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Bellingham Bay
Wood Waste
Screening Survey

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Quality Assurance Project Plan

Bellingham Bay Wood Waste Screening Survey

September 2015

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2.0 Abstract

This Quality Assurance Project Plan (QAPP) is designed to screen for wood waste contamination in the surface sediments within the subtidal area of Upper Bellingham Bay, Washington.

Since the 1800s through the mid to late 1900s, logging and forest industries were a vibrant part of Bellingham's resource-based economy. The waterfront continues to serve as an industrial hub, although most mills and lumber operations have since closed. Evidence suggests these historical activities have led to toxic and non-toxic contamination of marine sediments. Although legacy sediment contamination, including wood waste, is being addressed through cleanup activities in urbanized near-shore areas of the bay, recent findings show declining variability in benthic invertebrate communities and low dissolved oxygen in some areas. These findings indicate declining sediment quality in the bay overall, and yet the stressors have not been identified.

When wood waste is present in unnaturally large volumes, it can overwhelm the natural processes for assimilation into sediment. It can harm the environment by decreasing the availability and diversity of healthy habitat, creating an anoxic environment and creating a toxic environment. The effects can last for years, because large accumulations of wood waste are slow to decay and may persist for decades.

Unnaturally high amounts of wood debris that had accumulated on the north shores of Bellingham Bay beach raised concerns about the potential impacts to sensitive plant and benthic marine life. Because of these concerns, this study seeks to determine the possible presence of wood waste in the subtidal area of upper Bellingham Bay.

This study focuses on surveying the nature and presence of wood waste in Upper Bellingham Bay surface sediment.

3.0 Background

Bellingham Bay is located in the northern reaches of Puget Sound. It is part of the rich ecosystem of the Salish Sea, separated from the Strait of Georgia on the west by Lummi Peninsula, Portage Island, and Lummi Island.

Bellingham Bay has a number of contaminated sediment sites that are in various stages of the cleanup process. These efforts are improving sediment quality in urban nearshore areas. However, a 2010 status-and-trends, bay-wide study indicates that the sediment quality in Bellingham Bay is lower overall than in the encompassing region and Puget Sound and may be declining (Partridge et al., 2013). The study found some toxicity in sediments throughout most of the bay and adversely affected benthic communities at all sample locations. The reason for this apparent decline is unclear.

The large amount of wood waste found along the northern shorelines of Bellingham Bay have raised concerns and is one of the suspects in the bay's decline in overall health. Wood waste covers large sections of the beach area and in places is more than six feet (ft) deep (Eastman, 2011). The source of this wood waste is undetermined.

This study focuses on surveying the nature and presence of wood waste in the subtidal surface sediments of Upper Bellingham Bay. Ecology will screen for presence of wood waste, using underwater filming followed by surface sediment samples.

3.1 Study area and surroundings

Bellingham Bay is a relatively large, kidney-shaped embayment located in northwest Washington along the eastern part of the Puget Sound-Georgia Strait complex and San Juan Islands (Figure 1).

The bay is part of the Nooksack Water Resources Inventory Area (WRIA) #1, covering over 1,410 square miles mostly within Whatcom County but also including approximately 21 square miles in Skagit County and 147 square miles in British Columbia (Whatcom County, 2001 and 2011). The southern portion of the bay is part of the Lower Skagit-Samish WRIA #3, and more specifically the Samish Bay Watershed, draining 123 square miles and covering parts of Whatcom and Skagit Counties (Swanson, 2008).

Additional information about WRIAs for Bellingham Bay (WRIA #1 and #3) can be found at http://www.ecy.wa.gov/programs/eap/wrias/Planning/index.html.

Figure 1. Map of Bellingham Bay and surrounding area. Upper Bellingham Bay is the area north of Post Point and Point Francis (north of the geographic line).

The general area of interest (AOI) for this study is the upper portion of Bellingham Bay situated above an imaginary geographic line extending eastward from Point Frances to the southern tip of Post Point. The area above this line—located approximately along latitude 48° 43' N—was first defined by Collias et al. (1966) as Region I (Figure 2). This region is separated from other oceanographic regions because it is strongly influenced by the Nooksack River, receives the largest load of industrial and domestic wastes, and has the lowest current velocities within the Bellingham Bay system. Region I has been further subdivided into a second area known as the Inner Harbor (Region IA) in subsequent studies because of somewhat different dynamics and interest in that area.

Bellingham Bay is an urbanized bay that is used extensively for fishing, navigation and commerce, and recreation. Estuarine areas in the near shores of the bay contain sensitive ecosystems where native eelgrass beds and other sea-grasses support spawning and rearing fish, shellfish, and marine wildlife. Waterfront development dominates the eastern shore of the bay. Current and historic uses of the waterfront include industrial facilities, shipping terminals, parks, and the Alaska Ferry Terminal.

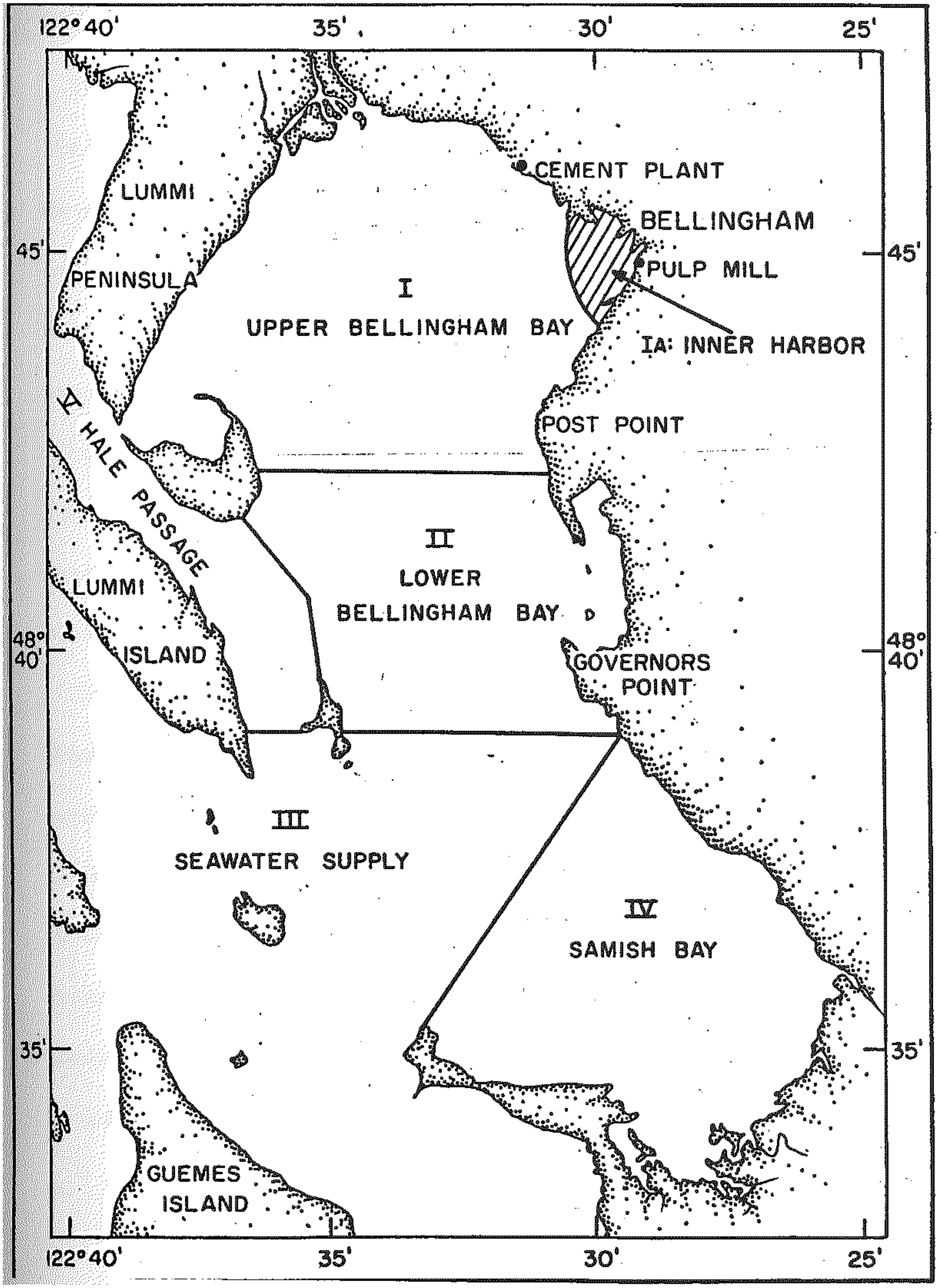

Figure 2. Oceanographic regions in the Bellingham-Samish Bay System described by Collias et al. (1966) (source Colyer, 1998).

Topography and Land Use

The topography around Bellingham Bay varies in elevation, ranging from sea level to the top of Mount Baker at 10,778 ft (3,285 m). Tributaries to Bellingham Bay include two main rivers, the Nooksack and Samish Rivers entering the bay from the north and south, respectively, and many smaller tributaries including nearby islands.

Land use in the eastern portion of WRIA #1 is primarily (about one-third) forested, while the western portion supports agriculture, residential development, and commercial or industrial development, with little forestry (Whatcom County, 2001 and 2011). In the southern end of the bay, the Samish Watershed contains less than 20% forest in the eastern portion, some rural towns scattered throughout, and about 75% agricultural land use (including dairy and cattle operations) in the lower and western basin. (Swanson, 2008). In the northwest area of Bellingham Bay, the Lummi Reservation is predominantly a mix of agriculture (including aquaculture) and mixed forest (Whatcom County, 2001; Stark, 2008).

Over half of Whatcom County's population of over 200,000 resides next to the bay, including the City of Bellingham in the northeastern area of the bay with over 80,000 residents (Whatcom County, 2001 and 2011; U.S. Census Bureau, 2014). The Lummi Indian Reservation borders the northwestern shoreline along with Lummi Island and includes other smaller islands. About 5,000 people live on the reservation (U.S. Census Bureau, 2014; Stark, 2008).

Climate

The climate is relatively mild year-round, due to the marine influence of Puget Sound, the Cascade Range to the east (about 30 miles) retaining the marine weather to the watershed, and the rain shadow effect of the Olympic Mountains to the southwest (about 60 miles). High and low temperatures averaging around 59° F (15° C) and 43° F (6° C) and precipitation of 35 inches annually are considered normal for this area (University of Washington, 2014). The amount of freshwater discharged into the system is influenced by direct precipitation and snowmelt.

Predominant winds occur from the southeast and southwest with frequent northeast winds (Broad et al., 1984; EPA, 1989; Wang et. al., 2010). Occasionally a harsh winter weather pattern of an upper level trough drives cold Arctic air from the Canadian interior southwesterly through the Fraser River Canyon and into this area.

Bathymetry and Hydrology

Bellingham Bay is part of a system of interconnected bays that exchange water with the Pacific Ocean through the Rosario Strait, feeding a complex network of channels and passages. Several earlier studies (Collias et al., 1966; Sternberg, 1967; Shea et al., 1981; and Broad et al., 1984) and more recent studies (Colyer, 1998 and Wang et al., 2010) describing Bellingham Bay's currents and oceanography are summarized here.

Bathymetry

The bathymetry of upper Bellingham Bay is shown in Figure 3 and based on Mean Sea Level (MSL). The north portion of the bay shallows into the Nooksack Delta, which is exposed during low tides. Exceptions include a small depression of about 125 ft (38 m) just off of Post Point. Bathymetric patterns seen in the bottom of the bay indicate the flow of the water from tidal influence and upland drainage. The main marine water entrance into Bellingham Bay on the western side lies between Eliza Island and Samish Island (Figure 4).

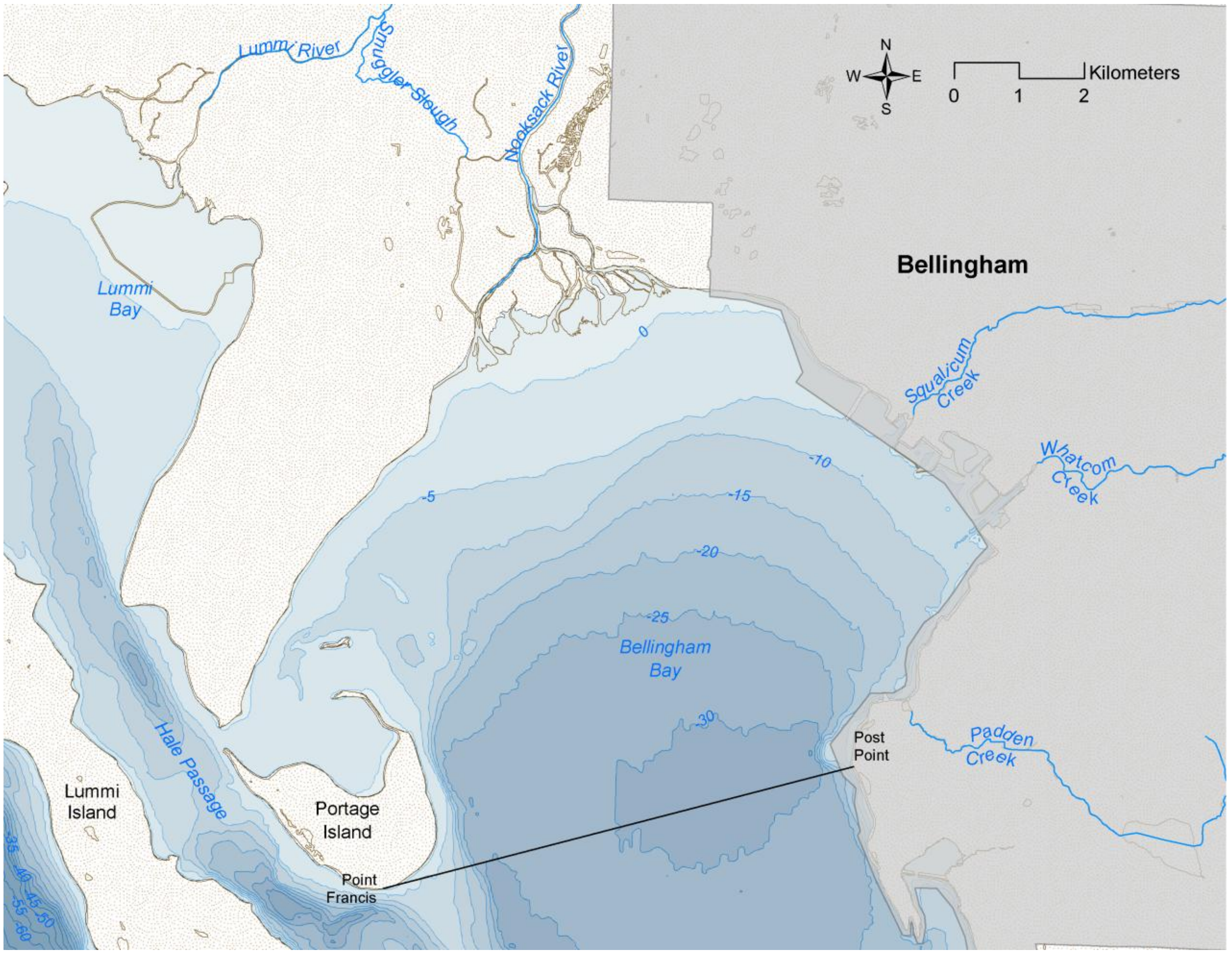

Figure 3. Bellingham Bay bathymetry. Depth in meters based on MSL. Geographic line denotes the southern boundary of the Upper Bellingham Bay AOI.

The depths of Lower Bellingham Bay consist of a flat shelf, the Samish delta, 30 to 60 ft (9.15 to 18.3 m) gradually deepening northward until it reaches the bay floor at more than 90 ft (27.5 m) depths (Collias et al., 1966; Sternberg 1967; Broad et al., 1984; Colyer, 1998; Ecology, 2014) (Figure 4).

