FIDALGO BAY CAUSEWAY

FEASIBILITY STUDY REPORT

FIDALGO BAY, WASHINGTON

PREPARED FOR THE

SAMISH INDIAN NATION

Fidalgo Bay Causeway
Feasibility Study Report

Fidalgo Bay, Washington

PREPARED FOR THE

SAMISH INDIAN NATION

Prepared by

RIDOLFI Inc.

September 2008

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LIST OF ABBREVIATIONS AND ACRONYMS

Ecology	Washington Department of Ecology
FS	Feasibility Study
MLLW	mean lower low water
PAH	polycyclic aromatic hydrocarbons
Ridolfi	RIDOLFI Inc.
SVOC	semi-volatile organic compounds
Tribe	Samish Indian Nation
WDNR	Washington Department of Natural Resources

LIST OF UNITS

CY	cubic yards
ft	feet
mg/kg	milligram per kilogram
mg/L	milligram per liter

1.0 INTRODUCTION

This report summarizes a feasibility study (FS) prepared on behalf of the Samish Indian Nation (Tribe) that evaluated modifying a former railroad trestle that roughly bisects Fidalgo Bay (Figure 1). Fill was added to a portion of the former trestle to form a causeway and a remaining section of trestle. As a result of the addition of fill material, the natural tidal circulation into Fidalgo Bay has been restricted to a narrow channel below the trestle. The goal of the project is enhance habitat in Fidalgo Bay by restoring tidal circulation while maintaining the function of the causeway and trestle as a walking and bicycle path. This study consisted of evaluating existing site conditions and possible future site conditions under scenarios where the causeway east of Weaverling Point would be modified or removed.

1.1 Project Background

Over the last several years, staff from the Natural Resources Department at the Tribe had observed that the causeway affects the flow of water within Fidalgo Bay and suspected that portions of the structure are having a detrimental effect on habitat quality. To address these issues, the Tribe and the Washington Department of Ecology (Ecology) developed intergovernmental agreement that provides funding for the study and outlines the terms of study. Funds for the study were secured by Ecology through the Puget Sound Initiative. As such, the study is one of several ongoing efforts to evaluate and improve conditions within Puget Sound.

Ecological conditions throughout Fidalgo Bay have been altered by shoreline armoring and development, dredging, and filling (Battelle, 2003; SAIC, 2007; Williams et al., 2003). Since 1891, approximately 47 acres of Fidalgo Bay have been filled, which includes the fill placed to create the causeway (Williams et al., 2003). A navigational channel is also maintained in Fidalgo Bay by periodic dredging. Filling and dredging activities alter marine habitat elevations and can result in loss of habitat functions and, thereby, result in loss of critical habitat (PSAT, 1998). Many aquatic species are dependent on specific tidal elevations without which they cannot complete their life cycles.

Approximately 29,000 feet or 64.7 percent of the shoreline in Fidalgo Bay is armored (Williams et al., 2003), including 4,800 feet of riprap along both sides of the causeway. Shoreline armoring impedes natural processes which can have negative impacts on aquatic habitats directly adjacent to the armored shoreline as well as habitats that may be quite far from the shoreline. Armoring can restrict tidal currents and increase turbulence and wave action. Armoring alters geological processes, reducing erosion and accretion of sediments along shorelines. Additionally, armoring disconnects riparian vegetation from the shoreline and blocks large woody debris from entering the system (Gerstel W.J. and J. Brown, 2006).

Overwater structures including docks and the trestle impair approximately eight acres of aquatic habitat in Fidalgo Bay (Williams, 2003). For example, overwater structures block sunlight from penetrating the water column which is necessary for eelgrass to flourish. Overwater structures can also affect the migration patterns of certain fish species, particularly juvenile salmonids (Simenstad, C.A., et al., 1999). Juvenile salmonids typically avoid shaded areas where predators may be present.

Since 1997, numerous environmental investigations have been conducted throughout Fidalgo Bay (SAIC, 2007). Results from the studies have shown that sediment quality within the project area and the inner bay is in compliance with screening criteria. Some contaminants, such as polycyclic aromatic hydrocarbons (PAHs) have been detected at higher concentrations than reference areas sampled in Padilla Bay (WDNR, 2007).

Fidalgo Bay is listed on Washington State's 2004 list of impaired waters for two contaminants, chrysene and benzo(a)anthracence. (Ecology, 2006). The PAHs, chrysene and benzo(a)anthracene, were detected in littleneck clam soft-parts at concentrations exceeding the National Toxic Rule criterion.

1.2 Site Description

Fidalgo Bay is a shallow bay located in Water Resource Inventory Area 3, Lower Skagit/Samish. The majority of the Bay is comprised of mudflats generally less than 10 feet deep at mean lower low water (MLLW). A natural channel approximately 15 to 20 feet deep runs through the central portion of the Bay. No significant freshwater streams discharge to Fidalgo Bay (Battelle, 2003).

Higher elevations of the Bay include salt marshes and sand and gravel beaches. Lower elevations function as highly productive mudflat habitats and support microalgae and macroalgae. Extensive native eelgrass beds are also found throughout the Bay. Eelgrass habitats provide spawning, rearing, and foraging areas for numerous migratory and resident fish species, as well as native shellfish and crab species. Migratory and resident bird species are found in the area as well.

The eelgrass beds in Fidalgo Bay are comprised of the native species *Zostera marina* and the non-native species *Zostera japonica*. The native, *Zostera marina*, is found at elevations ranging from approximately +1 to -18 feet MLLW in the Bay. The non-native, *Zostera japonica*, is found in the upper intertidal zone of the Bay, at elevations generally higher than *Zostera marina* (Battelle, 2003). A study conducted in Padilla Bay in 2000 found that *Zostera japonica* covered approximately 21 percent of the vegetated area in Padilla Bay; it is assumed that if a study of this nature was conducted in Fidalgo Bay, the findings would be similar (Battelle, 2003).

The 4,380-foot Tommy Thompson Trail was converted from a former railroad causeway and trestle that crosses Fidalgo Bay in Anacortes, Washington (Figure 1). The trail is used for recreational activities such as walking, running, and bicycling. The recreational trail is owned and managed by the City of Anacortes. The causeway and trestle runs parallel to tribally-owned land on the western shore of Fidalgo Bay at Weaverling Spit and extends over state-owned aquatic lands to the eastern shore of Fidalgo Bay on March Point. The aquatic lands are administered by the Tribe and Washington Department of Natural Resources (WDNR). WDNR has recently proposed establishing Fidalgo Bay as an Aquatic Reserve (WDNR, 2007).

The former railroad trestle was constructed on creosote pilings. Approximately 2,360 feet of the creosote pilings, beginning at Weaverling Spit and extending out into Fidalgo Bay, were backfilled with fill material and riprap to create the causeway. Soil along the causeway is fill material consisting of silty sand, gravel, and cobbles. Approximately 770 creosote pilings provide support for the remaining 2,020 feet of trestle (Figure 2). During a reconnaissance field trip to the Site, Ridolfi staff observed creosote dripping from several of the newer pilings (see cover photo). As a result, layered creosote rings surround the bases of the several of the newer creosote-pilings (see cover photo).

1.3 Scope of the Feasibility Study

The current study included several related but separate sub-studies. The scope of this feasibility study was to evaluate chemical and physical conditions around the causeway to help support a decision-making process regarding the disposition of the causeway. It is intended that this report will help provide a basis for decision making and as an aid in planning future studies as appropriate. This report was not intended to evaluate the cost of specific alternatives because some of the information that would be needed to develop cost estimates, such as the volume of contaminated sediment under the trestle is not available. First, there was a sample collection and chemical analysis. The results of the sampling and analysis were summarized in a Chemistry Results Report submitted to the Tribe in May, 2008 (Appendix A). The sampling was conducted to determine the extent of contamination from creosote pilings and potentially contaminated fill in the vicinity of the causeway. Additionally, the sampling was intended to document baseline environmental conditions that will support the feasibility study being conducted to evaluate removal or modification of the causeway, a former railroad trestle.

Second, a limited habitat survey was conducted to document biological conditions directly adjacent to the causeway. This survey was accomplished by observing conditions at the sediment-water interface and in shallow holes dug to examine subsurface fauna. This direct inspection of the substrate was supplemented by a video survey of biota recorded by a dive team while inspecting the physical condition of the pilings.

Third, hydrodynamic modeling was used to examine changes in water flow that might be induced by modifying the causeway portion of the structure (see Appendix B). This task helped evaluate the positive effects of removing the causeway, such as habitat creation, against the negative effects, such as the potential for scour.

2.0 DEVELOPMENT AND COMPARISON OF ALTERNATIVES

This section describes and compares five alternatives, including the "no-action" alternative, which is presented as a baseline against which the action alternatives are compared. More detail is given to the description of the No Action Alternative because this alternative describes current conditions at and adjacent to the causeway.

2.1 Alternative 1: No Action

2.1.1 Description of Existing Conditions

Under this alternative, the causeway and trestle would remain in the current condition. As described in Section 1.2, the combined structure is approximately 4,380 feet long, of which the trestle portion is approximate 2,020 feet long. The causeway portion of the structure covers approximately 4.1 acres of mudflat. Poor quality intertidal habitat on the riprap embankment supports barnacles and little else. The trestle portion of the structure allows relatively unobstructed flow of water within Fidalgo Bay. The trestle is constructed of approximately 770 creosote-treated pilings.

2.1.2 Biological Conditions

A biological survey was conducted to document the baseline environmental conditions in sediment adjacent to the causeway and trestle. The biological survey is intended to provide baseline information about the habitats and species found adjacent to the causeway. The baseline biological information is based on observations of the substrates and terrestrial and aquatic species that were encountered during the biological survey event.

The biological survey was conducted on June 3, 2008 during a -3.6 foot tide, which occurred at 10:37. The survey began at 10:20 and was completed at 14:00. The lowest elevation survey stations, in the vicinity of the trestle, were surveyed first to ensure that the areas were free of tidal water.

Each biological survey station occupied a sediment sample location as determined with a handheld GPS unit. The sediment sample locations are on the north and south of the causeway and trestle. Six stations are adjacent to the causeway and six stations are adjacent to the trestle. Table 3 provides the horizontal coordinates for each sediment sample location and Figure 2 provides an aerial overview of the sediment sample locations.

The biological survey was accomplished by placing a 0.25 square meter (0.5 x 0.5 meter) quadrat over each sediment sample location. After placing the quadrat, a surface survey was conducted. All organisms encountered on the surface were identified to species if possible and a description of the substrate was recorded. After the surface survey was completed, a clam shovel was used to dig in the area of the quadrat to a depth of approximately 12 inches. All benthic invertebrates encountered in the dug area were identified to species. When identifying mollusks, only intact shells, with a living organism inside, were included in the species count. General observations of the substrates and terrestrial and aquatic species encountered within the quadrat; including the dug survey hole, were documented in the field notebook. If possible, empty or broken shells encountered during the surface and subsurface survey were identified and recorded with the substrate descriptions.

Arthropods, marine worms, mollusks, and seaweed were encountered during the survey. A total of eighteen species were documented at the twelve survey stations. Table 3 provides the common names and scientific names of all species recorded during the survey and Table 3 summarizes the species that were present at each of the survey stations. Table 3 also provides the horizontal coordinates, elevations, and substrate descriptions for each of the survey stations.

At least one species was recorded at each of the survey stations. Species diversity ranged from 1 to 11 at each of the survey stations. The largest number of species was recorded at survey station SD-04. Survey station SD-04 had three species present during the surface survey and eight species present during the subsurface survey for a total of eleven species. Survey station SD-04 is at an elevation of approximately six feet and is on the north side of the causeway. The survey station with the least number of species recorded was SD-10. No species were documented during the surface survey at SD-10 and only one species, blood worm, was documented during the subsurface survey. SD-10 is at an elevation of 2.5 feet and is on the south side of the trestle.

Species assemblage was greatest at the six survey stations adjacent to the causeway (SD-01 thru SD-06). Survey stations adjacent to the causeway have elevations ranging from approximately 2 to 6 feet. Species diversity ranged from 7 to 11 in this area. Species assemblage was lowest at the six survey stations adjacent to the trestle (SD-07 thru SD-12), ranging from 1 to 8. Survey stations adjacent to the trestle have elevations ranging from approximately 2 to 7 feet.

Rockweed or sea lettuce was observed on the surface of all of the survey stations with the exception of SD-10 and SD-12. SD-10 was the only survey station where Manilla clams were not present. Although living Pacific oyster were observed throughout the study area, none were documented at any of the survey stations.

A dive survey was conducted in October 2007 to investigate the structural integrity of the pilings and record other observations.

Based on observations made during the dive survey, the pilings in the inter-tidal zone are covered with small sea anemones (coelenterate), sea squirts and sponges (tunicates), barnacles (arthropod), and sea stars (echinoderm). The animal population near the causeway includes Dungeness crab, red rock crab, decorator crab, oysters, perch, and other small fish (Nisqually Dive Technologies, 2008).

2.1.3 Chemical Conditions

Ridolfi staff collected soil, sediment, and surface water samples on and adjacent to the causeway in 2007 as described in detail in Appendix A. This section provides a brief summary of the important findings. Figure 2 shows where the samples were collected.

- **Sediments**: Copper was the only metal reported at concentrations greater than a sediment screening level, and only in one sample. Several semi-volatile organic compounds

(SVOCs), including polycyclic aromatic compounds (PAHs) were detected at concentrations greater than the screening levels in sediment at the site. The greatest concentrations of PAHs were detected at sediment sample locations adjacent to the creosote-piling trestle. Fourteen PAHs were detected in samples from this area with concentrations exceeding screening levels by up to one order of magnitude. The largest numbers of PAHs with the highest concentrations exceeding screening levels were detected in samples from SD-08 and SD-11 (Figure 3).

- **Soils:** Six metals and three PAHs were detected at concentrations greater than screening levels. The highest concentrations of PAHs were detected at SS-01 (Figure2). Arsenic, chromium, copper, mercury, and lead concentrations were slightly greater than natural background soil concentrations for Puget Sound in a few of the samples.
- **Surface Water:** The concentration of silver exceeded the screening criteria but the analytical method is relatively insensitive at the reported concentrations. Cadmium, copper, and lead were not detected, but may be present at concentrations above screening levels but below the detection limits. SVOCs were not detected in surface water.

2.2 Elements Common to the Action Alternatives

The sediment samples collected near the pilings on the eastern side of the structure indicate that there is an area of creosote-impacted sediment that exceeds sediment management standards. For planning purposes, it is assumed that the creosote-treated pilings and contaminated sediment will be removed. The extent of contaminated sediment has not been defined because that effort was beyond the scope of the current study. Assuming the trail is to be retained, the creosote pilings would be replaced with concrete or steel pilings or piers that would be environmentally benign.

2.3 Alternative 2: Maximal Causeway Removal

Alternative 2 is presented as a “bookend” to the existing conditions because it includes the most extensive removal of the causeway from the tip of Weaverling Spit eastward. The portion of the causeway removed would be replaced with an elevated bridge deck. Additionally, creosote-treated pilings under the trestle would be replaced with concrete pilings or a pier to reduce environmental impacts associated with creosote. This alternative would entail removing between 32,400 cubic yards (CY) of material including riprap fill material (Table 1). Additionally, approximately 630 pilings buried within the causeway would be removed, assuming the piling spacing is similar to that seen under the trestle (Table 2). The estimated length of removal is approximately 1,660 feet. This alternative would restore approximately 3.8 acres of intertidal habitat. The hydrodynamic modeling suggests that the tidal flow would be significantly dispersed relative to the existing pattern. The water velocities would be reduced in the deep north- south channel at the east end of the causeway. The flow of water around Weaverling Spit would approach its historical pattern which may change the configuration of the sand bar that is presently located off of the northeast tip of the spit.

2.4 Alternative 3: Six Hundred Foot Removal

Alternative 3 entails removing three separate 200-foot long sections of the causeway, which would be replaced with three bridge spans. This alternative was developed to allow significant and spatially distinct flow through the causeway at a lower cost than Alternative 3. If this alternative is implemented, the volume of riprap and fill requiring removal of approximately 11,700 CY of fill (Table 1). Approximately 230 pilings would require removal and disposal to create the openings (Table 2). The openings would provide a significant increase in flow to the southern portion of Fidalgo Bay without increasing velocities within the channels to the degree that scour is considered likely. Alternative 3 would restore approximately 1.4 acres of intertidal habitat by removing the causeway materials.

2.5 Alternative 4: One Hundred Foot Removal

Alternative 4 would involve removing a single 100-foot section of causeway and replacing it with a bridge to cross the span. This alternative was considered to be the smallest span that would reasonably be considered to meet the objectives established for the project. Approximately 3,900 CY of riprap and fill would be removed to create the opening, which would create approximately 0.23 acres of intertidal habitat (Table 1). While removing the fill, it is anticipated that some 38 pilings (Table 2) will be encountered and require removal. The hydrodynamic modeling for this alternative indicates that flow will be directed into the 100-foot opening, which would enhance circulation somewhat. However, the relatively small opening may promote localized scour due to a funneling effect.

2.6 Alternative 5: Two Hundred Foot Removal

Alternative 5 would involve removing a single 200-foot section of causeway and replacing it with a bridge to cross the span. This alternative would require removal and disposal of between 2,000 CY of fill and riprap, and create 0.46 acres of habitat within the footprint of the former causeway (Table 1). In the course of removing the causeway materials, it is anticipated that 76 pilings are within the footprint and would require removal and disposal. The hydrodynamic modeling indicates that water would flow through a 200 foot opening if created. This would enhance circulation in the southern portion of Fidalgo Bay. Although not quantified, it is anticipated that scour is less likely under Alternative 5 then under Alternative 4 because the opening is twice as wide.

3.0 OTHER CONSIDERATIONS

There are a variety of considerations that must be considered before any of the alternatives described above can be implemented. This section discusses some of these factors.

3.1 Geotechnical Data to Support Design

The action alternatives include removal and replacement of the creosote-treated pilings on the east half of the structure and replacing those pilings with either concrete or steel pilings or piers. Geotechnical data regarding the strength of the foundation materials under the trestle would be needed to facilitate this design. Collecting these data might require collecting samples of the material using a drill rig, using a cone penetrometer to push a tool that continuously measures soil properties, or conducting a seismic survey. A geotechnical engineer with marine experience should be consulted to develop a scope of work for these activities.

3.2 Contamination Issues

As described in Section 2.1.2 and in Appendix A, sediment adjacent to the pilings contains PAHs (creosote-related chemicals) at concentrations that exceed Ecology's sediment management standards. It was beyond the scope of this study to quantify the extent of contamination or develop remedial alternatives for the sediment. As a rough order of magnitude estimate, if the sediment under the entire 2,020-foot length of the trestle is contaminated to a width of 20 feet and a depth of 3 feet, the volume is approximately 4,500 CY. Typical remedies for contaminated sediments include dredging and offsite disposal, capping, and natural recovery. It bears emphasis that a significant amount of additional sampling would be required to calculate a representative volume estimate. The area requiring such sampling may include the historical sediment interface under the riprap embankment where creosote contamination may be buried. This contamination, should it exist, is currently entombed and as such is not likely to be causing substantial effect to aquatic receptors. However, if one of the action alternatives is implemented, this historical interface would likely be re-exposed and the chance of adverse effects would rise accordingly.

In addition to sediment contamination, the creosote-treated pilings represent an ongoing source of contamination to the environment. The cost of removing and disposing of these pilings will be a substantial cost factor in retrofitting the trestle. It may be prudent to collect wood cores of several pilings to characterize the chemical concentrations within the pilings for waste disposal purposes. This will aid in developing cost estimates for removal and disposal of the pilings.

3.3 Bridge Design

Once an alternative is selected for the causeway structure, it will be necessary to design replacement bridge spans for the openings. There are several manufacturers that offer design build solutions for pedestrian bridges. It may be cost effective to work with one of these companies on the design phase of the project.

3.4 Permitting Considerations

Given the location of the project, numerous permits and regulatory consultations will be required to complete the work. To apply for these permits, the design will need to be completed to sufficient detail that the regulatory agencies can evaluate the positive and negative effects of the project. The list of potential permits includes:

- Section 10 and Section 404 permits from the US Army Corps of Engineers;
- A Hydraulic Project Approval from the Washington Department of Fish and Wildlife;
- A Section 401 Water Quality Certificate from the Washington Department of Ecology;
- Endangered Species Act consultations with the National Oceanic and Atmospheric Administration Fisheries Service and the U.S. Fish and Wildlife Service, which requires completing a biological assessment report for the project; and
- Grading and building permits and State Environmental Policy Act checklist (at a minimum) from the City of Anacortes and or Skagit County.

4.0 SUMMARY

This study evaluated various factors regarding the feasibility of removing a portion the Tommy Thompson causeway and trail where it bisects Fidalgo Bay. The structure is currently used as a trail that is heavily used by local residents for walking and biking. As such, it converted a little-used railroad structure into something that provides significant benefit to the public. However, the pilings supporting the trestle degrade aquatic habitat by introducing creosote-related chemicals into the environment. Additionally, the presence of the riprap embankment on the western portion of the trail supplants the historical mudflats and alters tidal circulation in the southern portion of Fidalgo Bay.

Chemical testing of sediment, soil, and surface water identified PAHs, a creosote-related set of chemicals in surface sediment samples collected near the pilings. The extent of contamination was not determined either laterally or vertically but it is likely to be limited to a zone within a few feet or few tens of feet of pilings. Chemical concentrations in soil (the fill material in the causeway embankment) and surface water were below or near screening levels are not anticipated to drive cleanup decisions.

A limited biological survey was conducted in two phases. In the first phase, divers from Nisqually Aquatic Technologies shot video footage while inspecting the pilings under the trestle. Barnacles, sea anemones, and other organisms were observed to be attached to the pilings in subtidal and intertidal areas. In a second phase, the surface sediment and shallow subsurface sediment (6 inches) was surveyed in locations along the causeway and under the trestle. In these locations, a variety of clam species were observed to inhabit the sediment and numerous shell fragments were observed. These observations seemed “typical” of the environments that were sampled but a rigorous comparison to pristine or background areas was not conducted.

Hydrodynamic modeling was used to study surface water flow under existing conditions (Alternative 1) and under four action alternatives. The model was developed to simulate water elevations and predict velocity over several tidal cycles. Alternative 2 assumes that the causeway would be removed from the tip of Weaverling Spit east to the end of the trestle and replaced with a piling or pier supported bridge deck. This approach would allow restoration of intertidal habitat now covered with riprap and would restore historical flow patterns in the southern portion of Fidalgo Bay. Three other alternatives were modeled that had openings in the causeway ranging from 600 feet (Alternative 3), to 100 feet (Alternative 4), and 200 feet (Alternative 5). These alternatives were developed to predict flow patterns in the southern portion of Fidalgo Bay with less extensive and therefore less expensive restoration efforts. All of the alternatives are technically feasible, however, alternative 4 seemed to offer limited flow improvements and may promote localized scour because of the degree to which flow is funneled through a relatively small (100 foot) opening.

The next steps for the project are to engage stakeholder participation in an alternative selection process and to conduct additional studies to better define the extent of contaminated sediments under the trestle. These studies can be used to prepare cost estimates for the project and develop a funding plan for implementing the selected remedy.

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TABLES

Table 1 Causeway Removal Areas and Volumes

Alternative	Length (ft)	Area (acres)	Volume (cy)
2	1,660	3.8	32,362
3	600	1.38	11,718
4	100	0.23	3,906
5	200	0.46	1,953

The removal volumes were calculated using GIS spatial analyst tools.
ft = feet, cf = cubic feet, cy = cubic yards.

Table 2 Estimated Numbers of Pilings within the Causeway

Alternative	Length (ft)	Number of Pilings (1)
2	1,660	634
3	600	229
4	100	38
5	200	76

(1) The number of pilings within the causeway embankment is assumed to be similar to the number under the trestle on a linear foot basis. There are approximately 770 pilings under the 2,360 foot trestle, which equates to the equivalent of one piling per 2.62 linear feet of trestle.

