Bellingham Bay Wood Waste Survey, 2015-2016

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Cover photo: Bellingham Bay (photo by Patti Sandvik)

Bellingham Bay Wood Waste Survey, 2015-2016

by

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

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Table of Contents

List of Figures and Tables

Abstract

Wood debris is 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.

Unnaturally high amounts of wood waste on the north shores of Bellingham Bay raised concerns (1) about potential impacts to sensitive plant and benthic marine life and (2) that there may be an ongoing unknown source of the wood waste.

This 2015-2016 survey used a combination of physical measurements – total organic carbon (TOC), total volatile solids (TVS), and grain size – as well as qualitative observations – field descriptions, Float Test, towed underwater video, and digital photos – to screen for the presence of woody debris in the subtidal area[1] of Bellingham Bay.

Results show evidence of wood waste in the depositional areas around the mouth of the Nooksack River coming from the river and anthropogenic sources. Video coverage showed a patchy coverage of suspected woody and organic debris along transects within this area. Results from sediment samples showed higher levels of TOC/TVS in somewhat of a cluster pattern within two areas on the river delta. Confirmed observations of woody slivers and pieces in about one-third of the sediment samples were documented in field notes and during the Float Test.

Sediment coring and toxicity assessment are recommended to define the extent, depth, and toxicity of wood waste found in sediment during this study.

[1] The shallow area below mean low tide which is continuously underwater.

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Introduction

Bellingham Bay is a relatively large, kidney-shaped embayment located in the northern area of Puget Sound in northwest Washington State (Figure 1). It is part of the Salish Sea ecosystem, separated from the Strait of Georgia on the west by Lummi Peninsula, Portage Island, and Lummi Island.

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 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, Canada (Whatcom County, 2001 and 2011). 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.

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 seagrasses support spawning and rearing fish, shellfish, and other marine wildlife. Waterfront development dominates the eastern shore of the bay. Current uses of the waterfront include industrial facilities, shipping terminals, parks, and the Alaska Ferry Terminal.

Wood Waste

From the middle 1800s through the middle to late 1900s, the Bellingham waterfront served as an 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 led to toxic and non-toxic pollutant contamination of marine sediments (Shea et al., 1981; Elardo, 2001).

Bellingham Bay has several contaminated sediment sites that are in various stages of the cleanup process (Ecology, 2015a). These efforts are to improve sediment quality in urban nearshore areas. However, a 2010 status-and-trends, bay-wide study indicates declining variability in benthic invertebrate communities and varying degrees of toxicity. (Partridge et al., 2013). These findings indicate declining sediment quality in the bay overall, but the stressors have not been identified.

Unnaturally high amounts of wood waste have accumulated in portions of Bellingham Bay along the shores and in sediment. 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. There are concerns about unknown locations of wood waste, which may be impacting water and sediment quality and may be an ongoing source of the shoreline wood waste.

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 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).

Project Goals and Objectives

The large amount of wood waste found along the northern shorelines of Bellingham Bay has raised concerns because wood waste may be a contributing factor in the bay's overall health. Wood waste covered large sections of the beach area and in places was reported to be more than six feet (ft) deep (Eastman, 2011). Although some beach cleanup has begun, redeposit events have been observed. The source of this wood waste is undetermined.

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 studies have reported high quality data, the studies have been generally concentrated on areas suspected from source contamination or repetitive long-term sampling at designated locations. No previous 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 2015-2016 study focused on surveying the nature and presence of wood waste in the subtidal surface sediments of upper Bellingham Bay. The Washington State Department of Ecology (Ecology) screened for presence of wood waste, using underwater filming followed by surface sediment sampling.

The goals of this study were 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.

Objectives for this study included:

- 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 was not defined as part of this investigation.

Methods

Ecology surveyed Bellingham Bay for the presence of wood waste contamination in the subtidal area of the northern portion of Upper Bellingham Bay. The basic approach targeted discrete sites scattered throughout Bellingham Bay's subtidal area. Targeting discrete sites allowed for high quality data production that would otherwise be prohibitive on a comprehensive basis because of the large area of Bellingham Bay. A Quality Assurance Project Plan (QAPP) was developed to guide this effort to ensure that the data collected were representative of the environment and acceptable for their intended use to meet the goals and objectives of the project (Sandvik and Wong, 2015).

Study Area

The general area of interest (AOI) for this study was the upper portion of Bellingham Bay situated above an imaginary geographic line—located approximately along latitude 48° 43' N—extending eastward from Point Frances to the southern tip of Post Point (Figure 1). This region, defined by Collias et al. (1966), 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.

The subtidal zone of this area was the focus of the 2015-2016 wood waste study. For this investigation, the subtidal part of the beach 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 2 shows the AOI; depth <10 meters.

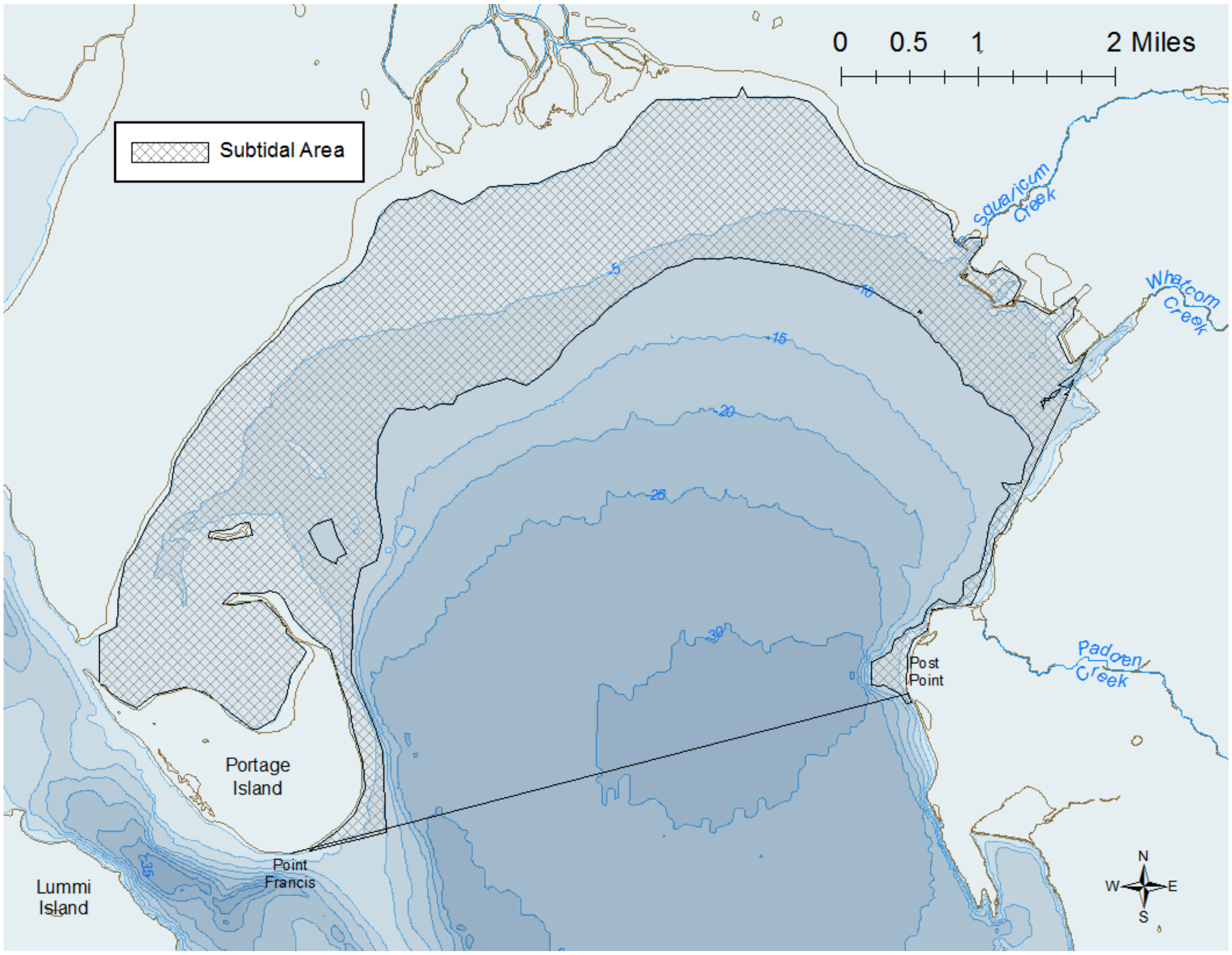

Figure 2. Subtidal zone.

Depth in meters based on Mean Lower Low Water (MLLW).
Geographic line denotes the southern boundary of the Upper Bellingham Bay area of interest (AOI).
Depth 10 meters or less.

This project surveyed surface sediments for wood waste within the subtidal zone of upper Bellingham Bay from north of Squalicum Creek to near Point Frances. Priority area selection was guided by literature research, historical Washington State Department of Natural Resources (DNR) seagrass video surveys, and communication with stakeholders (Sandvik and Wong, 2015). Areas outside of this target were areas of low priority, which included areas indicated by a healthy habitat such as native seagrass beds or documented fish spawning areas (Appendix A). Areas where substantial characterization of the sediment has been conducted, such as the inner harbor, generally south of Squalicum Creek were considered low priority also. These areas were surveyed either sparsely or not at all (healthy habitat and inner harbor, respectively).

Visual screening was followed by sediment sampling to describe the physical nature of the sediment in areas of suspected wood waste.

Visual Screening Methods

To investigate wood waste in subtidal areas, towed underwater filming was conducted along transects selected from a pool of underwater video transects collected by DNR during their seagrass surveys (DNR, 2013). Sixty-six DNR video files with over 100 video tracks were reviewed for wood waste presence. Thirty-seven of the DNR video tracks (transects) reviewed contained suspect wood waste. Areas around transects with suspected wood waste were selected for further exploration for this study (Figure 3).

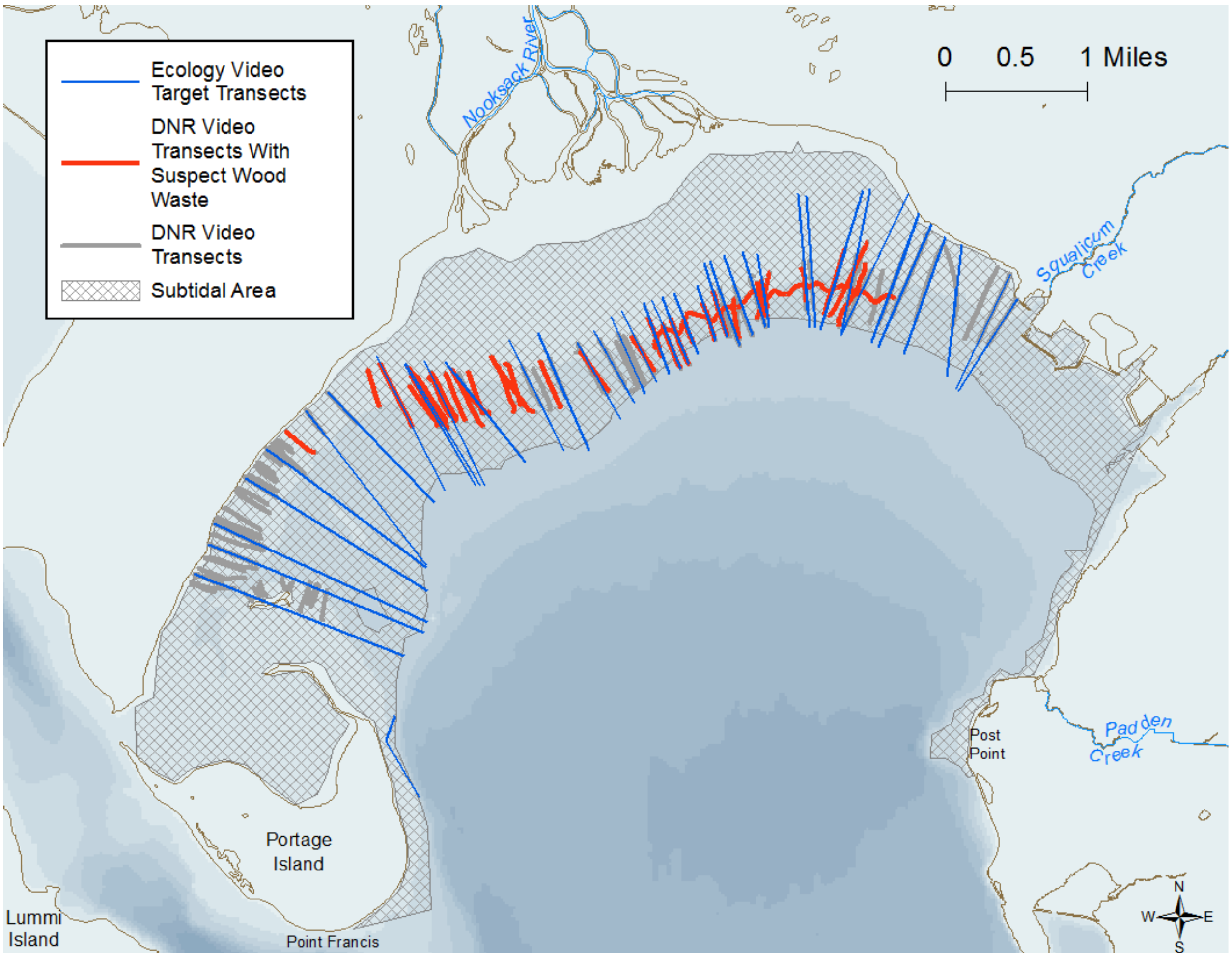

Figure 3. Ecology underwater video screening transects targeted from DNR transects.

Additional video screening was conducted in areas without suspected wood waste, for comparison. Filming transected perpendicular to the shore. Many transects started near the end or between more recent (i.e., 2015) DNR video survey transects to address data gaps within the subtidal area. More filming was conducted in areas where wood waste was suspected than where no wood waste evidence was found when reviewing the DNR videos.

Visual screening of the Bellingham Bay floor was conducted using an underwater SeaViewer video camera mounted with a downward-looking orientation on a stabilizer weighing approximately 48 pounds (Figure 4).

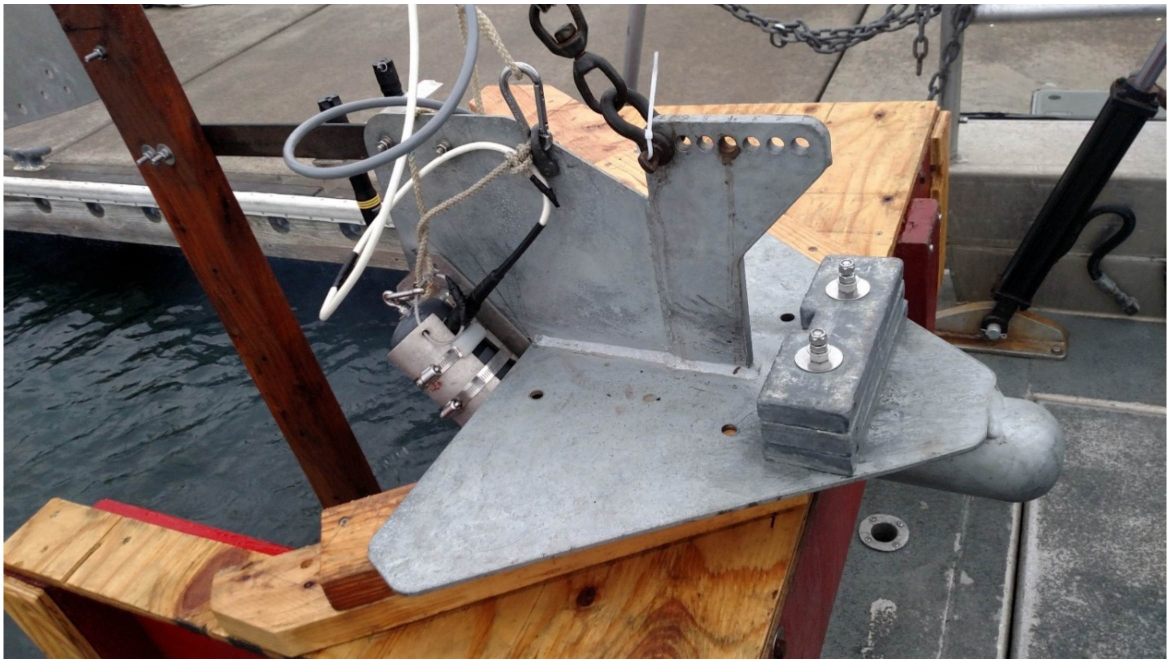

Figure 4. SeaViewer underwater camera mounted on a stabilizer for towing behind a boat.

The filming was conducted using Ecology's 26-ft Almar Sounder R/V Skookum. The camera was deployed off the stern, using an A-frame boom and hydraulic winch. An operator used the boom winch to control the height at about 1 meter above the bottom. Real-time video was viewed on a monitor by another person. The research vessel speed was greater than the target transect speed of approximately 1-2 mph; therefore, drogues were deployed to slow the vessel.

Depth were monitored with a depth sounder on board. Location and time data (UTC) was recorded with a recording device connected into the video from the MX 420 navigation system on board. The video overlay stamped the time and Global Position System (GPS) position on the video, continuously updating within seconds. The year stamped on the video was incorrect for most of the footage because of outdated technology within the MX 420 system. All other data stamped to the video was correct (Zulu time and location).

The video was recorded in digital video (DV) format and stored on an external hard drive (Seagate) and on an Ecology server drive.

Underwater video filming was conducted during periods of calm waters in September and October 2015 when the water was near peak for clarity based on transmissivity (clear water) and turbidity records. Transmissivity is highest and turbidity is lowest during low flow, low snow melt, and calmer weather seasons that affect the Nooksack River (Krembs, 2015; Sandvik and Wong, 2015).

An extensive review of Ecology's videos included assigning attributes every few (approximately two to four) seconds for the presence or absence of wood waste and other attributes. The video post processing method and an example table can be found in Appendix B.

Sediment Collection Methods

Sediments were collected during May and June 2016 from Ecology's 26-ft Almar Sounder R/V Skookum. Station coordinates are listed in the navigation report (Appendix C).

Sediment samples were collected from discrete sites scattered throughout Bellingham Bay's subtidal area. Sites were chosen based on where wood waste was suspected and on the video transect survey. Some samples were collected in areas where the visual survey was poor and the wood waste was uncertain. For comparison, samples were obtained from areas showing no evidence of wood waste.

Sediment samples were collected with a power grab measuring 50-cm square by 25-cm deep. The power grab used compressed nitrogen for powering the grab during sediment collection (Figure 5).

Target location for grabs included a 22-m radius buffer in order to accommodate variables such as wire angle, depth, and navigation accuracy. The buffer radius was based on Ecology's Marine Monitoring Unit's draft method for determining radius for sediment samples, the rounded sum of calculated 5-degree wire angle, depth, a measured distance from GPS antenna to meter wheel pulley on R/V Skookum (1.92 m), and navigation accuracy of 10-m each.

Each grab sample was visually checked for wood fibers. Large wood debris, biota, and/or shells were removed before collecting the sediment out of the grab. Approximately 12-cm of surface sediment was collected into a clean stainless-steel bowl to composite for grain size, total organic carbon (TOC), total volatile solids (TVS), and percent solids analyses. Replicate samples were taken from five sediment grab samples.

Figure 5. Power grab.

Grain Size

Grain size analyses were conducted by Analytical Resources, Incorporated (ARI) in Tukwila, Washington, using the modified Puget Sound Estuary Program (PSEP) protocol for analysis of marine sediments with salt correction (PSEP, 1986).

The PSEP grain size method is a sieve-pipette method. The PSEP method was modified to include percent gravel, sand, silt, and clay, with the sand subdivided into five categories: very coarse, coarse, medium, fine, and very fine, using the Wentworth scale.

Chemical Analyses

Laboratory analyses for percent solids, TVS, and TOC were performed by Ecology's Manchester Environmental Laboratory following methods listed in Table 1.

Table 1. Analytical methods.

Parameter	Methods	Reporting Limit (%)
Percent solids	PSEP, 1986 / SM2540G	0.001
Total volatile solids (TVS)	PSEP, 1986 / SM2540G	0.1
Total organic carbon (TOC)	PSEP, 1986	0.1

Percent solids estimates the percent of organic and inorganic materials remaining after a sample has been dried completely, whereas TVS represent the fraction of total solids that are lost on ignition at a higher temperature than that used to determine total solids. TOC measures the total amount of nonvolatile, volatile, partially volatile, and particulate organic compounds in a sample. A dilute (10%) hydrochloric acid (HCl) is used to remove carbonates that may interfere with TOC analysis.

Float Test

If small wood fibers were suspected but not visible during sediment collection, a portion of the sample was to be wetted to see if the wood fiber would float and then be accounted for. Because of lack of time between weather systems, this test was postponed and performed later in a laboratory setting using extra sediment from each sample.

One of the archive sample containers was opened, and the contents were examined for wood pieces before putting the sediment in a stainless steel bowl for homogenization. Sediment from the sample was then added to a 100-mL beaker filled with 50-mL of water. The sample was then reexamined for floating or other wood pieces using an extra light source and magnifier. The water was decanted into a clean bowl, and the decanted water was examined again for any evidence of wood pieces using a magnifier as needed.

Data Analyses

Pearson correlation coefficient (*r*-value) and the significance level (*p*-value) were calculated for correlations between parameters (i.e., TOC, TVS, and grain size).

Laboratory triplicates were averaged before statistical calculations. Field duplicates were retained and analyzed as separate samples. Likewise, the average of laboratory triplicates and individual samples for duplicates was used for mapping the spatial distributions.