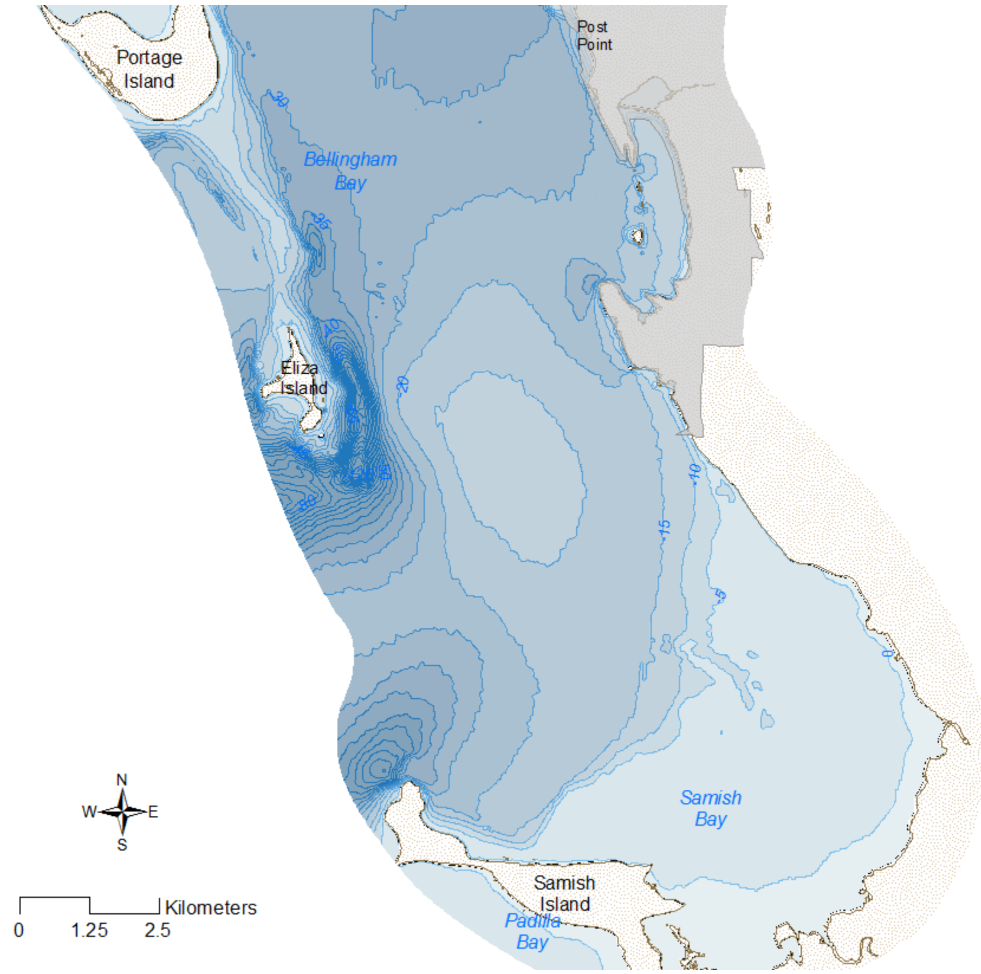

Figure 4. Lower Bellingham Bay bathymetry. Depth in meters based on MSL.

Dynamic Influences

Bellingham Bay continually changes in response to currents, mixing, exchange of mass and energy across the sea surface, and biological processes (Collias et al., 1966). The circulation of the system consists of a surface inflow of freshwater from the Nooksack River (and five other smaller tributaries) in the north that flows south out of the bay, and a bottom inflow of saline water from Rosario Strait that enters the system from the south and flows north into the bay (Collias et al., 1966; EPA, 1989; Wang et al., 2010). Water in the body of the bay is a variable mixture of these two sources that changes with time, position, and depth (Collias et al., 1966; EPA, 1989; Wang et al., 2010). The discharge of the Samish River at the southern end of the bay near the mouth is an order of magnitude smaller than the Nooksack River, providing roughly 2% of the flow of the Nooksack. It therefore has little effect on the overall circulation or other water properties (Collias et al., 1966; EPA, 1989; Wang et al., 2010). Fixed local conditions are influenced by tide, river runoff, and winds.

Tides

Bellingham Bay's tides are semidiurnal and mixed with unequal low and high waters over a tidal cycle. Mean tidal range is 1.6 m with a diurnal range of 2.9 m (Colyer, 1998). During a spring tide, the higher high and lower low will occur consecutively and can range by 3.8 m within the tidal cycle, whereas during a neap tide, the lower high and higher low will occur consecutively with little difference in tidal range (Colyer, 1998).

Surface currents in upper Bellingham Bay, as described by Collias et al. (1966), tend to rotate in a clockwise pattern with a counter clockwise eddy sometimes developing inshore near the City of Bellingham. During a flood tide, surface water flows in from Rosario Strait traveling in a circular pattern northward towards Samish Bay and is deflected northwest towards Point Frances by Governors Point. In the middle of the bay, the current splits with one part creating the clockwise flow pattern in the upper Bellingham Bay and the other part flowing west towards Hale Passage. The currents reverse during the ebb with some of the surface water flowing into the Bellingham Bay from Hale Passage and water flowing out of the bay in the deeper channels in the south. These surface patterns apply in the absence of wind.

Wind

South winds are predominant during most of the year (Wang et al., 2010), causing surface water to be retained in the northern part of the bay. A west or southwest winds directs surface waters to the east flowing down the shoreline past Post Point. In contrast, when winds are from the north or northwest, surface water flows south along the shorelines of Lummi Peninsula and the islands nearby.

Freshwater Discharge

Freshwater discharge influences the vertical mixing of water in the bay. Average freshwater resident time in upper Bellingham Bay is typically 4-5 days and ranges between 1-11 days (Collias et al., 1966; EPA, 1989; Coyler, 1998).

When freshwater discharge decreases, its rate of transport increases, due to density differences between the upper and lower layers (Coyler, 1998). Colyer (1998) explains that less freshwater results in less resistance to vertical mixing and, therefore, the faster moving surface layer contains a greater volume of water. When discharge is high, the surface layer is thin and more resistant to mixing, which results in less water moving out of the bay. The upper and lower layers tend to be stratified strongest in spring and early summer during the high freshwater runoff. In upper Bellingham Bay, the water currents are weaker, vertical mixing is less, and the Nooksack River has a strong influence on density stratification (Collias et al., 1966). Therefore, wood waste could conceivably remain longer within upper Bellingham Bay than in other areas where the flushing mechanisms are stronger.

Sediment Transport

Sediment deposits of approximately 650,000 m^3 per year from the Nooksack River have been reported (EPA, 1989). The Nooksack delta currently extends over 2 km^2 into the bay (EPA, 1989). Anchor and Crowser reported an average sedimentation rate of 1.60 cm per year for the Whatcom Waterway site that covers over 200 acres, located in the Inner Harbor portion of Upper Bellingham Bay (Anchor and Crowser, 2000). Most loading from the Nooksack River occurs during periods of high discharge found in the spring and fall. Greater discharges result in greater transport of suspended sediments into the bay from runoff. Lower discharges cause greater amounts of marine sediments to be reworked up in the bay (Colyer, 1998).

3.1.1 Logistical problems

Logistical problems for conducting this investigation include limited historical data in the AOI, access, and environmental conditions at the time of sampling.

Limited information is available for identifying wood waste-contaminated areas within upper Bellingham Bay. No studies have conducted investigations to identify wood waste contamination in the subtidal area.

Most of the shoreline access in Upper Bellingham Bay is on private property. A small public access is located off Locust Avenue traversing an old stairway. Boat access is available at several boat launch facilities, including Fairhaven and Squalicum Harbor.

Other logistics include obtaining access permissions, permits for sampling, or general communication with the following entities:

- Whatcom County
- City of Bellingham
- Protecting agencies (i.e., city or county police, harbor patrol)
- Lummi Nation
- U.S. Army Corps of Engineers (USACE)
- U.S. Coast Guard
- National Oceanic and Atmospheric Administration (NOAA)/Fisheries Department
- U.S. Fish and Wildlife Service
- Washington Department of Fish and Wildlife (WDFW)
- Washington State Department of Natural Resources (DNR)

Physical assessment for this study is dependent on several limitations that include:

- Water clarity for visual observation and underwater filming
- Tidal height to accommodate boat access in shallow subtidal waters
- Calm weather for safe working conditions and water clarity

3.1.2 History of study area

Beginning around the mid-1800s through the middle to late 1900s, the logging and forest industries were a vibrant part of Bellingham's historic resource-based economy. The Bellingham waterfront served as the industrial hub, where logs were processed at mills and lumber was exported overseas. After the mid-1900s, the logging and forest industries largely declined in Bellingham, and the majority of the mills have since been closed (Bellingham's Centennial). It is believed that past industrial practices along the waterfront have ultimately led to toxic and non-toxic pollutant contamination of marine sediments (Shea et al., 1981; Elardo, 2001).

A Total Maximum Daily Load (TMDL) was developed in 2001 to address the 1998 Section 303(d) listings of contaminated sediments in Inner Bellingham Bay (Elardo, 2001). The listings included metals (mercury, zinc, copper, and lead), arsenic, polyaromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), synthetic and semivolatile organic compounds, organochlorine pesticides, and sediment bioassays. Wood waste was not originally on the listings for Bellingham Bay; however, it was added based on cleanup investigation efforts that found wood debris at levels greater than 50% by volume in some marine sediment samples. There have been several other investigations in Puget Sound related to wood waste, such as Port Angeles Harbor (SAIC, 1999), Shelton Harbor (Ecology, 2000), and Port Gamble Bay (Ecology, 2012). These areas are comparable to Bellingham Bay, since they are interconnected within Puget Sound and had historical logging activities such as log raft staging, log transport, and milling practices.

Local residents of Bellingham have provided anecdotal accounts of substantial wood debris along the northern shore of the bay. Unnaturally high amounts of wood debris that had accumulated on the shores of Cliffside beach raised concerns about its potential impacts to sensitive plant and benthic marine life, as well as its contributions to low dissolved oxygen concentrations in Bellingham Bay.

The Cliffside Beach Wood Removal Project was initiated to identify the potential sources of the wood debris at Cliffside and to clean up the debris (Anchor Environmental, L.L.C. and Coastal Geologic Services, Inc., 2007). Because Cliffside Beach is not adjacent to current or historic industrial facilities, the source of the wood was uncertain. The prevailing assumptions were that: (1) the wood debris—fine debris including small twigs or wood fragments, sawdust-like material, and decomposing leaves—originated from historic industrial mill or municipal sites and was deposited along Cliffside Beach following marine or near-shore drift; and (2) the wood debris originated from the Nooksack River, known to experience major log jams, and was deposited along Cliffside Beach.

Prior to cleanup of the debris, baseline monitoring was conducted to document any potential changes in the invertebrate communities and sediments after wood removal (Dimond and Bingham, 2009). In 2010, plans to remove the wood debris at Cliffside were underway; however, by then the wood debris appeared to shift about a mile westward to Fort Bellingham Beach (Eastman, 2011).

3.1.3 Parameters of interest

Wood debris is often a natural part of an aquatic environment, creating habitat and a food source for many aquatic species. However, when wood waste is present in unnaturally large volumes, it can overwhelm the natural processes for assimilation into sediment and potentially harm the environment. Industrial processes can generate large volumes of bark, chips, and sawdust, which can affect the aquatic environment physically, chemically, and biologically. As wood waste decays into smaller, sometimes fibrous pieces and mixes with sediment, it impacts the benthic community. In large volumes, it decreases the availability of healthy habitat for benthic colonization and diversity of the benthic community (Kendall and Michelsen, 1997; Ecology, 2013b).

Just 20% wood waste by volume in the sediment could negatively impact the benthic community (Ecology, 2013b). These impacts include:

- The physical presence of wood waste, which could prevent biota from thriving in and on healthy native substrate.
- Decreased dissolved oxygen due to microbial decomposition, which can create an anoxic environment for fish and other wildlife.
- Decomposition by-products such as sulfides, ammonia, and phenols, which contribute to toxicity.

The effects can last for years, because large accumulations of wood waste are slow to decay and may persist for decades (Kendall and Michelsen, 1997; Ecology, 2013b). Impacts on the substrate and benthic community affect other plants and animals dependent on them. Effects include altered salmon behavior and significantly reduced fish productivity (Ecology, 2013b).

In addition to a visual assessment of wood waste, other parameters of interest include percent solids, sediment grain size, total organic carbon (TOC), and total volatile solids (TVS). Percent solids and grain size provide information regarding the physical nature of sediment. TOC and TVS describe conventional chemical concentrations.

3.1.4 Results of previous studies

Previous results were analyzed to help identify potential areas of concern for wood waste contamination in upper Bellingham Bay. Results for grain size, percent solids, TVS, and TOC were compiled from Ecology's Environmental Information Management (EIM) system and from literature reviews.

Sediments composed of greater than 90% fine mud and clay were found throughout much of the bay. Percent fines decrease somewhat with increasing proximity to the Nooksack River. The river delta has been described as predominately sands (Sternberg, 1967; EPA, 1989; Ecology, 2014). Decreased percent fines have also been found in the vicinity of Whatcom Creek Waterway, and the increased percent sands found there have been attributed to inputs from Whatcom Creek (EPA, 1989; Ecology, 2014).

Figure 5 displays historical and current percent solids. Percent solids can indicate how much water is contained in the sediment sample. Densely packed, clay-like sediment would have high percent solids and contain much less water than a porous wood waste sediment sample. Results are somewhat limited but show low percent solids mainly in central Bellingham Bay with some elevated areas around the perimeter in targeted sample areas.

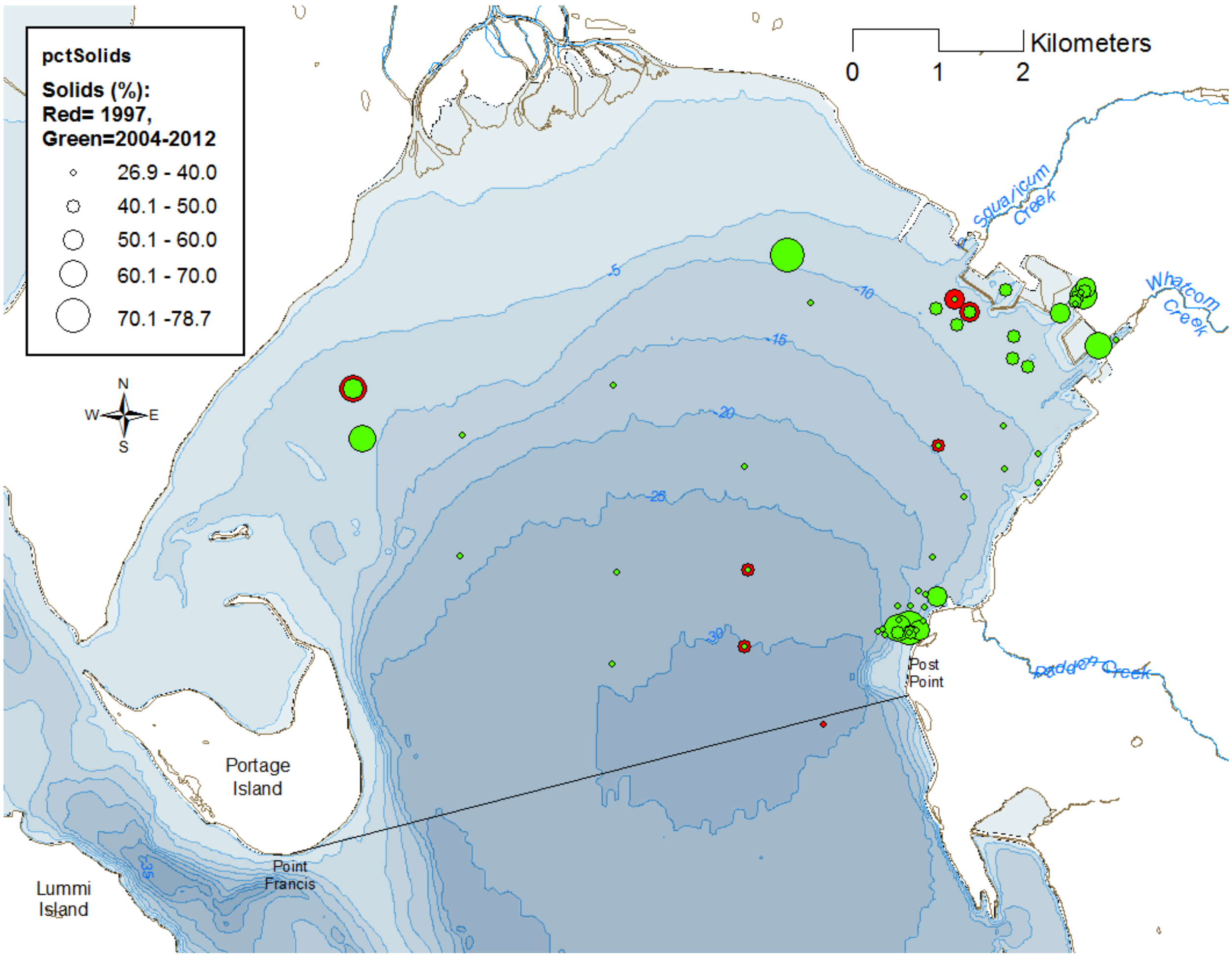

Figure 5. Historical and current percent solids in Bellingham Bay. Depth in meters based on MSL. Geographic line denotes the southern boundary of the Upper Bellingham Bay AOI.

TVS is used as an indicator of the amount of organic material in the sediment. Figure 6 shows historical and current TVS values in Bellingham Bay. High values of TVS (>10 %) can be indicative of anoxic sediments (EPA, 1989). TVS values measured in 1983 to 2003 ranged from 1.2 to 17.5% and decreased in areas with coarser-grained sediment (e.g., the Nooksack River delta) (EPA, 1989). Results from Ecology's EIM database show many TVS values elevated above 40% along the northern shore sampled between 2004 and 2013.