FIGURES

N

0 1

Miles

Legend

Project Area

Figure 1
Fidalgo Bay Location and Vicinity

Fidalgo Bay Causeway Feasibility Study
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Figure 2
Sample Locations

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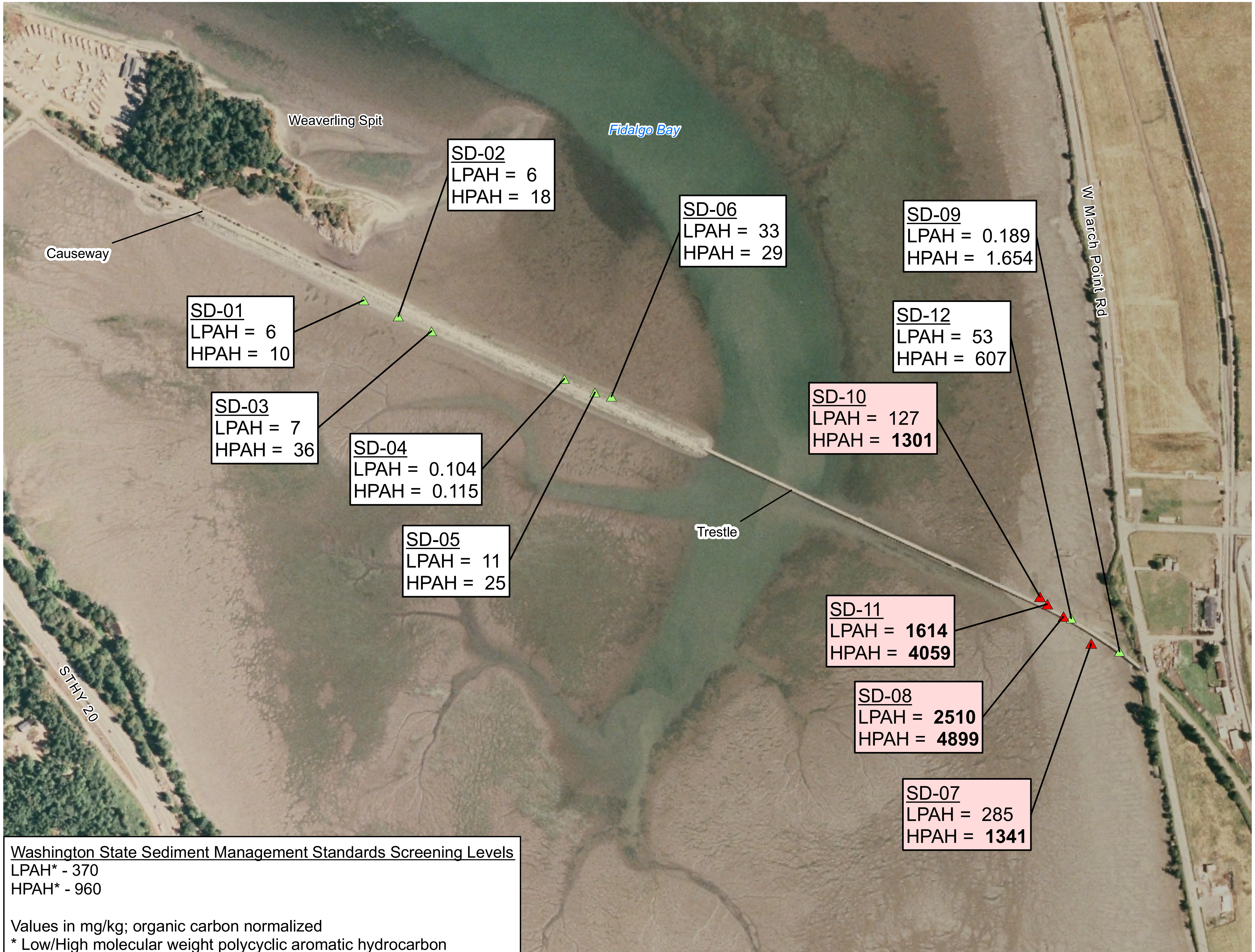

Legend

- ▲ (red) Samples Exceeding Washington State Sediment Management Standards Screening Levels
- ▲ (green) Sediment Sample
- 2006 Orthophoto

0 400
Feet

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Figure 3
Sediment Sample Results

Fidalgo Bay Causeway Feasibility Study
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APPENDIX A

CHEMISTRY RESULTS REPORT

CHEMISTRY RESULTS REPORT

FIDALGO BAY CAUSEWAY FEASIBILITY STUDY

FIDALGO BAY, WASHINGTON

PREPARED FOR THE

SAMISH INDIAN NATION

CHEMISTRY RESULTS REPORT

FIDALGO BAY CAUSEWAY FEASIBILITY STUDY

FIDALGO BAY, WASHINGTON

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Figure 2. Sample Locations

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Attachment A. Analytical Results

LIST OF ABBREVIATIONS AND ACRONYMS

AET	apparent effects threshold
ARI	Analytical Resources Inc.
DDT	dichlorodiphenyltrichloroethane
Eco-SSL	ecological soil screening level
Ecology	Washington State Department of Ecology
ERL	effects range-low
MDL	method detection limit
MLLW	mean lower low water
MRL	method reporting limit
MTCA	Model Toxics Control Act
NRWQC	National Recommended Water Quality Criteria
NWTPH-Dx	Northwest total petroleum hydrocarbon - diesel/motor oil-range hydrocarbons
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PRG	preliminary remediation goal
QA/QC	quality assurance/quality control
Site	Fidalgo Bay Causeway Project
SD	sediment sample
SMS	Sediment Management Standard
SS	soil sample
SVOC	semivolatile organics
SW	surface water sample
Tribe	Samish Indian Nation
WDNR	Washington Department of Natural Resources
U.S. EPA	U.S. Environmental Protection Agency

1.0 INTRODUCTION

This report describes the analytical results from a sampling event conducted in October 2007 at the Fidalgo Bay Causeway Project (Figure 1). This report has been prepared on behalf of the Samish Indian Nation (Tribe). The sampling was conducted to determine the extent of contamination from creosote-pilings and potentially contaminated fill in the vicinity of the causeway. Additionally, the sampling was intended to document baseline environmental conditions that will support the feasibility study being conducted to evaluate removal or modification of the causeway, a former railroad trestle.

The Tribe and Washington Department of Ecology (Ecology) entered an intergovernmental agreement that provides funding for the study and outlines the terms of study. Funds for the study were secured by Ecology through the Puget Sound Initiative.

2.0 SITE DESCRIPTION AND BACKGROUND

The 4,380-foot Tommy Thompson Trail is a former railroad causeway and trestle that crosses Fidalgo Bay in Anacortes, Washington (Figure 1). The trail is used for recreational activities such as walking, running, and bicycling. The recreational trail is owned and managed by the City of Anacortes. The causeway and trestle run parallel to tribally-owned land on the western shore of Fidalgo Bay at Weaverling Spit and extends over state-owned aquatic lands to the eastern shore of Fidalgo Bay on March Point. The properties are administered by the Tribe and Washington Department of Natural Resources (WDNR). WDNR has recently established Fidalgo Bay as an Aquatic Reserve. (WDNR, 2007 and 2008)

The former railroad trestle was constructed on creosote pilings. Approximately 2,360 feet of the creosote pilings, beginning at Weaverling Spit and extending out into Fidalgo Bay, were backfilled with fill material and riprap to create the causeway. Soil along the causeway is fill material consisting of silty sand, gravel, and cobbles. Approximately 770 creosote pilings remain and provide support for the remaining 2,020 feet of trestle (Figure 2). During a reconnaissance field trip to the Site, Ridolfi staff observed creosote dripping from several of the newer pilings. As a result, layered creosote rings surround the bases of the several of the newer creosote-pilings (Wagoner, personal communication, 2007).

Fidalgo Bay is a shallow bay located in Water Resource Inventory Area 3, Lower Skagit/Samish. The majority of the Bay is comprised of mudflats generally less than 10 feet deep at mean lower low water (MLLW). A natural channel approximately 15 to 20 feet deep runs through the central portion of the Bay. No significant freshwater streams discharge to Fidalgo Bay (Battelle, 2003).

Higher elevations of the Bay include salt marshes and sand and gravel beaches. Lower elevations function as highly productive mudflat habitats and support microalgae and macroalgae. Extensive native eelgrass beds are also found throughout the Bay. Eelgrass habitats provide spawning, rearing, and foraging areas for numerous migratory and resident fish species, as well as native shellfish and crab species. Migratory and resident bird species are found in the area as well.

The eelgrass beds in Fidalgo Bay are comprised of the native species *Zostera marina* and the non-native species *Zostera japonica*. The native, *Zostera marina,* is found at elevations ranging from approximately +1 to -18 ft MLLW in the Bay. The non-native, *Zostera japonica,* is found in the upper intertidal zone of the Bay, at elevations generally higher than *Zostera marina* (Battelle, 2003). A study conducted in Padilla Bay in 2000 found that *Zostera japonica* covered approximately 21 percent of the vegetated area in Padilla Bay; it is assumed that if a study of this nature was conducted in Fidalgo Bay, the findings would be similar (Battelle, 2003).

Several oil spills have occurred in the area. Since 1997, numerous environmental investigations have been conducted throughout Fidalgo Bay (SAIC, 2007). Results from the studies have shown that sediment quality within the project area and the inner bay is in compliance with screening criteria, similar to those described in Section 4. Some contaminants, such as polycyclic aromatic hydrocarbons (PAHs) have been detected at higher concentrations than reference areas sampled in Padilla Bay (WDNR, 2007).

Fidalgo Bay is listed for two contaminants, chrysene and benzo(a)anthracene in tissue, on Washington state's 2004 Water Quality 303(d) Category 5 list of water bodies that do not meet water quality standards (Ecology, 2006). The PAHs, chrysene and benzo(a)anthracene, were detected in littleneck clam soft-parts at concentrations exceeding the National Toxic Rule criterion.

3.0 PROJECT SCREENING LEVELS AND REPORTING LIMITS

To provide a basis for assessing results, the reported concentrations were compared to relevant screening criteria and background values when available. Analytical results for sediment were compared to Ecology's Sediment Management Standards (SMS), which include quality criteria for selected metals; semivolatile organics (SVOCs) and PAHs, a subset of SVOCs; pesticides and total polychlorinated biphenyls (PCBs) (Ecology, 1995). The SMS for some of the SVOCs and total PCBs are tabulated on an organic carbon basis. To allow comparison to these standards, results for these SVOCs and total PCBs were normalized to the organic carbon content of the respective sample.

Results for sediment were also compared to screening levels for sediment in a saltwater environment for the protection of ecological endpoints. These screening levels are the effects range-low (ERLs) (Long et al. 1998) and marine apparent effects threshold (AET) developed from bioassays (Buchman 1999). The ERLs represent the 10^{th} percentile for the dataset in which effects were observed or predicted in studies compiled by Long et al. 1998. The AET represents the concentration above which adverse biological impacts would be expected.

The screening levels for soil are the Oak Ridge National Laboratory final preliminary remediation goals (ORNL-PRGs) for ecological endpoints (Efroymson et al. 1997), the U.S. Environmental Protection Agency's (USEPA) ecological soil screening levels (Eco-SSL) (USEPA 2005), and the USEPA Region 6 preliminary remediation goals (PRGs) for residential soil (USEPA 2007). Results for metals were also compared to natural background soil concentrations for Puget Sound (Ecology, 1994). The analytical results for petroleum hydrocarbons were compared to the Washington State Department of Ecology (Ecology) Model Toxics Control Act (MTCA) ecological indicator soil concentrations for the protection of terrestrial plants and animals and Ecology's MTCA Method B Soil Direct Contact Screening Guidelines (Ecology, 2005).

Analytical results for surface water were compared to the National Recommended Water Quality Criteria (NRWQC) (U.S. EPA, 2006). Substances without NRWQC values were compared to values in the Screening Quick Reference Table for organics and inorganics in water (Buchman, 1999).

Laboratory results discussed as detected in this report are those results reported by the laboratory above their method reporting limit (MRL), which is the minimum concentration of an analyte that the laboratory can routinely identify and quantify above the method detection limit (MDL). The MDL is statistically derived and represents a "best case" sensitivity. The MDL is lower than the MRL and has inherently higher associated uncertainty. For PAHs and PCBs that were not detected in sediment and soil samples, one-half the MRL was used as the concentration to compare to screening guidelines for total PAHs and total PCBs.

4.0 SAMPLE COLLECTION AND ANALYSIS

Sediment, soil, and surface water samples were collected at the Site, according to procedures described in the Sampling and Analysis Plan for the Fidalgo Bay Causeway Feasibility Study (Ridolfi, 2007). Figure 2 shows the locations where the samples were collected.

The samples were submitted to Analytical Resources, Inc. (ARI) in Tukwila, Washington for chemical analyses. The analytical substances were selected based on results from historical investigations conducted in Fidalgo Bay and information obtained from the Tribe. The following contaminants were analyzed for:

- Metals [total metals (sediment and soil) and dissolved metals (surface water)] by U.S. EPA Method 6010B, 7060A, 7421, or 7470A/7471A depending on the metal
- SVOCs, PAHs by U.S. EPA Method 8270D
- Pesticides by U.S. EPA Method 8081A for selected sediment and soil samples
- PCBs by U.S. EPA Method 8082 for selected sediment and soil samples
- Diesel-range and motor oil-range petroleum hydrocarbons by the Northwest total petroleum hydrocarbon (NWTPH-Dx) method for selected soil samples

Sample identification information and analyses performed are provided in Table 1.

The data were reviewed by a chemist to evaluate compliance with data quality objectives and entered into a database. A data quality summary is provided in Section 8. Complete qualified analytical results for this sampling event are presented in Attachment A.

4.1 Sediment

Twelve primary samples and one field duplicate sample were collected adjacent to the causeway and the creosote-piling trestle. The samples were collected from north and south of the two structures. The samples were grab samples collected from 0 to 10 centimeters below the sediment/water interface. All sediment samples were analyzed for metals, SVOCs, and total organic carbon. Three of the twelve primary samples and the field duplicate sample were analyzed for pesticides and PCBs. The results of these analyses are presented in Tables 3a and 3b and are discussed in Section 5.0.

4.2 Soil

Ten primary soil samples and one field duplicate sample were collected along the causeway, approximately every 150 feet. The samples were collected from the north and south sides of the structure. The samples were grab samples collected from 0 to 10 centimeters below ground surface. All of the primary soil samples and the field duplicate sample were analyzed for metals and SVOCs. Additionally, three of the ten primary samples and the field duplicate sample were analyzed for pesticides and PCBs and five of the twelve primary samples and the field duplicate sample were analyzed for diesel-range and motor-oil hydrocarbons. Soils encountered during the sampling activities were described according to the Unified Soil Classification System; these descriptions are summarized in Table 1.

The results of these analyses are presented in Table 4 and are discussed in Section 6.0.

4.3 Surface Water

Six primary surface water samples and one field duplicate were collected from Fidalgo Bay north and south of the causeway. The surface water samples were field-filtered using a 0.45 micron filter. Water quality parameters including pH, salinity, specific electrical conductance, temperature, and dissolved oxygen were measured at each sample station; this information is summarized in Table 2. All six surface water samples and the field duplicate sample were analyzed for dissolved metals and SVOCs. The results of these analyses are presented in Table 5 and are discussed in Section 7.0.

5.0 SEDIMENT RESULTS

Metals, SVOCs, and total PCBs were detected at concentrations above laboratory MRLs. Pesticides were not detected at any of the sample locations.

All of the metals analyzed for, except cadmium, were detected at concentrations above laboratory MRLs (Table 3a and 3b). Metals were detected at all sample locations. Copper was the only metal that was detected at a concentration that exceeded a screening level. Copper, which slightly exceeded the ERL, was detected in the sample collected from sediment sample location SD-09.

SVOCs were detected at concentrations above laboratory MRLs. SVOCs, including PAHs, were detected at all sample locations. One or more PAHs were detected in various sediment samples at concentrations that exceeded the SMS (Table 3a). The PAHs with reported concentrations greater than screening criteria were detected in samples collected from adjacent to the creosote-piling trestle. Exceedences for PAHs ranged from slight to one order of magnitude greater than the SMS. The most contaminated samples were collected at SD-08 and SD-11. Seven PAHs were detected at these two locations. Concentrations for total low molecular weight PAHs (LPAH) exceeded SMS at SD-08 and SD-11. Concentrations for total high molecular weight PAHs (HPAH) exceeded SMS at SD-07, SD-08, and SD-11. Exceedences for total LPAH and HPAH ranged from slight to one order of magnitude greater than the SMS. The greatest concentrations of total LPAH and HPAH were detected at SD-08. The concentrations of dibenzofuran also exceeded the SMS in samples collected from SD-08 and SD-11.

Comparing the sediment concentrations to the ERL and AET guidelines gave similar results to the comparison to the SMS. The greatest exceedences for PAHs were associated with samples collected adjacent to the creosote-piling trestle, with one additional exceedence observed for fluoranthene in the sample collected at SD-06 (Table 3b). In addition the concentration of one of the two phthalate esters analyzed for exceeded the AET in sediment samples collected at a number of the sample locations. Screening levels are not available for comparison to the concentrations of the other phthalate ester that was analyzed for and detected at one of the sample locations (Table 3b).

Screening levels are not available for comparison to concentrations of the SVOC 1-methylnaphthalene detected in sediment samples.

Total PCBs were detected at four of the sample locations and in the field duplicate but did not exceed the SMS or ERLs.

6.0 SOIL RESULTS

Metals, SVOCs, the pesticide 4,4’-dichlorodiphenyltrichloroethane (DDT), total PCBs, and diesel-range and motor- oil hydrocarbons were detected at concentrations above laboratory MRLs (Table 4).

All of the metals, except cadmium, were detected in all of the soil samples. Six metals were detected at concentrations that exceeded the ORNL-PRGs and the ECO-SSLs at one or more of the sample locations. Exceedences ranged from slightly greater than to two orders of magnitude greater than screening levels. Chromium was detected at the greatest concentrations at all sample locations, with the detected concentration at SS-08 exceeding the ORNL-PRG by two orders of magnitude (Table 4). In comparison to the sediment results, there was no apparent spatial distribution.

Most of the metals were detected at concentrations that are consistent with natural background soil concentrations for Puget Sound (Table 4); (Ecology 1994). Arsenic concentrations slightly exceeded natural background soil concentrations for Puget Sound in two of the ten samples. Chromium and mercury concentrations slightly exceeded background soil concentrations for Puget Sound in one of the samples. Copper and lead concentrations slightly exceeded background soil concentrations for Puget Sound in three of the samples and lead concentrations slightly exceeded background soil concentrations for Puget Sound in the field duplicate sample as well.

SVOCs, including PAHs were detected at seven of the soil samples. Two PAHs were detected at concentrations that exceeded screening levels and one PAH was detected at a concentration that was equal to screening levels (Table 4). PAHs with concentrations exceeding the U.S. EPA Region 6 PRGs were detected at SS-01, SS-02, SS-05 and SS-06 in the field duplicate sample. Exceedences ranged from slightly greater than to one order of magnitude greater than screening levels. Benzo(a)pyrene exceeded the U.S. EPA Region 6 PRGs by one order of magnitude in a sample collected at SS-01 (Table 4).

Screening levels are not available for comparison to concentrations of acenaphthylene and benzo(g,h,i)perylene detected in soil samples.

The pesticide 4,4'-DDT and diesel-range and motor- oil hydrocarbons were detected in some soil samples but the concentrations did not exceed screening levels.

Total PCBs were detected at five of the sample locations and in the field duplicate but did not exceed the ORNL-PRGs.

7.0 SURFACE WATER RESULTS

Chromium and silver were the only substances detected at concentrations above laboratory MRLs (Table 5) in surface water. SVOCs were not detected in any of the samples. The method reporting limit (0.02 mg/L) is greater than the screening guideline (0.00190 mg/L AWQC). Silver reported as detected was either at the reporting limit or slightly greater (0.02 mg/L for five of the primary samples and 0.03 mg/L for the duplicate sample). Higher uncertainty is associated with reported quantitative results near the reporting limit. The difference between a nondetect at 0.2 mg/L and a detect at 0.2 or 0.3 mg/L therefore has relatively lower significance than the difference between, for example, 1.0 mg/L and 1.1 mg/L. To achieve greater certainty in this case would require a more sensitive analytical method. However, similar results for silver in surface water have been detected in past sampling events in the vicinity of the site.

Additionally, the reporting limits for cadmium, copper, lead, and silver were greater than the screening levels; it is possible that these metals are present in surface water at concentrations above screening levels but at or below the reporting limits. According to the Tribe, similar results for dissolved metals in surface water have been reported for prior sampling events in the vicinity of the Site.

8.0 DATA QUALITY SUMMARY

The quality of the chemical data was evaluated both by the laboratory and independently, as specified in the Sampling and Analysis Plan (SAP) (Ridolfi, 2008). Ridolfi performed a limited data quality review of laboratory data packages.

Laboratory chemistry results were either accepted as received from the laboratory (i.e., unqualified) or were qualified. No chemistry results were rejected. Unqualified results are considered valid with respect to the specified procedures and quality assurance/quality control (QA/QC) measures and may be used as intended. Results qualified with a J flag are considered usable with the understanding that the values are qualified as estimates.

The principal measures associated with chemical data quality are precision, accuracy, representativeness, completeness, and comparability. An evaluation of each of these measures determined that overall analytical performance and data quality are acceptable.

9.0 SUMMARY

9.1 Sediment

Metals, SVOCs (primarily PAHs), and total PCBs were detected at concentrations exceeding laboratory MRLs in sediment. Copper was the only metal reported at concentrations greater than the ERL screening level and only in one sample. Several SVOCs, including PAHs were detected at concentrations greater than the screening levels (SMS, ERLs, and AETs) in sediment at the site. The greatest concentrations of PAHs were detected at sediment sample locations adjacent to the creosote-piling trestle. Fourteen PAHs were detected in samples from this area with concentrations exceeding screening levels by up to one order of magnitude. The largest numbers of PAHs, with the highest concentrations exceeding screening levels, were detected in samples from SD-08 and SD-11.

9.2 Soil

For soil samples, metals, SVOCs, the pesticide 4,4’DDT, total PCBs, and diesel-range and motor-oil range hydrocarbons were reported above laboratory MRLs in soil. Six metals were detected at the Site at concentrations greater than screening levels. The results also show that three PAHs were detected at the Site above screening levels. The highest concentrations of PAHs were detected at SS-01. Most of the metals were detected in concentrations that are consistent with natural background soil concentrations for Puget Sound. Arsenic, chromium, copper, mercury, and lead concentrations were slightly greater than natural background soil concentrations for Puget Sound in a few of the samples.

9.3 Surface Water

Chromium and silver were the only constituents reported above laboratory MRLs in surface water samples. The concentration of silver exceeded the water screening criteria, but as described in Section 7, the analytical method is relatively insensitive at the reported concentrations. Cadmium, copper, and lead may be present at concentrations above screening levels but below the detection limits. No SVOCs were detected in surface water at the Site.