Nondetects (i.e., concentrations below the reporting limits) were censored at the reporting limits (quantification limits) specific to those samples. There was only one nondetect result for TOC. The reporting limit of 0.10% represented the TOC level in sample number 1606031-28, Location ID F10-27, for statistical and mapping spatial distributions.

Percent volume of wood waste was not determined because it was not measured.

Spatial Extent

Spatial extent of the various analytes were computed and graphically displayed using ESRI's ArcGIS 10.

Data Quality

All data have been reviewed for completeness, accuracy, and usability. Quality control (QC) procedures were followed as listed in the QAPP for this project (Sandvik and Wong, 2015).

Data collected for this study were determined to be comparable, representative, and complete (>95%). To produce usable data from the visual survey and sediment sampling objectives, this study followed the following Standard Operating Procedures (SOPs):

- 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).

Furthermore, the following were used as reference guides, even though the objective of this study was to provide a survey of contaminants and not a temporal comparison.

- Sediment Cleanup Users Manual II: *Guidance for Implementing the Cleanup Provisions of the Sediment Management Standards, Chapter 173-204 WAC* (Ecology, 2015b)
- 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)

Underwater Video Survey Data Quality

All underwater video survey transects were considered usable for this project (Figure 6).

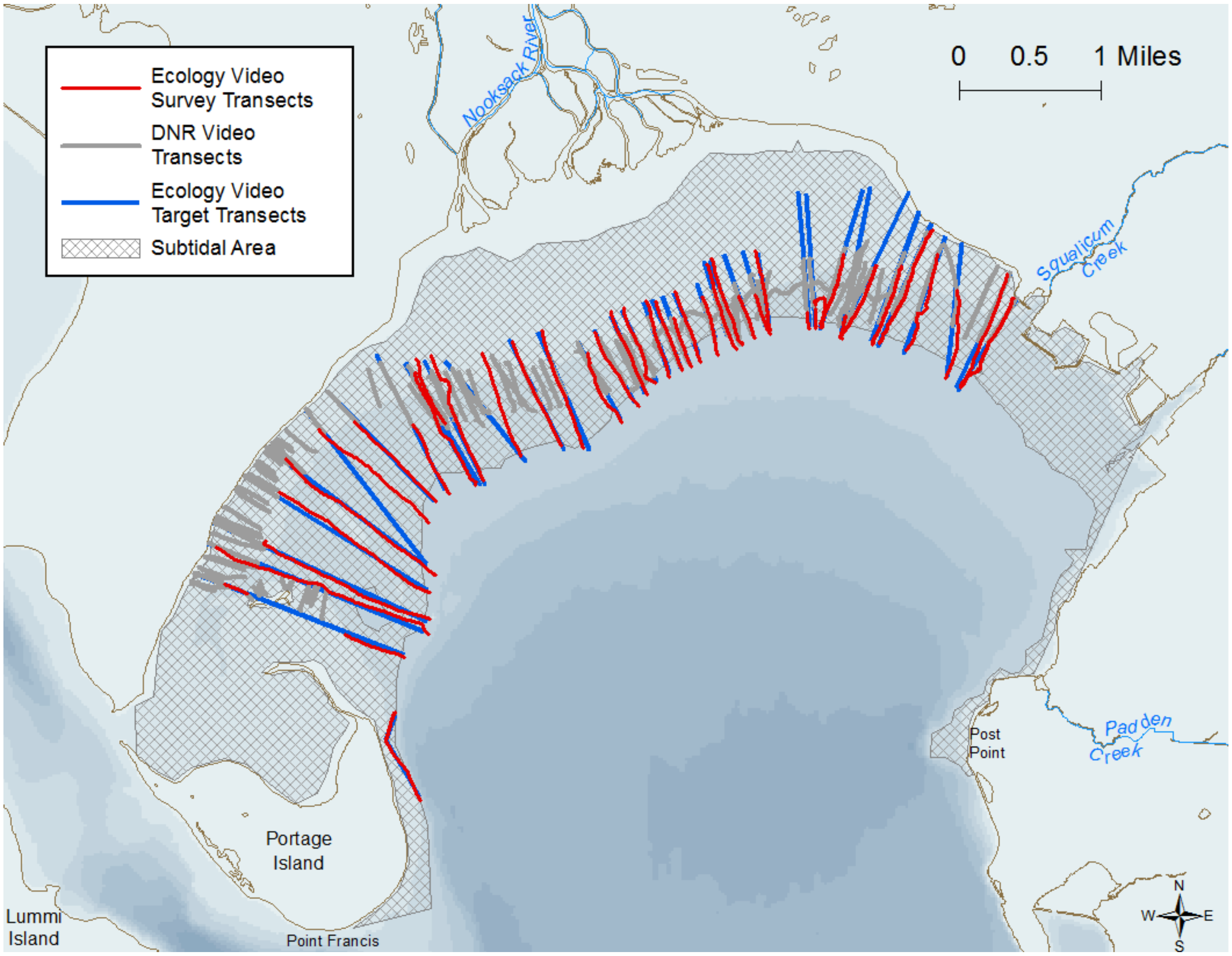

Figure 6. Ecology's underwater video screening transects compared with Ecology's targeted transects selected using DNR transects as a guide.

This study initially planned to discard any transects that deviated more than 25% of the total targeted transect length, but since all videos showed useful information for screening for wood waste, none were discarded. Four out of the 40 transects filmed fell outside of the 25% deviation limit. Two of these transects were rerouted in the field to cover obvious gaps between the proposed transects. The two other transects had less than 100-meters gap between the proposed transect and the transect created when filming. This difference seems negligible based on the scale of the subtidal area of interest (AOI) (approximately 10 square miles) and the length of transects (> 1000 meters).

To establish visual representativeness in the AOI, video footage was collected within the subtidal area from Squalicum Creek to near Point Frances regardless of wood waste findings found in the

DNR videos, but more videos transected areas of suspected wood waste. Upon video review, details of wood waste occurrence were coded using “1” or “0” for presence or absence.

Most videos were acceptable, yet some parts of certain videos remained difficult to review with any confidence due to turbidity or poor lighting. The angle of sunlight proved to be important for clear video images. When the sun was too low (very early or late in the day) or too high (bright, cloudless, midday sun), lighting was poor, making it difficult to determine the substances on the bottom of the bay. Video quality was assessed during review and marked “1” for good, “0” for poor, or “3” for too poor to determine wood waste.

Although water clarity was better in the fall and under calm conditions when the filming took place, some video portions showed poor clarity due to high turbidity from wave activity or river influence from sporadic rain shower activity. Those video portions were assigned “poor” quality and (1) based on nearby observations, assumed low priority or (2) if suspicious of wood waste, explored further with sediment collection.

Sediment Sampling Data Quality

Locations

All sediment samples were collected within the criteria of 22-meter radius of the targeted locations except one (NAV ID / Location ID BB-1423-07c) collected at 24 meters, which was well within the additional 20-meter buffer extended when conditions made collections within the 22-meter radius difficult.

Horizontal Dilution of Precision (HDOP) showed excellent precision with all locations taken with a value of 2.0, except one (NAV ID / Location ID BB-F10-06c), which showed good precision with a value of 2.2. HDOP describes error caused by the relative position of the GPS satellites. A HDOP <3 shows fairly accurate positional measurements.

Sediment Samples

Most grabs retained for collecting samples for laboratory analyses met the criteria for acceptability as listed below. These criteria are outlined in the QAPP following the SOPs and guidance documents for this project (Sandvik and Wong, 2015):

- The sampler was 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).

Some leakage was observed in a few samples due to the substrate being predominately very porous sand and a poor seal on the grab. The grab was adjusted to minimize leakage as much as possible. Additional grabs were collected to replace any grabs that were rejected.
Grab penetration ranged from 10-cm to 23.5-cm. This study targeted the top 12-cm, which represented the biologically active zone (BAZ) for Bellingham Bay (Ecology 2013a). Since this project was a screening survey for wood waste and not biota, and also since most of Puget Sound's BAZ targets 10-cm, the 12-cm grab samples under the targeted 12-cm BAZ were accepted. Furthermore, shallow penetration was due to the very hard-packed sediment found on the Nooksack River delta. This was not unexpected and hence the reason for using a power grab. Grabs that did not have at least 10-cm of sample material available were not accepted.

Percent fines and the Float Test were not conducted in the field, as described in the QAPP, due to time restraints and poor weather for processing. Percent fines were adequately analyzed during the grain size analysis. The Float Tests were conducted later in a laboratory setting.

Laboratory

All 91 samples followed handling, including chain-of-custody (COC), and preservation protocols, as outlined in the *Manchester Environmental Lab Users Manual, 9th edition,* PSEP, and Ecology SOPs (MEL, 2008; PSEP, 1997a,b; Aasen, 2007). Each set of field replicates was collected from the same location (grab) to assess precision of the sample collection process and variability in the sample. Archive samples were preserved frozen. See the QAPP for more method details (Sandvik and Wong, 2015).

All analyses were evaluated by established regulatory quality assurance (QA) guidelines (MEL, 2012). All results for TOC, TVS, and percent solids were determined to be usable. All quality control (QC) criteria were met for calibration, method blanks, laboratory control samples, and laboratory duplicates. One duplicate relative percent difference (RPD) for TVS was greater than the acceptance level (26 RPD > 20 RPD acceptance limit). The source sample (ID 1606031-69) and duplicate were qualified as estimates (J).

All grain size results were determined to be usable. About one-third of the samples (34) had low fines that prevented them from being re-split to try to collect more fines for analysis and stay within the capacity of the balance. All samples were analyzed and results reported as measured. There is less certainty for the fines results in samples with low fines, but the results are still usable since all analytical QC criteria were met.

Low fines were expected on the Nooksack River delta, but some samples may be somewhat biased low because of poor closure of the grab as mentioned above, which may have caused some loss of fines before collected as samples. The assumption was that this loss was minimal yet may be suspect for some of the low fines results.

QC results are listed in Appendix D.

Results

Visual Survey Results

Underwater video examination of the area of interest (AOI) indicated a patchy distribution of wood debris, ranging from a clean bottom to some form of organic debris accumulations that completely covered the sediment surface. A total of 27 out of 40 video transects conducted by Ecology contained some type of wood waste (Figure 7).

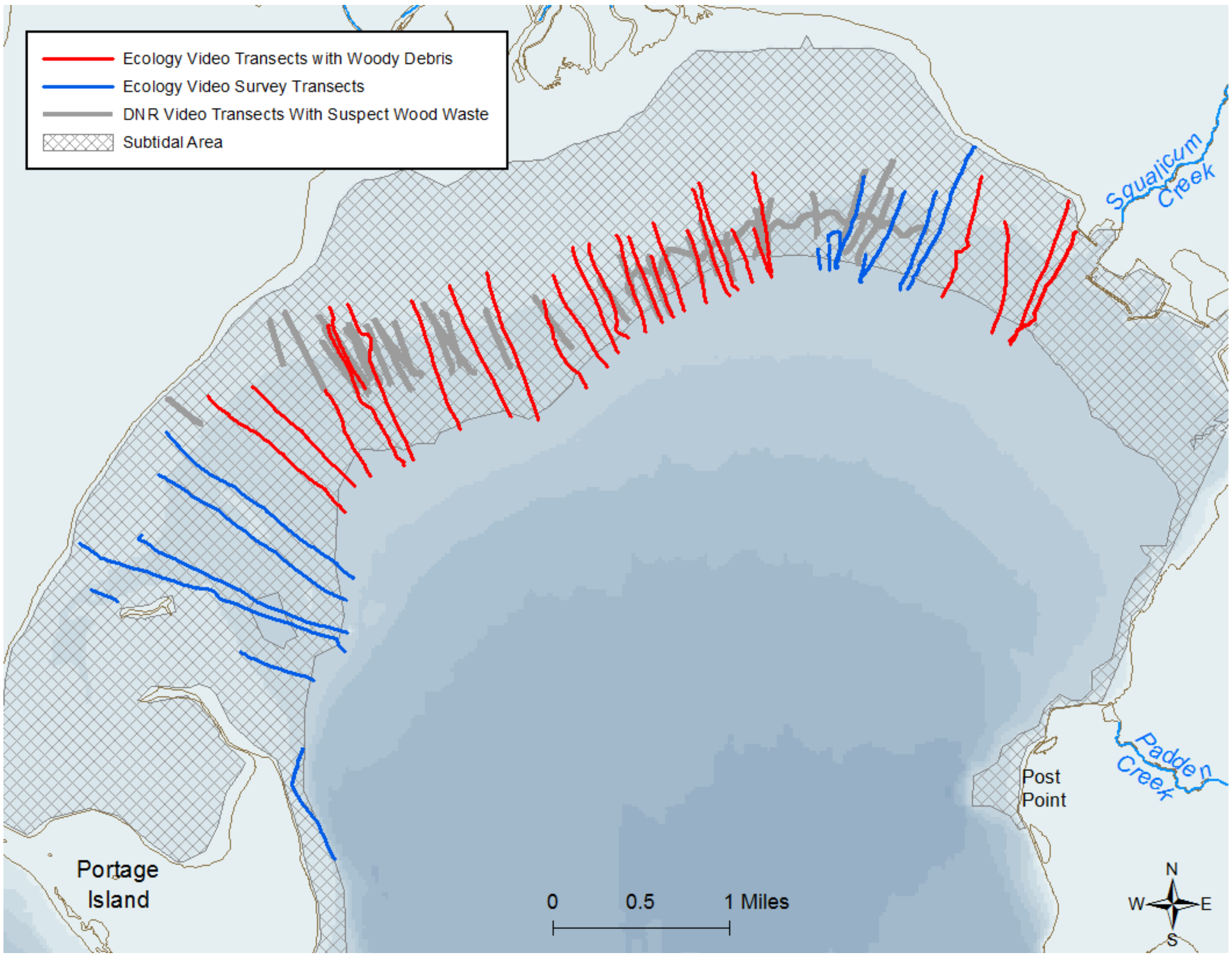

Figure 7. Ecology and DNR transects with woody debris.

Wood debris ranged from logs, sticks, and fine woody debris to undetermined debris. A white mass was observed covering several areas filmed. The white mass may have been sulfur-reducing bacteria mats, which would indicate anoxic conditions in the sediments, but is unconfirmed at the writing of this report.

No large deposit of wood waste was located for the area surveyed underwater by Ecology or observed from DNR videos. Therefore, no surface coverage or volume could be estimated. On the other hand, some areas were covered with debris that looked like fine woody debris. These areas may indicate a more extensive load of suspected fine woody debris not clearly visible using the underwater videos. Fine woody debris refers to fine wood or plant particles and small wood pieces generally < 6”. When reviewing the videos, the reviewer observed that the suspected debris areas appeared as small pieces of organic or wood debris or dark pockets with flocculent material (e.g., white mass) (Figure 8).

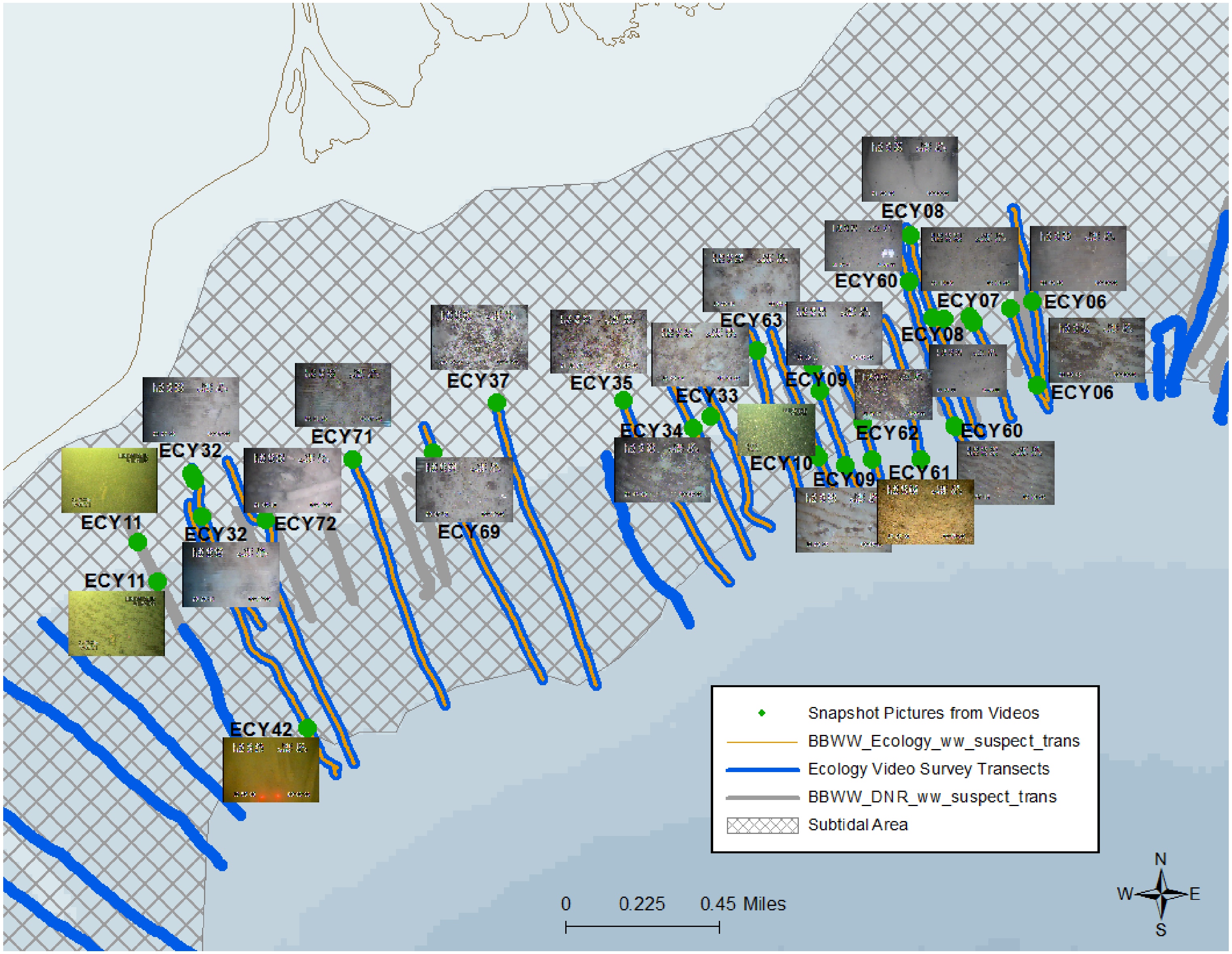

Figure 8. Pictures captured along transects showing examples of suspect fine woody or unknown debris.
These and additional pictures can be found in Appendix E.

Figure 9 shows selected transects where suspect fine woody debris were found during the video reviewing process for both Ecology and DNR. Several general locations were marked along transects where suspect fine woody debris was located. Most picture snapshots fall within these marked areas.

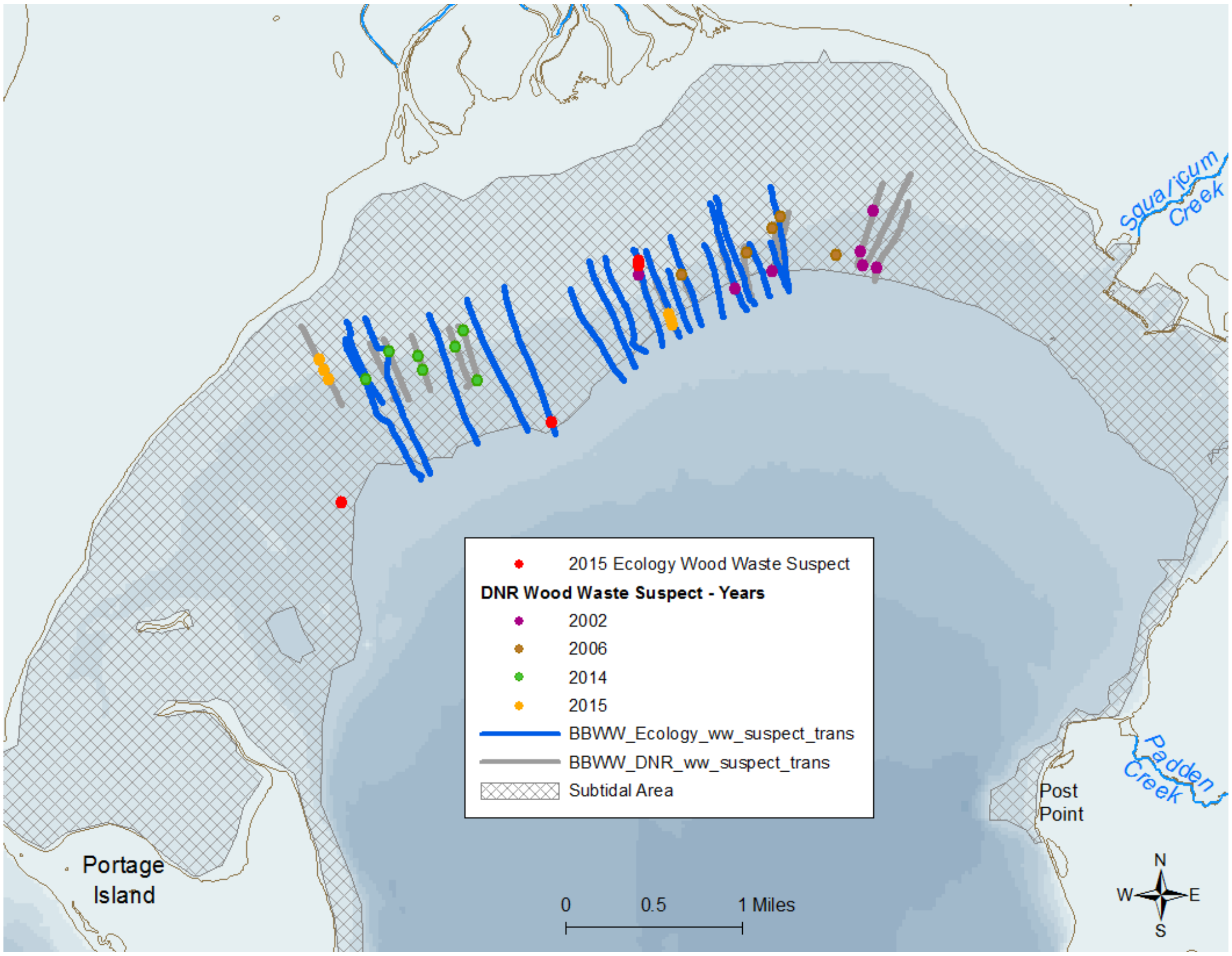

Figure 9. Video transects and locations where Ecology and DNR suspect woody debris was observed in underwater videos.

