# Little Squalicum Creek Estuary

## Soil and Groundwater Characterization

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Cover photo: Logging direct push cores at Little Squalicum Park, Bellingham, WA, September 2012 (photo by M. O'Herron)

# Little Squalicum Creek Estuary

# Soil and Groundwater Characterization

by

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

Water Resource Inventory Areas (WRIAs):
- 1 - Nooksack

Eight-digit Hydrologic Unit Code (HUC) numbers:
- 17110004

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# Abstract

In partnership with the Washington State Department of Ecology (Ecology), the City of Bellingham, Washington developed a design proposal to excavate and re-grade the southern portion of a city park (Little Squalicum Park). The goal of this excavation project will be to create a tidal estuary connecting Little Squalicum Creek and Bellingham Bay. The proposed estuary would restore critical habitat, a benefit consistent with the strategic goals of the Bellingham Bay Demonstration Pilot Project.

The proposed estuary is located hydraulically downgradient of areas contaminated by past practices at the Oeser Company wood treatment facility. Most of the affected soils and groundwater have been remediated under federal cleanup authority, with oversight by the U.S. Environmental Protection Agency, Region 10. However, some contaminated soil still remains in place immediately upgradient of the proposed estuary. In addition, shallow soil and groundwater petroleum contamination (identified as diesel) has been observed in reconnaissance test pits within the estuary boundary. The origin and extent of the test-pit contamination was unclear.

In September 2012, the Ecology Environmental Assessment Program conducted a field study in the area of the petroleum contamination. Soil and groundwater samples were collected from 8 borings. Twenty soil samples and 2 groundwater samples were collected from above the future estuary sediment surface and tested for a broad suite of organic contaminants. Eight additional soil samples were collected from immediately below that surface and tested for both organic and inorganic contaminants.

Four of the soil samples collected from above the future estuary sediment surface showed concentrations of diesel- and lube-oil-range petroleum products above (failing) Model Toxics Control Act Method A soil cleanup levels. This soil contamination does not appear to be related to wood-preserving activities. No organic contaminants were detected in groundwater. All of the soil samples collected below the future estuary sediment surface met (had concentrations less than) Washington State Sediment Management Standards marine sediment chemical criteria.

Additional investigation is recommended to determine the full extent of the petroleum contamination in the southern portion of the proposed estuary.

# Acknowledgements

The author of this report thanks the following people for their contributions to this study:

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# Introduction

Little Squalicum Park is located in the northwestern portion of Bellingham, Washington. The 21-acre public park comprises two areas, one northeast of Marine Drive (the *upper* park), and one southwest of Marine Drive (the *lower* park) (Figure 1).

The City of Bellingham, in partnership with the Department of Ecology, has proposed to excavate and re-grade portions of the lower park to create a 2-acre estuary (~28,000 cubic yard excavation volume), to enhance the shoreline habitat of Bellingham Bay.

Coastal Geologic Services (CGS), under contract to the City of Bellingham, prepared a final design document describing the construction elements of the proposed estuary, including the final surface topography of the embayment (CGS, 2010). During geotechnical investigations related to the estuary design, field observations of petroleum contamination in shallow test-pit soils near the northern end of the proposed estuary were reported by CGS. On the basis of odor, the soils were interpreted to be contaminated by diesel-based products. CGS recommended further investigation to determine the full extent of the contamination.

In August 2010, during remedial investigation activities associated with the off-property migration of wood preserving contaminants from the Oeser facility (Figure 1), a U.S. Environmental Protection Agency (EPA) Region 10 contractor completed 11 additional shallow soil test-pit excavations and follow-up field screening (olfactory observations, sheen tests, head-space tests) to delineate the extent of the petroleum contamination encountered by CGS (E&E, 2010; CH2M Hill, 2011). While no samples were submitted for laboratory analysis during this effort, E&E concluded that the extent of the petroleum contamination (again interpreted as diesel) was limited to a comparatively small (~3500 $ft^2$) area in the north-central portion of the lower park (E&E, 2010) (Figure 2). These findings were consistent with those reported by Herrenkohl (2009).

Confirmation sampling and laboratory analysis for soil and groundwater contaminant conditions within the proposed excavation boundary will assist project planning and cost estimating for the development of the estuary.

# Project Description

## Project Goal

The goal of this project is to characterize and map contaminant conditions within and immediately beneath the proposed estuary excavation volume. Wood-treating and petroleum-related contaminants are of particular interest due to previous reports of wood preservative and diesel contamination within or upgradient of the study area.

The work described in this report is focused in the area of previously reported shallow diesel contamination at the northern end of the estuary footprint. Due to logistical and budgetary concerns, project sampling occurred only within that portion of the proposed excavation that is clear of trees.

The results from the drilling and sampling activities described in this report will help:

- Delineate the presence and extent of soil and groundwater contamination within the proposed estuary excavation material and evaluate these conditions against state cleanup criteria.
- Determine if soils excavated during the construction of the proposed estuary are likely to require special handling and disposal.
- Characterize contaminant conditions in the deposits that will form the upper surface of the new estuarine habitat and evaluate these conditions against state Sediment Management Standards (SMS) chemical criteria (Ecology, 1995).

## Project Objectives

The objectives of the study were to:

- Collect and describe continuous interval soil cores from a network of environmental investigation wells installed at the site using direct-push drilling techniques, to a total depth ending just below the design estuary surface (depending on location).
- Sub-sample the soil cores above the estuary surface for target contaminants of concern [polycyclic aromatic hydrocarbons (PAHs), pentachlorophenol (PCP), and diesel).
- Collect soil samples from the horizon located immediately below the proposed estuary surface for analysis of potential contaminants of concern for the resulting estuarine habitat (PAHs, PCP, diesel, and metals)
- Where practicable, collect groundwater samples from the shallow, unconfined aquifer beneath the site, using temporary direct-push screen points. Submit the samples to the laboratory for analysis of target contaminants (PAHs, PCP, and diesel).

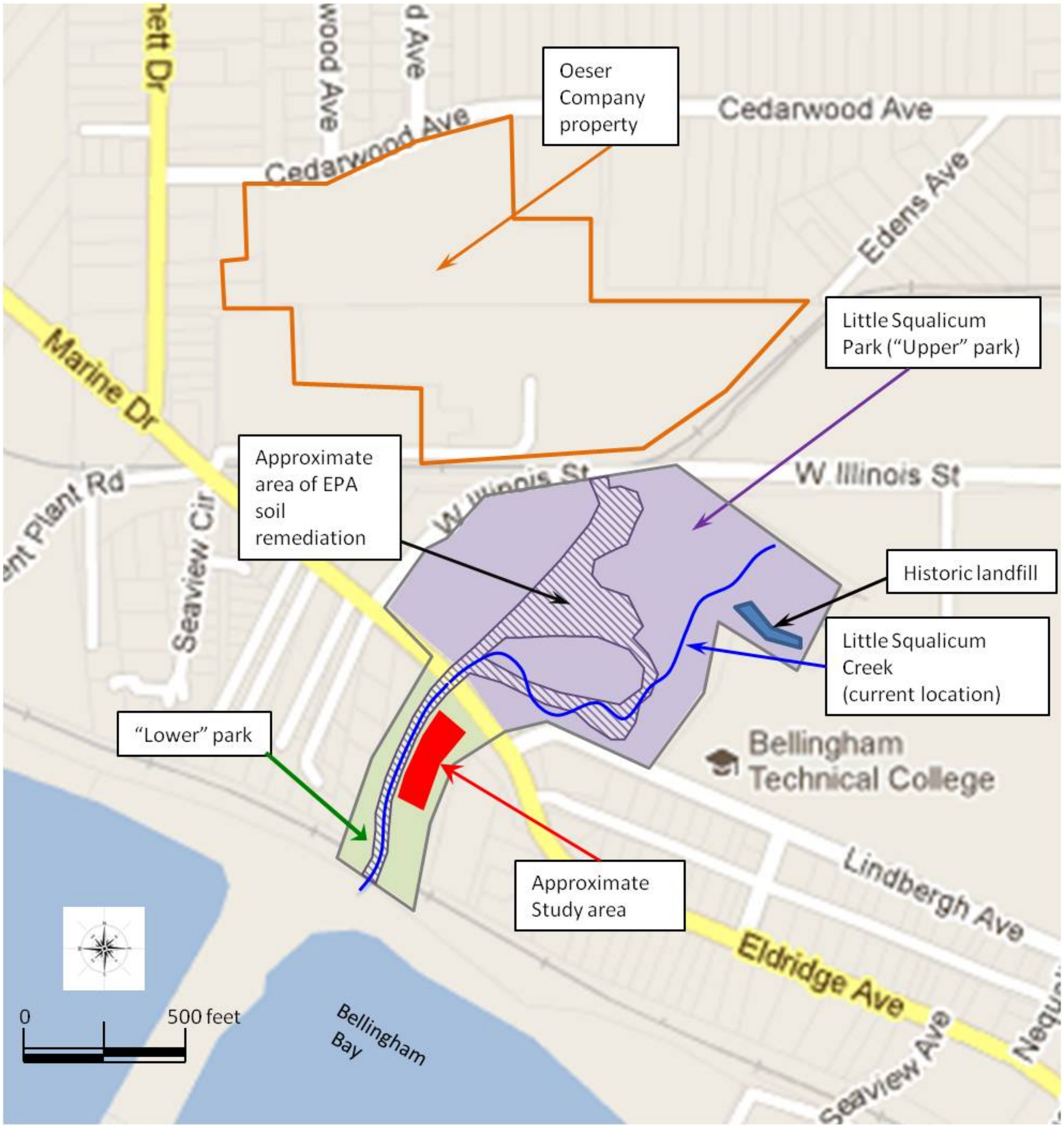
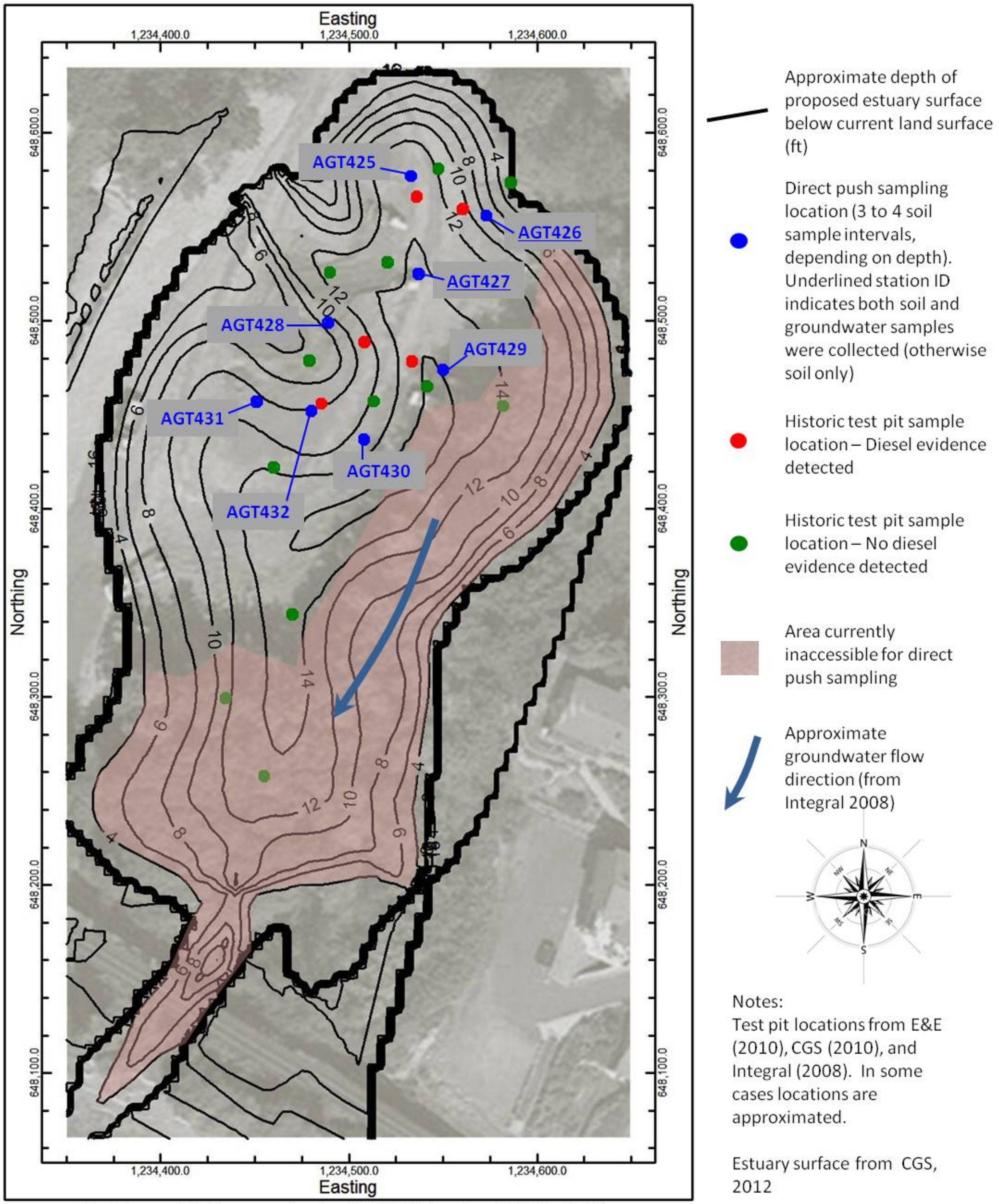


Figure 1. Project Location Map, Bellingham, Washington.