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TABLES

Table 1. Sample Identification, Description, Coordinates, and Analyses Performed

Station Identification	GPS Coordinates (decimal degrees)		Sample Identification	Sample Matrix	Sample Description	Date Collected	Time Collected	Analyses Performed						
	Latitude	Longitude						Total metals (U.S. EPA RCRA 8 Method 6010B, 7060A, 7421, 7470A/7471A)	Dissolved metals (U.S. EPA RCRA 8 Method 6010B, 7060A, 7421, 7470A/7471A)	NWTPH-Dx (GC/FID)	SVOCs (U.S. EPA 8270D)	PCBs (U.S. EPA 8082)	Pesticides (U.S. EPA 8081A)	Total Organic Carbon (Plumb, 1981)
SD-01	48.480943	-122.586097	07102303	Sediment	dark grey, wet sand/silt, gravel	10/23/2007	10:33	X			X			X
SD-02	48.480767	-122.585503	07102302	Sediment	dark grey, wet sand/silt, gravel	10/23/2007	10:23	X			X			X
SD-03	48.480610	-122.584931	07102301	Sediment	dark grey, wet sand/silt, gravel	10/23/2007	9:28	X			X	X	X	X
SD-04	48.480100	-122.582650	07102306	Sediment	brown grey, wet sand/silt with shells and organic matter	10/23/2007	11:15	X			X			X
SD-05	48.479955	-122.582124	07102305	Sediment	brown grey, wet sand/silt with shells and organic matter and gravel	10/23/2007	11:01	X			X			X
SD-06	48.479911	-122.581839	07102304	Sediment	dark grey, wet sand/silt, gravel	10/23/2007	10:51	X			X			X
SD-07	48.477239	-122.573569	07102502	Sediment	dark grey, wet sand/silt, gravel	10/25/2007	9:55	X			X			X
SD-08	48.477537	-122.574052	07102501	Sediment	dark grey, wet sand/silt, gravel and lots of broken shells	10/25/2007	9:45	X			X			X
SD-09	48.477152	-122.573080	07102405	Sediment	dark grey, wet sand/silt, gravel	10/24/2007	13:50	X			X	X	X	X
SD-10	48.477754	-122.574459	07102401	Sediment	black, wet sand/silt	10/24/2007	9:40	X			X	X	X	X
			07102402			10/24/2007	9:50	X			X	X	X	X
SD-11	48.477670	-122.574329	07102403	Sediment	dark grey, wet sand/silt, gravel and lots of broken shells	10/24/2007	10:00	X			X			X
SD-12	48.477517	-122.573918	07102404	Sediment	clay and sand	10/24/2007	10:20	X			X			X
SS-01	48.481426	-122.587629	07102317	Soil	sandy, dark	10/23/2007	16:40	X		X	X	X	X	
SS-02	48.481394	-122.587011	07102316	Soil	sandy, dark	10/23/2007	16:30	X			X			
SS-03	48.481114	-122.586606	07102315	Soil	sandy, dark	10/23/2007	16:20	X		X	X			
SS-04	48.481055	-122.586151	07102314	Soil	sandy, dark	10/23/2007	16:00	X			X			
SS-05	48.480790	-122.585295	07102313	Soil	sandy, dark	10/23/2007	15:50	X			X			
SS-06	48.480757	-122.584848	07102311	Soil	sandy, dark, organic matter	10/23/2007	15:00	X		X	X	X	X	
			07102312	Soil	sandy, dark, organic matter	10/23/2007	15:05	X		X	X	X	X	
SS-07	48.480495	-122.584222	07102310	Soil	sandy, dark	10/23/2007	14:40	X			X			

Table 2. Surface Water Sampling Event Field Parameters

Project Name: Fidalgo Bay Causeway Feasibilty Study	**Ridolfi Project No. 277J**						
Sampling Personnel: S. Duncan and H. DelaCruz	**Dates on Site:** October 23 - 25, 2007						
Sampling Equipment: Geopump peristaltic pump, polyethylene tubing, silicon head tubing, 0.45 micron filter, and YSI 30 conductivity, dissolved oxygen, pH, salinity, and temperature meter.	**Weather:** Overcast, breezy, 50 degrees Farenheit						
Sample ID	07102412	07102411	07102410	07102409	07102408	07102406	07102407
Sample Location	SW-01	SW-02	SW-03	SW-04	SW-05	SW-06	
Date/time sample collected	10/24/07; 17:20	10/24/07; 17:00	10/24/07; 16:45	10/24/07; 16:25	10/24/07; 15:15	10/24/07; 14:40	10/24/07; 14:45
Sample color	clear	clear	clear	clear	clear	turbid	turbid
Turbidity of sample	none	none	none	none	none	cloudy	cloudy
Odors observed during sampling	none	none	none	none	none	none	none
Sheen observed on sample	none	none	none	none	none	none	none
Field temp. (degrees Celsius)	11	10.7	10.97	10.67	11.28	11.01	
Field pH (standard units)	7.75	7.68	7.7	7.63	7.5	7.31	
Field dissolved oxygen (milligrams per liter)	9.31	8.18	9.27	8.79	9.35	7.98	
Field conductivity (microSiemen per centimeter)	33.63	33.57	33.67	33.52	32.81	33.77	
Field salinity (parts per thousand)	29.66	29.34	29.72	29.78	28.64	29.8	

Analytical Sampling Parameters: All samples were analyzed for dissolved metals and SVOCs. All samples were field filtered.

Table 3a. Sediment Analytical Results for Detected Constituents Compared to SMS

Sample ID:			07102301	07102302	07102303	07102304	07102305	07102306	07102401	07102402	07102403	07102404	07102405	07102501	07102502
Sample Location:			SD-03	SD-02	SD-01	SD-06	SD-05	SD-04*	SD-10		SD-11	SD-12	SD-09*	SD-08	SD-07
Lab ID:			07-22638-LV15L	07-22639-LV15M	07-22640-LV15N	07-22641-LV15O	07-22642-LV15P	07-22643-LV15Q	07-22644-LV16A	07-22645-LV16B	07-22646-LV16C	07-22647-LV16D	07-22648-LV16E	07-22649-LV16F	07-22650-LV16G
Date Collected:			10/23/2007	10/23/2007	10/23/2007	10/23/2007	10/23/2007	10/23/2007	10/24/2007	10/24/2007	10/24/2007	10/24/2007	10/24/2007	10/25/2007	10/25/2007
Matrix:			Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment
Compound	**CAS No.**	**Washington State SMS[a]**													
Metals (mg/kg)															
Arsenic	7440-38-2	57	*4.1***	*3.4*	*4.1*	*3.4*	*4.2*	*2.1*	*2.8* J	*2.5* J	*3.7* J	*3.5* J	*4.6* J	*3.0* J	*3.9* J
Chromium	7440-47-3	260	*38.3*	*45.6*	*25.9*	*20.7*	*27.6*	*17.3*	*23*	*24*	*20.3*	*27.1*	*40.6*	*20*	*28.4*
Copper	7440-50-8	390	*23.3* J	*16.3* J	*19.6* J	*16.5* J	*23.8* J	*17.4* J	*12.1*	*11.8*	*12.5*	*18.3*	*36.5*	*10.3*	*21.4*
Lead	7439-92-1	450	*7.6*	*5.9*	*6.2*	*7.1*	*7.0*	*4.7*	*4.3*	*3.6*	*4.5*	*4.9*	*5.9*	*4.0*	*5.2*
Zinc	7440-66-6	410	*45* J	*42* J	*57* J	*46* J	*76* J	*47* J	*34*	*32*	*52*	*43*	*63*	*28*	*48*
Semivolatile Organics (µg/kg)															
Phenol	108-95-2	420	20 U	*27*	20 U	20 U	20 U	20 U	*110*	20 U	*43*	20 U	20 U	*33*	*52*
4-Methylphenol	106-44-5	670	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	*32*	20 U	20 U	20 U	20 U
2,4-Dimethylphenol	105-67-9	29	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	*22*	20 U	20 U	20 U	20
(mg/kg organic carbon)															
Diethylphthalate	84-66-2	61	2 U	*1*	*3*	3 U	3 U	0.02 U	*3*	*4*	*2*	*11*	*0.029*	*4*	3 U
bis(2-Ethylhexyl)phthalate	117-81-7	47	2 U	1 U	2 U	3 U	3 U	0.02 U	2 U	3 U	1 U	4 U	0.02 U	*4*	3 U
Polycyclic Aromatic Hydorcarbons (mg/kg)															
1-Methylnaphthalene (µg/kg)	90-12-0	NA	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	*180*	20 U	20 U	*52*	20 U
(mg/kg organic carbon)															
2-Methylnaphthalene	91-57-6	38	2 U	1 U	2 U	3 U	3 U	0.02 U	2 U	3 U	*14*	4 U	0.02 U	3 U	3 U
Dibenzofuran	132-64-9	15	2 U	1 U	2 U	3 U	3 U	0.02 U	*3*	3 U	**94*****	4 U	0.02 U	**117**	*3*
LPAHs (mg/kg organic carbon)															
Naphthalene	91-20-3	99	2 U	1 U	2 U	3 U	3 U	0.02 U	2 U	3 U	*17*	4 U	0.02 U	3 U	3 U
Acenaphthylene	208-96-8	66	2 U	1 U	2 U	3 U	3 U	0.02 U	*8*	*15*	*51*	*8*	*0.022*	*53*	*17*
Acenaphthene	83-32-9	16	2 U	1 U	2 U	3 U	3 U	0.02 U	*3*	*4*	**81**	4 U	0.02 U	**93**	*5*
Fluorene	86-73-7	23	2 U	1 U	2 U	*4*	3 U	0.02 U	*5*	*6*	**100**	4 U	0.02 U	**158**	*9*
Phenanthrene	85-01-8	100	2	*3*	2 U	*1*	3 U	0.02 U	*94*	*90*	**1313**	*42*	*0.11*	**2167**	**243**
Anthracene	120-12-7	220	2 U	1 U	2 U	*23*	*3*	*0.054*	*7*	*11*	*53*	*5*	*0.027*	*37*	*8*
Total LPAH****		370	*7*	*6*	6	*33*	*11*	*0.104*	*118*	*127*	**1614**	*53*	*0.189*	**2510**	*285*
HPAHs (mg/kg organic carbon)															
Fluoranthene	206-44-0	160	*6*	*5*	2 U	*9*	5 U	*0.025*	**360**	**700**	**2250**	**320**	*0.76*	**2667**	**686**
Pyrene	129-00-0	1000	*5*	*3*	2 U	*4*	5 U	0.02 U	*200*	*400*	**1125**	*154*	*0.38*	**1367**	*414*
Benzo(a)anthracene	56-55-3	110	*3*	*1*	2 U	3 U	5 U	0.02 U	*27*	*50*	*106*	*19*	*0.087*	*108*	*27*
Chrysene	218-01-9	110	*5*	*2*	2 U	*5*	5 U	0.02 U	*80*	*16*	**369**	*56*	*0.21*	**417**	**119**
Total Benzofluoranthenes	205-99-2, 207-08-9	230	*10*	*3*	4 U	6 U	10 U	0.04 U	*58*	*102*	*150*	*44*	*0.156*	*267*	*76*
Benzo(a)pyrene	50-32-8	99	*3*	*2*	2 U	3 U	5 U	0.02 U	*10*	*18*	*35*	*8*	*0.031*	*40*	*11*
Indeno(1,2,3-cd)pyrene	193-39-5	34	*2*	2 U	2 U	3 U	5 U	0.02 U	*5*	*8*	*12*	4 U	0.02 U	*17*	*4*
Dibenz(a,h)anthracene	53-70-3	12	2 U	2 U	2 U	3 U	5 U	0.02 U	2 U	3 U	*6*	4 U	0.02 U	*7*	3 U
Benzo(g,h,i)perylene	191-24-2	31	2 U	2 U	2 U	3 U	5 U	0.02 U	*3*	*5*	*6*	4 U	0.02 U	*10*	*3*
Total HPAH ****		960	*36*	*18*	*10*	*29*	*25*	*0.115*	*744*	**1301**	**4059**	*607*	*1.654*	**4899**	**1341**
Polychlorinated biphenyls (mg/kg organic carbon)															
Aroclor 1016	12674-11-2	NA	1.5 U						2 U	3 U			0.019 U		
Aroclor 1242	53469-21-9	NA	1.5 U						2 U	3 U			0.019 U		
Aroclor 1248	12672-29-6	NA	1.5 U						2 U	3 U			0.019 U		
Aroclor 1254	11097-69-1	NA	1.5 U						2 U	3 U			0.019 U		
Aroclor 1260	11096-82-5	NA	1.5 U						2 U	3 U			0.019 U		
Aroclor 1221	11104-28-2	NA	1.5 U						2 U	3 U			0.019 U		
Aroclor 1232	11141-16-5	NA	1.5 U						2 U	3 U			0.019 U		
Total PCBs		12	*NC*						*NC*	*NC*			*NC*		
Total Organic Carbon (%)			1.31%	1.86%	1.01%	0.664%	0.823%	0.385%	0.972%	0.600%	1.620%	0.509%	0.260%	0.623%	0.742%
Total Organic Carbon			0.013	0.0186	0.010	0.007	0.008	0.004	0.010	0.006	0.016	0.005	0.003	0.006	0.007

Notes:

PCBs = polychlorinated biphenyls

SD = sediment sample

SMS = sediment management standards

mg/kg = milligrams per kilogram

µg/kg = micrograms per kilogram

LPAH = low molecular weight polycyclic aromatic hydrocarbon

HPAH = high molecular weight polycyclic aromatic hydrocarbon

* = Results are presented as dry weight concentrations. Contaminant values are not normalized to total organic carbon because total organic carbon for this sediment sample is less than 0.5%.

**Italicized contaminant values show detected concentrations
***Contaminant values in bold exceed screening guidelines.
****Estimates one half of the reporting limit.
a: Washington State Department of Ecology Sediment Management Standards (Ecology, 1995)
U: The material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantitation limit or the sample detection limit.
J: The associate value is an estimated quantity.
NA: Screening guideline not available
NC: Total PCBs were not calculated because none of the aroclors were above the reporting limit.

Table 3b. Sediment Analytical Results for Detected Constituents Compared to ERL and AET

Sample ID:			07102301	07102302	07102303	07102304	07102305	07102306	07102401	07102402	07102403	07102404	07102405	07102501	07102502
Sample Location:			SD-03	SD-02	SD-01	SD-06	SD-05	SD-04	SD-10		SD-11	SD-12	SD-09	SD-08	SD-07
Lab ID:			07-22638-LV15L	07-22639-LV15M	07-22640-LV15N	07-22641-LV15O	07-22642-LV15P	07-22643-LV15Q	07-22644-LV16A	07-22645-LV16B	07-22646-LV16C	07-22647-LV16D	07-22648-LV16E	07-22649-LV16F	07-22650-LV16G
Date Collected:			10/23/2007	10/23/2007	10/23/2007	10/23/2007	10/23/2007	10/23/2007	10/24/2007	10/24/2007	10/24/2007	10/24/2007	10/24/2007	10/25/2007	10/25/2007
Matrix:			Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment
Compound	**CAS No.**	**Fidalgo Bay Screening Levels[a]**													
Metals (mg/kg)															
Arsenic	7440-38-2	8.2	*4.1**	*3.4*	*4.1*	*3.4*	*4.2*	*2.1*	*2.8* J	*2.5* J	*3.7* J	*3.5* J	*4.6* J	*3.0* J	*3.9* J
Chromium	7440-47-3	81	*38.3*	*45.6*	*25.9*	*20.7*	*27.6*	*17.3*	*23*	*24*	*20.3*	*27.1*	*40.6*	*20*	*28.4*
Copper	7440-50-8	34	*23.3* J	*16.3* J	*19.6* J	*16.5* J	*23.8* J	*17.4* J	*12.1*	*11.8*	*12.5*	*18.3*	**36.5****	*10.3*	*21.4*
Lead	7439-92-1	46.7	*7.6*	*5.9*	*6.2*	*7.1*	*7.0*	*4.7*	*4.3*	*3.6*	*4.5*	*4.9*	*5.9*	*4.0*	*5.2*
Zinc	7440-66-6	150	*45* J	*42* J	*57* J	*46* J	*76* J	*47* J	*34*	*32*	*52*	*43*	*63*	*28*	*48*
Semivolatile Organics (µg/kg)															
Phenol	108-95-2	130[b]	20 U	*27*	20 U	20 U	20 U	20 U	*110*	20 U	*43*	20 U	20 U	*33*	*52*
4-Methylphenol	106-44-5	100[b]	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	*32*	20 U	20 U	20 U	20 U
2,4-Dimethylphenol	105-67-9	18[b]	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	**22**	20 U	20 U	20 U	20 U
Diethylphthalate	84-66-2	6[b]	20 U	**22**	**28**	20 U	20 U	20 U	**32**	**21**	**29**	**56**	**29**	**26**	20 U
bis(2-Ethylhexyl)phthalate	117-81-7	NA	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	*26*	20 U
Polycyclic Aromatic Hydrocarbons (µg/kg)															
Naphthalene	91-20-3	160	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	**270**	20 U	20 U	20 U	20 U
2-Methylnaphthalene	91-57-6	70	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	**230**	20 U	20 U	20 U	20 U
Acenaphthylene	208-96-8	44	20 U	20 U	20 U	20 U	20 U	20 U	**80**	**89**	**830**	*41*	*22*	**320**	**120**
Acenaphthene	83-32-9	16	20 U	20 U	20 U	20 U	20 U	20 U	**30**	**24**	**1300**	20 U	20 U	**560**	**37**
Dibenzofuran	132-64-9	110[b]	20 U	20 U	20 U	20 U	20 U	20 U	*33*	20 U	**1500**	20 U	20 U	**700**	*23*
Fluorene	86-73-7	19	20 U	20 U	20 U	**25**	20 U	20 U	**48**	**35**	**1600**	20 U	20 U	**950**	**64**
Phenanthrene	85-01-8	240	*20*	*49*	20 U	*71*	20 U	20 U	**940**	**540**	**21000**	*210*	*110*	**13000**	**1700**
Anthracene	120-12-7	85	20 U	20 U	20 U	**160**	*24*	*54*	*73*	*63*	**840**	*25*	*27*	**220**	*59*
Fluoranthene	206-44-0	600	*78*	*85*	20 U	*64*	20 U	*25*	**3600**	**4200**	**36000**	**1600**	**760**	**16000**	**4800**
Pyrene	129-00-0	665	*60*	*50*	20 U	*28*	20 U	20 U	**2000**	**2400**	**18000**	**770**	*380*	**8200**	**2900**
Benzo(a)anthracene	56-55-3	261	*40*	*26*	20 U	20 U	20 U	20 U	**270**	**300**	**1700**	*96*	*87*	**650**	*190*
Chrysene	218-01-9	384	*71*	*35*	20 U	*32*	20 U	20 U	**800**	**950**	**5900**	*280*	*210*	**2500**	**830**
Benzo(b)fluoranthene	205-99-2	1800[b]	*60*	*29*	20 U	20 U	20 U	20 U	*280*	*340*	*1200*	*79*	*88*	*790*	*290*
Benzo(k)fluoranthene	207-08-9	1800[b]	*58*	*25*	20 U	20 U	20 U	20 U	*300*	*270*	*1200*	*140*	*68*	*810*	*240*
Benzo(a)pyrene	50-32-8	430	*35*	*29*	20 U	20 U	20 U	20 U	*100*	*110*	**560**	*39*	*31*	*240*	*75*
Indeno(1,2,3-cd)pyrene	193-39-5	600[b]	*24*	20 U	20 U	20 U	20 U	20 U	*50*	*45*	*190*	20 U	20 U	*100*	*27*
Dibenz(a,h)anthracene	53-70-3	63	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	**94**	20 U	20 U	*42*	20 U
Benzo(g,h,i)perylene	191-24-2	670[b]	20 U	20 U	20 U	20 U	20 U	20 U	*32*	*30*	*100*	20 U	20 U	*59*	*22*
1-Methylnaphthalene	90-12-0	NA	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	*180*	20 U	20 U	*52*	20 U
Polychlorinated biphenyls (µg/kg)															
Aroclor 1016	12674-11-2	NA	20 U						20 U	20 U			19 U		
Aroclor 1242	53469-21-9	NA	20 U						20 U	20 U			19 U		
Aroclor 1248	12672-29-6	NA	20 U						20 U	20 U			19 U		
Aroclor 1254	11097-69-1	NA	20 U						20 U	20 U			19 U		
Aroclor 1260	11096-82-5	NA	20 U						20 U	20 U			19 U		
Aroclor 1221	11104-28-2	NA	20 U						20 U	20 U			19 U		
Aroclor 1232	11141-16-5	NA	20 U						20 U	20 U			19 U		
Total PCBs		22.7	*NC*						*NC*	*NC*			*NC*		
Total Organic Carbon (%)			1.31%	1.86%	1.01%	0.664%	0.823%	0.385%	0.972%	0.600%	1.620%	0.509%	0.260%	0.623%	0.742%
Total Organic Carbon			0.013	0.019	0.010	0.007	0.008	0.004	0.010	0.006	0.016	0.005	0.003	0.006	0.007

PCBs = polychlorinated biphenyls

SD = sediment sample

mg/kg = milligrams per kilogram

µg/kg = micrograms per kilogram

*Italicized contaminant values show positive results.

**Contaminant values in bold exceed screening guidelines.

***Estimates one half of the reporting limit.

a: Effects range-low (ERL) represents the 10th percentile for the dataset in which effects were observed or predicted in studies compiled by Long et al (1998).

b: Marine apparent effects threshold (AET) for bioassays. The AET represents the concentration above which adverse biological impacts would be expected.

U: The material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantitation limit or the sample detection limit.

J: The associate value is an estimated quantity.

NA: Screening guideline not available

Table 4. Soil Analytical Results for Detected Constituents

Compound	CAS No.	Fidalgo Bay Screening Levels[a]	Background Value Puget Sound Natural Background Soil Metals Concentrations[b]											
Sample ID:				07102307	07102308	07102309	07102310	07102311	07102312	07102313	07102314	07102315	07102316	07102317
Sample Location:				SS-10	SS-09	SS-08	SS-07	SS-06		SS-05	SS-04	SS-03	SS-02	SS-01
Lab ID:				07-22627-LV15A	07-22628-LV15B	07-22629-LV15C	07-22630-LV15D	07-22631-LV15E	07-22632-LV15F	07-22633-LV15G	07-22634-LV15H	07-22635-LV15I	07-22636-LV15J	07-22637-LV15K
Date Collected:				10/23/2007	10/23/2007	10/23/2007	10/23/2007	10/23/2007	10/23/2007	10/23/2007	10/23/2007	10/23/2007	10/23/2007	10/23/2007
Matrix:				Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil
Metals (mg/kg)														
Arsenic	7440-38-2	9.9	7	*3.8**	*4.6*	*3.3*	*7.2*	*5.0*	*4.7*	*2.9*	*3.9*	*4.0*	*3.1*	**17.7****
Cadmium	7440-43-9	0.36[c]	1	0.6 U	0.2 U	1 U	*0.2*	0.2 U	0.2 U	0.2 U	0.5 U	0.2 U	0.2 U	0.2 U
Chromium	7440-47-3	0.4	48	**36**	**33.2**	**66**	**25.9**	**25.6**	**27.3**	**32.4**	**42**	**34.7**	**23.4**	**32.7**
Copper	7440-50-8	28[c]	36	**34.3** J	**37.4** J	**40** J	**38.8** J	**30.0** J	**32.6** J	*24.6* J	**29.8** J	**29.9** J	*25.5* J	**33.8** J
Lead	7439-92-1	40.5	24	*7.8*	*8.4*	*2.3*	**49**	*30*	*30*	**58**	*11.1*	*16.4*	*11.6*	10.4
Mercury	7439-97-6	0.001	0.07	0.05 U	0.04 U	0.04 U	0.05 U	**0.04**	0.05 U	**0.10**	0.04 U	**0.05**	0.04 U	0.05 U
Zinc	7440-66-6	8.5	85	**56** J	**56** J	**51** J	**74** J	**77** J	**70** J	**58** J	**69** J	**57** J	**50** J	**53** J
Semivolatile Organics (µg/kg)*														
Carbazole	86-74-8	24,000[d]		63 U	66 U	65 U	64 U	65 U	64 U	63 U	66 U	65 U	65 U	*120*
bis(2-Ethylhexyl)phthalate	117-81-7	35,000[d]		63 U	66 U	65 U	64 U	65 U	64 U	63 U	*95*	65 U	65 U	65 U
Polycyclic Aromatic Hydrocarbons														
Acenaphthylene	208-96-8	NA		63 U	66 U	65 U	64 U	65 U	64 U	63 U	66 U	65 U	65 U	*99*
Anthracene	120-12-7	22,000,000[d]		63 U	66 U	65 U	64 U	65 U	64 U	63 U	66 U	65 U	65 U	*180*
Fluoranthene	206-44-0	2,300,000[d]		63 U	66 U	65 U	*82*	*70*	*150*	*110*	66 U	65 U	65 U	*83*
Pyrene	129-00-0	2,300,000[d]		63 U	66 U	65 U	*81*	*66*	*160*	*130*	66 U	65 U	65 U	*96*
Chrysene	218-01-9	15,000[d]		63 U	66 U	65 U	64 U	65 U	*110*	*66*	66 U	65 U	*81*	*140*
Benzo(b)fluoranthene	205-99-2	150[d]		*68*	66 U	65 U	64 U	*93*	*130*	*82*	*120*	65 U	**160**	**350**
Benzo(k)fluoranthene	207-08-9	1,500[d]		63 U	66 U	65 U	64 U	65 U	*98*	*63*	*82*	65 U	*100*	*400*
Benzo(a)pyrene	50-32-8	15[d]		63 U	66 U	65 U	64 U	65 U	**79**	**70**	66 U	65 U	65 U	**260**
Indeno(1,2,3-cd)pyrene	193-39-5	150[d]		63 U	66 U	65 U	64 U	65 U	64 U	63 U	66 U	65 U	65 U	**150**
Benzo(g,h,i)perylene	191-24-2	NA		63 U	66 U	65 U	64 U	65 U	64 U	63 U	66 U	65 U	65 U	*120*
Polychlorinated biphenyls (µg/kg)														
Aroclor 1016	12674-11-2	NA				32 U		31 U	33 U					33 U
Aroclor 1242	53469-21-9	NA				32 U		31 U	33 U					33 U
Aroclor 1248	12672-29-6	NA				32 U		31 U	33 U					33 U
Aroclor 1254	11097-69-1	NA				32 U		31 U	33 U					33 U
Aroclor 1260	11096-82-5	NA				32 U		31 U	33 U					33 U
Aroclor 1221	11104-28-2	NA				32 U		31 U	33 U					33 U
Aroclor 1232	11141-16-5	NA				32 U		31 U	33 U					33 U
Total PCBs		371				*NC*		*NC*	*NC*					*16.5*
Organochlorine Pesticides (µg/kg)														
4,4'-DDT	50-29-3	21[c]				3.2 U		*6.5*	*6.7*					3.3 U
Petroleum Hydrocarbons (mg/kg)														
Diesel Range Hydrocarbons	68334-30-5	200[e]		*6.8*		*5.2 U*		*12*	*21*			*5.8*		*34*
Motor Oil		2,000[f]		*71*		*37*		*110*	*140*			*46*		*300*

Notes:

PCBs = polychlorinated biphenyls
SS = soil samples
mg/kg = milligrams per kilogram
µg/kg = micrograms per kilogram
*Italicized contaminant values show positive results.
**Contaminant values in bold exceed or are equal to screening guidelines.
***Semivolatile organics, polychlorinated biphenyls, and organochlorine pesticide screening levels have been converted from mg/kg to µg/kg for comparison to analytical results.
a: Oak Ridge National Laboratory (ORNL) final preliminary remediation goals (PRG) for ecological endpoints (Efroymson et al. 1997).
b: Natural background soil metals concentrations for Puget Sound 90th percentile values in Washington State (Ecology, 1994a)
c: Ecological soil screening guidelines (USEPA 2007).
d: U.S. EPA Region 6 PRG for residental soil (U.S. EPA, 2007)
e: Washington State Department of Ecology Model Toxics Control Act (MTCA). Ecological Indicator Soil Concentrations (mg/kg) for Protection of Terrestrial Plants and Animals.
f: MTCA Method A (Ecology, 2005).
U: The material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantitation limit or the sample detection limit.
J: The associate value is an estimated quantity.
NC: Total PCBs were not calculated because none of the aroclors were above the detection limit.