Figure 9 refines the location of the suspect fine woody debris compared to Figure 7 by showing only those areas of unknown debris or with smaller debris, which was noted during the video review as suspected sawdust-type or bark chip-type wood waste. Obvious sticks or logs were not included unless they were in combination with the unknown or smaller debris. The assumption for refining the AOI was that larger sticks and logs would be newer river-derived sources rather than marine-derived, which may indicate historical anthropogenic sources (e.g., logging and milling).

Relatively few organisms were observed along transects with suspected woody debris shown above. Organisms observed include a few crabs, starfish, attached anemones, and some burrowing macroinvertebrates. Very little seagrass was noted.

In contrast, a higher density of organisms was observed in videos taken along transects on the parameters of the AOI (i.e., near Portage Island and Squalicum Creek) where woody debris was not suspected. These included more abundant crabs, sunstars, burrowing macroinvertebrates, and sea cucumbers. Seagrasses were plentiful in most of these transects. There was no evidence of any white mass (i.e., sulfur-reducing bacteria mats). Flatfish were observed in most transects but more abundant the further away from the suspect woody debris transects.

Video data and processing notes are available in Appendix F electronically.

Sediment Sampling Results

A total of 91 sediment samples were collected from 86 locations along video transects with suspect wood waste. Some samples were collected where no wood waste was suspected in order to address possible data gaps and for comparison (Figure 10).

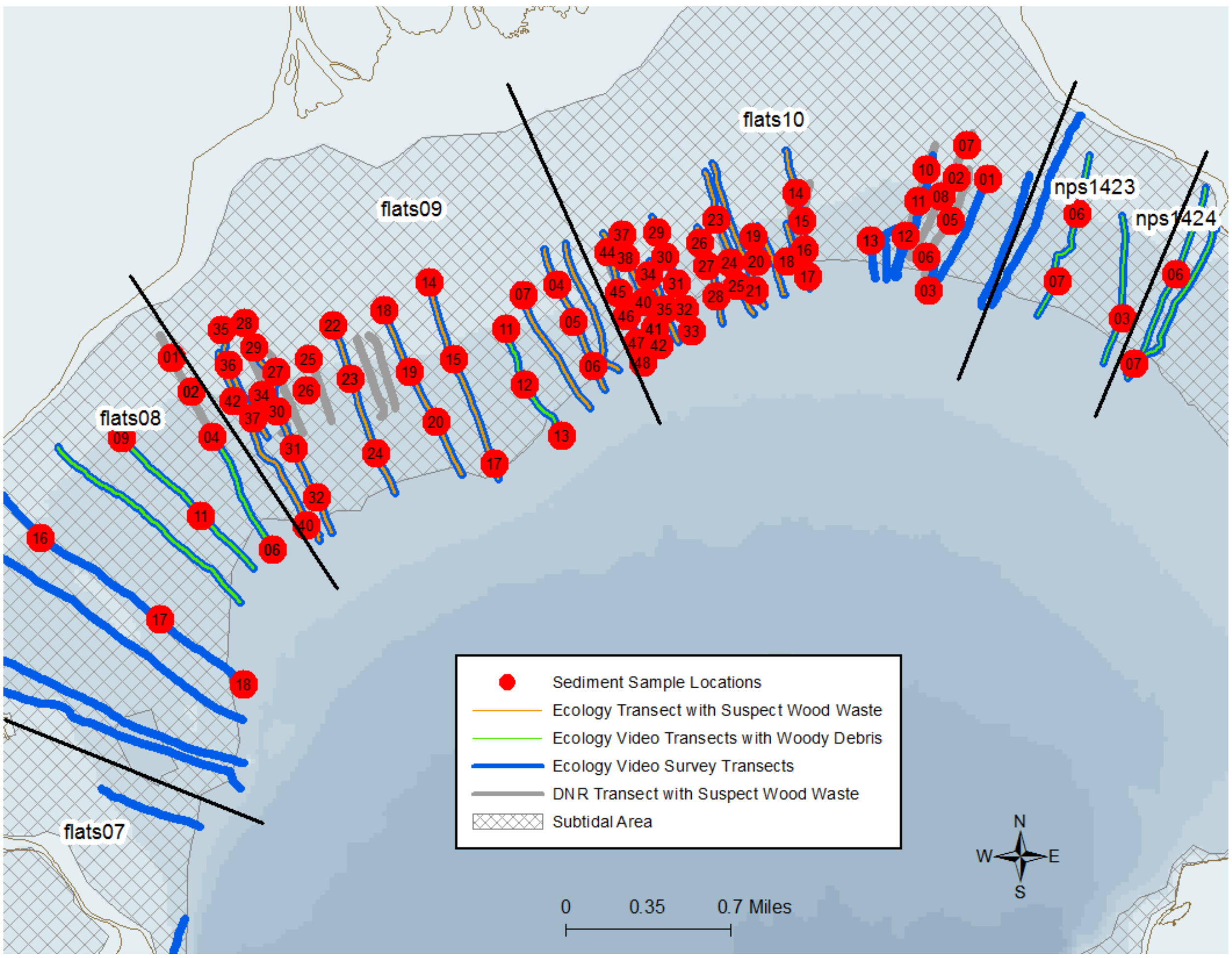

Figure 10. Sediment sample locations in Bellingham Bay.

The above map (Figure 10) divides the sampling locations into six areas based on DNR designations used for their seagrass surveys; flats 07 through flats10, nps1423, and nps1424. For identifying the samples, the reader can group the DNR area names with the two digits listed for each sediment sample, which are the last two digits in the Location ID of the data. This map can then be used to identify samples with their locations (e.g., flats10-14 (Location ID F10-14) or nps1424-07 (Location ID 1424-07).

The results of physical and chemical analysis of these samples, along with summary statistics, are shown in Appendix G, Tables G-1 through G-3, and include Location ID and Sample ID for cross references.

Total organic carbon (TOC) levels were generally low (under 3.5%), ranging from 1.0% to 5.7%, with a mean of 0.5% and a median of 0.2% (Figure 11).

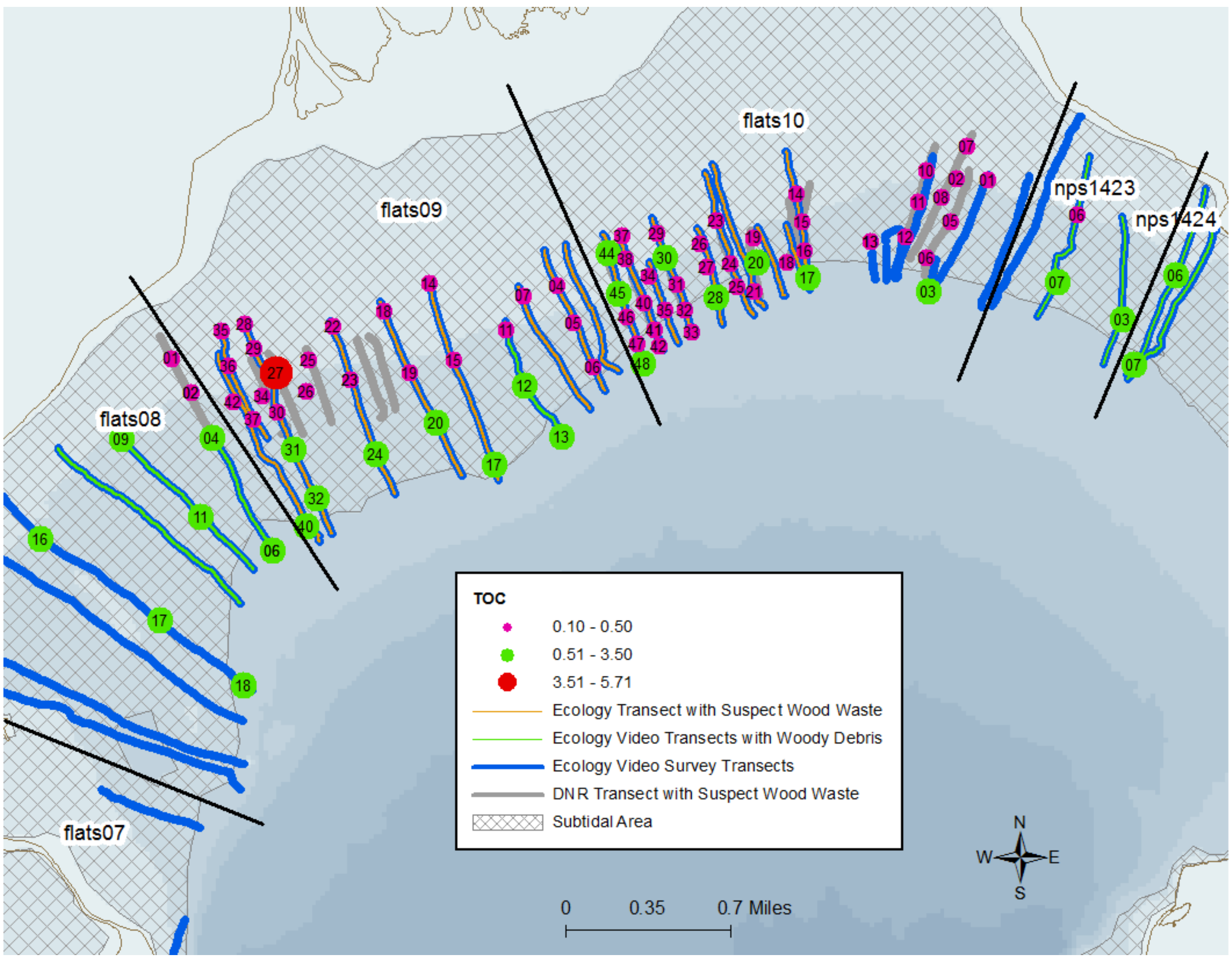

Figure 11. TOC levels found in sediment samples collected in Bellingham Bay.

Although TOC in marine sediment typically ranges from 0.5% to 5%, a TOC outside the range of 0.5 – 3.5% could be considered unusual (Ecology, 2015b). TOC concentrations were highest in the deeper, more depositional portion of the bay, or in areas outside of river influence, which is indicative of the less energetic areas that collect organic deposition.

The highest TOC level was found in a sample from the northwest area of Flats09 (Location ID F09-27), which did not follow the observed pattern. Woody and other organic debris was observed in this sample as well as several other samples nearby. Woody and organic debris were observed also in the northwest portion of Flats10. Examples are shown in Figures 12-14.

Figure 12. Woody and organic debris found in sediment sample, Location ID F09-27.

Figure 13. Woody and organic debris found in sediment sample, Location ID F10-14.

Figure 14. Woody and organic debris found in sediment sample, Location ID F10-30.

Total volatile solids (TVS) ranged from 0.9% to 15%, with a mean of 2.4% and a median of 1.4%. All TVS levels were below 6.0%, except one at 15% found in the same sample with the highest TOC (Location ID F09-27). Toxicity has been found to be more consistently observed where TVS exceeded 15% (Ecology, 2015b). These TVS levels were similar to TOC in that the higher levels were generally found in samples collected in the deeper and less energetic portions of the area of interest (AOI) (Figure 15).

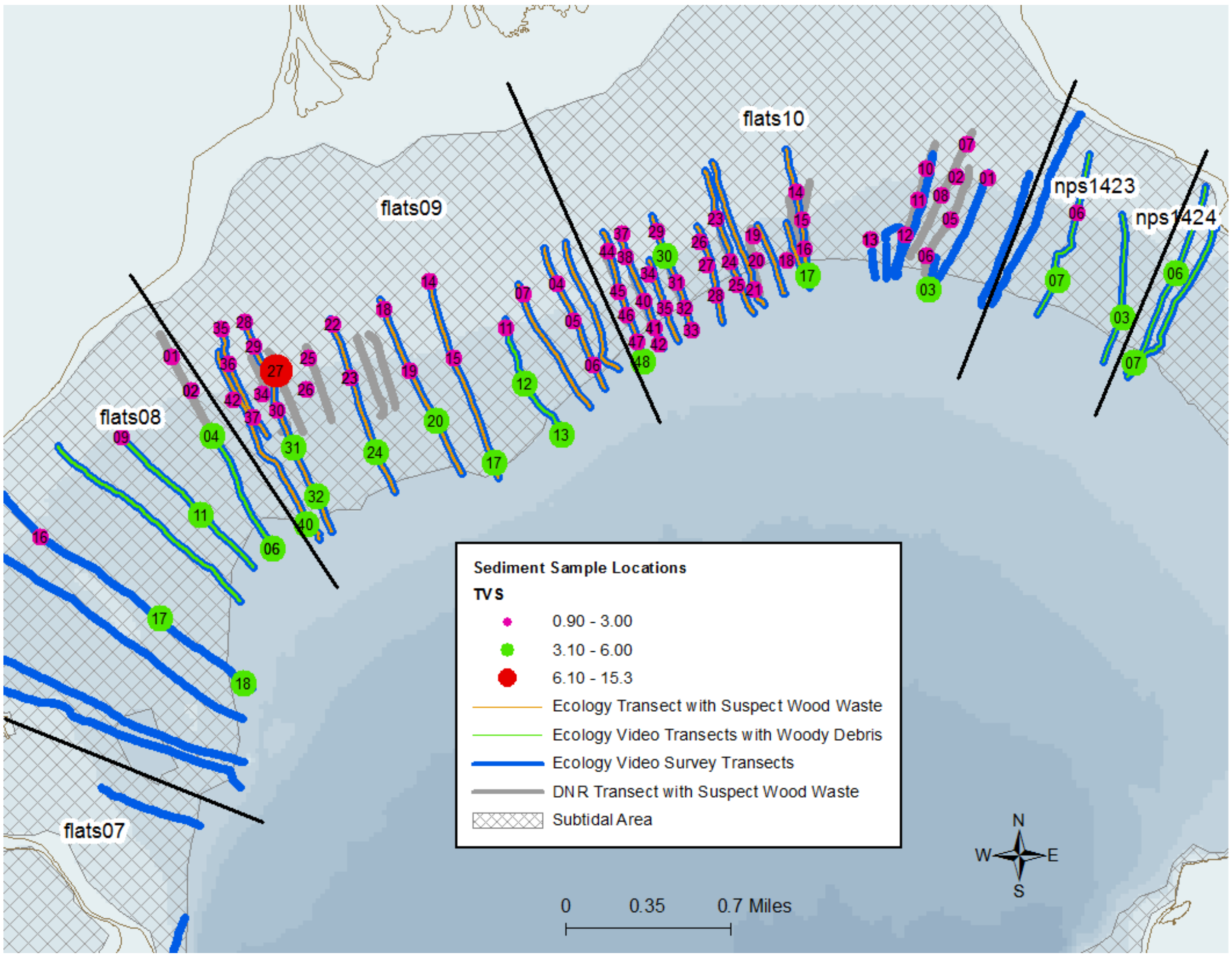

Figure 15. TVS levels found in sediment samples collected in Bellingham Bay.

Percent solids can indicate how much water is contained in the sediment sample. Densely packed, clay-like, or sandy sediment would have high percent solids and contain much less water than a porous wood-waste sediment sample. Figure 16 shows percent solid results, which ranged from 39% to 81%, with an average of 69%.

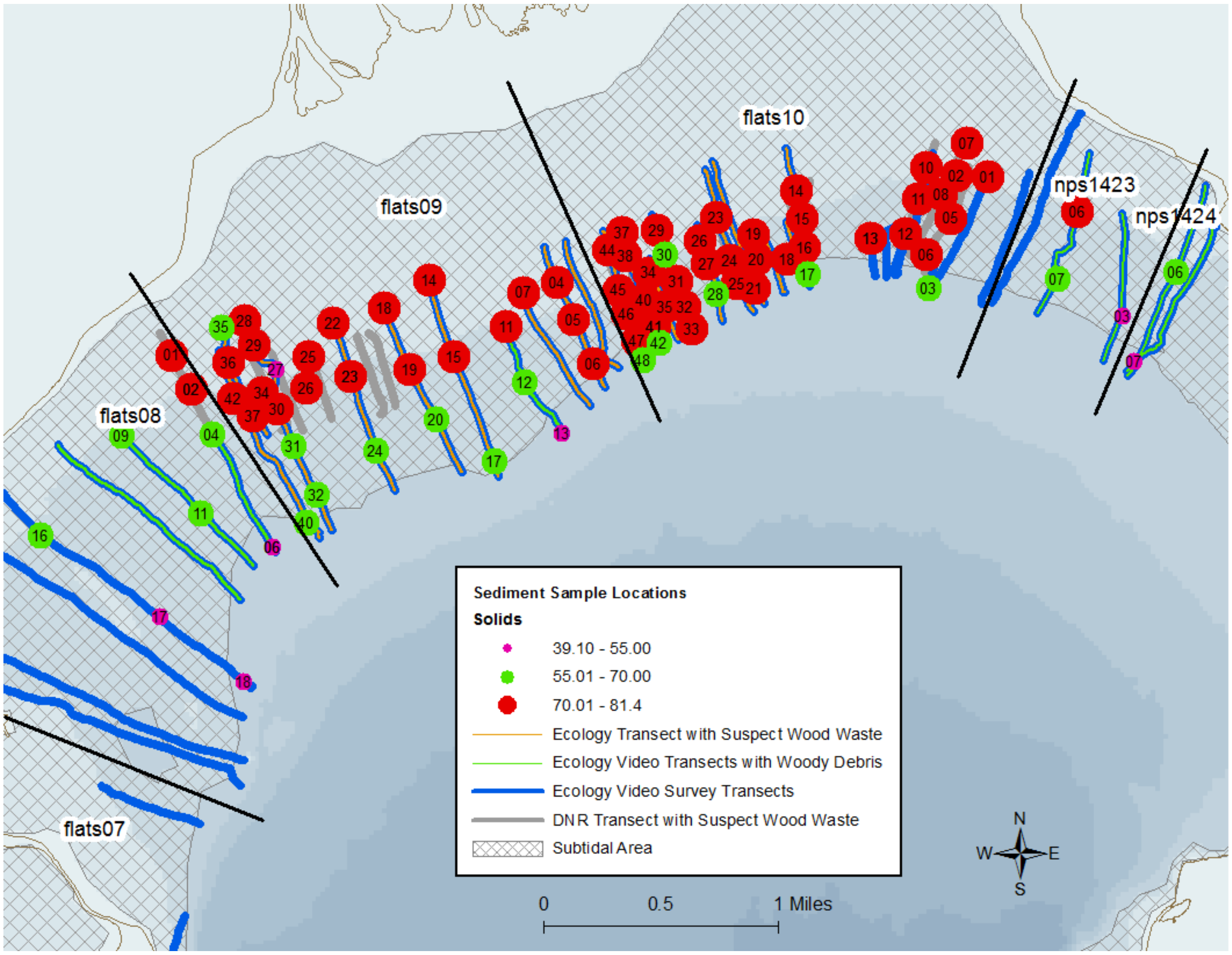

Figure 16. Percent solids found in sediment samples collected in Bellingham Bay.

These higher percent solid results appear to be in samples containing a high percentage of sand; these were collected from the head of the Nooksack Delta. The grain size distribution of sediments from the chemical screening sites is shown in Figure 17.