Approximate depth of proposed estuary surface below current land surface (ft)

● Direct push sampling location (3 to 4 soil sample intervals, depending on depth). Underlined station ID indicates both soil and groundwater samples were collected (otherwise soil only)

● Historic test pit sample location – Diesel evidence detected

● Historic test pit sample location – No diesel evidence detected

▨ Area currently inaccessible for direct push sampling

Approximate groundwater flow direction (from Integral 2008)

Notes:
Test pit locations from E&E (2010), CGS (2010), and Integral (2008). In some cases locations are approximated.

Estuary surface from CGS, 2012

Northing and Easting coordinates: NAD83 State plane WA North (ft)

Figure 2. Study Area and Sample Station Location Map.

# Study Area Description and Background

## Study Area Setting and Site History

Sampling and characterization activities for this study were focused in the northern end of lower Little Squalicum Park, immediately east of Little Squalicum Creek (Figures 1, 2, and 3). The ground surface in this area of the park is relatively flat, sloping gently towards the marine shoreline. The creek flows south-southwest through the park before discharging to Bellingham Bay. Creek flow (~1-10 $ft^3$/sec wet season discharge) is reported to be largely sustained by groundwater springs and storm runoff from adjacent properties (Integral, 2008; E&E, 2002).

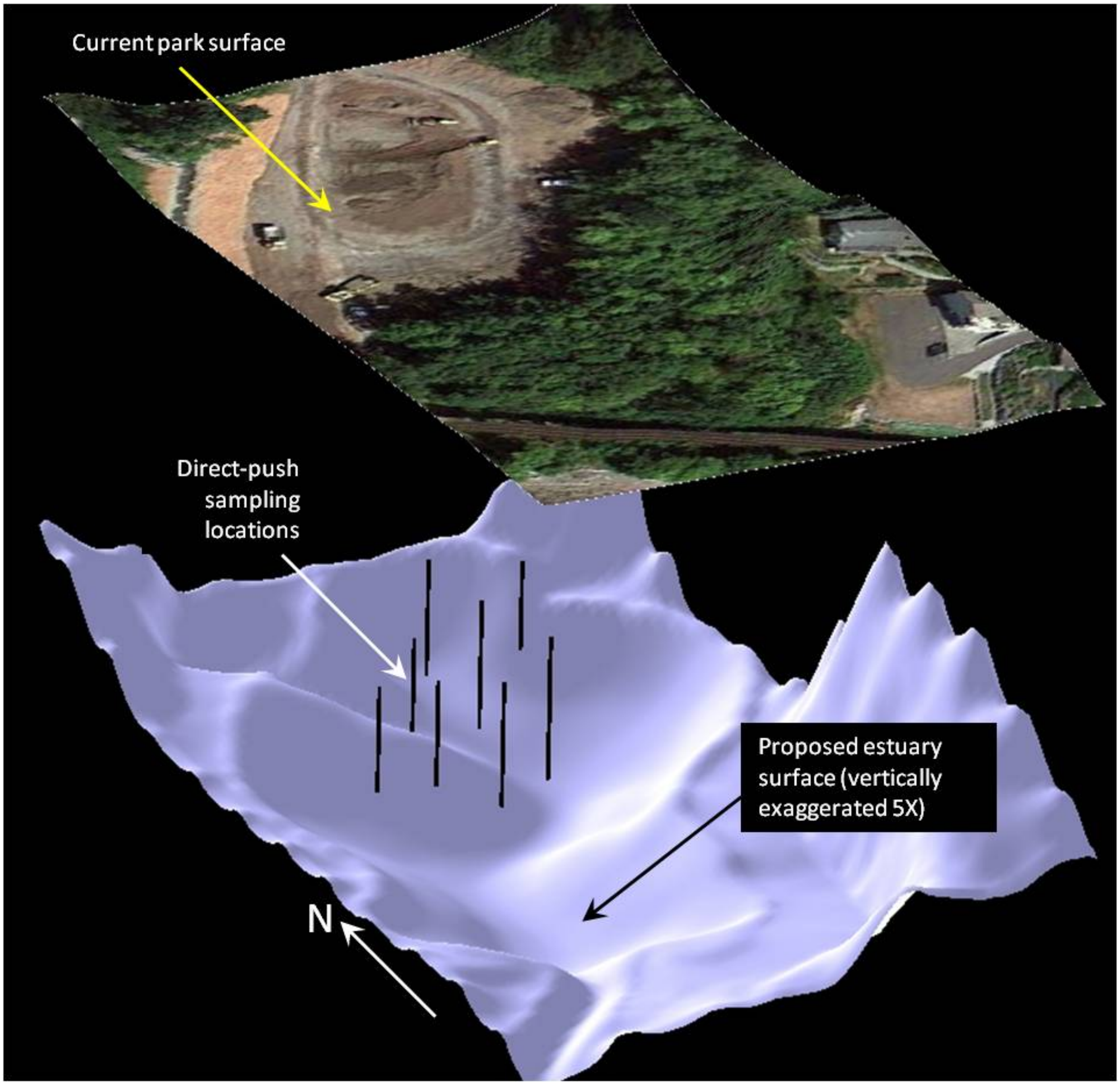
Little Squalicum Park is currently bordered by residential neighborhoods, industrial facilities, a railroad right-of-way, and a technical college. The park is hydraulically downgradient of the Oeser Company property (Figure 1). The Oeser Company has manufactured and treated utility poles at their facility since the mid 1940s. Treatment methods for poles included oil treatment using creosote, and treatment using a 5% pentachlorophenol (PCP) oil-based (Diesel No. 2) solvent mix.

Wood-preserving-related chemicals (PAHs and PCP) transported from the Oeser facility via stormwater drainage and groundwater flow have been identified in soil and groundwater samples collected and analyzed from the upper portion of the park (Integral, 2008). Although remediation activities conducted under the direction of the EPA during 2010 and 2011 resulted in the removal of most of this contamination (CH2M Hill, 2011), Herrenkohl (2010a; 2010b; 2011) reported concerns that obvious creosote contamination remained at depth in the southern portion of the upper park, possibly associated with a breach in a site-wide low permeability clay unit. Additional Oeser-related contamination was identified and remediated in the channel of Little Squalicum Creek in the lower park area during this same period (CH2M Hill, 2011).

The area of interest for this study was used for a variety of industrial or commercial purposes in the past, including sand and gravel mining operations during the 1920s to 1960s, and raw log storage in the early 1970s by the Mt. Baker Plywood company. Herrenkohl (2009) also reported the existence of an asphalt-batch plant in the vicinity of the lower park in the 1930s. A variety of alterations to the physical state of the property have been made over time, including rerouting of the creek channel and changes to the site topography and lithology (excavations, backfilling and landfilling, road development, etc.). The property was converted to a public park beginning in the mid to late 1970s.

A landfill used for the burial of local municipal waste (Eldridge Municipal Landfill) was also operated in the upper park in the 1930s (Figure 1) (Integral, 2008; Landau, 1993; Herrenkohl et al., 2011). In 2011, an interim cleanup action was conducted by the City of Bellingham at the landfill, under the terms of an agreed order with the Washington State Department of Ecology (Ecology). Approximately 4300 tons of landfill debris and contaminated soil were removed from the area during this effort (Herrenkohl et al., 2011). In mid-2012, a follow-up sampling effort was conducted to determine if groundwater was impacted by landfill leachate, with a focus on metals, PAHs, and PCP.

In association with remediation of contaminated sediments within the channel of Little Squalicum Creek, a portion of the proposed estuary area was logged, cleared, graded, and re-seeded with grass during 2010-2011 (Figures 2 and 3). This cleared area was the focus of the subsurface investigation work described in this report.



(Estuary surface contour modified from data provided by CGS, 2012; aerial photo from Google Maps, 2012)

Figure 3. 3D Schematic of Sampling Plan.

## Study Area Hydrogeology – Background Information

Previous remedial investigations conducted in association with the Oeser Superfund site have detailed the geologic and hydrogeologic conditions in the upper portion of the Little Squalicum Park. Borings completed during this work have revealed a stratified, variably distributed sequence of unconsolidated, Quaternary-age alluvial, glacial, and interglacial deposits (clays, silts, sands, gravels, peat). Integral (2008) distinguished three primary geologic units in this area. A discontinuous surficial sand and gravel unit is underlain by a low permeability gray clay unit of varying thickness (0.1 to over 6 ft.). The clay unit is, in turn, underlain by a laterally continuous silty-sand to clean-sand unit. A detailed description of the subsurface geology of the upper park is presented in Integral (2008).

Prior to this study, less was known about the subsurface conditions present in the lower park, particularly at depth. A number of shallow excavations had been completed throughout the lower park in the past 20 years, but all of these test pits were focused on the upper 5 to 7 feet of site deposits (Landau, 1993; Integral, 2008; CGS, 2010). The material encountered during these investigations (unconsolidated silts, sands, and gravels) were generally consistent with those described farther to the north. Previous investigations had also noted fill and compact fill in the upper 2 to 3 feet of the soil column in the lower-park test pits, including reworked, medium-dense to dense silts, sands, gravels, and occasional cobbles, as well as metal, glass, ash, and wood debris. Prior to this study it was unknown if the gray clay unit extended south to the area of the proposed estuary.

The groundwater flow direction in the park within the uppermost aquifer was previously mapped as south-southwest towards Bellingham Bay, although some groundwater in the lower park was thought to potentially discharge to Little Squalicum Creek prior to reaching the marine shoreline (Integral, 2008; CH2M Hill, 2011). Depth to groundwater beneath the study area had been reported during test-pit excavations to vary between approximately 1 to 5 feet below ground surface, depending on local topography. Water levels in the shallow aquifer are likely influenced by tidal fluctuations close to the Bellingham Bay shoreline; the inland extent of this influence has not been characterized.

Descriptions of the hydrogeologic conditions encountered during the drilling conducted for this study are presented later in this report.

# Methods

The field and laboratory methods used for this study are summarized below. Additional details on project methods and quality assurance criteria are discussed in the project plan (Pitz, 2012). A discussion of field and laboratory quality assurance testing results for the project is presented in Appendix A.

## Sampling Locations

The position and depth of the selected sampling locations were highly sensitive to both the current site topography and the three-dimensional geometry of the proposed estuary surface. In order to determine the depth to the estuary surface as precisely as possible, each sampling station was field located and surveyed to the NAVD88 vertical datum by a licensed surveyor prior to drilling and sampling. Table 1 presents the station coordinates for the eight sampling locations, and indicates the soil sampling frequency. Elevations are also presented in terms of the tidal datum Mean Lower Low Water (MLLW) to facilitate comparison to the estuary design plans prepared by CGS. All stations are identified in map view on Figure 2.

Table 1. Sampling Station Coordinates.

| Station ID[1] | X[2] | Y[2] | Surveyed land surface elevation (ft NAVD88)[3] | Surveyed land surface elevation (ft MLLW)[4] | Depth to estuary surface from current ground surface (ft)[5] | Number of soil samples collected above the estuary surface | Number of soil samples collected below the estuary surface |
|---|---|---|---|---|---|---|---|
| AGT425 | 1234533 | 648577 | 22.03 | 22.55 | 12.9 | 3 | 1 |
| AGT426 | 1234573 | 648556 | 22.23 | 22.75 | 7.6 | 2 | 1 |
| AGT427 | 1234537 | 648525 | 21.15 | 21.67 | 14.2 | 3 | 1 |
| AGT428 | 1234489 | 648499 | 20.33 | 20.85 | 9.4 | 2 | 1 |
| AGT429 | 1234550 | 648474 | 20.51 | 21.03 | 16.1 | 3 | 1 |
| AGT430 | 1234508 | 648437 | 19.35 | 19.87 | 13.4 | 3 | 1 |
| AGT431 | 1234451 | 648457 | 19.09 | 19.61 | 11.1 | 2 | 1 |
| AGT432 | 1234480 | 648452 | 19.35 | 19.87 | 10.8 | 2 | 1 |

[1] Station ID represents 6-digit Ecology well tag ID
[2] State Plane NAD83 North
[3] Land surface survey value from L. Steele and Assoc., Inc., September 24, 2012
[4] MLLW elevation derived by applying a +0.52 ft correction factor to the station NAVD88 elevation (CGS, 2012)
[5] Estuary surface position determined from data presented in CGS, 2010

## Soil Sampling

Subsurface soil samples were collected from the area of interest using direct-push drilling and sampling techniques, consistent with methods described in ASTM (2005a). Direct-push boreholes were drilled to a final depth 1 to 2 feet below the designed estuary topographic surface. A contract driller was employed to collect continuous 5-foot interval soil cores at each station using a 1.5 inch ID soil sampler, fitted with a clean, disposable liner and core catcher.

