habitat restoration. Long-term acceptance of a final alternative will depend on the public process defined by the Washington State Environmental Policy Act for significant projects and WDNR's ongoing public outreach efforts.

10.4 Impact on Historic and Cultural Resources

The Woodard Bay NRCA is considered a Rural Historic Landscape District. As such, not only are individual structures considered historically important, but so is the relationship among structures, and their relationship to the landscape. The removal of the anthropogenic structures (pier, trestle, and anchor pilings) represents a permanent loss of the physical evidence of the role of logging in Washington State history. Among the restoration alternatives, the greater the number of anthropogenic structures removed from the site, the greater the adverse affect on the historic resources of the Woodard Bay NRCA, to the extent that the site could be removed from the National Register of Historic Places. Alternative 4 (all versions) has the greatest deleterious impact on historic resources and the associated landscape. The loss of historic resources may be mitigated, in part, by photo documentation; creation of interpretive displays, models, and websites; and archiving of records, plans, and other evidence of the historic elements of the site. The extent of sufficient mitigation for the implemented action will be determined in consultation with the SHPO.

Actions that modify nearshore processes or shoreline features may also adversely affect archaeological resources, both in the short term (e.g., through disturbance of soils containing artifacts) and long term (e.g., changing shoreline erosion rates). To control these potential impacts, WDNR will consult with the SHPO and the THPO/CRS to develop plans for an archaeological assessment in areas that may be disturbed and to monitor shoreline erosion. This consultation may result in design modifications or changes in procedures or sequencing of restoration actions to avoid or minimize impacts to archaeological resources. Should erosion threaten identified archaeological sites, WDNR will develop an archaeological data recovery plan to address the adverse effects of erosion. An inadvertent discovery plan specifying procedures to be followed should archaeological materials or human remains be encountered during restoration activities has been prepared by WDNR.

10.5 Funding

The actual implementation and timing of aquatic restoration actions at Woodard Bay will be dependent on the availability and timing of funding. At this time, the amount of funding available for aquatic habitat restoration at Woodard Bay has not been established; however, funds are likely to be limited. Current programs, such as the Estuary and Salmon Restoration Program administered by WDFW, provide competitive grants for the types of restoration actions proposed in this FS. More funding may be available through watershed and salmon recovery programs managed by federal agencies such as NOAA Fisheries Service, USACE, and EPA.

10.6 Preferred Alternative

Alternative 3 is the recommended alternative based on the evaluation of the factors discussed above. This alternative provides the highest ecological services in relationship to cost and is therefore the most cost-effective of all the alternatives; it accomplishes many of the objectives expressed by public and agency stakeholders and preserves some elements of the historic landscape that triggered its listing on the National Register of Historic Places. Alternative 3 balances goals for the site, and thus there is a reasonable probability that the alternative can be implemented within likely funding mechanisms.

One of the limitations of Alternative 3 is that it does not remove all of the creosote timber structures from Woodard Bay, which will continue to slowly deteriorate over time. If not removed by the Woodard Bay aquatic restoration project, then the remnant timber structures will need to be removed by another public project at some point in the future.

11 Next Steps

Restoring the ecosystem functions at the Woodard Bay NRCA will require additional administrative, technical, and regulatory steps. WDNR will initially use the information in the FS to apply for grants to implement the selected alternative. Once funding is received, WDNR will seek contracts, first for design and later for construction of the project. The restoration concept will likely be further refined through preliminary design studies, research regarding specific restoration targets (i.e., bats and seals), and additional public outreach efforts.

As part of the design process, environmental and other permits must be sought. A formal public review of the project occurs as part of the permitting process. The following permits may be needed:

- Joint Aquatic Resources Permit Application (JARPA)
- Clean Water Act Section 404 Permit
- Rivers and Harbors Act Section 10
- Hydraulic Project Approval
- Private Aids to Navigation
- Clean Water Act Section 401 Water Quality Certification
- National Historic Preservation Act Section 106 consultation
- Local land use permits, including compliance with the State Environmental Policy Act

The JARPA is an administrative vehicle used to coordinate the permits triggered by any project that occurs in or may affect a water body. The application compiles information needed for multiple state and federal permits. Similar information is used in the applications for local permits. Removal of fill in the shoreline may require coordination with the Dredged Materials Management Program (included in the JARPA process). The Section 404 permit further requires that the NOAA Fisheries Service and USFWS be consulted regarding potential impacts to threatened or endangered species (per the Endangered Species Act). WDFW has a similar requirement for species that are protected by the state. If the project receives federal funding, compliance with the National Environmental Policy Act will be required. Any of the restoration activities must also show compliance with the Shoreline Management Act, as implemented by Thurston County; Ecology may also make a determination of the project's consistency with the Coastal Zone Management Act. An example of the permit process is provided in Figure 11-1. The permitting process adds significant cost and duration to the project; however, some requirements may be streamlined or waived, given the restoration objectives of the project.

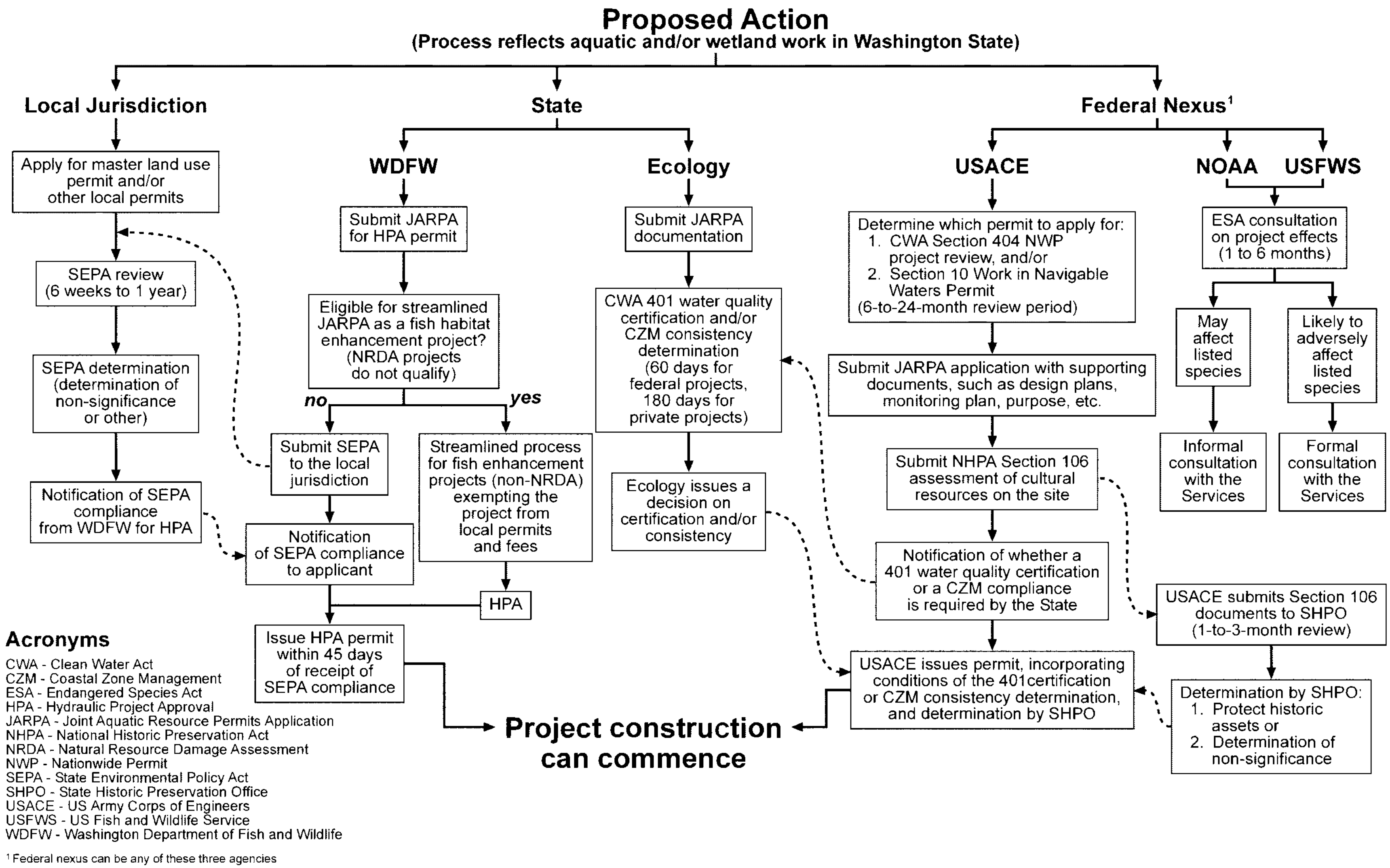

Figure 11-1. Permit flow chart

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APPENDIX A

Revised Chemistry and Bioassay Results for Woodard Bay Sediments

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MEMORANDUM

To: Russ McMillan, Washington State Department of Ecology

From: Nancy Musgrove, Windward Environmental

Cc: Michele Zukerberg and Joel Breems, Washington Department of Natural Resources

Subject: Revised chemistry and bioassay results for Woodard Bay sediments[1]

Date: 6 April 2009

Over the past 2 years, WDNR, in partnership with the US Army Corps of Engineers (USACE), US Environmental Protection Agency (EPA), Washington State Department of Ecology (Ecology), and The Nature Conservancy (TNC), has conducted an assessment of the potential contribution of in-water creosote-preserved structures to surface sediment contamination and distribution of wood waste at the site for the purpose of identifying potential sediment quality impacts and to support restoration planning. Initial investigations were qualitative or semi-quantitative and included a descriptive intertidal habitat survey, an assessment of the distribution and condition of piling and over-water structures, two underwater video surveys (one by a remotely operated vehicle and one by divers) and a sub-bottom acoustical profiling survey (Hart Crowser 2007a, 2007b, 2007c, 2007d). The results were used to design a field investigation that focused on delineating areas that were likely affected by wood waste or creosoted structures and determining the extent of impacts on sediment quality according to the SMS (Washington Administrative Code 173-204). Samples were collected in February 2008 from areas with some evidence of wood waste, in the vicinity of in-water structures built with creosoted pilings, and in areas known to have been used for log storage. The investigation included the collection of 44 plan and 47 profile images of the sediment, subsurface video probes at these same locations[2], 8 subsurface

[1] This memo represents a replacement for the previously submitted (26 March 2009) memo and provides corrections and clarifications discussed with Ecology on 30 March 2009.

[2] The video probe represented a new sampling technology and was deployed at the same locations where other sediment images were collected to test the efficacy of the equipment.

cores[3] for the visual evaluation of sediment characteristics (including wood waste) and chemical analysis[4], and 14 surface[5] sediment grabs[6] for chemical analysis (Map 1). Analyses included all chemicals required by SMS in addition to total volatile solids (TVS), total solids, total organic carbon (TOC), grain size, ammonia, and total sulfides.

Results of the sediment quality assessment showed that wood waste was composed only of bark and small pieces of wood and was not widespread at the site[7] and the sediment was generally of high quality[8] (SAIC 2008). However, Ecology's review of the sediment characterization results identified data gaps with respect to potential wood waste impacts on the benthic community. Specifically, the review revealed one sediment sample exceeded the cleanup screening level (CSL) for phenol and five samples exceeded the sediment quality standard (SQS) for this same chemical. These results were questionable because the exceedances only occurred when the samples were reanalyzed to achieve better detection limits (the original detected results were below the SQS). In absence of biological testing, Ecology was also concerned that there might be impacts at locations where other conventional sediment parameters (but not SMS chemicals) that might be associated with wood debris were elevated. Ecology examined ammonia, total sulfides, TOC, TVS, and total solids to determine a level of concern by applying a numerical score to each of these parameters. Individual scores were based on the magnitude of the value relative to defined thresholds and the potential for toxicity; final scores were based on a sum of individual parameter scores. Ten samples at six locations[9] had high (score > 6) final scores and were considered of high concern, one sample received a medium score (score = 6), and three samples received a low-medium (score = 5) score. In order to make a final determination of

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[3] Core tubes were 7 ft long.

[4] Only the 0-to-1-ft and 1-to-3-ft intervals were analyzed; all other intervals were archived. Two additional cores were collected but were archived without analysis.

[5] Surface was defined as the top foot for this investigation, due to the presence of large hard shell clam populations in some areas of the site.

[6] Five additional grabs were collected but were archived without analysis.

[7] Wood waste was absent in 72% of the surface images; where present, it accounted for less than 8%, on average, of the surface sediment coverage (range was 0 to 20%). This finding was generally confirmed by the video probe images and subsurface cores in which wood debris averaged about 10% by volume within the top foot of sediment.

[8] Most surface sediment chemical results were well below SMS criteria and similar to Puget Sound reference area performance standards (PTI 1991)

[9] Core samples from WB-08, WB-18, WB-28, WB-31, and WB-38 received high scores. The surface grab sample from WB-12 was also included in the high-concern category because phenol exceeded the CSL criterion; WB-30 received a medium score; and WB-06, WB-35, and WB-36 received low-medium scores (see Map 1 for sampling locations).

compliance with SMS, Ecology recommended that toxicity testing be conducted in samples with scores greater than 4.0.

In October 2008, WDNR directed Windward Environmental LLC (Windward) to complete the assessment of wood waste impacts as defined by SMS and conduct a feasibility study (FS) to evaluate restoration options for the nearshore area of the Woodard Bay site. As part of this effort, surface sediment sampling for chemical and toxicity testing was conducted in January 2009. This follow-on sample collection and analysis effort focused on:

- resolving the quantification of wood waste indicator chemicals (phenol, 2-methyl phenol, 2,4-dimethyl phenol and other selected semivolatile organic compounds) in previously collected samples by reanalyzing archived sediment;
- collecting additional sediment for toxicity testing at locations where Ecology rated the sediment as being of high, medium, or low-medium[10] concern and from reference areas; and,
- collecting additional sediment adjacent to in-water structures to assess the scale of potential PAH releases from creosoted piling[11].

Six archived samples[12] (WB-03, WB-09, WB-12, WB-16, WB-30, and WB-36) were analyzed by Analytical Resources, Inc. (ARI) for phenolic compounds and selected SVOCs using a selected ion monitoring (SIM) technique to improve quantification. Surface (top 10 cm) sediment was collected for toxicity testing from eight previously sampled site locations (WB-06, WB-08, WB-18, WB-28, WB-30, WB-31, WB-35, and WB-38) and two reference locations from Carr Inlet. Three bioassays (amphipod mortality, bivalve larval mortality and abnormal development, and juvenile polychaete growth) were conducted according to Puget Sound Estuaries Program (PSEP) protocol (and subsequent updates) by Northwestern Aquatic Sciences (NAS). Sediment chemistry in previously characterized sediment submitted for bioassays was not reanalyzed; existing data from the 2008 investigation were used represent the bioassay sampling locations. The two reference locations, representing fine- and coarse-grained sediment (CR-20W and CR-23W, respectively) have been previously analyzed and reported in Ecology's Environmental Information Management (EIM) for numerous studies and were also not

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[10] Toxicity testing was not conducted at two locations that Ecology ranked low-medium where the scores were based, in part, on a exceedance of the SMS phenol criterion because of the high uncertainty in the quantification of phenols (without the phenol exceedance, these samples would have been of low concern).

[11] PAHs were below SMS and similar to Puget Sound background in previously collected sediment samples; however, sampling equipment and field conditions prevented sample collection immediately adjacent to piling. WDNR and its partners were interested in refining this assessment, if possible.

[12] The original samples were collected in February 2008 and were analyzed within the 1-year holding time.

analyzed for SMS chemicals. The exception to this was that conventional parameters (TOC, TVS, ammonia, total sulfides, total solids, and grain size) were analyzed at all bioassay sampling locations.

Two surface (top 10 cm) sediment samples were also collected underneath the Chapman Bay pier to further assess the scale of PAH releases from creosoted pilings.

Table 1 summarizes the sampling design applied in this follow-on effort. Map 2 shows the 2009 sampling locations.

Table 1. Surface sediment sample analyses

Location	Chemical Analysis	Biological Analysis
WB-03[a]	phenol	na
WB-06	conventionals	amphipod mortality, larval mortality and abnormal growth, and juvenile polychaete growth
WB-08	conventionals	amphipod mortality, larval mortality and abnormal growth, and juvenile polychaete growth
WB-09[a]	phenol	na
WB-12[a]	phenol	na
WB-16[a]	phenol	na
WB-18	conventionals	amphipod mortality, larval mortality and abnormal growth, and juvenile polychaete growth
WB-28	conventionals	amphipod mortality, larval mortality and abnormal growth, and juvenile polychaete growth
WB-30[a]	phenol, conventionals	amphipod mortality, larval mortality and abnormal growth, and juvenile polychaete growth
WB-31	conventionals	amphipod mortality, larval mortality and abnormal growth, and juvenile polychaete growth
WB-35	conventionals	amphipod mortality, larval mortality and abnormal growth, and juvenile polychaete growth
WB-36[a]	phenol	na
WB-38	conventionals	amphipod mortality, larval mortality and abnormal growth, and juvenile polychaete growth
WB-50	PAHs, TOC	na
WB-51	PAHs, TOC	
CR-01 (=CR-20W)	conventionals[b]	amphipod mortality, larval mortality and abnormal growth, and juvenile polychaete growth
CR-02 (=CR-23W)	conventionals[b]	amphipod mortality, larval mortality and abnormal growth, and juvenile polychaete growth

[a] Archived sample to be reanalyzed

[b] Conventional parameters include TOC, TVS, total solids, total sulfides, ammonia and grain size.

na – not analyzed

PAHs – polycyclic aromatic hydrocarbons

SMS – Washington State Sediment Management Standards

TOC – total organic carbon

TVS – total volatile solids

Details of the collection and analysis protocol are provided in the Sampling and Analysis Plan (Windward 2008).

This memo presents the final results and interpretation of the chemical analyses and bioassay testing of the sediments collected from the Woodard Bay NRCA project area for Ecology's consideration. Chemistry results are summarized in Tables 2 and 3. Organic chemical results were validated by EcoChem (Attachment 1). Data, as qualified, are acceptable for any use. Phenol was flagged as undetected in all reanalyzed samples due to the presence of phenol in the blank sample; however, all phenol results from the reanalysis are an order of magnitude below the SQS. All other organic compounds associated with wood waste were not detected in the reanalyzed samples. Benzoic acid, although requested from ARI, was not analyzed due to an omission on the lab's part. No additional analyses were requested by Windward.

Sample results were compared to SMS criteria on either an organic carbon or dry weight normalized basis, as required by SMS (Tables 2 and 3, respectively). With the exception of the sample for WB-50-SS-010, which exceeded the CSL for fluoranthene, and exceeded the SQS for pyrene, no chemicals exceeded their respective criteria in any samples. WB-50-SS-010 was located directly adjacent to a piling supporting the Chapman Bay pier. There were no PAH exceedances in the other sample along the pier face nor in any prior characterization samples taken in close proximity to WB-50-SS-010. These results indicate that elevated PAH levels are isolated and not indicative of the entire site. PAHs are likely associated with the pier structure ; these results will be used to estimate the area that may be impacted by piling removal as part of a restoration action and to plan for engineering controls, should pilings be removed..

Bioassay results are summarized in Tables 4, 5, and 6 (laboratory data are provided as spreadsheets in Attachment 2). Bioassays were conducted according to PSEP protocol, with minor deviations. Salinity was slightly above protocol specifications during the amphipod bioassay (28±1 ppt versus a maximum of 31.5 ppt) in half the water quality beakers after Day 4 and temperature and pH were not measured in one beaker on Day 8 during the same test. In the bivalve larval bioassay, salinity was slightly below test protocol (28±1 versus a minimum of 26.5 ppt in several measurements). These deviations were unlikely to affect test results and were not considered further in the interpretation of the bioassay results.

The individual growth rate performance criterion for the juvenile polychaete growth rate was not met for the reference sample CR-01-SS-010 (71.1% versus ≥80% of control growth rate); therefore all growth results were compared to CR-02-SS-010 results. CR-01-SS-010 mean normal survival was only slightly below the Dredged Materials Management Program performance criterion (64.4 % versus 65%) that Ecology also uses informally in the interpretation of larval bioassay results; therefore, the data from this reference sample were retained for interpretation of the site larval bioassay results. All other SMS performance criteria for control and reference samples in all three bioassays were met. Reference area grain sizes (reported as percent fine-grained sediment) matched test samples within 20% (see conventional results in Table 3), per Ecology guidance; however, all juvenile polychaete growth endpoints were compared to the coarse-grained reference sample due to reference growth performance criterion failure in CR-01-SS-010.

All bioassay results were compared to SMS thresholds for determining compliance with these regulations. Average amphipod mortality ranged from 2% to 11% in the Woodard Bay samples and met the SMS criterion (<25% mortality) for that endpoint. Juvenile polychaete mortality in replicate samples was typically 0, but several single samples exhibited high mortality >40% (however, average mortality was ≤ 12%). The average growth rate of juvenile polychaetes in test samples was greater than 70% of the reference growth rate (based on comparison to CR-02-SS-010) for all samples and thus met its respective SMS criterion (there is no standard for juvenile polychaete mortality in test samples). Normal survivorship in the larval bioassays failed the SQS criterion for WB-35-SS-010 (average of 71% normal survivors) and WB-38-SS-010 (average of 68.6% normal survivorship) and the CSL criterion for WB-18-SS-010 (average of 59.4 % normal survivorship) and WB-SS-31-10 (60.7 % average normal survivorship). The samples that failed SMS criteria were all compared to the coarse-grained reference sample CR-02-SS-010, which had an average normal survivorship of 93%.

An evaluation of historical data (1995 or later) from other reference stations[13] in Carr Inlet (https://secureaccess.wa.gov/ecy/myeim) suggests that the average normal survival for bivalves is about 82.9% (all reference means would fall between 79.9% and 85.9% percent with 95% confidence) (Table 7). These reference data suggest that normal survivorship at WB-35-SS-010 and WB-38-SS-010 may not be indicative of an adverse effect, since the sample results fall within 85% of the range of means expected for reference samples in Carr Inlet. The CSL failure at the remaining two samples (WB-18-SS-010 and WB-31-SS-010) is also uncertain because the normal survivorship is greater than 70% of the Carr Inlet historical reference mean—it is more likely these results represent a minor adverse effect.

An examination of sample characteristics at WB-18-SS-010 and WB-31-SS-010 showed that although wood waste was present in surface sediment at WB-18-SS-010, it was absent in WB-31-SS-010. Wood waste indicator parameters at these two locations were similar to two other bioassay stations that passed the biological and chemical performance criteria (a comparison is provided in Table 8). In addition, these two

[13] Reference data were initially evaluated based on grain size however, normal survivorship was similar (p=0.3) between fine and coarse-grained samples

stations failing the CSL are spatially isolated from each other--WB-18-SS-010 is located adjacent to the east side Chapman Bay pier and WB-31-SS-010 is within the piling field in the Main Operational area. Based on this analysis of the data we interpret the bioassay results at WB-35-SS-010 and WB-38-SS-010 as meeting SMS criteria, and WB-18-SS-010 and WB-31-SS-010 as representing minor adverse effects. Further, it is our interpretation that these latter two failures do not require cleanup due to their spatial isolation and similarity to other sediment samples that passed all SMS and wood waste evaluation criteria.

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Table 2 – Organic carbon normalized chemical results for Woodard Bay surface sediment samples

Analyte	SMS SQS	Unit	Sampling Locations							
			WB-03	WB-06[a]	WB-08[a]	WB-09	WB-12	WB-16	WB-18[a]	WB-28[a]
Conventional										
Total Organic Carbon		%	2.1	NA	NA	2.75	2.63	2.56	NA	NA
SVOCs										
1,2,4-Trichlorobenzene	0.81	mg/kg TOC	0.3U	NA	NA	0.2 U	0.2 U	0.2 U	NA	NA
1,2-Dichlorobenzene	2.3	mg/kg TOC	0.3U	NA	NA	0.2 U	0.2 U	0.2 U	NA	NA
1,4-Dichlorobenzene	3.1	mg/kg TOC	0.3U	NA	NA	0.2 U	0.2 U	0.2 U	NA	NA
Butylbenzylphthalate	4.9	mg/kg TOC	0.7U	NA	NA	0.5 U	0.6 U	0.6 U	NA	NA
Dimethylphthalate	53	mg/kg TOC	0.7U	NA	NA	0.5 U	0.6 U	0.6 U	NA	NA
Hexachlorobenzene	0.38	mg/kg TOC	0.3U	NA	NA	0.2 U	0.2 U	0.2 U	NA	NA
Hexachlorobutadiene	3.9	mg/kg TOC	0.3U	NA	NA	0.2 U	0.2 U	0.2 U	NA	NA
n-Nitrosodiphenylamine	11	mg/kg TOC	0.3U	NA	NA	0.2 U	0.2 U	0.2 U	NA	NA
Dibenzofuran	15	mg/kg TOC	NA	NA	NA	NA	NA	NA	NA	NA
PAHs										
2-Methylnaphthalene	38	mg/kg TOC	NA	NA	NA	NA	NA	NA	NA	NA
Acenaphthene	16	mg/kg TOC	NA	NA	NA	NA	NA	NA	NA	NA
Acenaphthylene	66	mg/kg TOC	NA	NA	NA	NA	NA	NA	NA	NA
Anthracene	220	mg/kg TOC	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(a)anthracene	110	mg/kg TOC	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(a)pyrene	99	mg/kg TOC	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(b)fluoranthene	No criterion	mg/kg TOC	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(g,h,i)perylene	31	mg/kg TOC	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(k)fluoranthene	No criterion	mg/kg TOC	NA	NA	NA	NA	NA	NA	NA	NA
Chrysene	110	mg/kg TOC	NA	NA	NA	NA	NA	NA	NA	NA
Dibenz(a,h)anthracene	12	mg/kg TOC	NA	NA	NA	NA	NA	NA	NA	NA
Fluoranthene	160	mg/kg TOC	NA	NA	NA	NA	NA	NA	NA	NA
Fluorene	23	mg/kg TOC	NA	NA	NA	NA	NA	NA	NA	NA
Indeno(1,2,3-cd)pyrene	34	mg/kg TOC	NA	NA	NA	NA	NA	NA	NA	NA
Naphthalene	99	mg/kg TOC	NA	NA	NA	NA	NA	NA	NA	NA
Phenanthrene	100	mg/kg TOC	NA	NA	NA	NA	NA	NA	NA	NA
Pyrene	1,000	mg/kg TOC	NA	NA	NA	NA	NA	NA	NA	NA
Total benzofluoranthenes[b]	230	mg/kg TOC	NA	NA	NA	NA	NA	NA	NA	NA
Total LPAHs[b]	370	mg/kg TOC	NA	NA	NA	NA	NA	NA	NA	NA
Total HPAHs[b]	960	mg/kg TOC	NA	NA	NA	NA	NA	NA	NA	NA

Table 2 (continued)

Analyte	SMS SQS	Unit	Sampling Locations						
			WB-30S	WB-31S[a]	WB-35S[a]	WB-36S	WB-38S[a]	WB-50S	WB-52S
Conventional									
Total Organic Carbon		%	5.47	NA	NA	2.97	NA	4.73	1.59
SVOCs									
1,2,4-Trichlorobenzene	0.81	mg/kg TOC	0.1 U	NA	NA	0.2 U	NA	NA	NA
1,2-Dichlorobenzene	2.3	mg/kg TOC	0.1 U	NA	NA	0.2 U	NA	NA	NA
1,4-Dichlorobenzene	3.1	mg/kg TOC	0.1 U	NA	NA	0.2 U	NA	NA	NA
Butylbenzylphthalate	4.9	mg/kg TOC	0.3 U	NA	NA	0.5 U	NA	NA	NA
Dimethylphthalate	53	mg/kg TOC	0.3 U	NA	NA	0.5 U	NA	NA	NA
Hexachlorobenzene	0.38	mg/kg TOC	0.1 U	NA	NA	0.2 U	NA	NA	NA
Hexachlorobutadiene	3.9	mg/kg TOC	0.1 U	NA	NA	0.2 U	NA	NA	NA
n-Nitrosodiphenylamine	11	mg/kg TOC	0.1 U	NA	NA	0.2 U	NA	NA	NA
Dibenzofuran	15	mg/kg TOC	NA	NA	NA	NA	NA	1.0	1.3 U
PAHs									
2-Methylnaphthalene	38	mg/kg TOC	NA	NA	NA	NA	NA	0.5	1.3 U
Acenaphthene	16	mg/kg TOC	NA	NA	NA	NA	NA	1.2	1.3 U
Acenaphthylene	66	mg/kg TOC	NA	NA	NA	NA	NA	0.8	1.3 U
Anthracene	220	mg/kg TOC	NA	NA	NA	NA	NA	3.4	2.0
Benzo(a)anthracene	110	mg/kg TOC	NA	NA	NA	NA	NA	11.4	10.1 J
Benzo(a)pyrene	99	mg/kg TOC	NA	NA	NA	NA	NA	7.6	6.2 J
Benzo(b)fluoranthene	No criterion	mg/kg TOC	NA	NA	NA	NA	NA	16.9	10.7 J
Benzo(g,h,i)perylene	31	mg/kg TOC	NA	NA	NA	NA	NA	3.0	2.1
Benzo(k)fluoranthene	No criterion	mg/kg TOC	NA	NA	NA	NA	NA	10.4	7.5
Chrysene	110	mg/kg TOC	NA	NA	NA	NA	NA	25.4	22.0 J
Dibenz(a,h)anthracene	12	mg/kg TOC	NA	NA	NA	NA	NA	0.7	1.3U
Fluoranthene	160	mg/kg TOC	NA	NA	NA	NA	NA	76.1	42.8 J
Fluorene	23	mg/kg TOC	NA	NA	NA	NA	NA	1.6	1.3U
Indeno(1,2,3-cd)pyrene	34	mg/kg TOC	NA	NA	NA	NA	NA	3.8	2.5
Naphthalene	99	mg/kg TOC	NA	NA	NA	NA	NA	0.4U	1.3 U
Phenanthrene	100	mg/kg TOC	NA	NA	NA	NA	NA	19.9	12.6 J
Pyrene	1000	mg/kg TOC	NA	NA	NA	NA	NA	57.1	39.0 J
Total benzofluoranthenes[b]	230	mg/kg TOC	NA	NA	NA	NA	NA	27.3	18.2
Total LPAHs[b]	370	mg/kg TOC	NA	NA	NA	NA	NA	27.4	15.8
Total HPAHs[b]	960	mg/kg TOC	NA	NA	NA	NA	NA	212.3	142.8