Table 5. Surface Water Analytical Results for Detected Constituents at Site.

	Sample ID:		07102406	07102407	07102408	07102409	07102410	07102411	07102412
	Sample Location:		SW-06		SW-05	SW-04	SW-03	SW-02	SW-01
	Lab ID:		07-22651-LV16H	07-22652-LV16I	07-22653-LV16J	07-22654-LV16K	07-22655-LV16L	07-22656-LV16M	07-22657-LV16N
	Date Collected:		10/24/2007	10/24/2007	10/24/2007	10/24/2007	10/24/2007	10/24/2007	10/24/2007
	Matrix:		Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water
Compound	**CAS No.**	**Fidalgo Bay Screening Levels[a]**							
Metals (mg/L)									
Arsenic	7440-38-2	0.0360	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
Cadmium	7440-43-9	0.0088	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
Chromium	7440-47-3	0.050[b]	0.02 U	0.02 U	*0.03**	0.02 U	0.02 U	0.02 U	0.02 U
Copper	7440-50-8	0.0031	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
Lead	7439-92-1	0.0081	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
Mercury	7439-97-6	.00094[c]	0.0001 U	0.0001 U	0.0001 U	0.0001 U	0.0001 U	0.0001 U	0.0001 U
Silver	7440-22-4	.00190[d]	**0.02****	**0.03**	**0.02**	0.02 U	**0.02**	**0.02**	**0.02**
Zinc	7440-66-6	0.0810	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U

Notes:

SW = surface water sample

mg/L = milligrams per liter

*Italicized contaminant values show positive results.

**Contaminant values in bold exceed screening guidelines.

a: National recommended water quality criteria (NRWQC) for the protection of aquatic organisms (USEPA 2006). Marine chronic criteria presented.

b: Screening guidelines represent concentrations for Cr+6.

c: Derived from inorganic, but applied to total mercury.

d: Chronic criterion not available; acute criterion presented.

U: The material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantitation limit or the sample detection limit.

Table 1. Sample Identification, Description, Coordinates, and Analyses Performed

Station Identification	GPS Coordinates (decimal degrees)		Sample Identification	Sample Matrix	Sample Description	Date Collected	Time Collected	Analyses Performed						
	Latitude	Longitude						Total metals (U.S. EPA RCRA 8 Method 6010B, 7060A, 7421, 7470A/7471A)	Dissolved metals (U.S. EPA RCRA 8 Method 6010B, 7060A, 7421, 7470A/7471A)	NWTPH-Dx (GC/FID)	SVOCs (U.S. EPA 8270D)	PCBs (U.S. EPA 8082)	Pesticides (U.S. EPA 8081A)	Total Organic Carbon (Plumb, 1981)
SS-08	48.480357	-122.583614	07102309	Soil	rocks, sandy, dark grey	10/23/2007	14:20	X		X	X	X	X	
SS-09	48.480068	-122.583029	07102308	Soil	sandy with and root matter, slightly moist, dark grey	10/23/2007	14:10	X			X			
SS-10	48.480017	-122.582349	072102307	Soil	rocky, sandy, gravel, dark grey	10/23/2007	13:50	X		X	X			
SW-01	48.481292	-122.587116	07102412	Surface Water	clear, no smell	10/24/2007	17:20		X		X			
SW-02	48.480644	-122.584584	07102411	Surface Water	clear, no smell	10/24/2007	17:00		X		X			
SW-03	48.480085	-122.582811	07102410	Surface Water	clear, no smell	10/24/2007	16:45		X		X			
SW-04	48.479965	-122.582247	07102409	Surface Water	clear, no smell	10/24/2007	16:25		X		X			
SW-05	48.477083	-122.573027	07102408	Surface Water	clear, no smell	10/24/2007	15:15		X		X			
SW-06	48.477561	-122.574007	07102406	Surface Water	turbid, no smell	10/24/2007	14:40		X		X			
			07102407	Surface Water	turbid, no smell	10/24/2007	14:45		X		X			

NOTES:

GC/FID = gas chromatography/flame ionization detector

GPS = global positioning system

NWTPH-Dx = Northwest total petroleum hydrocarbon - diesel/motor oil-range hydrocarbons

RCRA = Resource Conservation and Recovery Act

SD = sediment sample

SS = soil sample

SVOCs = semivolatile organics

SW = surface water

U.S. EPA = U. S. Environmental Protection Agency

FIGURES

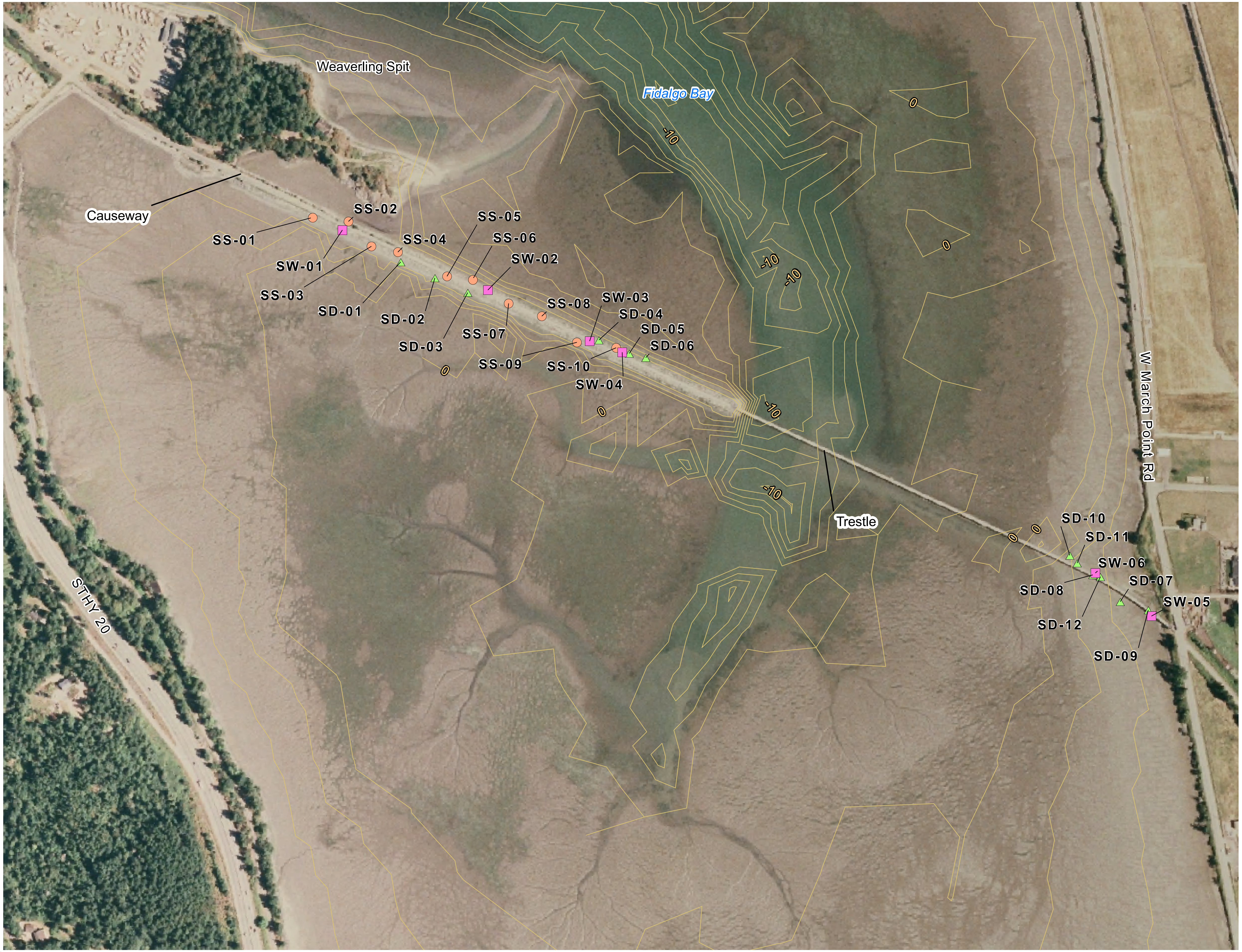
Figure 1
Fidalgo Bay Location and Vicinity

Chemistry Results Report
Fidalgo Bay Causeway Feasibility Study
Samish Indian Nation

September 2008

RIDOLFI Inc.

File Path: J:\277 SAMISH INDIAN NATION\277J Fidalgo Bay Causeway FS\GIS\mapfile\Chemistry_Results\Figure_01_location_cemresults.mxd



Legend

October 2007 Sampling

Sediment Sample

Soil Sample

Surface Water Sample

Bathymetry 2ft Interval

2006 Orthophoto

0 500

Feet

N

Figure 2
Sample Locations

Chemistry Results Report
Fidalgo Bay Causeway Feasibility Study
Samish Indian Nation

September 2008

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File Path: J:\277 SAMISH INDIAN NATION\277J Fidalgo Bay Causeway FS\GIS\mapfile\Chemistry_Results\Figure_02_sampling_cemresults.mxd

ATTACHMENT A

Analytical Results

Table A-1 Analytical Results (Sediment)

Compound	CAS No.	07102301	07102302	07102303	07102304	07102305	07102306	07102401	07102402	07102403	07102404	07102405	07102501	07102502
	Sample ID:	07102301	07102302	07102303	07102304	07102305	07102306	07102401	07102402	07102403	07102404	07102405	07102501	07102502
	Lab ID:	07-22638-LV15L	07-22639-LV15M	07-22640-LV15N	07-22641-LV15O	07-22642-LV15P	07-22643-LV15Q	07-22644-LV16A	07-22645-LV16B	07-22646-LV16C	07-22647-LV16D	07-22648-LV16E	07-22649-LV16F	07-22650-LV16G
	Date Collected:	10/23/2007	10/23/2007	10/23/2007	10/23/2007	10/23/2007	10/23/2007	10/24/2007	10/24/2007	10/24/2007	10/24/2007	10/24/2007	10/25/2007	10/25/2007
	Matrix:	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment
Petroleum Hydrocarbons (mg/kg dry wt., ug/L wet)														
Diesel Range Hydrocarbons	68334-30-5													
Motor Oil														
Total Organic Carbon (%)		1.31%	1.86%	1.01%	0.664%	0.823%	0.385%	0.972%	0.600%	1.620%	0.509%	0.260%	0.623%	0.742%
Semivolatile Organics (µg/kg dry wt., ug/L wet)														
Phenol	108-95-2	20 U	**27**	20 U	20 U	20 U	20 U	**110**	20 U	**43**	20 U	20 U	**33**	**52**
Bis-(2-Chloroethyl) Ether	111-44-4													
2-Chlorophenol	95-57-8													
1,3-Dichlorobenzene	541-73-1	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U
1,4-Dichlorobenzene	106-46-7	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U
Benzyl Alcohol	100-51-6	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U
1,2-Dichlorobenzene	95-50-1	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U
2-Methylphenol	95-48-7	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U
2,2'-Oxybis(1-Chloropropane)	108-60-1													
4-Methylphenol	106-44-5	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	**32**	20 U	20 U	20 U	20 U
N-Nitroso-Di-N-Propylamine	621-64-7													
Hexachloroethane	67-72-1	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U
Nitrobenzene	98-95-3													
Isophorone	78-59-1													
2-Nitrophenol	88-75-5													
2,4-Dimethylphenol	105-67-9	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	**22**	20 U	20 U	20 U	20 U
Benzoic Acid	65-85-0	200 U	200 U	200 U	200 U	200 U	200 U	200 U	200 U	200 U	200 U	200 U	200 U	200 U
bis(2-Chloroethoxy) Methane	111-91-1													
2,4-Dichlorophenol	120-83-2													
1,2,4-Trichlorobenzene	120-82-1	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U
Naphthalene	91-20-3	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	**270**	20 U	20 U	20 U	20 U
4-Chloroaniline	106-47-8													
Hexachlorobutadiene	87-68-3	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U
4-Chloro-3-methylphenol	59-50-7													
2-Methylnaphthalene	91-57-6	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	**230**	20 U	20 U	20 U	20 U
Hexachlorocyclopentadiene	77-47-4													
2,4,6-Trichlorophenol	88-06-2													
2,4,5-Trichlorophenol	95-95-4													
2-Chloronaphthalene	91-58-7													
2-Nitroaniline	88-74-4													
Dimethylphthalate	131-11-3	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U
Acenaphthylene	208-96-8	20 U	20 U	20 U	20 U	20 U	20 U	**80**	**89**	**830**	**41**	**22**	**320**	**120**
3-Nitroaniline	99-09-2													
Acenaphthene	83-32-9	20 U	20 U	20 U	20 U	20 U	20 U	**30**	**24**	**1,300**	20 U	20 U	**560**	**37**
2,4-Dinitrophenol	51-28-5													
4-Nitrophenol	100-02-7													
Dibenzofuran	132-64-9	20 U	20 U	20 U	20 U	20 U	20 U	**33**	20 U	**1,500**	20 U	20 U	**700**	**23**
2,6-Dinitrotoluene	606-20-2													
2,4-Dinitrotoluene	121-14-2													
Diethylphthalate	84-66-2	20 U	**22**	**28**	20 U	20 U	20 U	**32**	**21**	**29**	**56**	**29**	**26**	20 U
4-Chlorophenyl-phenylether	7005-72-3													
Fluorene	86-73-7	20 U	20 U	20 U	**25**	20 U	20 U	**48**	**35**	**1,600**	20 U	20 U	**950**	**64**
4-Nitroaniline	100-01-6													
4,6-Dinitro-2-Methylphenol	534-52-1													
N-Nitrosodiphenylamine	86-30-6	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U
4-Bromophenyl-phenylether	101-55-3													
Hexachlorobenzene	118-74-1	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U
Pentachlorophenol	87-86-5	99 U	100 U	100 U	98 U	100 U	100 U	99 U	99 U	100 U	99 U	99 U	99 U	99 U
Phenanthrene	85-01-8	**20**	**49**	20 U	**71**	20 U	20 U	**940**	**540**	**21,000**	**210**	**110**	**13,000**	**1,700**
Carbazole	86-74-8													
Anthracene	120-12-7	20 U	20 U	20 U	**160**	**24**	**54**	**73**	**63**	**840**	**25**	**27**	**220**	**59**
Di-n-Butylphthalate	84-74-2	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U
Fluoranthene	206-44-0	**78**	**85**	20 U	**64**	20 U	**25**	**3,600**	**4,200**	**36,000**	**1,600**	**760**	**16,000**	**4,800**
Pyrene	129-00-0	**60**	**50**	20 U	**28**	20 U	20 U	**2,000**	**2,400**	**18,000**	**770**	**380**	**8,200**	**2,900**
Butylbenzylphthalate	85-68-7	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U
3,3'-Dichlorobenzidine	91-94-1													

Table A-1 Analytical Results (Sediment)

	Sample ID:	07102301	07102302	07102303	07102304	07102305	07102306	07102401	07102402	07102403	07102404	07102405	07102501	07102502
	Lab ID:	07-22638-LV15L	07-22639-LV15M	07-22640-LV15N	07-22641-LV15O	07-22642-LV15P	07-22643-LV15Q	07-22644-LV16A	07-22645-LV16B	07-22646-LV16C	07-22647-LV16D	07-22648-LV16E	07-22649-LV16F	07-22650-LV16G
	Date Collected:	10/23/2007	10/23/2007	10/23/2007	10/23/2007	10/23/2007	10/23/2007	10/24/2007	10/24/2007	10/24/2007	10/24/2007	10/24/2007	10/25/2007	10/25/2007
	Matrix:	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment
Compound	**CAS No.**													
Benzo(a)anthracene	56-55-3	**40**	**26**	20 U	20 U	20 U	20 U	**270**	**300**	**1,700**	**96**	**87**	**650**	**190**
bis(2-Ethylhexyl)phthalate	117-81-7	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	**26**	20 U
Chrysene	218-01-9	**71**	**35**	20 U	**32**	20 U	20 U	**800**	**950**	**5,900**	**280**	**210**	**2,500**	**830**
Di-n-Octyl phthalate	117-84-0	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U
Benzo(b)fluoranthene	205-99-2	**60**	**29**	20 U	20 U	20 U	20 U	**280**	**340**	**1,200**	**79**	**88**	**790**	**290**
Benzo(k)fluoranthene	207-08-9	**58**	**25**	20 U	20 U	20 U	20 U	**300**	**270**	**1,200**	**140**	**68**	**810**	**240**
Benzo(a)pyrene	50-32-8	**35**	**29**	20 U	20 U	20 U	20 U	**100**	**110**	**560**	**39**	**31**	**240**	**75**
Indeno(1,2,3-cd)pyrene	193-39-5	**24**	20 U	20 U	20 U	20 U	20 U	**50**	**45**	**190**	20 U	20 U	**100**	**27**
Dibenz(a,h)anthracene	53-70-3	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	**94**	20 U	20 U	**42**	20 U
Benzo(g,h,i)perylene	191-24-2	20 U	20 U	20 U	20 U	20 U	20 U	**32**	**30**	**100**	20 U	20 U	**59**	**22**
1-Methylnaphthalene	90-12-0	20 U	20 U	20 U	20 U	20 U	20 U	20 U	20 U	**180**	20 U	20 U	**52**	20 U
PCBs (µg/kg dry wt., ug/L wet)														
Aroclor 1016	12674-11-2	20 U						20 U	20 U			19 U		
Aroclor 1242	53469-21-9	20 U						20 U	20 U			19 U		
Aroclor 1248	12672-29-6	20 U						20 U	20 U			19 U		
Aroclor 1254	11097-69-1	20 U						20 U	20 U			19 U		
Aroclor 1260	11096-82-5	20 U						20 U	20 U			19 U		
Aroclor 1221	11104-28-2	20 U						20 U	20 U			19 U		
Aroclor 1232	11141-16-5	20 U						20 U	20 U			19 U		
Organochlorine Pesticides (µg/kg dry wt., ug/L wet)														
alpha-BHC	319-84-6													
beta-BHC	319-85-7													
delta-BHC	319-86-8													
gamma-BHC (Lindane)	58-89-9	0.98 U						0.98 U	0.97 U			1.0 U		
Heptachlor	76-44-8	0.98 U						0.98 U	0.97 U			1.0 U		
Aldrin	309-00-2	0.98 U						3.2 U	0.97 U			1.0 U		
Heptachlor Epoxide	1024-57-3													
Endosulfan I	959-98-8													
Dieldrin	60-57-1	2.00 U						2.0 U	2.0 U			2.0 U		
4,4'-DDE	72-55-9	2.00 U						2.0 U	2.0 U			2.0 U		
Endrin	72-20-8													
Endosulfan II	33213-65-9													
4,4'-DDD	72-54-8	2.00 U						2.0 U	2.0 U			2.0 U		
Endosulfan Sulfate	1031-07-8													
4,4'-DDT	50-29-3	2.00 U						14 U	2.0 U			2.0 U		
Methoxychlor	72-43-5													
Endrin Ketone	53494-70-5													
Endrin Aldehyde	7421-93-4													
gamma Chlordane	5103-74-2	0.98 U						3.9 U	3.0 U			1.0 U		
alpha Chlordane	5103-71-9	0.98 U						0.98 U	0.97 U			1.0 U		
Toxaphene	8001-35-2													
Metals (mg/kg dry wt., mg/L wet)														
Arsenic	7440-38-2	**4.1**	**3.4**	**4.1**	**3.4**	**4.2**	**2.1**	**2.8** J	**2.5** J	**3.7** J	**3.5** J	**4.6** J	**3.0** J	**3.9** J
Cadmium	7440-43-9	0.3 U	0.3 U	0.2 U	0.3 U	0.3 U	0.2 U	0.7 U	0.7 U	0.3 U	0.3 U	0.3 U	0.6 U	0.3 U
Chromium	7440-47-3	**38.3**	**45.6**	**25.9**	**20.7**	**27.6**	**17.3**	**23**	**24**	**20.3**	**27.1**	**40.6**	**20**	**28.4**
Copper	7440-50-8	**23.3** J	**16.3** J	**19.6** J	**16.5** J	**23.8** J	**17.4** J	**12.1**	**11.8**	**12.5**	**18.3**	**36.5**	**10.3**	**21.4**
Lead	7439-92-1	**7.6**	**5.9**	**6.2**	**7.1**	**7.0**	**4.7**	**4.3**	**3.6**	**4.5**	**4.9**	**5.9**	**4.0**	**5.2**
Mercury	7439-97-6	0.06 U	0.07 U	0.06 U	0.05 U	0.06 U	0.05 U	0.06 U	0.06 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U
Silver	7440-22-4	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.3 U	1 U	1 U	0.4 U	0.4 U	0.4 U	1 U	0.4 U
Zinc	7440-66-6	**45** J	**42** J	**57** J	**46** J	**76** J	**47** J	**34**	**32**	**52**	**43**	**63**	**28**	**48**

Notes:

Bold values indicate compounds that were detected in sediment samples collected at the Site.
U: The material was analyzed for, but was not detected above the
level of the associated value. The associated value is either the
sample quantitation limit or the sample detection limit.
J: The associate value is an estimated quantity.
R: The data are unusable; the analyte may or may not be present.

APPENDIX B

HYDRODYNAMIC MODELING REPORT
FIDALGO BAY CAUSEWAY FEASIBILITY STUDY

HYDRODYNAMIC MODELING REPORT

FIDALGO BAY CAUSEWAY FEASIBILITY STUDY

FIDALGO BAY, WASHINGTON

PREPARED FOR THE

SAMISH INDIAN NATION

Prepared by

RIDOLFI Inc.

September 2008

HYDRODYNAMIC MODELING REPORT

FIDALGO BAY CAUSEWAY FEASIBILITY STUDY

FIDALGO BAY, WASHINGTON

PREPARED FOR THE

SAMISH INDIAN NATION

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ATTACHMENT A

Output Summary Tables and Figures

1.0 INTRODUCTION

This report describes hydrodynamic modeling that was conducted to support evaluations of various alternatives for modifying the Tommy Thompson Trail where it crosses Fidalgo Bay. Approximately one half of the trail is a piling supported trestle that does not significantly impede tidal flow from north to south within the bay. The other half of the trail is a fill causeway, which precludes flow. The modeling is intended to help predict how the flow would be altered under different scenarios. The remainder of the report describes the modeling software, the conceptualization of Fidalgo Bay to facilitate the modeling effort, the results of the modeling, and concludes with findings reached based on the modeling.