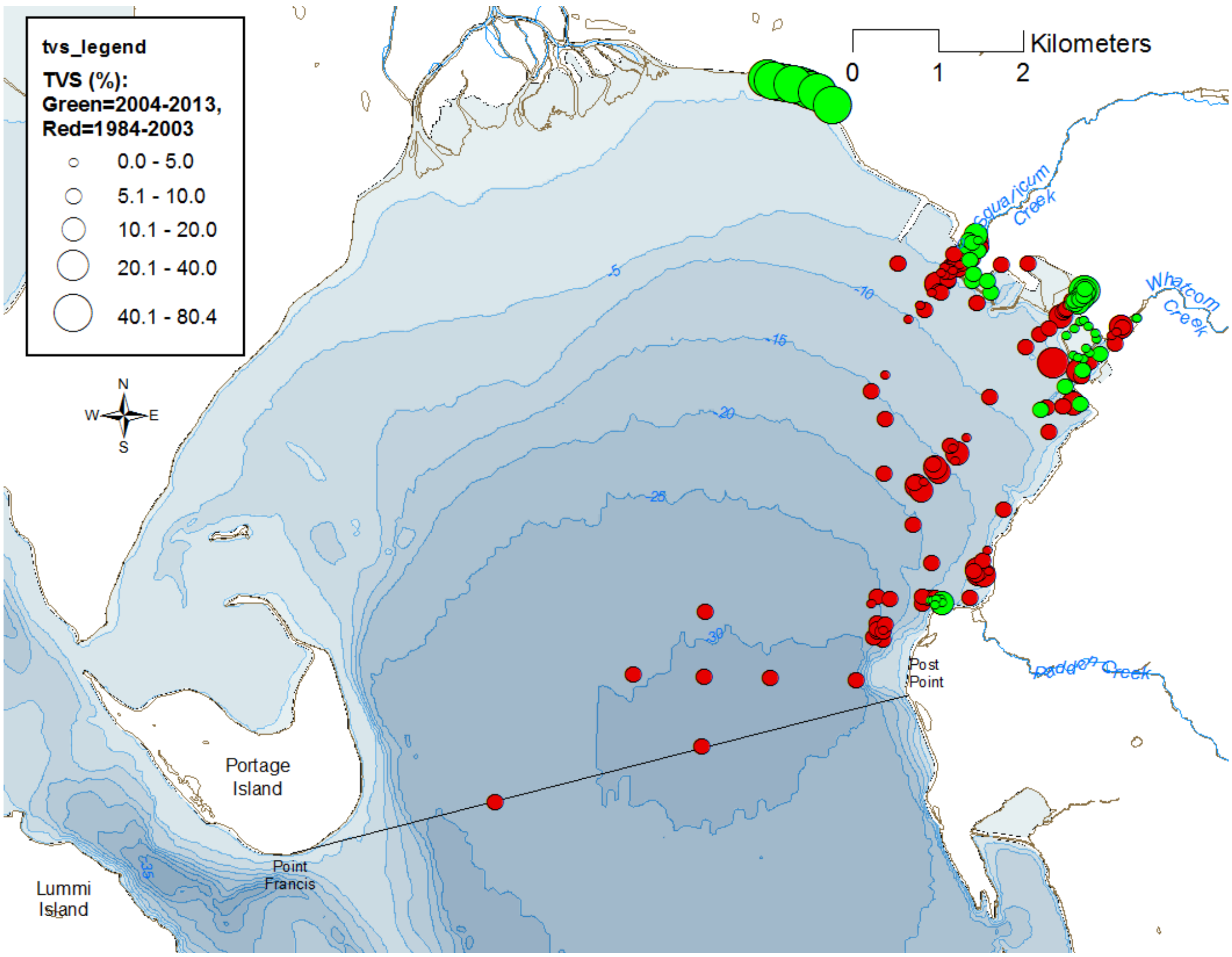

Figure 6. Historical and current total volatile solids (TVS) in Bellingham Bay. Depth in meters based on MSL. Geographic line denotes the southern boundary of the Upper Bellingham Bay AOI.

Results for TOC in Bellingham Bay are shown in Figure 7. TOC is used to indicate the amount of organic material in a sediment sample. Most results found within the bay were within normal range of 0.5 – 3.5%, but many samples along the shoreline had elevated values associated with higher levels of over 5% organic matter (e.g., wood waste) (EPA, 1989; Ecology, 2015a; Ecology 2015b). High TOC values were located within contaminated sediment sites (e.g., former lumber mills, shipyards) undergoing cleanup and observed wood waste along Cliffside Beach.

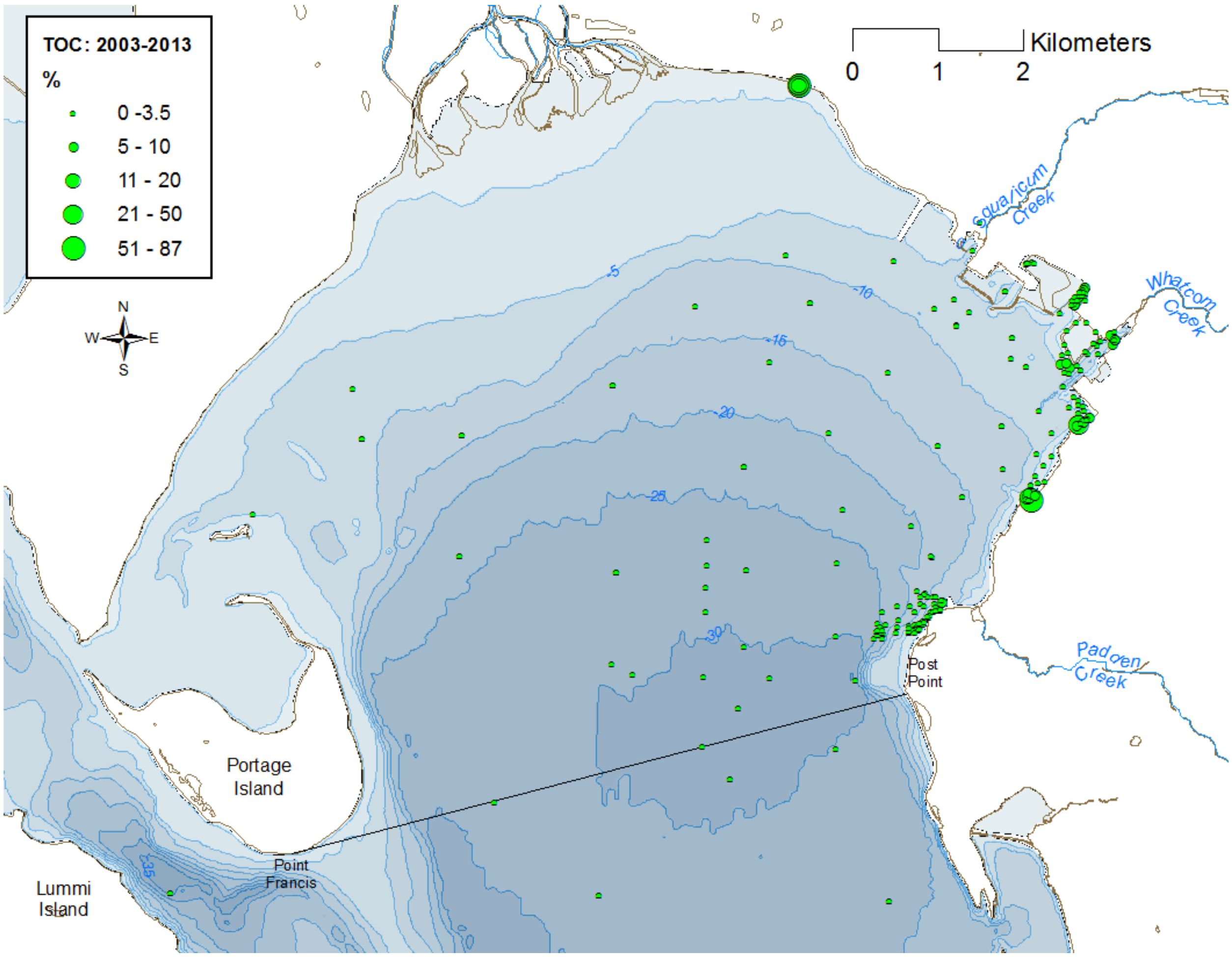

Figure 7. Total organic carbon (TOC) in Bellingham Bay dating from 2004 to 2013. Depth in meters based on MSL. Geographic line denotes the southern boundary of the Upper Bellingham Bay AOI.

Field data for wood waste observations during sampling was difficult to obtain for most studies. However, Ecology's Marine Monitoring Sediment Team provided field data that included locations of observed wood waste during sampling events in 1997, 2006, and 2010 (Figure 8). Additionally, wood waste was confirmed in one sample near the shore between Whatcom and I and J Waterway during the recent Bellingham Bay Background Sediment Characterization study (Ecology, 2015a).

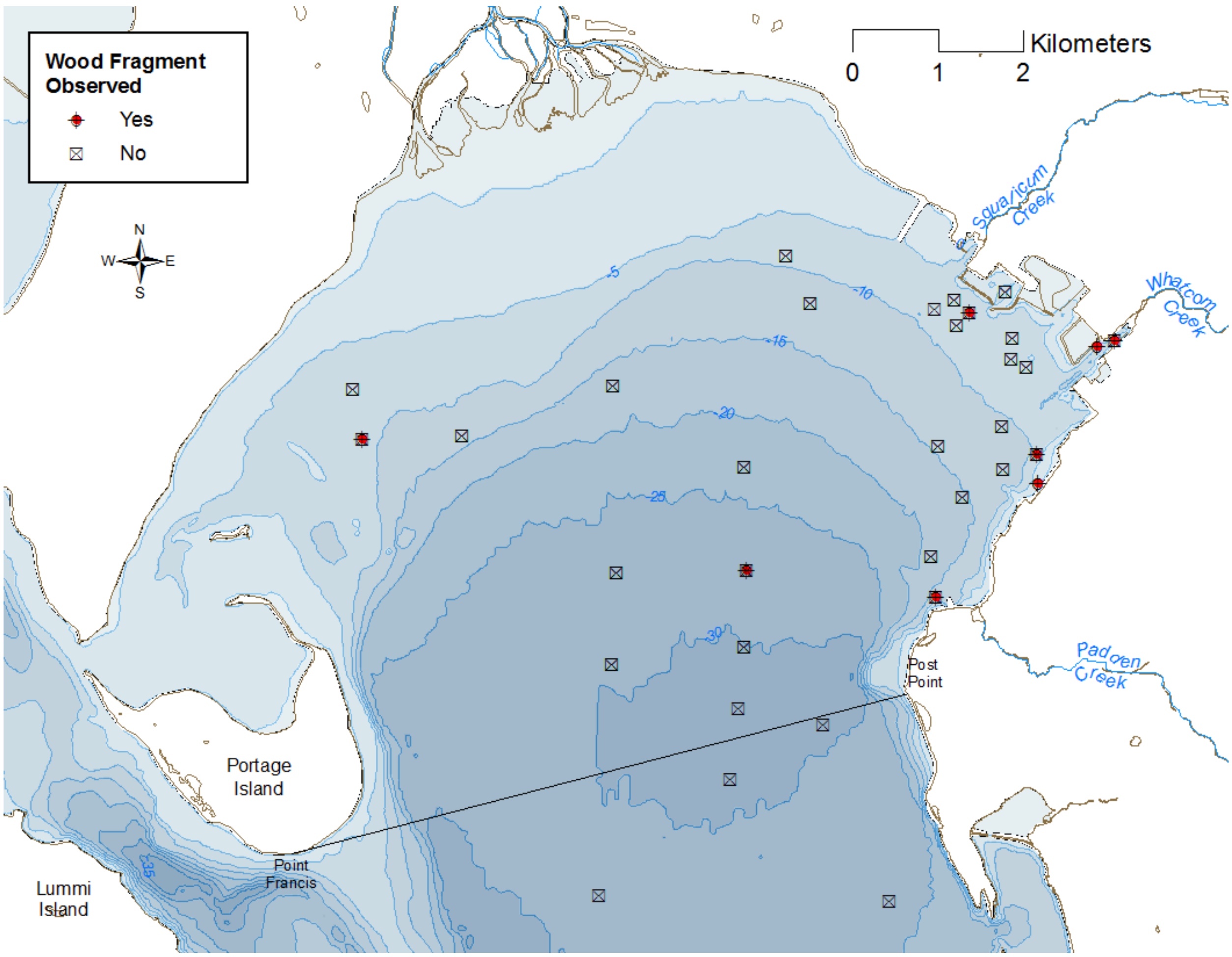

Figure 8. Observed wood waste in Bellingham Bay sediment samples. Depth in meters based on MSL. Geographic line denotes the southern boundary of the Upper Bellingham Bay AOI.

3.1.5 Regulatory criteria or standards

This study will screen for presence of wood waste in upper Bellingham Bay. Results may be used as part of a weight-of-evidence approach in subsequent studies for the presence or absence of wood waste. Since the Sediment Management Standards (WAC 173-204; Ecology, 2013a) only provide narrative standards for addressing wood waste, no compliance status is described in this plan. However, the Sediment Cleanup Users Manual II: *Guidance for Implementing the Cleanup Provisions of the Sediment Management Standards, Chapter 173-204 WAC* (Ecology, 2015b) along with *Wood Waste Cleanup: Identifying, Assessing, and Remediating Wood Waste in Marine and Freshwater Environments; Guidance for Implementing the Cleanup Provisions of the Sediment Management Standards, Chapter 173-204 WAC* (Ecology, 2013b) will be used as reference guides.

4.0 Project Description

Unnaturally high amounts of wood waste have accumulated in portions of Bellingham Bay along the shores and in sediments. Cleanup efforts are addressing known locations of contamination in documented cleanup sites along the shore where historical wood industries operated, but a large amount of wood waste appears to continue to pile up along the northern shoreline. Furthermore, a recent report has indicated that benthic communities in Bellingham Bay sediments have deteriorated since 1997 and 2006 surveys (Partridge et al., 2013). Because of this, there are concerns regarding unknown locations of wood waste, which may be impacting water and sediment quality and may be an on-going source of the shoreline wood waste.

4.1 Project goals

The goals of this study are to:

- Survey subtidal areas of Upper Bellingham Bay for accumulations of wood waste.
- Identify potential sources of wood waste including both past and continuing sources.
- Describe the nature and presence of wood waste found in subtidal areas.
- Provide recommendations on the need for future investigations of wood waste, based on results from this study.

4.2 Project objectives

Objectives for this study include:

- Conduct a literature review to identify historical sources of wood waste contamination.
- Screen locations reported in results from previous studies or from stakeholders that identified potential wood waste contamination.
- Visually survey areas of potential concern for wood waste contamination in surface sediment by using available underwater technology for filming the subtidal area.
- Conduct sediment sampling and conventional analyses to describe the nature and presence of the wood waste contamination, either identified or suspected during the visual assessment. Spatial extent of any regulatory exceedance will not be defined as part of this initial investigation.

4.3 Information needed and sources

Historical information on location, uses, and practices that pertain to potential sources of wood waste contamination in Upper Bellingham Bay will be gathered from literature reviews and local stakeholders.

Results from previous studies in Bellingham Bay have been collected from Ecology's EIM database or historical studies having similar types of data and mapped using Geographic Information Services (GIS). Communication with stakeholders may provide information on areas in Bellingham with suspected wood waste contamination.

GIS layers used for identifying areas of potential concern include:

- grain size
- percent solids
- TOC
- TVS
- wood waste observations
- Georgia Pacific diffuser outfall

Additional GIS layers from Ecology's GIS database may be screened for biological indicators of non-contaminated areas such as sea grass beds, fish distribution or spawning areas, and shellfish growing areas. These organisms are severely impacted or eliminated with wood waste contamination. Areas where sea grass beds or fish spawning biological indicators are present will not be included in the field assessment for this investigation. The assumption is that the presence of these sensitive organisms indicates areas that do not have wood waste contamination. Some overlap of fish distribution and shellfish growing areas may occur, since these areas may be more descriptive of scale rather than in actual production.

For the field assessment portion of this study, an underwater video camera will be towed to screen the subtidal area in the upper (northern portion) of Bellingham Bay. Necessary arrangements will be made for surface sediment sampling equipment and transport and for collecting and analyzing parameters of interest (percent solids, TOC, grain size, and TVS).

4.4 Target population

The target population is wood waste identification using visual assessment and sediment surface samples analyzed for percent solids, TOC, grain size, and TVS concentrations.

4.5 Study boundaries

The general AOI for this study is Upper Bellingham Bay situated above an imaginary geographic line extending eastward from Point Frances to the southern tip of Post Point, as described in section 3.1.

The subtidal zone of this area is the focus of the wood waste investigation. The subtidal zone is the shallower area of the sublittoral zone, which refers to the zone of the ocean where sunlight reaches the ocean floor. The sublittoral zone extends from the low tide mark to the edge of the continental shelf, with a relatively shallow depth extending to about 200 meters. For this investigation, the subtidal part of the beach (where it exists) extends from low water out to the approximate limit of storm erosion. The latter is typically located at a maximum water depth of 8 to 10 meters for moderate wave environments and is often identifiable on surveys by a break in the slope of the bed. Figure 9 shows the subtidal zone of the AOI; depth <10 meters.