[a] Historical chemistry results from SAIC (2008) will be used
[b] Totals based on sum of detected values
J – estimated concentration
HPAHs – high molecular weight PAHs
LPAHs – low molecular weight PAHs

NA – not analyzed
PAHs – polycyclic aromatic hydrocarbons
SVOCs – semivolatile organic compounds
TOC – total organic carbon
U – not detected at given concentration

Table 3 – Dry weight normalized chemical results for Woodard Bay surface sediment samples

Analyte	Wood waste SLs	Unit	WB-03S	WB-06S[a]	WB-08S[a]	WB-09S	WB-12S	WB-16S	WB-18S[a]	WB-28S[a]	WB-30S
Conventional											
N-Ammonia	>30	mg-N/kg	NA	6.94	20.4	NA	NA	NA	7.28	17.4	8.79
Sulfide	>200	mg/kg	NA	814	3.22U	NA	NA	NA	802	788	821
Total Fines	No criterion	%	NA	61.8	93.9	NA	NA	NA	38.4	80.1	71.0
Total Organic Carbon	>5	%	2.1	2.45	2.43	2.75	2.63	2.56	2.9	4.57	5.47
Total Solids	<50	%	NA	60	31.5	NA	NA	NA	41.6	34.9	36.2
Total Volatile Solids	>10	%	NA	12.49	8.86	NA	NA	NA	15.01	12.61	16.41
	SMS/LAET										
Phenolic Compounds											
2,4-Dimethylphenol	29	µg/kg	6.2UJ	NA	NA	6.1UJ	6.1UJ	6.1UJ	NA	NA	6UJ
2-Methylphenol	63	µg/kg	6.2U	NA	NA	6.1U	6.1U	6.1U	NA	NA	6U
4-Methylphenol	670	µg/kg	6.2U	NA	NA	6.1U	6.1U	6.1U	NA	NA	6U
Pentachlorophenol	360	µg/kg	31U	NA	NA	30U	30U	30U	NA	NA	30U
Phenol	420	µg/kg	17U	NA	NA	12U	12U	7.3U	NA	NA	10U
SVOCs											
1,2,4-Trichlorobenzene	31	µg/kg	6.2U	NA	NA	6.1U	6.1U	6.1U	NA	NA	6U
1,2-Dichlorobenzene	35	µg/kg	6.2U	NA	NA	6.1U	6.1U	6.1U	NA	NA	6U
1,4-Dichlorobenzene	110	µg/kg	6.2U	NA	NA	6.1U	6.1U	6.1U	NA	NA	6U
Benzyl Alcohol	57	µg/kg	31UJ	NA	NA	30UJ	30UJ	30UJ	NA	NA	30UJ
Butylbenzylphthalate	63	µg/kg	15U	NA	NA	15U	15U	15U	NA	NA	15U
Dibenzofuran	15	µg/kg	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dimethylphthalate	71	µg/kg	15U	NA	NA	15U	15U	15U	NA	NA	15U
Hexachlorobenzene	22	µg/kg	6.2U	NA	NA	6.1U	6.1U	6.1U	NA	NA	6U
Hexachlorobutadiene	11	µg/kg	6.2U	NA	NA	6.1U	6.1U	6.1U	NA	NA	6U
n-Nitrosodimethylamine	No criterion	µg/kg	31U	NA	NA	30U	30U	30U	NA	NA	30U
n-Nitroso-di-n-Propylamine	No criterion	µg/kg	31U	NA	NA	30U	30U	30U	NA	NA	30U
n-Nitrosodiphenylamine	28	µg/kg	6.2U	NA	NA	6.1U	6.1U	6.1U	NA	NA	6U

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Analyte	Wood waste SLs	Unit	WB-03S	WB-06S[a]	WB-08S[a]	WB-09S	WB-12S	WB-16S	WB-18S[a]	WB-28S[a]	WB-30S
PAHs											
1-Methylnaphthalene	No criterion	µg/kg	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Methylnaphthalene	670	µg/kg	NA	NA	NA	NA	NA	NA	NA	NA	NA
Acenaphthene	500	µg/kg	NA	NA	NA	NA	NA	NA	NA	NA	NA
Acenaphthylene	1,300	µg/kg	NA	NA	NA	NA	NA	NA	NA	NA	NA
Anthracene	960	µg/kg	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(a)anthracene	1,300	µg/kg	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(a)pyrene	1,600	µg/kg	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(b)fluoranthene	No criterion	µg/kg	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(g,h,i)perylene	670	µg/kg	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(k)fluoranthene	No criterion	µg/kg	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chrysene	1,400	µg/kg	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenz(a,h)anthracene	230	µg/kg	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fluoranthene	1,700	µg/kg	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fluorene	540	µg/kg	NA	NA	NA	NA	NA	NA	NA	NA	NA
Indeno(1,2,3-cd)pyrene	600	µg/kg	NA	NA	NA	NA	NA	NA	NA	NA	NA
Naphthalene	2,100	µg/kg	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phenanthrene	1,500	µg/kg	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pyrene	2,600	µg/kg	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total benzofluoranthenes[b]	3,200	µg/kg	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total LPAHs[b]	5,200	µg/kg	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total HPAHs[b]	12,000	µg/kg	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 3 – Continued

Analyte	Wood waste SLs	Unit	WB-30S	WB-31S[a]	WB-35S[a]	WB-36S	WB-38S[a]	WB-50S	WB-52S	CR-01S	CR-02S
Conventional											
N-Ammonia	>30	mg-N/kg	8.79	15.33	11.7	NA	19.4	NA	NA	8.91	8.61
Sulfide	>200	mg/kg	821	1065	1480	NA	862	NA	NA	22.15	6.26
Total Fines	No criterion	%	71.0	43.1	33.9	NA	38.0	NA	NA	78.7	26.2
Total Organic Carbon	>5	%	5.47	6.79	5.49	2.97	9.7	4.73	1.59	0.799	0.348
Total Solids	<50	%	36.2	36.8	46.6	NA	36.1	47.8	63.6	64.46	77.7
Total Volatile Solids	>10	%	16.41	24.34	18.88	NA	29.51	14.02	4.85	2.7	1.39
	SMS/LAET										
Phenolic Compounds											
2,4-Dimethylphenol	29	µg/kg	6UJ	NA	NA	6.2UJ	NA	NA	NA	NA	NA
2-Methylphenol	63	µg/kg	6U	NA	NA	6.2U	NA	NA	NA	NA	NA
4-Methylphenol	670	µg/kg	6U	NA	NA	6.2U	NA	NA	NA	NA	NA
Pentachlorophenol	360	µg/kg	30U	NA	NA	31U	NA	NA	NA	NA	NA
Phenol	420	µg/kg	10U	NA	NA	9.3U	NA	NA	NA	NA	NA
SVOCs											
1,2,4-Trichlorobenzene	31	µg/kg	6U	NA	NA	6.2U	NA	NA	NA	NA	NA
1,2-Dichlorobenzene	35	µg/kg	6U	NA	NA	6.2U	NA	NA	NA	NA	NA
1,4-Dichlorobenzene	110	µg/kg	6U	NA	NA	6.2U	NA	NA	NA	NA	NA
Benzyl Alcohol	57	µg/kg	30UJ	NA	NA	31UJ	NA	NA	NA	NA	NA
Butylbenzylphthalate	63	µg/kg	15U	NA	NA	15U	NA	NA	NA	NA	NA
Dibenzofuran	15	µg/kg	NA	NA	NA	NA	NA	47	20U	NA	NA
Dimethylphthalate	71	µg/kg	15U	NA	NA	15U	NA	NA	NA	NA	NA
Hexachlorobenzene	22	µg/kg	6U	NA	NA	6.2U	NA	NA	NA	NA	NA
Hexachlorobutadiene	11	µg/kg	6U	NA	NA	6.2U	NA	NA	NA	NA	NA
n-Nitrosodimethylamine	No criterion	µg/kg	30U	NA	NA	31U	NA	NA	NA	NA	NA
n-Nitroso-di-n-Propylamine	No criterion	µg/kg	30U	NA	NA	31U	NA	NA	NA	NA	NA
n-Nitrosodiphenylamine	28	µg/kg	6U	NA	NA	6.2U	NA	NA	NA	NA	NA
PAHs											
1-Methylnaphthalene	No criterion	µg/kg	NA	NA	NA	NA	NA	20U	20U	NA	NA

Analyte	Wood waste SLs	Unit	WB-30S	WB-31S[a]	WB-35S[a]	WB-36S	WB-38S[a]	WB-50S	WB-52S	CR-01S	CR-02S
2-Methylnaphthalene	670	µg/kg	NA	NA	NA	NA	NA	22	20U	NA	NA
Acenaphthene	500	µg/kg	NA	NA	NA	NA	NA	58	20U	NA	NA
Acenaphthylene	1,300	µg/kg	NA	NA	NA	NA	NA	40	20U	NA	NA
Anthracene	960	µg/kg	NA	NA	NA	NA	NA	160	32	NA	NA
Benzo(a)anthracene	1,300	µg/kg	NA	NA	NA	NA	NA	540	160J	NA	NA
Benzo(a)pyrene	1,600	µg/kg	NA	NA	NA	NA	NA	360	98J	NA	NA
Benzo(b)fluoranthene	No criterion	µg/kg	NA	NA	NA	NA	NA	800	170J	NA	NA
Benzo(g,h,i)perylene	670	µg/kg	NA	NA	NA	NA	NA	140	34	NA	NA
Benzo(k)fluoranthene	No criterion	µg/kg	NA	NA	NA	NA	NA	490	120	NA	NA
Chrysene	1,400	µg/kg	NA	NA	NA	NA	NA	1,200	350J	NA	NA
Dibenz(a,h)anthracene	230	µg/kg	NA	NA	NA	NA	NA	32	20U	NA	NA
Fluoranthene	1,700	µg/kg	NA	NA	NA	NA	NA	3,600	680J	NA	NA
Fluorene	540	µg/kg	NA	NA	NA	NA	NA	76	20U	NA	NA
Indeno(1,2,3-cd)pyrene	600	µg/kg	NA	NA	NA	NA	NA	180	39	NA	NA
Naphthalene	2,100	µg/kg	NA	NA	NA	NA	NA	20U	20U	NA	NA
Phenanthrene	1,500	µg/kg	NA	NA	NA	NA	NA	940	200J	NA	NA
Pyrene	2,600	µg/kg	NA	NA	NA	NA	NA	2,700	620J	NA	NA
Total benzofluoranthenes[b]	3,200	µg/kg	NA	NA	NA	NA	NA	1,290	290	NA	NA
Total LPAHs[b]	5,200	µg/kg	NA	NA	NA	NA	NA	1,296	252	NA	NA
Total HPAHs[b]	12,000	µg/kg	NA	NA	NA	NA	NA	10,042	2,271	NA	NA

[a] Historical chemistry results from SAIC (2008) will be used in the feasibility study.
[b] Totals based on sum of detected values
J – estimated concentration
NA – not analyzed
J – estimated concentration
HPAHs – high molecular weight PAHs
LAET – lowest adverse effect level
LPAHs – low molecular weight PAHs
NA – not analyzed
PAHs – polycyclic aromatic hydrocarbons
SL – screening level
SMS – Sediment Management Standard
SVOCs – semivolatile organic compounds
TOC – total organic carbon
U – not detected at given concentration

Table 4 - Mussel larval results

Sample Number	Matching Reference	Mean Effective Mortality (percent)	Mean Normal Survivors (percent)	SMS Compliance	
				SQS	CSL
Negative Control	—	0±4.9	100±4.9	—	—
WB-06-SS-010	CR-01-SS-010	21.4±4.1	78.6±4.1	Pass	Pass
WB-08-SS-010	CR-01-SS-010	24.4±3.0	75.6±3.0	Pass	Pass
WB-18-SS-010	CR-02-SS-010	40.6±10.1	59.4±10.1	Fail	Fail
WB-28-SS-010	CR-01-SS-010	29.1±11.4	70.9±11.4	Pass	Pass
WB-30-SS-010	CR-01-SS-010	30.5±14.5	69.5±14.5	Pass	Pass
WB-31-SS-010	CR-02-SS-010	39.3±10.6	60.7±10.6	Fail	Fail
WB-35-SS-010	CR-02-SS-010	29.0±2.0	71.0±2.0	Fail	Pass
WB-38-SS-010	CR-02-SS-010	31.4±6.9	68.6±6.9	Fail	Pass
CR-01-SS-010	—	35.6±1.8	64.4±1.8	Pass	Pass
CR-02-SS-010	—	6.9±8.8	93.1±8.8	Pass	Pass

Table 5 - Amphipod results

Sample Number	Matching Reference	Mortality (percent)	SMS Compliance
Negative control	—	0±0	—
WB-06-SS-010	CR-01-SS-010	6.0±2.2	Pass
WB-08-SS-010	CR-01-SS-010	4.0±6.5	Pass
WB-18-SS-010	CR-02-SS-010	11.0±6.5	Pass
WB-28-SS-010	CR-01-SS-010	8.0±5.7	Pass
WB-30-SS-010	CR-01-SS-010	9.0±6.5	Pass
WB-31-SS-010	CR-02-SS-010	5.0±5	Pass
WB-35-SS-010	CR-02-SS-010	5.0±8.7	Pass
WB-38-SS-010	CR-02-SS-010	2.0±4.5	Pass
CR-01-SS-010	—	2.0±2.7	Pass
CR-02-SS-010	—	6.0±8.9	Pass

Table 6 - Juvenile polychaete results

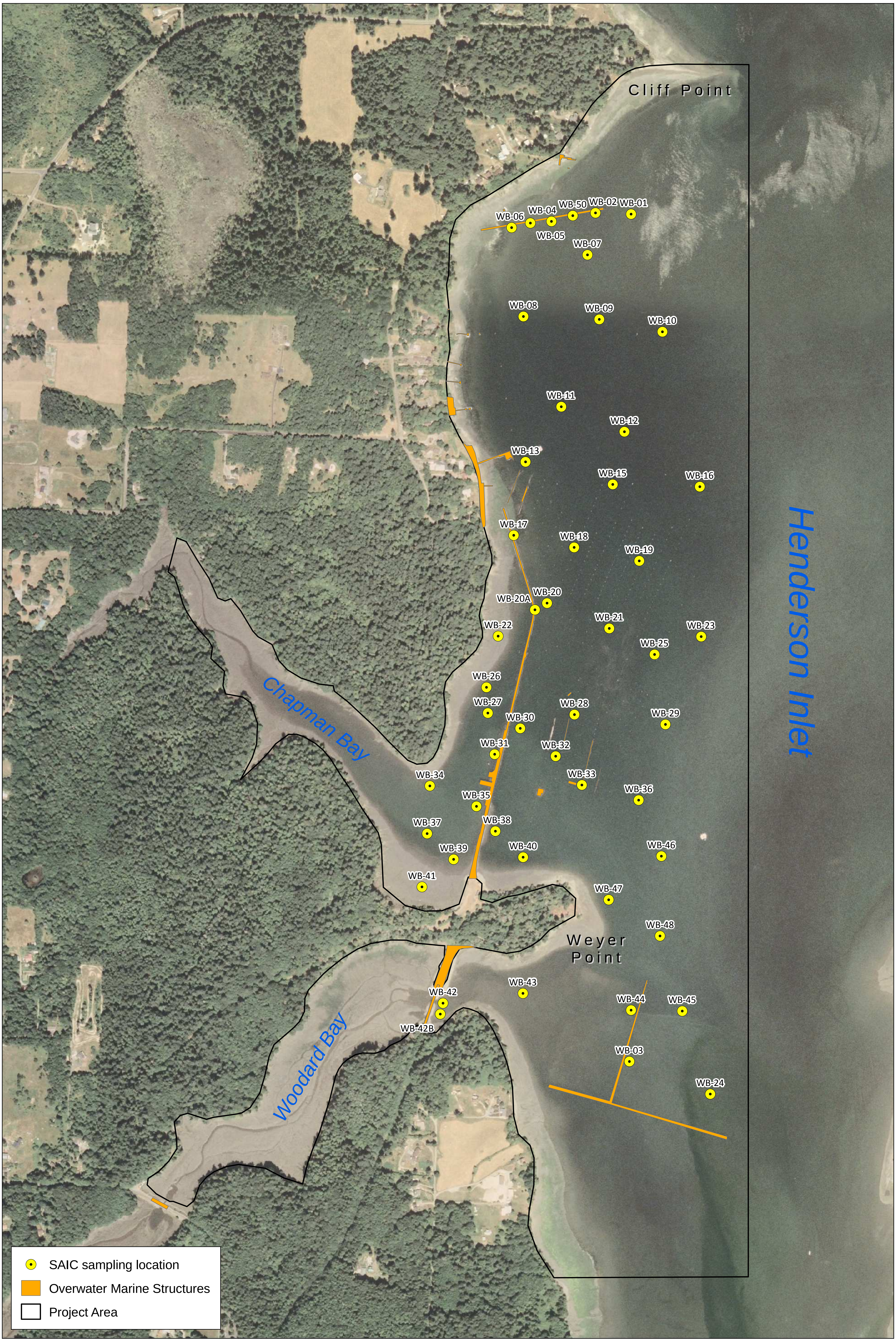
Sample Number	Matching Reference	Mean Growth Rate (mg/day)	Mean Mortality (percent)	SMS Compliance
Negative Control	—	1.14±0.07	0±0	—
WB-06-SS-010	CR-01-SS-010	0.77±0.18	4.0±8.9	Pass
WB-08-SS-010	CR-01-SS-010	0.90±0.27	12.0±26.8	Pass
WB-18-SS-010	CR-02-SS-010	0.86±0.18	0±0	Pass
WB-28-SS-010	CR-01-SS-010	0.89±0.17	0±0	Pass
WB-30-SS-010	CR-01-SS-010	0.95±0.12	0±0	Pass
WB-31-SS-010	CR-02-SS-010	0.79±0.06	0±0	Pass
WB-35-SS-010	CR-02-SS-010	0.84±0.18	12.0±26.8	Pass
WB-38-SS-010	CR-02-SS-010	0.80±0.11	8.0±17.9	Pass
CR-01-SS-010	—	0.81±0.19	0±0	Pass
CR-02-SS-010	—	1.1±0.06	0±0	Pass

Table 7 – Carr Inlet historical reference data for bivalve larval normal survivorship

Study ID	Study Date	Location ID	Sample ID	Mean Normal Survivors %
BCWTAC95	Sep-95	REF_CARR	RR-7	74.3 + 7.7
CHEVPW04	May-04	CPW-REF1	CPW-REF1	75.3 + 6.7
CHEVPW04	May-04	CPW-REF2	CPW-REF2	85.7 + 8.8
CONOCO04	Jul-04	REF36	ANCP-REF36	89.1 + 13.5
CONOCO04	Jul-02	REF66	ANCP-REF66	87.3 + 11.9
P&T_LF4	Jul-02	SG-R-20	SG-R-20	97.5 + 3.8
P&T_LF4	Jul-02	SG-R-20	SG-R-20	87.8 + 4.9
P&T_MILL	Nov-03	SG-R-20	SG-R-20	87.7 + 10
P&T_MILL	Jul-03	SG-R-50	SG-R-50	92.8 + 13.3
P&T_MILL	Aug-01	SG-R-80	SG-R-80	67.1 + 20.1
PA_STP04	Jun-01	REF-01	REF-01	86.4 + 14.2
POSTPT03	Oct-98	CR10	CR10	81.8 + 9.1
POSTPT03	Jul-04	CR23W	CR23W	88.6 + 11.4
POSTPT03	Jul-02	CR24	CR24	79.1 + 13.8
PPTox07	Jul-02	PPTox10	PPTox10	77.4 + 11.2
PSDDA_01	Jul-07	CR20	CR20	90.3 + 6.1
PSDDA_01	Aug-01	CR23W	CR23W	86 + 9.3
PSDDA_02	Jul-02	CR02	CR02	80.7 + 5.6
PSDDA_02	Jul-02	CR24	CR24	79.3 + 10.6
PT_2001	Oct-98	CR-23W	CR-23W	86.4 + 6.5
STARR98	Jul-03	CR-10	CR-10	76.3 + 8.1
STARR98	Jul-03	CR-22S	CR-22S	74.7 + 6.2
STARR98	Oct-98	CR-23W	CR-23W	74.8 + 3.9
Mean				**82.9**
95th UCL				**85.9**
95th LCL				**79.9**

Table 8 – Wood waste attributes for locations passing versus failing the larval bioassay

Station	SMS Bioassay Outcome	Wood Surface Coverage %	Wood Debris by Volume %	TOC %	TVS %	Solids %	Ammonia mg-N/kg	Sulfides mg/kg
WB-08-SS-010	Pass	0	10	6.0	18.1	37.5	37.5	365
WB-18-SS-010	Fail	6.7	7	8.0	18.1	33.3	33.3	699
WB-28-SS-010	Pass	2.3	5	11.7	29.3	34.2	34.2	458
WB-31-SS-010	Fail	0	0	14.4	33.5	34.0	34.0	463



N

0 240 480 Yards

0 175 350 Meters

Map 1. Existing sampling locations for 2008 sediment characterization (SAIC 2008). Woodard Bay Project Area

Wind Ward LLC environmental

Prepared by CEH, 12/03/08, Revised by MTY, 03/25/09; MAP #3551; W:\Projects\Woodard Bay FS\Data\GIS

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Map 2. 2009 Sediment characterization sampling locations
Woodard Bay Project Area

DRAFT

Prepared by CEH, 03/12/09, revised by MTY 03/13/09; MAP #3689; W:\Projects\Woodard Bay FS\Data\GIS

Attachment 1—Chemistry Data Validation Report

EcoChem, INC.
Environmental Data Quality

DATA VALIDATION REPORT

Woodard Bay Feasibility Study

Prepared for:

Windward Environmental, LLC
200 West Mercer Street, Suite 401
Seattle, Washington 98119

Prepared by:

EcoChem, Inc.
710 Second Avenue, Suite 660
Seattle, Washington 98104

EcoChem Project: C22015-1

February 23, 2009

Approved for Release:

Christine Ransom
Project Manager
EcoChem, Inc.

PROJECT NARRATIVE

Basis for the Data Validation

This report summarizes the results of the validation performed on sediment samples and the associated laboratory quality control samples. A **SAMPLE INDEX** is provided, followed by the validation report.

All analyses were done by Analytical Resources, Inc. (ARI), Tukwila, Washington. The analytical methods and EcoChem project chemists are listed in the table below.

ANALYSIS METHODS AND ECOCHEM CHEMISTS

Analysis	Method	Primary Review	Secondary Review
Polynuclear Aromatic Hydrocarbons	EPA 8270D	Jennifer Newkirk	Chris Ransom
Semivolatile Organic Compounds	EPA 8270D-SIM		

The data were reviewed using guidance and quality control criteria documented in the analytical methods; the quality assurance project plan (QAPP) from the *Woodard Bay Feasibility Study, Sampling and Analysis Plan: Surface Sediment Sampling for Chemical Analyses and Toxicity Testing* (December 30, 2008) and *National Functional Guidelines for Organic Data Review* (USEPA 1999).

Validation criteria are included as **APPENDIX A**. A qualified data summary table is included as **APPENDIX B.** Data validation worksheets will be kept on file at EcoChem.

Sample Index
Windward
Woodard Bay Fesibility Study

SDG	Sample ID	Laboratory ID	PAH	SVOC
OF94	WB-03D	08-34939-OF94A		✓
OF94	WB-09S	08-34940-OF94B		✓
OF94	WB-12S	08-34941-OF94C		✓
OF94	WB-16S	08-34942-OF94D		✓
OF94	WB-30S	08-34944-OF94F		✓
OF94	WB-36S	08-34945-OF94G		✓
OG52	WB-50-SS-010	09-389-OG52D	✓	
OG52	WB-52-SS-010	09-393-OG52H	✓	

DATA VALIDATION REPORT
Woodard Bay Feasibility Study
Semivolatile Compounds by SW846 Method 8270D-SIM

This report documents the review of analytical data from the analysis of sediment samples and the associated laboratory quality control (QC) samples. Samples were analyzed by Analytical Resources, Inc. (ARI), Tukwila, Washington. Refer to the **Sample Index** for a list of samples reviewed.

SDG	Number of Samples	Validation Level
OF94	6 Sediment	Full

I. DATA PACKAGE COMPLETENESS

The laboratory submitted all required deliverables. The laboratory followed adequate corrective action processes and all anomalies were discussed in the case narrative.

II. EDD TO HARDCOPY VERIFICATION

A complete (100%) verification of the electronic data deliverable (EDD) results was performed by comparison to the hardcopy laboratory data package. Laboratory QC results were also verified (10%). No errors were found.

III. TECHNICAL DATA VALIDATION

The QC requirements that were reviewed are listed below.

1 Holding Times and Sample Preservation
GC/MS Tuning
Initial Calibration (ICAL)
Continuing Calibration (CCAL)
2 Laboratory Blanks
Field Blanks
Surrogate Compounds
2 Laboratory Control Samples (LCS/LCSD)
Reference Material
1 Matrix Spikes/Matrix Spike Duplicates (MS/MSD)
Field Duplicates
Internal Standards
1 Target Analyte List
Reporting Limits
Compound Identification and Reported Results
1 Calculation Verification

---

[1] ***Quality control results are discussed below, but no data were qualified.***
[2] ***Quality control outliers that impact the reported data were noted. Data qualifiers were issued as discussed below.***

Holding Times and Sample Preservation

The validation guidance documents state that the cooler temperatures should be within an advisory temperature range of 2° C to 6°C. The laboratory received the cooler at a temperature of -2°C. This temperature outlier did not impact data quality and no qualifiers were required.

Laboratory Blanks

Phenol was detected in the method blank. To assess the impact of blank contamination on the reported sample results, an action level was established at five times (5x) the concentration reported in the blank. All associated results were less than the action level and were qualified as not-detected (U-7).

Laboratory Control Samples (LCS)

Laboratory control samples (LCS) analyses were performed at the required frequency. The recoveries were within the laboratory control limits, with the exceptions noted below.

Benzyl alcohol was not recovered in the LCS. Because the matrix spike/matrix spike duplicates recoveries were acceptable for this compound, the associated sample results were estimated (UJ-10) instead of being rejected. The percent recovery (%R) for 2,4-dimethylphenol was less than the lower control limit. This analyte was not detected in the associated samples; reporting limits were estimated (UJ-10).

Matrix Spike/Matrix Spike Duplicate (MS/MSD)

Matrix spike/matrix spike duplicate (MS/MSD) analyses were performed at the required frequency. The MS/MSD recovery values were within the laboratory control limits.

For QC Sample WB-12S, the MS/MSD relative percent difference (RPD) value for benzyl alcohol was greater than the laboratory control limit. No action was required as this analyte was not detected in the parent sample.

Target Analyte List

Benzoic acid was requested, but not reported. Samples were analyzed by SIM and the laboratory does not analyze benzoic acid by this method due to compound instability. The client was notified and no further action was taken.

Calculation Verification

Several results were verified by recalculation from the raw data. No calculation or transcription errors were noted.

IV. OVERALL ASSESSMENT

As was determined by this evaluation, the laboratory followed the specified analytical method. Accuracy was acceptable, as demonstrated by the surrogate, LCS, and MS/MSD recoveries, with the exception noted above. Precision was also acceptable as demonstrated by the MS/MSD RPD values, with the exception previously noted.