1.1 Modeling Software

RMA2 is a two-dimensional, depth-averaged, finite element hydrodynamic numerical model. It computes water surface elevations and horizontal velocity components for subcritical, free-surface two-dimensional flow fields.

RMA2 computes a finite element solution of the Reynolds form of the Navier-Stokes equations for turbulent flows. Friction is calculated with the Manning’s equation, and eddy viscosity coefficients are used to define turbulence characteristics. Both steady and unsteady (dynamic) problems can be analyzed using RMA2.

Surfacewater Modeling System (SMS) is a graphical user interface that was used in conjunction with RMA2 for pre- and post-processing of input and output data, including animations and other graphics and data analyses.

1.2 Fidalgo Bay Model

The purpose of the hydrodynamic model developed for this project was to gain a greater understanding of how modifications to the causeway would change the hydraulics and associated circulation patterns near the causeway, and in the southern portion of Fidalgo Bay. Hydraulic changes in the “back bay” area located in the northwest tip of the southern bay was of particular interest. Figure 2 details these locations.

A dynamic RMA2 model was developed for approximately 600 acres of Fidalgo Bay in the vicinity of the causeway. Though the model domain was over 600 acres, the main area of interest was the southern portion of the bay south of the causeway, consisting of approximately 300 acres. The greater model domain acts as a buffer for the model to stabilize as it approaches the area of interest. The model was "tidal driven" with no additional inputs.

2.0 MODEL DATA INPUT

Bathymetry and tidal data were required for model input. Input bathymetry data was obtained from multiple sources. To the north of the causeway, bathymetry data from a previous study of Fidalgo Bay were used (Williams et al, 2003). Bathymetric data from this study was very limited in the southern portion of the bay, therefore an aerial topographic survey during low tide was completed by Aerometric for this project. Data generated from the survey was used as the source of bathymetric data for the portion of the bay south of the causeway.

Tidal data were obtained using a Troll 4000 pressure transducer. The transducer was placed into the water under the trestle portion of trail and measured water elevations from March 7, 2008 to April 1, 2008 at five minute intervals. The field data were calibrated using modeled tidal data for Guemes Island obtained from tidal software WXTide.

Model “spin-down” was used to initiate the model to handle model instabilities associated with “wetting” and “drying”. “Spin-down” requires the model to be completed wetted and subsequently drawn down to real world conditions. For this simulation the model spin down ran from a 36-foot head to a 2-foot head in approximately 70 time steps. Results from this part of the model were not used in analyses or graphical output.

Though not required for model input, five instantaneous velocity measurements were recorded using a hand-held pygmy meter during the placement of the transducer. These measurements were highly localized and were not therefore considered as representative of the larger system, however, they do provide “order of magnitude” calibration information when analyzing model output.

The hydrodynamic model of the bay simulates approximately two and one-half days of hydraulic conditions within Fidalgo Bay with a time step of five minutes. The model input included a maximum tide of 8.95 feet and a minimum of 0.52 feet over two complete tidal cycles (MHHW, MLLW, MHW, MLW). This tidal range was ultimately selected due to experiencing model instability associated with wetting and drying at more extreme tides. The model consists of approximately 5,500 nodes and 2500 elements and completes 751 individual time steps. Input data from the model can be seen in Figure 1. Note the "spin-down" data over the first 70 steps.

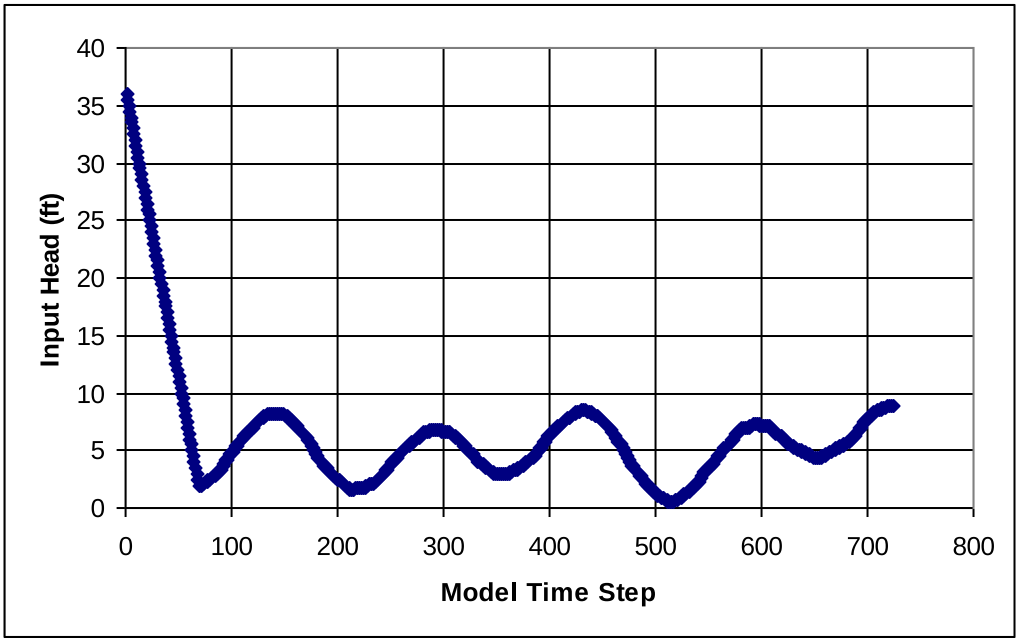


Figure 1. Tidal Data Input

2.1 Modeled Conditions

Five simulations were modeled for the purposes of this study. These conditions are described as follows:

* Alternative 1 (No Action): The existing conditions of the bay as dictated by existing bathymetric and tidal input data.

* Alternative 2: Alternative 2 is to remove the causeway from approximately the tip of Weaverling Spit eastward to the remaining trestle. Therefore, the model of this alternative simulates the hydraulic conditions associated with the removal of the causeway to a depth of 1-foot above mean lower low water (MLLW), matching the existing grades to the north and south of the existing causeway.

* Alternative 3: Alternative 3 is to remove several sections of the causeway. This model simulates the hydraulic conditions associated with removing three, two-hundred foot sections, leaving "islands" of approximately 250, 250 and 300- feet from west to east along the existing causeway alignment. The gaps created within the simulation descend from the existing grade to an elevation of 1-foot above MLLW in slopes that match the existing side slopes of the causeway.

* Alternative 4: Alternative 4 is to remove a single section of the causeway. The model of this alternative simulates the hydraulic conditions associated with removing a 100-foot section at approximately the middle point of the causeway. The gap created within the simulation descends from the existing grade to an elevation of 1-foot above MLLW in slopes that match the existing side slopes of the causeway.

* Alternative 5: Alternative 5 is an extension of Alternative 3. The model of this alternative simulates the hydraulic conditions associated with removing a 200-foot section at approximately the middle point of the causeway. The gap created within the simulation descends from the existing grade to an elevation of 1-foot above MLLW in slopes that match the existing side slopes of the causeway.

3.0 MODEL DATA OUTPUT AND ANALYSES

The two main metrics used to evaluate the change in hydraulics and circulation within the model domain are the magnitude and direction of the velocity vector. Water depth output was used to calibrate and verify the model, but was not used for hydraulic evaluation. The hydraulic effects of each design alternative could be compared by looking at changes in the velocity vector. It should be noted that a positive change in a flow rate in and of itself is not necessarily an indication of circulation improvement because localized peaks can skew the data. This is why flow direction is a critical element to making this assessment. As will be seen in the following sections, in some cases decreases in velocity magnitudes are seen under circumstances where local and global circulation appears to be improving. The output data were evaluated across the complete time series and at five discrete steps within the model domain.

3.1 Time Series Data Analyses

A global, qualitative understanding of the circulation patterns for each of the model conditions was gained by viewing the complete time series data output in a graphical format. Comparing design alternative circulation and velocity profiles to the base condition profiles, the hydraulic effects of each of the designs could be distilled. Several "movies" of the complete time series output for depth and the velocity vectors are provided on an accompanying compact-disc. A brief discussion of observations made for each of the simulated conditions follows. Refer to the figures in Attachment A for "snapshots" of these simulations.

3.1.1 Alternative 1: No Action

The greatest velocity magnitudes are seen around the tip of the existing causeway in an existing channel in the base condition. This is likely due to the "funneling-effect" that the causeway currently causes as water is forced around the causeway tip into and out of the southern portion of the bay. This effect is further evidenced by a channel that has been scoured around the causeway tip. The regions adjacent to the north and south of the causeway, and the "back bay area" experience very low tidal circulation except for eddy circulation in the southern portion of the bay. Flow vectors in this area run largely parallel to the causeway (east-west) on incoming and outgoing tides; also likely due to the funneling effect (See Figures A1-A25, Attachment A). The southern portion of the bay generally experiences very low surface velocities and circulation is attributed to eddies that form with incoming tides. The highest velocities seen in this portion of the bay are seen at tidal transitions.

3.1.2 Alternative 2: Complete Causeway Removal

Peak velocities observed associated with Alternative 2 are lower than those seen in Alternative 1. This is likely due to the fact that the “funneling” effect has been removed from the southern portion of the bay with the removal of the causeway. Velocity magnitudes from approximately 1000 feet north of the causeway are decreased and in the existing channel, flow vectors tend to diverge and spread out through the center of the bay. Peak velocities are shifted further west towards the tip of Weaverling Spit and a larger band of mid-range velocity values can be observed passing through what was the footprint of the causeway and through the “back bay” area. In this condition, Weaverling Spit serves as a focus point for flows into the back bay, therefore erosion and deposition around this point will likely be increased. The southern portion of the bay experiences a much broader band of mid-range velocity magnitudes and more tidal circulation with flow vectors running parallel to incoming and outgoing tides, and only slight variations observed in eddies located in the northwest corner of the southern bay (See Figures A1-A25, Attachment A).

3.1.3 Alternative 3: Three (200-foot) Causeway Breaches

Peak velocities observed under this simulation are seen at each of the causeway breaches and at the tip of the remaining section of the causeway. Current speeds are comparable to those seen in Alternative 1. Though attenuated, the “funneling effect” of the causeway can still be observed, though the thalweg of the incoming and outgoing flows appears to have shifted to the west towards the tip of Weaverling Spit. As with Alternative 2, increased velocity magnitudes in this area will likely change erosional and depositional patterns around the spit. The back bay experiences a broader band of mid-range velocities, and flow vectors generally parallel tidal flows (See Figures A1-A25, Attachment A). Turbulence can be observed behind each of the remaining "islands" and eddying is present around the causeway tip. The southern portion of the bay experiences more tidal circulation with flow vectors running parallel to incoming and outgoing tides and less global eddying.

3.1.4 Alternative 4: One (100-foot) Causeway Breach

Peak velocities observed in this simulation are mostly seen at the causeway tip. Some very localized peak velocities are observed within the causeway breach. These peak velocities are comparable to those seen in the base condition. The "funneling effect" of the causeway remains largely unchanged from Alternative 1 under this scenario. Flow vectors in the back bay and directly adjacent to the causeway alignment run parallel to the causeway (perpendicular to tidal cycles) as is seen in the base condition (See Figures A1-A25, Attachment A). Localized, very turbulent effects of the breach can be observed in the direct vicinity of the causeway, but are not propagated throughout the south bay. This is an indication that this design alternative does not provide adequate flow capacity to impact the larger hydraulic system in this portion of the bay. Velocity profiles in the southern portion of the bay are not noticeably affected by modifications to the causeway simulated under this alternative.

3.1.5 Alternative 5: One (200-foot) Causeway Breach

Peak velocities observed under this simulation occur at the causeway tip and within the causeway breach. The funneling effect is still present under this design, but is attenuated with a larger flow path available through the 200-foot breach. The thalweg of the incoming and outgoing tides appears to split and/or shift to the west towards the tip of Weaverling Spit, which may change erosional and depositional patterns in this area. Though the remaining causeway still forms a significant barrier to open tidal flow, as evidenced by the flow vectors running mostly parallel to the causeway (perpendicular to tidal flows), the breach appears large enough to influence circulation in the back bay (See Figures A1-A25, Attachment A). This can be seen in a larger band of mid-range flows that emanate from just north of the causeway breach through the back bay area. Also, flow vectors in this area appear to be less eddy influenced and more parallel to the tidal flows. Changes in the hydraulics and circulation in the southern portion of the bay are less pronounced. Less eddying appears to occur because restrictions to flow caused by the causeway are reduced with the causeway breach; however these changes are very subtle.

3.2 Discrete Time Step Analyses

Because of the subtle changes in hydraulics observed over much of the model domain under each design alternatives, a quantitative method of data comparison was employed. In order to quantitatively compare the circulation data across the five alternatives, output velocity data from five discrete time steps within the model were selected for statistical analyses. These time steps were selected from differing portions over the input data domain and tidal cycle by querying the input data for points with the greatest change in head from adjacent point data.

In addition to global maximum, minimum and mean velocity magnitudes for each discrete time step, localized velocity data were sampled along four alignments. The alignments selected represented: 1) a line parallel to the causeway approximately 800 feet to the north of the causeway alignment, 2) a line parallel to the causeway approximately 40 feet to the south of the causeway alignment, 3) a line parallel to the causeway approximately 800 feet south of the causeway alignment, and 4) a line which bisects the back bay portion of the model. These alignments can be seen in Figure 2.

For the purposes of this evaluation, all current speed data were compared to output from Alternative 1, No Action. From these data "percent-change" in speeds were calculated for each alternative and time step. As previously stated, positive change in speeds in and of itself is not necessarily an indication of increased circulation. Because of localized effects around the tip of the causeway, and in the established channels, speed information was combined with directions of flow (vectors) at each time step, for quantitative and qualitative circulation conclusions to be drawn.

Attachment A contains the Tables and Figures used for these analyses.

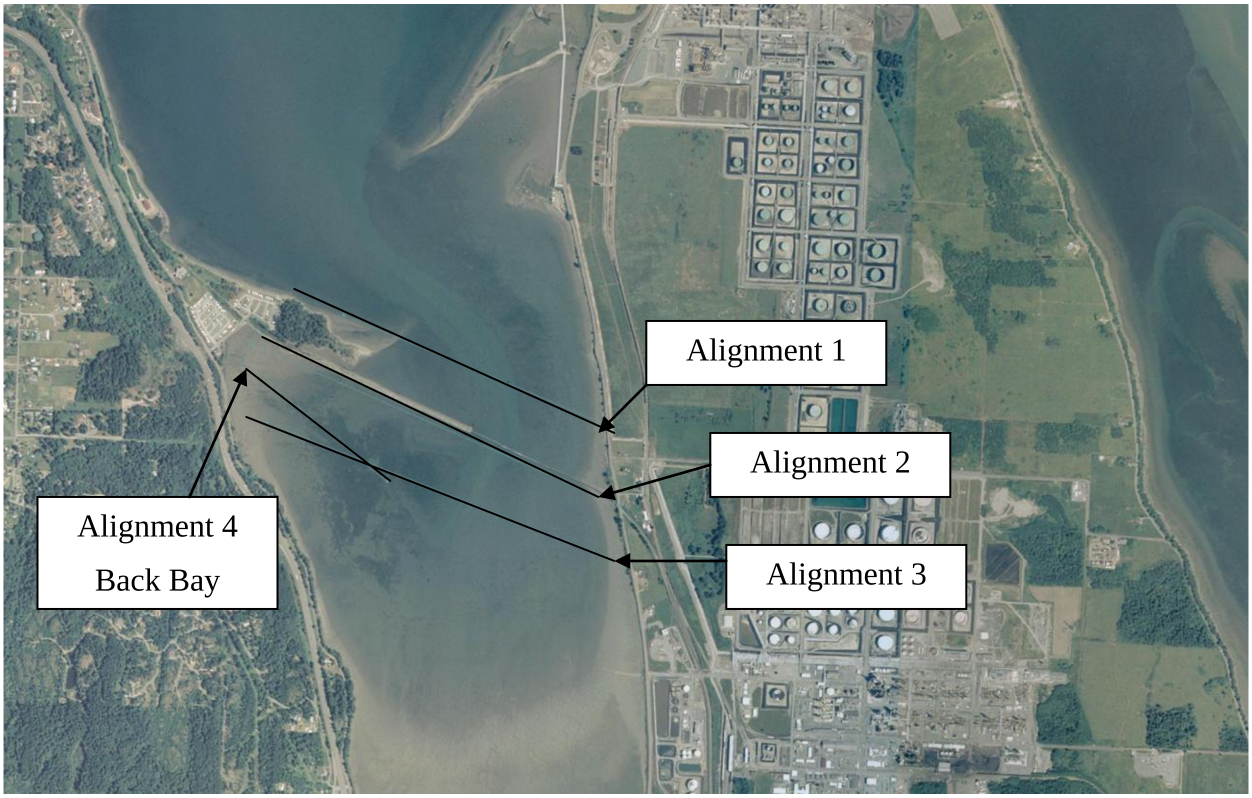


Figure 2. Velocity profile alignments.

3.2.1 Hydraulic Snapshot March 9, 2008 - 14:55:30

This snapshot represents the hydraulic conditions seen in the bay under each of the alternatives approximately three hours after low tide. As can be seen in Table A1 the mean velocity reported for Alternative 1, No Action, 0.35 feet per second (fps), with a maximum velocity of 1.3 fps. The maximum value agrees in magnitude with surface velocities of approximately 4 to 6 fps measured in the field. Also indicated in Table A1, the design alternatives produce mean velocity increases across the entire domain of 1.6 to 5.0 percent, with the largest change in global velocity values occurring under Alternative 2.

The statistical analysis results for the velocity magnitude data sampled along the four alignments at this time step can be seen in Table A2. The greatest percent change in mean velocities is seen in Alignment 2, just south of the existing causeway alignment. The largest percent change in calculated magnitude at this location is a 45 percent increase associated with Alternative 3. Increased velocities from the base condition can also be seen in Alignment 1 for Alternative 3 through 5. The back bay (Alignment 4) experiences increased velocities with all Alternatives with the largest recorded change of 15.82 percent associated with Alternative 2. Alignment 3, 800 feet south of the causeway, shows a global decrease in velocity magnitude for all of the design alternatives. This is likely due to the decrease in “funneling” caused by changes to the causeway.

Figures A1-A5 contain images of the model velocity data output at this time step. As can be seen in these figures, causeway modifications generally lead to significant changes in the prevailing direction of flows with Alternatives 2-5. However, the degree of change depends greatly on the design alternative. The largest changes at this time step are seen in Figure A2 and are associated with Alternative 2. In this design, areas with previously no or little circulation see dramatic increase. This is evidenced in the area just east of the tip of Weaverling Spit, and just south of the causeway and in the back bay area. However, circulation improvements associated with Alternatives 3 and 5 are also notable. Alternative 4 does not show marked changes in flow direction from the base condition.

3.2.2 Hydraulic Snapshot March 9, 2008 - 20:40:30

This snapshot represents the hydraulic conditions seen in the bay under each of the alternatives approximately two and one-half hours after high tide. As can be seen in Table A3 the mean velocity magnitude reported for the Base Condition is 0.324 feet per second (fps), with a maximum velocity magnitude of 1.18 fps. The maximum value agrees in magnitude with surface velocities of approximately 4 to 6 fps measured in the field. Also indicated in Table A3, alternatives 2-5 produce mean velocity increases across the entire model domain of 2.98 to 12.23 percent, with the largest change in global velocity values occurring under Alternative 2.

The statistical analysis results for the velocity magnitude data sampled along the four alignments at this time step can be seen in Table A4. The greatest percent change in mean velocities is seen in Alignment 4, in the back bay portion of the model. The largest percent change in calculated velocity at this location compared to the base condition is an 82 percent increase associated with Alternative 2. Moderate increases in velocity magnitudes from the base condition can be seen in Alignment 1 for all of the design alternatives, ranging from 2.6 to 4.8 percent. Alignment 2, just south of the causeway alignment, experiences velocity magnitude changes ranging from -3.35 percent under Alternative 4 to a 25 percent increase under Alternative 3. Alignment 3, 800 feet south of the causeway, shows a range of velocity changes from -2.74 percent to 17.8 percent.

Figures A6-A10 contain images of the model velocity data output at this time step. Alternatives 2, 3, and 5 show changes in the prevailing direction of flow, however, the most noticeable changes illustrated in these figures are associated with Alternatives 2 and 3. These changes are evidenced in the area just east of the tip of Weaverling Spit, and just south of the causeway and in the back bay area.

3.2.3 Hydraulic Snapshot March 10, 2008 – 03:25:30

This snapshot represents the hydraulic conditions seen in the bay under each of the alternatives approximately three and one-half hours after low tide. As can be seen in Table A5 the mean velocity reported for the Alternative 1 is 0.322 feet per second (fps), with a maximum velocity of 1.06 fps. The maximum value agrees in magnitude with surface velocities of approximately 4 to 6 fps measured in the field. Also indicated in Table A5, the design alternatives produce mean velocity increases across the entire model domain from -1.93 to 1.18 percent, with the largest change in global velocity values occurring under Alternative 5.

The statistical analysis results for the velocity magnitude data sampled along the four alignments at this time step can be seen in Table A6. The greatest percent change in mean velocities is seen in Alignment 4, in the back bay portion of the model. The largest percent change in calculated velocity at this location compared to Alternative 1 is a -33 percent decrease associated with Alternative 3. Slight increases in velocities from the base condition can be seen in Alignment 1 for Alternatives 3 through 5, with Alternative 2 showing a slight decrease. Alignment 2, just south of the causeway alignment, experiences velocity magnitude changes ranging from -0.71 percent under Alternative 2 to a 16 percent increase under Alternative 3. Alignment 3, 800 feet south of the causeway, shows a global decrease in velocity magnitudes ranging from -16 to -25 percent.

Figures A11-A15 contain images of the model velocity data output at this time step. As with the previous time steps, Alternatives 2, 3 and 4 show noticeable changes in the prevailing direction of flow. Again, the most significant changes are associated with Alternatives 2 and 3 and are illustrated in figures A12 and A13. Alternative 1 all but eliminates the eddying condition within the back bay that seen in Alternative 2, No Action, at this time step. Increases in average velocities at the tip of Weaverling Spit in the footprint of the causeway are also clearly represented in Figures A12 and A13. Alternative 5 also provides increased flows in these areas.

3.2.4 Hydraulic Snapshot March 10, 2008 – 09:40:30

This snapshot represents the hydraulic conditions seen in the bay under each of the alternatives approximately three and one-half hours after high tide. As can be seen in Table A7 the mean velocity reported for the Alternative 1, No Action, 0.436 feet per second (fps), with a maximum velocity of 1.764 fps. The maximum value agrees in magnitude with surface velocities of approximately 4 to 6 fps measured in the field. Also indicated in Table A7, the design alternatives produce mean velocity increases across the entire model domain from -6.65 to 1.58 percent, with the largest change in global velocity values occurring under Alternative 5.

The statistical analysis results for the velocity magnitude data sampled along the four alignments at this time step can be seen in Table A8. The greatest percent change in mean velocities is seen in Alignment 2, just south of the current causeway alignment. The largest percent change in calculated velocity at this location compared to the Alternative 1, No Action, is a -49 percent decrease associated with Alternative 4. Velocity magnitudes decrease from the Alternative 1 for the alternatives 2-5 along Alignment 1. Alignment 3, 800 feet south of the causeway, also shows a global decrease in velocity magnitudes ranging from -9 to -37 percent. This is likely due to a decrease in the funnel effect associated with causeway modifications. Alignment 4, which bisects the back bay portion of the model, shows a large range of velocity changes from a 26 percent gain under Alternative 2 to a -41 percent decrease under Alternative 4.

Figures A16-A20 contain images of the model velocity data output at this time step. Peak velocities seen at the tip of the causeway in the Alternative 1 are attenuated in all but Alternative 4. Alternatives 2, 3 and 4 show noticeable changes in the prevailing direction of flow. Again, the most significant changes are associated with Alternatives 2 and 3 and are illustrated in figures A17 and A18. Increases in average velocities at the tip of Weaverling Spit in the footprint of the causeway are also clearly represented in Figures A17 and A18. Figure A20 illustrates the enhanced flows seen in these areas associated with Alternative 5.