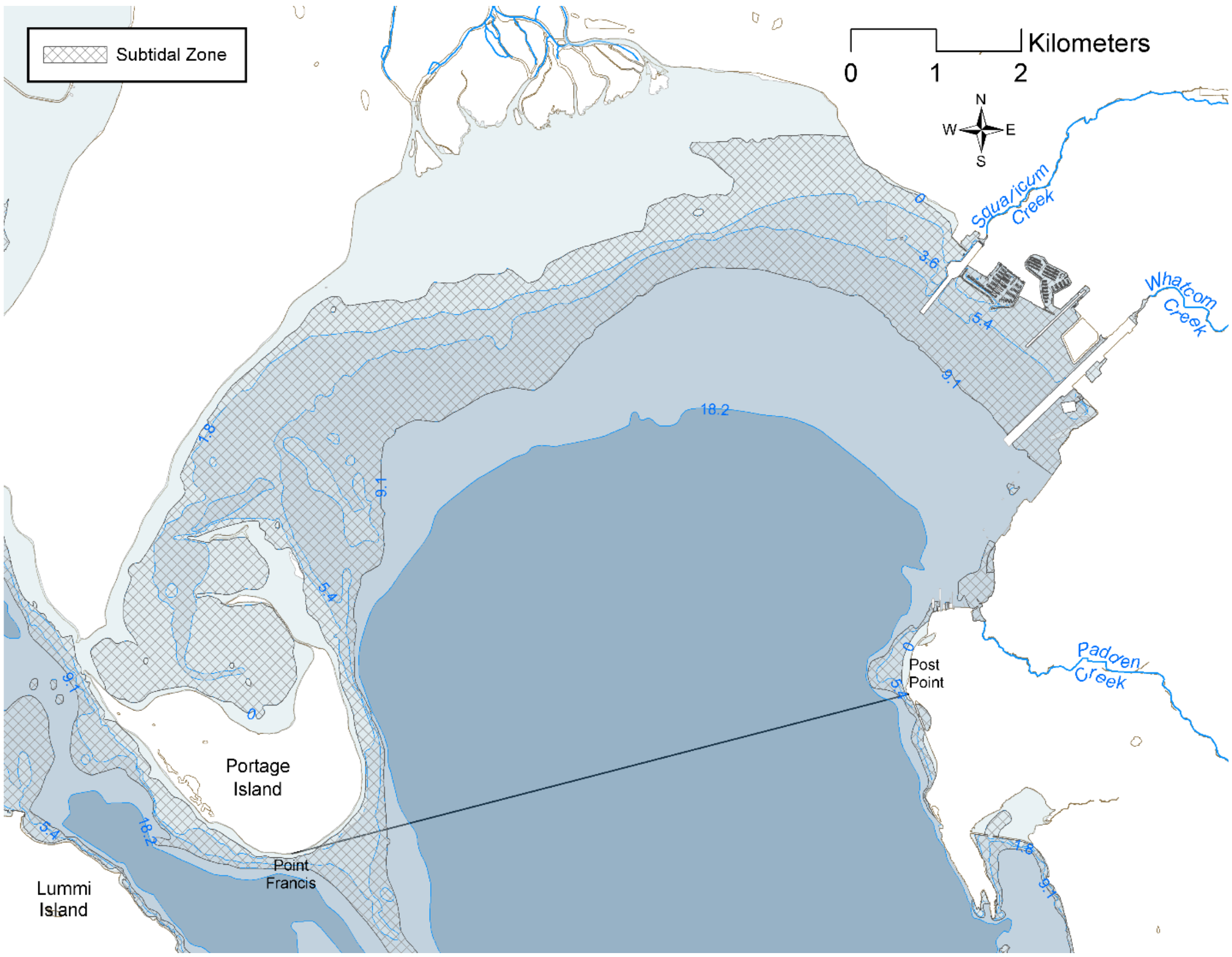

Figure 9. Subtidal zone; depth 10 meters or less. Depth in meters based on MLLW. Geographic line denotes the southern boundary of the Upper Bellingham Bay AOI.

Investigation for wood waste will include this shallow subtidal area with particular interest off the face of the Nooksack River delta and in areas where wood waste has been previously identified.

Water Resource Inventory Area (WRIA) and 8-digit Hydrologic Unit Code (HUC) numbers for the AOI

The AOI includes WRIA 1 and eight-digit Hydrologic Unit Code (HUC) numbers 17110004.

4.6 Tasks required

The project is anticipated to run until the summer of 2016. The overall study approach is to:

- Conduct a review of existing data on potential sources of wood waste.
- Screen Ecology's GIS database for biological indicators of non-contaminated areas such as sea grass beds, fish distribution or spawning areas, and shellfish growing areas.
- Prepare and approve a Quality Assurance Project Plan (QAPP) following recommended procedures found in Standard Operating Procedures (SOPs; Ecology, 2009).
- Screen DNR's underwater video data for presence or suspected wood waste-contaminated areas.
- Conduct an initial visual assessment survey to assess potential areas of concern and identify sample sites, using photographic technology.
- Develop a sampling scheme based on the results of the visual assessment survey.
- Conduct sediment sampling and conventional analyses to gather information for describing the presence and nature of the wood waste contamination that was either identified or suspected during the visual assessment.
- Conduct final data analyses, report writing, and recommendations.

4.7 Practical constraints

Some practical constraints for conducting this investigation include limited historical data and environmental conditions at the time of sampling.

Limited information is available for identifying wood waste-contaminated areas within the subtidal areas of Bellingham Bay. Most reports identifying wood waste issues were targeted for the commercial shoreline area next to the City of Bellingham and along the southern shore. These have since been dredged or filled. No studies have conducted investigations to identify wood waste contamination in the subtidal area.

Physical assessment for this study is dependent on several limitations that include:

- Water clarity for visual assessment and for underwater filming
- Tidal height to accommodate boat access in shallow subtidal waters
- Calm weather for safe working conditions and water clarity

Clear water is essential for obtaining clear images while filming underwater especially in shallow areas where disturbances are accentuated by water movement. Clear water (transmissivity) is highest and turbidity is lowest during low flow, low snow melt, and calmer weather seasons of the Nooksack River (Figure 10 and 11). These conditions most likely occur during the fall (September through early October) and spring (March, April, or May), depending on weather.

The tide needs to be high enough to cover the bottom with at least enough depth to accommodate flotation of the research vessel used for the assessment. Water 2 meters (5-6 ft) in depth would provide enough for RV Skookum, depending on weight of crew and equipment. Sampling would proceed during incoming tides that produce high enough water levels during daytime hours to cover the shallow areas by more than the depth needed to float the RV Skookum. The shallow areas would be sampled during the height of the tide and deeper areas during the low end of the tide.

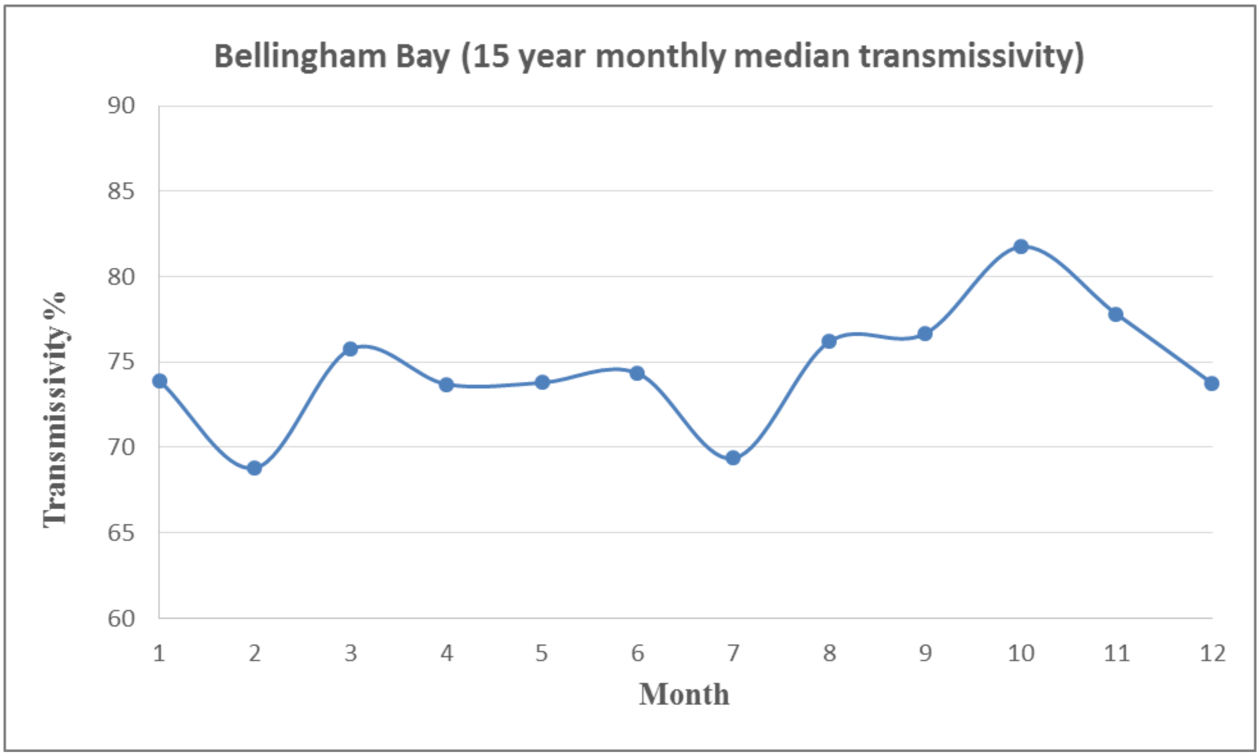

Figure 10. Transmissivity medians over 15 years for Bellingham Bay (Krembs, 2015).

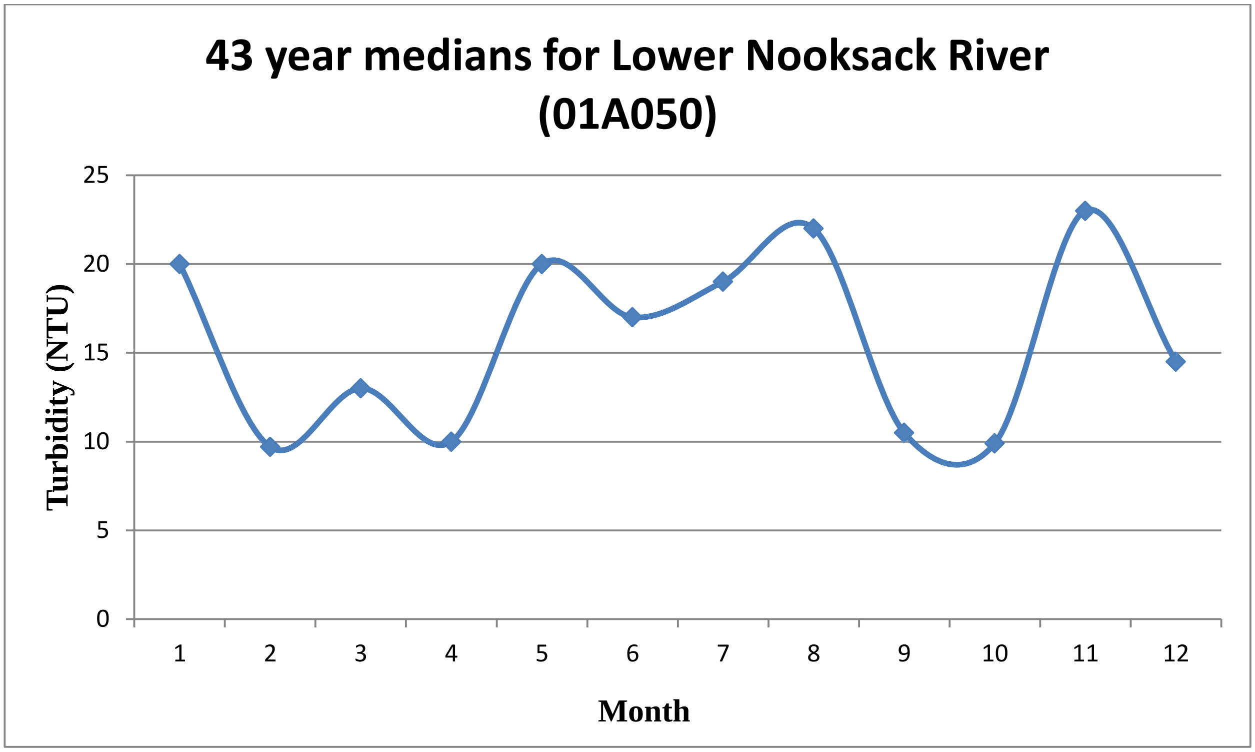

Figure 11. Turbidity medians over 43 years for lower Nooksack River (Ecology EIM database).

4.8 Systematic planning process

This Quality Assurance Project Plan follows the performance and acceptance criteria systematic planning process for generating data used for descriptive purposes and to generate estimates.

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities

Table 1 lists the individuals involved in this project. All are employees of Ecology unless otherwise noted.

Table 1. Organization of project staff and responsibilities.

Staff (all are EAP except client)	Title	Responsibilities
Lucy McInerney, P.E. TCP NW Regional Office Phone: 425-649-7272	EAP Client	Clarifies scope of the project. Provides internal review of the QAPP and approves the final QAPP.
Patti Sandvik TSU Unit EAP Section Phone: 360-407-7198	Project Manager / Principal Investigator	Writes the QAPP. Oversees field sampling and transportation of samples to the laboratory. Conducts QA review of data, analyzes and interprets data, and enters data into EIM. Writes the draft report and final report.
Siana Wong TSU Unit EAP Section Phone: 360-407-6432	Project Assistant	Helps collect samples and records field information. Enters data into EIM. Assist with data reduction and reporting.
Dale Norton TSU Unit EAP Section Phone: 360-407-6765	Unit Supervisor for the Project Manager	Provides internal review of the QAPP, approves the budget, and approves the final QAPP.
Will Kendra EAP Section Phone: 360-407-6698	Section Manager for the Project Manager	Reviews the project scope and budget, tracks progress, reviews the draft QAPP, and approves the final QAPP.
Joel Bird Manchester Environmental Laboratory Phone: 360-871-8801	Director	Reviews and approves the final QAPP.
Contract Laboratory	Project Manager	Reviews draft QAPP, coordinates with MEL QA Coordinator
William R. Kammin Phone: 360-407-6964	Ecology Quality Assurance Officer	Reviews and approves the draft QAPP and the final QAPP.

EAP: Environmental Assessment Program
EIM: Environmental Information Management database
QAPP: Quality Assurance Project Plan
TCP: Toxics Cleanup Program
TSU: Toxics Studies Unit

5.2 Special training and certifications

All Ecology personnel participating in the project field work have the necessary Ecology safety training. Experienced Ecology personnel will attend all field work and oversee and train those with less experience in using the equipment required for the collection of the proposed sample media. Staff will be familiar with applicable Ecology SOPs that are detailed in *Section 6.2.2.1 Comparability*.

5.3 Organization chart

Table 1 lists the key individuals, their positions, and their responsibilities for this project.

5.4 Project schedule

Table 2 presents the proposed schedule for this project.

Table 2. Proposed schedule for completing field and laboratory work, data entry into EIM, and reports.

Field and laboratory work	Due date	Lead staff
Field work completed	June 30, 2016	Patti Sandvik
Laboratory analyses completed	August 2016	
Environmental Information System (EIM) database		
EIM Study ID	PSAN0001	
Product	Due date	Lead staff
EIM data loaded	December 2016	Patti Sandvik
EIM data entry review	January 2017	Siana Wong
EIM complete	February 2017	Patti Sandvik
Final report		
Author lead / Support staff	Patti Sandvik	
Schedule		
Draft due to supervisor	October 2016	
Draft due to client/peer reviewer	November 2016	
Draft due to external reviewer(s)	December 2016	
Final (all reviews done) due to publications coordinator	January 2017	
Final report due on web	February 2017	

5.5 Limitations on schedule

The schedule of the sampling program relies on being able to successfully complete the visual screening and sample collection of sediment. Success depends on preparedness, which will be conducted according to this plan. Unforeseen events such as weather conditions, water conditions, or equipment malfunction that cannot be controlled will be thoroughly assessed before going out in the field. In the event of prohibitive conditions or equipment trouble, the schedule will be adjusted to accommodate a more favorable time when weather and water conditions improve or the equipment is operating properly. An alternate date will be chosen upon the scheduling of the research vessel and equipment.

5.6 Budget and funding

Table 3 presents the project budget funded through the Toxic Cleanup Program. The totals do not include costs for some Ecology staff time funded through other state or federal sources.

Table 3. Project budget and funding.

Analyte	Laboratory	Number of Samples	Number of QC Samples	Unit Cost[1]	Total Cost
Grain size	Contract Laboratory[2]	90	5	$100	$9,500
Percent solids	MEL	90	5	$12	$1,140
Total volatile solids	MEL	90	5	$24	$2,280
Total organic carbon	MEL	90	5	$46	$4,370
Equipment / Supplies	na	na	na	$3,000	$3,000
				Total:	$20,290

[1] MEL: Manchester Environmental Laboratory and analytical price list - FY 13.

[2] Contract Laboratory must be awarded the job. Listed cost is an estimate.

Na: not applicable.

6.0 Quality Objectives

6.1 Decision Quality Objectives (DQOs)

There are no specific decision quality objectives for this project.