Data were estimated due an LCS recovery outlier. Data were qualified as not-detected based on laboratory blank contamination.

All data, as qualified, are acceptable for use.

DATA VALIDATION REPORT
Woodard Bay Feasibility Study
Polynuclear Aromatic Hydrocarbons by SW846 Method 8270D

This report documents the review of analytical data from the analysis of sediment samples and the associated laboratory quality control (QC) samples. Samples were analyzed by Analytical Resources, Inc. (ARI), Tukwila, Washington. Refer to the **Sample Index** for a list of samples reviewed.

SDG	Number of Samples	Validation Level
OG52	2 Sediment	Full

I. DATA PACKAGE COMPLETENESS

The laboratory submitted all required deliverables. The laboratory followed adequate corrective action processes and all anomalies were discussed in the case narrative.

II. EDD TO HARDCOPY VERIFICATION

A complete (100%) verification of the electronic data deliverable (EDD) results was performed by comparison to the hardcopy laboratory data package. Laboratory QC results were also verified (10%). No errors were found.

III. TECHNICAL DATA VALIDATION

The QC requirements that were reviewed are listed below.

Holding Times and Sample Preservation		Reference Material
GC/MS Tuning	2	Matrix Spikes/Matrix Spike Duplicates (MS/MSD)
Initial Calibration (ICAL)		Field Duplicates
Continuing Calibration (CCAL)		Internal Standards
Laboratory Blanks	1	Target Analyte List
Field Blanks		Reporting Limits
Surrogate Compounds	2	Compound Identification and Reported Results
Laboratory Control Samples (LCS)	1	Calculation Verification

[1] ***Quality control results are discussed below, but no data were qualified.***
[2] ***Quality control outliers that impact the reported data were noted. Data qualifiers were issued as discussed below.***

Matrix Spike/Matrix Spike Duplicate (MS/MSD)

Matrix spike/matrix spike duplicate (MS/MSD) analyses were performed at the required frequency. The MS/MSD relative percent difference (RPD) values were within the laboratory control limits.

The MS/MSD recovery values were within the laboratory control limits, with the exceptions noted below. If the outliers indicated a potential high bias, associated positive results in the parent sample only were qualified as estimated (J-8). If the outliers indicated a potential low bias, positive results and reporting limits in the parent sample were estimated (J/UJ-8).

QC Sample WB-52-SS-010: The fluoranthene and pyrene were not recovered in the MS/MSD. The positive results for these analytes in the parent sample were estimated (J-8). The MS/MSD recoveries for chrysene, phenanthrene, benzo(a)anthracene, benzo(b)fluoranthene, and benzo(a)pyrene were less than the lower control limits. The results for these compounds were estimated (J-8) in the parent sample. The MS %R value for benzo(k)fluoranthene was also less than the lower control limit. The MSD recovery was acceptable, therefore no action was taken.

Target Analyte List

Perylene was noted as a target analyte in the QAPP, but not reported. The client was notified and no further action was taken.

Compound Identification and Reported Results

Results for fluoranthene and pyrene exceeded the calibration range of the instrument in Sample WB-50-SS-010. The laboratory flagged these results with an "E". The sample extracts were diluted and re-analyzed. Both sets of results were reported. The results in the original analysis that were over the calibration range were rejected (R-20). Results that were within the linear range in the initial analysis should be used. All results for these compounds in the dilutions were rejected (R-11).

Calculation Verification

Several results were verified by recalculation from the raw data. No calculation or transcription errors were noted.

IV. OVERALL ASSESSMENT

As was determined by this evaluation, the laboratory followed the specified analytical method. Accuracy was acceptable, as demonstrated by the surrogate, laboratory control sample (LCS), and MS/MSD recoveries, with the exceptions noted above. Precision was also acceptable as demonstrated by MS/MSD RPD values.

Data were estimated because of MS/MSD %R outliers.

Data were rejected in order to indicate which result from multiple reported analyses should be used. A usable result remains for all analytes in every sample, therefore completeness is unaffected.

Data that have been rejected should not used for any purpose. All other data, as qualified, are acceptable for use.

EcoChem, INC.
Environmental Data Quality

APPENDIX A

DATA QUALIFIER DEFINITIONS
REASON CODES
AND CRITERIA TABLES

DATA VALIDATION QUALIFIER CODES
National Functional Guidelines

The following definitions provide brief explanations of the qualifiers assigned to results in the data review process.

U	The analyte was analyzed for, but was not detected above the reported sample quantitation limit.
J	The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.
N	The analysis indicates the presence of an analyte for which there is presumptive evidence to make a "tentative identification".
NJ	The analysis indicates the presence of an analyte that has been "tentatively identified" and the associated numerical value represents the approximate concentration.
UJ	The analyte was not detected above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample.
R	The sample results are rejected due to serious deficiencies in the ability to analyze the sample and meet quality control criteria. The presence or absence of the analyte cannot be verified.

The following is an EcoChem qualifier that may also be assigned during the data review process:

DNR	Do not report; a more appropriate result is reported from another analysis or dilution.

DATA QUALIFIER REASON CODES

1	Holding Time/Sample Preservation
2	Chromatographic pattern in sample does not match pattern of calibration standard.
3	Compound Confirmation
4	Tentatively Identified Compound (TIC) (associated with NJ only)
5A	Calibration (initial)
5B	Calibration (continuing)
6	Field Blank Contamination
7	Lab Blank Contamination (e.g., method blank, instrument, etc.)
8	Matrix Spike(MS & MSD) Recoveries
9	Precision (all replicates)
10	Laboratory Control Sample Recoveries
11	A more appropriate result is reported (associated with “R” and “DNR” only)
12	Reference Material
13	Surrogate Spike Recoveries (a.k.a., labeled compounds & recovery standards)
14	Other (define in validation report)
15	GFAA Post Digestion Spike Recoveries
16	ICP Serial Dilution % Difference
17	ICP Interference Check Standard Recovery
18	Trip Blank Contamination
19	Internal Standard Performance (e.g., area, retention time, recovery)
20	Linear Range Exceeded
21	Potential False Positives
22	Elevated Detection Limit Due to Interference (i.e., laboratory, chemical and/or matrix)

EcoChem Validation Guidelines for Semivolatile Analysis by GC/MS
(Based on Organic NFG 1999)

VALIDATION QC ELEMENT	ACCEPTANCE CRITERIA	ACTION	REASON CODE
Cooler Temperature	4°C ±2°	J(+)/UJ(-) if greater than 6 deg. C (EcoChem PJ)	1
Holding Time	Water: 7 days from collection Soil: 14 days from collection Analysis: 40 days from extraction	<u>Water</u>: J(+)/UJ(-) if ext. > 7 and < 21 days J(+)/R(-) if ext > 21 days (EcoChem PJ) <u>Solids/Wastes</u>: J(+)/UJ(-) if ext. > 14 and < 42 days J(+)/R(-) if ext. > 42 days (EcoChem PJ) J(+)/UJ(-) if analysis >40 days	1
Tuning	DFTPP Beginning of each 12 hour period Method acceptance criteria	R(+/-) all analytes in all samples associated with the tune	5A
Initial Calibration (Minimum 5 stds.)	RRF > 0.05	(EcoChem PJ, see TM-06) If MDL= reporting limit: J(+)/R(-) if RRF < 0.05 If reporting limit > MDL: note in worksheet if RRF <0.05	5A
	%RSD < 30%	(EcoChem PJ, see TM-06) J(+) if %RSD > 30%	5A
Continuing Calibration (Prior to each 12 hr. shift)	RRF > 0.05	(EcoChem PJ, see TM-06) If MDL= reporting limit: J(+)/R(-) if RRF < 0.05 If reporting limit > MDL: note in worksheet if RRF <0.05	5B
	%D <25%	(EcoChem PJ, see TM-06) If > +/-90%: J+/R- If -90% to -26%: J+ (high bias) If 26% to 90%: J+/UJ- (low bias)	5B
Method Blank	One per matrix per batch No results > CRQL	U(+) if sample (+) result is less than CRQL and less than appropriate 5X or 10X rule (raise sample value to CRQL)	7
		U(+) if sample (+) result is greater than or equal to CRQL and less than appropriate 5X and 10X rule (at reported sample value)	7
	No TICs present	R(+) TICs using 10X rule	7
Field Blanks (Not Required)	No results > CRQL	Apply 5X/10X rule; U(+) < action level	6

EcoChem Validation Guidelines for Semivolatile Analysis by GC/MS (Based on Organic NFG 1999)

VALIDATION QC ELEMENT	ACCEPTANCE CRITERIA	ACTION	REASON CODE
MS/MSD (recovery)	One per matrix per batch Use method acceptance criteria	Qualify parent only unless other QC indicates systematic problems: J(+) if both %R > UCL J(+)/UJ(-) if both %R < LCL J(+)/R(-) if both %R < 10% PJ if only one %R outlier	8
MS/MSD (RPD)	One per matrix per batch Use method acceptance criteria	J(+) in parent sample if RPD > CL	9
LCS low conc. H2O SVOA	One per lab batch Within method control limits	J(+) assoc. cmpd if > UCL J(+)/R(-) assoc. cmpd if < LCL J(+)/R(-) all cmpds if half are < LCL	10
LCS regular SVOA (H2O & solid)	One per lab batch Lab or method control limits	J(+) if %R > UCL J(+)/UJ(-) if %R <LCL J(+)/R(-) if %R < 10% (EcoChem PJ)	10
LCS/LCSD *(if required)*	One set per matrix and batch of 20 samples RPD < 35%	J(+)/UJ(-) assoc. cmpd. in all samples	9
Surrogates	Minimum of 3 acid and 3 base/neutral compounds Use method acceptance criteria	Do not qualify if only 1 acid and/or 1 B/N surrogate is out unless <10% J(+) if %R > UCL J(+)/UJ(-) if %R < LCL J(+)/R(-) if %R < 10%	13
Internal Standards	Added to all samples Acceptable Range: IS area 50% to 200% of CCAL area RT within 30 seconds of CC RT	J(+) if > 200% J(+)/UJ(-) if < 50% J(+)/R(-) if < 25% RT>30 seconds, narrate and Notify PM	19
Field Duplicates	Use QAPP limits. If no QAPP: Solids: RPD <50% OR absolute diff. < 2X RL (for results < 5X RL) Aqueous: RPD <35% OR absolute diff. < 1X RL (for results < 5X RL)	Narrate and qualify if required by project (EcoChem PJ)	9
TICs	Major ions (>10%) in reference must be present in sample; intensities agree within 20%; check identification	NJ the TIC unless: R(+) common laboratory contaminants See Technical Director for ID issues	4
Quantitation/ Identification	RRT within 0.06 of standard RRT Ion relative intensity within 20% of standard All ions in std. at > 10% intensity must be present in sample	See Technical Director if outliers	14 21 (false +)

EcoChem, INC.
Environmental Data Quality

APPENDIX B
QUALIFIED DATA SUMMARY TABLE

Qualified Data Summary Table
Windward
Woodard Bay Feasibility Study

SDG	Sample ID	Laboratory ID	Analyte	Result	Units	Laboratory Qualifiers	Validation Qualifiers	Validation Reason
OF94	WB-03D	08-34939-OF94A	2,4-Dimethylphenol		ug/kg	U	UJ	10
OF94	WB-03D	08-34939-OF94A	Benzyl Alcohol		ug/kg	U	UJ	10
OF94	WB-03D	08-34939-OF94A	Phenol	17	ug/kg	B	U	7
OF94	WB-09S	08-34940-OF94B	2,4-Dimethylphenol		ug/kg	U	UJ	10
OF94	WB-09S	08-34940-OF94B	Benzyl Alcohol		ug/kg	U	UJ	10
OF94	WB-09S	08-34940-OF94B	Phenol	12	ug/kg	B	U	7
OF94	WB-12S	08-34941-OF94C	2,4-Dimethylphenol		ug/kg	U	UJ	10
OF94	WB-12S	08-34941-OF94C	Benzyl Alcohol		ug/kg	U	UJ	10
OF94	WB-12S	08-34941-OF94C	Phenol	12	ug/kg	B	U	7
OF94	WB-16S	08-34942-OF94D	2,4-Dimethylphenol		ug/kg	U	UJ	10
OF94	WB-16S	08-34942-OF94D	Benzyl Alcohol		ug/kg	U	UJ	10
OF94	WB-16S	08-34942-OF94D	Phenol	7.3	ug/kg	B	U	7
OF94	WB-30S	08-34944-OF94F	2,4-Dimethylphenol		ug/kg	U	UJ	10
OF94	WB-30S	08-34944-OF94F	Benzyl Alcohol		ug/kg	U	UJ	10
OF94	WB-30S	08-34944-OF94F	Phenol	10	ug/kg	B	U	7
OF94	WB-36S	08-34945-OF94G	2,4-Dimethylphenol		ug/kg	U	UJ	10
OF94	WB-36S	08-34945-OF94G	Benzyl Alcohol		ug/kg	U	UJ	10
OF94	WB-36S	08-34945-OF94G	Phenol	9.3	ug/kg	B	U	7
OG52	WB-50-SS-010	09-389-OG52D	Fluoranthene	3300	ug/kg	E	R	20
OG52	WB-50-SS-010	09-389-OG52D	Pyrene	2500	ug/kg	E	R	20
OG52	WB-50-SS-010	09-389-OG52DDL	1-Methylnaphthalene		ug/kg	U	R	11
OG52	WB-50-SS-010	09-389-OG52DDL	2-Methylnaphthalene		ug/kg	U	R	11
OG52	WB-50-SS-010	09-389-OG52DDL	Acenaphthene		ug/kg	U	R	11
OG52	WB-50-SS-010	09-389-OG52DDL	Acenaphthylene		ug/kg	U	R	11
OG52	WB-50-SS-010	09-389-OG52DDL	Anthracene	160	ug/kg		R	11
OG52	WB-50-SS-010	09-389-OG52DDL	Benzo(a)anthracene	560	ug/kg		R	11
OG52	WB-50-SS-010	09-389-OG52DDL	Benzo(a)pyrene	380	ug/kg		R	11
OG52	WB-50-SS-010	09-389-OG52DDL	Benzo(b)fluoranthene	830	ug/kg		R	11
OG52	WB-50-SS-010	09-389-OG52DDL	Benzo(g,h,i)perylene	150	ug/kg		R	11
OG52	WB-50-SS-010	09-389-OG52DDL	Benzo(k)fluoranthene	520	ug/kg		R	11
OG52	WB-50-SS-010	09-389-OG52DDL	Chrysene	1300	ug/kg		R	11
OG52	WB-50-SS-010	09-389-OG52DDL	Dibenz(a,h)anthracene		ug/kg	U	R	11
OG52	WB-50-SS-010	09-389-OG52DDL	Dibenzofuran		ug/kg	U	R	11
OG52	WB-50-SS-010	09-389-OG52DDL	Fluorene		ug/kg	U	R	11
OG52	WB-50-SS-010	09-389-OG52DDL	Indeno(1,2,3-cd)pyrene	180	ug/kg		R	11
OG52	WB-50-SS-010	09-389-OG52DDL	Naphthalene		ug/kg	U	R	11
OG52	WB-50-SS-010	09-389-OG52DDL	Phenanthrene	960	ug/kg		R	11
OG52	WB-52-SS-010	09-393-OG52H	Benzo(a)anthracene	160	ug/kg		J	8
OG52	WB-52-SS-010	09-393-OG52H	Benzo(a)pyrene	98	ug/kg		J	8
OG52	WB-52-SS-010	09-393-OG52H	Benzo(b)fluoranthene	170	ug/kg		J	8
OG52	WB-52-SS-010	09-393-OG52H	Chrysene	350	ug/kg		J	8
OG52	WB-52-SS-010	09-393-OG52H	Fluoranthene	680	ug/kg		J	8
OG52	WB-52-SS-010	09-393-OG52H	Phenanthrene	200	ug/kg		J	8
OG52	WB-52-SS-010	09-393-OG52H	Pyrene	620	ug/kg		J	8

Attachment 2—Laboratory Bioassay Reports

Amphipod Results

INIT=initial number
SURV=number survivors
REBUR=number survivors which reburied
MORT=number dead=INIT-SURV
NOBURY=number survivors not reburied=SURV-REBUR
TEM=total effective mortality=MORT+NOBURY

PSURV=%survival=100(SURV/INIT)
PMORT=%mortality=100(MORT/INIT)
PBURY=%reburial=100(REBUR/SURV)
PNOBURY=%survivors not reburied=100(NOBURY/SURV)
PTEM=%total effective mortality=100(TEM/INIT)

IN-DEX	BKR	NAS SMPL	CLIENT DESCRIP	REPL		INIT	SURV	REBUR	MORT	NO-BURY	TEM	PSURV	PMORT	PBURY	PNO-BURY	PTEM		SURV	MORT	NO-BURY	PSURV	PMORT	PBURY	PNO-BURY	PTEM
1	29	2335G	WB-06-SS-010	1		20	19	19	1	0	1	95.0	5.0	100.0	0.0	5.0									
2	56	2335G	WB-06-SS-010	2		20	19	19	1	0	1	95.0	5.0	100.0	0.0	5.0	Mean	18.8	1.2	0.0	94.0	6.0	100.0	0.0	6.0
3	49	2335G	WB-06-SS-010	3		20	18	18	2	0	2	90.0	10.0	100.0	0.0	10.0	SD	0.4	0.4	0.0	2.2	2.2	0.0	0.0	2.2
4	2	2335G	WB-06-SS-010	4		20	19	19	1	0	1	95.0	5.0	100.0	0.0	5.0	n	5	5	5	5	5	5	5	5
5	64	2335G	WB-06-SS-010	5		20	19	19	1	0	1	95.0	5.0	100.0	0.0	5.0									
6	52	2335G	WB-06-SS-010	6	wq repl	20																			
7	33	2336G	WB-08-SS-010	1		20	19	19	1	0	1	95.0	5.0	100.0	0.0	5.0									
8	9	2336G	WB-08-SS-010	2		20	20	20	0	0	0	100.0	0.0	100.0	0.0	0.0	Mean	19.2	0.8	0.0	96.0	4.0	100.0	0.0	4.0
9	38	2336G	WB-08-SS-010	3		20	20	20	0	0	0	100.0	0.0	100.0	0.0	0.0	SD	1.3	1.3	0.0	6.5	6.5	0.0	0.0	6.5
10	7	2336G	WB-08-SS-010	4		20	17	17	3	0	3	85.0	15.0	100.0	0.0	15.0	n	5	5	5	5	5	5	5	5
11	54	2336G	WB-08-SS-010	5		20	20	20	0	0	0	100.0	0.0	100.0	0.0	0.0									
12	46	2336G	WB-08-SS-010	6	wq repl	20																			
13	42	2337G	WB-18-SS-010	1		20	18	18	2	0	2	90.0	10.0	100.0	0.0	10.0									
14	35	2337G	WB-18-SS-010	2		20	17	17	3	0	3	85.0	15.0	100.0	0.0	15.0	Mean	17.8	2.2	0.2	89.0	11.0	98.8	1.2	12.0
15	1	2337G	WB-18-SS-010	3		20	17	16	3	1	4	85.0	15.0	94.1	5.9	20.0	SD	1.3	1.3	0.4	6.5	6.5	2.6	2.6	7.6
16	14	2337G	WB-18-SS-010	4		20	20	20	0	0	0	100.0	0.0	100.0	0.0	0.0	n	5	5	5	5	5	5	5	5
17	27	2337G	WB-18-SS-010	5		20	17	17	3	0	3	85.0	15.0	100.0	0.0	15.0									
18	5	2337G	WB-18-SS-010	6	wq repl	20																			
19	34	2338G	WB-28-SS-010	1		20	17	17	3	0	3	85.0	15.0	100.0	0.0	15.0									
20	19	2338G	WB-28-SS-010	2		20	18	18	2	0	2	90.0	10.0	100.0	0.0	10.0	Mean	18.4	1.6	0.0	92.0	8.0	100.0	0.0	8.0
21	10	2338G	WB-28-SS-010	3		20	20	20	0	0	0	100.0	0.0	100.0	0.0	0.0	SD	1.1	1.1	0.0	5.7	5.7	0.0	0.0	5.7
22	48	2338G	WB-28-SS-010	4		20	18	18	2	0	2	90.0	10.0	100.0	0.0	10.0	n	5	5	5	5	5	5	5	5
23	28	2338G	WB-28-SS-010	5		20	19	19	1	0	1	95.0	5.0	100.0	0.0	5.0									
24	51	2338G	WB-28-SS-010	6	wq repl	20																			
25	40	2339G	WB-30-SS-010	1		20	18	18	2	0	2	90.0	10.0	100.0	0.0	10.0									
26	3	2339G	WB-30-SS-010	2		20	19	19	1	0	1	95.0	5.0	100.0	0.0	5.0	Mean	18.2	1.8	0.0	91.0	9.0	100.0	0.0	9.0
27	24	2339G	WB-30-SS-010	3		20	20	20	0	0	0	100.0	0.0	100.0	0.0	0.0	SD	1.3	1.3	0.0	6.5	6.5	0.0	0.0	6.5
28	62	2339G	WB-30-SS-010	4		20	17	17	3	0	3	85.0	15.0	100.0	0.0	15.0	n	5	5	5	5	5	5	5	5
29	26	2339G	WB-30-SS-010	5		20	17	17	3	0	3	85.0	15.0	100.0	0.0	15.0									
30	44	2339G	WB-30-SS-010	6	wq repl	20																			
31	57	2340G	WB-31-SS-010	1		20	20	20	0	0	0	100.0	0.0	100.0	0.0	0.0									
32	22	2340G	WB-31-SS-010	2		20	20	20	0	0	0	100.0	0.0	100.0	0.0	0.0	Mean	19.0	1.0	0.0	95.0	5.0	100.0	0.0	5.0
33	58	2340G	WB-31-SS-010	3		20	19	19	1	0	1	95.0	5.0	100.0	0.0	5.0	SD	1.0	1.0	0.0	5.0	5.0	0.0	0.0	5.0
34	17	2340G	WB-31-SS-010	4		20	18	18	2	0	2	90.0	10.0	100.0	0.0	10.0	n	5	5	5	5	5	5	5	5
35	55	2340G	WB-31-SS-010	5		20	18	18	2	0	2	90.0	10.0	100.0	0.0	10.0									
36	6	2340G	WB-31-SS-010	6	wq repl	20																			
37	61	2341G	WB-35-SS-010	1		20	20	20	0	0	0	100.0	0.0	100.0	0.0	0.0									
38	25	2341G	WB-35-SS-010	2		20	16	16	4	0	4	80.0	20.0	100.0	0.0	20.0	Mean	19.0	1.0	0.0	95.0	5.0	100.0	0.0	5.0
39	41	2341G	WB-35-SS-010	3		20	20	20	0	0	0	100.0	0.0	100.0	0.0	0.0	SD	1.7	1.7	0.0	8.7	8.7	0.0	0.0	8.7
40	13	2341G	WB-35-SS-010	4		20	20	20	0	0	0	100.0	0.0	100.0	0.0	0.0	n	5	5	5	5	5	5	5	5
41	66	2341G	WB-35-SS-010	5		20	19	19	1	0	1	95.0	5.0	100.0	0.0	5.0									
42	11	2341G	WB-35-SS-010	6	wq repl	20																			

IN-DEX	BKR	NAS SMPL	CLIENT DESCRIP	REPL		INIT	SURV	REBUR	MORT	NO-BURY	TEM	PSURV	PMORT	PBURY	PNO-BURY	PTEM			SURV	MORT	NO-BURY	PSURV	PMORT	PBURY	PNO-BURY	PTEM
43	15	2342G	WB-38-SS-010	1		20	18	18	2	0	2	90.0	10.0	100.0	0.0	10.0										
44	4	2342G	WB-38-SS-010	2		20	20	20	0	0	0	100.0	0.0	100.0	0.0	0.0		Mean	19.6	0.4	0.0	98.0	2.0	100.0	0.0	2.0
45	36	2342G	WB-38-SS-010	3		20	20	20	0	0	0	100.0	0.0	100.0	0.0	0.0		SD	0.9	0.9	0.0	4.5	4.5	0.0	0.0	4.5
46	45	2342G	WB-38-SS-010	4		20	20	20	0	0	0	100.0	0.0	100.0	0.0	0.0		n	5	5	5	5	5	5	5	5
47	30	2342G	WB-38-SS-010	5		20	20	20	0	0	0	100.0	0.0	100.0	0.0	0.0										
48	59	2342G	WB-38-SS-010	6	wq repl	20																				
49	63	2343G	control	1		20	20	20	0	0	0	100.0	0.0	100.0	0.0	0.0										
50	47	2343G	control	2		20	20	20	0	0	0	100.0	0.0	100.0	0.0	0.0		Mean	20.0	0.0	0.0	100.0	0.0	100.0	0.0	0.0
51	60	2343G	control	3		20	20	20	0	0	0	100.0	0.0	100.0	0.0	0.0		SD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
52	50	2343G	control	4		20	20	20	0	0	0	100.0	0.0	100.0	0.0	0.0		n	5	5	5	5	5	5	5	5
53	16	2343G	control	5		20	20	20	0	0	0	100.0	0.0	100.0	0.0	0.0										
54	43	2343G	control	6	wq repl	20																				
55	39	2344G	CR-01-SS-010	1		20	20	20	0	0	0	100.0	0.0	100.0	0.0	0.0										
56	12	2344G	CR-01-SS-010	2		20	20	20	0	0	0	100.0	0.0	100.0	0.0	0.0		Mean	19.6	0.4	0.0	98.0	2.0	100.0	0.0	2.0
57	65	2344G	CR-01-SS-010	3		20	19	19	1	0	1	95.0	5.0	100.0	0.0	5.0		SD	0.5	0.5	0.0	2.7	2.7	0.0	0.0	2.7
58	20	2344G	CR-01-SS-010	4		20	19	19	1	0	1	95.0	5.0	100.0	0.0	5.0		n	5	5	5	5	5	5	5	5
59	37	2344G	CR-01-SS-010	5		20	20	20	0	0	0	100.0	0.0	100.0	0.0	0.0										
60	8	2344G	CR-01-SS-010	6	wq repl	20																				
61	31	2345G	CR-02-SS-010	1		20	16	16	4	0	4	80.0	20.0	100.0	0.0	20.0										
62	23	2345G	CR-02-SS-010	2		20	20	20	0	0	0	100.0	0.0	100.0	0.0	0.0		Mean	18.8	1.2	0.0	94.0	6.0	100.0	0.0	6.0
63	53	2345G	CR-02-SS-010	3		20	20	20	0	0	0	100.0	0.0	100.0	0.0	0.0		SD	1.8	1.8	0.0	8.9	8.9	0.0	0.0	8.9
64	32	2345G	CR-02-SS-010	4		20	18	18	2	0	2	90.0	10.0	100.0	0.0	10.0		n	5	5	5	5	5	5	5	5
65	21	2345G	CR-02-SS-010	5		20	20	20	0	0	0	100.0	0.0	100.0	0.0	0.0										
66	18	2345G	CR-02-SS-010	6	wq repl	20																				

Juvenile Polychaete Results

BKR=beaker number (=pan number)
INIT NO.=initial number of worms exposed
FINAL IW PPT=interstitial salinity in ppt on day 20
SURV=number of worms surviving after 20 days
MORT=number of worms dead after 20 days
INIT WT=mean weight of worms sampled on day zero (mg)
TARE WT=weight of pan used for that replicate on day 20 (mg)
WT COUNT=number of worms weighed at test end
FINAL WT=TARE WT + weight of worms recovered on day 20 (mg)
PSURV=% SURV=100(SURV/INIT NO.)
PMORT=%MORT=100(MORT/INIT NO.)
TWT=total biomass=FINAL-TARE
WT=individual biomass=TWT/WT COUNT
GR=individual growth rate=(WT-INIT WT)/20

INIT WT				
pan#	tare wt	total wt	# weighed	individual wt
1	51.15	56.10	5	0.99
2	48.58	50.79	5	0.44
4	48.63	50.92	5	0.46
			MEAN	0.63