Soil characteristics for each core were logged by the EAP project hydrogeologist. At each station, two to three 12- to 18-inch-long vertical intervals of the core above the estuary surface were selected and sub-sampled for analysis of target parameters (24" for duplicated intervals). The specific length of the sample interval was dictated by material type and sample volume required for analysis; the total number of samples collected was dependent on the overall length of the borehole. Soil intervals selected for sampling favored portions of the retrieved core showing obvious signs of contamination (sheen, odor). Otherwise, samples were selected to provide a representative vertical profile of the soil column above the estuary surface.

At each borehole, an additional soil sample was collected from a vertical interval starting as close as possible to the proposed estuary surface. These samples were collected to support characterization of the chemical condition of the deposits that will form the uppermost sediments of the new estuary. From a regulatory compliance standpoint, the vertical interval of greatest interest for this sample lies between 0 and 12 cm (0 to ~5 inches) below the estuary surface - the biologically active zone identified for Bellingham Bay sediments (McInerney, 2012). However, in order to meet sample-volume requirements for the chemical parameters of interest, samples were collected from a 12- to 24-inch-long interval. As a result, the final concentrations reported for these "estuary surface" samples represent conditions extending 1 to 2 feet downward from that proposed surface.

After description, soil from the selected sample interval was transferred from the core liner to a clean stainless steel bowl and mixed with a clean stainless steel spoon until color and texture were uniform. All soil particles greater than 0.75 inches in diameter were removed from the sample. The sample was then placed in clean, laboratory-supplied sampling containers. Soil sample containers were labeled and transferred immediately to an ice-filled cooler for transport to the laboratory, using standard Manchester Environmental Laboratory (MEL) chain-of-custody procedures (MEL, 2008).

Soil samples collected from above the proposed estuary surface were submitted for analysis of TPH-Dx diesel- and lube-oil-range organics, and base-neutral-acid (BNA) semivolatiles[1]. Soil samples collected from below the estuary surface were submitted in most cases for analysis of TPH-Dx, BNAs, total organic carbon (TOC)[2], and a suite of eight metals (Ag, As, Cd, Cr, Cu, Hg, Pb, Zn). Due to sample volume limitations, no analyses of TPH-Dx or mercury were conducted for the estuary surface sample at station AGT429. Appendix B lists the individual analytes included in the BNA semivolatile analysis.

## Groundwater Monitoring and Sampling

Based on field observations of subsurface soil conditions encountered during drilling, three of the soil sampling stations (AGT426, AGT427, and AGT432; see Figure 2) were selected for groundwater monitoring using procedures consistent with ASTM (2005b). At each of these locations, a second borehole was drilled within 12-18" of the original borehole, and a temporary casing with a 5-foot-long well screen was installed to a depth interval designated by the Ecology hydrogeologist. After equilibration, a static water level measurement was collected and recorded using a clean, calibrated e-tape.

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[1] The BNA semivolatile analysis method was used because it reports results for a number of the project analytes of interest, including PAHs, and pentachlorophenol.

[2] TOC is used to normalize organic contaminant concentrations on a total organic carbon basis.

After recording the static water level, an attempt was made to collect a groundwater sample with low enough turbidity to justify submitting an unfiltered sample to the laboratory for analysis (see discussion regarding groundwater sample volume, turbidity limits, and filtering in Pitz, 2012). Initial attempts to use a small-diameter Geoprobe® mechanical bladder pump did not recover adequate low-turbidity sample. As an alternative, a small-diameter, dedicated, fluorinated ethylene propylene tube connected to a peristaltic pump (with a short section of dedicated Silastic® tubing at the pump head) was lowered down the casing until the intake was adjacent to the mid-point of the screened interval. The screen point was then purged at a low-flow rate (~200 ml/min) until field water quality parameters [temperature, pH, specific conductance (SC), and dissolved oxygen (DO)] stabilized in a closed-atmosphere flow cell.

Once field parameters had stabilized, a confirmation DO measurement was collected using a field spectrophotometer. A subsample of the purge stream was also collected for field analysis of turbidity using a calibrated field turbidimeter. The decision to proceed with sampling was based on this turbidity measurement, and the ability of the screen point to produce adequate sample volume in a reasonable time frame. Groundwater samples were ultimately collected from the AGT426 and AGT427 stations; the sample stream from AGT432 remained too turbid to justify submitting samples to the laboratory.

Groundwater samples were collected directly into clean, laboratory-supplied containers without filtration; containers were then labeled and transferred immediately to an ice-filled cooler for transport to the laboratory, using standard chain of custody procedures.

Groundwater samples were submitted for the analysis of TPH-Dx diesel- and lube-oil-range organics, and BNA semivolatiles. Appendix B lists the individual analytes included in the BNA semivolatile analysis.

# Results

## Site Hydrogeology

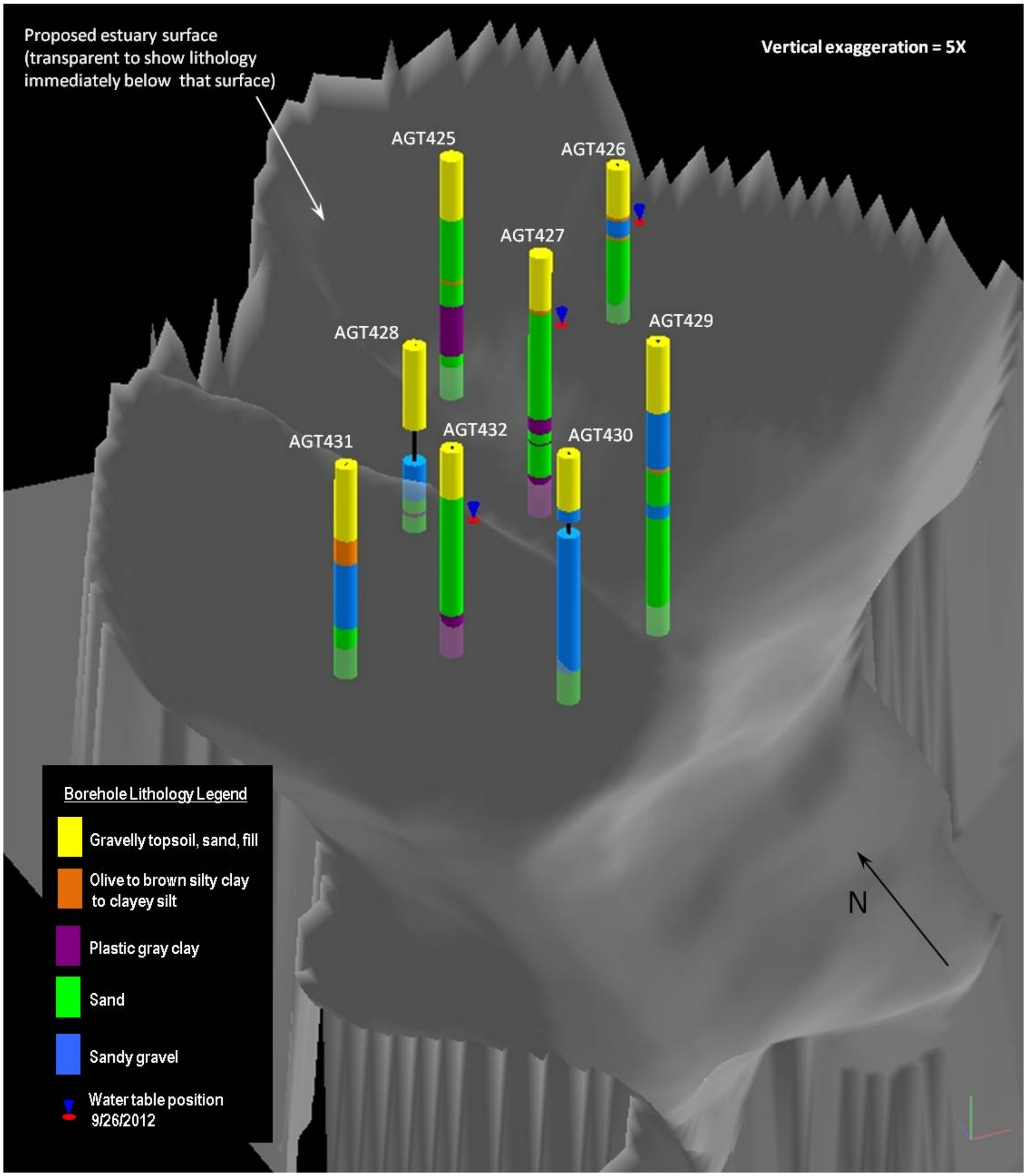
### Subsurface Geology

Boring and photo logs for each of the eight direct-push boreholes installed during the study are presented in Appendix C. Boreholes were drilled to a total depth between 9.6 and 18.1 feet below the current ground surface of the study area, depending on the relative vertical position of the proposed estuary surface at each point.

The lithology encountered during the boring program was generally consistent with conditions previously reported (Figure 4). A compact, dry, gravelly, sandy fill material was encountered in the top 3 to 5 feet of all of the boreholes, consistent with shallow test-pit observations made by previous investigators in this area. A laterally discontinuous sequence of looser, inter-bedded sand and gravel units with intermittent oxidation staining underlie the fill material, occasionally interspersed with finer-grained layers of silts or brownish silty clays.

In four of the eight boreholes, a highly plastic gray clay unit was encountered beneath the surficial sands and gravels, ranging in thickness between 0.1 to 3 feet. The clay unit was not observed in every borehole and, where it did occur, its vertical position and thickness was variable from station to station, suggesting the distribution of this unit in the lower park is perhaps less uniform than described in the upper park (where the unit is essentially continuous; Integral, 2008). The proposed estuary surface intersects the gray clay unit at stations AGT427 and AGT432 (Figure 4). At location AGT425 the gray clay unit was encountered above the estuary surface; at location AGT428 it was encountered a short distance below that surface. No gray clay was encountered in boreholes AGT426, AGT429, AGT430, and AGT431.

In most cases, the surficial sand and gravel units graded at depth to very well-sorted, medium- to coarse-grained gray sand, with typically little or no silt or gravel and often without any indication of oxidation staining. This unit was encountered in both of the boreholes that were drilled beyond the gray clay unit (AGT425, AGT428).



(Estuary surface contour data provided by CGS, 2012). See Appendix C for detailed logs and unit thicknesses.

Figure 4. 3D Schematic of Borehole Lithology.

## Groundwater Level

Table 2 summarizes the static water level measurement data collected from the three groundwater monitoring locations. The depth to water at the three stations was approximately 4 feet below ground surface. Groundwater elevations ranged between approximately 15 to 18.5 feet NAVD88 (~15.5 to 19 feet MLLW). As calculated from static water level measurements at locations AGT426 and AGT432, the horizontal hydraulic gradient across the site was approximately 0.024 ft/ft, presumably in a south-southwesterly direction[3]. Water levels for the three monitoring locations are presented in Figure 4.

Table 2. Groundwater Level Data Summary.

| | AGT426 | AGT427 | AGT432 |
|---|---|---|---|
| Date | 9/26/2012 | 9/26/2012 | 9/26/2012 |
| Time | 1120 | 1155 | 1350 |
| Static Water level depth below measuring point (ft) | 4.52 | 5.15 | 5.37 |
| Measuring point height above land surface (ft) | 0.78 | 0.99 | 1.21 |
| Static Water level depth below land surface (ft) | 3.74 | 4.16 | 4.16 |
| Station elevation (ft NAVD88) | 22.23 | 21.15 | 19.35 |
| Static Water level elevation (ft NAVD88) | 18.49 | 16.99 | 15.19 |
| Static Water level elevation (ft MLLW)* | 19.01 | 17.51 | 15.71 |

*+0.52 ft datum correction factor from NAVD88 elevation (CGS, 2012)

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[3] The three stations measured for static water level are aligned too closely to calculate an accurate 3-point-problem groundwater flow direction.

## Soil Quality Conditions Above the Proposed Estuary Surface

Table 3 compares the analytical results for soil samples collected from above the proposed estuary surface to the available Model Toxics Control Act (MTCA) soil cleanup chemical criteria (Ecology, 2007). Table 4 presents a summary of the individual BNA semivolatile detections (sample intervals not listed in Table 4 had no BNA detections reported by the laboratory).

The large majority of the analytes tested for this sample set were reported as non-detect. Four soil samples did show diesel- or lube-oil-range petroleum hydrocarbon contamination above MTCA standards[4]. Figure 5 presents a 3-dimensional schematic of the diesel-range concentration distribution; Figure 6 presents a similar schematic for the lube-oil-range concentrations.

Three of the four petroleum hydrocarbon samples that were above MTCA criteria were reported from the uppermost (shallowest) sampling interval (AGT426, AGT427, AGT428). The fourth location (from AGT430; 26,000 mg/Kg) was collected from a deep interval just above the proposed estuary surface (Figures 2, 5, and 6).

Naphthalenes, benzo(a)pyrene, and pentachlorophenol were detected in a few of the soil samples above the estuary surface, but at concentrations below the MTCA criteria. Table 4 indicates that the majority of the individual BNA analyte detections were observed in the uppermost sampling intervals at stations AGT426, AGT428, and AGT431.