6.2 Measurement Quality Objectives (MQOs)

A complete summary of measurement quality objectives (MQOs) for this project is detailed in Table 4.

Table 4. Measurement Quality Objectives (MQOs).

Parameter	Verification Standards (LCS, CRM, CCV)	Duplicate Samples	Matrix Spikes	Matrix Spike-Duplicates	Surrogate Standards	Lowest Concentrations of Interest
	% Recovery Limits	RPD	% Recovery Limits	RPD	% Recovery Limits	Units of Concentration
Grain size	na	±20%	na	na	na	na
Percent solids	na	±20%	na	na	na	0.1%
Total volatile solids	na	±20%	na	na	na	0.1%
Total organic carbon	80-120%	±20%	75-125%	na	na	0.1%

LCS: Laboratory Control Sample
CRM: Certified Reference Material
CCV: Continuing Calibration Verification
RPD: Relative Percent Difference
na: not applicable

In addition to MQOs, the data must be comparable, complete, and sensitive (measureable) to meet monitoring objectives (Lombard and Kirchmer, 2004). These are described in more detail below.

6.2.1 Targets for precision, bias, and sensitivity

6.2.1.1 Precision

Field duplicates consist of a single sample homogenized and split in the field. The duplicates will be designated for the same analysis as the original samples. Results from field duplicates are used to assess precision of the sample collection process and to help determine the representativeness of the sample. Field duplicate samples will be collected at a 5% frequency as recommended in the Puget Sound Estuary Protocols (PSEP) (PSEP, 1997c).

6.2.1.2 Bias

The bias of the lab instruments will be assessed by MEL and the contract lab. MEL will report results for all field samples submitted, which include quality control (QC) results. The data package from the contract lab (grain size analysis) will provide MEL with all the raw data, which will include a text narrative and analytical result reports. These include analytical logs, environmental samples, and batch QC samples, and preparation benchsheets. In addition, all of the necessary quality assurance and control documentation will be provided, including results from replicates. Expected bias is detailed in Table 4.

6.2.1.3 Sensitivity

The expected lowest concentration of interest for each parameter is detailed in Table 4. These values are based on the method detection limits for each parameter.

6.2.2 Targets for comparability, representativeness, and completeness

6.2.2.1 Comparability

To ensure comparability among projects, the following SOPs will be followed:

- Recommended Protocols for Measuring Conventional Sediment Variables in Puget Sound (PSEP, 1986).
- Recommended Protocols for Measuring Selected Environmental Variables in Puget Sound (PSEP, 1996)
- Recommended Guidelines for Measuring Organic Compounds in Puget Sound (PSEP, 1997a).
- Recommended Guidelines for Sampling Marine Sediment, Water Column, and Tissue in Puget Sound (PSEP, 1997b).
- Recommended Guidelines for Station Positioning in Puget Sound (PSEP, 1998).
- Recommended Quality Assurance and Quality Control Guidelines for the Collection of Environmental Data in Puget Sound (PSEP, 1997c).

The objective of this sampling plan is to provide a spatial survey of contaminants and not a temporal comparison. Although this plan is not regulatory in nature, The Sediment Cleanup Users Manual II: *Guidance for Implementing the Cleanup Provisions of the Sediment Management Standards, Chapter 173-204 WAC* (Ecology, 2015b) will be used as a reference guide for this project along with Wood Waste Cleanup: Identifying, Assessing, and Remediating Wood Waste in Marine and Freshwater Environments; *Guidance for Implementing the Cleanup Provisions of the Sediment Management Standards, Chapter 173-204 WAC* (Ecology, 2013a).

Achieving the recommended PQLs identified in the Sediment Cleanup Users Manual II: *Guidance for Implementing the Cleanup Provisions of the Sediment Management Standards, Chapter 173-204 WAC* (Ecology, 2015)will allow comparison with the SMS benthic chemical criteria for sediment with a normal range of TOC (0.5 – 3.5%).

6.2.2.2 Representativeness

Initial effort will be made to use data and stakeholder recommendations that indicate potential areas for wood waste. However, data that are more than 10 years old may not be representative of current site conditions, due to natural recovery processes or potential new or ongoing sources of contamination. This is particularly true when: (a) the source of contamination is known or suspected to be historical; (b) the chemicals of concern degrade rapidly in the environment; or (c) the area has a high sedimentation rate. Use of underwater technology in the suspected areas will guide the sediment sampling to target areas that are representative of current conditions.

To increase representativeness, field efforts will target the fall time period where flow, tidal, and weather conditions are more favorable for high water clarity. Low water and low glacier melt time periods along with generally calmer and dryer weather conditions result in the highest transmissivity (light filtering through) in the waters of Bellingham Bay. These time periods generally occur August through October with the highest 15-year average found in October. Spring sampling in February through April will remain an option for completion of the survey.

6.2.2.3 Completeness

The target for usable data for this project will be 95%. To ensure this target, up to 10 extra samples will be collected (10% of the total number of samples). These extra samples will be collected either as a duplicate or collected separately at a nearby location, so if one sample is compromised, other samples will be available to analyze. These redundant samples will not be analyzed unless deemed necessary.

7.0 Sampling Process Design (Experimental Design)

7.1 Study design

The design of this project is targeted for a simple survey for the presence of wood waste contamination in the subtidal area of the northern portion of upper Bellingham Bay. The basic approach is to sample portions of the subtidal area rather than a comprehensive survey. Intensive techniques targeting discrete sites scattered throughout Bellingham Bay's subtidal area allows for high quality data production that would otherwise be prohibitive on a comprehensive basis.

Sediment samples will be collected from areas where wood waste is evident or suspected, based on the video transect surveys. Conventional analyses describe the physical nature of the sediments, which help access impacts of the wood waste.

7.1.1 Field measurements

Field measurements for this project will include the estimation of fines and a visual check for wood fiber in sediment samples.

For comparability, percent fines will be determined through wet-sieving a portion of the sample, following a modified method described by Wakeman (1990). The procedure includes rinsing 50 mL of the homogenized sediment through a 62.5 µm sieve until the water is clear. Two fractions result from this field grain size determination: (1) greater than 62.5 µm represents sand and gravel; and (2) less than 62.5 µm represents silt and clay. Percent fines are equal to 50 minus the volume of remaining sediment divided by 50. The amount of sediment retained on the sieve will be recorded in the field log.

Sediment samples will be visually checked for wood fibers. Large wood debris as well as large rocks or shells will be removed before homogenization. If small wood fibers are suspected but not visible, a portion of the sample will be wetted to see if the wood fiber will float and then be accounted for.

The visual assessment will include an observation of wood waste presence. Any observed wood waste will be recorded in the field log.

7.1.2 Sampling location and frequency

To investigate wood waste in subtidal sediments, towed underwater video will be deployed along transects selected from a pool of video transects that were collected from the Department of Natural Resources (DNR) during their sea grass surveys (Figure 12). These transects will be reviewed for wood waste accumulations and transects with wood waste or suspected wood waste will be selected for further exploration. Additionally, suspect locations (areas of potential concern) may be surveyed as identified by stakeholders, previous evidence, or data gaps. Thus an element of field adaptability is necessarily built into this plan.

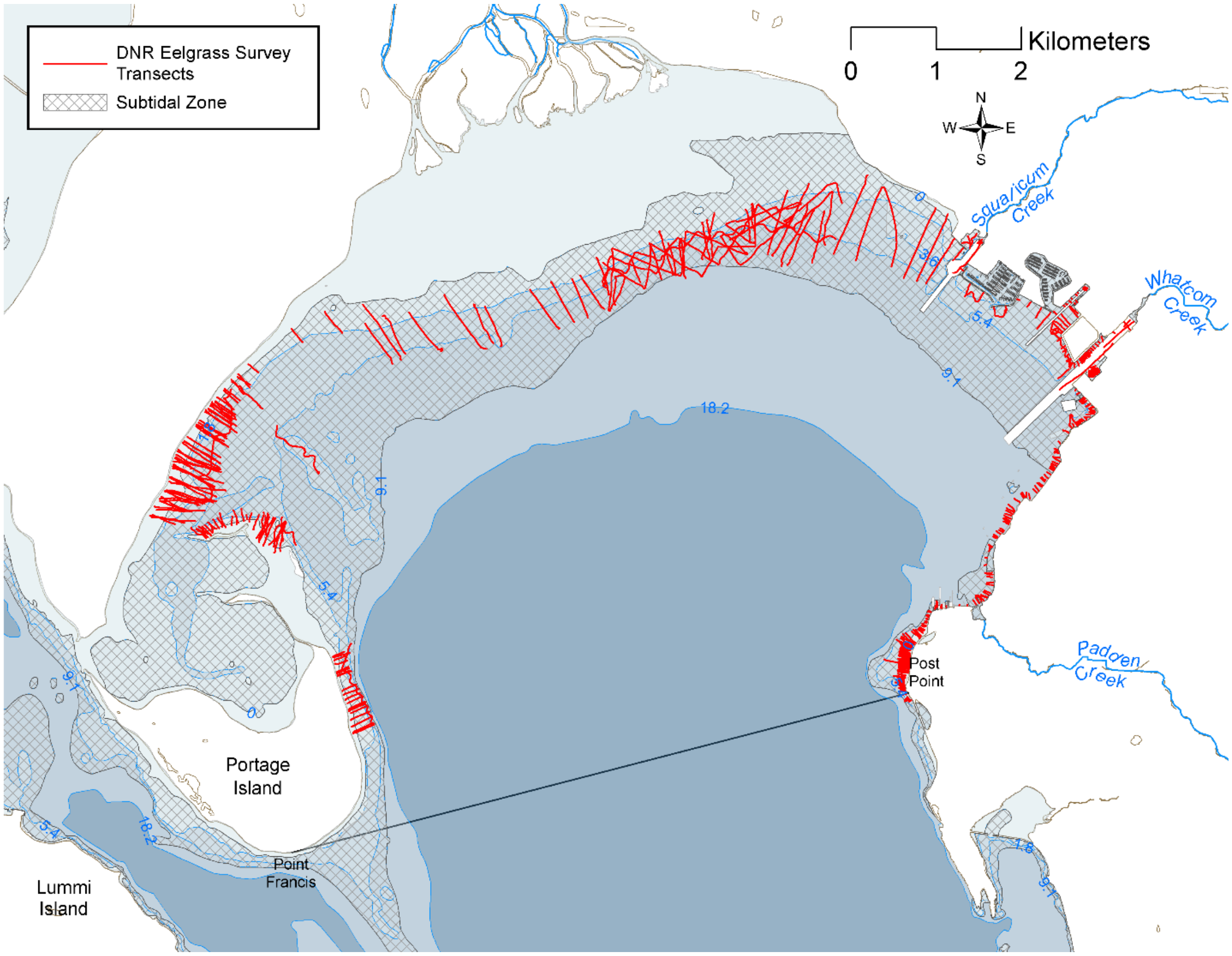

Figure 12. Department of Natural Resources sea grass video transects within the subtidal zone of the AOI (DNR, 2013). Depth in meters based on MLLW. Geographic line denotes the southern boundary of the Upper Bellingham Bay AOI.

Visual screening transects will start nearshore at depths the research vessel can safely operate (about 2 m, or 5-6 ft). To ensure amble depth, sampling will take place with tides of +1.8 meters Mean Lower Low Water (MLLW) or higher, so the research vessel can reach the shallow extent of transects. But even this can vary by site and scheduling restrictions.

The research vessel will travel generally perpendicular to the shore from the shallow end to the deeper. To explore areas of suspect wood waste accumulations, some transects will include following along the contour, keeping the elevation as nearly the same as when initiated. The assumption is that different deposition types tend to remain (deposit) along a contour of the same depth rather than across different elevations, because currents typically flow along contours of equal depth rather than across them (Ecology, 2015b). It is with intention that these transects will not be in a straight line but rather follow the natural curve of the bay and seafloor patterns (e.g., the Nooksack River delta).

In cases where obstacles such as buoys, moored boats, or submerged rocks force the boat to deviate from a pre-chosen transect more than 25% of the total transect length, then that transect may be discarded and another transect initiated nearby. The discarded transect will be logged as obstructed.

The number of selected transects varies, depending on previously observed wood waste along DNR sea grass transects or lack of information for a suspect area that warrants more exploration. Geographical coordinates will be logged for any wood waste observed during the assessment.

Certain areas of interest that may be of potential concern will be examined separately. These include the leading edge of the Nooksack River delta, estimated area of historical barge dumping, deeper holes in the bay that collect deposition, and other areas that may be suspect and yet to be determined.

Areas of low priority include areas indicated by a healthy habitat such as native seagrass beds or documented fish spawning areas (Appendix A). Low priority also includes areas where substantial characterization of the sediment has been conducted, such as the inner harbor; generally south of Squalicum Creek.

For the purpose of this sediment investigation, sampling within areas that have recently been dredged, capped, or otherwise affected by construction activities will be avoided. Other factors that may preclude sampling are bottom slope, currents, vessel traffic, and debris or obstructions on the sediment bed. Careful planning and timing of sampling may allow access to locations that would otherwise be inaccessible, e.g., low tidal areas, swift currents, vessel traffic, and others.

After the visual assessment is complete and the results have been reviewed, sediment sample locations will be chosen based on evidence of wood waste or suspect areas. Samples may also be collected in areas along transects where images were unclear or not available or where there is evidence to suspect wood waste.

7.1.3 Parameters to be determined

A visual investigation of wood waste in Bellingham Bay includes observations for wood waste in sediments and surrounding shoreline subtidal areas. In addition, analyses for grain size, percent solids, TVS, and TOC will be conducted for sediment samples collected in areas of potential or suspected concern as determined from review of the videos collected during the visual survey.

Post processing the videos collected during the visual survey includes classifying each transect into presence/absence categories for wood waste deposits. The assessment may also include a subjective observation of wood waste surface coverage in accordance with the following criteria (Ecology, 2013b):

- Wood waste surface coverage between 5% and 25% may need further investigation.
- Wood waste surface coverage of 25% and greater may adversely impact the benthic community and should be investigated further, depending on habitat, coverage area, and depth.

Estimations of wood waste surface coverage from video filming are difficult and depend on the post processer's determinations. Wood fibers are not always visible when small or mixed in with sediment. Also, video scale can vary depending on the distance of the camera to the bottom. Closer to the bottom, the objects appear larger in proportion. Therefore, any estimates will be considered subjective. Follow-up investigation will be recommended if observations suggest wood waste surface coverage may be greater than the guidelines listed above.

Variations in density are not captured. Video quality will be classified as good or poor for each transect. High turbidity or very low light conditions can produce poor quality in underwater videos. In practice, interpretation of the videos is subjective, and results should be considered a guide for future investigation rather than an absolute determination. Appendix B includes attributes to spatial data collected.

Locations for sediment collection will be selected from areas of suspected wood waste contamination, as determined from the visual surveys to help describe the physical nature of the location. Sediment grain size helps in the interpretation of sediment transport and deposition and interpretation of sediment toxicity data and benthic macro abundance data.

Percent solids provide information on how much water is contained in the sediment sample. A porous wood waste sediment sample contains much more water than densely packed, clay-like sediment sample.

TVS and TOC provide measures of the overall organic content in sediment and the ratio of TVS/TOC can indicate areas of anoxic conditions. Elevated TOC is frequently found in sediments impacted by wood waste and can indicate presence of eutrophic and low dissolved oxygen conditions (Ecology, 2013b). TOC in marine sediments typically ranges from 0.5% to 5% (Ecology, 2013b). A TOC outside of this range could be considered unusual.

TVS can be used to estimate the overall volume of wood waste and provides a less variable measure of wood waste than TOC. TVS represents nitrogen-, oxygen-, and sulfur-containing compounds and their associated hydrogen atoms in sediment samples (Ecology, 2013b).

7.2 Maps or diagram

The proposed measurement and sampling locations will follow transects chosen from DNR sea grass video surveys (Figure 12) as described in Section 7.1.2. Additional transects may be conducted to include investigating areas of suspect wood waste contamination as identified by stakeholders or previous evidence, but may also include areas where little information was available (data gaps).

This study will select transects after reviewing the underwater video data collected from DNR sea grass surveys. Figure 13 shows DNR transects in relation to sea grass and fish spawning locations. Low priority will be transects coinciding with the location of sea grass and fish spawning locations. Also, low priority will be given to the area east of Squalicum Creek, since that area has been fairly well studied during cleanup and restoration activities.