INDEX	BKR	NAS SMPL	CLIENT DESCRIP	REPL		INIT NO.	FINAL IW PPT	SURV	MORT	INIT WT	TARE WT	WT COUNT	FINAL WT	PSURV	PMORT	TWT	WT	GR		TWT	WT	GR	PSURV	PMORT
1	4	2335G	WB-06-SS-010	1		5		5	0	0.63	89.32	5	151.68	100.0	0.0	62.4	12.5	0.59						
2	47	2335G	WB-06-SS-010	2		5		5	0	0.63	86.11	5	168.65	100.0	0.0	82.5	16.5	0.79	Mean	77.3	16.0	0.77	96.0	4.0
3	43	2335G	WB-06-SS-010	3		5		5	0	0.63	80.20	5	160.62	100.0	0.0	80.4	16.1	0.77	S.D.	20.8	3.5	0.18	8.9	8.9
4	5	2335G	WB-06-SS-010	4		5		5	0	0.63	92.82	5	200.30	100.0	0.0	107.5	21.5	1.04	n	5	5	5	5	5
5	38	2335G	WB-06-SS-010	5		5		4	1	0.63	89.99	4	143.55	80.0	20.0	53.6	13.4	0.64						
6	20	2335G	WB-06-SS-010	6	wq replicate	5	28.0																	
7	44	2336G	WB-08-SS-010	1		5		5	0	0.63	87.90	5	158.64	100.0	0.0	70.7	14.1	0.68						
8	28	2336G	WB-08-SS-010	2		5		5	0	0.63	84.13	5	166.25	100.0	0.0	82.1	16.4	0.79	Mean	76.4	18.6	0.90	88.0	12.0
9	53	2336G	WB-08-SS-010	3		5		5	0	0.63	83.75	5	170.06	100.0	0.0	86.3	17.3	0.83	S.D.	13.2	5.3	0.27	26.8	26.8
10	1	2336G	WB-08-SS-010	4		5		5	0	0.63	84.60	5	171.45	100.0	0.0	86.9	17.4	0.84	n	5	5	5	5	5
11	65	2336G	WB-08-SS-010	5		5		2	3	0.63	94.00	2	149.79	40.0	60.0	55.8	27.9	1.36						
12	7	2336G	WB-08-SS-010	6	wq replicate	5	27.5																	
13	26	2337G	WB-18-SS-010	1		5		5	0	0.63	91.92	5	158.26	100.0	0.0	66.3	13.3	0.63						
14	33	2337G	WB-18-SS-010	2		5		5	0	0.63	90.53	5	180.24	100.0	0.0	89.7	17.9	0.87	Mean	88.8	17.8	0.86	100.0	0.0
15	2	2337G	WB-18-SS-010	3		5		5	0	0.63	85.73	5	202.79	100.0	0.0	117.1	23.4	1.14	S.D.	18.4	3.7	0.18	0.0	0.0
16	51	2337G	WB-18-SS-010	4		5		5	0	0.63	89.52	5	178.83	100.0	0.0	89.3	17.9	0.86	n	5	5	5	5	5
17	59	2337G	WB-18-SS-010	5		5		5	0	0.63	90.18	5	171.60	100.0	0.0	81.4	16.3	0.78						
18	60	2337G	WB-18-SS-010	6	wq replicate	5	28.5																	
19	37	2338G	WB-28-SS-010	1		5		5	0	0.63	89.35	5	168.63	100.0	0.0	79.3	15.9	0.76						
20	32	2338G	WB-28-SS-010	2		5		5	0	0.63	84.74	5	187.04	100.0	0.0	102.3	20.5	0.99	Mean	91.7	18.3	0.89	100.0	0.0
21	30	2338G	WB-28-SS-010	3		5		5	0	0.63	95.70	5	178.21	100.0	0.0	82.5	16.5	0.79	S.D.	17.2	3.4	0.17	0.0	0.0
22	62	2338G	WB-28-SS-010	4		5		5	0	0.63	92.70	5	170.45	100.0	0.0	77.8	15.6	0.75	n	5	5	5	5	5
23	6	2338G	WB-28-SS-010	5		5		5	0	0.63	88.27	5	205.13	100.0	0.0	116.9	23.4	1.14						
24	31	2338G	WB-28-SS-010	6	wq replicate	5	28.0																	
25	17	2339G	WB-30-SS-010	1		5		5	0	0.63	86.62	5	199.91	100.0	0.0	113.3	22.7	1.10						
26	12	2339G	WB-30-SS-010	2		5		5	0	0.63	86.01	5	169.11	100.0	0.0	83.1	16.6	0.80	Mean	97.7	19.5	0.95	100.0	0.0
27	49	2339G	WB-30-SS-010	3		5		5	0	0.63	83.35	5	180.95	100.0	0.0	97.6	19.5	0.94	S.D.	11.6	2.3	0.12	0.0	0.0
28	55	2339G	WB-30-SS-010	4		5		5	0	0.63	87.93	5	178.65	100.0	0.0	90.7	18.1	0.88	n	5	5	5	5	5
29	3	2339G	WB-30-SS-010	5		5		5	0	0.63	89.07	5	192.67	100.0	0.0	103.6	20.7	1.00						
30	46	2339G	WB-30-SS-010	6	wq replicate	5	28.0																	
31	16	2340G	WB-31-SS-010	1		5		5	0	0.63	87.05	5	160.40	100.0	0.0	73.4	14.7	0.70						
32	15	2340G	WB-31-SS-010	2		5		5	0	0.63	86.84	5	168.55	100.0	0.0	81.7	16.3	0.79	Mean	82.0	16.4	0.79	100.0	0.0
33	18	2340G	WB-31-SS-010	3		5		5	0	0.63	93.01	5	175.15	100.0	0.0	82.1	16.4	0.79	S.D.	6.5	1.3	0.06	0.0	0.0
34	10	2340G	WB-31-SS-010	4		5		5	0	0.63	86.89	5	178.43	100.0	0.0	91.5	18.3	0.88	n	5	5	5	5	5

		NAS	CLIENT			INIT	FINAL			INIT	TARE	WT	FINAL												
INDEX	BKR	SMPL	DESCRIP	REPL		NO.	IW PPT	SURV	MORT	WT	WT	COUNT	WT	PSURV	PMORT	TWT	WT	GR			TWT	WT	GR	PSURV	PMORT
35	39	2340G	WB-31-SS-010	5		5		5	0	0.63	85.12	5	166.43	100.0	0.0	81.3	16.3	0.78							
36	54	2340G	WB-31-SS-010	6	wq replicate	5	28.0																		
37	8	2341G	WB-35-SS-010	1		5		5	0	0.63	87.94	5	174.79	100.0	0.0	86.9	17.4	0.84							
38	40	2341G	WB-35-SS-010	2		5		5	0	0.63	83.85	5	165.69	100.0	0.0	81.8	16.4	0.79		Mean	73.0	17.4	0.84	88.0	12.0
39	24	2341G	WB-35-SS-010	3		5		5	0	0.63	82.80	5	157.53	100.0	0.0	74.7	14.9	0.72		S.D.	15.4	3.6	0.18	26.8	26.8
40	29	2341G	WB-35-SS-010	4		5		5	0	0.63	92.51	5	167.03	100.0	0.0	74.5	14.9	0.71		n	5	5	5	5	5
41	41	2341G	WB-35-SS-010	5		5		2	3	0.63	91.22	2	138.35	40.0	60.0	47.1	23.6	1.15							
42	27	2341G	WB-35-SS-010	6	wq replicate	5	28.0																		
43	35	2342G	WB-38-SS-010	1		5		5	0	0.63	95.82	5	176.60	100.0	0.0	80.8	16.2	0.78							
44	52	2342G	WB-38-SS-010	2		5		3	2	0.63	82.25	3	128.63	60.0	40.0	46.4	15.5	0.74		Mean	76.9	16.6	0.80	92.0	8.0
45	48	2342G	WB-38-SS-010	3		5		5	0	0.63	86.17	5	188.69	100.0	0.0	102.5	20.5	0.99		S.D.	20.0	2.2	0.11	17.9	17.9
46	50	2342G	WB-38-SS-010	4		5		5	0	0.63	84.30	5	160.39	100.0	0.0	76.1	15.2	0.73		n	5	5	5	5	5
47	11	2342G	WB-38-SS-010	5		5		5	0	0.63	83.33	5	162.19	100.0	0.0	78.9	15.8	0.76							
48	36	2342G	WB-38-SS-010	6	wq replicate	5	28.0																		
49	9	2343G	control	1		5		5	0	0.63	88.05	5	206.71	100.0	0.0	118.7	23.7	1.16							
50	58	2343G	control	2		5		5	0	0.63	82.77	5	189.72	100.0	0.0	107.0	21.4	1.04		Mean	117.2	23.4	1.14	100.0	0.0
51	61	2343G	control	3		5		5	0	0.63	85.74	5	205.90	100.0	0.0	120.2	24.0	1.17		S.D.	7.4	1.5	0.07	0.0	0.0
52	66	2343G	control	4		5		5	0	0.63	90.61	5	204.13	100.0	0.0	113.5	22.7	1.10		n	5	5	5	5	5
53	21	2343G	control	5		5		5	0	0.63	84.02	5	210.54	100.0	0.0	126.5	25.3	1.23							
54	57	2343G	control	6	wq replicate	5	28.0																		
55	45	2344G	CR-01-SS-010	1		5		5	0	0.63	81.80	5	179.48	100.0	0.0	97.7	19.5	0.95							
56	23	2344G	CR-01-SS-010	2		5		5	0	0.63	87.99	5	189.48	100.0	0.0	101.5	20.3	0.98		Mean	83.8	16.8	0.81	100.0	0.0
57	25	2344G	CR-01-SS-010	3		5		5	0	0.63	82.99	5	154.12	100.0	0.0	71.1	14.2	0.68		S.D.	18.9	3.8	0.19	0.0	0.0
58	64	2344G	CR-01-SS-010	4		5		5	0	0.63	80.42	5	137.69	100.0	0.0	57.3	11.5	0.54		n	5	5	5	5	5
59	42	2344G	CR-01-SS-010	5		5		5	0	0.63	81.18	5	172.66	100.0	0.0	91.5	18.3	0.88							
60	56	2344G	CR-01-SS-010	6	wq replicate	5	28.0																		
61	63	2345G	CR-02-SS-010	1		5		5	0	0.63	83.45	5	195.06	100.0	0.0	111.6	22.3	1.08							
62	34	2345G	CR-02-SS-010	2		5		5	0	0.63	82.76	5	197.62	100.0	0.0	114.9	23.0	1.12		Mean	113.1	22.6	1.10	100.0	0.0
63	22	2345G	CR-02-SS-010	3		5		5	0	0.63	83.53	5	202.54	100.0	0.0	119.0	23.8	1.16		S.D.	6.3	1.3	0.06	0.0	0.0
64	13	2345G	CR-02-SS-010	4		5		5	0	0.63	85.22	5	202.24	100.0	0.0	117.0	23.4	1.14		n	5	5	5	5	5
65	19	2345G	CR-02-SS-010	5		5		5	0	0.63	99.67	5	202.58	100.0	0.0	102.9	20.6	1.00							
66	14	2345G	CR-02-SS-010	6	wq replicate	5	27.5																		

Mussel Larval Results

BKR=beaker number
INIT=number of inoculated embryos (from average of zero-time counts)
NORM=number normal
ABN=number abnormal
TOTAL=NORM+ABN
PMORT=percent mortality=100((INIT-TOTAL)/INIT)
PABN=percent abnormality=100(ABN/TOTAL)
PABND=combined percent mortality and abnormality=100((INIT-NORM)/INIT)
NPM=normalized percent mortality=100(1-(TOTAL/TS)),
where TS=average of total larvae counted in seawater controls
NCMA=normalized combined percent mortality and abnormality=100(1-(NORM/NS)),
where NS=average of normal larvae counted in seawater controls

zero counts	
a	267
b	251
c	263
d	273
e	268
Mean =	264

NS (mean normal)	TS (mean total)
264.4	271.6

%normal in SW cont relative to INIT
100.0

INDEX	BKR	NAS SMPL	CLIENT DESCRIP	REPL		INIT	NORM	ABN	TOTAL	PMORT	PABN	PABND	NPM	NCMA		NORM	PMORT	PABN	PABND	NPM	NCMA
1	51	swcontrol	swcontrol	1		264	275	7	282	-6.7	2.5	-4.0	-3.8	-4.0							
2	64	swcontrol	swcontrol	2		264	249	10	259	2.0	3.9	5.8	4.6	5.8	Mean	264.4	-2.7	2.7	0.0	0.0	0.0
3	41	swcontrol	swcontrol	3		264	280	4	284	-7.4	1.4	-5.9	-4.6	-5.9	S.D.	12.9	4.2	0.9	4.9	4.1	4.9
4	43	swcontrol	swcontrol	4		264	262	8	270	-2.1	3.0	0.9	0.6	0.9	n	5	5	5	5	5	5
5	48	swcontrol	swcontrol	5		264	256	7	263	0.5	2.7	3.2	3.2	3.2							
6	33	swcontrol	swcontrol	6	wq replicate	264															
7	40	2335G	WB-06-SS-010	1		264	220	3	223	15.7	1.3	16.8	17.9	16.8							
8	30	2335G	WB-06-SS-010	2		264	210	4	214	19.1	1.9	20.6	21.2	20.6	Mean	207.8	20.3	1.3	21.4	22.5	21.4
9	20	2335G	WB-06-SS-010	3		264	191	3	194	26.6	1.5	27.8	28.6	27.8	S.D.	10.8	4.1	0.5	4.1	3.9	4.1
10	8	2335G	WB-06-SS-010	4		264	213	1	214	19.1	0.5	19.4	21.2	19.4	n	5	5	5	5	5	5
11	57	2335G	WB-06-SS-010	5		264	205	3	208	21.3	1.4	22.5	23.4	22.5							
12	14	2335G	WB-06-SS-010	6	wq replicate	264															
13	52	2336G	WB-08-SS-010	1		264	192	9	201	24.0	4.5	27.4	26.0	27.4							
14	27	2336G	WB-08-SS-010	2		264	205	3	208	21.3	1.4	22.5	23.4	22.5	Mean	200.0	21.9	3.2	24.4	23.9	24.4
15	50	2336G	WB-08-SS-010	3		264	199	9	208	21.3	4.3	24.7	23.4	24.7	S.D.	8.1	3.2	1.4	3.0	3.1	3.0
16	37	2336G	WB-08-SS-010	4		264	193	4	197	25.5	2.0	27.0	27.5	27.0	n	5	5	5	5	5	5
17	63	2336G	WB-08-SS-010	5		264	211	8	219	17.2	3.7	20.2	19.4	20.2							

INDEX	BKR	NAS SMPL	CLIENT DESCRIP	REPL		INIT	NORM	ABN	TOTAL	PMORT	PABN	PABND	NPM	NCMA			NORM	PMORT	PABN	PABND	NPM	NCMA
18	13	2336G	WB-08-SS-010	6	wq replicate	264																
19	44	2337G	WB-18-SS-010	1		264	182	1	183	30.8	0.5	31.2	32.6	31.2								
20	4	2337G	WB-18-SS-010	2		264	125	3	128	51.6	2.3	52.7	52.9	52.7		Mean	157.0	39.3	2.2	40.6	40.9	40.6
21	2	2337G	WB-18-SS-010	3		264	138	4	142	46.3	2.8	47.8	47.7	47.8		S.D.	26.7	10.0	1.0	10.1	9.7	10.1
22	56	2337G	WB-18-SS-010	4		264	154	5	159	39.9	3.1	41.8	41.5	41.8		n	5	5	5	5	5	5
23	60	2337G	WB-18-SS-010	5		264	186	4	190	28.1	2.1	29.7	30.0	29.7								
24	25	2337G	WB-18-SS-010	6	wq replicate	264																
25	34	2338G	WB-28-SS-010	1		264	188	0	188	28.9	0.0	28.9	30.8	28.9								
26	49	2338G	WB-28-SS-010	2		264	150	3	153	42.1	2.0	43.3	43.7	43.3		Mean	187.4	27.1	2.6	29.1	29.0	29.1
27	15	2338G	WB-28-SS-010	3		264	197	13	210	20.6	6.2	25.5	22.7	25.5		S.D.	30.3	12.5	2.3	11.4	12.2	11.4
28	23	2338G	WB-28-SS-010	4		264	171	3	174	34.2	1.7	35.3	35.9	35.3		n	5	5	5	5	5	5
29	5	2338G	WB-28-SS-010	5		264	231	8	239	9.6	3.3	12.6	12.0	12.6								
30	29	2338G	WB-28-SS-010	6	wq replicate	264																
31	3	2339G	WB-30-SS-010	1		264	182	5	187	29.3	2.7	31.2	31.1	31.2								
32	16	2339G	WB-30-SS-010	2		264	157	10	167	36.8	6.0	40.6	38.5	40.6		Mean	183.8	28.1	3.7	30.5	30.0	30.5
33	24	2339G	WB-30-SS-010	3		264	193	2	195	26.2	1.0	27.0	28.2	27.0		S.D.	38.4	13.2	3.0	14.5	12.8	14.5
34	7	2339G	WB-30-SS-010	4		264	144	12	156	41.0	7.7	45.5	42.6	45.5		n	5	5	5	5	5	5
35	21	2339G	WB-30-SS-010	5		264	243	3	246	7.0	1.2	8.1	9.4	8.1								
36	66	2339G	WB-30-SS-010	6	wq replicate	264																
37	28	2340G	WB-31-SS-010	1		264	149	7	156	41.0	4.5	43.6	42.6	43.6								
38	46	2340G	WB-31-SS-010	2		264	132	3	135	48.9	2.2	50.1	50.3	50.1		Mean	160.6	38.2	1.8	39.3	39.8	39.3
39	18	2340G	WB-31-SS-010	3		264	182	2	184	30.4	1.1	31.2	32.3	31.2		S.D.	28.1	10.5	1.7	10.6	10.2	10.6
40	59	2340G	WB-31-SS-010	4		264	142	0	142	46.3	0.0	46.3	47.7	46.3		n	5	5	5	5	5	5
41	62	2340G	WB-31-SS-010	5		264	198	2	200	24.4	1.0	25.1	26.4	25.1								
42	65	2340G	WB-31-SS-010	6	wq replicate	264																
43	55	2341G	WB-35-SS-010	1		264	188	3	191	27.8	1.6	28.9	29.7	28.9								
44	32	2341G	WB-35-SS-010	2		264	182	1	183	30.8	0.5	31.2	32.6	31.2		Mean	187.6	28.4	0.8	29.0	30.3	29.0
45	35	2341G	WB-35-SS-010	3		264	183	2	185	30.0	1.1	30.8	31.9	30.8		S.D.	5.3	2.1	0.6	2.0	2.0	2.0
46	22	2341G	WB-35-SS-010	4		264	195	2	197	25.5	1.0	26.2	27.5	26.2		n	5	5	5	5	5	5
47	36	2341G	WB-35-SS-010	5		264	190	0	190	28.1	0.0	28.1	30.0	28.1								
48	26	2341G	WB-35-SS-010	6	wq replicate	264																
49	17	2342G	WB-38-SS-010	1		264	151	2	153	42.1	1.3	42.9	43.7	42.9								
50	11	2342G	WB-38-SS-010	2		264	197	1	198	25.1	0.5	25.5	27.1	25.5		Mean	181.4	30.9	0.8	31.4	32.7	31.4
51	38	2342G	WB-38-SS-010	3		264	186	1	187	29.3	0.5	29.7	31.1	29.7		S.D.	18.2	6.7	0.7	6.9	6.5	6.9
52	47	2342G	WB-38-SS-010	4		264	180	3	183	30.8	1.6	31.9	32.6	31.9		n	5	5	5	5	5	5
53	10	2342G	WB-38-SS-010	5		264	193	0	193	27.0	0.0	27.0	28.9	27.0								
54	39	2342G	WB-38-SS-010	6	wq replicate	264																
55	58	2344G	CR-01-SS-010	1		264	163	12	175	33.8	6.9	38.4	35.6	38.4								
56	6	2344G	CR-01-SS-010	2		264	170	5	175	33.8	2.9	35.7	35.6	35.7		Mean	170.4	32.5	4.5	35.6	34.3	35.6
57	45	2344G	CR-01-SS-010	3		264	172	10	182	31.2	5.5	34.9	33.0	34.9		S.D.	4.7	1.8	1.9	1.8	1.8	1.8

Test no. 782-3 Larval Sediment Test 4/7/2009

INDEX	BKR	NAS SMPL	CLIENT DESCRIP	REPL		INIT	NORM	ABN	TOTAL	PMORT	PABN	PABND	NPM	NCMA			NORM	PMORT	PABN	PABND	NPM	NCMA
58	31	2344G	CR-01-SS-010	4		264	176	9	185	30.0	4.9	33.4	31.9	33.4		n	5	5	5	5	5	5
59	53	2344G	CR-01-SS-010	5		264	171	4	175	33.8	2.3	35.3	35.6	35.3								
60	19	2344G	CR-01-SS-010	6	wq replicate	264																
61	9	2345G	CR-02-SS-010	1		264	280	5	285	-7.8	1.8	-5.9	-4.9	-5.9								
62	12	2345G	CR-02-SS-010	2		264	241	2	243	8.1	0.8	8.9	10.5	8.9		Mean	246.2	5.2	1.8	6.9	7.7	6.9
63	54	2345G	CR-02-SS-010	3		264	257	5	262	0.9	1.9	2.8	3.5	2.8		S.D.	23.3	8.8	0.7	8.8	8.6	8.8
64	61	2345G	CR-02-SS-010	4		264	219	6	225	14.9	2.7	17.2	17.2	17.2		n	5	5	5	5	5	5
65	1	2345G	CR-02-SS-010	5		264	234	4	238	10.0	1.7	11.5	12.4	11.5								
66	42	2345G	CR-02-SS-010	6	wq replicate	264																

APPENDIX B

HEA Model Details

Appendix B HEA Model Details

The primary tool used in the Woodard Bay aquatic restoration feasibility study (FS) to evaluate the ecological impacts and benefits of the proposed restoration actions was the Habitat Equivalency Analysis (HEA). This appendix describes the theoretical background of this analytical tool and summarizes the approach, methods, inputs, and results obtained for the FS.

1 HEA Background

HEA was developed by the National Oceanic and Atmospheric Administration (NOAA) (2000) to evaluate impacts in natural resource damage assessments (NRDAs) as allowed under the Comprehensive Environmental Response, Compensation, and Liability Act (also known as Superfund). In that context, HEA is used to quantify natural resource injuries and allows negotiating parties to agree on the scale of restoration.

HEA is principally a numeric model, with an injury component and a restoration component. Its equations and theoretical basis are described in detail by NOAA (2000) and are not repeated here. In the injury component of the model, ecological or human service[1] losses are estimated quantitatively for the potentially affected site (e.g., an oiled beach). The restoration component calculates the size of the restoration project needed to offset those losses, with benefits assigned to elements of each restoration action.

An important concept of HEA is the "baseline." For the purpose of assessing injury, baseline refers to the services provided at the impacted site under current conditions in the hypothetical absence of the hazardous substance release. In the restoration side of the model, baseline refers to services provided under current conditions but prior to any restoration actions. The concept of baseline acknowledges that services can be influenced by conditions unrelated to contamination. For example, habitat may be functioning poorly because of piers or riprap banks.

"Habitat value" is another important concept in HEA. NOAA first incorporated habitat value in the HEA model as part of settlement negotiations for the Hylebos Waterway in Tacoma, Washington (NOAA 2002). Earlier, the HEA model assumed that each acre of injured (or restored) habitat was equivalent. In reality, habitats have variable value, depending on many physical and biological factors. Services and habitat values are defined relative to a specific resource type, for example salmon habitat. Multiple

[1] The term used for injury quantification in HEA is "services," which refers to the functions provided by a natural resource. For example, an estuary provides ecological services such as food and shelter for animals, sediment stabilization, nutrient cycling, and primary production. It also provides human services such as recreational fishing and bird-watching.

resource types can be evaluated, but each calculation is typically undertaken independently.

The primary input variables for the injury side of the HEA model are the size of the injured habitat, value of the habitat, and services provided as a percentage of baseline conditions. Time is also a key input variable. Services may be different at the time of injury, at the start of restoration, and when the restored services have reached their potential.

The currency of the HEA model is discounted service acre years (dSAYs). A discount rate is applied to the "service acre year" portion of the calculation to reflect the greater weight in present-day terms of past injuries relative to future injuries. Taken from economic practice, this convention is akin to calculating the present and future values of money.

A single dSAY does not always define the same effect. For example, a single dSAY could be 1 acre of high-quality habitat that was completely devoid of services for a period of 1 year in the present or 4 acres of lower quality habitat that provided only half of its baseline services for the same time period. The two examples can be expressed mathematically as follows:

1 (acre) × 1 (relative habitat value) × 1 (100% service loss) × 1 (year) **Example 1**

4 (acres) × 0.5 (relative habitat value) × 0.5 (50% service loss) × 1 (year) **Example 2**

HEA model calculations are relatively straightforward, although the mathematics become slightly more complicated when discount rates are applied. A typical annual discount rate is 3%. If Example 1 included a 2-year period of service loss and a discount rate of 3%, the model result would be 1.97 to 2.03 dSAYs, depending on whether one of the years was in the future (1 dSAY + 0.97 dSAY) or the past (1.03 dSAY + 1 dSAY).

The input variables for the restoration side of the model are similar to those described above, with dSAY from the injury calculation included in the restoration calculation input and number of acres needed to compensate for the dSAY is the output.

2 MODELING APPROACH FOR FS

In an NRDA application, the dSAYs from the injury component of the model are used to establish the scale (and cost) of restoration actions. An alternative use, implemented for this FS, uses the HEA model to compare alternative restoration actions. In this mode, the results for a given restoration alternative are only meaningful relative to those for other restoration alternatives. Although this is not a traditional application of the HEA model, the theoretical basis of the model is well-suited to such a comparative analysis and has been used at other sites (Gala et al. 2008); Buchman et al. 2003).

For the FS, only the injury side of the model was used. The dSAYs generated for each of several restoration actions were compared, as were the dSAYs generated for various combinations of actions (i.e., alternatives), as discussed in Sections 7 and 8 of the FS.

2.1 Resource Types

As described in Section 1, the input data for the HEA model were typically based on one or a very small number of resource types. In HEA model applications for Pacific Northwest sites, the critical resource type is often salmon habitat. For the Woodard Bay Natural Resources Conservation Area (NRCA), however, multiple resource types are of high importance. The HEA model was used to evaluate natural resources identified in the Woodward Bay NRCA management plan (WDNR 2002), specifically the following:

- Bats – roosting and foraging/flyway areas were evaluated separately
- Seals – haulout and foraging areas were evaluated separately
- Olympia oyster
- Forage fish – spawning and foraging areas were evaluated separately
- Salmonids, primarily juvenile salmon
- Nearshore processes – sediment quality, water quality, and sediment transport were evaluated separately
- Benthic community
- Riparian vegetation
- Great blue heron
- Purple martin
- Shorebirds
- Waterfowl – spawning and foraging areas were evaluated separately

2.2 Restoration Actions

Several individual restoration actions were considered:

- Pier removal (mouth of Chapman Bay) – none, all, or part
- Fill removal (Chapman Bay Main Operational Area) – none or all
- Piling removal (North Operational Area, Main Operational Area, South Operational Area) – none, all, or part
- Seal haulout improvements – no action, maintain status quo with occasional repairs, or reconstruct haulout structure (as engineered floats) and maintain over time
- Trestle and trestle fill removal (mouth of Woodard Bay) – none, all, or part

- Woodard Bay bridge – no action, modification, or complete removal with reconstruction
- Riparian restoration (Weyer Point) – none, all, or part

In addition, No Action options were evaluated. Although No Action implies stasis, impacts occur because baseline conditions may decline naturally over time. Assumptions about changes associated with No Action options are further described in Section 3.4.

2.3 Model Scenarios

The effects of each individual restoration action were evaluated for each resource type prior to the identification of more comprehensive alternatives, yielding 742 scenarios that were initially evaluated with the HEA model. Many of the scenarios resulted in no effect to a specific resource, but the power of the comparative approach outlined here is only fully realized if all possible combinations of action and resource are evaluated.

3 Model Inputs

Inputs to the HEA model included the following:

- Areal extent of the potentially affected location
- Relative habitat value
- Duration (temporal milestones such as time to recovery, completion of a restoration action)
- Services

The specific values used in the model for each model input parameter are discussed below.

3.1 Areal Extent

The boundaries of the project area (as presented in the FS) defined the model's maximum value for areal extent, even though seals, bats, and bald eagles may range more widely. The primary reason for this constraint was to maintain comparability between resource types. Because the model output is highly sensitive to areal extent, it was not reasonable to include habitat beyond the project area for some resources and not for others, thereby overweighting results for the wide-ranging species.

Areas were established using geographic information system (GIS) tools and physical features such as elevation (or depth) and slope (Table 1). Habitat area use was based on available information from reconnaissance surveys, censuses, and field observations made by multiple parties.