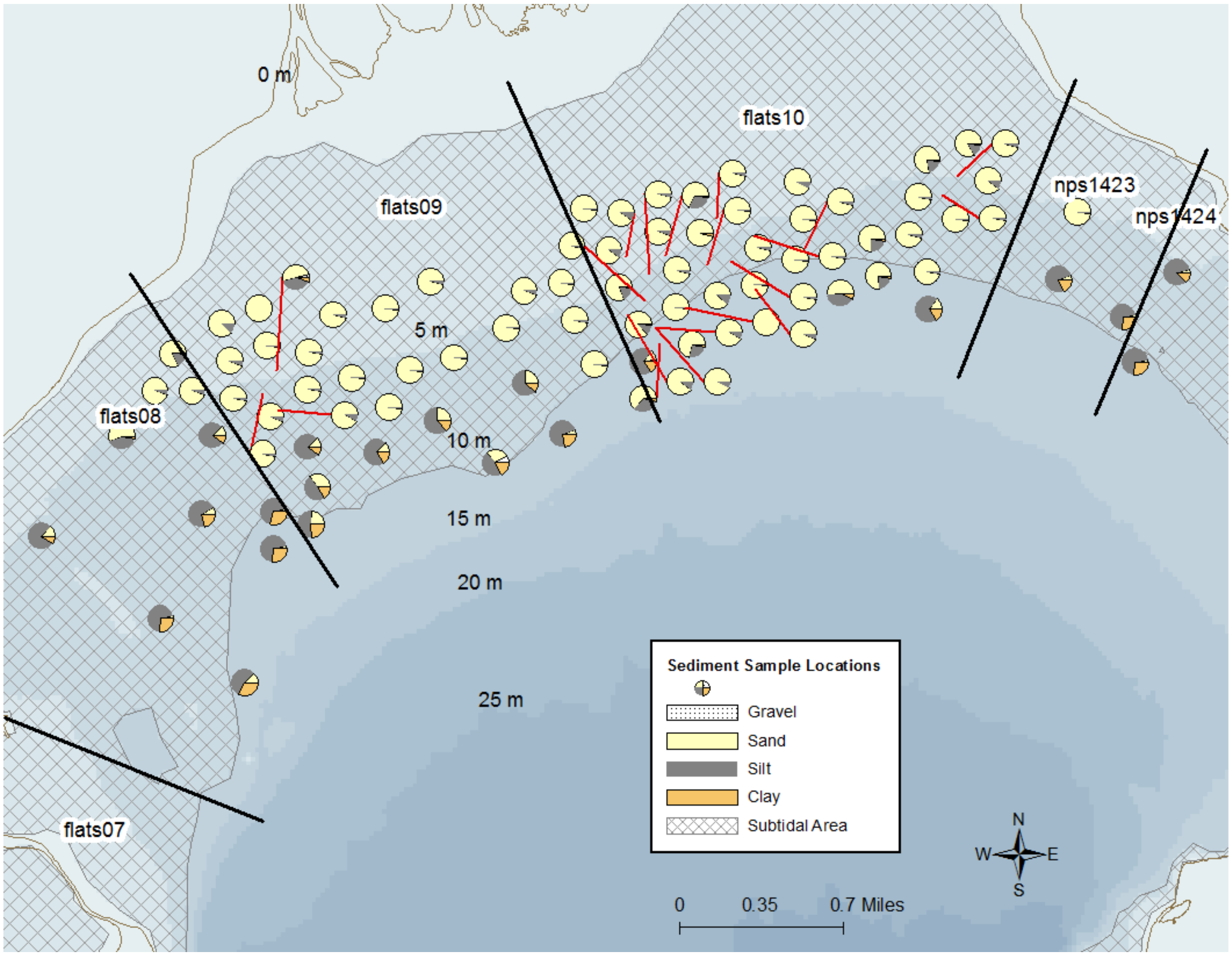

Figure 17. Grain size distribution from surface sediments collected in Bellingham Bay.

The segments of the pie charts represent the gravel, sand, silt, and clay fractions of the grain size. Sand dominated the Nooksack River delta subtidal area. Percent fines primarily varied with bathymetry and energy level. A lower percent of fines was found along the steep, shallow delta fan forming at the mouth of the Nooksack River, while a higher percent of fines was generally in the deeper and more depositional areas and along the edges away from the river mouth.

The correlation between percent fines and percent TOC was *r* = 0.68 (*p* < 0.0001) (Figure 18).

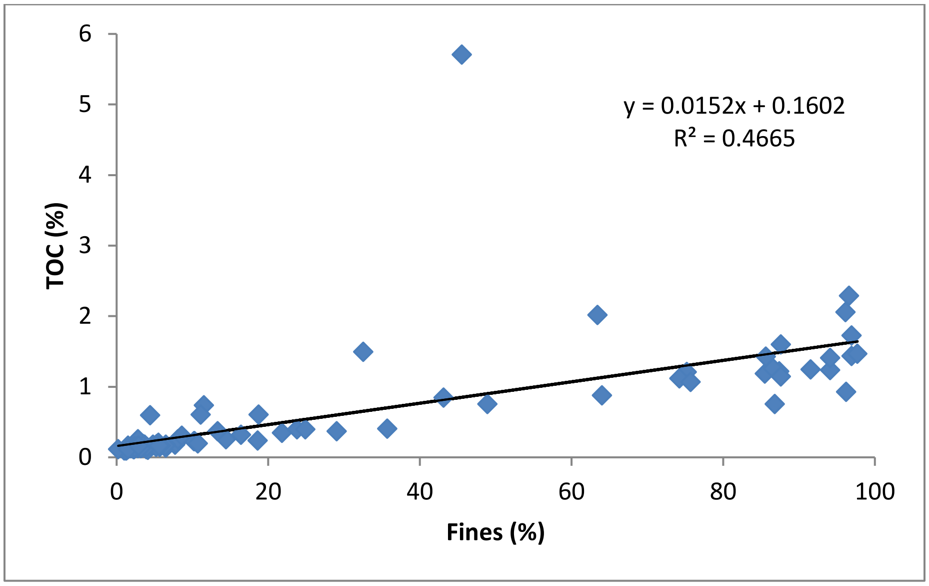

Figure 18. Percent fines and TOC regression.

An even stronger association (*r* = 0.91, *p* < 0.0001) between TOC and fines was evident without the higher TOC percent found in one sample (Location ID F09-27) at 5.7%. Since this study is screening for anomalies (i.e., evidence of wood waste), all samples were included for assessment.

TVS concentrations were strongly correlated to TOC (*r* = 0.98) and less so to grain size fines (*r* = 0.73) (Figures 19 and 20).

Location ID F09-27 had the highest TVS level (15%); this site also had the highest levels of TOC. Current or historical sources could not be determined using TOC and TVS results. Other factors were considered that may explain the elevated values, such as gradients or patterns in the data set (or lack thereof), correlations with natural geologic factors (e.g., grain size), sediment transport processes, etc.

Even with the higher TOC or TVS levels from the one sample biasing the results low, an association between the TOC, TVS, and fines is clearly evident.

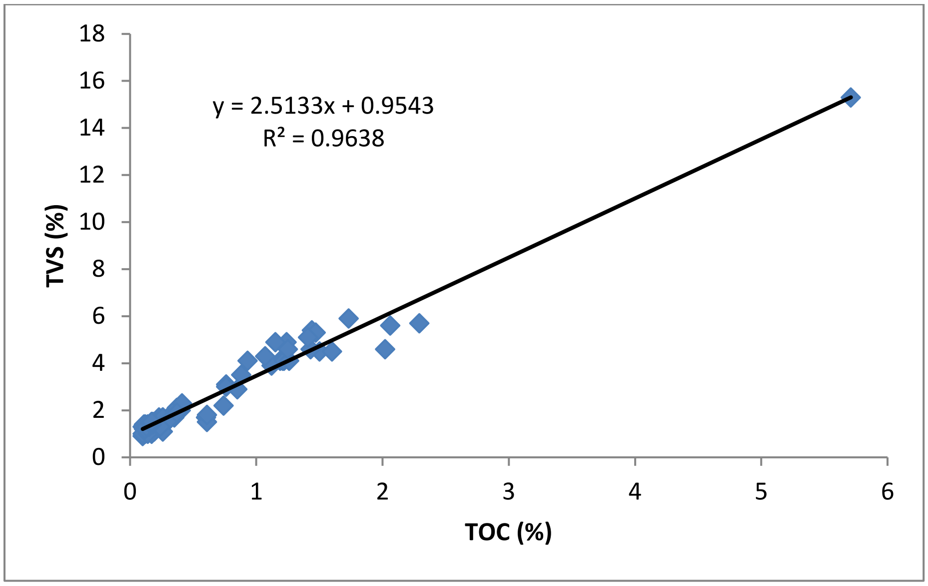

Figure 19. TOC and TVS regression.

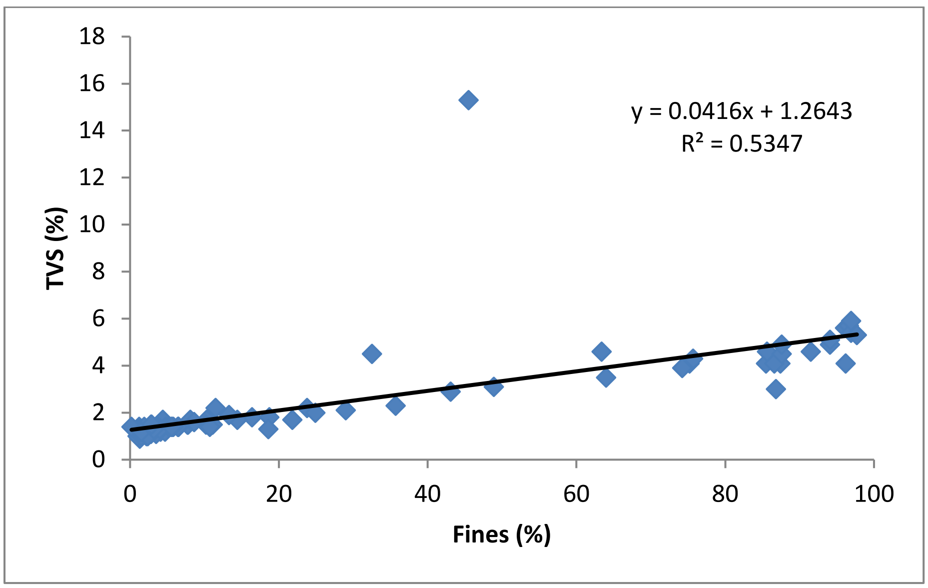

Figure 20. Percent fines and TVS regression.

Discussion

No clear correlation was observed between different areas and the amount of woody or organic debris observed on the sediment surface. All areas examined had a patchy distribution of organic debris with some areas of heavy accumulation. The variable distribution is likely due to current (tidal and river included) and wave-action dispersion of the debris over a wide area.

Another site-specific tool for determining sampling locations for toxicity is the ratio of TVS to TOC (TVS/TOC). Generally, as the ratio increases above 2, the organic matter is more labile or subject to breakdown, and above 2.5 to 3, there is a greater likelihood that toxicity will be observed due to conditions resulting from chemical or microbial breakdown as per the Wood Waste Cleanup guidance document (Ecology, 2013b). This often results in anaerobic conditions and elevated concentrations of sulfides (Ecology, 2015b). Sulfides were not analyzed for this study.

When this ratio was applied to the sediment samples collected for this study, ratios for all samples were greater than 2, which diminishes the usefulness in distinguishing toxicity in a given area. TVS/TOC ratios for Bellingham Bay sediment samples are shown in Figure 21.

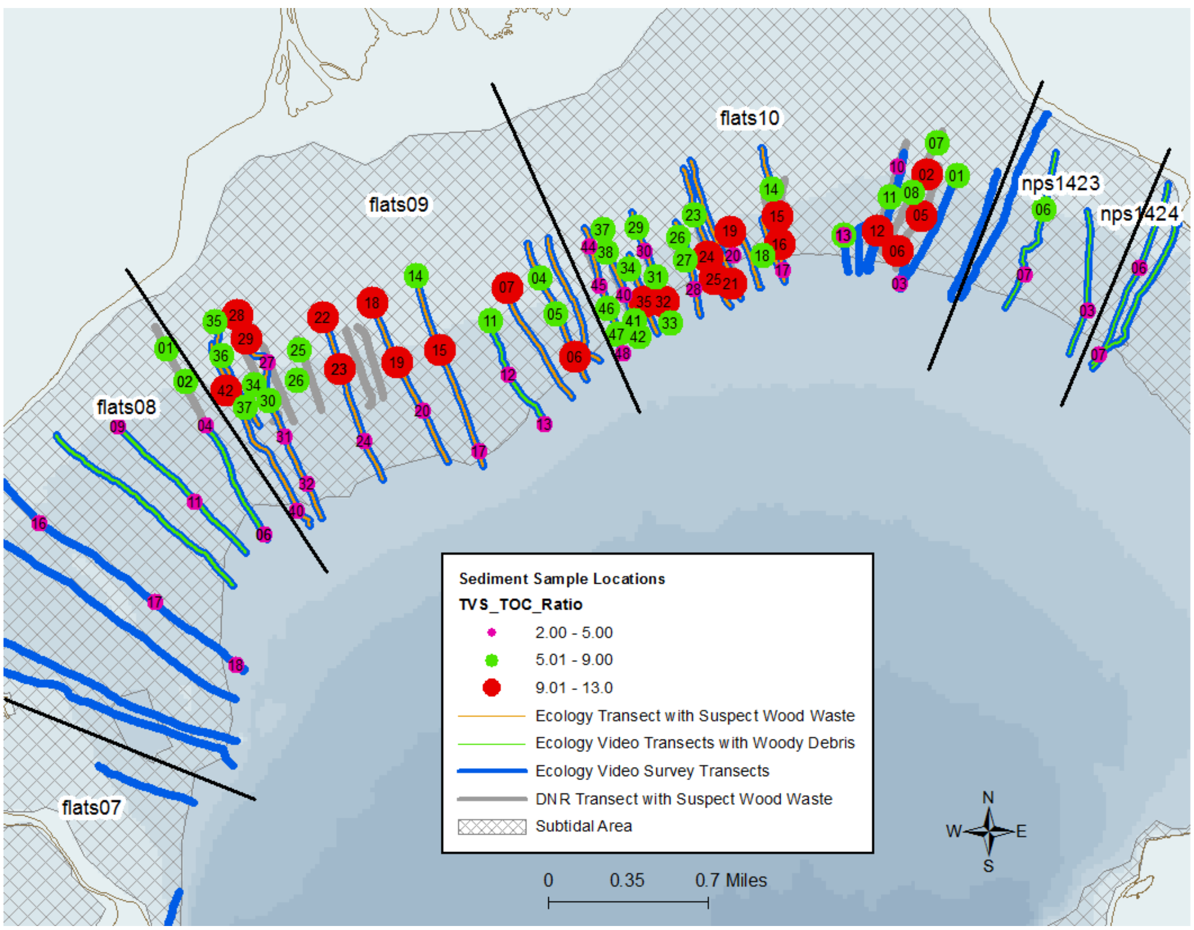

Figure 21. TVS/TOC ratio in sediment samples collected in Bellingham Bay.

Samples containing the highest TVS/TOC ratio showed a somewhat mixed and patchy pattern in the AOI. They were associated with low TVS and TOC and substrate consisting predominantly of sand. All these samples were found in flats09 and flats10, which is at the mouth of the Nooksack River. With wood waste, there is no single perfect indicator of potential impacts to the benthic community. Rather, a weight-of- evidence approach helps to sort out the potential for adverse effects. Sediment cores and tests for sulfides and other chemicals of concern (including phenols, resins, guaiacols, benzoic acid, and benzyl alcohol) may show a clearer pattern for adverse effects on biota than only the results listed here.

A clearer picture emerged from observation during sediment sample collection and when screening the sediment samples in the laboratory for woody debris (i.e., the Float Test). Each sediment grab collected was examined for woody debris, with results recorded in field notes. Also a portion of the samples were taken back to the laboratory, and a small portion of the sample was wetted and then allowed to settle before examining for woody debris that may not have been obvious in the field (a.k.a. the Float Test).

Woody debris, along with organic debris, was observed in about one-fourth of the sediment samples during field collection. Small pieces of woody and organic debris were confirmed in about a third of the samples upon close examination when conducting the Float Test (Figure 22).

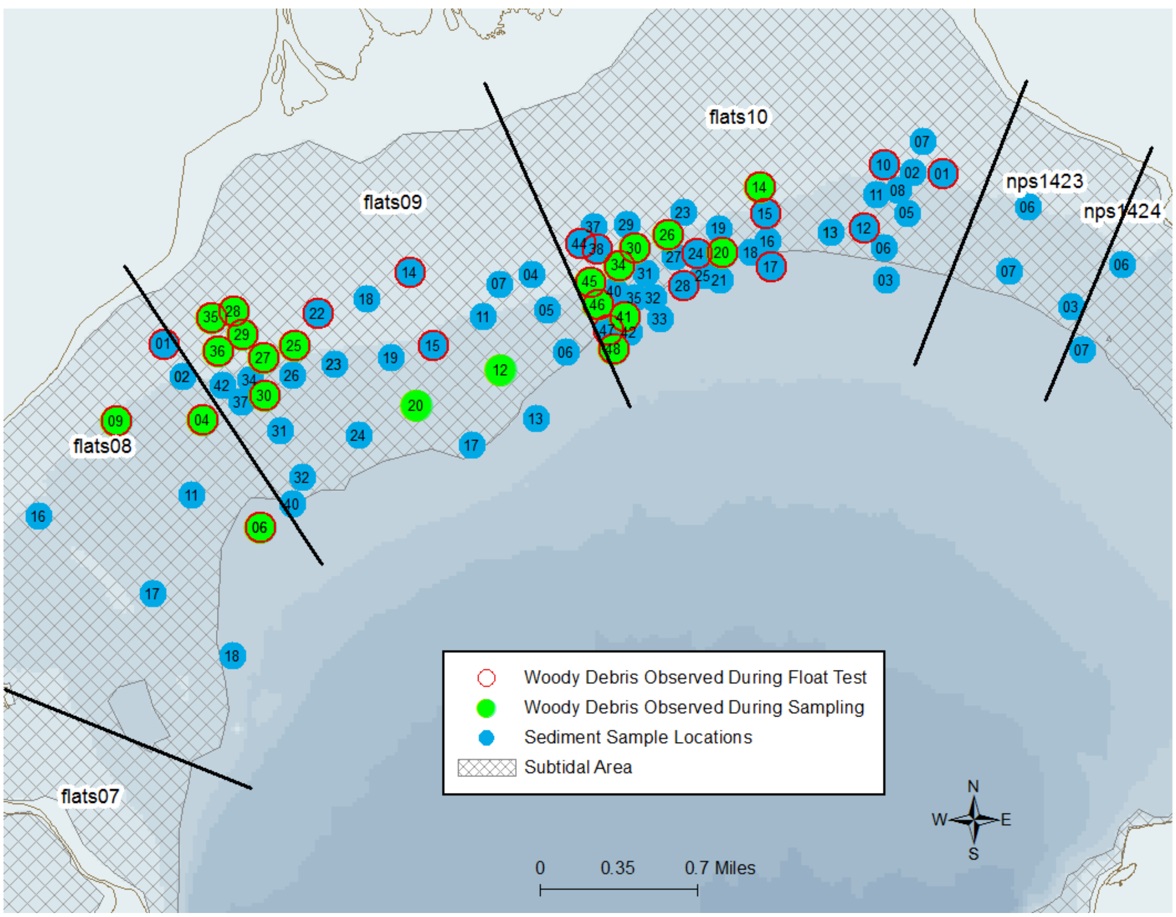

Figure 22. Woody debris observed during sediment sampling field collection and in the laboratory using the Float Test.

The woody debris appears to cluster in two large areas both near the northwest sides of flats09 and flats10. This is similar to the pattern observed in the results from the chemical tests (i.e., TOC and TVS). This patchy yet somewhat clustered pattern is likely due to deposition by currents and other water energy sources.

Undeniably, the Nooksack River is one source of some of the woody debris. When compared to an aerial photo background, the clusters lay within the Nooksack River flow influence (Figure 23). Woody debris such as fresh logs and sticks certainly could be explained by the river deposition in this AOI.

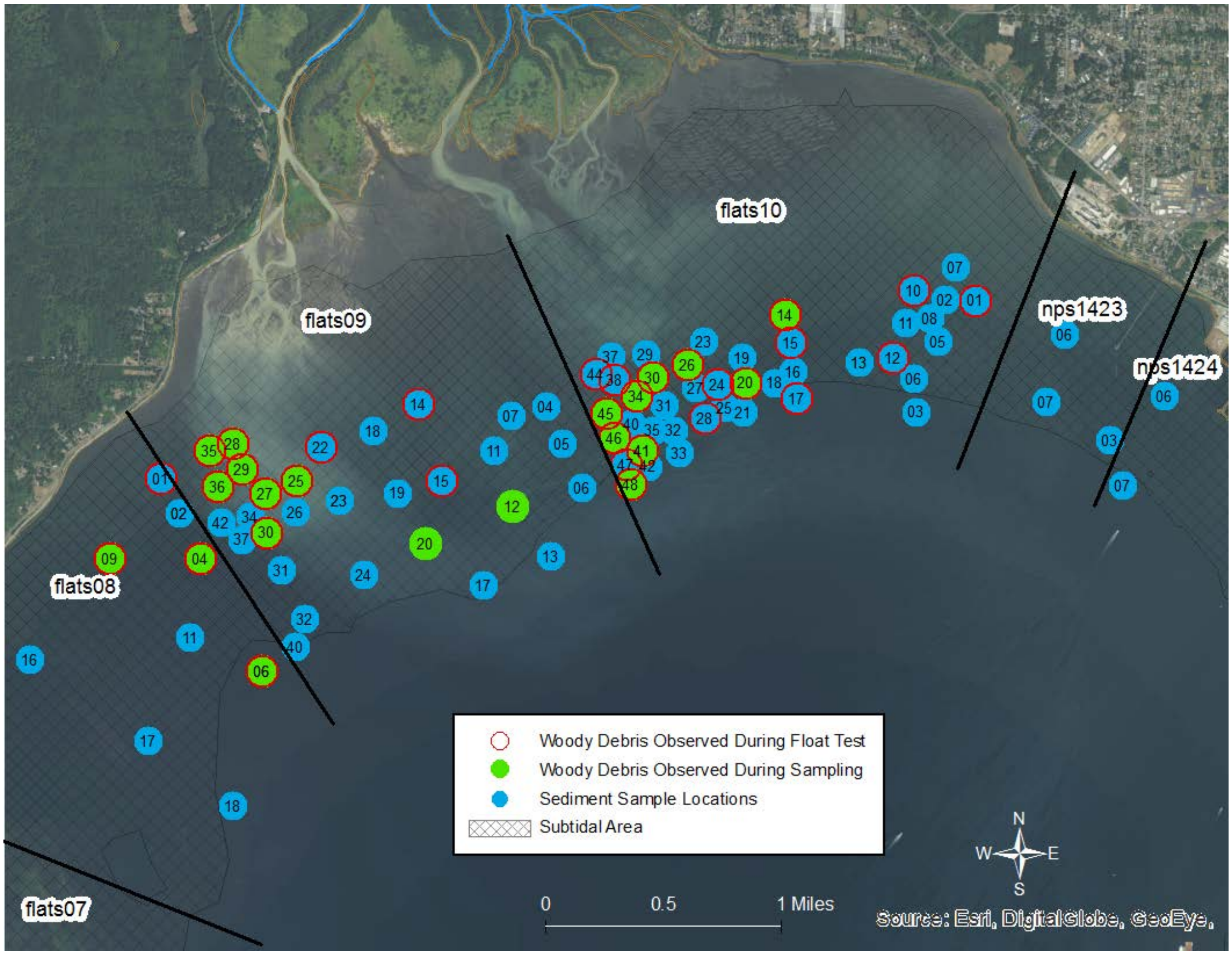

Figure 23. Arial photo background with observed woody debris.