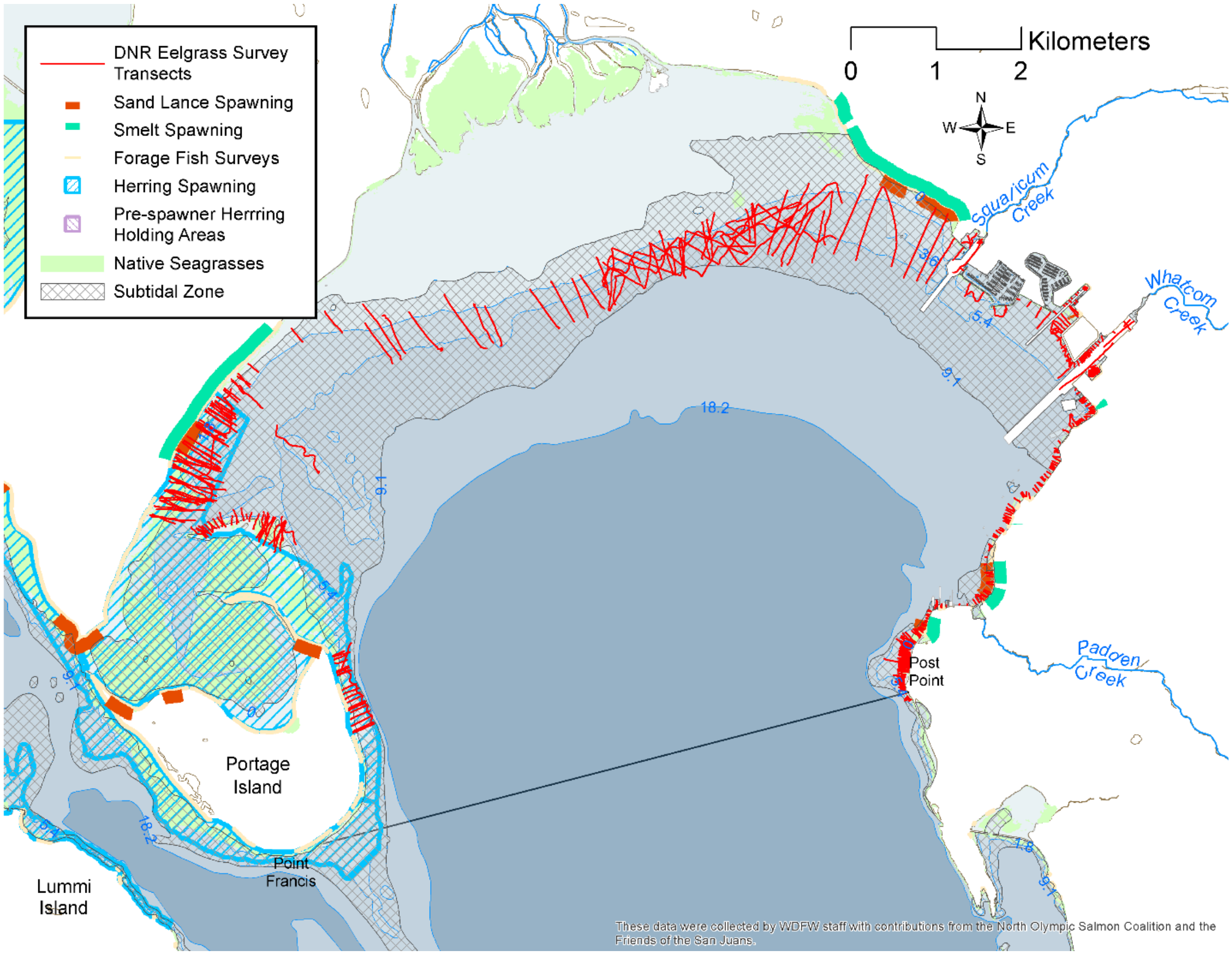

Figure 13. Department of Natural Resource sea grass video transects within in this project's subtidal area in Bellingham Bay in relation to sea grass and fish spawning locations and areas of data gaps. Depth in meters based on MLLW. Geographic line denotes the southern boundary of the Upper Bellingham Bay AOI.

Transects selected from the DNR study will be extended in areas where no data have been collected in the subtidal area. These data gaps include a large area on the west side of the AOI and around the delta face. Adaptability will be necessary to accommodate various circumstances likely in the field, e.g., tides, obstructions, and turbidity. New transection will be initiated as needed.

Sample collection sites will generally be accurate to within ± 3 meters. The sampling location will be referenced to the actual deployment location of the sampler, using GPS or a similar system. Locations of samples will be recorded in latitude and longitude to the nearest hundredth of a second. Final location will be reported using state plane coordinates as the Washington State Plane North Zone with a datum of NAD 83 HARN in units of U.S. survey feet.

7.3 Assumptions underlying design

An assumption in this sampling design is that this snapshot assessment is representative of the environmental conditions. The results from this study may not fully capture the range of conditions or unique events found in this region. Even though steps are taken to ensure representativeness, data users must be careful not to overstate these measurements. Sediment samples cannot ascertain all areas, depths, or variability with transport and deposition. Not all areas of Bellingham Bay will be investigated.

7.4 Relation to objectives and site characteristics

Upon completion of the screening survey for the presence of wood waste in the subtidal area of upper Bellingham Bay, spatial distribution of identified presence of wood waste will be reported. Recommendations for follow up actions will be made if needed. Future assessments will be able to focus resources on the appropriate areas and type of analyses.

7.5 Characteristics of existing data

Historical data and more recent data have described many characteristics about Bellingham Bay such as water and sediment qualities, chemical contamination, and some dynamic attributes of the currents and marine water interaction. Although these have reported high quality data, they have been generally concentrated on areas suspected from source contamination or repetitive long term sampling at designated locations. No studies have looked at the subtidal area for possible deposits of wood waste that may be impacting the quality of sediment habitat for the biota.

This project will survey surface sediments for wood waste within the subtidal zone of upper Bellingham Bay. Specific locations identified as suspect or areas of potential concern will also be examined. Visual screening will be followed by sediment samples to help describe the physical nature of the sediment in areas of suspected wood waste.

8.0 Sampling Procedures

8.1 Field measurement and field sampling SOPs

8.1.1 Visual Screening

Visual screening of Bellingham Bay floor will be conducted using an underwater SeaViewer video camera. The camera will be mounted with a downward-looking orientation on a stabilizer weighing approximately 48 pounds with options to increase weight if necessary. Accessories options such as lighting will be mounted on a frame attached to the stabilizer.

The sampling will be conducted primarily from Ecology's 26-ft Almar Sounder R/V Skookum. The camera will be deployed off the stern, using an A-frame boom and hydraulic winch. An operator uses the boom winch to control the height at about 1 meter above the bottom while viewing real-time video. The research vessel speed along transects will be approximately 1-2 mph. Depths will be measured with the depth sounder on board. Location data will be recorded with the GPS unit on board or a recording device connected into the video. Video will be recorded in digital video (DV) format and stored on (standard definition (SD) memory cards. A video overlay stamps the time on the video, continuously updating within seconds.

A test run will be conducted so the boat operator, instrument operator, and field crew will have opportunities for training, calibrating instruments, and adjusting boat and support equipment.

Absolute and repeatable accuracy for visual assessment (e.g., towing) and point investigations in the bay will be accomplished following the instructions found in the Sediment Cleanup Users Manual II (Ecology, 2015b) and SOPs for Puget Sound sampling (Ecology, 2012 and PSEP, 1998). The research vessel will be equipped with positional instruments, e.g. Automatic Identification System (AIS), to allow locations to be generally accurate within ± 3 meters. The sampling location should be referenced to the actual deployment location of the sampler using GPS or a similar system. Station locations should be reported in: (1) latitude and longitude (to the nearest hundredth of a second) or (2) state plane coordinates as the Washington State Plane North or South Zone with a datum of NAD 83 HARN in units of U.S. survey feet.

Field observations will be captured in field logs. They may be useful for interpreting data and related water conditions. These observations include:

- Water color
- Debris
- Sightings of fronts, eddies, and other surface current features
- Plankton blooms and presence of algal mats
- Waves and wave height

The weather and related conditions are also recorded during a survey. These data include:

- Wind speed and direction
- Cloud cover (%) and cloud type
- Presence of direct sunlight

• General weather condition (overcast, cool, rainy, foggy, sunny, and warm)
• Recent past weather conditions

8.1.2 Sample Collection

Samples will be collected using standardized procedures and instructions from Ecology's and PSEP's SOPs and manuals. These include instructions and SOPs for field sampling and sediment collections, measuring environmental variables, and QA-QC controls (Aasen, S., 2007; Ecology, 2013b and 2015b; PSEP, 1986, and 1997a, b, and c).

Sampling location coordinates will be recorded by and programmed into the R/V Skookum navigation system. The actual position will be recorded once the device reaches the seafloor and the deployment cable is in a vertical position. Latitude and longitude station coordinates will be recorded in the field log, using degrees decimal minutes in 1983 North American Datum (NAD83). Water depths will be measured with the winch meter wheel and verified by the ship's fathometer.

A 0.1 m^2 Van Veen stainless steel sampler will be used to collect marine sediments. This grab sampler achieves good penetration (generally 10 – 20 cm in soft sediment) with minimal disturbance of the sediment surface. Procedures for using sediment grab samplers are described in detail in the PSEP protocols (PSEP, 1986).

The top 12 cm of the sediment will be collected. This is considered the biological active zone (BAZ) where species critical to the function, diversity, and integrity of the benthic community are located in Bellingham Bay (Ecology 2013a). The 0- to 12-cm depth represents the BAZ of the sediments in Bellingham Bay based on previous work for the Whatcom Waterway site (Ecology, 2015a).

Sediment samples collected with a grab sampler should be carefully inspected to ensure the following PSEP and Ecology (PSEP, 1986 and 1997b and Ecology, 2015b) criteria are met:

- The sampler is not over-filled so the sediment surface is not pressed against the top of the sampler.
- Overlying water is present (indicates minimal leakage).
- The overlying water is not excessively turbid (indicates minimal sample disturbance).
- The sediment surface is relatively flat (indicates minimal disturbance or winnowing).
- The necessary penetration depth is achieved (e.g., several centimeters more than the targeted sample depth).

If a sediment sample does not meet all of these criteria, it will be rejected, and another sample will be taken nearby or at another site altogether. In the event a successful grab cannot be obtained at the target location, the project officer or lead Ecology personnel will be notified and additional attempts may be made at a revised location.

Excess sediment (collected but not needed for analysis) will be returned to the water near the station where it was collected.

Upon retrieving a successful grab, overlying water will be siphoned off and the top 12 cm layer of the sediment will be removed with stainless steel scoops, placed in stainless steel containers, and then stirred to homogenize the sample. Material in contact with the side walls of the grab will not be retained for analyses. At the discretion of the project lead, larger debris (e.g., wood, rocks, and shells) found in the sample that cannot be homogenized will be removed and discarded after recorded in the field log.

Sample handling and preservation will be conducted according to PSEP and Ecology SOPs (PSEP, 1997a and b; Aasen, 2007). Appropriate sample containers, preservation conditions, and chain-of-custody procedures (below) will be followed according to these SOPs.

8.2 Containers, preservation methods, holding times

Details of sample containers, preservation method, and holding times are found in Table 5. Samples collected in the field will be placed on ice immediately. They will be transported to the analytical laboratory on ice at 4 °C. Upon receipt at the laboratory, storage temperature and maximum holding time will be determined based on the analyses to be performed. Although sediment samples may be archived for later analysis by freezing and storing at -18 °C, samples to be analyzed for grain size and sulfides should not be frozen. If samples are frozen, extra space should be left in containers to allow for expansion of samples, which will help prevent breakage of the sample bottles upon freezing. The archived samples will be thawed and analyzed for the appropriate analytes within the maximum holding times listed in Table 5.

Table 5. Sample containers, preservation, and holding times.

Parameter	Matrix	Minimum Quantity Required (g)	Container[1]	Preservative	Holding Time
Grain size	Sediment	100	8 oz plastic or glass jar	Cool, ≤4°C	6 months
Percent solids	Sediment	50	4 oz glass jar	Cool, ≤4°C; Freeze, -18°C	14 days 6 months
Total volatile solids	Sediment	50	4 oz glass jar	Cool, ≤4°C; Freeze, -18°C	14 days 6 months
Total organic carbon	Sediment	25	2 oz glass jar	Cool, ≤4°C; Freeze, -18°C	14 days 6 months

[1] Plastic jars: linear polyethylene; glass jars: borosilicate glass.

Sample containers will have self-adhesive labels attached. Pre-made labels will be attached to the outside of every sediment sample container. Label information will include at minimum:

- Sample identification number
- Field identification
- Site or project name
- Sampling date and time
- Analysis

8.3 Invasive species evaluation

There is a low probability of aquatic invasive species within Bellingham Bay (Parsons et al., 2012). Currently, there are no "Extreme Concern" marine areas. Standard precautions will be taken, including not wearing felt-soled boots and decontaminating any equipment between uses if necessary.

8.4 Equipment decontamination

Decontamination procedures will follow the SOP for decontaminating field sampling equipment described by Friese (2014), PSEP (1997b) and recommendations by Ecology (2015b). In general, decontamination procedures for field sampling equipment used for marine or estuarine sediment should include scrubbing the equipment with a brush and phosphate-free detergent solution (e.g., Liquinox), followed by a rinse with clean site water.

Sample processing equipment, e.g., spoons, bowls, and reusable containers from which samples are transferred to sample jars, will be washed with a laboratory-grade detergent (e.g., Liquinox) and water solution, rinsed with site or tap water, and then rinsed a final time with distilled water prior to field operations. Decontaminated equipment will be wrapped or covered with aluminum foil. Between sites, processing equipment will be thoroughly brushed with on-site water in order to prevent cross-contamination of samples. If oil or visible contamination is encountered, the grab will be cleaned between samples with detergent (e.g., Liquinox) and rinsed with on-site water. Any deviations from these procedures will be documented in the field notebook.

Non-disposable field equipment such as boots, waterproof gloves, and garments will be rinsed with water and brushed clean prior to leaving the immediate vicinity of the sample collection area. Special attention will be given to removing mud that may adhere to boot treads.

8.5 Sample ID

All collected samples will be labeled with a unique field name and sample identification number, and these will be recorded in the field log. The sample identification number will be copied onto chain-of-custody forms and analysis logs for internal laboratory samples, which are eventually loaded into Ecology’s EIM database.

All samples will be reconciled against forms to verify completeness, as samples move through the analytical process.

Samples will be identified following the same protocol as for the Bellingham Bay Regional Background Sediment Characterization study (Ecology, 2015a). Identification is based on the project, sampling area, location, and sample type as shown in Table 6.

Table 6. Sample identification schematic.

Category	Definition	Example	Interpretation
Project	Four characters describing the project.	WW15-	Wood Waste 2015
Study Area	Two characters describing the sampling area.	BB-	Bellingham Bay
Location Number	Two characters identifying the site location number.	01-	Site number 1
Sample Type	One or two characters indicating the sample type or QA/QC identification.	S	Sediment sample
		D	Duplicate
		T	Triplicate

8.6 Chain-of-custody, if required

Standard chain-of-custody protocols, as outlined in the *Manchester Environmental Lab Users Manual*, *9th edition* and PSEP and Ecology SOP (described above), will be followed. Chain-of-custody forms will be initiated at the time of sample collection to ensure that all collected samples are properly documented and traceable through storage, transport, and analysis. Each individual who subsequently assumes responsibility for the sample will sign the chain-of-custody form and provide the reason for assuming custody. The field chain-of-custody terminates when the laboratory receives the samples. The project officer will receive and retain a copy of the completed, signed, chain-of-custody form(s) for project files.

8.7 Field log requirements

The field log for collecting sediment samples follows the example from Bellingham Bay's Regional Background Sediment Characterization study (Appendix C). The log will be printed on waterproof paper.

8.8 Other activities

Sediment samples may need to be composited during sample collection if the sampling device does not contain enough sediment volume for the required analyses in a single cast. If more than one cast is necessary for larger volumes of sediment, the sampling device will target the same location and depth. Care will be taken to sample as close as possible to the original cast at the same location. The same volume of sediment will be collected from each cast to ensure equal representation.

Sediment from each subsample will be accumulated and stored in a stainless steel bowl and covered with aluminum foil between casts. Unrepresentative material such as woody debris, shells, and rocks will be removed before combining. When sufficient sediment volume is collected, the composited sediment will be thoroughly homogenized. Subsamples will be taken from the homogenized composite sediment sample for chemical and physical analyses.

9.0 Measurement Methods

9.1 Field procedures table/field analysis table

No field analyses are planned, with the exception of estimating wood fiber and sediment fines. Wood fiber will be estimated visually. Sediment fines will be estimated by wet washing, using one sieve, and calculated from original amount, as described above in section 7.1.1.

9.2 Lab procedures table

Laboratory procedures are detailed in Table 7. The contract laboratory will be responsible for the grain size analysis. MEL will conduct analysis of percent solids, total volatile solids, and total organic carbon.

Table 7. Measurement methods (laboratory).

Analyte	Sample Matrix	Number of Samples	Expected Range of Results	Reporting Limit	Sample Prep Method	Analytical (Instrumental) Method
Grain size	Sediment	90	0-100% fines	NA	described in analytical method	PSEP, 1997b / ASTM D-422
Percent solids	Sediment	90	25-80%	0.1%	described in analytical method	PSEP, 1997b
Total volatile solids	Sediment	90	1.0-75%	0.1%	described in analytical method	PSEP, 1997b
Total organic carbon	Sediment	90	0.1-65%	0.1%	described in analytical method	EPA 9060/ SW-846

9.3 Sample preparation method(s)

Established sample preparation methods are detailed in Table 7.

9.4 Special method requirements

Requirements for Laboratory analyses will be followed as directed by methods recommended in MEL's Laboratory Users Manual (MEL, 2008). Any special requirements will be communicated between the laboratories and the project officer. At this time, no special requirements are expected.