Table 1. Areal extent of potential influence by resource type

Resource	Areal Extent Within the NRCA (ac)	Basis for Determination of Areal Extent
Bat – foraging/flyway	947	Although bats forage primarily over fresh water (most of this colony forages over Capitol Lake in Olympia based on radio tracking), all water and upland areas within the project area were included in the model to emphasize the overall importance of the ecosystem to the bats and their use of specific features of the site to travel to and from major feeding/roosting areas.
Bat – roosting	0.5	435-ft length × 50-ft width of current roosting area on Chapman Bay pier (includes a potential buffer area)
Olympia oyster	287	Although intertidal areas with hard substrates and freshwater influence are expected to be the primarily habitat, all intertidal and nearshore areas down to -20 ft MLLW were considered potential habitat.
Seal – foraging	544	All aquatic habitats within the project area are expected to be used by seals.
Seal – haulout	0.8	600-ft length × 30-ft buffer on either side
Nearshore processes (sediment quality, water quality, and sediment transport, except for pier removal)	149 (Zone 1) 221 (Zone 2) 121 (Zone 3) 15 (Zone 4) 38 (Zone 5)	The project area was divided into zones to reflect more localized spheres of influence: North Operational Area (Zone 1), Main Operational Area (Zone 2), South Operational Area (Zone 3), Woodard Bay lower basin between trestle and Woodard Bay Road bridge (Zone 4), and Woodard Bay upper basin above Woodard Bay Road bridge (Zone 5).
Riparian restoration	13 (total) 7 (partial)	Riparian and upland vegetation at Weyer Point will require restoration, including invasive species removal, following shoreline restoration actions that involve the use of heavy equipment; “total” area is equivalent to all of Weyer Point, “partial” area is only that portion of Weyer Point potentially affected by restoration actions around the trestle, Chapman Bay fill removal, and pier removal.
Sediment transport (pier removal only)	44 (Option 1) 38 (Option 2) 9 (Option 3)	Areas between pier and shoreline calculated for three different options of pier removal: 76% of total pier length (Option 1), 49% of total pier length (Option 2), 38% of total pier length (Option 3)
Great blue heron	530	All intertidal plus all upland area within the project area; intertidal area is primarily for foraging, while upland area is primarily for roosting
Purple martin	544	All aquatic area within the project area because of the location of artificial nest boxes on pilings and over-water foraging behavior
Forage fish – spawning	128	All intertidal habitats within the project area; primary forage fish modeled was Pacific herring, which spawns in intertidal zone.
Forage fish – foraging	544	All aquatic habitats within the project area
Juvenile salmonids	287	All intertidal/nearshore habitats down to -20 ft MLLW
Shorebirds	128	All intertidal habitats within the project area
Benthic community	544	All aquatic area (intertidal and subtidal) within the project area
Waterfowl – foraging	544	All aquatic habitats within the project area
Waterfowl – nesting	1.5	Primary waterfowl species modeled for this resource was pigeon guillemot, which nests primarily in shoreline bluffs.

Resource	Areal Extent Within the NRCA (ac)	Basis for Determination of Areal Extent
Bald eagle	947	All water and upland habitats within the project area; eagles may use all habitat for foraging or roosting.

MLLW – mean lower low water

3.2 Habitat Value

For the FS, the habitat value input in the HEA model establishes the relative importance of each resource. The weighting factors (i.e., habitat values) are based on priorities established by the Washington State Department of Natural Resources (WDNR) in the Woodard Bay NRCA Management Plan (WDNR 2002) and the management goals established by the WDNR staff and natural resource partners. The specific habitat values have no intrinsic meaning or units. They are meaningful only relative to other habitat values used in the same model run (Table 2).

Table 2. Habitat values by resource type

Resource	Habitat Value
Bat – foraging/flyways	1.00[a]
Bat – roosting	1.00
Olympia oyster	0.75
Seal – foraging	0.01
Seal – haulout	0.99
Sediment quality, water quality, and sediment transport	0.75
Riparian restoration	0.25
Great blue heron	0.50
Purple martin	0.50
Forage fish – spawning	0.75
Forage fish – foraging	0.05
Juvenile salmonids	0.75
Shorebirds	0.50
Benthic community	0.30
Waterfowl foraging	0.25
Waterfowl nesting	0.25
Bald eagle	0.30

[a] The Chapman Bay colony primarily forages at Capitol Lake in Olympia. A foraging value was included in the model to emphasize the overall importance of the Woodard Bay ecosystem for these species and their use of specific features to travel to and from major feeding/roosting areas.

3.3 Temporal Milestones

The HEA model includes multiple temporal milestones at which services may change (see Section 3.4). These milestones are typically related to specific actions, such as the action's beginning or completion. One additional milestone relates to the year in which the affected resource has recovered (or improved) to the maximum extent. The temporal milestones used in this HEA model are presented in Table 3. By convention, all start years for restoration actions are the same, as are all end years. In reality, different actions could occur in different years, but specific action timelines are not known at this time. The relative influence of this variable on model output is minor.

Table 3. Temporal milestones by resource type

Resource	Year	Basis for Determination of Temporal Milestones
All – baseline year	2009	By convention, baseline year was assumed to be present time.
All – start remediation year	2010	By convention, start and end remediation years were made equivalent for all restoration actions in the absence of an approved restoration timeline.
All – end remediation year	2011	
Bat – full function year	2012	Construction during non-breeding period was assumed to have maximum effect by following year.
Olympia oyster – full function year	2013	Oysters are 2 years old before spawning
Seal – full function year	2021	Model assumed creosote pilings would be replaced with steel pilings in 2020, achieving maximum effect by following year.
Sediment quality – full function year	2021	Assumed biologically active zone of 10 cm and sedimentation rate of 1 cm/yr; assumed a 10-yr period for full recovery.
Water quality – full function year	2013	Assumed sediment-water interface is no more than 2 cm thick and sedimentation rate is 1 cm/yr; assumed 2-yr period for full recovery.
Sediment transport – full function year	2043	Existing sediment transport regime was established over the decades that existing structures have been in place; the return to conditions that existed before structures were built will likely also take several decades. The model assumed the full function year was established the year before end of calculation year (2044).
Riparian restoration	2013	Assumed a 2-yr recovery period for establishment of replanted native species.
Great blue heron	2014	Based on assumed 3-yr period for full recovery of infaunal benthic community (primary prey base for other species).
Purple martin	2012	Construction during non-breeding period assumed to have maximum effect by following year.
Forage fish – spawning	2016	Assume a 5-yr period to return to equilibrium conditions.
Forage fish – foraging	2014	Based on assumed 3-yr period for full recovery of infaunal benthic community (primary prey base).
Juvenile salmonids	2014	Based on assumed 3-yr period for full recovery of infaunal benthic community (primary prey base).
Shorebirds	2012	Construction during non-breeding period was assumed to have maximum effect by following year.
Benthic community	2016	Assumed a v5-yr recovery, with emphasis on Olympia oyster rather than infaunal community.

Resource	Year	Basis for Determination of Temporal Milestones
Waterfowl – foraging	2012	Construction during a non-breeding period was assumed to have the maximum effect by following year.
Waterfowl – nesting	2012	Construction during a non-breeding period was assumed to have the maximum effect by following year.
Bald eagle	2012	Construction during a non-breeding period was assumed to have the maximum effect by following year.
All – end remediation year for No Action	2042	By convention, set 1 year from full function year for No Action.
All – full function year for No Action	2043	By convention, set 1 year from end of calculation year.
All – end of calculation year	2044	By convention; although services may be provided in perpetuity, model output for years greater than 35 yrs from present had little impact on model conclusions.

3.4 Services

Ecological service is the primary input variable used in the HEA model to document changes to resources from specific actions (or No Action). By convention, the baseline service level is set at 1. The value of 1 has no intrinsic meaning (or unit); it simply refers to existing conditions. Change to an ecological service is shown as a number greater than 1 if it represents an improvement relative to baseline, or less than 1 if it represents a decline. To the extent possible, the changes in ecological services were based on quantifiable metrics; in some cases, they were based on best professional judgment. The best professional judgment was influenced by a preliminary sensitivity analysis (results not shown) that indicated how model results varied with changes to services.

A total of 742 modeled restoration scenarios were evaluated in the HEA model. For most scenarios, services remained at 1 for each temporal milestone, indicating neither beneficial nor detrimental effect for that combination of resource and action. Table 4 documents the ecological service changes for model scenarios with predicted effects.

Table 4. Services by resource type and restoration action

Restoration Action	Services			Basis for Service Value
	End Restoration Year	Full Function Year	End Calculation Year	
Bald Eagle				
Chapman fill removal	1	1.000512	1.000512	Incremental increase in intertidal surface area; additional area assumed to be 50% more valuable than habitat it replaces.
Pier removal 1 – 76%	1.001244	1.001244	1.001244	Increased overwater habitat
Pier removal 2 – 49%	1.000802	1.000802	1.000802	Increased overwater habitat
Pier removal 3 – 38%	1.000622	1.000622	1.000622	Increased overwater habitat
Bat – Foraging/Flyway				
Pier removal 1 – 76%	0.999930	0.999930	0.999930	Removal of part of flyway represents a 5% service loss in the area around the pier (575 ft in length x 100 ft in width).
Pier removal 2 – 49%	0.999930	0.999930	0.999930	Removal of part of flyway represents a 5% service loss in the area around the pier (575 ft in length x 100 ft in width).
Pier removal 3 –38%	0.999964	0.999964	0.999964	Removal of part of flyway represents a 5% service loss in the area around the pier (300 ft in length x 100 ft in width).
Bat – Roosting				
Pier removal – no action	1	0.866667	0.866667	2 of 15 spans are damaged and will continue to deteriorate.
Pier removal 1 – 76%	1	0.866667	0.866667	2 of 15 spans are damaged and will continue to deteriorate.
Pier removal 2 – 49%	1	0.866667	0.866667	2 of 15 spans are damaged and will continue to deteriorate.
Pier removal 3 – 38%	1	0.866667	0.866667	2 of 15 spans are damaged and will continue to deteriorate.
Trestle and fill removal (all fill)	0.99	0.99	0.99	Assume 10% of population uses trestle 10% of the time = 1%
Trestle and fill removal (south side only)	0.99	0.99	0.99	Assume 10% of population uses trestle 10% of the time = 1%
Trestle removal only (no fill removal)	0.99	0.99	0.99	Assume 10% of population uses trestle 10% of the time = 1%
Benthic Invertebrates				
Chapman fill removal	1	1.001782	1.001782	Incremental increase in intertidal surface area
Pier removal – no action	1	0.999236	0.999236	Decaying timbers continue to fall in water, releasing creosote adjacent to pier; assume 25% of pilings fall apart.

Table 4. Services by resource type and restoration action (cont.)

Restoration Action	Services			Basis for Service Value
	End Restoration Year	Full Function Year	End Calculation Year	
Pier removal 1 – 76%	0.992677	1.004646	1.004646	Assume halo around each piling relative to total area; assume 2 x premium for sediment quality improvement upon full function; short-term increase in smothering from increased sediment transport (0.5% decline)
Pier removal 2 – 49%	0.993502	1.002996	1.002996	Assume halo around each piling relative to total area; assume 2 x premium for sediment quality improvement upon full function; short-term increase in smothering from increased sediment transport (0.5% decline)
Pier removal 3 – 38%	0.993838	1.002323	1.002323	Assume halo around each piling relative to total area; assume 2 x premium for sediment quality improvement upon full function; short-term increase in smothering from increased sediment transport (0.5%)
Piling removal (Zone 2) – 90%	0.999000	1	1	Short-term increase in smothering (0.1%)
Trestle and fill removal (all fill)	1	1.001449	1.001449	Incremental increase in intertidal surface area
Trestle and fill removal (south side only)	1	1.000725	1.000725	Incremental increase in intertidal surface area
Woodard bridge partial removal/ reconstruction	0.995	1.000077	1.000077	Increased intertidal habitat; assume 0.5% decline over short-term (smothering)
Woodard bridge complete removal/ reconstruction	0.995	1.000155	1.000155	Increased intertidal habitat; assume 0.5% decline over short-term (smothering)
Forage Fish – Foraging				
Chapman fill removal	1	1.000891	1.000891	Incremental increase in intertidal surface area, assuming 50% of fill area becomes intertidal
Seal haulout– no action	1	1.005	1.005	Decreased predation from relocated seal population; 0.5% increase
Trestle and fill removal (all fill)	1	1.001449	1.001449	Incremental increase in intertidal surface area
Trestle and fill removal (south side only)	1	1.000725	1.000725	Incremental increase in intertidal surface area
Forage Fish – Spawning				
Chapman fill removal	1	1.003802	1.003802	Incremental increase in intertidal surface area, assuming 50% of fill area becomes intertidal
Pier removal 1 – 76%	1	1.001881	1.001881	Increased intertidal foraging habitat
Pier removal 2 – 49%	1	1.000922	1.000922	Increased intertidal foraging habitat
Pier removal 3 – 38%	1	1.000715	1.000715	Increased intertidal foraging habitat
Seal haulout – no action	1	1.005	1.005	Decreased predation from relocated seal population; 0.5% increase
Trestle and fill removal (all fill)	1	1.006184	1.006184	Incremental increase in intertidal surface area

Table 4. Services by resource type and restoration action (cont.)

Restoration Action	Services: End Restoration Year	Services: Full Function Year	Services: End Calculation Year	Basis for Service Value
Trestle and fill removal (south side only)	1	1.003092	1.003092	Incremental increase in intertidal surface area
Heron				
Chapman fill removal	1	1.002289	1.002289	Incremental increase in intertidal surface area, assuming 50% of fill area becomes intertidal; 5x weighting on intertidal habitat; new habitat provides 50% service benefit compared to existing habitat
Pier removal 1 – 76%	1	1.001033	1.001033	Increased intertidal foraging habitat (weighted intertidal by 3 x)
Pier removal 2 – 49%	1	1.000666	1.000666	Increased intertidal foraging habitat (weighted intertidal by 3 x)
Pier removal 3 – 38%	1	1.000516	1.000516	Increased intertidal foraging habitat (weighted intertidal by 3 x)
Juvenile Salmonids				
Chapman fill removal	1	1.003381	1.003381	Incremental increase in intertidal surface area (Chapman fill plus salmon area); 2 x weighting on intertidal habitat
Pier removal 1 – 76%	1	1.000636	1.000636	Removed shading in intertidal, improved benthic habitat in intertidal
Pier removal 2 – 49%	1	1.000410	1.000410	Removed shading in intertidal, improved benthic habitat in intertidal
Pier removal 3– 38%	1	1.000318	1.000318	Removed shading in intertidal, improved benthic habitat in intertidal
Seal haulout – no action	1	1.001	1.001	Decreased predation from relocated seal population; 0.1% increase
Trestle and fill removal – no action	1	0.995	0.995	Fish entrapment; assume 0.5% decline at full function
Trestle and fill removal (all fill)	1	1.012750	1.012750	Incremental increase in intertidal surface area, reduced entrapment + increased LWD transport (1% increase)
Trestle and fill removal (south side only)	1	1.006375	1.006375	Incremental increase in intertidal surface area, reduced entrapment + increased LWD transport (0.5% increase)
Woodard bridge – no action	1	0.99	0.99	Increased fish entrapment; assume 1% decline
Woodard bridge partial removal/ reconstruction	0.995	1.000147	1.000147	Increased intertidal habitat; assume 0.5% decline over short term (increased turbidity with increased sediment transport)
Woodard bridge complete removal/ reconstruction	0.995	1.000294	1.000294	Increased intertidal habitat; assume 0.5% decline over short term (increased turbidity with increased sediment transport)
Oyster				
Chapman fill removal	1	1.003381	1.003381	Incremental increase in intertidal surface area (Chapman fill plus oyster area); 2 x weighting on intertidal habitat
Trestle and fill removal (all fill)	0.98	1.002750	1.002750	Incremental increase in intertidal surface area, but increased sedimentation (short-term impact, assume 2% decline)

Table 4. Services by resource type and restoration action (cont.)

Restoration Action	Services			Basis for Service Value
	End Restoration Year	Full Function Year	End Calculation Year	
Trestle and fill removal (south side only)	0.99	1.001375	1.001375	Incremental increase in intertidal surface area, but increased sedimentation (short-term impact, assume 1% decline)
Trestle removal only (no fill removal)	0.99	1.002750	1.002750	Incremental increase in intertidal surface area, but increased sedimentation (short-term impact, assume 1% decline)
Woodard bridge partial removal/reconstruction	0.995	1.000147	1.000147	Increased intertidal habitat; assume 0.5% decline over short term (smothering)
Woodard bridge complete removal /reconstruction	0.995	1.000294	1.000294	Increased intertidal habitat; assume 0.5% decline over short term (smothering)
Riparian Vegetation				
Chapman fill removal	0.975	1	1	Short-term damage from equipment, long-term improvement back to baseline through natural regrowth (10% area affected - 25% decline)
Pier removal 1 – 76%	0.9375	1	1	Short-term damage from equipment, long-term improvement back to baseline through natural regrowth (25% area affected - 25% decline)
Pier removal 2 – 49%	0.95	1	1	Short-term damage from equipment, long-term improvement back to baseline through natural regrowth (20% area affected - 25% decline)
Pier removal 3 – 38%	0.9625	1	1	Short-term damage from equipment, long-term improvement back to baseline through natural regrowth (15% area affected - 25% decline)
Riparian restoration – no action	1	0.9	0.9	Increasing growth of invasive species, 10% loss in habitat value over time
Riparian restoration – Weyer Point	1	1.1	1.1	Remove invasive species, revegetate with native species, 10% increase in habitat value
Riparian restoration – Weyer Point (partial)	1	1.1	1.1	Remove invasive species, revegetate with native species, 10% increase in habitat value
Trestle and fill removal (all fill)	0.9250	1	1	Short-term damage from equipment, long-term improvement back to baseline through natural regrowth (30% area affected - 25% decline)
Trestle and fill removal (south side only)	0.9375	1	1	Short-term damage from equipment, long-term improvement back to baseline through natural regrowth (25% area affected - 25% decline)
Trestle removal only (no fill removal)	0.9500	1	1	Short-term damage from equipment, long-term improvement back to baseline through natural regrowth (20% area affected - 25% decline)
Seal – Foraging				
Chapman fill removal	1	1.002061	1.002061	Increase due to increase in forage fish and salmonids - average services for those two resources
Pier removal 1 – 76%	1	1	1	Increase due to increase in forage fish and salmonids – average services for those two resources

Table 4. Services by resource type and restoration action (cont.)

Restoration Action	Services			Basis for Service Value
	End Restoration Year	Full Function Year	End Calculation Year	
Pier removal 2 – 49%	1	1	1	Increase due to increase in forage fish and salmonids – average services for those two resources
Pier removal 3 – 38%	1	1.000763	1.000763	Increase due to increase in forage fish and salmonids – average services for those two resources
Seal haulout – no action	1	0.95	0.95	Increased energy expenditure for foraging with loss of haulout; assume 5% decline in services
Trestle and fill removal (all fill)	1	1	1	Increase due to increase in forage fish and salmonids – average services for those two resources
Trestle and fill removal (south side only)	1	1	1	Increase due to increase in forage fish and salmonids – average services for those two resources
Seal – Haulout				
Seal haulout – no action	1	0	0	All haulout services will be lost once existing haulout falls apart.
Seal haulout – status quo with enhancement	1.05	1.05	1.05	New haulout platforms provide 5% service increase.
Sediment Quality – Zone 1				
Piling removal (Zone 1) – 100%	0.999877	1.000246	1.000246	Assume halo around each piling relative to total area; assume 2x premium for sediment quality improvement upon full function
Piling removal (Zone 1) – no action	1	0.999961	0.999961	Decaying timbers continue to fall in water, releasing creosote adjacent to pier; assume 25% of pilings fall apart.
Sediment Quality – Zone 2				
Pier removal – no action	1	0.999236	0.999236	Decaying timbers continue to fall in water, releasing creosote adjacent to pier; assume 25% of pilings fall apart.
Pier removal 1 – 76%	0.997677	1.004646	1.004646	Assume halo around each piling relative to total area; assume 2 x premium for sediment quality improvement upon full function
Pier removal 2 – 49%	0.998502	1.002996	1.002996	Assume halo around each piling relative to total area; assume 2 x premium for sediment quality improvement upon full function
Pier removal 3 – 38%	0.998838	1.002323	1.002323	Assume halo around each piling relative to total area; assume 2 x premium for sediment quality improvement upon full function
Piling removal (Zone 2) – 90%	0.999335	1.001330	1.001330	Assume halo around each piling relative to total area; assume 2 x premium for sediment quality improvement upon full function
Piling removal (Zone 2) – no action	1	0.999792	0.999792	Decaying timbers continue to fall in water, releasing creosote adjacent to pier; assume 25% of pilings fall apart.

Table 4. Services by resource type and restoration action (cont.)

Restoration Action	Services			Basis for Service Value
	End Restoration Year	Full Function Year	End Calculation Year	
Seal haulout - status quo with enhancement	0.999918	1.000163	1.000163	Assume halo around each piling relative to total area; assume 2 x premium for sediment quality improvement upon full function
Sediment Quality – Zone 3				
Piling removal (Zone 3) – 100%	0.99981	1.000380	1.000380	Assume halo around each piling relative to total area; assume 2 x premium for sediment quality improvement upon full function
Piling removal (Zone 3) – no action	1	0.999952	0.999952	Decaying timbers continue to fall in water, releasing creosote adjacent to pier; assume 25% of pilings fall apart.
Sediment Quality – Zone 4				
Trestle removal only (no fill removal)	0.946869	1.106263	1.106263	Halo effect, using whole area of trestle rather than pilings
Sediment Transport – Zone 1				
Piling removal (Zone 1) – 100%	1.002	1.002	1.002	Slight increase in sediment transport, restoring natural processes; effects on other target resources captured elsewhere
Piling removal (Zone 1) – no action	1	0.999320	0.999320	Steadily worsening restriction of "natural" sediment transport from piling presence; scaled to service impact from under-pier pilings using piling ratio
Sediment Transport – Zone 2				
Chapman fill removal	0.99	1.026318	1.026318	Slight decrease in shoreline/water interface (impact, 2 x weight to area of fill removal); short-term increase in sedimentation (impact, 1% decline); increase in incremental increase in intertidal surface area (benefit, 3 x weight to area of fill removal); removal of armored bank (benefit, 5 x weight to area of fill removal); aggregate 6 x weight (-2 + 3 + 5) over long term
Pier removal – no action	1	0.98	0.98	Steadily worsening restriction of "natural" sediment transport from piling presence
Pier removal 1 – 76%	1	2	2	Over affected area, service value doubles over long term.
Pier removal 2 – 49%	1	2	2	Over affected area, service value doubles over long term.
Pier removal 3 – 38%	1	2	2	Over affected area, service value doubles over long term.
Piling removal (Zone 2) – 90%	1.01	1.01	1.01	Slight increase in sediment transport, restoring natural processes; effects on other target resources captured elsewhere
Piling removal (Zone 2) –- no action	1	0.994560	0.994560	Steadily worsening restriction of "natural" sediment transport from piling presence; scaled to service impact from under-pier pilings using piling ratio
Sediment Transport – Zone 3				
Piling removal (Zone 3) – 100%	1.003	1.003	1.003	Slight increase in sediment transport, restoring natural processes; effects on other target resources captured elsewhere

Table 4. Services by resource type and restoration action (cont.)

Restoration Action	Services			Basis for Service Value
	End Restoration Year	Full Function Year	End Calculation Year	
Piling removal (Zone 3) – no action	1	0.999320	0.999320	Steadily worsening restriction of "natural" sediment transport from piling presence; scaled to service impact from under-pier pilings using piling ratio
Trestle and fill removal (all fill)	1.006529	1.006529	1.006529	Incremental increase in intertidal surface area.
Trestle and fill removal (south side only)	1.003265	1.003265	1.003265	Incremental increase in intertidal surface area.
Sediment Transport – Zone 4				
Trestle and fill removal – no action	1	0.98	0.98	Steadily worsening sediment transport function; assume 2% decline at full function
Trestle and fill removal (all fill)	1.02	1.02	1.02	Increased flushing of Zone 4; increase potential by 2%
Trestle and fill removal (south side only)	1.01	1.01	1.01	Increased flushing of Zone 4; increase potential by 1%
Trestle removal only (no fill removal)	1.005	1.005	1.005	Increased flushing of Zone 4; increase potential by 0.5%
Sediment Transport – Zone 5				
Woodard bridge removal/ reconstruction	1.01	1.01	1.01	Increased flushing by 1%
Woodard bridge removal/ reconstruction	1.02	1.02	1.02	Increased flushing by 2%
Shorebirds				
Chapman fill removal	1	1.007603	1.007603	Incremental increase in intertidal surface area
Pier removal 1 – 76%	0.999377	1.001247	1.001247	Foraging quality slight decrease initially, then increase at full function, using halo percentage
Pier removal 2 – 49%	0.999598	1.000804	1.000804	Foraging quality slight decrease initially, then increase at full function, using halo percentage
Pier removal 3 – 38%	0.999688	1.000623	1.000623	Foraging quality slight decrease initially, then increase at full function, using halo percentage
Trestle and fill removal (all fill)	1	1.011184	1.011184	Incremental increase in intertidal surface area+increased transport of LWD (0.5% increase)

Table 4. Services by resource type and restoration action (cont.)

Restoration Action	Services			Basis for Service Value
	End Restoration Year	Full Function Year	End Calculation Year	
Trestle and fill removal (south side only)	1	1.008092	1.008092	Incremental increase in intertidal surface area+increased transport of LWD (0.5% increase)
Trestle removal only (no fill removal)	1.006184	1.006184	1.006184	Incremental increase in intertidal surface area
Woodard bridge partial removal/ reconstruction	1.00033	1.00033	1.00033	Increased intertidal habitat
Woodard bridge complete removal/ reconstruction	1.000661	1.000661	1.000661	Increased intertidal habitat
Water Quality – Zone 1				
Chapman fill removal	0.995	1	1	Very slight short-term decrease in water quality (0.5%)
Piling removal (Zone 1) – 100%	0.980162	1	1	Assume 300-ft water quality compliance boundary around each piling relative to total area, then apply 20% service loss to that affected portion, improving back to baseline.
Piling removal (Zone 1) – no action	1	0.993801	0.993801	Decaying timbers continue to fall in water, releasing creosote to water near pier; assume 25% of pilings fall apart and 20% service loss for affected water quality area.
Water Quality – Zone 2				
Chapman fill removal	0.99	1	1	Short-term increase in turbidity
Pier removal – no action	1	0.991024	0.991024	Decaying timbers continue to fall in water, releasing creosote to water near pier; assume 25% of pilings fall apart and 20% service loss for affected water quality area.
Pier removal 1 – 76%	0.972712	1	1	Assume 300-ft water quality compliance boundary around each piling relative to total area, then apply 20% service loss to that affected portion, improving back to baseline.
Pier removal 2 – 49%	0.991203	1	1	Assume 300-ft water quality compliance boundary around each piling relative to total area, then apply 20% service loss to that affected portion, improving back to baseline.
Pier removal 3 – 38%	0.993178	1	1	Assume 300-ft water quality compliance boundary around each piling relative to total area, then apply 20% service loss to that affected portion, improving back to baseline.
Piling removal (Zone 2) – 90%	0.971276	1	1	Assume 300-ft water quality compliance boundary around each piling relative to total area, then apply 20% service loss to that affected portion, improving back to baseline.

Table 4. Services by resource type and restoration action (cont.)

Restoration Action	Services			Basis for Service Value
	End Restoration Year	Full Function Year	End Calculation Year	
Piling removal (Zone 2) – no action	1	0.991024	0.991024	Decaying timbers continue to fall in water, releasing creosote to water near pier; assume 25% of pilings fall apart and 20% service loss for affected water quality area.
Water Quality – Zone 3				
Chapman fill removal	0.995	1	1	Very slight short-term decrease in water quality (0.5%)
Piling removal (Zone 3) – 100%	0.960776	1	1	Assume 300-ft water quality compliance boundary around each piling relative to total area, then apply 20% service loss to that affected portion, improving back to baseline
Piling removal (Zone 3) – no action	1	0.980388	0.980388	Decaying timbers continue to fall in water, releasing creosote to water near pier; assume 25% of pilings fall apart and 20% service loss for affected water quality area
Trestle removal only (no fill removal)	0.967354	1	1	Assume 300-ft water quality compliance boundary around each piling relative to total area, then apply 20% service loss to that affected portion, improving back to baseline; assume 5x time trestle area for affected area
Waterfowl Foraging				
Chapman fill removal	1	1.001782	1.001782	Incremental increase in intertidal surface area
Pier removal 1 – 76%	0.999604	0.999604	0.999604	Reduced under-pier forage area (10% impact in that area) + increase disturbance potential from increased boater access; 79 days (Fri-Sat-Sun) in spring-fall seasons; assume motor boat traffic on 2/3 of those days, each associated with 1% service decline for 1 hr = 0.018% decline)
Pier removal 2 – 49%	0.999680	0.999680	0.999680	Reduced under-pier forage area (10% impact in that area) + increase disturbance potential from increased boater access; 79 days (Fri-Sat-Sun) in spring-fall seasons; assume motor boat traffic on 2/3 of those days, each associated with 1% service decline for 1 hr = 0.018% decline)
Pier removal 3 – 38%	0.999712	0.999712	0.999712	Reduced under-pier forage area (10% impact in that area) + increase disturbance potential from increased boater access; 79 days (Fri-Sat-Sun) in spring-fall seasons; assume motor boat traffic on 2/3 of those days, each associated with 1% service decline for 1 hr = 0.018% decline)
Piling removal (Zone 1) – 100%	0.999908	0.999908	0.999908	Reduced under-pier forage area (5% impact in that area) + increase disturbance potential from increased boater access; 79 days (Fri-Sat-Sun) in spring-fall seasons; assume motor boat traffic on 1/3 of those days, each associated with 1% service decline for 1 hr = 0.009% decline)

Table 4. Services by resource type and restoration action (cont.)