---

[4] The analytical chemist who conducted the soil TPH-Dx analysis added the following comment to the case narrative laboratory report:

> "What I have reported as diesel is in fact not diesel, except in the case of sample 1209076-23 (*the uppermost sample from AGT431; Table 3),* but represents two distinct products with boiling ranges consistent with diesel. What these materials are is open to speculation but I suggest they were produced from an aromatic crude oil, unlike true diesel which is produced from an aliphatic crude oil and have a similar boiling range to that of diesel oil.
>
> The first of these products is found in samples 1209076-05 (*uppermost sample from AGT426; Table 3*), 11 (*bottommost sample from AGT427; Table D-1*), 19 (*uppermost sample from AGT430; Table 3*), 22 (*bottommost sample from AGT430; Table D-1*), 23 (*uppermost sample from AGT431; Table 3*), 25 (*bottommost sample from AGT431; Table D-1*), and 31 (*duplicate of second sample from AGT429*) and the second is found in sample 1209076-12 (*uppermost sample from AGT428; Table 3*) and 21 (*third sample from AGT430; Table 3*). All of these were quantitated and reported as diesel oil since we do not have a "diesel range organics" parameter which would be more appropriate in these cases. It needs to be remembered that the material reported as diesel is not true diesel." (*Italics by author*)

The observation that the petroleum product identified in the third AGT430 sample (11.0-12.5 feet BGS) is composed primarily of aromatic hydrocarbons is somewhat inconsistent with the other analytical data for this sample. Although the TPH-Dx diesel-range organic concentration for this sample was reported at 26,000 mg/Kg (dry weight), no polycyclic aromatic hydrocarbons were detected in the sample. The reason for this inconsistency is unknown; no indication of error in record keeping or laboratory reporting was evident on review.

Table 3. Comparison of Lab Results for Soil Samples Collected from Above the Proposed Estuary Surface to Available MTCA Soil Cleanup Chemical Criteria.

| | Naphthalenes[(A)] (ug/Kg DW) | Benzo[a]pyrene (ug/Kg DW) | Carcinogenic PAHs (ug/Kg DW)[(B)] | PCP (ug/Kg DW) | TPH-Dx Diesel Range Organics (mg/Kg DW) | TPH-Dx Lube Oil Range Organics (mg/Kg DW) |
|---|---|---|---|---|---|---|
| MTCA Criteria: | 5000[(C)] | 100[(C)] | 100[(C)] | 2500[(D)] | 2000[(C)] | 2000[(C)] |
| AGT425 (2.0-3.0' BGS) | 44 | 14 U | 12 U | 140 U | 5.7 U | 14 U |
| AGT425 (7.0-8.0' BGS) | 42 | 14 U | 12 U | 140 U | 5.9 U | 15 U |
| AGT425 (12.0-12.9' BGS) | 40 | 16 U | 14 U | 160 U | 6.1 U | 29 U |
| AGT426 (3.4-4.4' BGS)* | 384 | 13 U | 12 J | 130 U | 810 | **3800** |
| AGT426 (6.0-7.0' BGS) | 45 | 15 U | 13 U | 150 U | 5.8 U | 15 U |
| AGT427 (2.9-3.9' BGS) | 42 | 49 | 54 J | 140 U | 5.4 U | **2100** |
| AGT427 (6.5-8.5' BGS) | 44 | 15 U | 13 U | 150 U | 5.8 U | 15 U |
| AGT427 (11.0-12.5' BGS) | 39 | 14 U | 12 U | 140 U | 5.7 U | 14 U |
| AGT428 (3.0-4.0' BGS)* | 70 | 39 | 54 J | 140 U | **5400** | 680 |
| AGT428 (7.3-8.3' BGS) | 39 | 13 U | 11 U | 130 U | 5.2 U | 13 U |
| AGT429 (3.5-5.0' BGS) | 41 | 13 U | 11 U | 130 U | 5.3 U | 13 U |
| AGT429 (8.0-10.0' BGS) | 48 | 16 U | 14 U | 160 U | 6 UJ | 15 U |
| AGT429 (12.0-13.0' BGS) | 45 | 15 U | 13 U | 150 U | 6 U | 15 U |
| AGT430 (3.0-4.0' BGS)* | 35 | 14 U | 12 U | 140 U | 560 | 44 |
| AGT430 (8.0-9.5' BGS) | 41 | 14 U | 12 U | 140 U | 5.1 U | 13 U |
| AGT430 (11.0-12.5' BGS)* | 42 | 14 U | 12 U | 140 U | **26000 J** | 14 U |
| AGT431 (3.0-4.0' BGS)* | 41 | 76 | 106 J | 14 J | 13 | 72 |
| AGT431 (7.3-8.8' BGS) | 42 | 14 U | 12 U | 140 U | 5.5 U | 14 U |
| AGT432 (2.9-3.9' BGS) | 110 | 15 U | 13 U | 150 U | 6.2 U | 85 |
| AGT432 (7.0-9.0' BGS) | 45 | 15 U | 13 U | 150 U | 5.8 U | 15 U |

(See Notes on next page)

**Notes for Table 3:**

DW: dry weight basis

MTCA: Model Toxics Control Act

PCP: pentachlorophenol

TPH-Dx: Total Petroleum Hydrocarbons (Diesel Extended Range)

BGS: below ground surface

Shaded concentrations indicate detection.

Concentrations in boxes indicate value above a MTCA criteria.

U: The analyte was analyzed for, but was not detected at or above the reported quantitation limit.

J: The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.

UJ: The analyte was not detected above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately measure the analyte in the sample.

(A) Values shown are the sum of the reported concentrations for naphthalene, 1-methylnaphthalene, and 2-methylnaphthalene. If any of the three values were reported as non-detect, ½ the detection limit was used to calculate the total.

(B) Sum of benzo[a]pyrene toxicity equivalent factor (TEF) concentrations of benzo[a]pyrene, benzo[a]anthracene, benzo[b]fluoranthene, benzo[k]fluoranthene, chrysene, dibenz[a,h]anthracene, and indeno[1,2,3-cd]pyrene. Non-detect values are replaced with ½ the reported detection limit before summing. WAC 173-340-708 (8)(e); TEF values from MTCA Table 708-2 (WAC 173-340-900).

(C) Ecology, 2007; MTCA Soil, Method A, Unrestricted Land Use, Table Value

(D) Washington State Cleanup Levels and Risk Calculations (CLARC) Database: Soil, Method B, Carcinogen, standard formula value, direct contact (ingestion only), unrestricted land use.

*see Footnote 4 on page 20 regarding diesel-range-organic designation.

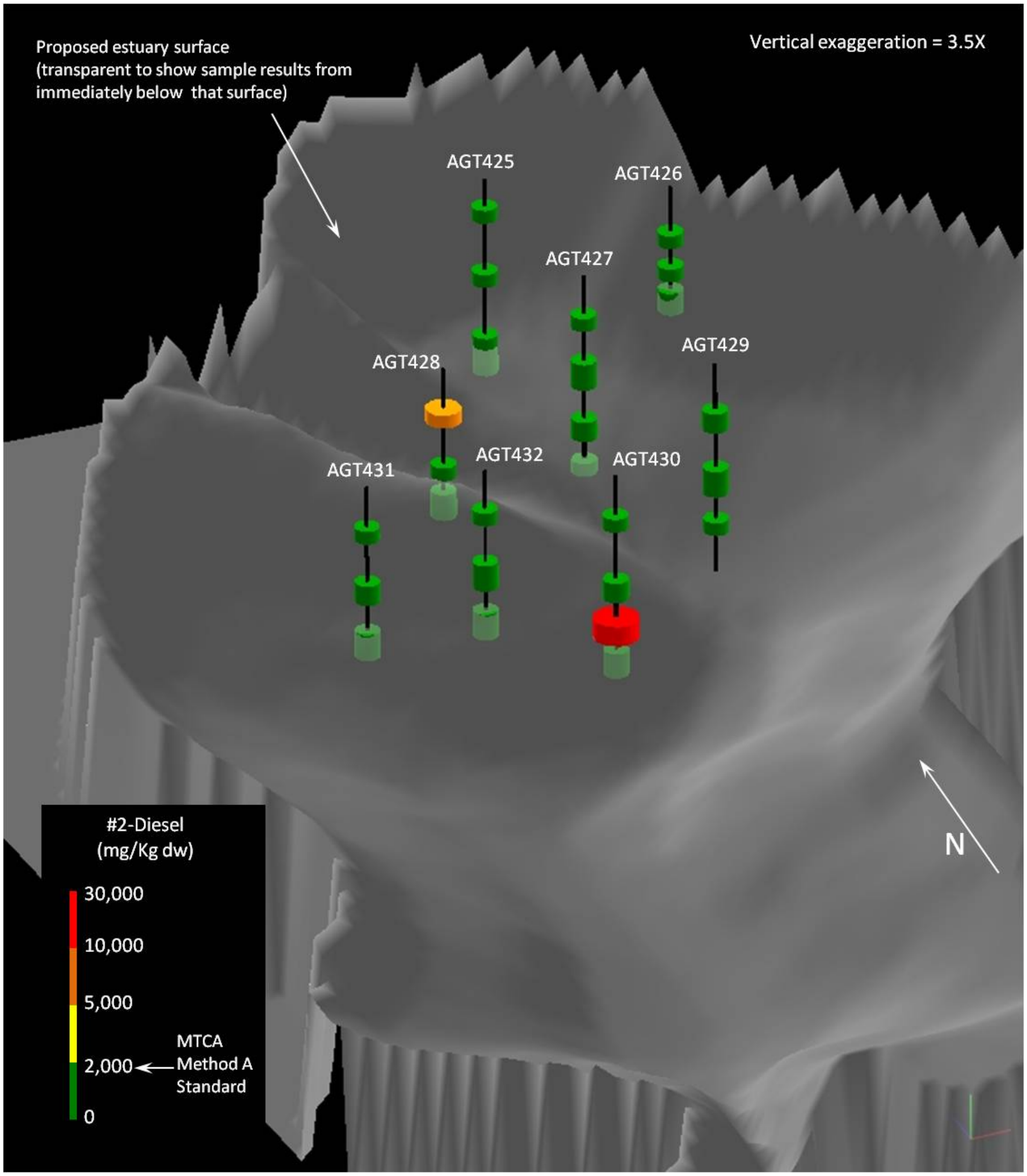
Table 4. Summary of Individual BNA Semivolatile Analyte Detections in Soil Samples Collected Above the Proposed Estuary Surface.

| | AGT425 (2.0-3.0' BGS) | AGT425 (12.0-12.9' BGS) | AGT426 (3.4-4.4' BGS) | AGT426 (6.0-7.0' BGS) | AGT427 (2.9-3.9' BGS) | AGT427 (6.5-8.5' BGS) | AGT427 (11.0-12.5' BGS) | AGT428 (3.0-4.0' BGS) | AGT430 (3.0-4.0' BGS) | AGT431 (3.0-4.0' BGS) | AGT432 (2.9-3.9' BGS) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1-Methylnaphthalene | 29 U | 32 U | **280** | 30 U | 28 U | 29 U | 29 U | **18 J** | 27 U | 27 U | 31 U |
| 2-Methylnaphthalene | 29 U | **7.5 J** | **37 NJ** | 30 U | 28 U | 29 U | **9.7 J** | **27 J** | 27 U | 27 U | 31 U |
| Naphthalene | 29 U | 32 U | **67** | 30 U | 28 U | 29 U | 29 U | **25 J** | **7.9 J** | 27 U | **79** |
| Acenaphthylene | 14 U | 16 U | 13 U | 15 U | 14 U | 15 U | 14 U | **7.3 J** | 14 U | 13 U | 15 U |
| Fluorene | 14 U | 16 U | **42** | 15 U | 14 U | 15 U | 14 U | 14 U | 14 U | 13 U | 15 U |
| Phenanthrene | 29 U | **10 J** | **120** | 30 U | 28 U | 29 U | **11 J** | **46** | **6.3 J** | **26 J** | **6.9 J** |
| Anthracene | 29 U | 32 U | **35 NJ** | 30 U | 28 U | 29 U | 29 U | **15 J** | 27 U | **18 J** | 31 U |
| Fluoranthene | 29 U | 32 U | 26 U | 30 U | 28 U | 29 U | 29 U | **46** | 27 U | **59** | 31 U |
| Pyrene | 29 U | 32 U | **190** | 30 U | **32** | 29 U | 29 U | **47** | **7.9 J** | **85** | 31 U |
| Benz[a]anthracene | 29 U | 32 U | 26 U | 30 U | 28 U | 29 U | 29 U | **22 J** | 27 U | **42** | 31 U |
| Chrysene | 14 U | 32 U | **120** | 30 U | 28 U | 29 U | 29 U | **56** | 27 U | **120** | 31 U |
| Benzo(b)fluoranthene | 14 U | 16 U | 13 U | 15 U | 14 U | 15 U | 14 U | **73** | 14 U | **110** | 15 U |
| Benzo(k)fluoranthene | 14 U | 16 U | 13 U | 15 U | 14 U | 15 U | 14 U | 14 U | 14 U | **39** | 15 U |
| Benzo(a)pyrene | 14 U | 16 U | 13 U | 15 U | **49** | 15 U | 14 U | **39** | 14 U | **76** | 15 U |
| Indeno(1,2,3-cd)pyrene | 14 U | 16 U | 13 U | 15 U | 14 U | 15 U | 14 U | **31** | 14 U | **80** | 15 U |
| Dibenzo(a,h)anthracene | 29 U | 32 U | 26 U | 30 U | 28 U | 29 U | 29 U | 28 UJ | 27 U | **20** | 31 U |
| Benzo(ghi)perylene | 29 U | 32 U | **19 J** | 30 U | **21** | 29 U | 29 U | **26 J** | 27 U | **69** | 31 U |
| Bis(2-Ethylhexyl)Phthalate | 57 U | 64 U | **190** | 60 U | 56 U | 59 U | 58 U | 56 U | 54 U | 54 U | 62 U |
| Di-N-Butylphthalate | 14 U | 16 U | 34 U | 15 U | 14 U | 15 U | 14 U | **79** | 14 U | 13 U | 15 U |
| 1,2-Dichlorobenzene | 57 U | 64 U | 53 U | 60 U | 56 U | **9.1 J** | 58 U | 56 U | 54 U | 54 U | 62 U |
| 1,3-Dichlorobenzene | 57 U | 64 U | 53 U | 60 U | 56 U | **6.4 J** | 58 U | 56 U | 54 U | 54 U | 62 U |
| 1,4-Dichlorobenzene | 57 U | 64 U | 53 U | 60 U | 56 U | **6.7 J** | 58 U | 56 U | 54 U | 54 U | 62 U |
| Hexachloroethane | 14 U | 16 U | 13 U | 15 U | 14 U | **7.1 J** | 14 U | 14 U | 14 U | 13 U | 15 U |
| Bisphenol A | **57 J** | 64 U | 53 U | 60 U | 56 U | 59 U | 58 U | 56 U | 54 U | 54 U | 62 U |
| 4-Methylphenol | 140 J | 160 U | 130 U | 150 U | 140 U | 150 U | 140 U | **18 J** | 140 U | **54 J** | **35 J** |
| 4-Nonylphenol | 57 U | 64 U | 53 U | **10 J*** | 56 U | 59 U | 58 U | 56 U | 54 U | 54 U | 62 U |
| Dibenzofuran | 29 U | 32 U | 26 U | 30 U | 28 U | 29 U | 29 U | **11 J** | 27 U | 27 U | 31 U |
| Cholesterol | **630** | 320 U | 260 U | 300 U | 280 U | 290 UJ | 290 UJ | 280 UJ | 270 UJ | **650** | 310 U |
| Retene | **9.7 J** | **11 J** | 26 U | 30 U | 28 U | 29 U | **7.5 J** | **47** | 27 U | **17 J** | **33** |
| Triclosan | **17 NJ** | 32 U | 26 U | 30 U | 28 U | **16 NJ** | 29 U | 28 U | 27 U | 27 U | 31 U |
| Pentachlorophenol | 140 UJ | 160 UJ | 130 UJ | 150 J | 140 UJ | 150 UJ | 140 UJ | 140 UJ | 140 UJ | **14 J** | 150 UJ |
| **Total BNA detects** | **4** | **3** | **10** | **1** | **3** | **5** | **3** | **18** | **3** | **16** | **4** |