3.2.5 Hydraulic Snapshot March 11, 2008 – 04:09:30

This snapshot represents the hydraulic conditions seen in the bay under each of the alternatives approximately three and one-half hours after low tide. As can be seen in Table A9 the mean velocity reported for the Alternative 1, No Action, is 0.329 feet per second (fps), with a maximum velocity of 1.167 fps. The maximum value agrees in magnitude with surface velocities of approximately 4 to 6 fps measured in the field. Also indicated in Table A9, alternatives 2-5 produce mean velocity increases across the entire model domain from 0.56 to 3.35 percent, with the largest change in global velocity values occurring under Alternative 3.

The statistical analysis results for the velocity magnitude data sampled along the four alignments at this time step can be seen in Table A10. The greatest percent change in mean velocities is seen in Alignment 4, in the back bay portion of the model. The largest percent change in calculated velocity at this location compared to Alternative 1 is a 33 percent decrease associated with Alternative 2. Velocity magnitudes show moderate changes relative to Alternative 1 for alternatives 2-5 along Alignment 1, ranging from -1.33 to 2.14 percent. Alignment 2, just south of the causeway, recorded significant increases in velocities for all design alternatives; these increases range from a 5.42 percent increase under Alternative 4 to a 28 percent increase in velocities under Alternative 3. Alignment 3, 800 feet south of the causeway, also shows a global decrease in velocity magnitudes ranging from -12 to -25 percent. This is likely due to a decrease in the funnel effect associated with causeway modifications.

Figures A21-A25 contain images of the model velocity data output at this time step. As seen in these figures, the band of peak velocities seen at the tip of the causeway in the Base Condition have moved west to the tip of Weaverling Spit in Alternative 2, 3 and 5, with little change from the Alternative 1 seen in Alternative 3. As with the other time steps, the most significant changes in flow direction are associated with Alternatives 2 and 3 and are illustrated in figures A22 and A23.

4.0 DATA ANALYSES SUMMARY

As described in the previous sections, there is a substantial variability in velocity within the model. However, the velocity data and graphical analyses generally support the conclusion that modifications involving removing all or part of the causeway would increase circulation in the near vicinity of the current alignment, in the back bay and southern bay. From these data, it appears the Alternatives 2 and 3 have the greatest effect on the direction of flow around Weaverling Spit, the causeway footprint and in the back bay area. Grand averages of all of the discrete time step analyses described in the previous sections were calculated in order to quantify this trend. Tables 1 and 2 contain the results of these calculations.

Table 1. Grand Average of Global Current Speed Changes

Alternative	Average Change in Current Speed Compared to Alternatives
2	1.17%
3	4.47%
4	1.43%
5	2.22%

As can be seen in Table 1, all of the design alternatives produce an increase in the magnitude of the velocities across the entire model domain. Alternative 3 produces the greatest increases on average. This is likely due to the localized effects of the three causeway breaches within the model. Alternative 2, which entails removal of the entire causeway structure results in the smallest average increase in average speeds across the entire model domain. This is likely due to incremental increases made in the footprint of the causeway where previously no flow was permitted. Alternatives 4 and 5 have the second and third biggest increases in speed, but are only half what is seen in the Alternative 3. This can likely be explained by the fact that because of these designs only alter a small portion of the entire causeway, the effects do not propagate through the bay to achieve the gains seen in Alternative 3. Although these changes in magnitude are not extreme, when coupled with the flow directions data, they support the assertion that circulation in the target areas is improved with any modifications to the causeway.

Table 2. Grand averages of localized current speed changes.

Alternative	Alignment 1: 800 feet North of the Causeway Alignment	Alignment 2: 50 feet South of the Causeway Alignment	Alignment 3: 800 feet South of the Causeway Alignment	Back Bay	Grand Average
2	-2.15%	9.26%	-6.13%	31.89%	8.22%
3	1.01%	23.43%	-14.05%	5.93%	4.08%
4	-0.36%	-7.64%	-20.17%	-6.69%	-8.72%
5	2.42%	9.02%	-13.27%	6.17%	1.08%

* All changes are relative to Alternative 1, No Action.

The results presented in Table 2 indicate that, on average, all but Alternative 4, produce a net increase in flow velocities from the base condition. The most significant changes are seen in the back bay area of the model. However, velocity decreases should be noted along Alignment 3 for all of the design alternatives and in Alignment 1 for Alternative 2 and 4. These decreases are likely due to the location of these alignments within the "funneling" channel in the base model. Therefore, high velocity profiles in these sections tend to skew the data. However, in general for the selected alignments, Alternative 2 produced the greatest average increases in velocities. This is followed closely by Alternative 3. These are the two designs that have the greatest relative impact on the causeway structure, and therefore effects are propagated throughout the model. These results paired with flow vector information at these time steps support the assertion that an increase in circulation occurs within the areas of interest with causeway modifications.

4.1 Conclusions

The results of the analyses of the output from the RMA2 model completed for this study support the assertion that removal of all or part of the causeway will result in localized changes in hydraulics and circulation in the areas around Weaverling Spit, the southern back bay and the current causeway alignment. Circulation changes in the extreme southern portion of the bay were also noted, but the extent of these changes are subtle and very design alternative dependent. From the alternatives modeled for this study, it is clear that the more of the causeway structure that is removed, the more tidally driven circulation will occur in the southern portion of the bay. This is contrasted by a point of diminishing return on the lower end, with very little hydraulic effects being noted using a simple 100-foot breach. The minimum size breach with sufficient positive effects is the 200-foot breach modeled under Design Alternative 5.

5.0 REFERENCES

Williams, B.W., Wyllie-Escheverria, S., Bailey, A. Historic Nearshore Habitat Change Analysis Fidalgo Bay and Guemes Channel. January 2003.

ATTACHMENT A

OUTPUT SUMMARY TABLES AND FIGURES

Table A1. Global Velocity Data: Time Step 3/9/08, 14:55

Velocity (ft/s)	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
Minimum	0.0006	0.0005	0.0006	0.0001	0.0001
Maximum	1.290	1.126	1.283	1.659	1.332
Range	1.290	1.125	1.282	1.659	1.332
Mean	0.352	0.357	0.369	0.358	0.361
Standard Deviation	0.234	0.213	0.234	0.237	0.235
% Change in Mean Velocity from Base Condition		1.63%	5.00%	1.73%	2.77%

Table A2. Alignment Mean Velocity Data: Time Step 3/9/08, 14:55

Model	Alignment 1 North of Causeway Mean Velocity (ft/s)	Percent Change from Alternative 1	Alignment 2 Causeway Mean Velocity (ft/s)	Percent Change from Alternative 1	Alignment 3 South of Causeway Mean Velocity (ft/s)	Percent Change from Alternative 1	Alignment 4 Back Bay Mean Velocity (ft/s)	Percent Change from Alternative 1
Alternative 1	0.694		0.264		0.351		0.134	
Alternative 2	0.688	-0.98%	0.347	31.61%	0.313	-10.80%	0.155	15.82%
Alternative 3	0.721	3.78%	0.383	45.43%	0.300	-14.63%	0.135	0.80%
Alternative 4	0.732	5.39%	0.287	8.98%	0.311	-11.33%	0.140	4.57%
Alternative 5	0.724	4.21%	0.315	19.36%	0.303	-13.72%	0.145	8.69%

Table A3. Global Velocity Data: Time Step 3/9/08, 20:40

Velocity (ft/s)	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
Minimum	0.0002	0.0002	0.0002	0.0002	0.0002
Maximum	1.177	1.219	1.508	2.010	1.618
Range	1.176	1.219	1.508	2.010	1.618
Mean	0.324	0.364	0.362	0.334	0.343
Standard Deviation	0.175	0.175	0.187	0.186	0.185
% Change in Mean Velocity from Base Condition		12.23%	11.61%	2.98%	5.81%

Table A4. Alignment Mean Velocity Data: Time Step 3/9/08, 20:40

Model	Alignment 1 North of Causeway Mean Velocity (ft/s)	Percent Change from Alternative 1	Alignment 2 Causeway Mean Velocity (ft/s)	Percent Change from Alternative 1	Alignment 3 South of Causeway Mean Velocity (ft/s)	Percent Change from Alternative 1	Alignment 4 Back Bay Mean Velocity (ft/s)	Percent Change from Alternative 1
Alternative 1	0.559		0.354		0.246		0.103	
Alternative 2	0.586	4.77%	0.404	14.21%	0.290	17.80%	0.188	82.23%
Alternative 3	0.583	4.38%	0.442	24.87%	0.256	4.17%	0.160	54.96%
Alternative 4	0.574	2.64%	0.342	-3.35%	0.239	-2.74%	0.114	10.54%
Alternative 5	0.580	3.79%	0.385	8.90%	0.243	-1.22%	0.136	31.29%

Table A5. Global Velocity Data: Time Step 3/10/08, 03:25

Velocity (ft/s)	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
Minimum	0.0001	0.00002	0.0001	9.75E-05	0.0001
Maximum	1.066	0.959	0.953	1.191	1.083
Range	1.066	0.959	0.953	1.191	1.083
Mean	0.322	0.315	0.324	0.324	0.325
Standard Deviation	0.209	0.187	0.202	0.186	0.208
% Change in Mean Velocity from Base Condition		-1.93%	0.81%	0.69%	1.18%

Table A6. Alignment Velocity Data: Time Step 3/10/08, 03:25

Model	Alignment 1 North of Causeway Mean Velocity (ft/s)	Percent Change from Alternative 1	Alignment 2 Causeway Mean Velocity (ft/s)	Percent Change from Alternative 1	Alignment 3 South of Causeway Mean Velocity (ft/s)	Percent Change from Alternative 1	Alignment 4 Back Bay Mean Velocity (ft/s)	Percent Change from Alternative 1
Alternative 1	0.652		0.269		0.335		0.110	
Alternative 2	0.636	-2.42%	0.267	-0.71%	0.282	-16.02%	0.113	2.86%
Alternative 3	0.652	0.01%	0.313	16.31%	0.254	-24.20%	0.074	-32.67%
Alternative 4	0.658	0.93%	0.269	0.09%	0.252	-24.69%	0.105	-4.39%
Alternative 5	0.668	2.37%	0.287	6.73%	0.261	-22.00%	0.090	-18.24%

Table A7. Global Velocity Data (ft/s): Time Step 3/10/08, 09:40

Velocity (ft/s)	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
Minimum	0.0001	0.0004	0.0003	0.0003	0.0002
Maximum	1.764	1.478	3.847	1.832	1.692
Range	1.764	1.478	3.846	1.832	1.692
Mean	0.436	0.407	0.443	0.438	0.433
Standard Deviation	0.279	0.244	0.318	0.294	0.285
% Change in Mean Velocity from Base Condition		-6.65%	1.58%	0.52%	-0.57%

Table A8. Alignment Velocity Data: Time Step 3/10/08, 09:40

Model	Alignment 1 North of Causeway Mean Velocity (ft/s)	Percent Change from Alternative 1	Alignment 2 Causeway Mean Velocity (ft/s)	Percent Change from Alternative 1	Alignment 3 South of Causeway Mean Velocity (ft/s)	Percent Change from Alternative 1	Alignment 4 Back Bay Mean Velocity (ft/s)	Percent Change from Alternative 1
Alternative 1	0.742		0.532		0.402		0.178	
Alternative 2	0.662	-10.78%	0.474	-10.83%	0.364	-9.55%	0.225	25.89%
Alternative 3	0.718	-3.25%	0.546	2.77%	0.351	-12.67%	0.199	11.58%
Alternative 4	0.658	-11.29%	0.269	-49.35%	0.252	-37.24%	0.105	-40.93%
Alternative 5	0.739	-0.40%	0.518	-2.49%	0.367	-8.86%	0.195	9.15%

Table A9. Global Velocity Data: Time Step 3/11/08, 04:09

Velocity (ft/s)	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
Minimum	0.00001	0.00006	0.00010	0.00003	0.00004
Maximum	1.167	1.211	1.147	1.428	1.241
Range	1.167	1.211	1.147	1.428	1.241
Mean	0.329	0.331	0.340	0.333	0.335
Standard Deviation	0.215	0.192	0.209	0.217	0.214
% Change in Mean Velocity from Base Condition		0.56%	3.35%	1.21%	1.92%

Table A10. Alignment Velocity Data: Time Step 3/11/08, 04:09

Model	Alignment 1 North of Causeway Mean Velocity (ft/s)	Percent Change from Alternative 1	Alignment 2 Causeway Mean Velocity (ft/s)	Percent Change from Alternative 1	Alignment 3 South of Causeway Mean Velocity (ft/s)	Percent Change from Alternative 1	Alignment 4 Back Bay Mean Velocity (ft/s)	Percent Change from Alternative 1
Alternative 1	0.665		0.268		0.334		0.098	
Alternative 2	0.656	-1.33%	0.300	12.00%	0.294	-12.09%	0.130	32.68%
Alternative 3	0.666	0.14%	0.342	27.73%	0.258	-22.92%	0.093	-5.02%
Alternative 4	0.668	0.56%	0.282	5.42%	0.251	-24.86%	0.095	-3.23%
Alternative 5	0.679	2.14%	0.302	12.60%	0.266	-20.56%	0.098	-0.05%

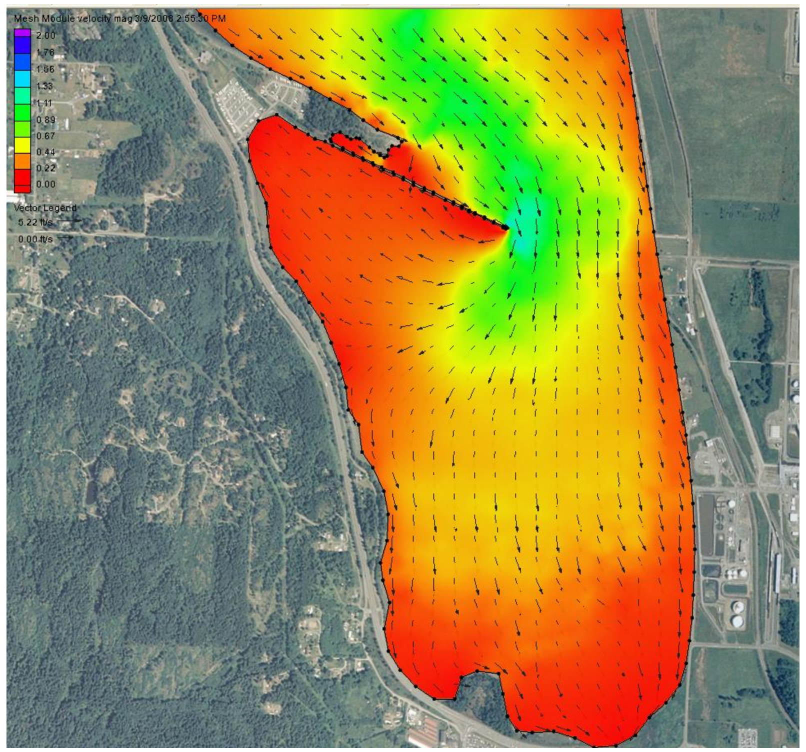


Figure A1. Alternative 1 data output: 3/9/08, 14:55.

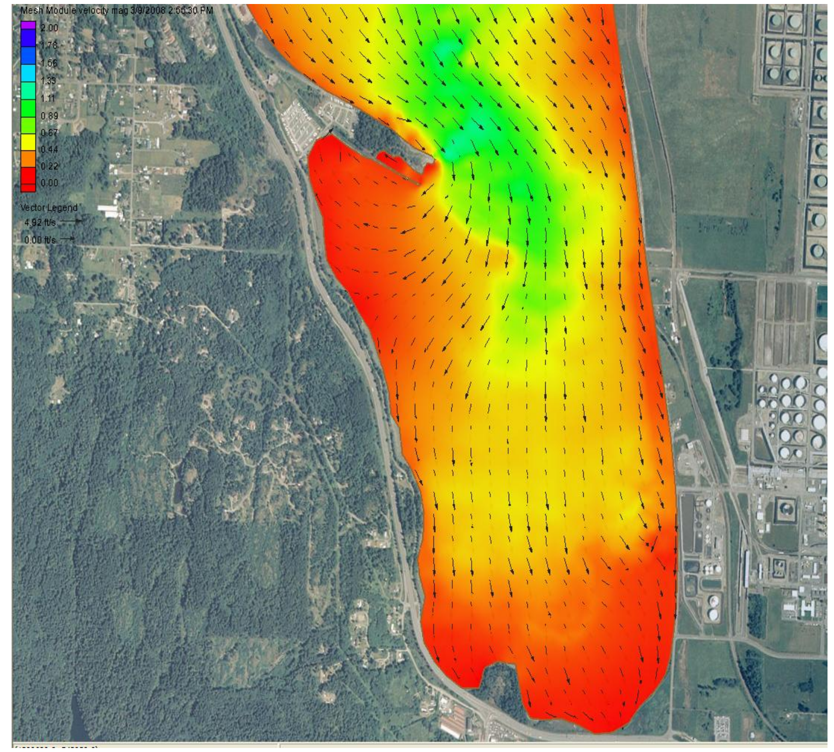


Figure A2. Alternative 2 velocity data output: 3/9/08, 14:55.

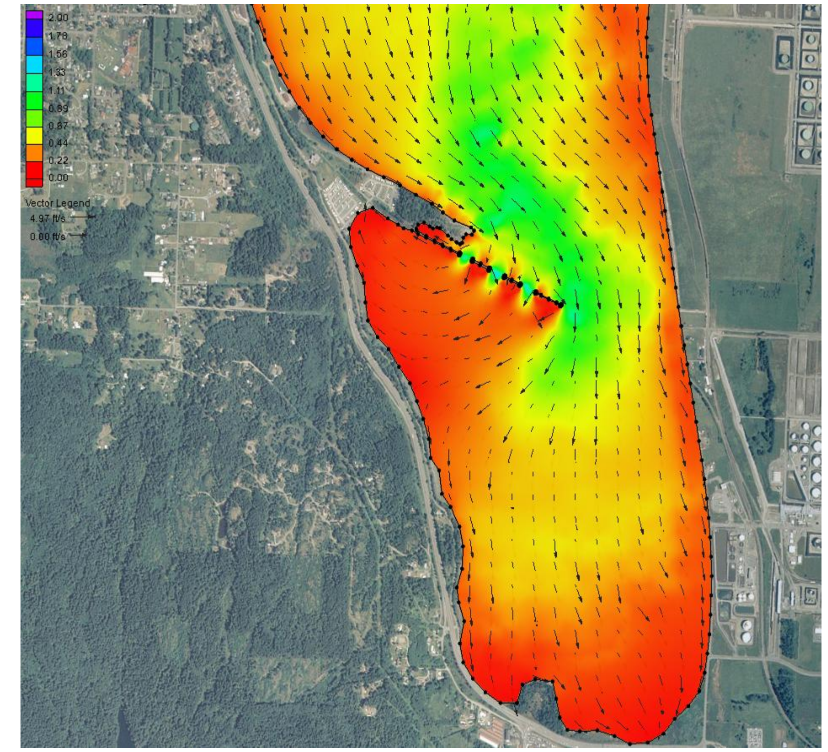


Figure A3. Alternative 3 velocity data output: 3/9/08, 14:55.

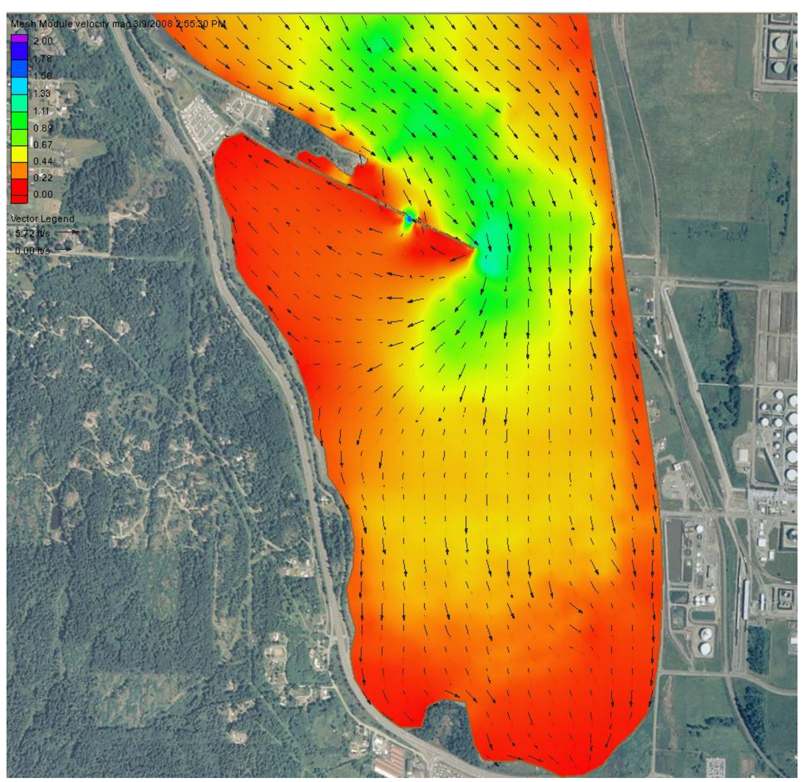


Figure A4. Alternative 4 velocity data output: 3/9/08, 14:55.

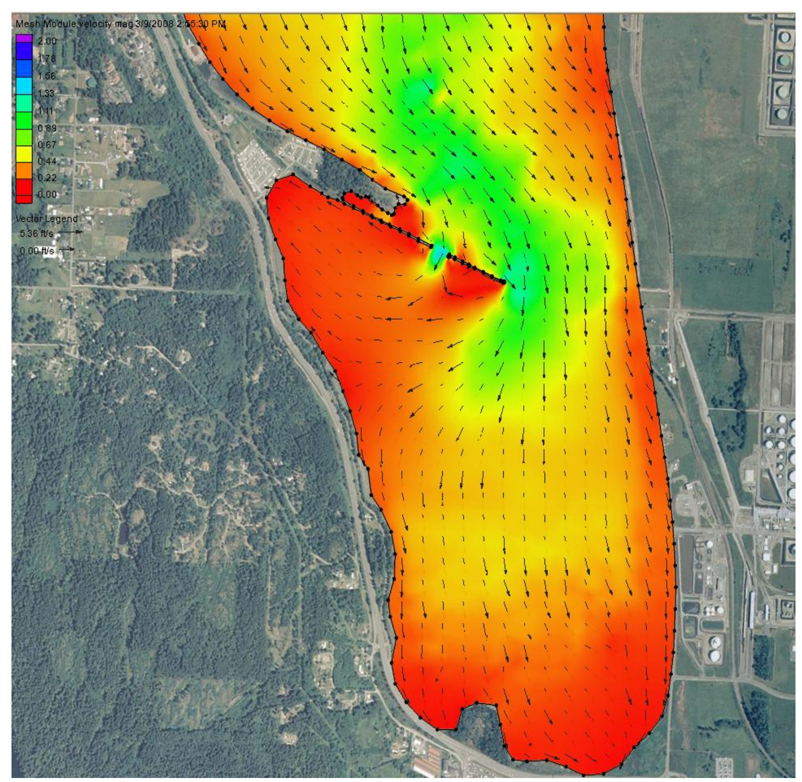
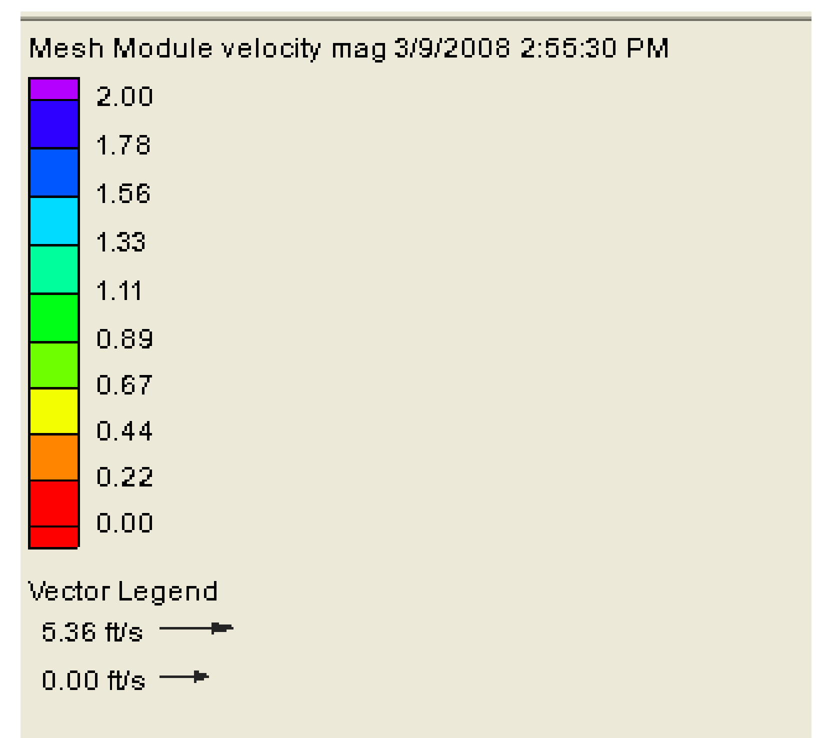


Figure A5. Alternative 5 velocity data output: 3/9/08, 14:55.