Restoration Action	Services			Basis for Service Value
	End Restoration Year	Full Function Year	End Calculation Year	
Piling removal (Zone 2) – 90%	0.999893	0.999893	0.999893	Reduced under-pier forage area (5% impact in that area) + increase disturbance potential from increased boater access; 79 days (Fri-Sat-Sun) in spring-fall seasons; assume motor boat traffic on 1/3 of those days, each associated with 1% service decline for 1 hr = 0.009% decline)
Piling removal (Zone 3) – 100%	0.999908	0.999908	0.999908	Reduced under-pier forage area (5% impact in that area) + increase disturbance potential from increased boater access; 79 days (Friday, Saturday, and Sunday) in spring-fall seasons; assume motor boat traffic on 1/3 of those days, each associated with 1% service decline for 1 hr = 0.009% decline)
Trestle and fill removal (all fill)	1	1.006269	1.006269	Incremental increase in intertidal surface area + increased transport of large woody debris (0.5% increase in services) + slight increase in disturbance potential from increased boater access (assume 0.018% as in pier removal alternatives)
Trestle and fill removal (south side only)	1	1.005545	1.005545	Incremental increase in intertidal surface area + increased transport of large woody debris (0.5% increase in services) + slight increase in disturbance potential from increased boater access (assume 0.018% as in pier removal alternatives)
Woodard bridge partial removal/reconstruction	1.000077	1.000077	1.000077	Increased intertidal habitat, removed overwater structure
Woodard bridge complete removal/reconstruction	1.000155	1.000155	1.000155	Increased intertidal habitat, removed overwater structure

LWD – large woody debris

In some scenarios, changes to specific habitat within the larger areal extent for a given resource was weighted more heavily,[2] reflecting the critical nature of that habitat for a specific restoration target. For example, changes to intertidal foraging habitat likely affect great blue heron more significantly than do changes to subtidal habitat, so the intertidal area was weighted by a factor of 5 in some model scenarios.

Some of the restoration actions increase the available intertidal habitat, which benefits many of the resources that use such habitat. The service calculations in these scenarios were based on a ratio of the future intertidal habitat area (after restoration) to the current intertidal habitat area.

3.5 Miscellaneous Input Values

Several miscellaneous input values for the HEA model are described here. Service changes between each temporal milestone described in Table 3 occurred incrementally over each year. By default, the change per year was assumed to be linear. The discount rate used in the model was 3%.

Several miscellaneous areas were used in the service calculations shown in Table 4. These miscellaneous areas, most of which were calculated using GIS, are presented in Table 5.

Table 5. Miscellaneous areas used in service calculations

Area	Value (acres)	Notes
Chapman fill area	0.97	
Area under pier – total	1.55	
Area under pier – subtidal	1.31	
Area under pier – intertidal	0.24	
Area under trestle	0.789	
Area under Woodard Bay bridge	0.0843	
Area under Woodard Bay bridge – partial removal alternative	0.0421	assume half the area to be removed
Area of sediment quality influence per piling	0.000451	2.5-ft radial sphere of influence = 19.63 sq ft/piling
Area of water quality influence for piling removal – North Operational Area	18.5	300-ft buffer around piling area
Area of water quality influence for piling removal – Main Operational Area	39.7	300-ft buffer around piling area
Area of water quality influence for piling removal – South Operational Area	47.4	300-ft buffer around piling area

[2] Weighting factors ranged from 2 to 6 for various resources in the HEA model. See Table 4 for target-specific factors.

Table 6 presents other miscellaneous input values.

Table 6. Other miscellaneous HEA input values

Input Parameter	Input Value
Number of pilings under piers	1,500
Number of pilings outside piers	510
Number of pilings in North Operational Area	51
Number of pilings in Main Operational Area	408
Number of pilings in South Operation Area	51
Number of pilings associated with seal haulouts to be replaced	40
Chapman Bay shoreline length (ft)	14,717
Chapman fill removal length (ft)	548

4 MODEL RESULTS

The model results are presented in Table 7. A discussion of the model results and the manner in which the different actions are combined into restoration alternatives is presented in Sections 7 and 8 of the FS.

Table 7. HEA model results

Restoration Action	HEA Results by Restoration Target																			
	Bald Eagle	Forage Fish – Foraging	Forage Fish – Spawning	Heron	Juvenile Salmonids	Oyster	Purple Martin	Shorebirds	Seal – Foraging	Seal – Haulout	Bat – Foraging/Flyway	Bat – Roosting	Waterfowl – Foraging	Waterfowl – Nesting	Benthic	Riparian	Sediment Quality	Water Quality	Sediment Transport	Grand Total
Chapman fill removal	4.4	0.7	9.8	18.0	21.6	21.9	0.0	14.8	0.4	0.0	0.0	0.0	7.4	0.0	7.0	-0.1	0.0	-0.2	4.6	110.1
Chapman fill removal – no action	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pier removal 1 – 76%[b, c]	11.1	0.0	4.8	8.1	4.1	0.0	0.0	2.4	0.1	0.0	-2.1	-1.3	-1.7	0.0	6.3	-0.3	1.3	-0.4	44.0	76.5
Pier removal 2 – 49%[b, c]	7.2	0.0	2.4	5.2	2.6	0.0	0.0	1.5	0.1	0.0	-2.1	-1.3	-1.4	0.0	3.8	-0.2	0.8	-0.1	38.0	56.5
Pier removal 3 – 38%[b, c]	5.6	0.0	1.8	4.1	2.0	0.0	0.0	1.2	0.1	0.0	-1.1	-1.3	-1.2	0.0	2.8	-0.2	0.6	-0.1	9.0	23.2
Pier removal – no action[a]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.8	0.0	0.0	-0.5	0.0	-0.1	-1.2	-2.7	-5.3
Piling removal (Zone 1) – 100%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.4	0.0	0.0	0.0	0.0	-0.2	0.5	-0.1
Piling removal (Zone 1) – no action	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.6	-0.1	-0.6
Piling removal (Zone 2) – 90%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.5	0.0	-0.1	0.0	0.4	-0.4	3.5	2.8
Piling removal (Zone 2) – no action	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.2	-0.7	-2.0
Piling removal (Zone 3) – 100%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.4	0.0	0.0	0.0	0.1	-0.3	0.6	-0.1
Piling removal (Zone 3) – no action	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.4	-0.1	-1.5
Riparian restoration – Weyer Point (all)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.7	0.0	0.0	0.0	9.7
Riparian restoration – Weyer (partial)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.2	0.0	0.0	0.0	5.2
Riparian restoration – no action	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-3.9	0.0	0.0	0.0	-3.9

Restoration Action	HEA Results by Restoration Target																			
	Bald Eagle	Forage Fish – Foraging	Forage Fish – Spawning	Heron	Juvenile Salmonids	Oyster	Purple Martin	Shorebirds	Seal – Foraging	Seal – Haulout	Bat – Foraging/Flyway	Bat – Roosting	Waterfowl – Foraging	Waterfowl – Nesting	Benthic	Riparian	Sediment Quality	Water Quality	Sediment Transport	Grand Total
Seal haulout – status quo with enhancement	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**1.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**1.0**
Seal haulout – no action[d]	0.0	**4.0**	**13.0**	0.0	**6.3**	0.0	0.0	0.0	**-7.9**	**-22**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**-6.9**
Trestle and fill removal (south and north side)	0.0	**0.8**	**11.1**	0.0	**54.9**	**-37.2**	0.0	**14.3**	**1.1**	0.0	0.0	**-0.2**	**17.1**	0.0	**5.7**	**-0.3**	0.0	0.0	**1.7**	**68.9**
Trestle and fill removal (south side only)	0.0	**0.4**	**5.5**	0.0	**27.5**	**-18.6**	0.0	**10.3**	**0.6**	0.0	0.0	**-0.2**	**15.1**	0.0	**2.8**	**-0.3**	0.0	0.0	**0.9**	**44.0**
Trestle removal only – no fill removal	0.0	0.0	0.0	0.0	0.0	**14.9**	0.0	**12.4**	0.0	0.0	0.0	**-0.2**	0.0	0.0	0.0	**-0.3**	**1.9**	**-0.3**	**0.1**	**28.5**
Trestle and fill removal – no action	0.0	0.0	0.0	0.0	**-13.1**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**-0.2**	**-13.3**
Woodard bridge partial removal/reconstruction	0.0	0.0	0.0	0.0	**-1.0**	**-0.5**	0.0	**-0.7**	0.0	0.0	0.0	0.0	**0.3**	0.0	**-1.5**	0.0	0.0	0.0	**0.6**	**-1.4**
Woodard bridge complete removal/reconstruction	0.0	0.0	0.0	0.0	**-0.1**	**0.4**	0.0	**1.3**	0.0	0.0	0.0	0.0	**0.7**	0.0	**-1.2**	0.0	0.0	0.0	**1.2**	**2.4**
Woodard bridge – no action	0.0	0.0	0.0	0.0	**-26.3**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**-26.3**

Note: Positive numbers reflect a positive impact; negative numbers reflect an adverse impact.

[a] There is an assumed loss in bat roost quality and sediment and water quality over time as the pier structure deteriorates under the No Action alternative.
[b] Some impacts to bats (based on reductions in pier flyway length) and waterfowl foraging are anticipated with the removal of any pier sections.
[c] Bat habitat is repaired and maintained under all action alternatives.
[d] The No Action alternative for seal haulout assumes the deterioration of haulout areas over time.

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APPENDIX C

Sitts & Hill Cost Estimates

BUDGETARY CONSTRUCTION COST ESTIMATE
WOODARD BAY RESTORATION ALTERNATIVES

WOODARD BAY NATURAL RESOURCES
CONSERVATION AREA

HENDERSON INLET
Near Olympia, WA

PREPARED FOR

WINDWARD ENVIRONMENTAL

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September 14th, 2009

S&H JOB Number 14127

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1 INTRODUCTION

1.1 Background

This report presents budgetary construction cost estimates for four Woodard Bay restoration alternatives. The work was completed as a component of a feasibility study for the Washington Department of Natural Resources (WDNR) for the aquatic portions of the Woodard Bay Natural Resources Conservation Area in Henderson Inlet of the Puget Sound near Olympia, WA.

The overall goal of the feasibility study was to develop and evaluate alternatives for restoring, enhancing, and protecting the aquatic ecosystem structure, functions, and processes that support native species and wildlife communities. To this end, Windward Environmental, working with WDNR and other stakeholders, developed four alternatives. These restoration actions focused primarily on the removal of anthropogenic structures (piers, trestles, piling, and earth fills) to differing degrees, as well as the restoration and maintenance of existing habitat for bats and seals.

As detailed in this report, Sitts & Hill Engineers developed budgetary construction costs estimates for each action alternative (no action costs were provided by WDNR). The purpose of the cost estimates is to provide a relative indication of the cost of implementing the various alternatives at the site. The feasibility report utilizes these relative costs in comparison to the benefits derived from the alternatives to complete a benefit/cost evaluation of the alternatives.

1.2 Summary of Alternatives

Table 1, below, contains a summary of the action items for each alternative. In addition to this table, a narrative summary is presented in section 4.[1]

Action	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Remove sections of Chapman Bay pier	No Action	1,150 ft.	1,500 ft.	2,510 ft.
Repair & maintain 280 lineal feet of bat habitat on Chapman Bay pier		X	X	X
Remove fill at base of Chapman Bay pier (28,000 cy)	No Action	No Action	X	X
Maintain & incrementally replace seal haul-out and piles over 15 years	No Action	X	No Action	No Action
Construct new floats and guide piles for seal haul-out, and maintain	No Action	No Action	X	X
Restore riparian zone	No Action	7 acres	15 acres	15 acres
Remove 100% of pilings in north and south operational areas (78 piles)	No Action	X	X	X
Remove 90% of pilings in main operational area (440 piles)	No Action	X	X	X
Remove last 10% of pilings (40 piles) in main operational area	No Action	No Action	X	X
Remove trestle over Woodard Bay	No Action	X	X	X
Remove fill/berm on north side of Woodard Bay trestle (40,000 cy)	No Action	No Action	No Action	X
Remove fill on south side of Woodard Bay trestle (11,000 cy)	No Action	No Action	X	X
Remove/reconstruct Woodard Bay Road bridge (remove 91,000 cy fill & construct 440' long new bridge)	No Action	No Action	No Action	X

Table 1. Summary of Proposed Alternatives

[1] For more detailed descriptions of each alternative, the reader is referred to the body of the feasibility study.

1.3 Summary of Estimated Costs

Table 2 below shows the total estimated construction costs associated with each alternative.

Action	Description	Estimated Costs
Alternative 1	"No Action"	$1,050,000
Alternative 2	Minimal Removal of Anthropogenic Structures	$4,600,000
Alternative 3	Moderate Removal of Anthropogenic Structures	$7,100,000
Alternative 4	A - Maximum Removal of Anthropogenic Structures	$10,200,000
	B - Add for Woodard Bay Drive Bridge Modification	$400,000
	C - Add for Woodard Bay Drive Bridge Reconstruction	$8,200,000

Table 2. Estimated Construction Costs for Each Alternative

The intent of this estimate is not to establish the actual cost of performing this work. It represents our best judgment as experienced professional engineers familiar with the construction industry of what is a reasonable price that a competitive contractor would charge for this work under the anticipated construction conditions. As such, this budgetary-level cost estimate has an accuracy range of minus 10 percent to plus 30 percent.

1.4 Basis of Costs

Costs included in the estimates were derived from many sources, including National cost estimating guides and "in-house" historical records of previous projects with similar elements. The data are adjusted when, in our professional judgment, recent experience or job specific information indicates such modifications are prudent and appropriate. Due to the great volatility of the construction industry at the beginning of 2009, the estimated costs, in aggregate, are based on 3 percent above 2008 prices.

Additionally, the cost estimates include 10 percent for contractor overhead and profit. Due to the uncertainty associated with the site, a 30 percent contingency has also been added.

Where applicable, the costs in the estimate have been totaled over a 30-year project life. As stated above, all costs are in 2009 prices. As such, no opportunity costs or amortization was carried out on future construction items.

1.5 Organization of Document

The remainder of this report presents the following information:

- The METHODOLOGY associated with the production of the cost estimate;
- A summary SITE DESCRIPTION identifying the major areas and components of the site;
- A GENERAL DESCRIPTION OF ALTERNATIVES and the ASSUMPTIONS used to produce the cost estimate;
- The DURATION OF WORK estimated for each action item within a given alternative;
- And finally, a diagram showing the SHORELINE DELINEATION used for calculations of earth fill volume to be removed.

Along with the aforementioned sections, this report contains a bibliography of the REFERENCES used, and Attachments 1 to 4 have detailed cost estimates for each alternative.

2 METHODOLOGY

The methodology used to produce the associated Cost estimate consisted of two parts. First, we compiled data related to the site. Because it was outside Sitts & Hill Engineers' scope to conduct a detailed site inventory and/or produce as-built drawings, much of the data used for the creation of this cost estimate is associated with documents prepared by others. Please refer to the REFERENCES section for a list of the documents utilized in the production of this report.

Next, the above-referenced information was distilled and costs were estimated based on the parameters identified in a given alternative. Lastly, this report was written to expand upon the assumptions used in creating the Cost estimate.

3 SITE DESCRIPTION

3.1 General

As stated in the INTRODUCTION, the site is located in Henderson Inlet at the South end of Puget Sound, near Olympia, Washington. The structures under discussion in this report are scattered over portions of Woodard and Chapman Bays on the West side of the inlet. Figure 1, below, shows the various areas and structures associated with the site. [2]

[2] Figure taken from SAIC (2008).

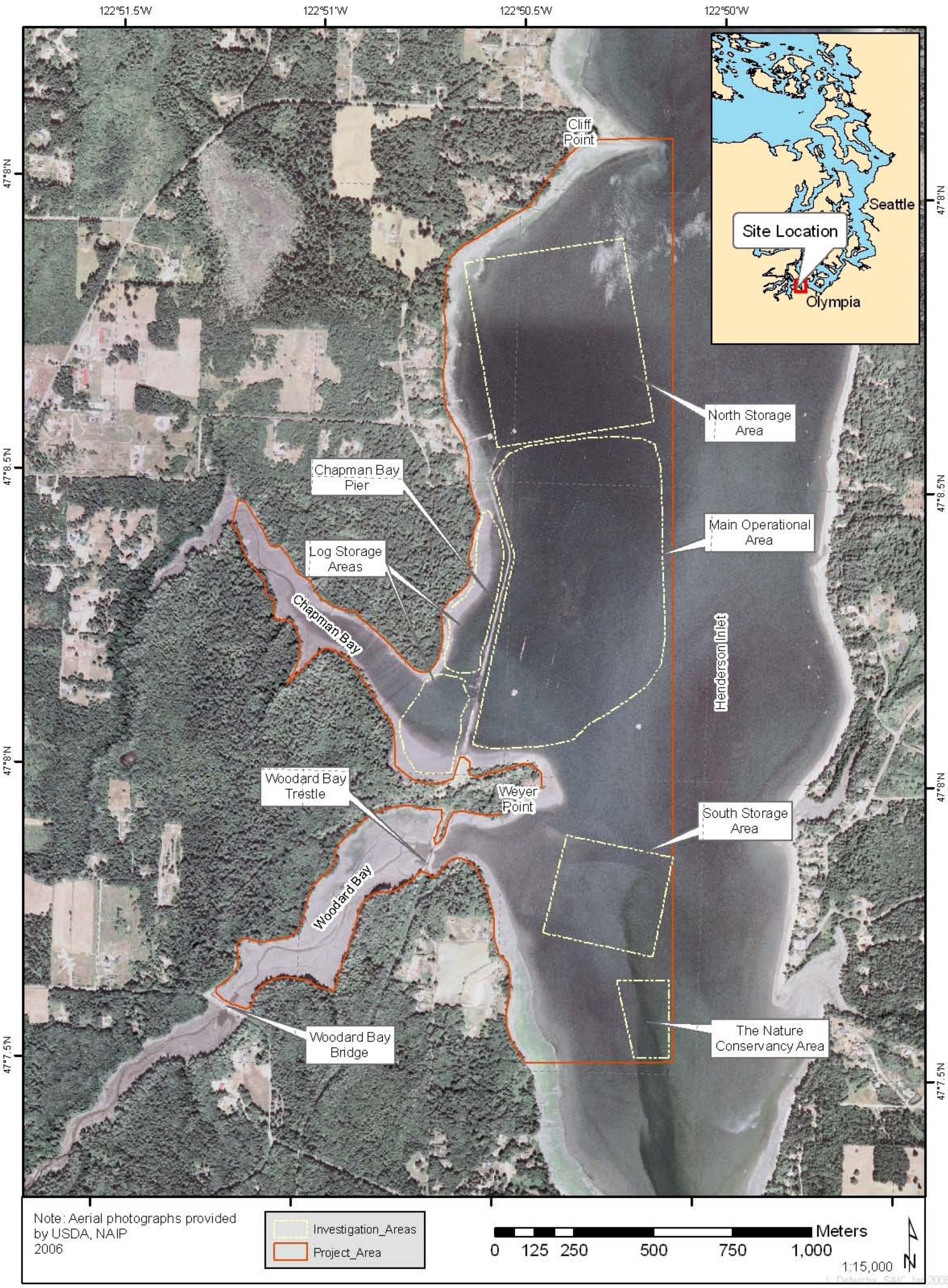

Figure 1. Woodard Bay Natural Resources Conservation Area

3.2 Chapman Bay Pier

As will be discussed below, the various alternatives remove different parts of the Chapman Bay pier. Figure 2 shows a satellite photo of the Southern portion of the pier describing the different elements used in the alternative descriptions below.[3]

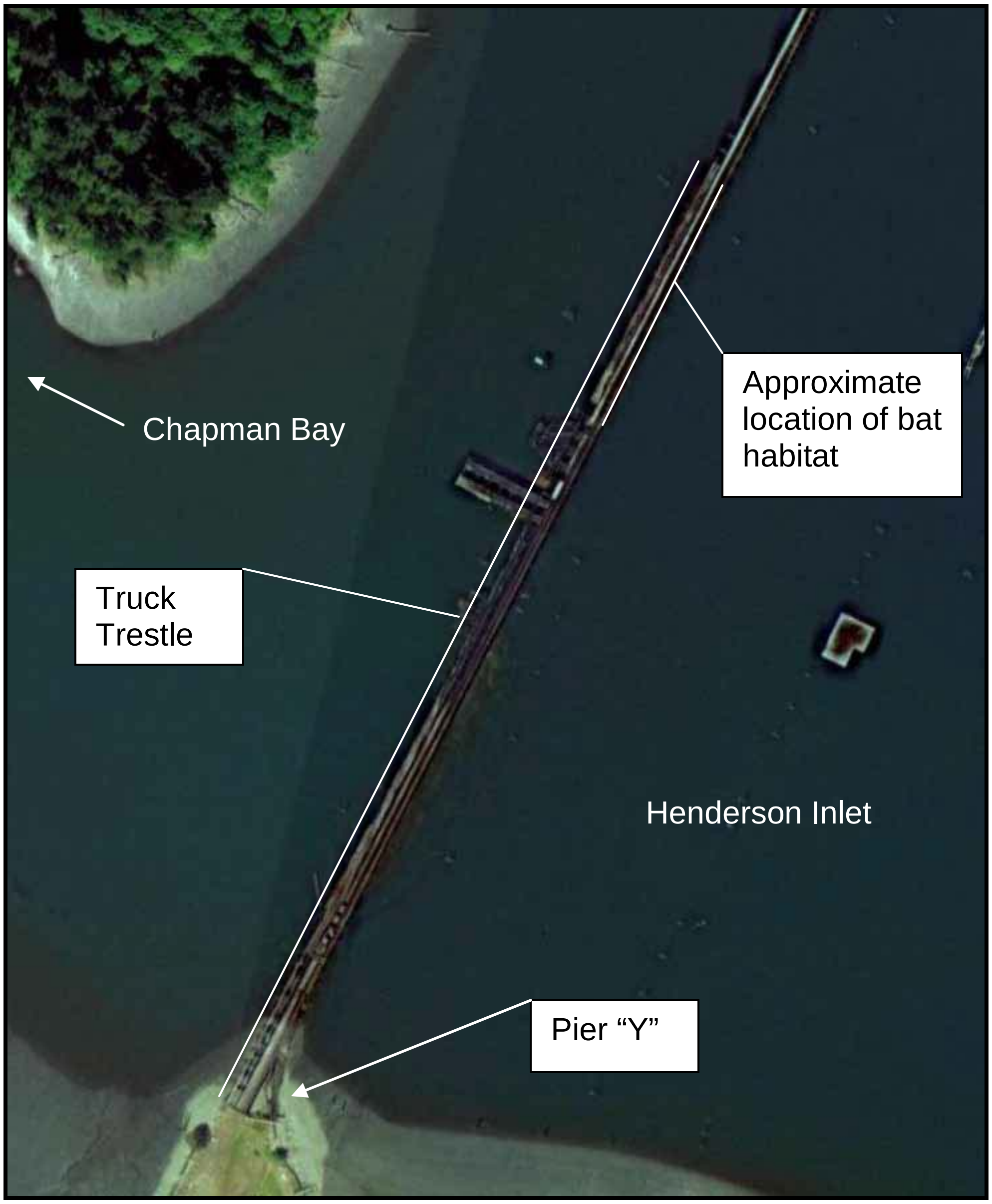

Figure 2. South End of Chapman Bay Pier

[3] The reader is referred to WDNR (1990) for detailed drawings of the Chapman Bay pier.

4 GENERAL DESCRIPTION OF ALTERNATIVES

4.1 Alternative 1

Alternative 1 is the "No Action" alternative. As such, no restoration of habitat or removal of anthropogenic structures will be conducted. This alternative only includes a yearly maintenance fee established by WDNR, summed over 30 years.

4.2 Alternative 2

Alternative 2 entails minimal removal of anthropogenic structures. The structures or portions thereof to be removed are as follows:

- Remove approximately 300 feet at the South end and approximately 830 feet at the North end of the Chapman Bay pier. The portion to be removed includes the associated Truck Trestle track on the West side of the pier and the "Y" located near the Pier Abutment.
- Demolish all of the Woodard Bay trestle.
- Remove 100 percent of the piles in the North and South Operational areas, and all but 40 piles in the Main Operational area.[4]

In addition to removing the above-referenced structures, the following restoration/improvement efforts will be conducted:

- Approximately 280 feet of the Chapman Bay pier currently used as bat roost will be stabilized and maintained in an attempt to preserve this habitat. Additional stabilization/repair will be conducted at 10 years past the date of initial construction, and again at the 20 and 30 year marks.
- Restore 7 acres of riparian zone on Weyer Point between Chapman and Woodard bays.

Lastly, this alternative involves maintenance of the log booms currently used by seals.[5] These structures consist of one or more untreated logs that may or may not be tied together, which rapidly degrade (or sink) and are only opportunistically replaced. We reviewed the potential of maintaining these structures by recycling piles collected from other parts of the site, however, Washington State law does not allow for the re-use of creosote-treated piles once they are removed from the water. [6] Therefore, re-use of existing piles for seal haul-out floats is not possible.

---

[4] The piles that are to be left in place are slated to be used as guide piles for existing log boom floats and for "attaching purple martin nest boxes, and for use by other wildlife (perching, etc.)" (Windward, 2009).

[5] For a detailed description of the uses of the existing structures by seals, refer to Calambokidis and Jeffries (1991).

[6] The existing piles are predominantly creosote-treated logs. The creosote treatment extends the life of the log booms because treated logs do not degrade as quickly as untreated logs.

Based on available data, there are only three main alternatives to creosote for treating Douglas Fir (the predominant wooden pile in the Northwest): Copper Chromated Arsenate (CCA), Ammoniacal Copper Zinc Arsenate (ACZA), and Ammoniacal Copper Quaternary (ACQ). The first two contain inorganic arsenic and are considered undesirable for use when in contact with people or wildlife. The last of the three, ACQ, is considered more environmentally inert, but is not certified for use in saltwater applications when treating Douglas Fir.

Because of the limitations regarding the use of treated wood, it was determined to be infeasible to use log floats for the seal haul-outs. Therefore, maintenance of the seal haul-outs involves phased replacement of approximately 600 linear feet of existing log boom with dock floats. During the initial work cycle, approximately 200 linear feet of log boom will be replaced with 600 square feet (200 linear feet at 3 feet wide) of new floats. Approximately 200 linear feet of log boom will also be replaced with 600 square feet of new floats after 5 years from the date of initial construction, and again at 10 years. Floats will be designed to allow easy access by seal pups (e.g., the decking will be within 12 inches of the water surface) and 30 pounds per square foot, live load to support the weight of adult seals.

The following figure (Figure 3) shows a structure similar to the proposed alternative.

Figure 3. Proposed Seal Haul-out Float Structure

This type of dock consists of polyethylene floats surrounded by composite plastic deck material. As can be seen in the photo, the deck can be constructed sufficiently low to the water to allow for seal access without foam ramps or other structures. With yearly maintenance of the deck material, the floats have a likely lifespan of more than 30 years.

Along with the final float replacement at the 10-year mark, 30 of the existing guide piles for the floats will be removed and replaced (leaving 10 existing, free-standing piles for nesting boxes and wildlife perches). Steel Pipe Piles were chosen for several reasons. As stated above, the nature of the work makes Arsenic-treated wooden piles undesirable. This leaves polyethylene, concrete, or steel. Polyethylene piles tend to be significantly more expensive that concrete or steel, and do not have the same structural capacity for a given weight when compared to the other two options. Concrete piles generally have a longer lifespan when compared to steel, but we have had contractors experience difficulty driving concrete piles in some areas due to overly dense soils. For these reasons, un-painted steel pipe piles with a corrosion allowance were deemed to provide the greatest value within the established lifespan (30 years).

With this scenario, maintenance would be minimal. The pipe piles and floats likely have a greater than 30 year lifespan. The only maintenance, therefore, would be periodic replacement of the decking and anchorage to the piles. This could be accomplished by a tradesperson in a smaller boat, rather than deployment of a large construction barge (with the associated mobilization costs). In order to maximize the available lifespan, we would recommend a yearly allotment for maintenance.

4.3 Alternative 3

For this alternative, moderate removal of anthropogenic structures, the Woodard Bay trestle and the Southern portion of the Chapman Bay pier (including the truck trestle and Y) will be demolished per Alternative 2. In addition to the Southern portion of the Chapman Bay pier, approximately 1200 feet of the North end will also be demolished. All of the piles in each of the operational areas will be removed, and the earth fill at the South end of the Woodard Bay trestle will be excavated and hauled away. Lastly, the concrete abutment at the base of the Chapman Bay pier will be demolished. The earth fill at the base of the pier will also be removed and hauled away.