(See notes on next page)

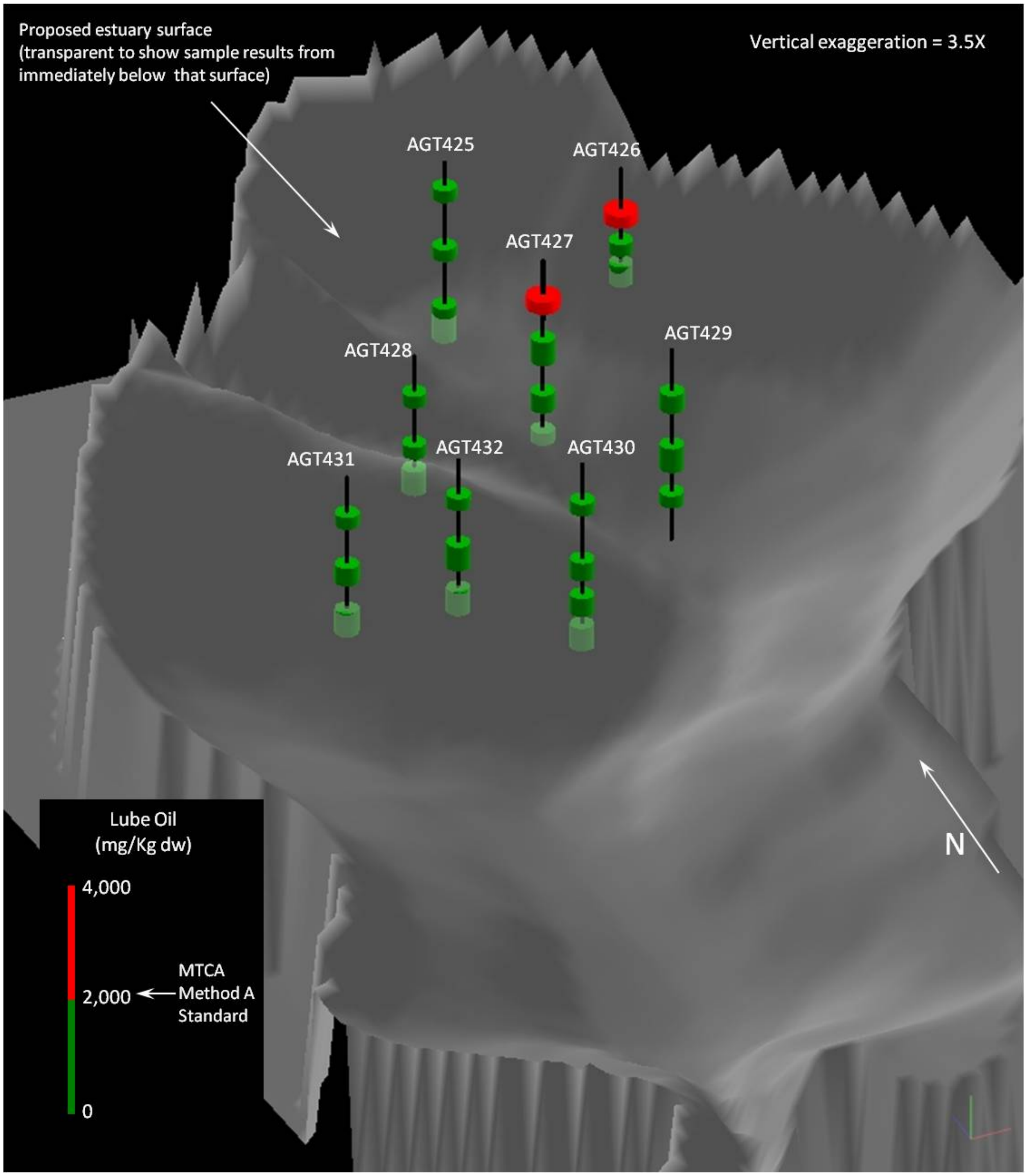
**Notes for Table 4:**

Sample intervals with no reported BNA detections are not shown on the table.
Bolded values indicate detection.
U: The analyte was analyzed for, but was not detected at or above the reported quantitation limit.
J: The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample
UJ: The analyte was not detected above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately measure the analyte in the sample.
N: The analyte was tentatively identified.
*value from duplicate sample



Estuary surface contour data provided by CGS, 2012. Specific sample interval depths below current ground surface are provided in Appendix C.

Figure 5. 3D Schematic of Diesel-Range Petroleum Hydrocarbon Soil Results.



Estuary surface contour data provided by CGS, 2012. Specific sample interval depths below current ground surface are provided in Appendix C.

Figure 6. 3D Schematic of Lube Oil-Range Petroleum Hydrocarbon Soil Results.

## Soil Quality Conditions Below the Proposed Estuary Surface

Table D-1 in Appendix D presents the analytical results for the soil samples collected immediately below the proposed estuary surface and compares those results to state SMS chemical criteria for marine sediments (Ecology, 1995). Table 5 summarizes the results for the organic chemical detections reported for this sample set.

The percent solids reported for the future sediment-surface samples ranged between 72% and 83%. The percent total organic carbon (TOC) for these samples was consistently below 0.2%. These TOC values are below the recommended range for TOC normalization of organic contaminants, therefore the reported concentrations for these constituents are compared to the Apparent Effects Threshold (AET)/Sediment Cleanup Objective (SCO) values reported in Ecology (2012).

The majority of organic contaminants were non-detect in this sample set. Three of the samples (AGT427, AGT430, AGT432; Figure 7) had one detected PAH analyte each, at concentrations well below the sediment chemical criteria. It should be noted, however, that PAH organics are considered bioaccumulative contaminants in a marine environment. As a result, cleanup levels for these parameters would normally be established by conducting sediment bioassays, and performing a human-health/ecological-health risk assessment. In lieu of this information, the cleanup level would default to the practical quantitation limit.

Diesel range organics were detected at three of the stations (AGT427, AGT430, and AGT431; Figure 5,6,7). The diesel concentrations were below the MTCA Method A criteria for soils. There are no state SMS chemical criteria for diesel-range organics, and biological testing was not conducted as part of this study to assess toxicity.

All metals (Ag, As, Cd, Cr, Cu, Hg, Pb, Zn) tested in samples from below the estuary surface had concentrations well below the marine Sediment Quality Standard (SQS) chemical criteria.

Table 5. Summary of Organic Chemical Detections in Soil Samples Collected Immediately Below the Proposed Estuary Surface.

| | Marine Sediment SQS | Marine Sediment AET SCO | AGT427 (14.2-15.2' BGS) | AGT430 (13.4-15.4' BGS) | AGT431 (11.1-13.1' BGS) | AGT432 (10.8-12.8' BGS) |
|---|---|---|---|---|---|---|
| TOC @ 104°C (%) | NA | NA | 0.19 | 0.15 | 0.10 U | 0.19 |
| TPH-Dx diesel-range organics (mg/Kg DW) | NA | NA | **1300*** | **440*** | **450*** | 6.0 U |
| Phenanthrene (ug/Kg DW) | (A) | **1500** | 34 U | **14 J** | 30 U | **10 J** |
| 2-Methylnaphthalene (ug/Kg DW) | (A) | **670** | **8.1 J** | 30 U | 30 U | 30 U |

Stations with no reported organic detections are not shown on the table.
DW: dry weight
NA: Not applicable
SQS: Sediment Quality Standard; Ecology, 1995
AET: Apparent Effects Threshold (see Ecology Publication No. 12-09-057)
SCO: Sediment Cleanup Objective
BGS: Below ground surface
Bold value indicates detection.
U: The analyte was analyzed for, but was not detected at or above the reported quantitation limit.
J: The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.
(A) Sample TOC is below recommended range for TOC normalization, criteria do not apply (see Ecology, 2012)
*See Footnote 4 on page 20 regarding diesel-range-organic designation.

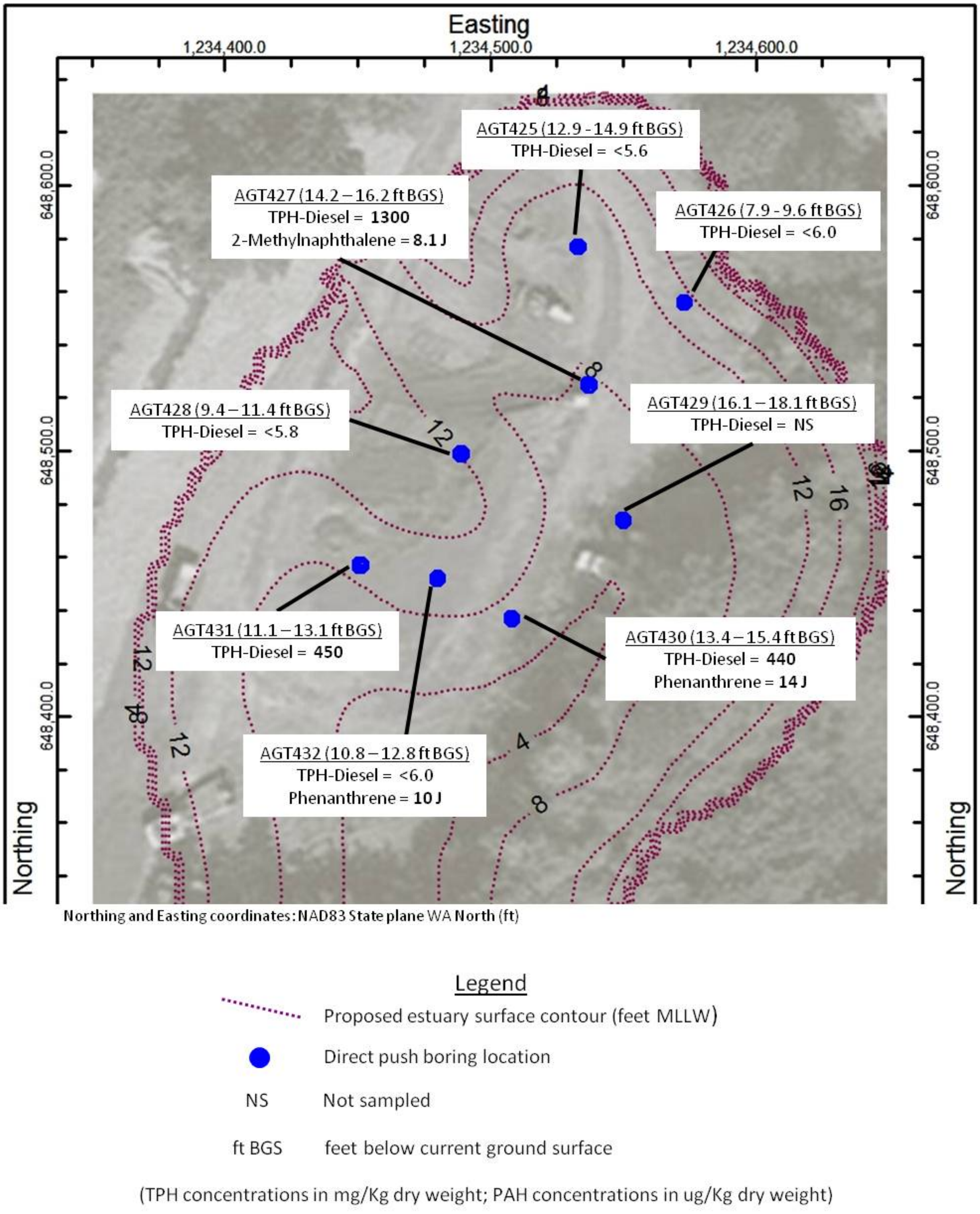


Figure 7. Map View of Organic Contaminant Detections in Samples Collected from Immediately Below the Proposed Estuary Surface.