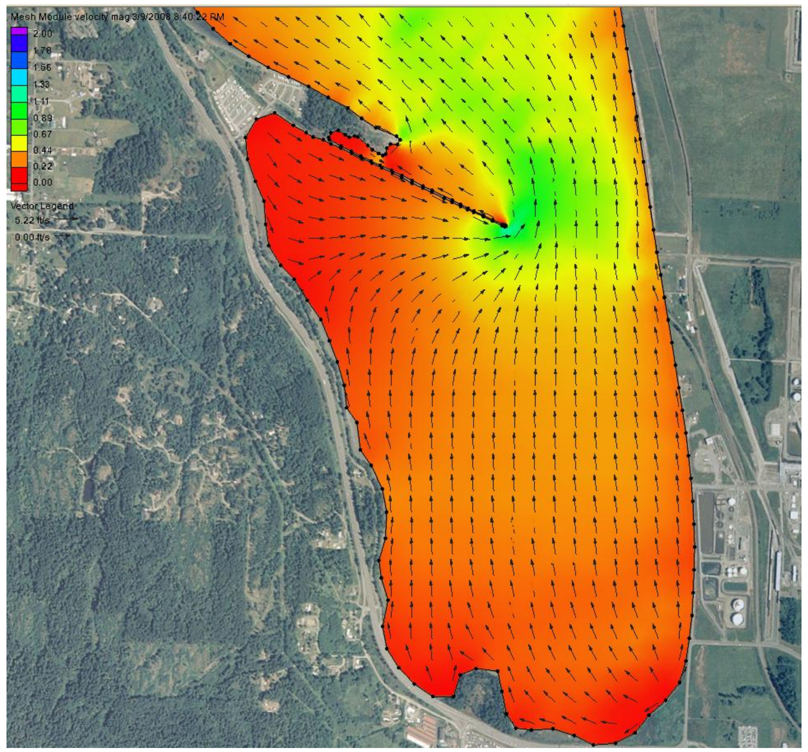


Figure A6. Alternative 1 velocity data output: 3/9/08, 20:40.

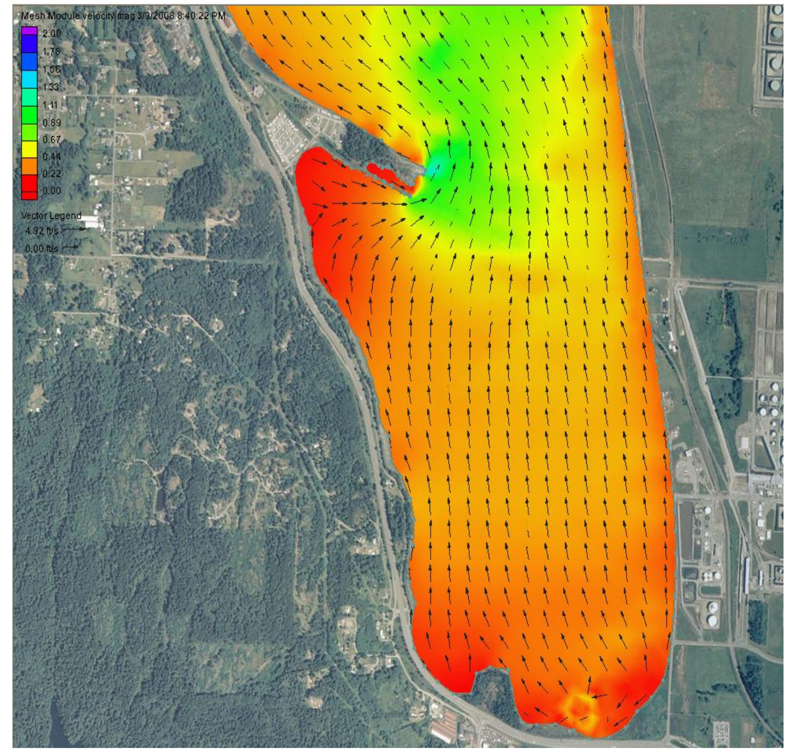


Figure A7. Alternative 2 velocity data output: 3/9/08, 20:40.

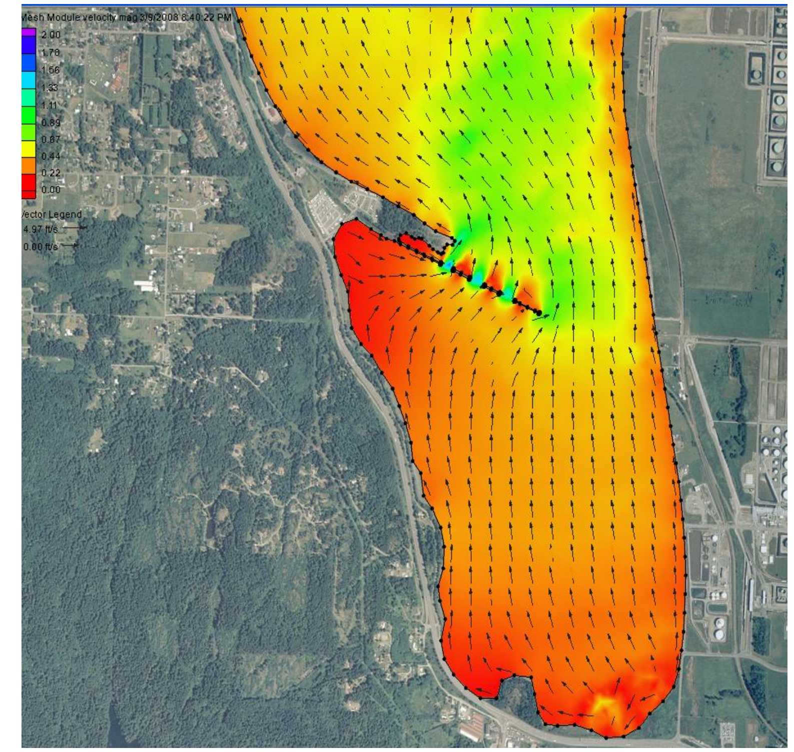


Figure A8. Alternative 3 velocity data output: 3/9/08, 20:40.

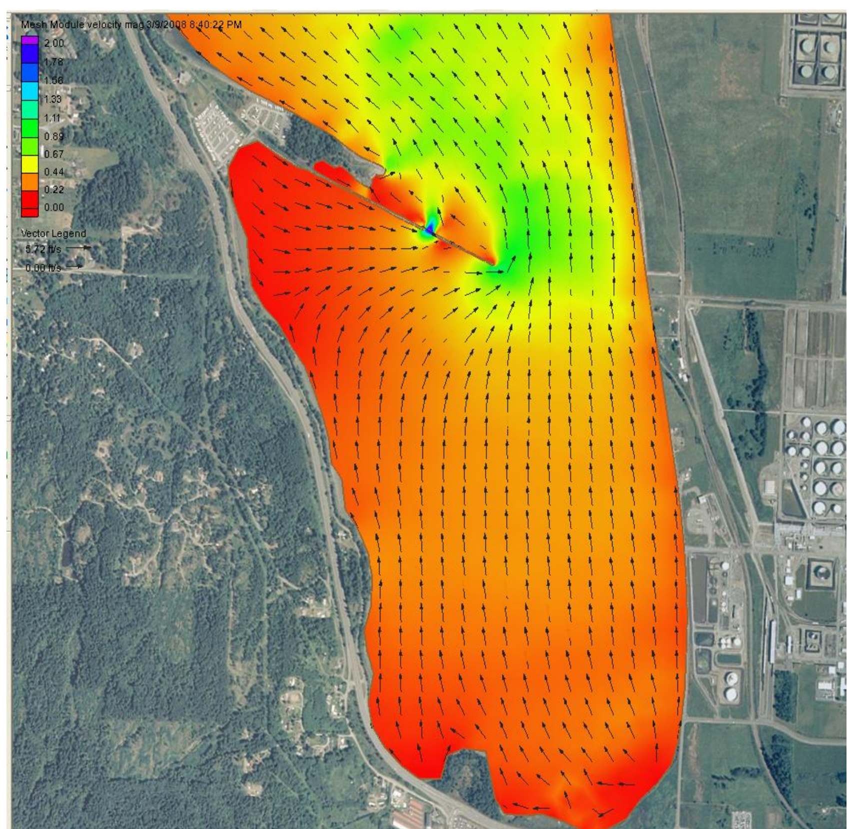


Figure A9. Alternative 4 velocity data output: 3/9/08, 20:40.

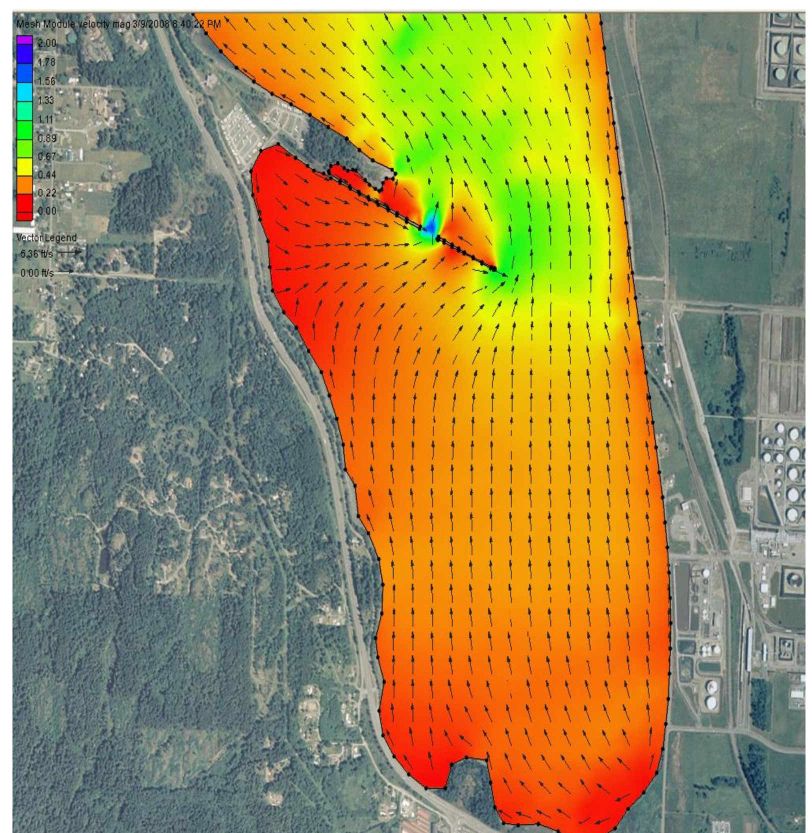
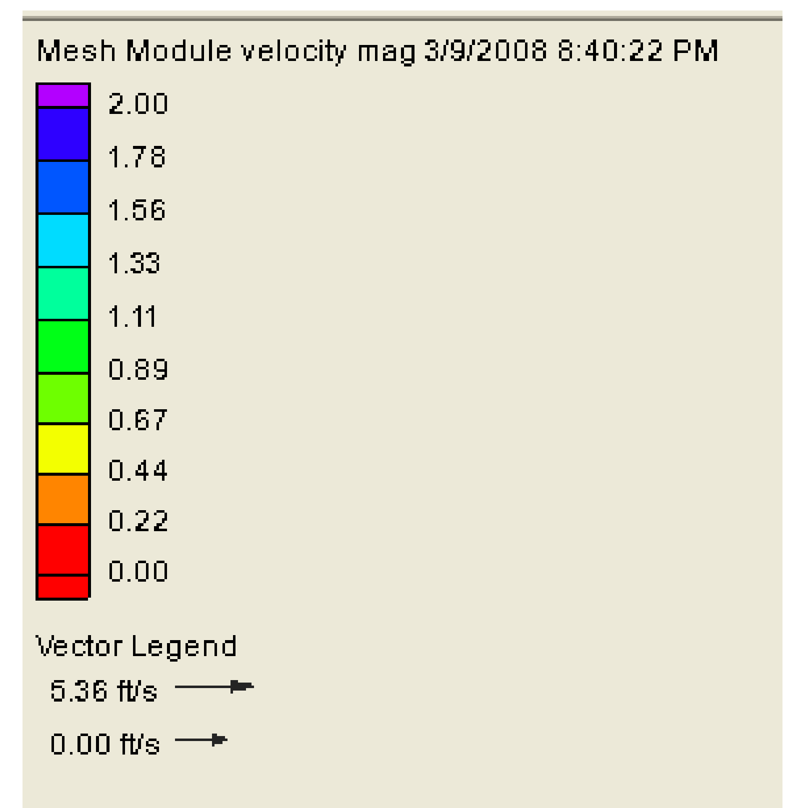


Figure A10. Alternative 5 velocity data output: 3/9/08, 20:40.



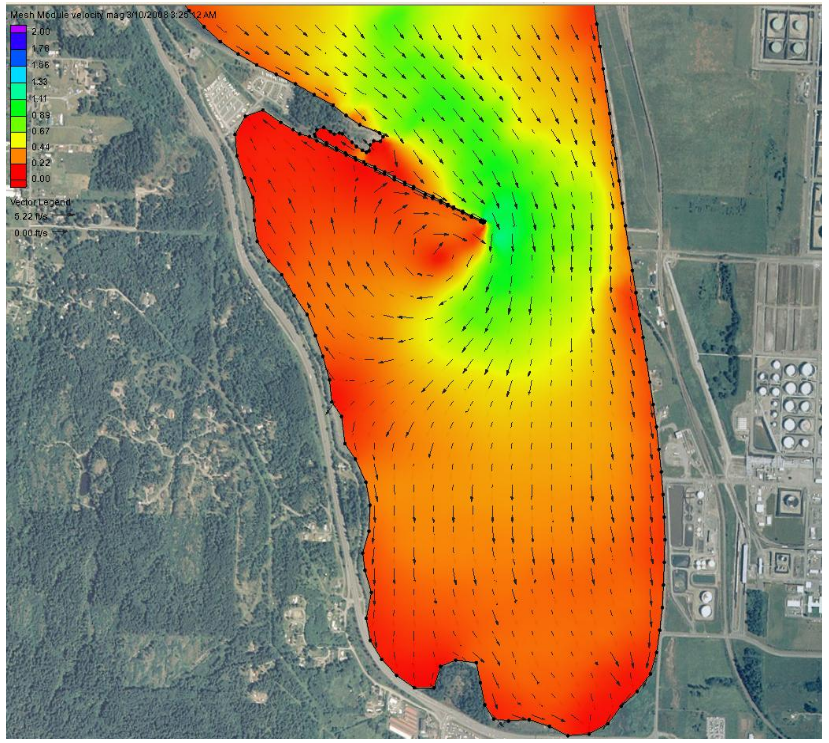


Figure A11. Alternative 1 velocity data output: 3/10/08, 03:25

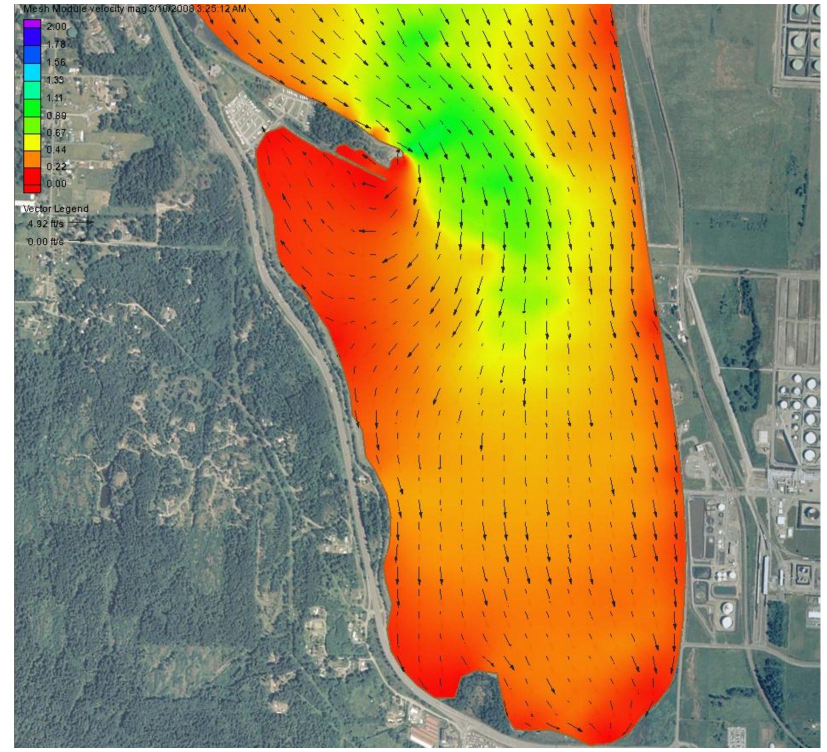


Figure A12. Alternative 2 velocity data output: 3/10/08, 03:25

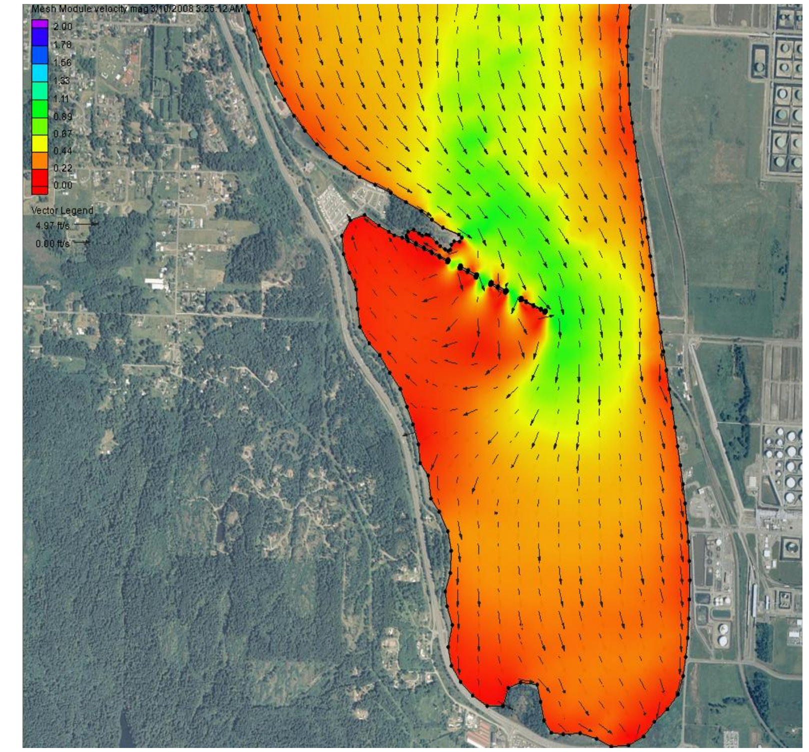


Figure A13. Alternative 3 velocity data output: 3/10/08, 03:25

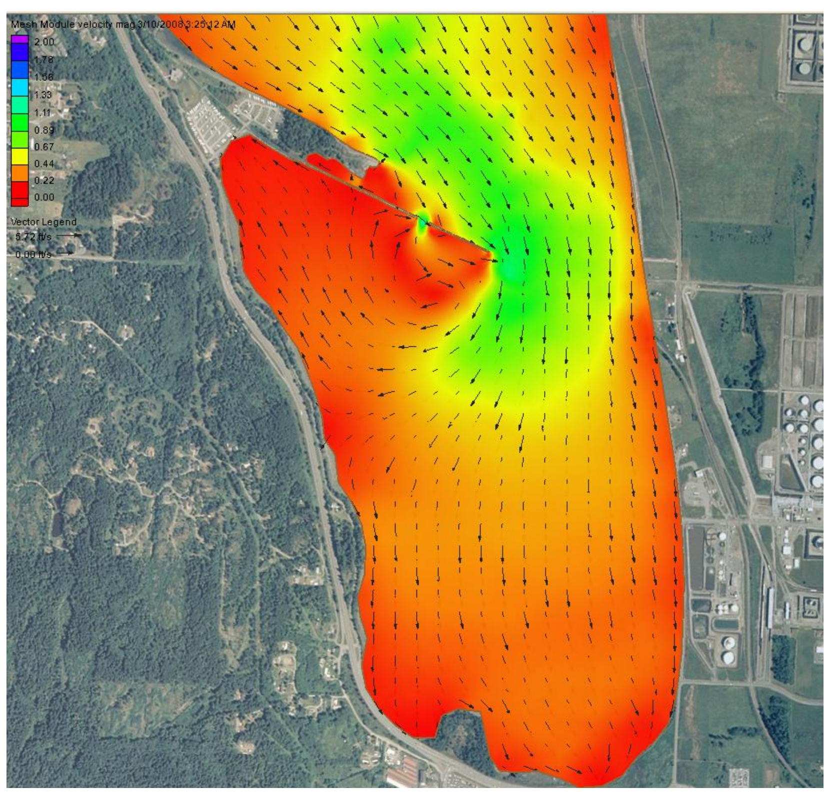


Figure A14. Alternative 4 velocity data output: 3/10/08, 03:25

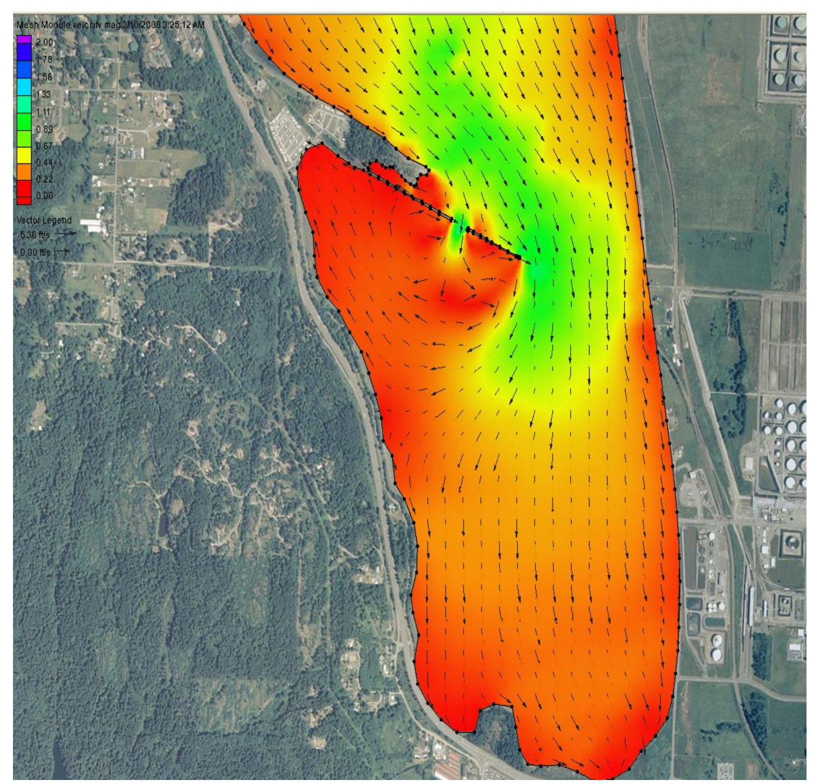
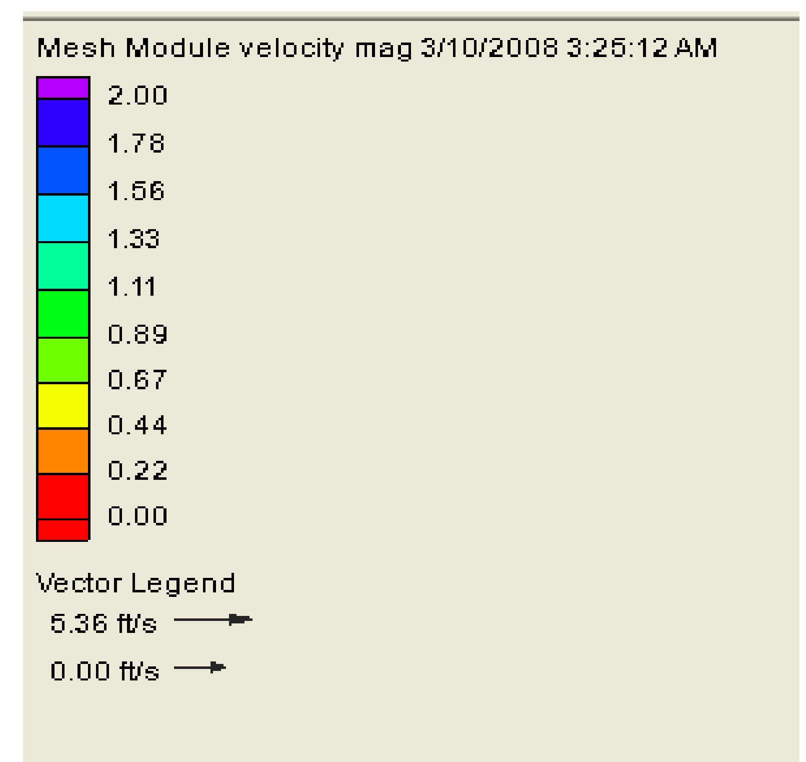


Figure A15. Alternative 5 velocity data output: 3/10/08, 03:25



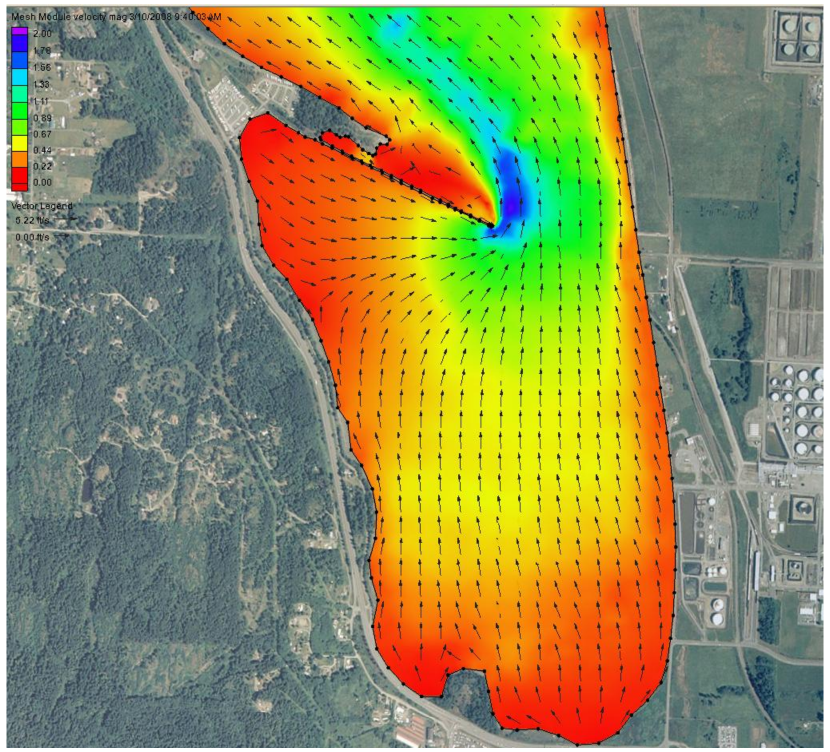


Figure A16. Alternative 1 velocity data output: 3/10/08, 09:40.