The riparian zone of Weyer Point will be restored as in Alternative 2, but the area will be expanded to 15 acres. The bat habitat improvement is the same as Alternative 2, but the phased replacement of the log booms with constructed floats will take place all at once. Lastly, 30 new guide piles and 10 free-standing piles will be emplaced for use with the floats and as nesting box attachment.

4.4 Alternative 4

Alternative 4, maximum removal of anthropogenic structures, is composed of two parts. As with Alternatives 2 and 3, removal of anthropogenic structures and habitat restoration will take place, but this alternative also includes modification or replacement of the Woodard Bay bridge.

4.4.1 Alternative 4A: Removal of anthropogenic structures and habitat restoration

As per the previous alternative, the Woodard Bay trestle and all of the anchor piles will be removed; and the riparian zone restoration, bat habitat improvements, log boom replacement, and new pile emplacement will take place. Additionally, the following removal/demolition will be conducted:

- All of the Chapman Bay pier is to be demolished except for approximately 475 feet surrounding and including the bat habitat.
- The earth fill on the South and North ends of the Woodard Bay trestle will be removed.
- The fill and concrete abutment of the Chapman Bay pier will be excavated and hauled away.

4.4.2 Woodard Bay bridge

Alternative 4B involves modifying the Woodard Bay bridge by removing the center two pile bents in order to increase the clear-span of the bridge. Alternative 4C calls for demolishing and rebuilding the bridge.

5 ASSUMPTIONS

5.1 General

This section details the assumptions used in order to create the cost estimates for each of the alternatives. As can be seen from the descriptions of the alternatives above, they are additive. Therefore, assumptions made for one alternative are valid for all alternatives unless modified accordingly.

5.2 Alternative 1

No assumptions were made for this alternative, with the yearly lump sum cost for maintenance of the site being provided by WDNR.

5.3 Alternative 2

5.3.1 Partial Chapman Bay pier removal

Based on WDNR (1990) drawings, the South section of the pier to be removed comprises bents from Stations 0 to 3. The North section extends from the bent at Station 21+70 to the end of the pier (Station 30).

5.3.2 Bat habitat improvements

Conceptual repairs to the bat habitat that were included in the Cost estimate are shown in Figure 4.[7] Out of the 280 linear feet of wood

[7] Components of the bat habitat restoration are derived from Falxa (2007).

beam used as a roost, it was assumed that approximately 30 percent (80 feet) would need replacement. It is further assumed that the replacement beams could be salvaged from the demolished portion(s) of the pier.

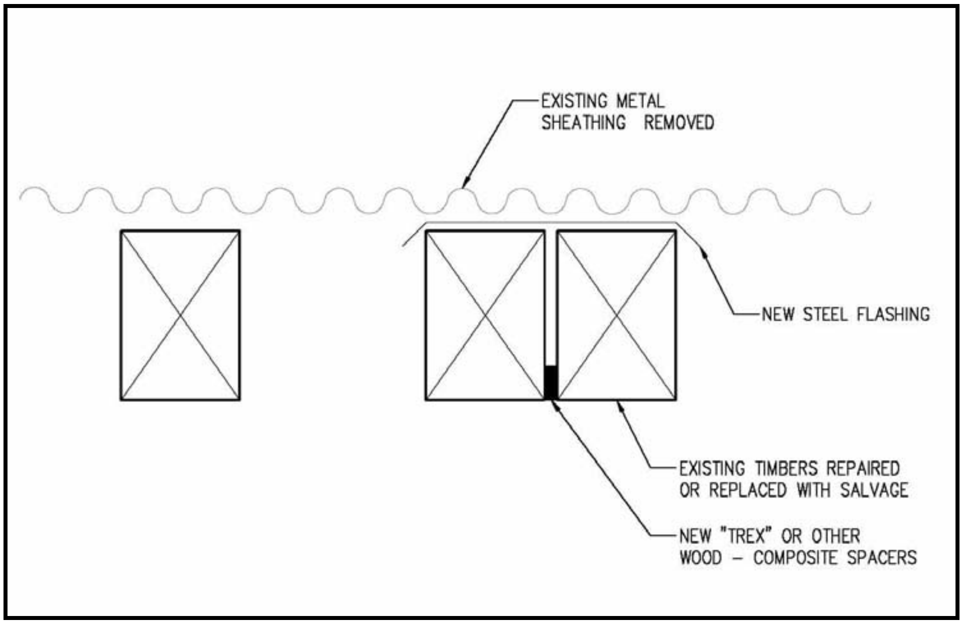

Figure 4. Sketch of Conceptual Bat Habitat Repair and Maintenance

Lastly, an allotment has been included for maintenance work to be conducted at 10, 20, and 30 years from the initial construction date. The allotment was based on replacement of any degraded beams, as salvage will not be possible after the initial construction period.

5.3.3 Woodard Bay Trestle

Due to the layout of the site in relation to the Trestle, it is unclear whether or not the demolition work could be completed using land-based machinery. Therefore, the cost estimate conservatively uses complete removal by barge.

5.3.4 Anchor piles

The numbers of piles to be removed in the North, Main, and South operational areas were obtained from reports by others (Hart Crowser, 2007). Independent verification of pile numbers was outside our scope of work.

Due to the age of the structure and past experience on similar jobs, as few as 5 percent and as much as 15 to 17 percent of the piles will likely break-off during extraction. Therefore, it was conservatively assumed that 20 percent of the piles would break.

Most of the piles in the three operational areas are clustered in some fashion. As such, it was estimated that 400 to 600 Vertical Linear Feet per day could be removed (or roughly 6 to 10 piles).

5.3.5 Seal haul-out maintenance

As stated above, maintenance of the seal haul-outs involves phased replacement of the existing log booms with constructed floats. The major limitation of this type of structure versus using logs is that the un-supported length is smaller, necessitating a greater number of new guide piles. The longest practical span is 30 feet versus the 60-foot assumption used for log-boom style floats. Therefore, 30 piles were estimated for use as guide piles on 1800 square feet of replacement floats (600 linear feet at 3 feet wide).

5.3.6 Riparian zone restoration

Estimates of acreage and price per acre were provided by WDNR based on their experience with riparian habitat restoration on Weyer Point. As such, they were directly translated into the cost estimate without adjustment and no further assumptions were made.

5.4 Alternative 3

5.4.1 Partial Chapman Bay pier removal

The Southern section of the pier to be removed for this alternative is the same as Alternative 2, and the North section correlates to the bents from Station 18 to the end of the pier.

5.4.2 Woodard Bay trestle fill removal

Based on the site geography, the cost estimate uses shore-based equipment for the excavation and removal of the earth fill at the Southern end of the Woodard Bay trestle. Based on the new shoreline delineation shown in Section 7, approximately 11,000 cubic yards of fill will need to be removed.

5.5 Alternative 4

5.5.1 Partial Chapman Bay pier removal

For this alternative, the entire pier is to be removed except for approximately 475 feet surrounding and including the bat habitat. The part of the pier not being removed stretches between the bent at Station 6+50 to the bent at Station 11+40.

5.5.2 Woodard Bay bridge

5.5.2.1 Demolition. Unlike the Woodard Bay Trestle, the majority of demolition of this bridge could likely take place on the bridge itself or using shore-based equipment. Therefore, the Cost estimate contains pricing of conventional demolition.

5.5.2.2 New Bridge Construction. The associated square-foot cost is based on a multiple-span concrete bridge, with spans up to 30 feet.

5.5.2.3 Woodard Bay bridge modification. Alternatively, the existing bridge would be modified to provide greater clear distance between bents. Figure 5 and Figure 6 below outline the method used to produce a cost estimate for this alternative. No value engineering was performed on the modification plan shown. As such, it is one possible alternative among many, and should be used from a relative costing standpoint only, not as a preferred alternative.

APPENDIX C

Sitts & Hill Cost Estimates

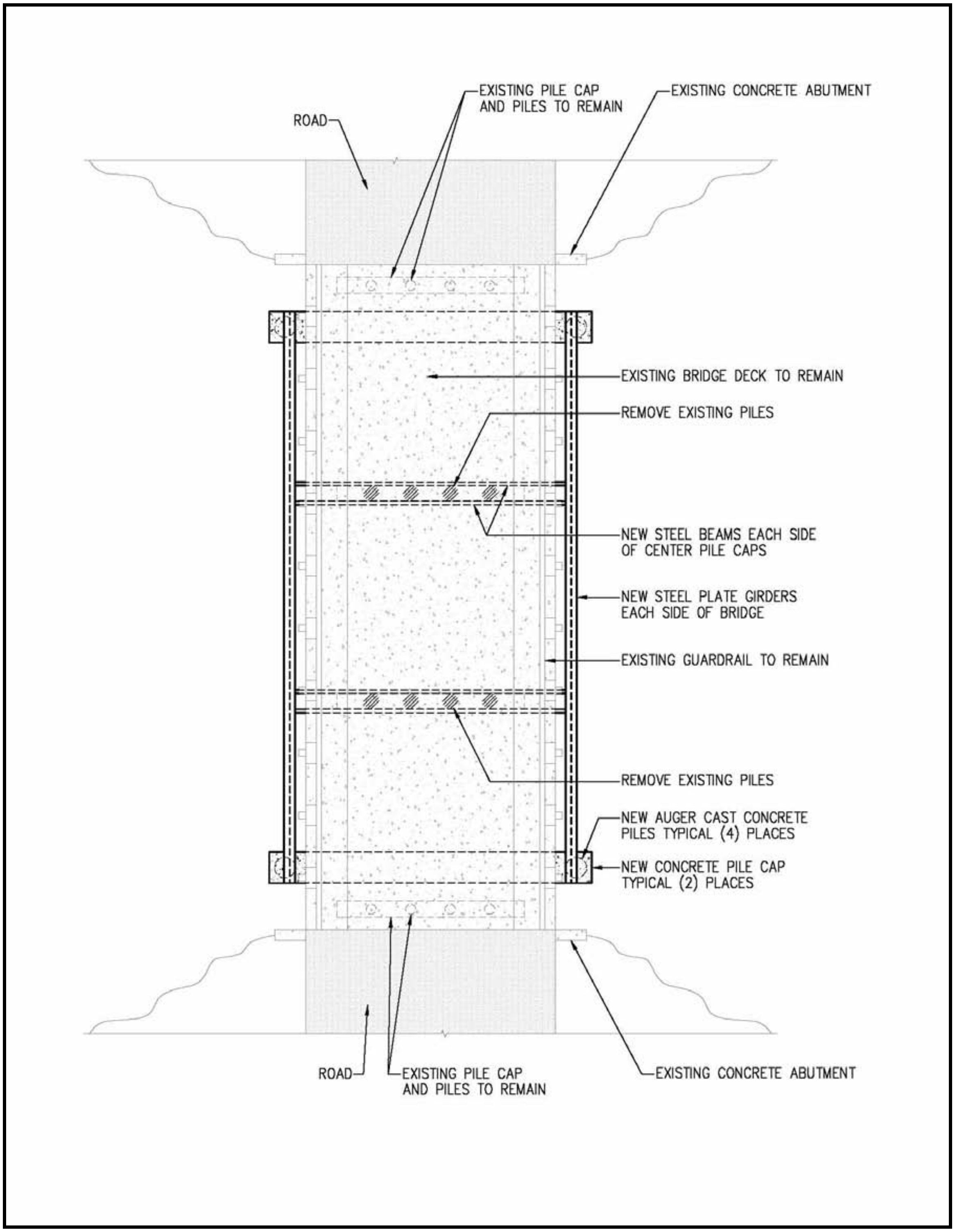

Figure 5. Conceptual Woodard Bay Drive Bridge Modification, Plan View

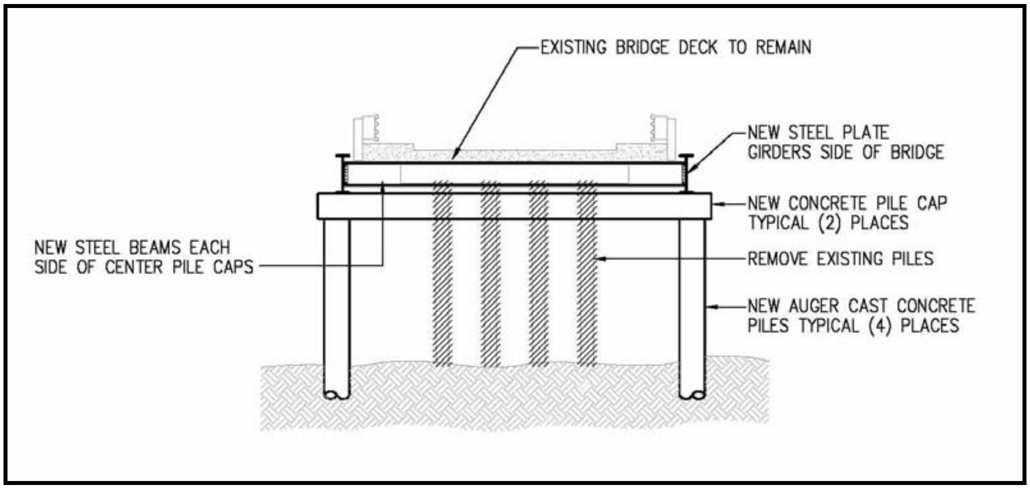

Figure 6. Conceptual Woodard Bay Drive Bridge Modification, Section View

6 DURATION OF WORK

In the Puget Sound, timing of in-water work is restricted based on animals that may be present and negatively impacted by the work-related disturbance. Currently, in-water activities are restricted as follows (Windward, 2009):

- Fish Disturbance Periods—the Corps, NMFS, and WDFW restrict in-water work between March 15th and June 14th for the protection of migrating juvenile salmonids. This applies primarily to all near shore areas at the site.
- Seal Disturbance Periods—WDFW and USFWS restrict activities around pupping and molting seals from April through June and again from September through October. This primarily affects the Main Operational Area and pier in Chapman Bay.
- Bat Disturbance Periods—Bats are present from April through September. This primarily affects any work on or use of the Chapman Bay Pier.

Based on these parameters, the main component of in-water work shall take place between November and February of any given winter. It is our opinion that a work schedule based in these months is possible given the following restrictions:

- Work would only be conducted during a single, 8-hour shift each day during daylight hours. This would minimize disruption to surrounding landowners, and provide the greatest safety at the work site.
- Work could continue 7 days a week as necessary to complete a given task within the allotted time period. This would require overtime pay for approximately 30 percent of the total time to complete a task, which has been incorporated into the Cost estimate (approximately ½ the total cost is labor, resulting in a 15 percent surcharge).
- Additional days would have to be allotted to account for missed work due to inclement weather. This estimate assumes the contractor will be unable to work 15 percent of the time due to weather. A line item for “contractor hold-over” has been added to the “Time to Complete” table to account for missed days.
- Winter work necessitates greater “overhead”. It takes longer to emplace personnel, and construction takes longer due to poor working conditions. The extra time for this overhead has been included in the Time to Complete table, and a “Winter Surcharge” of 20 percent has been added to each alternative in order to compensate for this additional time.

Based on the above-mentioned parameters, a time-to-complete has been established for each task within a given alternative. Table 3 below summarizes the estimated time to completion for various tasks.

		Days to Complete	Hold-over	Total
ALTERNATIVE 2				
Chapman Bay Pier Removal - 1130ft Removal		73	11	84
Bat Habitat Improvement		6	1	7
Anchor Pile Removal		82	12	94
Seal Haul-out Maintenance	Ea of Yrs 0&5	3	0	3
	Year 10	8		
Woodard Bay Trestle		28	4	32
			Total for Alt 2	220
ALTERNATIVE 3				
Chapman Bay Pier Removal - 1500ft Removal		91	14	105
Pier Landing Fill Removal		56	8	64
Bat Habitat Improvement		6	1	7
Anchor Pile Removal		90	14	104
Seal Haul-out Construction		15	2	17
Woodard Bay Trestle		28	4	32
South Embankment Fill Removal		22	3	25
			Total for Alt 3	354
ALTERNATIVE 4A				
Chapman Bay Pier Removal - 2500ft Removal		165	25	190
Pier Landing Fill Removal		56	8	64
Bat Habitat Improvement		6	1	7
Anchor Pile Removal		90	14	104
Seal Haul-out Construction		15	2	17
Woodard Bay Trestle		28	4	32
North and South Embankment Fill Removal		102	15	117
			Total for Alt 4A	531
ALTERNATIVE 4B				
Add for Woodard Bay Road Bridge Modification		40	6	46
			Total for Alt 4B	577
ALTERNATIVE 4C				
Add for Woodard Bay Road Bridge Replacement		98	15	113
			Total for Alt 4C	644

Table 3. Estimated Time to Completion of Each Alternative

As can be seen in Table 3, every alternative would require more than the approximate 120-day window available to complete the work. In order to perform all of the tasks of a given alternative within a single work cycle, the

Contractor would be required to use multiple crews/barges working simultaneously.

Additionally, all but Alternative 2 would require three or more crews (total time to complete is greater than 240 days). Few contractors have that kind of resources available in the Puget Sound. Therefore, we would recommend that the chosen alternative be broken down into multiple contracts or multiple seasons. This would allow for an increased number of available bidders, and thus likely decrease the construction costs.

The actual construction sequence is difficult to estimate, however, given the large number of unknowns. Therefore, the cost estimate conservatively assumes a single contractor will complete the work in one season. As such, mobilization costs have been broken out for each task within a given alternative based on the equipment necessary to be brought to the site in order to complete all of the tasks within the allotted construction window. For example, mobilization of 2 barges/crews is included in the Chapman Bay pier removal of Alternative 4, were as only one barge/crew has been estimated for the pier removal of Alternatives 2 and 3. A second or third barge/crew mobilization has been added for the pile removal, etc.

Division 1 costs, in contrast, have been grouped for a given alternative presuming a single working season. [8] Additionally, an out-of-state mobilization surcharge has been added to Alternatives 3 and 4 to account for the additional costs required to bring the requisite number of barges into the Puget Sound. This surcharge may be subtracted if the work is divided into multiple contracts or seasons.

[8] Division 1 costs include such items as safety barricades, construction site facilities and temporary utilities (project office, portable toilets, electrical power, telephone), third-party quality control inspection services, and similar costs associated with project facilitation.

7 SHORELINE DELINEATION

Figure 7 below shows the approximate, reconstructed shorelines (in red) used for calculations of fill volume to be removed. The associated topography was obtained from the Thurston County GIS website (http://geomap1.geodata.org/website/cadastral/viewer.htm).

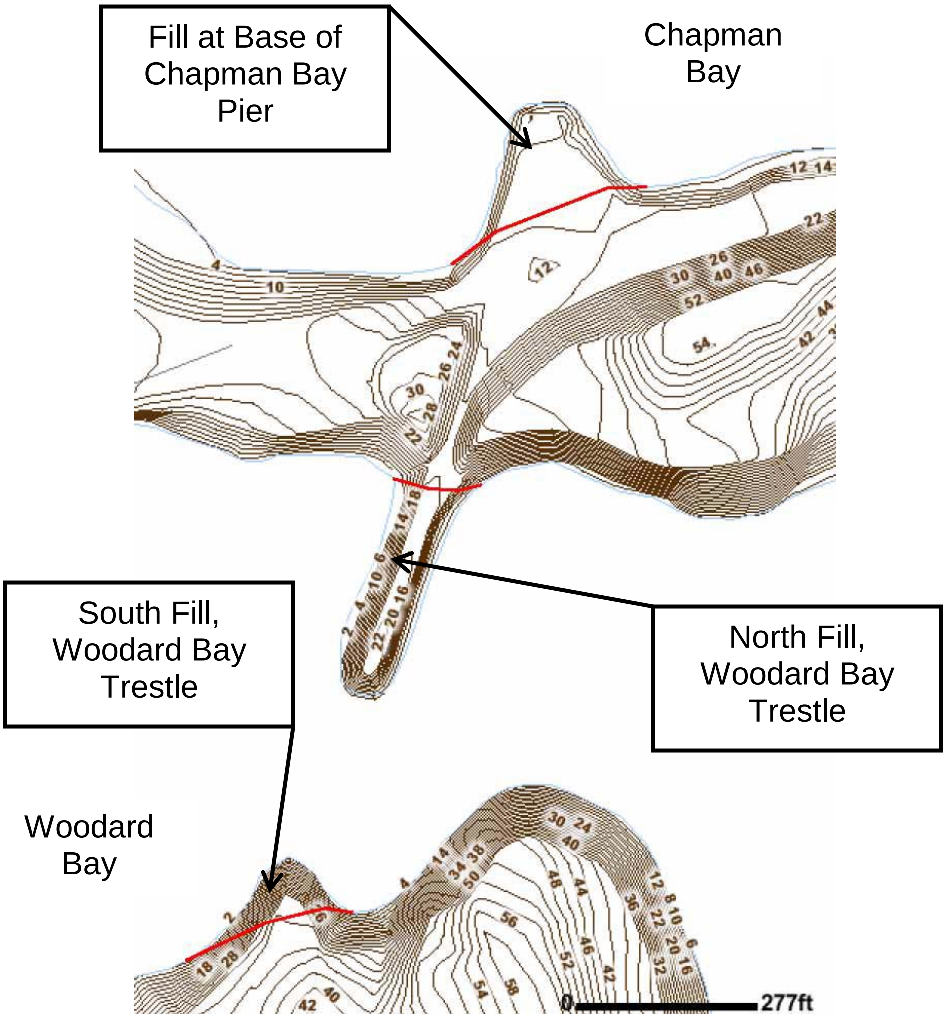

Figure 7. Approximate, Reconstructed Shorelines for Earth Fill Removal

8 REFERENCES

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ATTACHMENT 1

BUDGETARY COST ESTIMATE
ALTERNATIVE 1

CONSTRUCTION COST ESTIMATE
WINDWARD ENVIRONMENTAL

FILE: 2009-07-31 Budgetary Alt 1
DATE: Sep-09
ESTIMATE BY: M. Bock
STATUS OF DESIGN: BUDGETARY FEASIBILITY
JOB No.: 14127

SITTS AND HILL ENGINEERS, INC.
4815 CENTER ST.
TACOMA, WA. 98409
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FAX. (253) 474-0153

PROJECT: WOODARD BAY FEASIBILITY STUDY - ALTERNATIVE 1

ITEM DESCRIPTION	QUANTITY	UNIT	BARE UNIT COST	SUBTOTAL
STRUCTURAL ESTIMATE - "NO ACTION" ALTERNATIVE				
YEARLY MAINTENANCE COSTS	30	EA	$35,000	$1,050,000
TOTAL YEARLY COSTS FOR THIS ALTERNATIVE =				$1,050,000

ATTACHMENT 2

BUDGETARY COST ESTIMATE
ALTERNATIVE 2

CONSTRUCTION COST ESTIMATE
WINDWARD ENVIRONMENTAL

FILE: 2009-07-31 Budgetary Alt 2
DATE: Sep-09
ESTIMATE BY: M. Bock
STATUS OF DESIGN: BUDGETARY FEASIBILITY
JOB No.: 14127

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PROJECT: WOODARD BAY FEASIBILITY STUDY - ALTERNATIVE 2

ITEM DESCRIPTION		QUANTITY	UNIT	BARE UNIT COST	SUBTOTAL
STRUCTURAL ESTIMATE - CHAPMAN BAY PIER DEMO					
MOBILIZATION		1	EA	$20,000	$20,000
PIER SECTION 5 (Stations 24 to 30) Approx Ln = 560ft					
Pile Removal		3900	VLF	$18	$70,200
Pile Disposal		390	CY	$175	$68,250
Lumber Removal		70	MBF	$2,750	$192,500
Lumber Disposal		216	CY	$175	$37,800
		Subtotal Section 5 w/o Mobilization			$368,750
Gravel Fill Around Pulled Piles		1650	CY	$15	$24,750
Add for Cut/Fill at Broken Piles		25	EA	$500	$12,500
PIER SECTION 4(-) (Stations 21.7 to 24) Approx Ln = 270ft					
Pile Removal		2900	VLF	$18	$52,200
Pile Disposal		290	CY	$175	$50,750
Lumber Removal		13	MBF	$2,750	$35,750
Lumber Disposal		40	CY	$175	$7,000
		Subtotal Section 4 w/o Mobilization			$145,700
Gravel Fill Around Pulled Piles		800	CY	$15	$12,000
Add for Cut/Fill at Broken Piles		15	EA	$500	$7,500
PIER SECTION 1 (Stations 0 to 3) Approx Ln = 320ft					
Pile Removal	Includes 650 VLF for 'Y'	3950	VLF	$18	$71,100
Pile Disposal		395	CY	$175	$69,125
Lumber Removal	Includes 14.5 MBF for 'Y'	85.5	MBF	$2,750	$235,125
Lumber Disposal		264	CY	$175	$46,200
		Subtotal Section 1 w/o Mobilization			$421,550
Gravel Fill Around Pulled Piles	Includes 300 CY for 'Y'	1300	CY	$15	$19,500
Add for Cut/Fill at Broken Piles		30	EA	$500	$15,000
PARTIAL TRUCK TRESTLE (Stations 0 to 3.2)					
Pile Removal		1980	VLF	$18	$35,640
Pile Disposal		198	CY	$175	$34,650
Lumber Removal		8	MBF	$2,750	$22,000
Lumber Disposal		25	CY	$175	$4,375
		Subtotal Truck Trestle w/o Mobilization			$96,665
Add for Cut/Fill at Broken Piles		13	EA	$500	$6,500
		SUB-TOTAL CONSTRUCTION COSTS THIS SHEET =			$1,150,415

CONSTRUCTION COST ESTIMATE
WINDWARD ENVIRONMENTAL

FILE: 2009-07-31 Budgetary Alt 2
DATE: Sep-09
ESTIMATE BY: M. Bock
STATUS OF DESIGN: BUDGETARY FEASIBILITY
JOB No.: 14127

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PROJECT: WOODARD BAY FEASIBILITY STUDY - ALTERNATIVE 2

ITEM DESCRIPTION	QUANTITY	UNIT	BARE UNIT COST	SUBTOTAL
STRUCTURAL ESTIMATE - BAT HABITAT REPAIR				
REMOVE EXISTING RAILS/METAL SHEATHING	1	TON	$250	$250
EPOXY REPAIR MAIN TIMBERS	200	SF	$10	$2,000
REPLACE 30% TIMBERS FROM SALVAGE	80	LF	$25	$2,000
SPACERS BETWEEN TIMBERS AT 10' O.C.	40	LF	$6	$240
SHEET METAL CAP ON TIMBERS	450	SF	$8	$3,600
ALLOTMENT FOR MAINTENANCE IN YEARS 10, 20, AND 30	3	EA	$10,000	$30,000
SUB-TOTAL CONSTRUCTION COSTS THIS SHEET =				$38,090

CONSTRUCTION COST ESTIMATE
WINDWARD ENVIRONMENTAL

FILE: 2009-07-31 Budgetary Alt 2
DATE: Sep-09
ESTIMATE BY: M. Bock
STATUS OF DESIGN: BUDGETARY FEASIBILITY
JOB No.: 14127

SITTS AND HILL ENGINEERS, INC.
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PROJECT: WOODARD BAY FEASIBILITY STUDY - ALTERNATIVE 2

ITEM DESCRIPTION	QUANTITY	UNIT	BARE UNIT COST	SUBTOTAL
STRUCTURAL ESTIMATE - WOODARD BAY TRESTLE BRIDGE DEMO				
MOBILIZATION	1	EA	$20,000	$20,000
TRESTLE REMOVAL				
Pile Removal	6000	VLF	$12	$72,000
Pile Disposal	600	CY	$175	$105,000
Lumber Removal	90	MBF	$2,750	$247,500
Lumber Disposal	278	CY	$175	$48,650
Sub-total, Trestle Removal and Disposal				$493,150
SUB-TOTAL CONSTRUCTION COSTS THIS SHEET =				$493,150

CONSTRUCTION COST ESTIMATE
WINDWARD ENVIRONMENTAL

FILE: 2009-07-31 Budgetary Alt 2
DATE: Sep-09
ESTIMATE BY: M. Bock
STATUS OF DESIGN: BUDGETARY FEASIBILITY
JOB No.: 14127

SITTS AND HILL ENGINEERS, INC.
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PROJECT: WOODARD BAY FEASIBILITY STUDY - ALTERNATIVE 2

ITEM DESCRIPTION	QUANTITY	UNIT	BARE UNIT COST	SUBTOTAL
STRUCTURAL ESTIMATE - ANCHOR PILE REMOVAL				
MOBILIZATION	1	EA	$20,000	$20,000
PILE REMOVAL AND DISPOSAL				
North Storage Area (Est 49 Piles, Barge removal at 6/day)	6	DAYs	$3,600	$21,600
Disposal	200	C.Y.	$175	$35,000
Main Operational Area (Est 440 Piles, Barge removal at 6/day)	74	DAYs	$3,600	$266,400
Disposal	220	C.Y.	$175	$38,500
South Storage Area (Est 29 Piles, Barge removal at 6/day)	4	DAYs	$3,600	$14,400
Disposal	120	C.Y.	$175	$21,000
CUT-OFF/FILL AT BROKEN PILES				
North Storage Area (Est 10 Piles, Diver w/ barge fill, add for small job)	2	DAYs	$3,000	$6,000
Main Operational Area (Est 90 Piles, Diver w/ barge fill)	18	DAYs	$2,500	$45,000
South Storage Area (Est 6 Piles, Diver w/ barge fill, add for small job)	1	DAYs	$3,000	$3,000
SUB-TOTAL CONSTRUCTION COSTS THIS SHEET =				$470,900