## Groundwater Water Quality Conditions

Table 6 presents a summary of the analytical results for the groundwater samples collected during the project, and compares those results to the appropriate MTCA criteria. There were no BNA or TPH-Dx organic detections for either of the two groundwater samples.

Table 6. Summary of Groundwater Sample Results.

| | MTCA Groundwater Cleanup Criteria | AGT426 (4.0-9.0' BGS) | AGT427 (4.0-9.0' BGS) |
|---|---|---|---|
| **Field Parameters (End of Purge)** | | | |
| pH (stnd. units) | NA | 6.08 | 6.46 |
| Temperature (°C) | NA | 14.6 | 14.8 |
| Specific conductance (uS/cm) | NA | 451.9 | 534.1 |
| Dissolved oxygen (mg/L)(A) | NA | 0.84 | 0.44 |
| Turbidity (NTU) | NA | 1.94 | 9.14 |
| **Laboratory Parameters** | | | |
| Naphthalenes(B) (ug/L) | 160(C) | 0.12 U | 0.12 U |
| Benzo[a]pyrene (ug/L) | 0.1(C) | 0.083 U | 0.08 U |
| Pentachlorophenol (ug/L) | 0.22(D) | 0.083 UJ | 0.08 UJ |
| TPH-Dx Diesel Range Organics (ug/L) | 500(C) | 50 U | 50 U |
| TPH-Dx Lube Oil Range Organics (ug/L) | 500(C) | 120 U | 120 U |

MTCA: Model Toxics Control Act
BGS: below ground surface
NA: not applicable
TPH-Dx: Total Petroleum Hydrocarbons (Diesel Extended Range)
U: The analyte was analyzed for, but was not detected at or above the reported quantitation limit.
J: The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.
UJ: The analyte was not detected above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately measure the analyte in the sample.
(A)Concentration determined by spectrophotometer.
(B)Total of naphthalene, 1-methyl naphthalene, and 2-methyl naphthalene. Values shown are the sum of the reported concentrations for these three parameters. If any of the three parameters were reported as non-detect, ½ the detection limit was substituted to calculate the total.
(C)MTCA Groundwater Method A Table Value.
(D)Washington State Cleanup Levels and Risk Calculations (CLARC) Database: Groundwater, Method B, Carcinogen, standard formula value.

# Discussion

The following observations are presented regarding the data:

- The spatial positions of the soil samples were located (and are reported) as accurately as possible, but there may be up to one-half foot of uncertainty in these positions in the vertical dimension. This uncertainty could be most important for samples that were used to represent conditions in the uppermost sediments of the future estuary surface. Location AGT430 would be an area of particular concern for vertical accuracy due to the elevated concentration of diesel reported for the interval immediately above the proposed estuary surface.

- The observations of subsurface geologic conditions and contaminant distribution made during this study are generally consistent with previous reports and information. On the basis of the sampling results reported here, the large majority of the soils in the northern portion of the proposed estuary are not likely to contain contaminant concentrations above MTCA cleanup criteria.

- The majority of the contamination that was observed at the site is concentrated in the uppermost 4 to 5 feet of the soil column, at a vertical position generally consistent with the position of the local water table (Figures 4, 5, and 6). In several cases, the downward transport of the contamination appeared to be limited by a relatively thin low-permeability unit (see logs for AGT426, AGT427 in Appendix C).

- The area that encompasses all of the locations where *shallow* (0-5 feet BGS) petroleum contamination has been reported in soils (either by laboratory analysis during this study or by field observation during previous studies) is approximately 7800 $ft^2$. This is slightly more than twice the area of contamination estimated by E&E (2010). Assuming that a continuous, 5-foot-thick zone of soil contamination occurs within that area, the total maximum contaminated soil volume in the shallow soils in the northern half of the proposed estuary is approximately 1450 cubic yards (CY) in situ volume. This volume equals approximately 5% of the total estimated estuary excavation volume (27,800 CY; CGS, 2010). This volume does not include the deep contamination observed at station AGT430.

- The shallow petroleum hydrocarbon contamination within the estuary footprint appears to be of local origin; there is no clear evidence that the observed chemicals in this area of the site were transported by subsurface migration from contaminated areas north of Marine Drive. This interpretation is supported by the shallow position of the contamination, the absence of pentachlorophenol, and the absence of adjacent groundwater contamination.

- Diesel-related petroleum contamination was also observed at one deep soil location closer to the central portion of the estuary footprint (AGT430; Figure 5). This contamination was detected in a permeable gravel unit (see photo log in Appendix C), suggesting transport of contaminants to this point from an upgradient source area may have occurred through a preferential pathway. The absence of groundwater contamination upgradient of this point and the absence of chemicals closely related to wood preservation (e.g., PCP) suggest this deep soil contamination is more likely derived from the downward infiltration of contamination from surface activities, rather than the migration of contamination by groundwater flow from north of Marine Drive. No other observations of deep contamination were observed within the study area.

- Organic chemical contamination was limited in the soil samples collected from immediately beneath the proposed estuary surface. However, the length of the sample cores used to represent this interval (12-24”) is significantly longer than the interval representative of the biologically active zone used to determine compliance with state marine sediment criteria (~5”). In addition, no biological testing or risk assessment was performed to evaluate toxicity or food chain risks posed by the petroleum or PAH contamination that was observed. The data presented for these samples should therefore be considered screening quality information.

- A 2-foot deep over-excavation of the area that encompasses the organic contamination observed just beneath the proposed estuary surface would generate approximately 625 CY (in situ volume) of additional material for further handling.

# Conclusions

Results of this 2012 study support the following conclusions:

- Soil overlying the northern portion of the proposed Little Squalicum estuary surface is, for the most part, below concentrations of regulatory concern. The large majority of the soil excavated from this area during future estuary construction activities is unlikely to be categorized as a listed waste and is unlikely to require special handling and disposal.
- A limited amount of diesel-range and heavier oil-range organic contamination was identified in soils above the estuary surface at concentrations greater than the MTCA Method A cleanup level:
    - Diesel and lube oil concentration above the MTCA criteria were noted at three shallow (< 4.5 feet BGS) soil stations at the northern end of the estuary footprint, in the vicinity of areas previously identified as contaminated. This shallow contamination is interpreted to be the result of historic industrial land use that occurred directly over this portion of the park. The areal extent of this shallow contamination is generally consistent with earlier reports.
    - Diesel-range organic contamination was also observed at depth (11 to 12.5 feet BGS) in one sample station near the central portion of the proposed estuary area. The elevated concentration reported at this location is interpreted to be associated with the downward migration of surface contamination through a zone of higher permeability sediments, possibly through a preferential pathway. No detectable PAH or PCP was observed at this sampling interval, suggesting that this contamination is not associated with the migration of wood-preservative-related chemicals reported in soils and groundwater in the upper portion of the Little Squalicum Park. The downgradient extent of the petroleum contamination in this area is unknown.
- Low concentrations of individual semivolatile organics were detected in soils overlying the proposed estuary surface, but no values were above MTCA Method A cleanup standards.
- No contaminants were detected in the two groundwater samples collected from the northern end of the proposed estuary, suggesting that the mobility of the shallow soil contamination observed in this area is currently limited. The absence of detectable groundwater contamination further supports the interpretation that the observed soil contamination in this area of the park is of local origin and is not the result of downgradient transport by groundwater flow from the north.
- No contamination was identified above Washington State marine sediment chemical standards in soil samples collected from immediately below the proposed estuary surface. Several samples from this horizon did show detectable levels of diesel-range organics, but the concentrations were below the MTCA Method A soil criteria. No biological testing or risk evaluation was conducted, so the results from these samples should be considered screening level information.
- Soil and groundwater conditions remain unknown in the southern portion of the proposed estuary. Access to this area is currently complicated by surface conditions (trees, saturated soils, permitting considerations).

# Recommendations

Results of this 2012 study support the following recommendations:

- Prior to construction, proponents of the estuary development project should consider additional investigation of subsurface soil conditions in the southern half of the estuary footprint. Particular focus should be given to determining the downgradient extent of the deep soil contamination observed at boreholes AGT430, AGT431, and AGT432. The logistical challenges of conducting drilling and sampling in this area of the park should be anticipated during planning for such work.
- If the estuary construction project moves forward, follow-up sampling of the surface sediments remaining after the excavation is completed is recommended to confirm contaminant conditions specifically in the biologically active zone. Bioassay testing and risk evaluation should be considered, as necessary.

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# Appendices

# Appendix A. Project Quality Assurance

## Quality Assurance – Laboratory

The precision and accuracy of the project analytical results were estimated by the MEL chemists using laboratory quality control tests conducted for each batch of 20 or fewer samples. Laboratory quality control testing consisted of method blanks, lab duplicate samples, matrix spike samples, and control standards. MEL's quality control procedures are discussed in detail in MEL, 2012.

Quality assurance reviews of the analytical data were completed by MEL and forwarded to the project manager. The laboratory reviews revealed that the data were of generally good quality, meeting or exceeding the data quality objectives established in Pitz (2012). The laboratory reviews indicated that the data may be used without qualification with minor exceptions. Sample results that did not meet the laboratory's quality control measures were in most cases flagged with an appropriate qualifier.

The data were further evaluated for quality by the project manager by reviewing the field quality control sampling results. On the basis of this review (discussed below), additional qualifiers were assigned to the MEL data as necessary.

## Quality Assurance – Field

### Soil Sampling Equipment Rinsate Blank

Prior to collecting soil samples, a rinsate blank sample of the soil sampling equipment was collected and submitted for analysis. The rinsate blank was collected by pouring clean, laboratory-supplied, organic-free, de-ionized water over a previously decontaminated set of soil sample contact equipment (bowl and spoon). The rinsate was captured in clean, lab-supplied sample containers. This equipment blank was collected to test the quality of the equipment decontamination procedures, and to determine if any component of the soil sample field processing equipment was contributing a positive bias to the analytical results. This equipment blank sample was submitted as a blind sample to the laboratory and was analyzed for BNAs and TPH-Dx.

The analytical results for the groundwater equipment blank sample are presented in Table A-1. The results indicate that the decontamination procedures and soil sampling equipment did not introduce a bias into the study results for the parameters of interest.

Table A-1. Soil Sampling Equipment Rinsate Blank Results.

| Sample ID | Sample Date | TPH-Dx (mg/L) | | BNA Semivolatiles[a] (mg/L) |
|---|---|---|---|---|
| | | #2-Diesel | Lube Oil | |
| LS-13-R1 | 9/25/2012 | 0.05 U | 0.12 U | No detections |

[A] See Appendix B for a complete list of analytes included in this analysis.
U: The analyte was analyzed for but was not detected at or above the reported quantitation limit.

## Groundwater Equipment Blank

Prior to collecting groundwater samples, clean, laboratory-supplied, organic-free, de-ionized water was pumped through new components of the groundwater sampling system and collected in a clean set of sample containers. This equipment blank sample was collected to determine if any component of the sampling system was contributing a positive bias to the analytical results for groundwater samples. This equipment blank sample was submitted as a blind sample to the laboratory and was analyzed for BNAs and TPH-Dx.

The analytical results for the groundwater equipment blank sample are presented in Table A-2. The results indicate that the sample collection and filtration system did not introduce a bias into the study results for the parameters of interest.

Table A-2. Groundwater Sampling Equipment Rinsate Blank Results.

| Sample ID | Sample Date | TPH-Dx (mg/L) | | BNA Semivolatiles[A] (mg/L) |
|---|---|---|---|---|
| | | #2-Diesel | Lube Oil | |
| LS-13-R2 | 9/26/2012 | 0.05 U | 0.12 U | No detections |

[A] See Appendix A for a complete list of analytes included in this analysis.
U: The analyte was analyzed for, but was not detected at or above the reported quantitation limit.