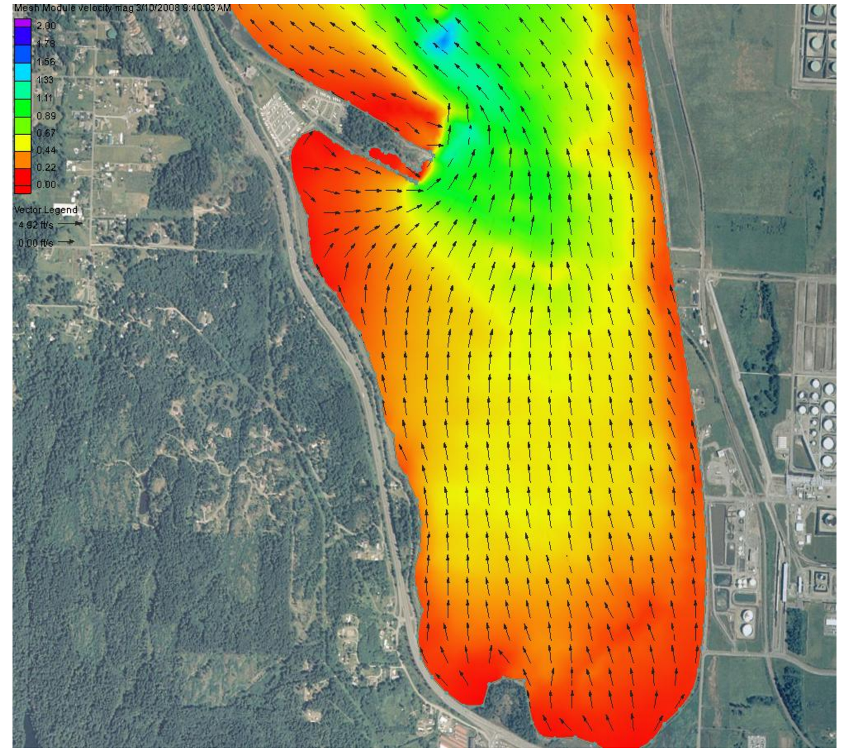


Figure A17. Alternative 2 velocity data output: 3/10/08, 09:40.

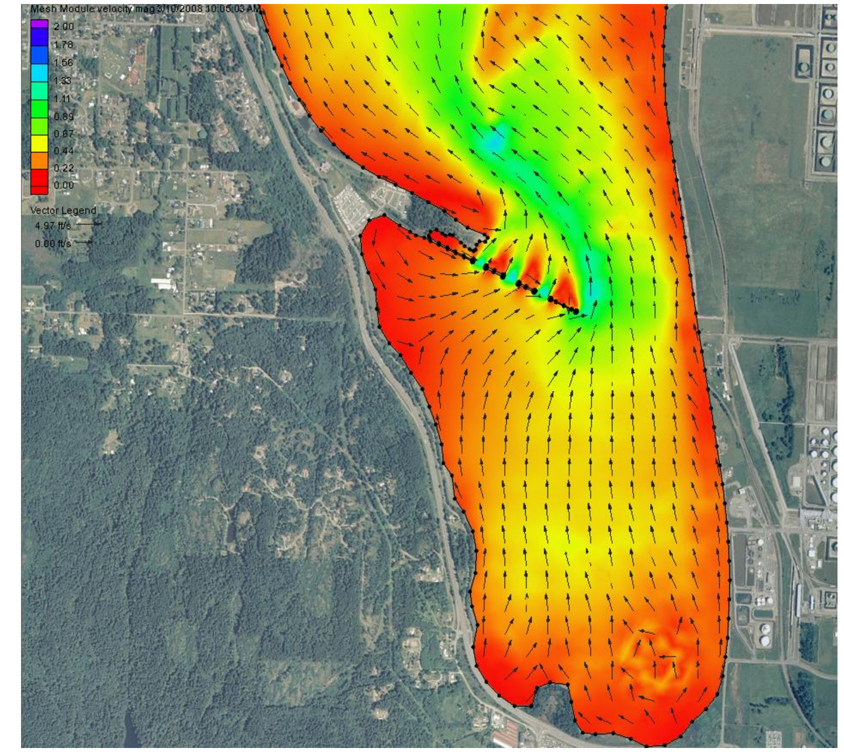


Figure A18. Alternative 3 velocity data output: 3/10/08, 09:40.

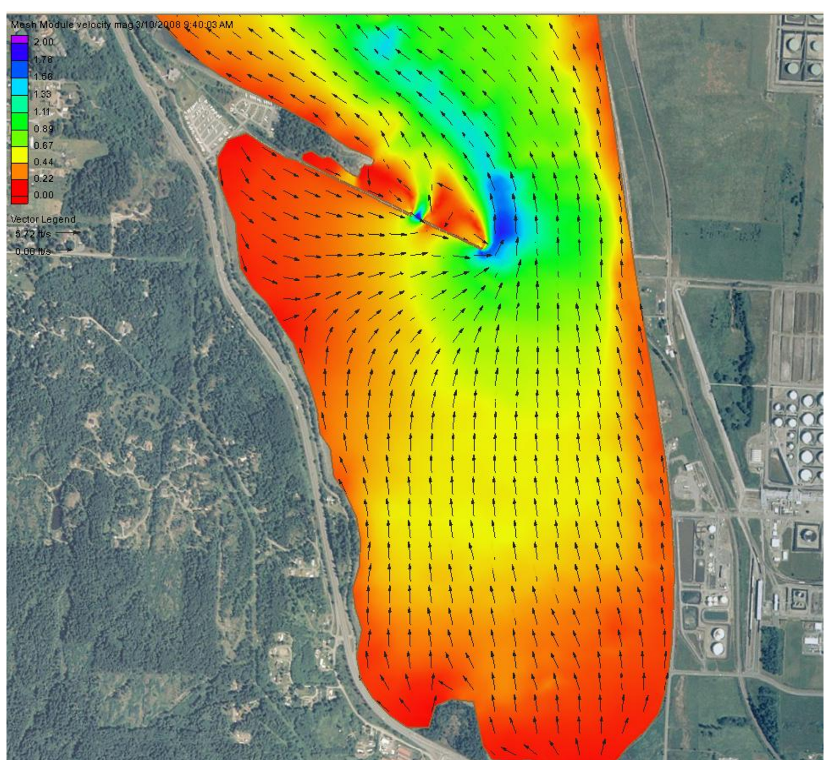


Figure A19. Alternative 4 velocity data output: 3/10/08, 09:40.

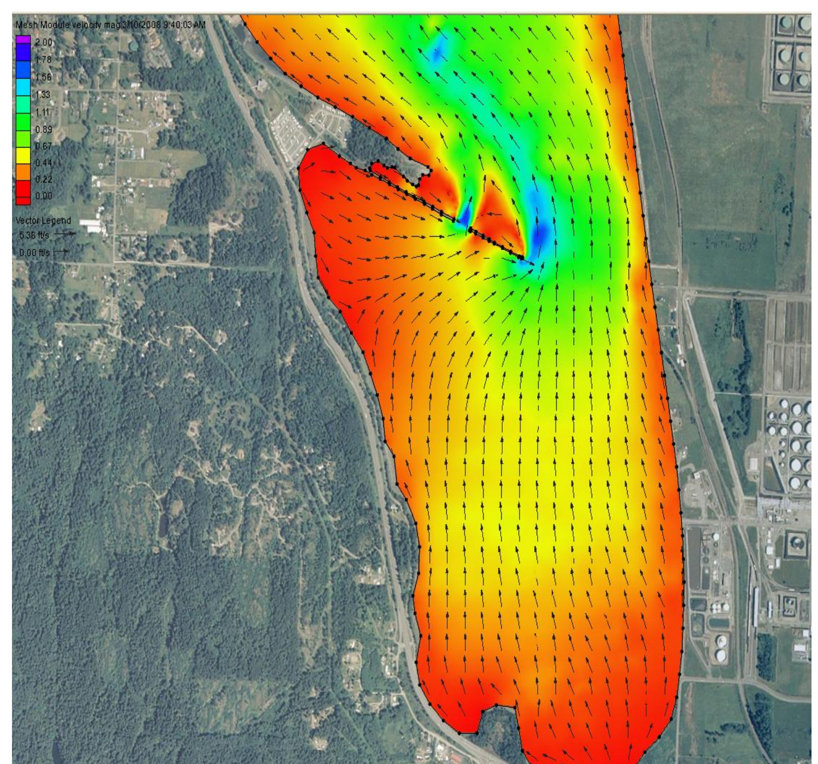
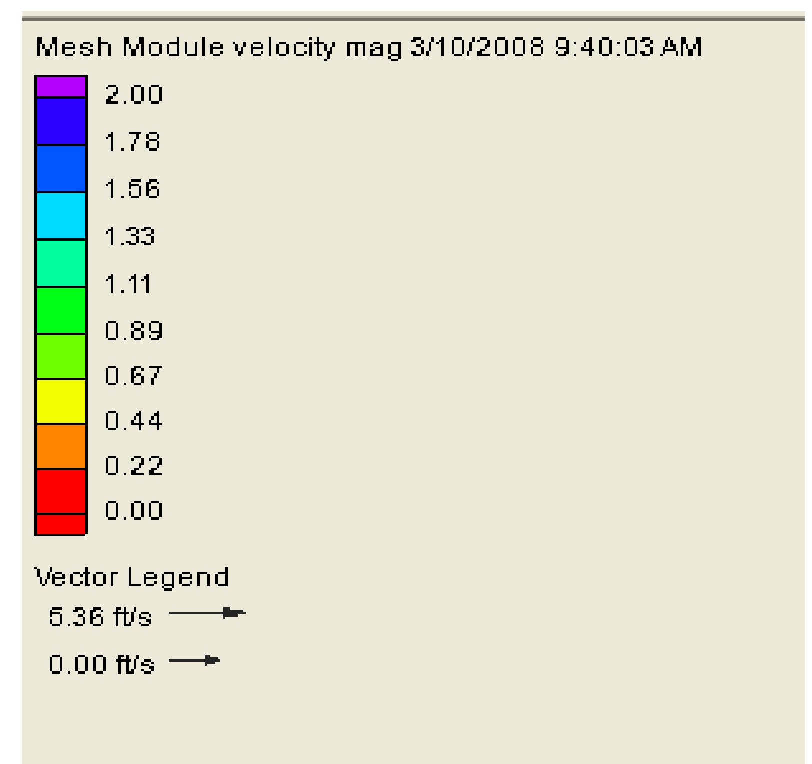


Figure A20. Alternative 5 velocity data output: 3/10/08, 09:40.



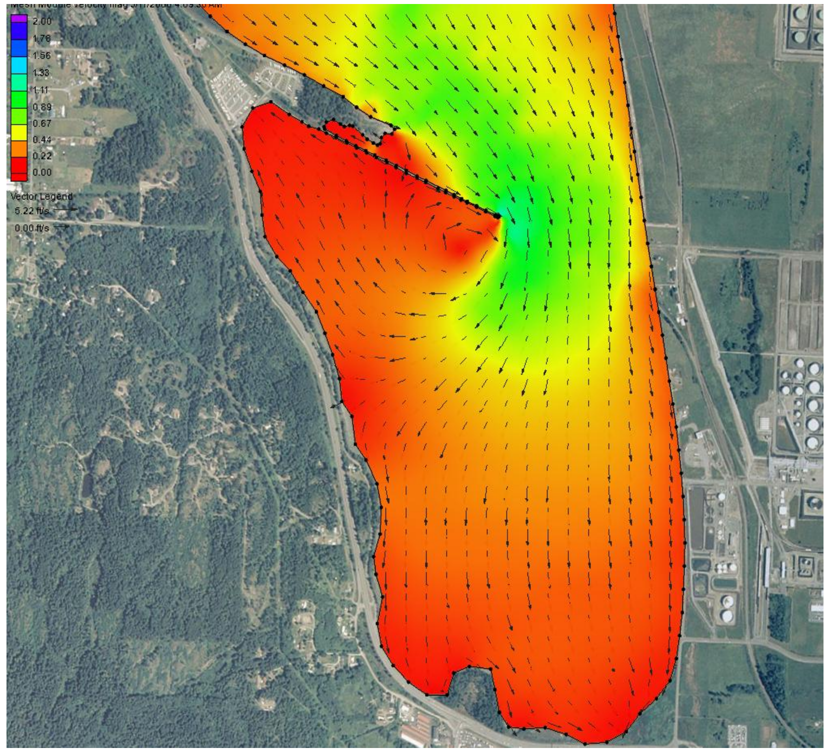


Figure A21. Alternative 1 velocity data output: 3/11/08, 04:09.

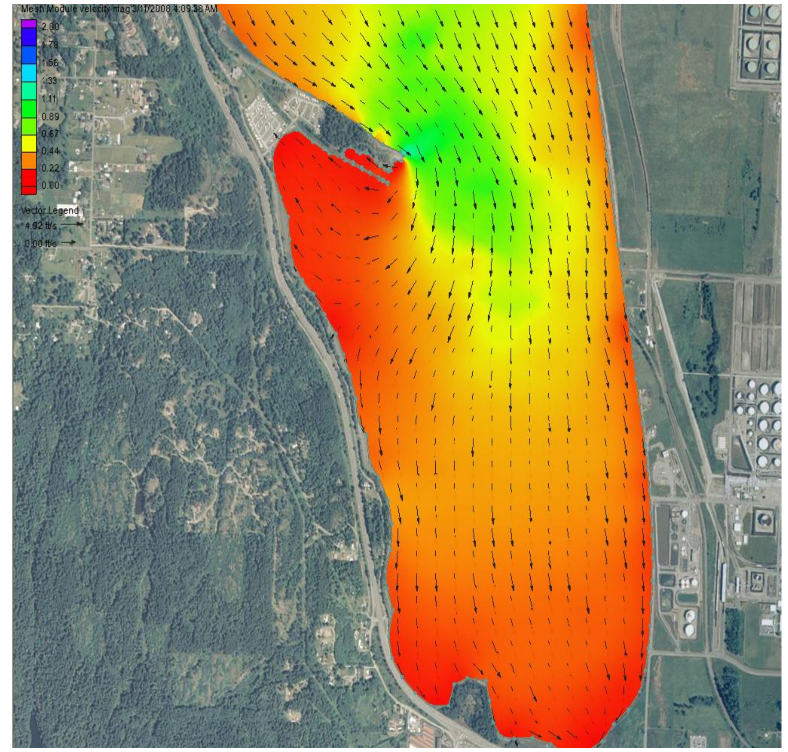


Figure A22. Alternative 2 velocity data output: 3/11/08, 04:09.

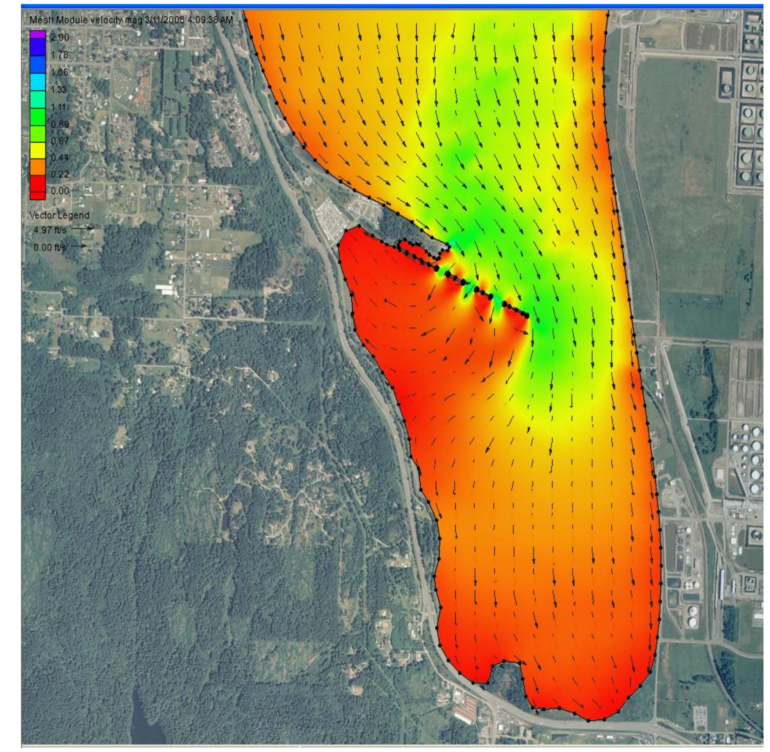


Figure A23. Alternative 3 velocity data output: 3/11/08, 04:09.

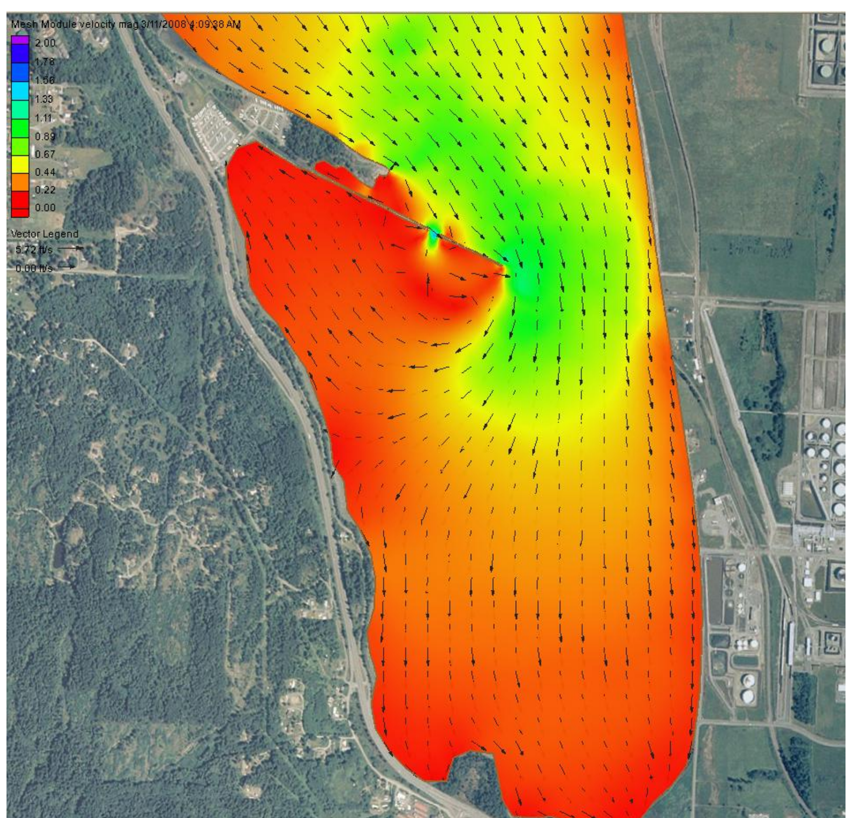


Figure A24. Alternative 4 velocity data output: 3/11/08, 04:09

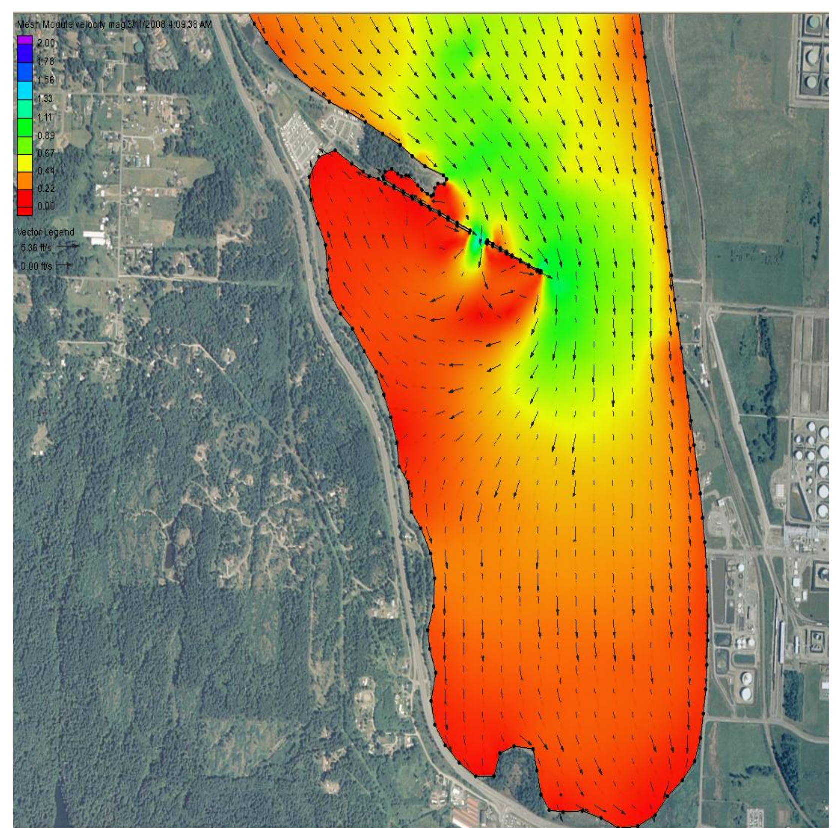


Figure A24. Alternative 5 velocity data output: 3/11/08, 04:09