9.5 Lab(s) accredited for method(s)

All lab methods proposed here will be accredited by Ecology's Laboratory Accreditation Program. A contract lab will be awarded a portion of the analysis, based on their documented experience with the necessary methods, their ability to achieve the QC standards, and cost-efficiency. Services will be issued under the original Solicitation for State Master Contract.

10.0 Quality Control (QC) Procedures

10.1 Table of field and laboratory QC required

QC procedures for field and laboratory methods are detailed in Table 8.

Table 8. Quality control samples, types, and frequency.

Parameter	Field		Laboratory			
	Blanks	Replicates	Check Standards	Method Blanks	Analytical Triplicates	Matrix Spikes
Grain size	na	5	na	na	1/batch	na
Percent solids	0	5	1/batch	1/batch	1/batch	na
Total volatile solids	0	5	1/batch	1/batch	1/batch	1/batch
Total organic carbon	0	5	1/batch	1/batch	1/batch	1/batch

Note: 1/batch or every 20 samples (5%), whichever is more frequent.

Laboratory quality assurance/quality control (QA/QC) measures are documented in MEL's Laboratory Quality Assurance Manual (MEL, 2012). Laboratory quality control measures include the analysis of check standards, blanks, duplicates or triplicates, and spikes. Check standards or laboratory control samples are important for evaluating analytical precision and bias. Duplicates or triplicates and spikes help evaluate any effects of sample matrix on the data quality. Blanks aid in determining interferences and precision for concentrations near analytical detection limits.

10.2 Corrective action processes

This project is a one-time sampling event and, therefore, there will be no opportunity for corrective actions once samples are shipped to the laboratories. Therefore, it is imperative that field procedures are followed in detail. During field collection, adjustments made during sampling will be documented in the field logs.

The laboratories are responsible for monitoring the analyses, identifying analytical problems, and taking corrective actions throughout the procedures, following appropriate methods. The laboratories should tell the project lead about any problems during analysis that may impact the project. When reasonable corrective actions do not result in bringing QC sample results within control limits, data may need to be qualified.

There are no plans for this project to collect more or additional samples outside of this QAPP. To compensate for this limitation, if QC criteria are not met, remnant sediment in samples will be held in case samples need to be rerun, with the exception of grain size analysis. There will be no remnant sediment from grain size analysis. This does not pose a limitation, because most grain size analyses are completed within criteria, with the exception of catastrophic loss of the sample. In this event, fines estimated in the field can be used as a qualified estimate of grain size.

11.0 Data Management Procedures

11.1 Data recording/reporting requirements

After completion of the project, the sediment data will be entered into Ecology's EIM. A final report will be prepared by the project lead. At a minimum, the report will contain:

- A map of the study area showing sample sites.
- Latitude and longitude coordinates for each sample site and visual transects.
- Description of the field and laboratory methods.
- Discussion of the data quality.
- Results from the visual survey.
- Summary tables of the physical and chemical data collected.
- Maps of physical and chemical data and of wood waste if located.
- Discussion of the distribution of wood waste.
- Conclusions.
- Recommendations for follow-up work if warranted.

11.2 Laboratory data package requirements

A laboratory data package will be generated or overseen by MEL. A project data package will include: a narrative discussing condition of samples upon receipt and anomalies encountered in the analyses, corrective actions, changes to the referenced method, and an explanation of data qualifiers, results for samples and quality controls.

11.3 Electronic transfer requirements

All laboratory data will be accessed and downloaded from MEL's Laboratory Information Management System (LIMS) into Excel spreadsheets. The contract lab will provide an electronic data deliverable (EDD) that meets the format defined by MEL.

11.4 Acceptance criteria for existing data

All detection limits will be defined as to what type of detection limits applied to the analyzing method and qualifiers assigned appropriately. The following data qualifiers will be used:

- "J" – The analyte was positively identified. The reported result is an estimate.
- "U" – The analyte was not detected at or above the reported result.
- "UJ" – The analyte was not detected at or above the reported estimate.

After initial data processing and QA/QC activities confirm that all instrument operations, laboratory analyses, and field information collection were performed without error or failure, data are accepted for use.

11.5 EIM data upload procedures

Data will be entered into Ecology's Environmental Information Management (EIM) system after project personnel verify and validate data.

12.0 Audits and Reports

12.1 Number, frequency, type, and schedule of audits

Data collected for this study will be reviewed for data quality and usability by MEL and the project lead. If necessary, review and discussion will be conducted by other scientists. During sampling events, the project lead and assistant scientists will review the sampling and data collected. The project plan can then be adjusted if needed.

To ensure accurate entry of data into the database, the monitoring coordinator or data manager checks 10% of all values against the source data. If errors are found, an additional 10% of values are checked. This process continues until no errors are found or all values have been verified or corrected.

All laboratories participate in routine performance and system audits of various analytical procedures. Audit results are available upon request. The Laboratory Accreditation Unit of Ecology's EAP accredits all contract laboratories that conduct environmental analyses for the agency. This accreditation process includes performance testing and periodic lab assessments. No additional audits are envisioned.

12.2 Responsible personnel

The quality assurance officer for MEL, Karin Feddersen, will carry out the review of all MEL and contract lab data packages.

12.3 Frequency and distribution of report

One report will be issued after all results are received, reviewed, and tabulated. The report will be distributed to Ecology regional managers and interested stakeholders.

12.4 Responsibility for reports

The project lead will be the lead author.

13.0 Data Verification

Data verification and review is conducted by MEL and the project lead by examining all field and laboratory-generated data to ensure:

- Methods and protocols were followed.
- Data are consistent, correct, and complete, with no errors or omissions.
- Established criteria for QC results were met.
- Data qualifiers (QC codes) are properly assigned.

13.1 Field data verification, requirements, and responsibilities

During field sampling, the project lead and assistants are responsible for assuring location positioning and sample collection. Additionally, all field crew will review the field documents (field logs, chain-of-custody sheets, and sample labels) to ensure data entries are consistent, correct, and complete with no errors or omissions.

13.2 Lab data verification

MEL will oversee the review and validation of all laboratory data packages. All data generated by the contract lab must be included in the final data package, including but not limited to: a text narrative; analytical result reports; analytical sequence (run) logs, chromatograms, spectra for all standards, environmental samples, batch QC samples, and preparation benchsheets. All of the necessary QA/QC documentation must be provided, including results from matrix spikes, replicates, and blanks.

13.3 Validation requirements, if necessary

No external validation is expected to be necessary for this project.

14.0 Data Quality (Usability) Assessment

14.1 Process for determining whether project objectives have been met

The primary objective of this project is to conduct an initial investigation for wood waste contamination within the subtidal zone of Bellingham Bay. The project is designed to include visual survey and chemical and physical analyses to describe the physical nature of wood waste in potential areas of concern or suspect. Since this survey examines only portions of the bay, data gaps are possible. Evidence for the presence or absence of wood waste at the sampled locations will be determined from the results, as well as whether further investigation is needed.

Results need to meet MQO criteria to be used in this evaluation. If MQOs are met, the quality of the data is considered usable for meeting the project objectives. If MQOs have not been met, the project lead in consult with other staff members will examine the data to determine whether they are still usable and whether the quantity is sufficient to meet project objectives.

Recommendations for further wood waste investigation or additional sampling to add to or replace failed results can address data gaps if results from this project suggest wood waste contamination is likely.

14.2 Data analysis and presentation methods

The data will be summarized and displayed using a range of standard scientific graphical methods. Outliers and out-of-range data will be reviewed to determine if these are errors or possible real events. If data anomalies are found during data analysis, they will be evaluated and resolved. Data errors will be removed or corrected and reanalyzed.

14.3 Treatment of non-detects

The handling of non-detects is not relevant to the parameters measured for this project, because they will be reported as percentage. Parameters include grain size, percent solids, TVS, and TOC. Field parameters include a visual estimation of wood fiber and the estimation of sediment fines.

14.4 Sampling design evaluation

The study design for this project is a spatial survey. Sample distribution is both exploratory and targeted to suspected wood waste contamination within the subtidal region of Bellingham Bay. Adaptation during field collection is part of the study design in order to investigate potential areas of concern or suspected areas. For example, early sample collection may direct subsequent sample collections.

14.5 Documentation of assessment

The final report will present the results, interpretations, and recommendations from this study.

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16.0 Figures

Figures are presented in this document after they are first mentioned in the text.

17.0 Tables

Tables are presented in this document after they are first mentioned in the text.

18.0 Appendices

Appendix A. Bellingham Bay Sea Grass Beds and Fish Spawning Areas

Figure A-1. Bellingham Bay Sea Grass Beds. Depths in meters based on MSL.

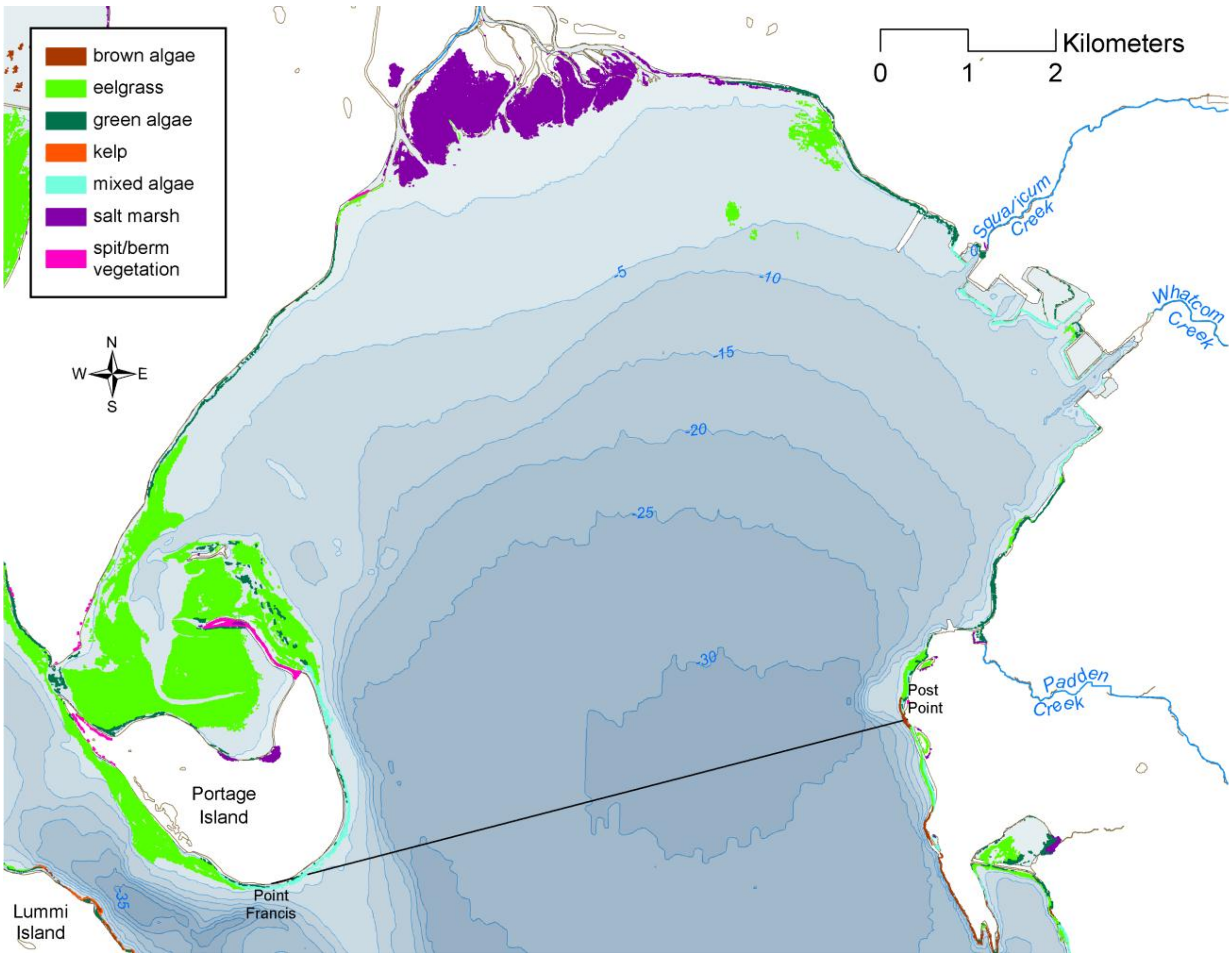

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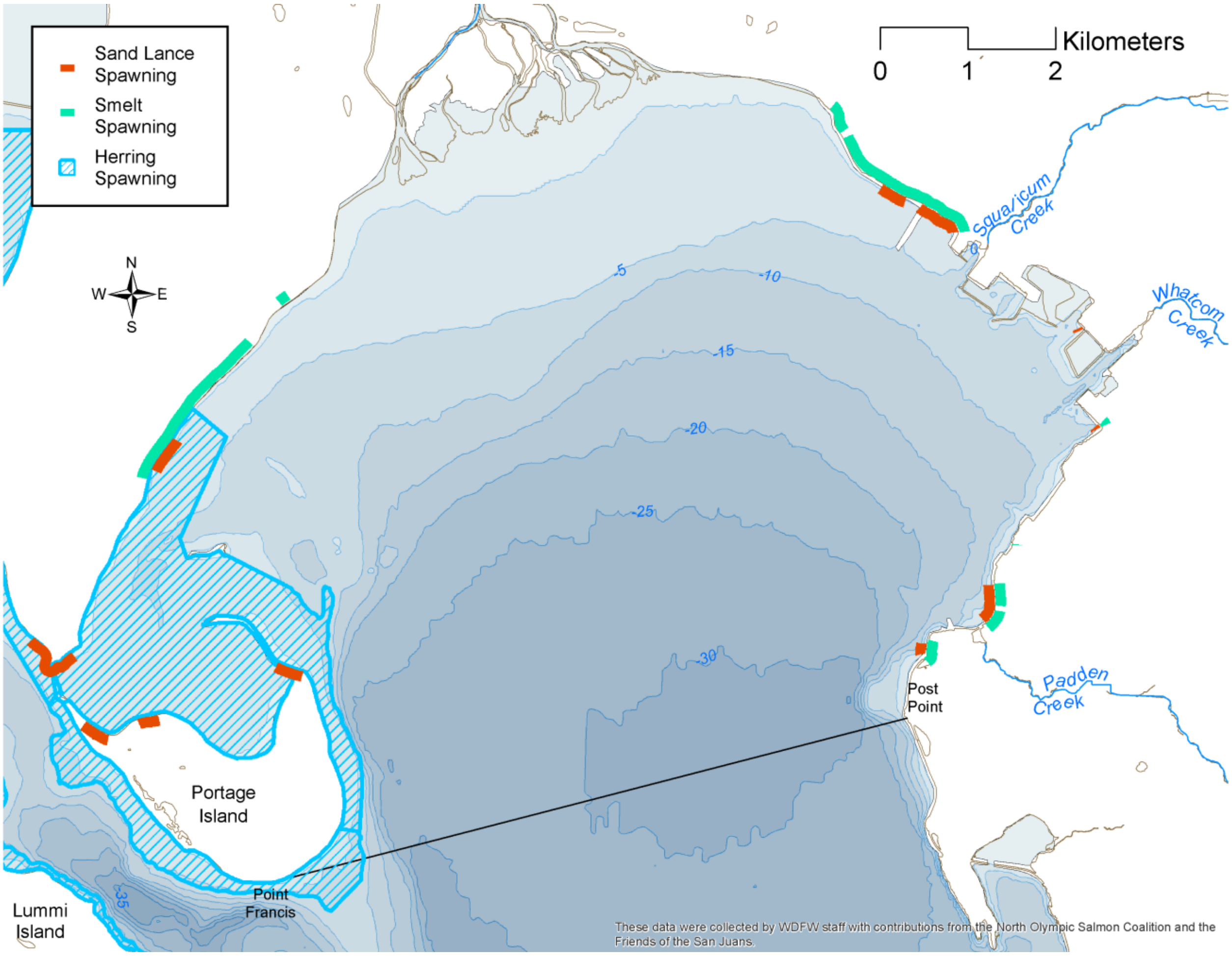
Figure A-2. Bellingham Bay Fish Spawning Areas. Depths in meters based on MSL.



Appendix B. Spatial Data

The main elements of the spatial dataset includes but not limited to:

- Study area polygon feature class that depicts the entire study area.
- Site boundary polygon feature class that covers the area of interest.
- Location point feature class that represent observed suspected wood waste accumulation.
- Transects (point feature class) represented as a sequence of points along each transect with a nominal spacing ranging approximately 1 to 10 meters between points (varies with boat speed and video processer subjective determination).
- Generalized wood waste accumulation area polygon feature classes that may be estimated depending on observations.
- Physical and chemical data (point feature class) that represent concentrations.

In addition, a simple base layer will be included that represents Washington State and may include political boundaries such as the City of Bellingham. Attributes were made similar to DNR sea grass survey tables for compatibility and ease of use when reviewing and selecting video transects within the AOI of this study. Similarities include some field names, region codes, sample status, and description formats.

Figure B-1. Attributes of Location feature class.