Uncertainty remains for the source of the woody debris observed in many of these samples during the Float Test. Most samples that had positive results (woody debris presence) in the Float Test were made up of small woody slivers and pieces that look like decaying sawdust or bark (Figure 24 and Appendix H).

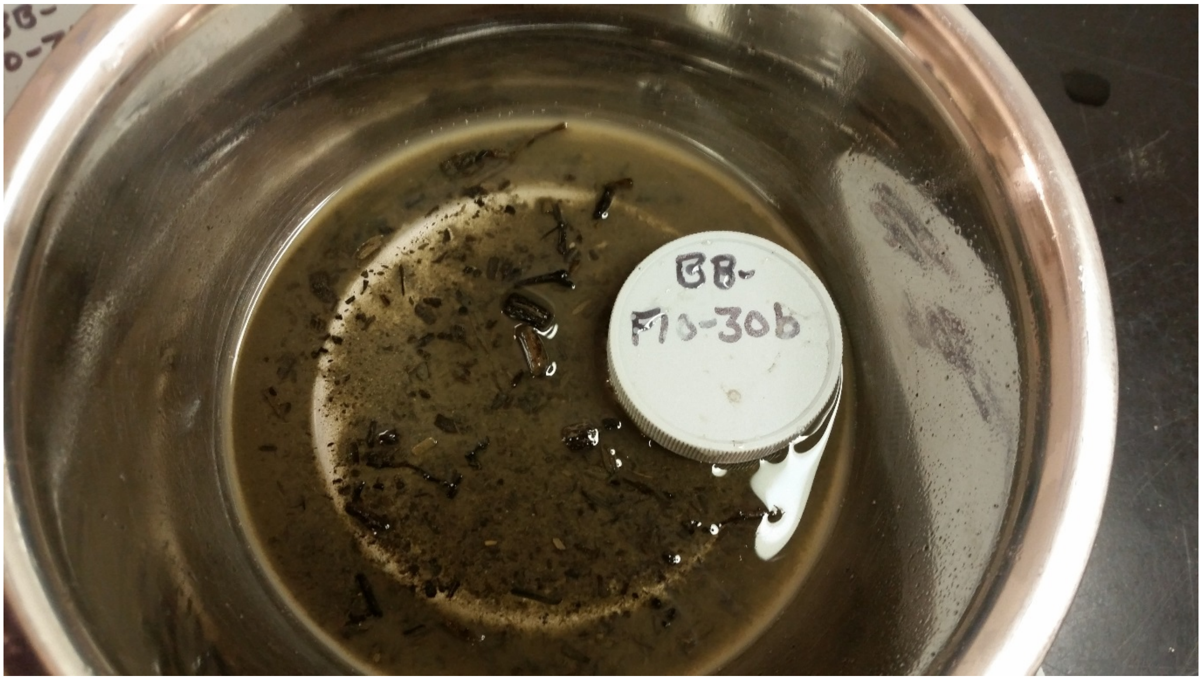

Figure 24. Example of woody debris found in samples during the Float Test.

This type of woody debris indicates another source, likely anthropogenic, such as historical sawmills and log operations that are well documented in Bellingham Bay.

Since this 2015-16 study collected only about 12 inches or less in each grab, the depth and area of buried woody debris remains unknown. Percent wood-waste volume was not determined since it was not measured. Sediment cores could help identify sources and extent of this debris by capturing sediment below the freshly deposited river particulates.

Historical woody debris found in this area could be considered mobile and able to move and redeposit in different marine, as well as on shore, areas due to the river and intertidal dynamic energies where currents, wind, and waves can affect the bottom of the bay (Figure 25 and 26). This likely explains, in part, the patchy pattern of the woody debris observed.

Figure 25. Woody and organic debris on shore at Fort Bellingham beach area, 2015.

Figure 26. Buried woody and organic debris in the upper intertidal area of Fort Bellingham beach, 2015.

The beach area from northwest of downtown Bellingham extending to the Nooksack River is naturally positioned to receive material due to the northwest net shore-drift, predominant winds from the south, and surface currents in a general clockwise rotating gyre in northern Bellingham Bay (Sandvik and Wong, 2015). When these factors are considered in total, this beach area is positioned to receive sediment and flotsam input from both marine and river systems.

Although wood-waste source assessment was not in the scope of this project, it is worth noting that the Cliffside Beach Wood Removal Project conducted a study in 2007 to identify the potential sources of the wood debris at Cliffside and to clean up the debris (Anchor Environmental, LLC 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:

- 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.
- The wood debris originated from the Nooksack River, known to experience major log jams, and was deposited along Cliffside Beach.

The wood waste found in sediments collected for this study was of the fine debris-type theorized as originating from historic industrial mill or municipal sites. Uncertainty remains as to whether this wood waste is the same as the wood waste deposited on shore. Since the scope of this study was limited to the survey of the subtidal area, no tests were conducted to assess or compare the composition of wood waste found in sediments versus wood waste deposited on shore.

As the delta has grown throughout the decades, it continues to bury the older woody debris, leaving only the newer logs, sticks, and larger pieces, as seen along the shores in other parts of Bellingham Bay and throughout Puget Sound. Yet the long-term toxicity of the buried or mobile anthropogenic woody waste remains in question.

Conclusions

A combination of physical measurements (TOC, TVS, percent solids, grain size, and Float Test) and qualitative observations (field descriptions, towed underwater video, and digital photos) was used to screen for the presence of woody debris in the intertidal area of Bellingham Bay.

Results of this study support the following conclusions:

- Total organic carbon (TOC) and total volatile solids (TVS) levels were highest towards the deeper, more depositional portion of the intertidal area of Bellingham Bay, except for one sample towards the northwest area. Woody and organic debris were observed in this sample.
- Lower percent fines were found along the steep, shallow delta fan forming at the mouth of the Nooksack River, while higher percent fines were generally in the deeper and more depositional areas and along the edges away from the river mouth.
- TOC, TVS, and percent fines were correlated.
- Samples containing the highest TVS/TOC ratio showed a somewhat mixed and patchy pattern in the area of interest (AOI) and were located basically centered below the mouth of the Nooksack River.
- Underwater video examination of the area indicated a patchy distribution of wood debris, ranging from a clean bottom to accumulations of woody and organic debris that completely covered the sediment surface.
- Sulfur-reducing bacteria mats may also be present, as observed as a white mass in the underwater videos. These would indicate anoxic conditions in the sediments, but is unconfirmed at this time.
- Relatively few organisms were observed along transects with suspected woody debris, in contrast to a higher density of organisms found along transects outside of these areas.
- Woody and organic debris were observed in about one-fourth of the sediment samples during field collection.
- Small woody slivers and pieces (sawdust or bark-type) were confirmed for about one-third of the sediment samples during the Float Test.
- Samples with woody debris observed in sediment samples had a patchy distribution basically centered at the mouth of the Nooksack River.
- Wood waste found in sediment samples was of the fine debris-type of material similar to wood waste found on shore, which is theorized as originating from historic industrial mill or municipal sites.
- Sediment coring and toxicity assessment would define depth, extent, and impact of the buried woody debris.

Recommendations

Results of this study support the following recommendations:

- Conduct tests to assess the depth, extent, and percent volume of buried woody debris found in the flats09 and flat10 areas.
- Determine the toxicity impact of the buried woody debris.
- Conduct tests to assess and compare composition of wood waste found in sediments versus wood waste deposited on shore east of the Nooksack River.

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Appendices

Appendix A. Bellingham Bay Seagrass Beds and Fish Spawning Areas

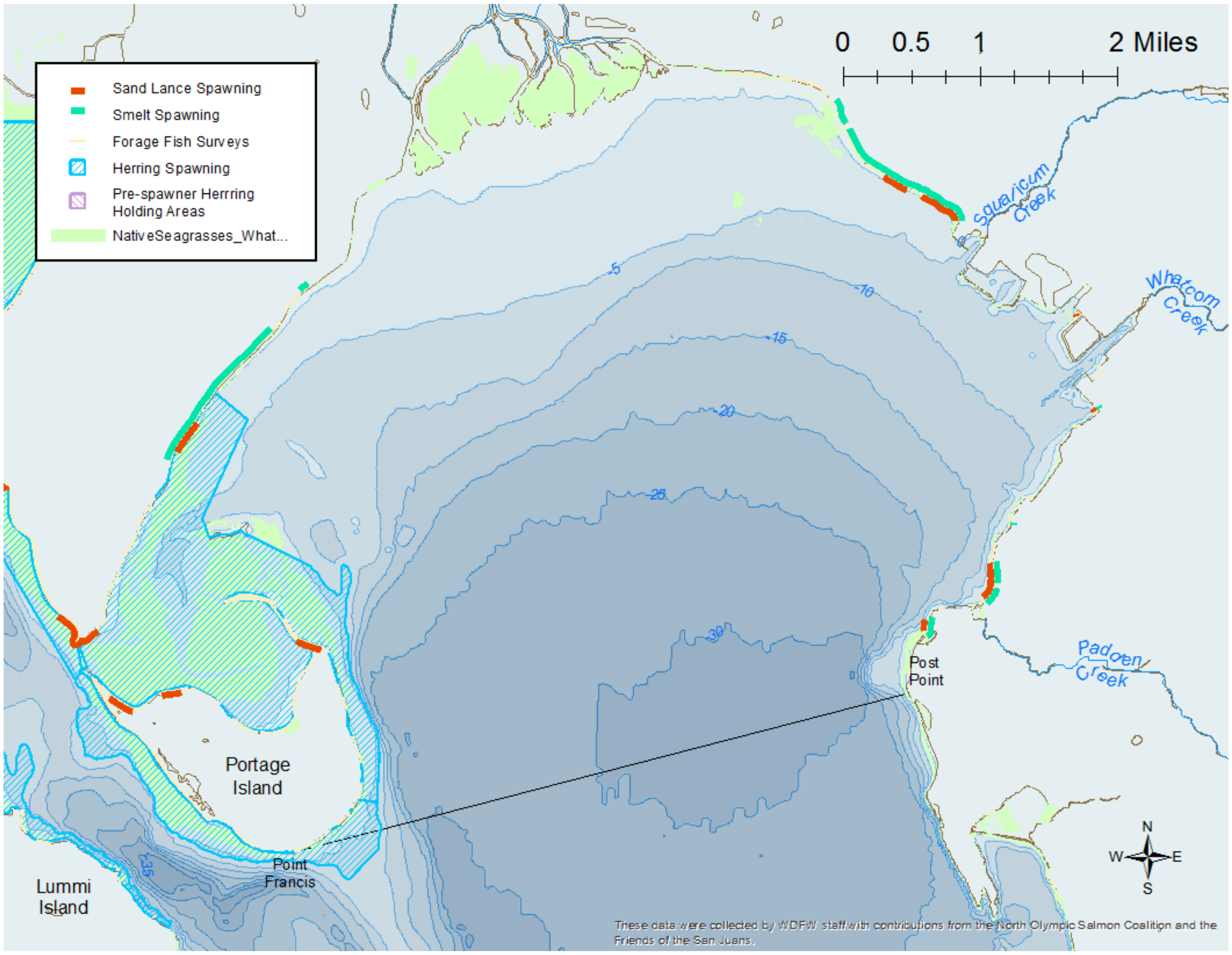

Figure A-1. Bellingham Bay seagrass beds and fish spawning areas. Depths in meters based on mean sea level.

Appendix B. Post-Processing of Ecology Underwater Video

Post-processing underwater video includes reviewing the video data from field sampling for identifying target parameters.

Equipment needed for post-processing video data includes

1. Computer with Microsoft Office
2. Media player (e.g. Windows media player or VLC media player).
3. TV or monitor.

General procedures

1. Access videos, video track points spreadsheet, field logs, field notes, and processing status table.
2. Transcribe field logs and notes into electronic format.
3. Export video tracks from navigation system and import into GIS, then export table of points.
4. Open the video spreadsheet file and begin video review -- one video at a time.
5. After video review, save documents in accessible location (preferably on a shared drive that is backed up).

Video processing (detailed)

1. Transcribe field logs and notes into an Excel spreadsheet.
2. Match transects to other studies' surveys as appropriate (e.g. Department of Natural Resources (DNR) seagrass survey videos).
3. Export video tracks from navigation system and import into GIS.
4. Export track point table from GIS into spreadsheet (i.e. Excel).
5. Add columns for presence/absence of target parameters, video quality, or other attributes.
    a. Type code "1" for presence or good quality video and "0" for absence or poor quality video.
    b. May choose to add columns specific for each type of parameter and code "1" or "0".
6. Log the beginning of each video review into the "Processing Status" table.
7. Review field log and notes then review video and mark appropriate code (e.g. mark "1" or "0") in designated columns per point on track table for every increment of geo-coordinate (e.g. every 2 seconds). Can fill in "0"s at the end of each transect review.
8. Add comments during review to explain findings or define video quality.
9. Use keys to help review video:
    a. Space bar to pause video
    b. E to view frame by frame
    c. +/- to change film speed
    d. Shift arrows to move video forward or backward by approximately 3 seconds
    e. Control arrows to move video forward or backward by approximately 1 minute
10. Save documents often and in accessible location (preferably on a shared drive that is backed up).

Action for video review for wood waste (WW)

1. Mark "1" in appropriate column for presence and type of wood waste. These will be formulated to automatically populate "1" in the "WW presence/absence" column:
    a. SD = sawdust
    b. BC = bark or chips
    c. Logs = logs
    d. DL = dimensional lumber
    e. Com = combination
    f. UN = undetermined
    g. ST = sticks
2. Mark "0" for absence of wood waste in the "WW presence/absence" column.
3. Mark "1" for good video quality or "3" in the "Video" quality column when water clarity is too poor to determine presence/absence of wood waste.
4. Mark "1" in the "Invertebrates" or "Seagrass" columns where sea life (e.g. sun stars, crabs) or seagrass is present.
5. Mark "1" in the "Snow" column where film shows floating debris or flakes of an unknown identity. (This is an extra request by Ecology's Marine Monitoring Unit for their studies.)

Action limits for wood waste video review

1. If single wood waste type spans more than 1 second, the technician assigns "1" (presence) for all frames to account for full location possibilities.
2. If there is a gap in the wood waste type, and it is less than 2 seconds, the technician may continuously assign "1" (presence) across all frames. If the gap is greater than 5 seconds, the technician must assign "0" (absence) to the corresponding seconds or frames.
3. If there are different types of wood waste that are distinguishable, the technician should mark "1" (presence) in each column for each type. Otherwise, mark "1" in the undetermined ("UN") column.
4. If the technician is not able to confidently identify wood waste due to a poor video image, the technician should mark those frames with a "3" in the "Video" quality column. A comment may be added if this area needs explanation or the technician is suspicious of wood waste presence.
5. Insert comments for other items of interest and anything needing to be defined.
6. If the technician notices that there are unrecorded or mislabeled transects, the technician should make corrections if possible. Unrecorded transects may need to be interpolated by best judgement of the technician or project officer and then documented in comments.

Quality assurance

1. Check for completeness by making sure that all rows are filled in with "1", "0", or "3" as appropriate.
2. Be sure that "WW" quality marked "3" also shows "3" in "Video" quality column and "0"s in all wood waste columns.

Table B-1. Example of Ecology's post processed underwater videos.

Video Name	Date	Time (Zulu)	Video Time Elapse	Video Time Cum	x (-dd)	y (dd)	WW	Video Qual	SD	BC	Logs	DL	Com	UN	ST	Sea	Invert
BW-032	10/22/2015	20:27:22	0:00:03	0:05:45	-122.6058	48.75065	1	1	0	0	0	0	0	0	1	0	0
BW-032	10/22/2015	20:27:24	0:00:02	0:05:47	-122.6057	48.75064	1	1	0	0	0	0	0	0	1	0	0
BW-032	10/22/2015	20:27:26	0:00:02	0:05:49	-122.6057	48.75062	1	1	0	0	0	0	0	0	1	0	0
BW-032	10/22/2015	20:27:27	0:00:01	0:05:50	-122.6057	48.75061	1	1	0	0	0	0	0	0	1	0	0
BW-032	10/22/2015	20:27:30	0:00:03	0:05:53	-122.6057	48.75060	1	1	0	0	0	0	0	0	1	0	0
BW-032	10/22/2015	20:27:30	0:00:00	0:05:53	-122.6057	48.75060	1	1	0	0	0	0	0	0	1	0	0
BW-032	10/22/2015	20:27:32	0:00:02	0:05:55	-122.6057	48.75058	1	1	0	0	0	0	0	0	1	0	0
BW-032	10/22/2015	20:27:34	0:00:02	0:05:57	-122.6057	48.75057	1	1	0	0	0	0	0	0	1	0	0
BW-032	10/22/2015	20:27:36	0:00:02	0:05:59	-122.6057	48.75055	1	1	0	0	0	0	0	0	1	0	0
BW-032	10/22/2015	20:27:38	0:00:02	0:06:01	-122.6057	48.75054	1	1	0	0	0	0	0	0	1	0	0
BW-032	10/22/2015	20:27:40	0:00:02	0:06:03	-122.6057	48.75053	1	1	0	0	0	0	0	0	1	0	0
BW-032	10/22/2015	20:27:43	0:00:03	0:06:06	-122.6057	48.75051	1	1	0	0	0	0	0	0	1	0	0
BW-032	10/22/2015	20:27:44	0:00:01	0:06:07	-122.6057	48.75050	1	1	0	0	0	0	0	0	1	0	0
BW-032	10/22/2015	20:27:46	0:00:02	0:06:09	-122.6056	48.75049	1	1	0	0	0	0	0	0	1	0	0
BW-032	10/22/2015	20:27:48	0:00:02	0:06:11	-122.6056	48.75047	1	1	0	0	0	0	0	0	1	0	0
BW-032	10/22/2015	20:27:50	0:00:02	0:06:13	-122.6056	48.75046	1	1	0	0	0	0	0	0	1	0	0
BW-032	10/22/2015	20:27:52	0:00:02	0:06:15	-122.6056	48.75045	1	1	0	0	0	0	0	0	1	0	0
BW-032	10/22/2015	20:27:54	0:00:02	0:06:17	-122.6056	48.75043	1	1	0	0	0	0	0	0	1	0	0
BW-032	10/22/2015	20:27:56	0:00:02	0:06:19	-122.6056	48.75042	1	1	0	0	0	0	0	0	1	0	0

ECY TRANS: Ecology transect
BC: bark chips
Com: combination
DL: dimensional lumber
Invert: invertebrates
Sea: Seagrass
ST: sticks
UN: undetermined
Video Qual: video quality
WW: wood waste

Appendix C. Navigation Report

Table C-1. Navigation Report

NAV ID	Actual Latitude (DD)	Actual Longitude (DD)	Field Split[a] (Y, N)	Sample Target[b] (T, A, X)	Sampled[c] (Y, X, ND)	Sample Date	Time[d] (DST)	Event Mark	Dist. To Target (m)	Depth[e] (m)	Depth Source[e] (T1, T2, MW)	Tide Height[f] (ft)	Power Grab Weight (lbs)	Grab (#)	Grab Fail (#)	Grab Fail Code[g] (DS, PC, SP, R)	Target Latitude (DD)	Target Longitude (DD)
BB-F10-01a	48.76294	-122.53546	N	T (A F10-04a)	Y	5/31/2016	17:55	320	14	1.6	T2	3.49	150	2	1	PC	48.76303	-122.53561
BB-F10-02b	48.76294	-122.53829	N	T	Y	5/31/2016	19:04	331	2	2.1	T1	2.95	150	1	-	-	48.75857	-122.53827
BB-F10-03c	48.75600	-122.54068	N	T	Y	6/1/2016	19:47	345	7	8.8	T1	3.85	150	1	-	-	48.75605	-122.54063
BB-F10-04a	-	-	N	A (T F10-01a)	ND	-	-	-	-	-	-	-	-	-	-	-	48.76256	-122.53745
BB-F10-05b	48.76033	-122.53878	N	T	Y	5/31/2016	18:40	327	6	1.7	T1	3.09	150	1	-	-	48.76035	-122.53886
BB-F10-06c	48.75803	-122.54094	N	T (A F10-09c)	Y	6/1/2016	19:32	343	2	3.3	T1	3.97	150	1	-	-	48.75803	-122.54090
BB-F10-07a	48.76497	-122.53743	N	T	Y	6/1/2016	18:35	336	7	1.6	T1	4.67	150	1	-	-	48.76500	-122.53750
BB-F10-08b	48.76179	-122.53965	N	T	Y	5/31/2016	18:15	323	15	1.7	T2	3.31	150	1	-	-	48.76193	-122.53961
BB-F10-09c	-	-	N	A (T F10-06c)	ND	-	-	-	-	-	-	-	-	-	-	-	48.75813	-122.54263
BB-F10-10a	48.76342	-122.54115	N	T	Y	6/1/2016	18:57	338	2	1.6	T1	4.35	150	1	-	-	48.76344	-122.54116
BB-F10-11b	48.76143	-122.54187	N	T	Y	5/31/2016	18:27	325	7	1.7	T1	3.20	150	1	-	-	48.76148	-122.54196
BB-F10-12c	48.75930	-122.54293	N	T	Y	5/31/2016	18:52	329	3	2.2	T1	3.01	150	1	-	-	48.75932	-122.54295
BB-F10-13a	48.75897	-122.54612	Y	T	Y	6/1/2016	19:10	341	6	3.3	T1	4.19	150	2	1	SP	48.75900	-122.54605
BB-F10-13a	48.75897	-122.54612	Y	T	Y	6/1/2016	19:10	341	6	3.3	T1	4.19	150	2	1	SP	48.75900	-122.54605
BB-F10-14a	48.76174	-122.55317	N	T	Y	6/2/2016	19:20	367	15	1.9	T1	5.59	200	4	1, 2, 3	SP	48.76162	-122.55310
BB-F10-15b	48.76007	-122.55256	N	T	Y	6/2/2016	18:52	363	14	2.3	T1	5.99	200	1	-	-	48.76013	-122.55271
BB-F10-16c	48.75830	-122.55226	N	T	Y	6/1/2016	20:40	351	6	2.1	T1	3.69	150	1	-	-	48.75825	-122.55223
BB-F10-17d	48.75665	-122.55188	N	T	Y	6/1/2016	20:07	347	6	5.6	T1	3.74	150	1	-	-	48.75659	-122.55185
BB-F10-18a	48.75756	-122.55393	N	T	Y	6/1/2016	20:23	349	9	2.1	T1	3.70	150	1	-	-	48.75753	-122.55380
BB-F10-19a	48.75902	-122.55705	N	T	Y	6/15/2016	20:13	482	4	2	T2	4.96	200	1	-	-	48.75900	-122.55700
BB-F10-20b	48.75751	-122.55664	N	T	Y	6/2/2016	18:33	361	6	3.9	T1	6.26	200	1	-	-	48.75754	-122.55671
BB-F10-21a	48.75572	-122.55680	N	T	Y	6/2/2016	18:05	357	17	3.2	T1	6.58	200	4	1, 2, 3	SP	48.75570	-122.55656