## Field Duplicates

### *Soil*

A duplicate sample was collected from a total of four of the soil sampling intervals. Three of these duplicate samples were collected from intervals lying above the proposed estuary surface; one of the duplicate samples was collected from an interval lying below the proposed estuary surface.

Duplicate soil samples were collected by increasing the normal vertical length of the borehole sample interval to obtain extra soil volume, homogenizing the soil from this entire interval in a stainless steel bowl with a stainless steel spoon, and then splitting the homogenized material equally between two matching sample container sets. The duplicate samples were submitted as blind samples to the laboratory. The soil duplicate samples above the estuary surface were analyzed for TPH-Dx, BNAs, and percent solids. The soil duplicate sample below the estuary surface was only analyzed for metals, percent solids and TOC; no TPH-Dx or BNA analyses were conducted on the “sediment” duplicate sample due to sample volume limitations.

Field duplicates provide a measure of the overall sampling and analytical precision. Precision estimates are influenced not only by the random error introduced by collection and measurement procedures, but are also a reflection of the natural variability of the parameter concentrations in the media being sampled.

Table A-3 presents the reported concentration data for each of the duplicate pairs.

In most cases the duplicate sample results match closely to the concentrations reported for the original sample; all duplicates were within project data quality objectives (Pitz, 2012). Notable exceptions include:

- The #2-Diesel soil concentration for the duplicate sample for the AGT429 station was reported as 760 mg/Kg (dry weight), while the original sample was reported as non-detect at 6 mg/Kg. In light of the other quality assurance data, this difference is attributed to sample heterogeneity. These two results were assigned a “J” qualifier to indicate the results are an estimate.
- Low concentrations of several BNA analytes were reported for several soil samples from the mid-depth AGT427 station (qualified as estimates) but were reported as non-detect at higher concentrations in the corresponding duplicates.

The soil duplicate results indicate good overall data precision.

Table A-3. Soil Duplicate Results.

| Sample Interval | Date | Specific Analyte | Value | Qualifier | RPD (%)[1] |
|---|---|---|---|---|---|
| **TPH-Dx #2-Diesel (mg/Kg dry weight)** | | | | | |
| AGT427 (6.5-8.5' BGS) | 9/25/2012 | | 5.8 | U | Cannot calculate |
| Duplicate | | | 5.8 | U | |
| AGT429 (8.0-10.0' BGS) | 9/25/2012 | | 6.0 | UJ | Cannot calculate |
| Duplicate | | | 760 | J | |
| AGT432 (7.0-9.0' BGS) | 9/26/2012 | | 5.8 | U | Cannot calculate |
| Duplicate | | | 5.7 | U | |
| **TPH-Dx Lube Oil Range Organics (mg/Kg dry weight)** | | | | | |
| AGT427 (6.5-8.5' BGS) | 9/25/2012 | | 15 | U | Cannot calculate |
| Duplicate | | | 15 | U | |
| AGT429 (8.0-10.0' BGS) | 9/25/2012 | | 15 | U | Cannot calculate |
| Duplicate | | | 16 | U | |
| AGT432 (7.0-9.0' BGS) | 9/26/2012 | | 15 | U | Cannot calculate |
| Duplicate | | | 14 | U | |
| **BNA semivolatiles (ug/Kg dry weight)[2]** | | | | | |
| AGT427 (6.5-8.5' BGS) | 9/25/2012 | 1,2-Dichlorobenzene | 9.1 | J | Cannot calculate |
| Duplicate | | | 57 | U | |
| AGT427 (6.5-8.5' BGS) | 9/25/2012 | 1,3-Dichlorobenzene | 6.4 | J | Cannot calculate |
| Duplicate | | | 57 | U | |
| AGT427 (6.5-8.5' BGS) | 9/25/2012 | 1,4-Dichlorobenzene | 6.7 | J | Cannot calculate |
| Duplicate | | | 57 | U | |
| AGT427 (6.5-8.5' BGS) | 9/25/2012 | Hexachloroethane | 7.1 | J | Cannot calculate |
| Duplicate | | | 14 | U | |
| AGT427 (6.5-8.5' BGS) | 9/25/2012 | Triclosan | 16 | NJ | Cannot calculate |
| Duplicate | | | 29 | U | |
| AGT429 (8.0-10.0' BGS) | 9/25/2012 | No BNA detections | | | Cannot calculate |
| Duplicate | | | | | |
| AGT432 (7.0-9.0' BGS) | 9/26/2012 | No BNA detections | | | Cannot calculate |
| Duplicate | | | | | |
| **Percent Solids (%)** | | | | | |
| AGT427 (6.5-8.5' BGS) | 9/25/2012 | | 84.7 | | 0.2 |
| Duplicate | | | 84.9 | | |
| AGT429 (8.0-10.0' BGS) | 9/25/2012 | | 78.1 | | 1.8 |
| Duplicate | | | 79.5 | | |
| AGT432 (7.0-9.0' BGS) | 9/26/2012 | | 82.3 | | 0.8 |
| Duplicate | | | 83.0 | | |
| AGT426 (7.9-9.6' BGS) | 9/25/2012 | | 82.4 | | 13.2 |
| Duplicate | | | 94.0 | | |

| Sample Interval | Date | Specific Analyte | Value | Qualifier | RPD (%)[1] |
|---|---|---|---|---|---|
| **Total Organic Carbon (104 C) (%)** | | | | | |
| AGT426 (7.9-9.6' BGS) | 9/25/2012 | | 0.10 | U | Cannot calculate |
| Duplicate | | | 0.10 | U | |
| **Total Organic Carbon (70 C) (%)** | | | | | |
| AGT426 (7.9-9.6' BGS) | 9/25/2012 | | 0.10 | U | Cannot calculate |
| Duplicate | | | 0.10 | U | |
| **Arsenic (mg/Kg dry weight)** | | | | | |
| AGT426 (7.9-9.6' BGS) | 9/25/2012 | | 1.91 | | 8.5 |
| Duplicate | | | 2.08 | | |
| **Cadmium (mg/Kg dry weight)** | | | | | |
| AGT426 (7.9-9.6' BGS) | 9/25/2012 | | 0.085 | | 12.2 |
| Duplicate | | | 0.096 | | |
| **Chromium (mg/Kg dry weight)** | | | | | |
| AGT426 (7.9-9.6' BGS) | 9/25/2012 | | 31.5 | | 17.9 |
| Duplicate | | | 37.7 | | |
| **Copper (mg/Kg dry weight)** | | | | | |
| AGT426 (7.9-9.6' BGS) | 9/25/2012 | | 16.3 | | 7.1 |
| Duplicate | | | 17.5 | | |
| **Lead (mg/Kg dry weight)** | | | | | |
| AGT426 (7.9-9.6' BGS) | 9/25/2012 | | 2.15 | | 7.6 |
| Duplicate | | | 2.32 | | |
| **Mercury (mg/Kg dry weight)** | | | | | |
| AGT426 (7.9-9.6' BGS) | 9/25/2012 | | 0.0179 | | 1.1 |
| Duplicate | | | 0.0177 | | |
| **Silver (mg/Kg dry weight)** | | | | | |
| AGT426 (7.9-9.6' BGS) | 9/25/2012 | | 0.061 | | Cannot calculate |
| Duplicate | | | 0.050 | U | |
| **Zinc (mg/Kg dry weight)** | | | | | |
| AGT426 (7.9-9.6' BGS) | 9/25/2012 | | 34.1 | | 1.7 |
| Duplicate | | | 34.7 | | |

[1] %RPD (relative percent difference) was not calculated if one or both of the samples were reported as non-detect.

[2] The BNA semivolatile scan includes multiple individual analytes; only detected concentrations are reported here.

U: The analyte was analyzed for, but was not detected at or above the reported quantitation limit.

J: The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.

UJ: The analyte was not detected above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately measure the analyte in the sample.

*Groundwater*

One duplicate groundwater sample was collected during the project. The groundwater duplicate was collected at the end of the purge stabilization process, after measurement of field parameters. The duplicate was collected by alternately directing the flow from the sample pump line between two identical sets of laboratory containers. The groundwater duplicate was submitted as a blind sample to the laboratory and was analyzed for TPH-Dx and BNA scan.

Table A-4 presents the reported concentration data for the duplicate pairs. No detections were reported for any of the duplicate pairs, indicating good overall data precision.

Table A-4. Groundwater Duplicate Results.

| Station | Date | Value | Qualifier | %RSD[1] |
|---|---|---|---|---|
| **TPH-Dx #2-Diesel (mg/L)** | | | | |
| AGT426 (4.0-9.0' BGS) | 9/25/2012 | 0.05 | U | Cannot calculate |
| Duplicate | | 0.05 | U | |
| **TPX-Dx Lube Oil Range Organics (mg/L)** | | | | |
| AGT426 (4.0-9.0' BGS) | 9/25/2012 | 0.12 | U | Cannot calculate |
| Duplicate | | 0.12 | U | |
| **BNA semivolatiles (ug/L)[2]** | | | | |
| AGT426 (4.0-9.0' BGS)<br>Duplicate | 9/25/2012 | No BNA detections | | Cannot calculate |

[1] %RPD (relative percent difference) was not calculated if one or both of the samples was reported as non-detect.
[2] The BNA semivolatile scan includes multiple individual analytes; only detected concentrations are reported here.
U: The analyte was analyzed for, but was not detected at or above the reported quantitation limit.

# Appendix B.  Analyte List for BNA (Semivolatile) Analysis by EPA Method 8270

Phenol
Bis(2-Chloroethyl)Ether
2-Chlorophenol
1,3-Dichlorobenzene
1,4-Dichlorobenzene
1,2-Dichlorobenzene
Benzyl Alcohol
2-Methylphenol
Bis(2-chloro-1-methylethyl) ether
N-Nitrosodi-n-propylamine
4-Methylphenol
Hexachloroethane
Nitrobenzene
Isophorone
2-Nitrophenol
2,4-Dimethylphenol
Bis(2-Chloroethoxy)Methane
Benzoic Acid
2,4-Dichlorophenol
1,2,4-Trichlorobenzene
Naphthalene
4-Chloroaniline
Hexachlorobutadiene
4-Chloro-3-Methylphenol
2-Methylnaphthalene
1-Methylnaphthalene
Hexachlorocyclopentadiene
2,4,6-Trichlorophenol
2,4,5-Trichlorophenol
2-Chloronaphthalene
2-Nitroaniline
Dimethyl phthalate
2,6-Dinitrotoluene
Acenaphthylene
3-Nitroaniline
Acenaphthene
2,4-Dinitrophenol
4-Nitrophenol
Dibenzofuran
2,4-Dinitrotoluene
Diethyl phthalate
Fluorene
4-Chlorophenyl-Phenylether
4-Nitroaniline
4,6-Dinitro-2-Methylphenol
N-Nitrosodiphenylamine
1,2-Diphenylhydrazine
Triethyl citrate
4-Bromophenyl phenyl ether
Hexachlorobenzene
Tris(2-chloroethyl) phosphate (TCEP)
Pentachlorophenol
Phenanthrene
Anthracene
Caffeine
4-nonylphenol
Carbazole
Di-N-Butylphthalate
Triclosan
Fluoranthene
Pyrene
Bisphenol A
Retene
Butyl benzyl phthalate
Benz[a]anthracene
3,3'-Dichlorobenzidine
Chrysene
Bis(2-Ethylhexyl) Phthalate
Di-N-Octyl Phthalate
Benzo(b)fluoranthene
Benzo(k)fluoranthene
Benzo(a)pyrene
3B-Coprostanol
Cholesterol
Indeno(1,2,3-cd)pyrene
Dibenzo(a,h)anthracene
Benzo(ghi)perylene
2-Fluorophenol

**Surrogates**

Phenol-D5
2-Chlorophenol-D4
Bis(2-Chloroethyl)Ether-D8
1,2-Dichlorobenzene-D4
4-Methylphenol-D8
Nitrobenzene-D5
2-Nitrophenol-D4
2,4-Dichlorophenol-D3
4-Chloroaniline-D4
2-Fluorobiphenyl
Dimethylphthalate-D6
Acenaphthylene-D8
4-Nitrophenol-D4
Fluorene-D10
4,6-Dinitro-2-methylphenol-D2
Anthracene-D10
Pyrene-D10
Terphenyl-D14
Benzo(a)pyrene-D12
1,4-Dichlorobenzene-D4
Naphthalene-D8
Acenaphthene-D10
Phenanthrene-D10
Chrysene-D12
Perylene-D12