Field Name	Type	Description
SITE_CODE	Text	Unique site identifier (alpha numeric)
SITE_NAME	Text	Site name typically based on nearby community name or geographic landmark
REGION	Text	Region where site is located (3-letter code developed by DNR sea grass survey)
		nps = North Puget Sound
SAMP_STATUS	Text	Sampling status of the site
		sampled = site visited
		unsampled = site was not visited
		obstructed = site was visited but not sampled due to obstruction
WW_OBSERVED	Text	Presence of wood waste accumulation observed at the site.
		present = wood waste observed to be present
		absent = the site was visited but there were no observations of wood waste accumulation
		trace = wood waste was observed, but abundance was low; did not completely cover substrate or thin
		no_data = the site has not been sampled
WOOD_TYPE	Text	Description of the observed type or form the wood waste
		SD = sawdust
		BC = bark or chips
		Log = logs
		DL = dimensional lumber
		Com = combination
		UN = undetermined
		Null = not sampled
LATEST_SRVY	Date	Most recent date of survey at the site
		Null = not sampled
FIRST_SRVY	Date	First date of survey at the site
		Null = not sampled
SHALLOWEST_FT	Double	Shallowest depth of wood waste observations in feet with respect to mean lower low water (MLLW)
		-9999 = not sampled
DEEPEST_FT	Double	Deepest depth of wood waste observations in feet with respect to mean lower low water (MLLW)
		-9999 = not sampled
SHALLOWEST_M	Double	Shallowest depth of wood waste observations in meters with respect to mean lower low water (MLLW)
		-9999 = not sampled
DEEPEST_M	Double	Deepest depth of wood waste observations in meters with respect to mean lower low water (MLLW)
		-9999 = not sampled

Figure B-2. Attributes of Transect feature class.

Field Name	Type	Description
SITE_CODE	Text	Unique site identifier (alpha numeric)
TRAN_NUM	Text	Transect number assigned in the field
DATE_SAMP	Date	Date on which transect video was collected
TIME24HR	Text	Time at which video was collected for each transect point
WW_OBSERVED	Integer	Presence of wood waste accumulation observed at the site
		1 = present
		0 = not present
VIDEO	Integer	Video quality in video frames with the same time stamp
		1 = good video quality.
		0 = poor video quality due to turbidity or low light conditions
TRKTYPE	Text	Type of transect.
		SLPR = random transect oriented perpendicular to shoreline
		RECN = reconnaissance
		MEAN = meandering transect
		ZZAG = zig-zag transect
		BATH = transect collected for bathymetry data
		SLPL = transect oriented parallel to shoreline
		SLOB = obstructed transect
		ABRT = aborted transect
		-9999 = unspecified transect type
DEPTH_OBS_M	Double	Observed depth of transect points in meters (MLLW)
		-9999 = missing data value
DEPTH_INTERP_M	Double	Interpolated depth of transect points in meters (MLLW). Where possible, missing depth values in the observations were replaced with interpolated values.
		-9999 = missing data value
DEPTH_OBS_FT	Double	Observed depth of transect points in feet (MLLW).
		-9999 = missing data value
DEPTH_INTERP_FT	Double	Interpolated depth of transect points in feet (MLLW). Where possible, missing depth values in the observations were replaced with interpolated values
		-9999 = missing data value
WOOD_TYPE	Text	Description of the observed type or form the wood waste
		SD = sawdust
		BC = bark or chips
		Log = logs.
		DL = dimensional lumber
		Com = combination
		UN = undetermined
		Null = not sampled.

Appendix C. Field Log Example

Figure C-2. Field Log Example.

Project: Bellingham Bay Wood Waste Screening Survey	Field ID: ______________________ Sample #: ______________________
Location: ______________________	Date/Time: ______________________
Lat: ____________________________	Lat: ____________________________
Crew: ________________________	Weather: ________________________

Grab #	Bottom Depth	Penetration Depth	Time / % Fines=[(40 ml-(vol))/40]
Sediment Type:	Sediment Color:	Sediment Odor:	Comments:
Cobble	Drab olive	None	
Gravel	Brown	Slight	
Sand C M F	Brown surface	Moderate	
Silt / Clay	Gray	Strong	
Organic matter	Black	Overwhelming	
Woody debris	Other:	H_2S	
Shell debris		Petroleum	
Grab #	Bottom Depth	Penetration Depth	Time
Sediment Type:	Sediment Color:	Sediment Odor:	Comments:
Cobble	Drab olive	None	
Gravel	Brown	Slight	
Sand C M F	Brown surface	Moderate	
Silt / Clay	Gray	Strong	
Organic matter	Black	Overwhelming	
Woody debris	Other:	H_2S	
Shell debris		Petroleum	
Grab #	Bottom Depth	Penetration Depth	Time
Sediment Type:	Sediment Color:	Sediment Odor:	Comments:
Cobble	Drab olive	None	
Gravel	Brown	Slight	
Sand C M F	Brown surface	Moderate	
Silt / Clay	Gray	Strong	
Organic matter	Black	Overwhelming	
Woody debris	Other:	H_2S	
Shell debris		Petroleum	
Grab #	Bottom Depth	Penetration Depth	Time
Sediment Type:	Sediment Color:	Sediment Odor:	Comments:
Cobble	Drab olive	None	
Gravel	Brown	Slight	
Sand C M F	Brown surface	Moderate	
Silt / Clay	Gray	Strong	
Organic matter	Black	Overwhelming	
Woody debris	Other:	H_2S	
Shell debris		Petroleum	

Appendix D. Glossaries, Acronyms, and Abbreviations

Glossary of General Terms

Mean Lower Low Water: The average height of the lower low waters over a 19-year period. For shorter periods of observation, corrections are applied to eliminate known variations and reduce the result to the equivalent of a mean 19-year value.

Mean Sea Level: A land-based vertical survey datum. The regional vertical or MSL datum was based on sea level data collected over several years (mostly the 1910s to 1940s, but sometimes later, depending on the region).

Sediment: Soil and organic matter that is covered with water (for example, river or lake bottom).

Sublittoral zone: refers to that zone of the ocean where sunlight reaches the ocean floor (photic zone). It extends from the low tide mark to the edge of the continental shelf, with a relatively shallow depth extending to about 200 meters.

Subtidal zone: The shallower regions of the sublittoral zone extending not far from shore.

Turbidity: A measure of water clarity. High levels of turbidity can have a negative impact on aquatic life.

Watershed: A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

Acronyms and Abbreviations

AOI	Area of interest
Ecology	Washington State Department of Ecology
e.g.	For example
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
et al.	And others
GIS	Geographic Information System software
GPS	Global Positioning System
i.e.	In other words
MEL	Manchester Environmental Laboratory
MLLW	Mean Lower Low Water
MQO	Measurement quality objective
MSL	Mean Sea Level
PSEP	Puget Sound Estuary Protocols
QA	Quality assurance
RPD	Relative percent difference
RSD	Relative standard deviation
SMS	Sediment Management Standards

SOP	Standard operating procedures
TOC	Total organic carbon
TVS	Total volatile solids
USGS	United States Geological Survey
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WRIA	Water Resource Inventory Area

Units of Measurement

°C	degrees centigrade
dw	dry weight
°F	Fahrenheit
ft	feet
m	meter
mL	milliliter
NTU	nephelometric turbidity units
ppt	parts per trillion
um	micrometer
ww	wet weight

Quality Assurance Glossary

Accreditation: A certification process for laboratories, designed to evaluate and document a lab's ability to perform analytical methods and produce acceptable data. For Ecology, it is "Formal recognition by (Ecology)…that an environmental laboratory is capable of producing accurate analytical data." [WAC 173-50-040] (Kammin, 2010)

Accuracy: The degree to which a measured value agrees with the true value of the measured property. USEPA recommends that this term not be used, and that the terms precision and bias be used to convey the information associated with the term accuracy. (USGS, 1998)

Analyte: An element, ion, compound, or chemical moiety (pH, alkalinity) which is to be determined. The definition can be expanded to include organisms, e.g., fecal coliform, Klebsiella. (Kammin, 2010)

Bias: The difference between the population mean and the true value. Bias usually describes a systematic difference reproducible over time, and is characteristic of both the measurement system, and the analyte(s) being measured. Bias is a commonly used data quality indicator (DQI). (Kammin, 2010; Ecology, 2004)

Blank: A synthetic sample, free of the analyte(s) of interest. For example, in water analysis, pure water is used for the blank. In chemical analysis, a blank is used to estimate the analytical response to all factors other than the analyte in the sample. In general, blanks are used to assess possible contamination or inadvertent introduction of analyte during various stages of the sampling and analytical process. (USGS, 1998)

Calibration: The process of establishing the relationship between the response of a measurement system and the concentration of the parameter being measured. (Ecology, 2004)

Check standard: A substance or reference material obtained from a source independent from the source of the calibration standard; used to assess bias for an analytical method. This is an obsolete term, and its use is highly discouraged. See Calibration Verification Standards, Lab Control Samples (LCS), Certified Reference Materials (CRM), and/or spiked blanks. These are all check standards, but should be referred to by their actual designator, e.g., CRM, LCS. (Kammin, 2010; Ecology, 2004)

Comparability: The degree to which different methods, data sets and/or decisions agree or can be represented as similar; a data quality indicator. (USEPA, 1997)

Completeness: The amount of valid data obtained from a project compared to the planned amount. Usually expressed as a percentage. A data quality indicator. (USEPA, 1997)

Continuing Calibration Verification Standard (CCV): A QC sample analyzed with samples to check for acceptable bias in the measurement system. The CCV is usually a midpoint calibration standard that is re-run at an established frequency during the course of an analytical run. (Kammin, 2010)

Control chart: A graphical representation of quality control results demonstrating the performance of an aspect of a measurement system. (Kammin, 2010; Ecology 2004)

Control limits: Statistical warning and action limits calculated based on control charts. Warning limits are generally set at +/- 2 standard deviations from the mean, action limits at +/- 3 standard deviations from the mean. (Kammin, 2010)

Data Integrity: A qualitative DQI that evaluates the extent to which a data set contains data that is misrepresented, falsified, or deliberately misleading. (Kammin, 2010)

Data Quality Indicators (DQI): Commonly used measures of acceptability for environmental data. The principal DQIs are precision, bias, representativeness, comparability, completeness, sensitivity, and integrity. (USEPA, 2006)

Data Quality Objectives (DQO): Qualitative and quantitative statements derived from systematic planning processes that clarify study objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions.
(USEPA, 2006)

Data set: A grouping of samples organized by date, time, analyte, etc. (Kammin, 2010)

Data validation: An analyte-specific and sample-specific process that extends the evaluation of data beyond data verification to determine the usability of a specific data set. It involves a detailed examination of the data package, using both professional judgment, and objective criteria, to determine whether the MQOs for precision, bias, and sensitivity have been met. It may also include an assessment of completeness, representativeness, comparability and integrity, as these criteria relate to the usability of the data set. Ecology considers four key criteria to determine if data validation has actually occurred. These are:

- Use of raw or instrument data for evaluation.
- Use of third-party assessors.
- Data set is complex.
- Use of EPA Functional Guidelines or equivalent for review.

Examples of data types commonly validated would be:

- Gas Chromatography (GC).
- Gas Chromatography-Mass Spectrometry (GC-MS).
- Inductively Coupled Plasma (ICP).

The end result of a formal validation process is a determination of usability that assigns qualifiers to indicate usability status for every measurement result. These qualifiers include:

- No qualifier, data is usable for intended purposes.
- J (or a J variant), data is estimated, may be usable, may be biased high or low.
- REJ, data is rejected, cannot be used for intended purposes (Kammin, 2010; Ecology, 2004).

Data verification: Examination of a data set for errors or omissions, and assessment of the Data Quality Indicators related to that data set for compliance with acceptance criteria (MQOs). Verification is a detailed quality review of a data set. (Ecology, 2004)

Detection limit (limit of detection)**:** The concentration or amount of an analyte which can be determined to a specified level of certainty to be greater than zero. (Ecology, 2004)

Duplicate samples: Two samples taken from and representative of the same population, and carried through and steps of the sampling and analytical procedures in an identical manner. Duplicate samples are used to assess variability of all method activities including sampling and analysis. (USEPA, 1997)

Field blank: A blank used to obtain information on contamination introduced during sample collection, storage, and transport. (Ecology, 2004)

Initial Calibration Verification Standard (ICV): A QC sample prepared independently of calibration standards and analyzed along with the samples to check for acceptable bias in the measurement system. The ICV is analyzed prior to the analysis of any samples. (Kammin, 2010)

Laboratory Control Sample (LCS): A sample of known composition prepared using contaminant-free water or an inert solid that is spiked with analytes of interest at the midpoint of the calibration curve or at the level of concern. It is prepared and analyzed in the same batch of regular samples using the same sample preparation method, reagents, and analytical methods employed for regular samples. (USEPA, 1997)

Matrix spike: A QC sample prepared by adding a known amount of the target analyte(s) to an aliquot of a sample to check for bias due to interference or matrix effects. (Ecology, 2004)

Measurement Quality Objectives (MQOs)**:** Performance or acceptance criteria for individual data quality indicators, usually including precision, bias, sensitivity, completeness, comparability, and representativeness. (USEPA, 2006)

Measurement result: A value obtained by performing the procedure described in a method. (Ecology, 2004)

Method: A formalized group of procedures and techniques for performing an activity (e.g., sampling, chemical analysis, data analysis), systematically presented in the order in which they are to be executed. (EPA, 1997)

Method blank: A blank prepared to represent the sample matrix, prepared and analyzed with a batch of samples. A method blank will contain all reagents used in the preparation of a sample, and the same preparation process is used for the method blank and samples. (Ecology, 2004; Kammin, 2010)

Method Detection Limit (MDL): This definition for detection was first formally advanced in 40CFR 136, October 26, 1984 edition. MDL is defined there as the minimum concentration of an analyte that, in a given matrix and with a specific method, has a 99% probability of being identified, and reported to be greater than zero. (Federal Register, October 26, 1984)

Percent Relative Standard Deviation (%RSD): A statistic used to evaluate precision in environmental analysis. It is determined in the following manner:

$$\%RSD = (100 * s)/x$$

where s is the sample standard deviation and x is the mean of results from more than two replicate samples (Kammin, 2010)

Parameter: A specified characteristic of a population or sample. Also, an analyte or grouping of analytes. Benzene and nitrate + nitrite are all "parameters." (Kammin, 2010; Ecology, 2004)

Population: The hypothetical set of all possible observations of the type being investigated. (Ecology, 2004)

Precision: The extent of random variability among replicate measurements of the same property; a data quality indicator. (USGS, 1998)

Quality Assurance (QA): A set of activities designed to establish and document the reliability and usability of measurement data. (Kammin, 2010)

Quality Assurance Project Plan (QAPP): A document that describes the objectives of a project, and the processes and activities necessary to develop data that will support those objectives. (Kammin, 2010; Ecology, 2004)

Quality Control (QC): The routine application of measurement and statistical procedures to assess the accuracy of measurement data. (Ecology, 2004)

Relative Percent Difference (RPD): RPD is commonly used to evaluate precision. The following formula is used:

$$[Abs(a-b)/((a + b)/2)] * 100$$

where "Abs()" is absolute value and a and b are results for the two replicate samples. RPD can be used only with 2 values. Percent Relative Standard Deviation is (%RSD) is used if there are results for more than 2 replicate samples (Ecology, 2004).

Replicate samples: Two or more samples taken from the environment at the same time and place, using the same protocols. Replicates are used to estimate the random variability of the material sampled. (USGS, 1998)

Representativeness: The degree to which a sample reflects the population from which it is taken; a data quality indicator. (USGS, 1998)

Sample (field): A portion of a population (environmental entity) that is measured and assumed to represent the entire population. (USGS, 1998)

Sample (statistical): A finite part or subset of a statistical population. (USEPA, 1997)

Sensitivity: In general, denotes the rate at which the analytical response (e.g., absorbance, volume, meter reading) varies with the concentration of the parameter being determined. In a specialized sense, it has the same meaning as the detection limit. (Ecology, 2004)

Spiked blank: A specified amount of reagent blank fortified with a known mass of the target analyte(s); usually used to assess the recovery efficiency of the method. (USEPA, 1997)

Spiked sample: A sample prepared by adding a known mass of target analyte(s) to a specified amount of matrix sample for which an independent estimate of target analyte(s) concentration is available. Spiked samples can be used to determine the effect of the matrix on a method's recovery efficiency. (USEPA, 1997)

Split Sample: The term split sample denotes when a discrete sample is further subdivided into portions, usually duplicates. (Kammin, 2010)

Standard Operating Procedure (SOP): A document which describes in detail a reproducible and repeatable organized activity. (Kammin, 2010)

Surrogate: For environmental chemistry, a surrogate is a substance with properties similar to those of the target analyte(s). Surrogates are unlikely to be native to environmental samples. They are added to environmental samples for quality control purposes, to track extraction efficiency and/or measure analyte recovery. Deuterated organic compounds are examples of surrogates commonly used in organic compound analysis. (Kammin, 2010)

Systematic planning: A step-wise process which develops a clear description of the goals and objectives of a project, and produces decisions on the type, quantity, and quality of data that will be needed to meet those goals and objectives. The DQO process is a specialized type of systematic planning. (USEPA, 2006)

References for QA Glossary

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