NAV ID	Actual Latitude (DD)	Actual Longitude (DD)	Field Split[a] (Y, N)	Sample Target[b] (T, A, X)	Sampled[c] (Y, X, ND)	Sample Date	Time[d] (DST)	Event Mark	Dist. To Target (m)	Depth[e] (m)	Depth Source[e] (T1, T2, MW)	Tide Height[f] (ft)	Power Grab Weight (lbs)	Grab (#)	Grab Fail (#)	Grab Fail Code[g] (DS, PC, SP, R)	Target Latitude (DD)	Target Longitude (DD)
BB-F10-22a	-	-	N	A (T F10-23a)	ND	-	-	-	-	-	-	-	-	-	-	-	48.75870	-122.55907
BB-F10-23a	48.75998	-122.56055	N	T (A F10-22a)	Y	6/15/2016	19:58	480	8	1.7	T2	4.99	200	1	-	-	48.76004	-122.56058
BB-F10-24b	48.75734	-122.55919	N	T	Y	6/16/2016	12:52	487	1.0	1.6	T2	2.54	200	2	1	SP	48.75734	-122.55918
BB-F10-25c	48.75594	-122.55847	N	T	Y	6/2/2016	18:19	359	1.8	4.5	T1	6.42	200	1	-	-	48.75595	-122.55842
BB-F10-26a	48.75852	-122.56202	N	T	Y	6/16/2016	14:03	498	19	1.5	T2	4.13	200	1	-	-	48.75840	-122.56184
BB-F10-27b	48.75714	-122.56129	N	T	Y	6/16/2016	13:04	489	13	1.6	T2	2.85	200	1	-	-	48.75718	-122.56112
BB-F10-28c	48.75526	-122.56033	N	T	Y	6/16/2016	12:15	485	11	1.4	T2	1.90	200	1	-	-	48.75530	-122.56020
BB-F10-29a	48.75908	-122.56597	N	T	Y	6/15/2016	19:42	478	6	1.7	T2	5.05	200	1	-	-	48.75910	-122.56604
BB-F10-30b	48.75766	-122.56521	N	T	Y	6/16/2016	14:16	500	22	2.2	T2	4.38	200	1	-	-	48.75750	-122.56503
BB-F10-31c	48.75602	-122.56408	N	T	Y	6/16/2016	13:19	492	6	1.6	T2	3.13	200	2	1	PC	48.75606	-122.56403
BB-F10-32d	48.75447	-122.56321	N	T	Y	6/3/2016	15:08	409	1	1.9	T1	5.07	200	1	-	-	48.75448	-122.56321
BB-F10-33e	48.75308	-122.56257	N	T	Y	6/3/2016	9:10	371	4	3.9	T1	-0.81	200	3	1, 2	SP	48.75310	-122.56252
BB-F10-34a	48.75649	-122.56668	N	T (A F10-39c)	Y	6/16/2016	14:35	502	4	1.7	T2	4.78	200	1	-	-	48.75652	-122.56665
BB-F10-35b	48.75444	-122.56511	N	T	Y	6/3/2016	14:56	407	18	1.7	T1	4.70	200	1	-	-	48.75440	-122.56535
BB-F10-36c	-	-	N	A (T F10-42f)	ND	-	-	-	-	-	-	-	-	-	-	-	48.75279	-122.56416
BB-F10-37c	48.75888	-122.56923	N	T	Y	6/15/2016	18:47	470	22	1.6	T2	5.40	200	1	-	-	48.75893	-122.56954
BB-F10-38b	48.75746	-122.56883	N	T	Y	6/15/2016	19:29	476	7	1.4	T2	5.11	200	1	-	-	48.75752	-122.56881
BB-F10-39c	-	-	N	A (T F10-34a)	ND	-	-	-	-	-	-	-	-	-	-	-	48.75568	-122.56753
BB-F10-40d	48.75479	-122.56709	N	T	Y	6/16/2016	13:30	494	21	1.7	T2	3.54	200	1	-	-	48.75468	-122.56686
BB-F10-41e	48.75317	-122.56603	Y	T	Y	6/3/2016	14:37	405	14	2	T1	4.10	200	2	1	SP	48.75325	-122.56617
BB-F10-41e	48.75317	-122.56603	Y	T	Y	6/3/2016	14:37	405	14	2	T1	4.10	200	2	1	SP	48.75325	-122.56617
BB-F10-42f	48.75222	-122.56548	N	T (A F10-36c)	Y	6/3/2016	9:27	373	7	4.4	T1	-1.16	200	1	-	-	48.75229	-122.56538
BB-F10-43a	-	-	N	T	A	-	-	-	-	-	-	-	200	A	1, 2, 3	SP	48.75904	-122.57112
BB-F10-44b	48.75782	-122.57050	N	T	Y	6/15/2016	19:15	474	12	1.4	T2	5.19	200	3	1, 2	SP, PC	48.75790	-122.57038
BB-F10-45c	48.75538	-122.56948	N	T	Y	6/16/2016	14:45	504	10	1.9	T2	4.97	200	1	-	-	48.75548	-122.56947
BB-F10-46d	48.75391	-122.56865	N	T	Y	6/16/2016	13:44	496	10	1.9	T2	3.75	200	1	-	-	48.75389	-122.56851

NAV ID	Actual Latitude (DD)	Actual Longitude (DD)	Field Split[a] (Y, N)	Sample Target[b] (T, A, X)	Sampled[c] (Y, X, ND)	Sample Date	Time[d] (DST)	Event Mark	Dist. To Target (m)	Depth[e] (m)	Depth Source[e] (T1, T2, MW)	Tide Height[f] (ft)	Power Grab Weight (lbs)	Grab (#)	Grab Fail (#)	Grab Fail Code[g] (DS, PC, SP, R)	Target Latitude (DD)	Target Longitude (DD)
BB-F10-47e	48.75230	-122.56754	N	T	Y	6/3/2016	10:02	378	6	3	T1	-1.54	200	1	-	-	48.75234	-122.56760
BB-F10-48f	48.75108	-122.56705	N	T	Y	6/3/2016	9:42	376	18	7.5	T1	-1.37	200	2	1	SP	48.75122	-122.56719
BB-F09-01a	-	-	N	T	ND	-	-	-	-	-	-	-	-	-	-	-	48.75554	-122.57292
BB-F09-02b	-	-	N	A (T F09-05b)	ND	-	-	-	-	-	-	-	-	-	-	-	48.75438	-122.57187
BB-F09-03c	-	-	N	A (T F09-06c)	ND	-	-	-	-	-	-	-	-	-	-	-	48.75246	-122.57033
BB-F09-04a	48.75573	-122.57516	N	T	Y	6/15/2016	18:05	646	7	1.9	T2	5.66	200	1	-	-	48.75577	-122.57523
BB-F09-05b	48.75350	-122.57352	N	T (A F09-02b)	Y	6/16/2016	15:15	506	12	2.3	T2	5.49	200	1	-	-	48.75355	-122.57366
BB-F09-06c	48.75082	-122.57161	N	T (A F09-03c)	Y	6/3/2016	11:24	386	9	2.6	T1	-1.06	200	1	-	-	48.75084	-122.57173
BB-F09-07a	48.75508	-122.57827	N	T	Y	6/15/2016	17:43	462	14	2.1	T2	5.79	200	1	-	-	48.75509	-122.57850
BB-F09-08b	-	-	N	A (T F09-11a)	ND	-	-	-	-	-	-	-	-	-	-	-	48.75333	-122.57730
BB-F09-09c	-	-	N	A (T F09-12b)	ND	-	-	-	-	-	-	-	-	-	-	-	48.75016	-122.57387
BB-F09-10d	-	-	N	A (T F09-13c)	ND	-	-	-	-	-	-	-	-	-	-	-	48.74826	-122.57181
BB-F09-11a	48.75293	-122.57982	N	T (A F09-08b)	Y	6/16/2016	15:28	509	10	2.4	T1	5.70	200	1	-	-	48.75291	-122.57968
BB-F09-12b	48.74956	-122.57794	N	T (A F09-09c)	Y	6/3/2016	11:04	384	7	4.2	T1	-1.34	200	1	-	-	48.74963	-122.57795
BB-F09-13c	48.74651	-122.57435	N	T (A F09-10d)	Y	6/3/2016	10:22	380	17	9.7	T1	-1.60	200	1	-	-	48.74664	-122.57446
BB-F09-14a	48.75566	-122.58701	N	T	Y	6/15/2016	17:29	460	7	1.6	T2	5.86	200	2	1	SP	48.75572	-122.58705
BB-F09-15b	48.75101	-122.58461	N	T	Y	6/16/2016	15:40	511	11	2.5	T2	5.87	200	1	-	-	48.75095	-122.58473
BB-F09-16c	-	-	N	A (T F09-20c)	ND	-	-	-	-	-	-	-	-	-	-	-	48.74734	-122.58220
BB-F09-17d	48.74465	-122.58052	N	T (A F09-21d)	Y	6/3/2016	10:44	382	10	8	T1	-1.52	200	1	-	-	48.74465	-122.58066
BB-F09-18a	48.75392	-122.59115	N	T	Y	6/15/2016	17:04	457	7	1.7	T2	5.96	200	1	-	-	48.75392	-122.59125
BB-F09-19b	48.75018	-122.58868	N	T	Y	6/16/2016	15:50	513	5	2.3	T1	6.01	200	1	-	-	48.75022	-122.58868
BB-F09-20c	48.74712	-122.58601	N	T (A F09-16c)	Y	6/3/2016	14:10	402	11	7.2	T1	3.24	200	1	-	-	48.74717	-122.58614
BB-F09-21d	-	-	N	A (T F09-17d)	ND	-	-	-	-	-	-	-	-	-	-	-	48.74455	-122.58408

NAV ID	Actual Latitude (DD)	Actual Longitude (DD)	Field Split[a] (Y, N)	Sample Target[b] (T, A, X)	Sampled[c] (Y, X, ND)	Sample Date	Time[d] (DST)	Event Mark	Dist. To Target (m)	Depth[e] (m)	Depth Source[e] (T1, T2, MW)	Tide Height[f] (ft)	Power Grab Weight (lbs)	Grab (#)	Grab Fail (#)	Grab Fail Code[g] (DS, PC, SP, R)	Target Latitude (DD)	Target Longitude (DD)
BB-F09-22a	48.75285	-122.59591	N	T	Y	6/15/2016	16:50	455	5	1.8	T2	6.00	200	1	-	-	48.75285	-122.59599
BB-F09-23b	48.74963	-122.59412	Y	T	Y	6/16/2016	16:01	515	6	2.2	T1	6.15	200	1	-	-	48.74967	-122.59408
BB-F09-23b	48.74963	-122.59412	Y	T	Y	6/16/2016	16:01	515	6	2.2	T1	6.15	200	1	-	-	48.74967	-122.59408
BB-F09-24c	48.74508	-122.59157	N	T	Y	6/3/2016	13:48	400	4	8	T1	2.54	200	1	-	-	48.74510	-122.59162
BB-F09-25a	48.75079	-122.59809	N	T	Y	6/15/2016	16:36	453	14	2	T2	6.02	200	1	-	-	48.75090	-122.59799
BB-F09-26a	48.74884	-122.59817	N	T	Y	6/16/2016	16:13	517	5	2.4	T1	6.28	200	1	-	-	48.74885	-122.59824
BB-F09-27a	48.74995	-122.60102	N	T	Y	6/15/2016	16:15	451	20	2.5	T1	6.00	200	1	-	-	48.75013	-122.60101
BB-F09-28a	48.75291	-122.60411	N	T	Y	6/15/2016	15:27	445	9	1.8	T2	5.74	200	1	-	-	48.75285	-122.60418
BB-F09-29b	48.75140	-122.60321	N	T (A F09-33a)	Y	6/15/2016	15:45	447	16	2.2	T2	5.87	200	1	-	-	48.75154	-122.60329
BB-F09-30c	48.74754	-122.60080	N	T	Y	6/16/2016	16:45	523	2	2.6	T1	6.54	200	1	-	-	48.74752	-122.60080
BB-F09-31d	48.74526	-122.59927	N	T	Y	6/3/2016	13:32	398	2	6.4	T1	2.05	200	1	-	-	48.74526	-122.59930
BB-F09-32e	48.74230	-122.59697	N	T	Y	6/3/2016	12:48	392	7	8.3	T1	0.79	200	1	-	-	48.74224	-122.59700
BB-F09-33a	-	-	N	A (T F09-29b)	ND	-	-	-	-	-	-	-	-	-	-	-	48.75024	-122.60360
BB-F09-34b	48.74847	-122.60229	N	T	Y	6/16/2016	16:25	519	12	2.3	T1	6.40	200	1	-	-	48.74852	-122.60243
BB-F09-35a	48.75245	-122.60624	N	T	Y	6/15/2016	15:09	443	14	1.4	T1	5.57	200	1	-	-	48.75249	-122.60643
BB-F09-36b	48.75029	-122.60547	N	T (A F09-41a)	Y	6/15/2016	16:01	449	15	1.9	T2	5.95	200	1	-	-	48.75040	-122.60560
BB-F09-37c	48.74707	-122.60305	N	T	Y	6/15/2016	10:02	415	8	1.4	T2	1.26	150	1	-	-	48.74700	-122.60300
BB-F09-38a	-	-	N	T	ND	-	-	-	-	-	-	-	-	-	-	-	48.74579	-122.60277
BB-F09-39b	-	-	N	T	A	-	-	-	-	-	-	-	200	A	1, 2, 3	SP	48.74298	-122.59969
BB-F09-40c	48.74056	-122.59783	N	T	Y	6/3/2016	12:26	390	10	9.2	T1	0.23	200	3	1, 2	PC, SP	48.74055	-122.59770
BB-F09-41a	-	-	N	A (T F09-36b)	ND	-	-	-	-	-	-	-	-	-	-	-	48.74931	-122.60679
BB-F09-42b	48.74809	-122.60499	N	T	Y	6/16/2016	16:35	521	10	2.3	T1	6.48	200	1	-	-	48.74800	-122.60500
BB-F08-01a	48.75066	-122.61077	N	T (A F08-07a)	Y	6/15/2016	14:52	441	13	2	T1	5.39	200	1	-	-	48.75054	-122.61078
BB-F08-02b	48.74858	-122.60887	Y	T (A F08-08b)	Y	6/15/2016	14:34	439	14	2.7	T1	5.17	200	1	-	-	48.74848	-122.60900
BB-F08-02b	48.74858	-122.60887	Y	T (A F08-08b)	Y	6/15/2016	14:34	439	14	2.7	T1	5.17	200	1	-	-	48.74848	-122.60900
BB-F08-03c	-	-	N	T	ND	-	-	-	-	-	-	-	-	-	-	-	48.74661	-122.60746

NAV ID	Actual Latitude (DD)	Actual Longitude (DD)	Field Split[a] (Y, N)	Sample Target[b] (T, A, X)	Sampled[c] (Y, X, ND)	Sample Date	Time[d] (DST)	Event Mark	Dist. To Target (m)	Depth[e] (m)	Depth Source[e] (T1, T2, MW)	Tide Height[f] (ft)	Power Grab Weight (lbs)	Grab (#)	Grab Fail (#)	Grab Fail Code[g] (DS, PC, SP, R)	Target Latitude (DD)	Target Longitude (DD)
BB-F08-04d	48.74584	-122.60685	N	T	Y	6/16/2016	9:32	412	19	5	T1	0.44	150	3	1, 2	PC	48.74572	-122.60665
BB-F08-05e	-	-	N	T	ND	-	-	-	-	-	-	-	-	-	-	-	48.74150	-122.60339
BB-F08-06f	48.73900	-122.60093	Y	T	Y	6/15/2016	11:34	423	9	10.4	T1	2.25	150	1	-	-	48.73892	-122.60095
BB-F08-06f	48.73900	-122.60093	Y	T	Y	6/15/2016	11:34	423	9	10.4	T1	2.25	150	1	-	-	48.73892	-122.60095
BB-F08-07a	-	-	N	A (T F08-01a)	ND	-	-	-	-	-	-	-	-	-	-	-	48.74939	-122.61283
BB-F08-08b	-	-	N	A (T F08-02b)	ND	-	-	-	-	-	-	-	-	-	-	-	48.74794	-122.61209
BB-F08-09a	48.74565	-122.61524	N	T (A F09-10b)	Y	6/15/2016	14:20	437	6	4.4	T1	4.98	200	2	1	PC	48.74560	-122.61526
BB-F08-10b	-	-	N	A (T F08-09a)	ND	-	-	-	-	-	-	-	-	-	-	-	48.74369	-122.61221
BB-F08-11c	48.74099	-122.60767	N	T (A F08-12d)	Y	6/15/2016	12:31	428	15	8	T1	3.20	150	4	1, 2, 3	R, DS	48.74110	-122.60781
BB-F08-12d	-	-	N	A (T F08-11c)	ND	-	-	-	-	-	-	-	-	-	-	-	48.73864	-122.60378
BB-F08-13a	-	-	N	A (T F08-16a)	ND	-	-	-	-	-	-	-	-	-	-	-	48.74305	-122.61778
BB-F08-14b	-	-	N	A (T F08-17b)	ND	-	-	-	-	-	-	-	-	-	-	-	48.74015	-122.61134
BB-F08-15c	-	-	N	T	ND	-	-	-	-	-	-	-	-	-	-	-	48.73641	-122.60481
BB-F08-16a	48.73937	-122.62248	N	T (A F08-13a)	Y	6/15/2016	13:11	432	5	5	T1	3.90	150	3	1, 2	PC	48.73934	-122.62242
BB-F08-17b	48.73454	-122.61122	N	T (A F08-14b)	Y	6/15/2016	11:13	421	13	4.4	T1	1.92	150	2	1	PC	48.73443	-122.61126
BB-F08-18c	48.73072	-122.60329	N	T	Y	6/15/2016	10:48	418	13	11.5	T1	1.64	150	2	1	PC	48.73064	-122.60315
BB-F08-19a	-	-	N	X	X	-	-	-	-	-	-	-	-	-	-	-	48.72815	-122.61415
BB-F08-20b	-	-	N	X	X	-	-	-	-	-	-	-	-	-	-	-	48.72645	-122.60674
BB-1424-01a	-	-	N	X	X	-	-	-	-	-	-	-	-	-	-	-	48.75947	-122.51460
BB-1424-02b	-	-	N	A (T 1423-06b)	ND	-	-	-	-	-	-	-	-	-	-	-	48.75799	-122.51556
BB-1424-03c	-	-	N	A (T 1424-07d)	ND	-	-	-	-	-	-	-	-	-	-	-	48.75360	-122.51897
BB-1424-04a	-	-	N	X	X	-	-	-	-	-	-	-	-	-	-	-	48.76222	-122.51536
BB-1424-05b	-	-	N	A (T 1423-06b)	ND	-	-	-	-	-	-	-	-	-	-	-	48.75991	-122.51647

NAV ID	Actual Latitude (DD)	Actual Longitude (DD)	Field Split[a] (Y, N)	Sample Target[b] (T, A, X)	Sampled[c] (Y, X, ND)	Sample Date	Time[d] (DST)	Event Mark	Dist. To Target (m)	Depth[e] (m)	Depth Source[e] (T1, T2, MW)	Tide Height[f] (ft)	Power Grab Weight (lbs)	Grab (#)	Grab Fail (#)	Grab Fail Code[g] (DS, PC, SP, R)	Target Latitude (DD)	Target Longitude (DD)
BB-1424-06c	48.75738	-122.51770	N	T	Y	5/31/2016	17:21	317	13	3.6	T1	3.84	150	1	-	-	48.75729	-122.51783
BB-1424-07d	48.75182	-122.52136	N	T (A 1424-03c, 1423-04c)	Y	5/31/2016	16:37	314	14	9.3	T1	4.43	100	2	1	PC	48.75189	-122.52118
BB-1423-01a	-	-	N	T	A	-	-	-	-	-	-	-	100	A	-	-	48.76069	-122.52288
BB-1423-02b	-	-	N	A (T 1423-06b)	ND	-	-	-	-	-	-	-	-	-	-	-	48.75828	-122.52269
BB-1423-03c	48.75458	-122.52257	N	T	Y	5/31/2016	16:06	310	20	8.1	T1	4.78	100	1	-	-	48.75457	-122.52292
BB-1423-04c	-	-	N	A (T 1424-07d)	ND	-	-	-	-	-	-	-	-	-	-	-	48.75183	-122.52430
BB-1423-05a	-	-	N	X	X	-	-	-	-	-	-	-	-	-	-	-	48.76448	-122.52607
BB-1423-06b	48.76095	-122.52704	N	T (A 1423--02b, 1423-05b, 1424-02b)	Y	5/31/2016	15:10	303	10	2.7	T1	5.28	100	1	-	-	48.76101	-122.52712
BB-1423-07c	48.75679	-122.52866	N	T	Y	5/31/2016	15:49	307	24	7.2	T1	4.95	100	2	1	SP	48.75698	-122.52896

a. Field Split: Y = yes, N = no.
b. Sample Designation: T = Target, A = alternate, X = do not sample, (identification of sample to another sample).
c. Sampled: Y = yes, X = do not sample, ND = not doing, A = abandon.
d. Time: converted from Coordinated Universal Time (UTC) (MX navigation system record) to Daylight Savings Time (DST), which is minus 7 hours.
e. Depth Source: T1 = Depth Sounder inside cabin, transducer on stern approximately half meter below water surface. T2 = Depth Sounder outside cabin (bulkhead), transducer under hull at midship approximately half meter below water surface. MW = meter wheel.
f. Tide Height: tide station = Bellingham Bay.
g. Grab Fail Code: DS = disturbed surface, PC = poor closure, R = rejected, SP = shallow penetration.