CONSTRUCTION COST ESTIMATE
WINDWARD ENVIRONMENTAL

FILE: 2009-07-31 Budgetary Alt 2
DATE: Sep-09
ESTIMATE BY: M. Bock
STATUS OF DESIGN: BUDGETARY FEASIBILITY
JOB No.: 14127

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PROJECT: WOODARD BAY FEASIBILITY STUDY - ALTERNATIVE 2

ITEM DESCRIPTION	QUANTITY	UNIT	BARE UNIT COST	SUBTOTAL
STRUCTURAL ESTIMATE - SEAL HAUL-OUT MAINTENANCE				
1ST YEAR MAINTENANCE - 1/3 LOG BOOM REPLACEMENT				
Mobilization	1	EA	$5,000	$5,000
New Haul-out Floats	600	SF	$60	$36,000
YEAR 5 MAINTENANCE - 1/3 LOG BOOM REPLACEMENT				
Mobilization	1	EA	$5,000	$5,000
New Haul-out Floats	600	SF	$60	$36,000
YEAR 10 MAINTENANCE - REMAINDER LOG BOOM + ANCHOR PILE REPLACEMENT				
Additional Division 1 Costs	1	EA	$15,000	$15,000
Mobilization	1	EA	$20,000	$20,000
New Haul-out Floats	600	SF	$60	$36,000
Embedded Pile Length	1800	VLF	$20	$36,000
YEAR 10 TO 30 ANNUAL MAINTENANCE COSTS	20	YEARS	$1,500	$30,000
SUB-TOTAL CONSTRUCTION COSTS THIS SHEET =				$219,000

CONSTRUCTION COST ESTIMATE
WINDWARD ENVIRONMENTAL

FILE: 2009-07-31 Budgetary Alt 2
DATE: Sep-09
ESTIMATE BY: M. Bock
STATUS OF DESIGN: BUDGETARY FEASIBILITY
JOB No.: 14127

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PROJECT: WOODARD BAY FEASIBILITY STUDY - ALTERNATIVE 2

ITEM DESCRIPTION	QUANTITY	UNIT	BARE UNIT COST	SUBTOTAL
STRUCTURAL ESTIMATE - RESTORE RIPARIAN ZONE				
RESTORE RIPARIAN ZONE	7	AC	$15,000	$105,000
SUB-TOTAL CONSTRUCTION COSTS THIS SHEET =				$105,000

CONSTRUCTION COST ESTIMATE
WINDWARD ENVIRONMENTAL

FILE: 2009-07-31 Budgetary Alt 2
DATE: Sep-09
ESTIMATE BY: M. Bock
STATUS OF DESIGN: BUDGETARY FEASIBILITY
JOB No.: 14127

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PROJECT: WOODARD BAY FEASIBILITY STUDY - ALTERNATIVE 2

ITEM DESCRIPTION	QUANTITY	UNIT	BARE UNIT COST	SUBTOTAL
SUMMARY AND DIVISION 1 COSTS				
MISCELLANEOUS DIVISION 1 COSTS FOR ALTERNATIVE 2	1	EA	$150,000	$150,000
CHAPMAN BAY PIER				$1,150,415
BAT HABITAT REPAIR				$38,090
WOODARD BAY TRESTLE				$493,150
ANCHOR PILE REMOVAL				$470,900
SEAL HAUL-OUT MAINTENANCE				$219,000
RIPARIAN ZONE IMPROVEMENT				$105,000
SUB-TOTAL CONSTRUCTION COSTS ALT 2 =				$2,626,555
15% OVERTIME PAY SURCHARGE =				$393,983
20% WINTER PREMIUM =				$525,311
30% CONTINGENCY =				$787,967
10% CONTRACTOR OVERHEAD AND PROFIT =				$262,656
TOTAL CONSTRUCTION COSTS ALT 2 =				$4,596,471

ATTACHMENT 3

BUDGETARY COST ESTIMATE
ALTERNATIVE 3

CONSTRUCTION COST ESTIMATE
WINDWARD ENVIRONMENTAL

FILE: 2009-07-31 Budgetary Alt 3
DATE: Sep-09
ESTIMATE BY: M. Bock
STATUS OF DESIGN: BUDGETARY FEASIBILITY
JOB No.: 14127

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PROJECT: WOODARD BAY FEASIBILITY STUDY - ALTERNATIVE 3

ITEM DESCRIPTION		QUANTITY	UNIT	BARE UNIT COST	SUBTOTAL
STRUCTURAL ESTIMATE - CHAPMAN BAY PIER DEMO					
MOBILIZATION		1	EA	$20,000	$20,000
PIER SECTION 5 (Stations 24 to 30) Approx Ln = 560ft					
Pile Removal		3900	VLF	$18	$70,200
Pile Disposal		390	CY	$175	$68,250
Lumber Removal		70	MBF	$2,750	$192,500
Lumber Disposal		216	CY	$175	$37,800
		Subtotal Section 5 w/o Mobilization			$368,750
Gravel Fill Around Pulled Piles		1650	CY	$15	$24,750
Add for Cut/Fill at Broken Piles		25	EA	$500	$12,500
PIER SECTION 4 (Stations 18 to 24) Approx Ln = 620ft					
Pile Removal		5800	VLF	$18	$104,400
Pile Disposal		580	CY	$175	$101,500
Lumber Removal		64	MBF	$2,750	$176,000
Lumber Disposal		198	CY	$175	$34,650
		Subtotal Section 4 w/o Mobilization			$416,550
Gravel Fill Around Pulled Piles		1800	CY	$15	$27,000
Add for Cut/Fill at Broken Piles		29	EA	$500	$14,500
PIER SECTION 1 (Bents 0 to 3) Approx Ln = 320ft					
Pile Removal	Includes 650 VLF for 'Y'	3950	VLF	$18	$71,100
Pile Disposal		395	CY	$175	$69,125
Lumber Removal	Includes 14.5 MBF for 'Y'	85.5	MBF	$2,750	$235,125
Lumber Disposal		264	CY	$175	$46,200
		Subtotal Section 1 w/o Mobilization			$421,550
Gravel Fill Around Pulled Piles	Includes 300 CY for 'Y'	1300	CY	$15	$19,500
Add for Cut/Fill at Broken Piles		30	EA	$500	$15,000
PARTIAL TRUCK TRESTLE (Stations 0 to 3.2)					
Pile Removal		1980	VLF	$18	$35,640
Pile Disposal		198	CY	$175	$34,650
Lumber Removal		8	MBF	$2,750	$22,000
Lumber Disposal		25	CY	$175	$4,375
		Subtotal Truck Trestle w/o Mobilization			$96,665
Add for Cut/Fill at Broken Piles		13	EA	$500	$6,500
CONCRETE ABUTMENT REMOVAL AND DISPOSAL		24	CY	$200	$4,800
PIER LANDING FILL REMOVAL AND DISPOSAL		28000	CY	$18	$504,000
		SUB-TOTAL CONSTRUCTION COSTS THIS SHEET =			$1,952,065

CONSTRUCTION COST ESTIMATE
WINDWARD ENVIRONMENTAL

FILE: 2009-07-31 Budgetary Alt 3
DATE: Sep-09
ESTIMATE BY: M. Bock
STATUS OF DESIGN: BUDGETARY FEASIBILITY
JOB No.: 14127

SITTS AND HILL ENGINEERS, INC.
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TACOMA, WA. 98409
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PROJECT: WOODARD BAY FEASIBILITY STUDY - ALTERNATIVE 3

ITEM DESCRIPTION	QUANTITY	UNIT	BARE UNIT COST	SUBTOTAL
STRUCTURAL ESTIMATE - BAT HABITAT REPAIR				
REMOVE EXISTING RAILS/METAL SHEATHING	1	TON	$250	$250
EPOXY REPAIR MAIN TIMBERS	200	SF	$10	$2,000
REPLACE 30% TIMBERS FROM SALVAGE	80	LF	$25	$2,000
SPACERS BETWEEN TIMBERS AT 10' O.C.	40	LF	$6	$240
SHEET METAL CAP ON TIMBERS	450	SF	$8	$3,600
ALLOTMENT FOR MAINTENANCE IN YEARS 10, 20, AND 30	3	EA	$10,000	$30,000
SUB-TOTAL CONSTRUCTION COSTS THIS SHEET =				$38,090

CONSTRUCTION COST ESTIMATE
WINDWARD ENVIRONMENTAL

FILE: 2009-07-31 Budgetary Alt 3
DATE: Sep-09
ESTIMATE BY: M. Bock
STATUS OF DESIGN: BUDGETARY FEASIBILITY
JOB No.: 14127

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4815 CENTER ST
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PROJECT: WOODARD BAY FEASIBILITY STUDY - ALTERNATIVE 3

ITEM DESCRIPTION	QUANTITY	UNIT	BARE UNIT COST	SUBTOTAL
STRUCTURAL ESTIMATE - WOODARD BAY TRESTLE BRIDGE DEMO				
MOBILIZATION	1	EA	$20,000	$20,000
TRESTLE REMOVAL				
Pile Removal	6000	VLF	$12	$72,000
Pile Disposal	600	CY	$175	$105,000
Lumber Removal	90	MBF	$2,750	$247,500
Lumber Disposal	278	CY	$175	$48,650
Sub-total, Trestle Removal and Disposal				$493,150
SOUTH EMBANKMENT REMOVAL AND HAUL (5 Mile Haul)	11000	CY	$18	$198,000
SUB-TOTAL CONSTRUCTION COSTS THIS SHEET =				$691,150

CONSTRUCTION COST ESTIMATE
WINDWARD ENVIRONMENTAL

FILE: 2009-07-31 Budgetary Alt 3
DATE: Sep-09
ESTIMATE BY: M. Bock
STATUS OF DESIGN: BUDGETARY FEASIBILITY
JOB No.: 14127

SITTS AND HILL ENGINEERS, INC.
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PROJECT: WOODARD BAY FEASIBILITY STUDY - ALTERNATIVE 3

ITEM DESCRIPTION	QUANTITY	UNIT	BARE UNIT COST	SUBTOTAL
STRUCTURAL ESTIMATE - ANCHOR PILE REMOVAL				
MOBILIZATION	1	EA	$20,000	$20,000
PILE REMOVAL AND DISPOSAL				
North Storage Area (Est 49 Piles, Barge removal at 6/day)	6	DAYs	$3,600	$21,600
Disposal	200	C.Y.	$175	$35,000
Main Operational Area (Est 480 Piles, Barge removal at 6/day)	80	DAYs	$3,600	$288,000
Disposal	240	C.Y.	$175	$42,000
South Storage Area (Est 29 Piles, Barge removal at 6/day)	4	DAYs	$3,600	$14,400
Disposal	120	C.Y.	$175	$21,000
CUT-OFF/FILL AT BROKEN PILES				
North Storage Area (Est 10 Piles, Diver w/ barge fill, add for small job)	2	DAYs	$3,000	$6,000
Main Operational Area (Est 100 Piles, Diver w/ barge fill)	20	DAYs	$2,500	$50,000
South Storage Area (Est 6 Piles, Diver w/ barge fill, add for small job)	1	DAYs	$3,000	$3,000
LOG BOOM				
Removal	1000	LF	$75	$75,000
Disposal (Assume Creosote Treated Logs)	30	CY	$150	$4,500
SUB-TOTAL CONSTRUCTION COSTS THIS SHEET =				$580,500

CONSTRUCTION COST ESTIMATE
WINDWARD ENVIRONMENTAL

FILE: 2009-07-31 Budgetary Alt 3
DATE: Sep-09
ESTIMATE BY: M. Bock
STATUS OF DESIGN: BUDGETARY FEASIBILITY
JOB No.: 14127

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PROJECT: WOODARD BAY FEASIBILITY STUDY - ALTERNATIVE 3

ITEM DESCRIPTION	QUANTITY	UNIT	BARE UNIT COST	SUBTOTAL
STRUCTURAL ESTIMATE - NEW SEAL HAUL-OUT				
MOBILIZATION	1	EA	$20,000	$20,000
EMBEDDED PILE LENGTH (Steel Pipe Piles)	2400	VLF	$20	$48,000
HAUL-OUT FLOATS	1800	SF	$60	$108,000
Sub-Total, Construct New Seal Haul-out				$176,000
STRUCTURAL ESTIMATE - SEAL HAUL-OUT MAINTENANCE				
YEARLY MAINTENANCE	29	EA	$1,500	$43,500
SUB-TOTAL CONSTRUCTION COSTS THIS SHEET =				$219,500

CONSTRUCTION COST ESTIMATE
WINDWARD ENVIRONMENTAL

FILE: 2009-07-31 Budgetary Alt 3
DATE: Sep-09
ESTIMATE BY: M. Bock
STATUS OF DESIGN: BUDGETARY FEASIBILITY
JOB No.: 14127

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PROJECT: WOODARD BAY FEASIBILITY STUDY - ALTERNATIVE 3

ITEM DESCRIPTION	QUANTITY	UNIT	BARE UNIT COST	SUBTOTAL
STRUCTURAL ESTIMATE - RESTORE RIPARIAN ZONE				
RESTORE RIPARIAN ZONE	15	AC	$15,000	$225,000
SUB-TOTAL CONSTRUCTION COSTS THIS SHEET =				$225,000

CONSTRUCTION COST ESTIMATE
WINDWARD ENVIRONMENTAL

FILE: 2009-07-31 Budgetary Alt 3
DATE: Sep-09
ESTIMATE BY: M. Bock
STATUS OF DESIGN: BUDGETARY FEASIBILITY
JOB No.: 14127

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PROJECT: WOODARD BAY FEASIBILITY STUDY - ALTERNATIVE 3

ITEM DESCRIPTION	QUANTITY	UNIT	BARE UNIT COST	SUBTOTAL
SUMMARY AND DIVISION 1 COSTS				
MISCELLANEOUS DIVISION 1 COSTS FOR ALTERNATIVE 3	1	EA	$200,000	$200,000
OUT-OF-STATE MOBILIZATION	1	EA	$170,000	$170,000
CHAPMAN BAY PIER				$1,952,065
BAT HABITAT REPAIR				$38,090
WOODARD BAY TRESTLE				$691,150
ANCHOR PILE REMOVAL				$580,500
SEAL HAUL-OUT MAINTENANCE				$219,500
RIPARIAN ZONE IMPROVEMENT				$225,000
SUB-TOTAL CONSTRUCTION COSTS ALT 3 =				$4,076,305
15% OVERTIME PAY SURCHARGE =				$611,446
20% WINTER PREMIUM =				$815,261
30% CONTINGENCY =				$1,222,892
10% CONTRACTOR OVERHEAD AND PROFIT =				$407,631
TOTAL CONSTRUCTION COSTS ALT 3 =				$7,133,534

ATTACHMENT 4

BUDGETARY COST ESTIMATE
ALTERNATIVE 4

CONSTRUCTION COST ESTIMATE
WINDWARD ENVIRONMENTAL

FILE: 2009-07-31 Budgetary Alt 4
DATE: Sep-09
ESTIMATE BY: M. Bock
STATUS OF DESIGN: BUDGETARY FEASIBILITY
JOB No.: 14127

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PROJECT: WOODARD BAY FEASIBILITY STUDY - ALTERNATIVE 4

ITEM DESCRIPTION		QUANTITY	UNIT	BARE UNIT COST	SUBTOTAL
STRUCTURAL ESTIMATE - TRESTLE PIER DEMO					
MOBILIZATION		2	EA	$20,000	$40,000
PIER SECTION 5 (Stations 24 to 30) Approx Ln = 560ft					
Pile Removal		3900	VLF	$18	$70,200
Pile Disposal		390	CY	$175	$68,250
Lumber Removal		70	MBF	$2,750	$192,500
Lumber Disposal		216	CY	$175	$37,800
		Subtotal Section 5 w/o Mobilization			$368,750
Gravel Fill Around Pulled Piles		1650	CY	$15	$24,750
Add for Cut/Fill at Broken Piles		25	EA	$500	$12,500
PIER SECTION 4 (Stations 18 to 24) Approx Ln = 620ft					
Pile Removal		5800	VLF	$18	$104,400
Pile Disposal		580	CY	$175	$101,500
Lumber Removal		64	MBF	$2,750	$176,000
Lumber Disposal		198	CY	$175	$34,650
		Subtotal Section 4 w/o Mobilization			$416,550
Gravel Fill Around Pulled Piles		1800	CY	$15	$27,000
Add for Cut/Fill at Broken Piles		29	EA	$500	$14,500
PIER SECTION 3(-) (Stations 11.4 to 18) Approx Ln = 680ft					
Pile Removal		5300	VLF	$18	$95,400
Pile Disposal		530	CY	$175	$92,750
Lumber Removal		51	MBF	$2,750	$140,250
Lumber Disposal		157	CY	$175	$27,475
		Subtotal Section 3 w/o Mobilization			$355,875
Gravel Fill Around Pulled Piles		2000	CY	$15	$30,000
Add for Cut/Fill at Broken Piles		26	EA	$500	$13,000
PIER SECTION 2(-) (Stations 3 to 6.5) Approx Ln = 330ft					
Pile Removal		3400	VLF	$18	$61,200
Pile Disposal		340	CY	$175	$59,500
Lumber Removal		45	MBF	$2,750	$123,750
Lumber Disposal		139	CY	$175	$24,325
		Subtotal Section 2 w/o Mobilization			$268,775
Gravel Fill Around Pulled Piles		1000	CY	$15	$15,000
Add for Cut/Fill at Broken Piles		19	EA	$500	$9,500
PIER SECTION 1 (Stations 0 to 3) Approx Ln = 320ft					
Pile Removal	Includes 650 VLF for 'Y'	3950	VLF	$18	$71,100
Pile Disposal		395	CY	$175	$69,125
Lumber Removal	Includes 14.5 MBF for 'Y'	85.5	MBF	$2,750	$235,125
Lumber Disposal		264	CY	$175	$46,200
		Subtotal Section 1 w/o Mobilization			$421,550
Gravel Fill Around Pulled Piles	Includes 300 CY for 'Y'	1300	CY	$15	$19,500
Add for Cut/Fill at Broken Piles		30	EA	$500	$15,000
	SUB-TOTAL CONSTRUCTION COSTS THIS SHEET =				$2,052,250

CONSTRUCTION COST ESTIMATE
WINDWARD ENVIRONMENTAL

FILE: 2009-07-31 Budgetary Alt 4
DATE: Sep-09
ESTIMATE BY: M. Bock
STATUS OF DESIGN: BUDGETARY FEASIBILITY
JOB No.: 14127

SITTS AND HILL ENGINEERS, INC.
4815 CENTER ST.
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PROJECT: WOODARD BAY FEASIBILITY STUDY - ALTERNATIVE 4

ITEM DESCRIPTION	QUANTITY	UNIT	BARE UNIT COST	SUBTOTAL
STRUCTURAL ESTIMATE - TRESTLE PIER DEMO				
PARTIAL TRUCK TRESTLE (Stations 0 to 6.5)				
Pile Removal	4100	VLF	$18	$73,800
Pile Disposal	410	CY	$175	$71,750
Lumber Removal	38	MBF	$2,750	$104,500
Lumber Disposal	117	CY	$175	$20,475
	Subtotal Truck Trestle w/o Mobilization			$270,525
Add for Cut/Fill at Broken Piles	26	EA	$500	$13,000
CONCRETE ABUTMENT REMOVAL AND DISPOSAL	24	CY	$200	$4,800
PIER LANDING FILL REMOVAL AND DISPOSAL	28000	CY	$18	$504,000
			SUB-TOTAL CONSTRUCTION COSTS THIS SHEET =	$792,325
			TOTAL FOR PIER REMOVAL =	$2,844,575

CONSTRUCTION COST ESTIMATE
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PROJECT: WOODARD BAY FEASIBILITY STUDY - ALTERNATIVE 4

ITEM DESCRIPTION	QUANTITY	UNIT	BARE UNIT COST	SUBTOTAL
STRUCTURAL ESTIMATE - BAT HABITAT REPAIR				
REMOVE EXISTING RAILS/METAL SHEATHING	1	TON	$250	$250
EPOXY REPAIR MAIN TIMBERS	200	SF	$10	$2,000
REPLACE 30% TIMBERS FROM SALVAGE	80	LF	$25	$2,000
SPACERS BETWEEN TIMBERS AT 10' O.C.	40	LF	$6	$240
SHEET METAL CAP ON TIMBERS	450	SF	$8	$3,600
ALLOTMENT FOR MAINTENANCE IN YEARS 10, 20, AND 30	3	EA	$10,000	$30,000
SUB-TOTAL CONSTRUCTION COSTS THIS SHEET =				$38,090

CONSTRUCTION COST ESTIMATE
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PROJECT: WOODARD BAY FEASIBILITY STUDY - ALTERNATIVE 4

ITEM DESCRIPTION	QUANTITY	UNIT	BARE UNIT COST	SUBTOTAL
STRUCTURAL ESTIMATE - TRESTLE BRIDGE DEMO				
MOBILIZATION	1	EA	$20,000	$20,000
TRESTLE REMOVAL				
Pile Removal	6000	VLF	$12	$72,000
Pile Disposal	600	CY	$175	$105,000
Lumber Removal	90	MBF	$2,750	$247,500
Lumber Disposal	278	CY	$175	$48,650
Sub-total, Trestle Removal and Disposal				$493,150
NORTH EMBANKMENT REMOVAL AND HAUL (5 Mile Haul)	40000	CY	$18	$720,000
SOUTH EMBANKMENT REMOVAL AND HAUL (5 Mile Haul)	11000	CY	$18	$198,000
SUB-TOTAL CONSTRUCTION COSTS THIS SHEET =				$1,411,150

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PROJECT: WOODARD BAY FEASIBILITY STUDY - ALTERNATIVE 4

ITEM DESCRIPTION	QUANTITY	UNIT	BARE UNIT COST	SUBTOTAL
STRUCTURAL ESTIMATE - WOODARD BAY DR BRIDGE				
DEMOLITION				
MOBILIZATION	1	EA	$15,000	$15,000
ADDITIONAL DIVISION 1 COSTS FOR BRIDGE REPLACEMENT	1	EA	$50,000	$50,000
BRIDGE REMOVAL AND DISPOSAL				
12" Dia Steel Pile Removal and Disposal	360	VLF	$35	$12,600
Concrete Removal and Disposal	110	C.Y.	$250	$27,500
Guard Rail Removal and Disposal	130	LF	$15	$1,950
EMBANKMENT REMOVAL AND HAUL (5 Mile Haul)				
East Embankment	46700	C.Y.	$19	$887,300
West Embankment	44500	C.Y.	$19	$845,500
Sub-total, Bridge and Embankment Demolition				$1,839,850
REPLACEMENT CONSTRUCTION				
PROFESSIONAL SERVICES / ADMINISTRATION	1	EA	$400,000	$400,000
EMBANKMENT SITE WORK FILL	1000	C.Y.	$75	$75,000
ROAD (ASPHALT) RECONSTRUCTION	1000	S.F.	$50	$50,000
BRIDGE RECONSTRUCTION (440 ft long, 30 ft wide, 30' clear spans)	13200	S.F.	$175	$2,310,000
SUB-TOTAL CONSTRUCTION COSTS THIS SHEET =				$4,674,850

CONSTRUCTION COST ESTIMATE
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PROJECT: WOODARD BAY FEASIBILITY STUDY - ALTERNATIVE 4

ITEM DESCRIPTION	QUANTITY	UNIT	BARE UNIT COST	SUBTOTAL
STRUCTURAL ESTIMATE - WOODARD BAY DR BRIDGE MODIFICATION				
MOBILIZATION	1	EA	$15,000	$15,000
ADDITIONAL DIVISION 1 COSTS FOR BRIDGE MODIFICATION	1	EA	$50,000	$50,000
PROFESSIONAL SERVICES / ADMINISTRATION	1	EA	$25,000	$25,000
BRIDGE MODIFICATION				
Auger-cast Concrete Piles	120	VLF	$150	$18,000
Concrete Pile Cap	15	C.Y.	$350	$5,250
Structural Steel	20	Ton	$3,500	$70,000
EXISTING PIPE PILE REMOVAL AND DISPOSAL	180	VLF	$35	$6,300
SUB-TOTAL CONSTRUCTION COSTS THIS SHEET =				$189,550

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PROJECT: WOODARD BAY FEASIBILITY STUDY - ALTERNATIVE 4

ITEM DESCRIPTION	QUANTITY	UNIT	BARE UNIT COST	SUBTOTAL
STRUCTURAL ESTIMATE - ANCHOR PILE REMOVAL				
MOBILIZATION	1	EA	$20,000	$20,000
PILE REMOVAL AND DISPOSAL				
North Storage Area (Est 49 Piles, Barge removal at 6/day)	6	DAYs	$3,600	$21,600
Disposal	200	C.Y.	$175	$35,000
Main Operational Area (Est 480 Piles, Barge removal at 6/day)	80	DAYs	$3,600	$288,000
Disposal	240	C.Y.	$175	$42,000
South Storage Area (Est 29 Piles, Barge removal at 6/day)	4	DAYs	$3,600	$14,400
Disposal	120	C.Y.	$175	$21,000
CUT-OFF/FILL AT BROKEN PILES				
North Storage Area (Est 10 Piles, Diver w/ barge fill, add for small job)	2	DAYs	$3,000	$6,000
Main Operational Area (Est 100 Piles, Diver w/ barge fill)	20	DAYs	$2,500	$50,000
South Storage Area (Est 6 Piles, Diver w/ barge fill, add for small job)	1	DAYs	$3,000	$3,000
LOG BOOM				
Removal	1000	LF	$75	$75,000
Disposal (Assume Creosote Treated Logs)	30	CY	$150	$4,500
SUB-TOTAL CONSTRUCTION COSTS THIS SHEET =				$580,500

CONSTRUCTION COST ESTIMATE
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ITEM DESCRIPTION	QUANTITY	UNIT	BARE UNIT COST	SUBTOTAL
STRUCTURAL ESTIMATE - NEW SEAL HAUL-OUT				
MOBILIZATION	1	EA	$20,000	$20,000
EMBEDDED PILE LENGTH (Steel Pipe Piles)	2400	VLF	$20	$48,000
HAUL-OUT FLOATS	1800	SF	$60	$108,000
Sub-Total, Construct New Seal Haul-out				$176,000
STRUCTURAL ESTIMATE - SEAL HAUL-OUT MAINTENANCE				
YEARLY MAINTENANCE	29	EA	$1,500	$43,500
SUB-TOTAL CONSTRUCTION COSTS THIS SHEET =				$219,500

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ITEM DESCRIPTION	QUANTITY	UNIT	BARE UNIT COST	SUBTOTAL
STRUCTURAL ESTIMATE - RESTORE RIPARIAN ZONE				
RESTORE RIPARIAN ZONE	15	AC	$15,000	$225,000
SUB-TOTAL CONSTRUCTION COSTS THIS SHEET =				$225,000

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ITEM DESCRIPTION	QUANTITY	UNIT	BARE UNIT COST	SUBTOTAL
SUMMARY AND DIVISION 1 COSTS				
MISCELLANEOUS DIVISION 1 COSTS FOR ALTERNATIVE 4	1	EA	$200,000	$200,000
OUT-OF-STATE MOBILIZATION	2	EA	$150,000	$300,000
CHAPMAN BAY PIER				$2,844,575
BAT HABITAT REPAIR				$38,090
WOODARD BAY TRESTLE				$1,411,150
ANCHOR PILE REMOVAL				$580,500
SEAL HAUL-OUT REPLACEMENT				$219,500
RIPARIAN ZONE IMPROVEMENT				$225,000
SUB-TOTAL CONSTRUCTION COSTS ALT 4 =				$5,818,815
15% OVERTIME PAY SURCHARGE =				$872,822
20% WINTER PREMIUM =				$1,163,763
30% CONTINGENCY =				$1,745,645
10% CONTRACTOR OVERHEAD AND PROFIT =				$581,882
TOTAL CONSTRUCTION COSTS ALT 4A =				$10,182,926
Add for Woodard Bay View Drive BRIDGE MODIFICATION (Includes Overtime Pay Surcharge, Winter Premium, Contingency, Overhead and Profit) TOTAL COSTS ALT 4B =				$331,713
Add for Woodard Bay View Drive BRIDGE REPLACEMENT (Includes Overtime Pay Surcharge, Winter Premium, Contingency, Overhead and Profit) TOTAL COSTS ALT 4C =				$8,180,988