A = abandon.
DD = Decimal Degrees
ft = feet.
lbs = pounds.
NAV ID: Navigation Sample Identification.
= number.

Appendix D. Quality Control Results

Table D-1. Laboratory Blanks

Analyte	Sample ID	QC Result (%)	Qualifier
TOC	B16F013-BLK1	0.10	U
	B16F018-BLK1	0.10	U
	B16F078-BLK1	0.10	U
	B16F088-BLK1	0.10	U
	B16F094-BLK1	0.10	U
	B16F103-BLK1	0.10	U
TVS	B16F060-BLK1	0.10	U
	B16F062-BLK1	0.10	U
	B16F062-BLK2	0.10	U
	B16F134-BLK1	0.10	U
	B16F134-BLK2	0.10	U
	B16F134-BLK3	0.10	U
Percent Solids	B16F059-BLK1	0.001	U
	B16F061-BLK1	0.001	U
	B16F061-BLK2	0.001	U
	B16F133-BLK1	0.001	U
	B16F133-BLK2	0.001	U
	B16F133-BLK3	0.001	U

QC = Quality Control
TOC = Total Organic Carbon
TVS = Total Volatile Solids
U = not detected

Table D-2. Laboratory Control Samples

Analyte	Sample ID	Spiked Amount	Spiked Rec	LCS Rec (%)
TOC	B16F013-SRM1	2.99	2.86	96
	B16F018-SRM1	2.99	2.73	91
	B16F078-SRM1	2.99	2.81	94
	B16F088-SRM1	2.99	2.84	95
	B16F094-SRM1	2.99	3.01	101
	B16F103-SRM1	2.99	2.83	95

LCS = Laboratory Control Sample
QC = Quality Control
Rec = Recovery
TOC = Total Organic Carbon

Table D-3. Laboratory Duplicates

Analyte	Sample ID	Sample Result (%)	Sample Qualifier	Duplicate ID	Duplicate Result (%)	Duplicate Qualifier	% RPD[a,b]
TOC	1606031-01	0.231		B16F013-DUP1	0.204		13
TOC	1606031-01	0.231		B16F013-DUP2	0.220		5.0
TOC	1606031-03	1.19		B16F018-DUP1	1.31		10
TOC	1606031-03	1.19		B16F018-DUP2	1.14		4.0
TOC	1606032-12	0.765		B16F094-DUP1	0.778		2.0
TOC	1606032-12	0.765		B16F094-DUP2	0.741		3.0
TOC	1606031-20	0.131		B16F088-DUP1	0.131		0.2
TOC	1606031-20	0.131		B16F088-DUP2	0.138		6.0
TOC	1604039-47[c]	2.34		B16F078-DUP1	2.41		3.0
TOC	1604039-47[c]	2.34		B16F078-DUP2	2.35		0.5
TOC	1606031-95	0.166		B16F103-DUP1	0.179		7.0
TOC	1606031-95	0.166		B16F103-DUP2	0.166		0.1
TVS	1606031-01	1.70		B16F060-DUP1	1.60		6.0
TVS	1606031-11	1.40		B16F060-DUP2	1.50		7.0
TVS	1606031-10	1.70		B16F062-DUP1	2.00		16
TVS	1606031-18	3.10		B16F062-DUP2	3.00		3.0
TVS	1606031-50	4.60		B16F062-DUP3	4.90		6.0
TVS	1606031-62	4.10		B16F062-DUP4	4.20		2.0
TVS	1606032-07	4.60		B16F134-DUP1	4.50		2.0
TVS	1606031-25	1.30		B16F134-DUP2	1.30		0.0
TVS	1606031-46	1.50		B16F134-DUP3	1.40		7.0
TVS	1606031-69	1.30		B16F134-DUP4	1.00		26
TVS	1606031-85	1.30		B16F134-DUP5	1.40		7.0
TVS	1606031-93	1.30		B16F134-DUP6	1.20		8.0
Percent Solids	1606031-01	73.4		B16F059-DUP1	74.5		1.0
Percent Solids	1606031-11	73.9		B16F059-DUP2	74.0		0.1
Percent Solids	1606031-10	70.7		B16F061-DUP1	70.7		0.1
Percent Solids	1606031-18	67.9		B16F061-DUP2	68.3		0.6
Percent Solids	1606031-50	58.4		B16F061-DUP3	58.4		0.0
Percent Solids	1606031-62	60.0		B16F061-DUP4	60.1		0.2
Percent Solids	1606032-07	59.2		B16F133-DUP1	58.9		0.5
Percent Solids	1606031-25	74.9		B16F133-DUP2	74.8		0.2
Percent Solids	1606031-46	71.7		B16F133-DUP3	71.7		0.0
Percent Solids	1606031-69	74.7	J	B16F133-DUP4	74.2	J	0.7
Percent Solids	1606031-85	74.1		B16F133-DUP5	74.2		0.2
Percent Solids	1606031-93	74.7		B16F133-DUP6	74.5		0.2

Notes for Table D-3

a. RPD as reported by Manchester Environmental Laboratory.
b. Minor discrepancies due to rounding differences.
c. Sample 1604039-47 is not part of this study's samples but was used as batch duplicate source for samples 1606031-29 and -30.
MQO = Measurement Quality Objectives
RPD = Relative Percent Difference.
TOC = Total Organic Carbon.
TVS = Total Volatile Solids.

Table D-4. Laboratory Triplicates

Phi Size	1606031-03 (Rep 1) (%)	1606031-03 (Rep 2) (%)	1606031-03 (Rep 3) (%)	AVE (%)	STDEV	% RSD[a,b]
-3	100	100	100	100	0.00	0.00
-2	100	100	100	100	0.00	0.00
-1	100	99.8	100	99.9	0.12	0.12
0	99.9	99.7	99.9	99.8	0.12	0.10
1	99.6	99.4	99.5	99.5	0.10	0.10
2	99.0	98.9	99.0	99.0	0.06	0.10
3	97.2	97.1	97.3	97.2	0.10	0.10
4	85.4	85.8	85.3	85.5	0.26	0.35
5	NA	NA	NA	NA	NA	NA
6	NA	NA	NA	NA	NA	NA
7	NA	NA	NA	NA	NA	NA
8	17.8	14.6	14.6	15.6	1.85	11.8
9	NA	NA	NA	NA	NA	NA
10	NA	NA	NA	NA	NA	NA

Phi Size	1606032-30 (Rep 1) (%)	1606032-30 (Rep 2) (%)	1606032-30 (Rep 3) (%)	AVE (%)	STDEV	% RSD[a,b]
-3	100	100	100	100	0.00	0.00
-2	100	100	100	100	0.00	0.00
-1	100	100	100	100	0.00	0.00
0	99.9	99.9	99.9	99.9	0.00	0.00
1	99.5	99.2	99.3	99.3	0.15	0.10
2	98.3	98.7	98.8	98.6	0.26	0.30
3	97.5	98.2	98.4	98.0	0.47	0.51
4	94.5	95.6	95.4	95.2	0.58	0.63
5	NA	NA	NA	NA	NA	NA
6	NA	NA	NA	NA	NA	NA
7	NA	NA	NA	NA	NA	NA
8	18.1	17.6	18.6	18.1	0.50	2.76
9	NA	NA	NA	NA	NA	NA
10	NA	NA	NA	NA	NA	NA

Table D-4. Laboratory Triplicates continued

Phi Size	1606032-26 (Rep 1) (%)	1606032-26 (Rep 2) (%)	1606032-26 (Rep 3) (%)	AVE (%)	STDEV	% RSD[a,b]
-3	100	100	100	100	0.00	0.00
-2	100	100	100	100	0.00	0.00
-1	100	100	100	100	0.00	0.00
0	99.8	99.9	99.9	99.9	0.06	0.10
1	99.7	99.8	99.8	99.8	0.06	0.10
2	99.3	99.5	99.4	99.4	0.10	0.06
3	98.8	99.0	99.1	98.9	0.15	0.10
4	97.3	97.7	97.8	97.6	0.26	0.27
5	NA	NA	NA	NA	NA	NA
6	NA	NA	NA	NA	NA	NA
7	NA	NA	NA	NA	NA	NA
8	26.8	26	26.3	26.4	0.40	1.52
9	NA	NA	NA	NA	NA	NA
10	NA	NA	NA	NA	NA	NA

Phi Size	1606032-13 (Rep 1) (%)	1606032-13 (Rep 2) (%)	1606032-13 (Rep 3) (%)	AVE (%)	STDEV	% RSD[a,b]
-3	100	100	100	100	0.00	0.00
-2	100	100	100	100	0.00	0.00
-1	100	100	100	100	0.00	0.00
0	99.9	99.9	99.9	99.9	0.00	0.00
1	99.4	99.4	99.6	99.5	0.12	0.10
2	99.0	98.9	99.0	98.9	0.06	0.00
3	98.4	98.5	98.4	98.4	0.06	0.00
4	96.8	97.1	96.7	96.9	0.21	0.21
5	NA	NA	NA	NA	NA	NA
6	NA	NA	NA	NA	NA	NA
7	NA	NA	NA	NA	NA	NA
8	27.4	27.0	26.5	27.0	0.45	1.48
9	NA	NA	NA	NA	NA	NA
10	NA	NA	NA	NA	NA	NA

Table D-4. Laboratory Triplicates continued

Phi Size	1606032-01 (Rep 1) (%)	1606032-01 (Rep 2) (%)	1606032-01 (Rep 3) (%)	AVE (%)	STDEV	% RSD[a,b]
-3	100	100	100	100	0.00	0.00
-2	100	100	100	100	0.00	0.00
-1	99.9	99.9	100	99.9	0.06	0.12
0	99.8	99.8	99.8	99.8	0.00	0.00
1	99.4	99.3	99.4	99.4	0.06	0.10
2	98.7	98.7	98.8	98.7	0.06	0.06
3	97.5	97.6	97.9	97.7	0.21	0.20
4	96.0	96.0	96.3	96.1	0.17	0.21
5	NA	NA	NA	NA	NA	NA
6	NA	NA	NA	NA	NA	NA
7	NA	NA	NA	NA	NA	NA
8	31.2	29.3	28.3	29.6	1.47	5.07
9	NA	NA	NA	NA	NA	NA
10	NA	NA	NA	NA	NA	NA

a. RSD as reported by Materials Testing and Consultant, Inc. Laboratory.
b. Minor discrepancies due to rounding differences.
AVE = average.
MQO = Measurement Quality Objectives.
RSD = Relative Standard Deviation.
STDEV = standard deviation.

Table D-5. Field Replicates

Analyte	Sample ID	Replicate Sample ID	Sample Result (%)	Replicate Result (%)	AVE (%)	STDEV	% RPD
TOC	1606031-13	1606031-14	0.40	0.40	0.40	0.00	0.0
	1606031-42	1606031-43	0.20	0.26	0.23	0.04	26
	1606031-73	1606031-74	0.14	0.14	0.14	0.00	0.0
	1606031-95	1606031-96	0.17	0.17	0.17	0.00	0.0
	1606032-01	1606032-02	2.06	2.29	2.18	0.16	11
TVS	1606031-13	1606031-14	2.20	2.00	2.10	0.14	10
	1606031-42	1606031-43	1.50	1.70	1.60	0.14	12
	1606031-73	1606031-74	1.30	1.40	1.35	0.07	7.4
	1606031-95	1606031-96	1.40	1.40	1.40	0.00	0.0
	1606032-01	1606032-02	5.60	5.70	5.65	0.07	1.8
Percent Solids	1606031-13	1606031-14	70.6	71.7	71.2	0.78	1.5
	1606031-42	1606031-43	71.9	71.2	71.6	0.49	1.0
	1606031-73	1606031-74	73.3	75.1	74.2	1.27	2.4
	1606031-95	1606031-96	72.6	72.7	72.6	0.07	0.1
	1606032-01	1606032-02	49.3	48.0	48.6	0.92	2.7
Gravel	1606031-13	1606031-14	0.40	0.20	0.30	0.14	67
	1606031-42	1606031-43	0.00	0.00	0.00	0.00	0.0
	1606031-73	1606031-74	0.10	0.00	0.05	0.07	200
	1606031-95	1606031-96	0.00	0.00	0.00	0.00	0.0
	1606032-01 (Lab Rep 1)	1606032-02	0.10	0.00	0.05	0.07	200
	1606032-01 (Lab Rep 2)	1606032-02	0.10	0.00	0.05	0.07	200
	1606032-01 (Lab Rep 3)	1606032-02	0.00	0.00	0.00	0.00	0.0
Sand	1606031-13	1606031-14	75.8	75.0	75.4	0.56	1.1
	1606031-42	1606031-43	92.2	91.9	92.1	0.21	0.3
	1606031-73	1606031-74	98.4	98.1	98.2	0.21	0.3
	1606031-95	1606031-96	94.2	94.4	94.3	0.14	0.2
	1606032-01 (Lab Rep 1)	1606032-02	3.90	3.40	3.65	0.35	14
	1606032-01 (Lab Rep 2)	1606032-02	3.90	3.40	3.65	0.35	14
	1606032-01 (Lab Rep 3)	1606032-02	3.70	3.40	3.55	0.21	8.4
Silt	1606031-13	1606031-14	21.5	21.5	21.5	0.00	0.0
	1606031-42	1606031-43	7.50	7.60	7.55	0.07	1.3
	1606031-73	1606031-74	1.30	1.70	1.50	0.28	27
	1606031-95	1606031-96	5.30	5.20	5.25	0.07	1.9
	1606032-01 (Lab Rep 1)	1606032-02	64.8	70.5	67.6	4.03	8.4
	1606032-01 (Lab Rep 2)	1606032-02	66.7	70.5	68.6	2.69	5.5
	1606032-01 (Lab Rep 3)	1606032-02	68.0	70.5	69.2	1.77	3.6

Analyte	Sample ID	Replicate Sample ID	Sample Result (%)	Replicate Result (%)	AVE (%)	STDEV	% RPD
Clay	1606031-13	1606031-14	2.30	3.40	2.85	0.78	38
	1606031-42	1606031-43	0.30	0.50	0.40	0.14	50
	1606031-73	1606031-74	0.20	0.20	0.20	0.00	0.0
	1606031-95	1606031-96	0.50	0.40	0.45	0.07	22
	1606032-01 (Lab Rep 1)	1606032-02	31.2	26.1	28.6	3.61	18
	1606032-01 (Lab Rep 2)	1606032-02	29.3	26.1	27.7	2.26	12
	1606032-01 (Lab Rep 3)	1606032-02	28.3	26.1	27.2	1.56	8.1
Fines (Silt/Clay)	1606031-13	1606031-14	23.8	24.9	24.3	0.78	4.5
	1606031-42	1606031-43	7.80	8.10	7.95	0.21	3.8
	1606031-73	1606031-74	1.50	1.90	1.70	0.28	24
	1606031-95	1606031-96	5.80	5.60	5.70	0.14	3.5
	1606032-01 (Lab Rep 1)	1606032-02	96.0	96.6	96.3	0.42	0.6
	1606032-01 (Lab Rep 2)	1606032-02	96.0	96.6	96.3	0.42	0.6
	1606032-01 (Lab Rep 3)	1606032-02	96.3	96.6	96.4	0.21	0.3

AVE = average.
RSD = Relative Standard Deviation.
TOC = Total Organic Carbon
TVS = Total Volatile Solids.
STDEV = standard deviation.

Appendix E. Video Snapshots Captured Along Video Transects

Appendix E is available only online as a zip file. It is linked to this report at:
https://fortress.wa.gov/ecy/publications/SummaryPages/1703025.html

Appendix F. Ecology Video Survey Data and Information

Appendix F is available in Excel only online as zip files. They are linked to this report at:
https://fortress.wa.gov/ecy/publications/SummaryPages/1703025.html

Appendix G. Laboratory Results

Table G-1. Laboratory results for Solids, Total Volatile Solids, and Total Organic Carbon @ 70°F.

Location ID	Sample ID	Solids (%)	TVS (%)	TOC (%)	Replicates	Field/Lab Rep #
BB-F10-01a	1606031-01	73.4	1.70	0.23		
BB-F10-02b	1606031-02	74.4	1.40	0.12		
BB-F10-03c	1606031-03	60.5	4.10	1.19		
BB-F10-05b	1606031-05	74.1	1.30	0.14		
BB-F10-06c	1606031-06	73.1	1.30	0.13		
BB-F10-07a	1606031-07	71.6	1.80	0.32		
BB-F10-08b	1606031-08	73.2	1.40	0.18		
BB-F10-10a	1606031-10	70.7	1.70	0.35		
BB-F10-11b	1606031-11	73.9	1.40	0.16		
BB-F10-12c	1606031-12	74.6	1.40	0.14		
BB-F10-13a	1606031-13	70.6	2.20	0.40	Sample 1606031-14 is a field replicate of Sample 1606031-13	1
BB-F10-13a	1606031-14	71.7	2.00	0.40	Sample 1606031-14 is a field replicate of Sample 1606031-13	2
BB-F10-14a	1606031-15	73.2	1.50	0.18		
BB-F10-15b	1606031-16	73.8	1.20	0.12		
BB-F10-16c	1606031-17	74.4	1.20	0.11		
BB-F10-17d	1606031-18	67.9	3.10	0.76		
BB-F10-18a	1606031-19	73.9	1.00	0.12		
BB-F10-19a	1606031-20	73.4	1.30	0.13		
BB-F10-20b	1606031-21	74.8	1.70	0.60		
BB-F10-21a	1606031-22	73.7	1.40	0.14		
BB-F10-23a	1606031-24	74.1	1.40	0.18		
BB-F10-24b	1606031-25	74.9	1.30	0.14		
BB-F10-25c	1606031-26	73.2	1.40	0.11		
BB-F10-26a	1606031-27	72.0	1.40	0.19		
BB-F10-27b	1606031-28	81.4	0.90	0.10U		
BB-F10-28c	1606031-29	68.2	2.20	0.74		
BB-F10-29a	1606031-30	74.8	1.40	0.21		
BB-F10-30b	1606031-31	66.3	4.50	1.50		
BB-F10-31c	1606031-32	75.9	1.20	0.17		
BB-F10-32d	1606031-33	76.5	1.00	0.10		
BB-F10-33e	1606031-34	71.5	2.10	0.37		
BB-F10-34a	1606031-35	73.5	1.10	0.19		

Location ID	Sample ID	Solids (%)	TVS (%)	TOC (%)	Replicates	Field/Lab Rep #
BB-F10-35b	1606031-36	74.5	1.30	0.11		
BB-F10-37a	1606031-38	80.4	1.00	0.17		
BB-F10-38b	1606031-39	72.3	1.50	0.23		
BB-F10-40d	1606031-41	73.7	1.10	0.26		
BB-F10-41e	1606031-42	71.9	1.50	0.20	Sample 1606031-43 is a field replicate of Sample 1606031-42	1
BB-F10-41e	1606031-43	71.2	1.70	0.26	Sample 1606031-43 is a field replicate of Sample 1606031-42	2
BB-F10-42f	1606031-44	69.2	2.30	0.41		
BB-F10-44b	1606031-46	71.7	1.50	0.61		
BB-F10-45c	1606031-47	72.0	1.80	0.61		
BB-F10-46d	1606031-48	72.2	1.40	0.20		
BB-F10-47e	1606031-49	72.1	1.70	0.26		
BB-F10-48f	1606031-50	58.4	4.60	1.43		
BB-F09-04a	1606031-54	74.0	1.30	0.16		
BB-F09-05b	1606031-55	73.3	1.50	0.17		
BB-F09-06c	1606031-56	76.4	1.30	0.10		
BB-F09-07a	1606031-57	73.1	1.40	0.15		
BB-F09-11a	1606031-61	76.0	1.20	0.14		
BB-F09-12b	1606031-62	60.0	4.10	1.21		
BB-F09-13c	1606031-63	50.7	4.90	1.24		
BB-F09-14a	1606031-64	72.7	1.40	0.17		
BB-F09-15b	1606031-65	74.8	1.30	0.13		
BB-F09-17d	1606031-67	57.8	4.60	2.02		
BB-F09-18a	1606031-68	76.9	1.20	0.13		
BB-F09-19b	1606031-69	74.7	1.30J	0.14		
BB-F09-20c	1606031-70	59.4	3.90	1.12		
BB-F09-22a	1606031-72	73.2	1.40	0.15		
BB-F09-23b	1606031-73	73.3	1.30	0.14	Sample 1606031-74 is a field replicate of Sample 1606031-73	1
BB-F09-23b	1606031-74	75.1	1.40	0.14	Sample 1606031-74 is a field replicate of Sample 1606031-73	2
BB-F09-24c	1606031-75	60.3	4.10	1.22		
BB-F09-25a	1606031-76	72.8	1.40	0.17		
BB-F09-26a	1606031-77	75.1	1.00	0.14		
BB-F09-27a	1606031-78	39.1	15.3	5.71		
BB-F09-28a	1606031-79	74.7	1.40	0.12		
BB-F09-29b	1606031-80	75.4	1.20	0.12		
BB-F09-30c	1606031-81	72.6	1.60	0.31		

Location ID	Sample ID	Solids (%)	TVS (%)	TOC (%)	Replicates	Field/Lab Rep #
BB-F09-31d	1606031-82	60.7	4.10	1.26		
BB-F09-32e	1606031-83	61.3	3.50	0.88		
BB-F09-34b	1606031-85	74.1	1.30	0.15		
BB-F09-35a	1606031-86	70.0	1.90	0.37		
BB-F09-36b	1606031-87	71.8	1.40	0.18		
BB-F09-37c	1606031-88	70.7	1.40	0.17		
BB-F09-40c	1606031-91	55.9	4.30	1.07		
BB-F09-42b	1606031-93	74.7	1.30	0.13		
BB-F08-01a	1606031-94	72.0	1.30	0.24		
BB-F08-02b	1606031-95	72.6	1.40	0.17	Sample 1606031-96 is a field replicate of Sample 1606031-95	1
BB-F08-02b	1606031-96	72.7	1.40	0.17	Sample 1606031-96 is a field replicate of Sample 1606031-95	2
BB-F08-04d	1606031-98	59.3	4.50	1.60		
BB-F08-06f	1606032-01	49.3	5.60	2.06	Sample 1606032-02 is a field replicate of Sample 1606032-01	1
BB-F08-06f	1606032-02	48.0	5.70	2.29	Sample 1606032-02 is a field replicate of Sample 1606032-01	2
BB-F08-09a	1606032-05	68.7	2.90	0.85		
BB-F08-11c	1606032-07	59.2	4.60	1.25		
BB-F08-16a	1606032-12	66.1	3.00	0.76		
BB-F08-17b	1606032-13	51.6	5.40	1.44		
BB-F08-18c	1606032-14	50.9	4.90	1.15		
BB-1424-06c	1606032-22	62.1	4.10	0.93		
BB-1424-07d	1606032-23	47.7	5.90	1.73		
BB-1423-03c	1606032-26	54.6	5.30	1.47		
BB-1423-06b	1606032-29	74.0	1.50	0.17		
BB-1423-07c	1606032-30	57.4	5.10	1.41		

J = The analyte was positively identified. The associated numerical result is an estimate.
TOC = Total Organic Carbon @ 70° F.
TVS = Total Volatile Solids.
U = The analyte was not detected at or above the reported result.

Table G-2. Laboratory results for Grain Size.

Location ID	Sample ID	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Fines[a] (%)	Phi Scale -1 to 0 (%)	Phi Scale 0 to 1 (%)	Phi Scale 1 to 2 (%)	Phi Scale 2 to 3 (%)	Phi Scale 3 to 4 (%)	Replicates	Field / Lab Rep #
BB-F10-01a	1606031-01	0.0	89.7	9.70	0.60	10.3	0.10	0.70	10.1	48.0	30.8		
BB-F10-02b	1606031-02	0.0	96.0	3.70	0.20	3.90	0.10	1.10	21.0	58.4	15.5		
BB-F10-03c	1606031-03	0.0	14.6	67.6	17.8	85.4	0.10	0.30	0.50	1.80	11.9	Lab Replicate	1
BB-F10-03c	1606031-03	0.2	14.0	71.2	14.6	85.8	0.00	0.30	0.50	1.80	11.4	Lab Replicate	2
BB-F10-03c	1606031-03	0.0	14.7	70.7	14.6	85.3	0.10	0.40	0.50	1.80	12.0	Lab Replicate	3
BB-F10-05b	1606031-05	0.0	97.5	2.30	0.20	2.50	0.10	2.20	24.3	59.4	11.6		
BB-F10-06c	1606031-06	0.1	97.5	2.30	0.10	2.40	0.10	2.40	38.2	50.3	6.40		
BB-F10-07a	1606031-07	0.0	83.6	14.9	1.50	16.4	0.10	0.70	7.30	39.7	35.9		
BB-F10-08b	1606031-08	0.0	96.3	3.30	0.40	3.70	0.10	1.00	18.3	60.3	16.7		
BB-F10-10a	1606031-10	0.0	78.1	20.1	1.70	21.8	0.10	0.40	3.10	33.9	40.6		
BB-F10-11b	1606031-11	0.0	97.0	2.70	0.30	3.00	0.00	0.20	8.60	66.7	21.4		
BB-F10-12c	1606031-12	0.0	95.6	4.20	0.20	4.40	0.00	0.90	19.8	60.4	14.5		
BB-F10-13a	1606031-13	0.4	75.8	21.5	2.30	23.8	0.20	0.50	8.70	49.0	17.4	Sample 1606031-14 is a field replicate of Sample 1606031-13	1
BB-F10-13a	1606031-14	0.2	75.0	21.5	3.40	24.9	0.10	0.50	9.00	47.7	17.7	Sample 1606031-14 is a field replicate of Sample 1606031-13	2
BB-F10-14a	1606031-15	0.1	92.2	7.20	0.50	7.70	0.10	0.50	15.1	43.5	33.1		
BB-F10-15b	1606031-16	0.1	97.6	2.10	0.20	2.30	0.10	0.80	29.5	52.4	14.8		
BB-F10-16c	1606031-17	0.0	95.9	4.00	0.10	4.10	0.00	0.30	22.7	66.0	6.90		
BB-F10-17d	1606031-18	0.0	51.1	42.3	6.60	48.9	0.10	0.40	1.90	17.8	30.9		
BB-F10-18a	1606031-19	0.0	97.9	2.00	0.20	2.20	0.00	0.60	35.7	57.3	4.20		
BB-F10-19a	1606031-20	0.0	97.2	2.60	0.20	2.80	0.00	1.00	28.6	56.4	11.1		
BB-F10-20b	1606031-21	0.1	95.6	4.20	0.20	4.40	0.20	1.40	28.1	55.0	11.0		
BB-F10-21a	1606031-22	0.0	93.4	6.20	0.30	6.50	0.00	0.20	10.6	56.2	26.4		
BB-F10-23a	1606031-24	0.1	95.1	4.30	0.50	4.80	0.10	1.00	27.9	48.9	17.3		

Location ID	Sample ID	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Fines[a] (%)	Phi Scale -1 to 0 (%)	Phi Scale 0 to 1 (%)	Phi Scale 1 to 2 (%)	Phi Scale 2 to 3 (%)	Phi Scale 3 to 4 (%)	Replicates	Field / Lab Rep #
BB-F10-24b	1606031-25	0.2	96.4	3.00	0.40	3.40	0.10	1.10	20.0	59.6	15.6		
BB-F10-25c	1606031-26	0.0	98.7	1.10	0.10	1.20	0.00	0.30	21.3	66.2	10.8		
BB-F10-26a	1606031-27	0.0	94.7	0.20	5.10	5.30	0.00	0.20	6.40	62.3	25.8		
BB-F10-27b	1606031-28	0.0	98.7	1.20	0.10	1.30	0.00	0.20	21.9	65.2	11.4		
BB-F10-28c	1606031-29	0.2	88.2	10.7	0.80	11.5	0.20	0.60	15.1	50.7	21.6		
BB-F10-29a	1606031-30	0.1	94.4	4.80	0.70	5.50	0.10	1.40	33.2	49.4	10.3		
BB-F10-30b	1606031-31	0.6	66.9	30.2	2.30	32.5	0.80	1.40	25.2	19.7	19.9		
BB-F10-31c	1606031-32	0.0	95.3	4.50	0.20	4.70	0.00	0.30	14.6	53.0	27.4		
BB-F10-32d	1606031-33	0.0	99.0	0.90	0.10	1.00	0.00	0.30	24.7	68.2	5.70		
BB-F10-33e	1606031-34	0.0	70.9	25.4	3.60	29.0	0.00	0.30	3.70	28.5	38.4		
BB-F10-34a	1606031-35	0.0	96.5	3.20	0.30	3.50	0.10	1.00	20.8	53.2	21.3		
BB-F10-35b	1606031-36	0.0	98.7	1.30	0.00	1.30	0.00	0.40	15.0	74.4	9.00		
BB-F10-37a	1606031-38	0.0	98.5	1.30	0.20	1.50	0.00	0.10	18.8	71.6	8.00		
BB-F10-38b	1606031-39	0.1	89.8	9.50	0.70	10.2	0.10	0.70	13.7	39.4	35.8		
BB-F10-40d	1606031-41	0.2	97.1	2.60	0.20	2.80	0.00	0.30	16.1	67.3	13.3		
BB-F10-41e	1606031-42	0.0	92.2	7.50	0.30	7.80	0.00	0.20	9.70	60.6	21.6	Sample 1606031-43 is a field replicate of Sample 1606031-42	1
BB-F10-41e	1606031-43	0.0	91.9	7.60	0.50	8.10	0.10	0.20	10.0	60.8	20.8	Sample 1606031-43 is a field replicate of Sample 1606031-42	2
BB-F10-42f	1606031-44	0.0	64.3	32.0	3.70	35.7	0.00	0.10	0.70	22.1	41.3		
BB-F10-44b	1606031-46	0.0	88.9	10.2	0.90	11.1	0.00	0.30	6.70	42.4	39.4		
BB-F10-45c	1606031-47	0.0	81.3	17.1	1.60	18.7	0.10	0.60	6.90	37.9	35.9		
BB-F10-46d	1606031-48	0.0	89.3	10.0	0.70	10.7	0.00	0.30	10.9	52.8	25.2		
BB-F10-47e	1606031-49	0.0	85.6	13.1	1.30	14.4	0.10	0.40	5.40	49.8	29.9		
BB-F10-48f	1606031-50	1.7	12.7	71.0	14.6	85.6	0.30	0.50	0.50	2.50	8.90		
BB-F09-04a	1606031-54	0.1	97.6	2.00	0.40	2.40	0.00	0.70	20.5	61.5	14.8		

Location ID	Sample ID	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Fines[a] (%)	Phi Scale -1 to 0 (%)	Phi Scale 0 to 1 (%)	Phi Scale 1 to 2 (%)	Phi Scale 2 to 3 (%)	Phi Scale 3 to 4 (%)	Replicates	Field / Lab Rep #
BB-F09-05b	1606031-55	0.2	97.1	2.50	0.30	2.80	0.10	1.00	29.0	56.2	10.8		
BB-F09-06c	1606031-56	0.2	98.7	1.10	0.10	1.20	0.10	2.10	55.4	38.8	2.40		
BB-F09-07a	1606031-57	0.1	94.1	5.30	0.40	5.70	0.00	1.70	27.8	35.9	28.7		
BB-F09-11a	1606031-61	0.1	98.6	1.30	0.00	1.30	0.00	1.10	31.1	60.4	5.90		
BB-F09-12b	1606031-62	0.0	24.8	63.8	11.4	75.2	0.20	0.70	1.30	4.50	18.1		
BB-F09-13c	1606031-63	0.1	5.8	71.4	22.7	94.1	0.10	0.40	0.80	1.00	3.70		
BB-F09-14a	1606031-64	0.3	95.9	3.20	0.60	3.80	0.10	0.40	11.8	57.1	26.5		
BB-F09-15b	1606031-65	0	98.1	1.70	0.20	1.90	0.10	0.70	19.6	61.9	15.8		
BB-F09-17d	1606031-67	7.9	28.7	45.6	17.8	63.4	5.60	3.50	5.10	9.50	5.00		
BB-F09-18a	1606031-68	0.1	98.2	1.50	0.20	1.70	0.00	1.70	39.0	46.7	10.8		
BB-F09-19b	1606031-69	0.0	98.1	1.90	0.10	2.00	0.00	0.50	16.9	70.4	10.3		
BB-F09-20c	1606031-70	0.1	25.7	60.7	13.5	74.2	0.40	0.90	3.00	9.50	11.9		
BB-F09-22a	1606031-72	0.0	94.8	4.80	0.40	5.20	0.00	0.70	27.2	51.5	15.3		
BB-F09-23b	1606031-73	0.1	98.4	1.30	0.20	1.50	0.10	1.00	23.1	63.0	11.2	Sample 1606031-74 is a field replicate of Sample 1606031-73	1
BB-F09-23b	1606031-74	0.0	98.1	1.70	0.20	1.90	0.10	1.00	23.8	61.9	11.3	Sample 1606031-74 is a field replicate of Sample 1606031-73	2
BB-F09-24c	1606031-75	0.0	12.6	70.8	16.6	87.4	0.00	0.50	2.80	5.60	3.70		
BB-F09-25a	1606031-76	0.0	96.2	3.30	0.20	3.50	0.00	0.80	21.1	50.2	24.0		
BB-F09-26a	1606031-77	0.0	97.7	2.20	0.20	2.40	0.00	1.50	38.5	46.8	10.8		
BB-F09-27a	1606031-78	3.7	50.8	40.5	5.00	45.5	4.60	5.10	24.4	10.0	6.80		
BB-F09-28a	1606031-79	0.0	99.8	0.10	0.10	0.20	0.30	10.1	51.4	32.2	5.90		
BB-F09-29b	1606031-80	0.0	98.5	1.40	0.10	1.50	0.00	0.70	28.9	63.6	5.30		
BB-F09-30c	1606031-81	0.0	91.3	8.10	0.50	8.60	0.10	0.60	15.5	54.0	21.2		
BB-F09-31d	1606031-82	0.0	13.4	76.6	10.0	86.6	0.00	0.40	0.50	1.40	11.1		
BB-F09-32e	1606031-83	0.4	35.6	47.5	16.5	64.0	0.00	0.30	5.40	23.5	6.40		

Location ID	Sample ID	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Fines[a] (%)	Phi Scale -1 to 0 (%)	Phi Scale 0 to 1 (%)	Phi Scale 1 to 2 (%)	Phi Scale 2 to 3 (%)	Phi Scale 3 to 4 (%)	Replicates	Field / Lab Rep #
BB-F09-34b	1606031-85	0.0	96.0	3.70	0.30	4.00	0.00	0.60	19.6	57.8	18.0		
BB-F09-35a	1606031-86	0.1	86.6	12.5	0.80	13.3	0.20	0.80	8.40	39.1	38.1		
BB-F09-36b	1606031-87	0.0	93.5	6.20	0.30	6.50	0.00	0.50	13.7	45.7	33.5		
BB-F09-37c	1606031-88	0.0	93.5	6.00	0.40	6.40	0.00	0.10	3.20	44.9	45.4		
BB-F09-40c	1606031-91	0.8	23.5	52.7	23.0	75.7	0.20	0.40	3.50	15.1	4.30		
BB-F09-42b	1606031-93	0.0	96.8	2.90	0.30	3.20	0.00	0.60	23.1	58.0	15.1		
BB-F08-01a	1606031-94	0.0	81.3	17.6	1.00	18.6	0.00	0.10	2.30	16.2	62.8		
BB-F08-02b	1606031-95	0.0	94.2	5.30	0.50	5.80	0.00	0.30	11.3	58.7	23.9	Sample 1606031-96 is a field replicate of Sample 1606031-95	1
BB-F08-02b	1606031-96	0.0	94.4	5.20	0.40	5.60	0.00	0.30	11.0	58.7	24.4	Sample 1606031-96 is a field replicate of Sample 1606031-95	2
BB-F08-04d	1606031-98	0.3	12.0	77.1	10.5	87.6	0.30	0.70	0.70	1.20	9.00		
BB-F08-06f	1606032-01	0.1	3.90	64.8	31.2	96.0	0.10	0.40	0.70	1.20	1.50	Sample 1606032-02 is a field replicate of Sample 1606032-01 / Lab Replicate	1 / 1
BB-F08-06f	1606032-01	0.1	3.90	66.7	29.3	96.0	0.10	0.50	0.60	1.10	1.60	Sample 1606032-02 is a field replicate of Sample 1606032-01 / Lab Replicate	1 / 2
BB-F08-06f	1606032-01	0.0	3.70	68.0	28.3	96.3	0.10	0.40	0.60	1.00	1.60	Sample 1606032-02 is a field replicate of Sample 1606032-01 / Lab Replicate	1 / 3
BB-F08-06f	1606032-02	0.0	3.40	70.5	26.1	96.6	0.30	0.50	0.50	0.80	1.40	Sample 1606032-02 is a field replicate of Sample 1606032-01	2
BB-F08-09a	1606032-05	0.6	56.3	39.1	4.00	43.1	0.20	0.30	0.50	4.40	50.8		
BB-F08-11c	1606032-07	0.0	8.50	70.0	21.5	91.5	0.10	0.10	0.80	4.10	3.40		
BB-F08-16a	1606032-12	0.0	13.2	78.5	8.30	86.8	0.20	0.30	0.60	1.20	10.9		
BB-F08-17b	1606032-13	0.0	3.20	69.4	27.4	96.8	0.10	0.50	0.40	0.60	1.60	Lab Replicate	1
BB-F08-17b	1606032-13	0.0	2.90	70.2	27.0	97.2	0.10	0.50	0.50	0.40	1.40	Lab Replicate	2

Location ID	Sample ID	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Fines[a] (%)	Phi Scale -1 to 0 (%)	Phi Scale 0 to 1 (%)	Phi Scale 1 to 2 (%)	Phi Scale 2 to 3 (%)	Phi Scale 3 to 4 (%)	Replicates	Field / Lab Rep #
BB-F08-17b	1606032-13	0.0	3.30	70.2	26.5	96.7	0.10	0.30	0.60	0.10	1.70	Lab Replicate	3
BB-F08-18c	1606032-14	0.1	12.3	55.6	32.0	87.6	0.20	0.60	5.30	3.90	2.30		
BB-1424-06c	1606032-22	0.0	3.90	84.0	12.2	96.2	0.10	0.30	0.30	0.40	2.80		
BB-1424-07d	1606032-23	0.1	3.00	70.0	26.9	96.9	0.10	0.20	0.50	0.70	1.50		
BB-1423-03c	1606032-26	0.0	2.60	70.6	26.8	97.4	0.20	0.10	0.40	0.50	1.50	Lab Replicate	1
BB-1423-03c	1606032-26	0.0	2.30	71.8	26.0	97.8	0.10	0.10	0.30	0.40	1.30	Lab Replicate	2
BB-1423-03c	1606032-26	0.0	2.20	71.5	26.3	97.8	0.00	0.10	0.40	0.30	1.30	Lab Replicate	3
BB-1423-06b	1606032-29	0.1	97.0	2.40	0.50	2.90	0.00	0.20	11.6	68.8	16.4		
BB-1423-07c	1606032-30	0.0	5.50	76.4	18.1	94.5	0.10	0.40	1.10	0.80	3.00	Lab Replicate	1
BB-1423-07c	1606032-30	0.0	4.40	78.0	17.6	95.6	0.10	0.60	0.50	0.50	2.70	Lab Replicate	2
BB-1423-07c	1606032-30	0.0	4.60	76.8	18.6	95.4	0.10	0.60	0.50	0.40	3.00	Lab Replicate	3

a. Fines = silt and clay.

Table G-3. Summary Statistics for TOC, TVS, and Grain Size.

Parameter	N	Min	Max	Median	Mean	Std Dev
Solids	91	39.1	81.4	72.6	69.1	8.33
TVS	91	0.90	15.3	1.40	2.38	1.97
TOC	91	0.10	5.71	0.20	0.57	0.77
Gravel	91	0.00	7.90	0.00	0.22	0.92
Sand	91	2.40	99.8	93.5	72.9	34.9
Silt	91	0.10	84.0	6.20	21.8	27.1
Clay	91	0.00	32.0	0.50	5.07	8.48
Fines	91	0.20	97.7	6.50	26.9	34.7

Std Dev = standard deviation.
TOC = Total Organic Carbon @ 70° F.
TVS = Total Volatile Solids.

Appendix H. Pictures of Woody Debris Observed in Float Tests of Sediment Samples

Appendix H is available only online as a zip file. It is linked to this report at:
https://fortress.wa.gov/ecy/publications/SummaryPages/1703025.html

Appendix I. Glossary, Acronyms, and Abbreviations

Glossary

Anthropogenic: Human-caused.

Mean Lower Low Water (MLLW): 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).

Parameter: Water quality constituent being measured (analyte). A physical, chemical, or biological property whose values determine environmental characteristics or behavior.

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

Subtidal zone: refers to that portion of the tidal-flat environment which lies below the level of mean low water. Normally it is covered by water at all states of the tide.

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
DNR	Washington State Department of Natural Resources
Ecology	Washington State Department of Ecology
e.g.	For example
EIM	Environmental Information Management database
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
QAPP	Quality Assurance Project Plan

RPD	Relative percent difference
RSD	Relative standard deviation
SMS	Sediment Management Standards
SOP	Standard operating procedures
TOC	Total organic carbon
TVS	Total volatile solids
WAC	Washington Administrative Code
WRIA	Water Resource Inventory Area

Units of Measurement

DD	decimal degrees
ft	feet
lbs	pounds
m	meter
x	number