# Appendix C.  Direct Push Boring Logs and Photos

## Soil Boring and Sample Log

| | | | |
|---|---|---|---|
| Project: Little Squalicum Park | Boring #: AGT425 | Date: 9/25/2012 | Logged by: C. Pitz/P. Marti |
| Driller: Cascade | Drilling Method: Direct push | LAT DD: 48.765800 LONG DD: 122.516309 NAD83HARN | |
| Ground surface elevation: 22.03 feet | Vertical Datum: NAVD88 | | |

| Depth BGS (feet) | Formation Description (color, grain size, moisture content, density, %fines, sorting) | Sample Interval | Sample Info |
|---|---|---|---|
| 0 | | | |
| 1 | 0-0.8' – buff to light brown sandy soil w/ ~10% gravel (<3/4"), minor silt, dry | | |
| 2 | 0.8-2.9' – brown to dk. brown poorly-sorted gravelly sand w/ minor silt, gravel ~20-30%, <1.5", broken. Fill? | ☒ | 2.0-3.0' |
| 3 | 2.9-3.7' - moist, gray, compact, angular gravel in silt/clay/sand matrix (fill?, gravel <2.5", broken). Orange oxidation staining at base of interval (*photo 2604*) | | |
| 4 | 3.7-5.0' – brown silty medium-grained well-sorted sand, saturated, no gravel, ~10% silt, trace clay (*photo 2605*) | | |
| 5 | 5.0–6.7' brown silty medium-grained sand w/no gravel, ~20% silt, ~5% clay, | | |
| 6 | @6.7' iron oxidation staining | | |
| 7 | 6.7-7.5' gray, wet, well-sorted very coarse sand w/<5% silt | ☒ | 7.0-8.0' |
| 8 | 7.5-7.7' moist, highly plastic, light brown clay (*photo 8193*) | | |
| 9 | 7.7-9.1' moist to wet, brownish gray, well sorted fine to medium grained sand w/ <10% silt/clay, no gravel (*photo 8193*) | | |
| 10 | 9.1-10.0' dry to slightly moist, highly plastic brown clay (*photo 8194*) | | |
| 11 | 10.0-12.9' poor recovery, slough – recovered core continues highly plastic light gray to gray clay, no sand, no gravel, dry to slightly moist. Clay overlies a silty, wet, very well sorted medium-grained gray to dark gray sand, no gravel (12.2-12.9'). Decayed plant material at contact? | | |
| 12 | | ☒ | 12.0-12.9' |
| 13 | | | 12.9' to estuary surface |
| 14 | 12.9-14.9' very well sorted, wet, lt. gray to gray, medium- to coarse grained sand, <5% silt, no gravel (*photo 8208*) | ☒ | 12.9-14.9' |
| 15 | Bottom of hole | | |

# Photo Log – Boring AGT425

Top

#2604

#2605

#8193

#8194

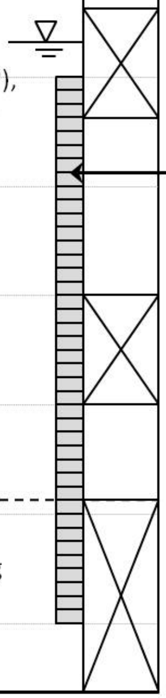
#8208

Bottom

# Soil Boring and Sample Log

| | | | |
|---|---|---|---|
| Project: Little Squalicum Park | Boring #: AGT426 | Date: 9/25/2012 | Logged by: C. Pitz/P. Marti |
| Driller: Cascade | Drilling Method: Direct push | LAT DD: 48.765744 | LONG DD: 122.516142 NAD83HARN |
| Ground surface elevation: 22.23 feet | | Vertical Datum: NAVD88 | |

| Depth BGS (feet) | Formation Description (color, grain size, moisture content, density, %fines) | Sample Interval | Sample Info |
|---|---|---|---|
| 0 | | | |
| 0–1 | 0.0-1.0' no core retrieved | | **Static water Level** 9/26/2012 @1120: 3.74 feet BGS |
| 1–3 | 1.0-3.0' loose, dry, light brwn top soil w/ roots, grading to silty, gravelly sand (gravel <1", broken) (*photo 8214*) | | |
| 3 | 3.0-3.2' brown to olive brown silty clay, dry, plastic, trace sand, noticeable petroleum odor (diesel?) (*photo 8215*) | | |
| 3–4 | 3.2-4.4' moist to wet, gray, loose, silty sandy gravel (<1.5") w/ trace clay (silt/clay content increasing to ~15-20% at the bottom of this interval), noticeable petroleum odor (diesel?), possible sheen on gravels just above base of interval, some pockets of iron oxidation staining (*photo 8216*) | ☒ | 3.4-4.4' |
| 4–5 | 4.4-5.2' well sorted, wet, brown, medium-grained sand, no gravel, <10% silt, compact | | 4.0-9.0' - groundwater sample interval |
| 5–7 | 5.2-7.9' wet to saturated, compact brown, well sorted, medium-grained sand w/ <10% silt, sand coarsening downward (*photo 8221*) | ☒ | 6.0-7.0' |
| 8 | | | 7.9' to estuary surface |
| 8–9 | 7.9-9.6' wet, loose, well sorted brown coarse-grained sand w/ minor silt (<15%), no gravel, some iron oxidation staining (*photo 8228*) | ☒ | 7.9-9.6' (duplicate) |
| 10 | Bottom of hole | | |



# Photo Log – Boring AGT426

Top




Bottom

#8214 #8215 #8216 #8221 #8228

# Soil Boring and Sample Log

| | | | |
|---|---|---|---|
| Project: Little Squalicum Park | Boring #: AGT427 | Date: 9/25/2012 | Logged by: C. Pitz/P. Marti |
| Driller: Cascade | Drilling Method: Direct push | LAT DD: 48.765657 | LONG DD: 122.516288 NAD83HARN |
| Ground surface elevation: 21.15 feet | | Vertical Datum: NAVD88 | |

| Depth BGS (feet) | Formation Description (color, grain size, moisture content, density, %fines) | Sample Interval | Sample Info |
|---|---|---|---|
| 0 | 0.0-1.5' no core retrieved | | **Static water level**<br>9/26/2012 @1155:<br>4.16' BGS |
| 1 | 1.5-2.0' Dry, loose gravelly sand w roots. Sand coarse, gray to brown, gravel broken ,<3", ~30-40% (*photo 8235*) | | |
| 2 | 2.0' sand coarsening, moist, gravel ~20-30%, brown<br>2.7-3.3' v. moist, gray gravelly silty sand or sandy silty gravel w/ ~30-40% gravel (<2"), ~15% silt, trace roots, diesel odor (*photo 8236*) | | |
| 3 | | ☒ | 2.9-3.9' |
| 4 | 3.3' light brown silty clay unit w/ iron oxidation on top surface (*photo 8236*) ▽ | ▤ | |
| 5 | 3.3-4.1' fine silty sand, brown, wet, no gravel, ~15% silt<br>4.1' iron oxidation surface (*photo 8237*) | ▤ | 4.0-9.0' - groundwater sample interval |
| 6 | | ▤ | |
| 7 | 4.1-10.1' coarse-grained, well sorted, moist gray to brown sand w/ <5% silt, small clay nodule? wet, loose. Sand grains fining downward through interval, silt increasing to ~15-20%, no gravel, iron oxidation staining, no diesel odor (*photo 8237*) | ▤ ☒ | 6.5-8.5'(duplicate) |
| 8 | | ▤ ☒ | |
| 9 | | | |
| 10 | 10.1-11.0' very plastic gray clay, no sand, no gravel, dry (*photo 8252*)<br>11.0-11.6' wet, gray, silty sandy gravel, gravel <1.5" (*photo 8252*) | | |
| 11 | 11.6' very plastic gray clay, no sand, no gravel, dry | ☒ | 11.0-12.5' |
| 12 | 11.7-13.7' well-sorted, wet to saturated, gray, medium grained loose sand, no gravel, <15% silt (*photo 8253*) | ☒ | |
| 13 | | | |
| 14 | - - - - - - - - - - - - - - - - | | 14.2' to estuary surface |
| 15 | 13.7-16.2' moist, very plastic gray clay, no sand, no gravel (*photos 8253, 8260*) | ☒ | 14.2-16.2' |
| 16 | Bottom of hole | ☒ | |
| 17 | | | |

# Photo Log – Boring AGT427

Top

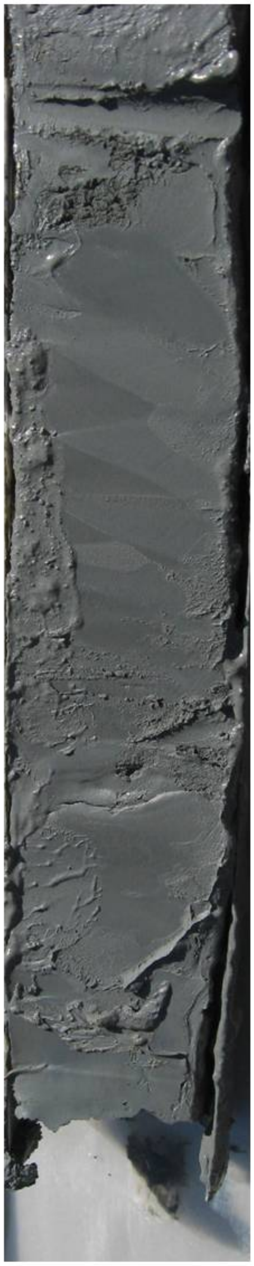
#8235

#8236

#8237

#8252

#8253



#8260

Bottom

# Soil Boring and Sample Log

| | | | |
|---|---|---|---|
| Project: Little Squalicum Park | Boring #: AGT428 | Date: 9/25/2012 | Logged by: C. Pitz/P. Marti |
| Driller: Cascade | Drilling Method: Direct push | LAT DD: 48.765583 LONG DD: 122.516485 | NAD83HARN |
| Ground surface elevation: 20.33 feet | Vertical Datum: NAVD88 | | |

| Depth BGS (feet) | Formation Description (color, grain size, moisture content, density, %fines) | Sample Interval | Sample Info |
|---|---|---|---|
| 0 | | | |
| 1 | 0.0-2.0’ no core retrieved | | |
| 2 | 2.0-3.0’ dry brown gravelly sand topsoil slough overlying medium to coarse grained sand w/ <15% silt (*photo 8264*) | | |
| 3 | 3.0-5.0’ transitioning to gray to dk brown gravelly coarse sand to sandy gravel, moist, ~10-20% silt, trace clay? occasional iron ox. staining, gravel <3/4”, no odor (*photo 8267*) | ☒ | 3.0-4.0’ |
| 4 | | | |
| 5 | 5.0-7.2’ no recovery | | |
| 6 | | | |
| 7 | 7.2-9.4’ gray, wet to saturated sandy gravel w/ minor silt, gravel <1/2”, no odor<br>intermittent gravel-free sand lense @8.5’ (*photo 8271*) | ☒ | 7.3-8.3’ |
| 8 | | | |
| 9 | 9.4-10.2’ wet, gray well-sorted coarse sand w/ iron oxidation staining, loose (*photo 8274*) | | 9.4’ to estuary surface |
| 10 | 10.2-10.4’ dry, vey plastic gray clay, no sand, no gravel (*photo 8274*) | ☒ | |
| | 10.4-11.4’ wet, gray, coarse-grained well-sorted sand, no gravel, <5% silt, some iron oxidation staining (*photo 8274*) | | 9.4-11.4’ |
| 11 | | | |
| | Bottom of hole | | |
| 12 | | | |

# Photo Log – Boring AGT428

#8264

#8267

Top

Bottom

#8271

#8274

## Soil Boring and Sample Log

| | | | |
|---|---|---|---|
| Project: Little Squalicum Park | Boring #: AGT429 | Date: 9/25/2012 | Logged by: C. Pitz/P. Marti |
| Driller: Cascade | Drilling Method: Direct push | LAT DD: 48.765518 | LONG DD: 122.516230 NAD83HARN |
| Ground surface elevation: 20.51 feet | Vertical Datum: NAVD88 | | |

| Depth BGS (feet) | Formation Description (color, grain size, moisture content, density, %fines) | Sample Interval | Sample Info |
|---|---|---|---|
| 0 | | | |
| 1 | 0.0-2.0' no core retrieved | | |
| 2 | 2.0-2.6' dry brown top soil/fill, w/ silt, sand and ~15% gravel, roots, minor clay (*photo 8279*) | | |
| 3 | 2.6-3.5' increasing amount of <1" gravel, dry to slightly moist, fill w/ clay in matrix, no odor | | |
| 4 | 3.5-4.2' very coarse (<3") gravel (broken) in silty sandy matrix, gray to dk. brown, no odor, fill? (*photo 8280*) | ☒ | 3.5-5.0' |
| 5 | 4.2-7.7' wet to saturated, loose, gray sandy gravel w/ <15% silt/clay, gravel <1", rounded (*photo 8281*) | | |
| 6 | starting at 5.0' same, but increasing iron oxidation staining, and gravel coarser (<3"). | | |
| 7 | 7.7-7.9' brown to dk. brown clayey silt layer w/ large gravel, wet (*photo 8286*) | | |
| 8 | 7.9-10.0' saturated, well-sorted, medium to coarse grained sand w/ <10% silt, brown with iron oxidation staining, no gravel (*photo 8286*) | ☒ | |
| 9 | | | 8.0-10.0' (duplicate) |
| 10 | 10.0-10.8' silty sandy gravel, wet, gray to brown, gravel <1" (*photo 8291*) | | |
| 11 | 10.8-13.3' brown, iron oxidation stained well sorted sand w/ <10% silt (*photo 8291*) | | |
| 12 | | ☒ | 12.0-13.0' |
| 13 | | | |
| 14 | 13.3-16.1' ~20% core recovery, very well sorted, gray, medium to coarse-grained sand w/ <5% silt, occasional clayey nodules? wet, compact (*photo 8292*) | | |
| 15 | | | |
| 16 | | | 16.1' to estuary surface |
| 17 | 16.1-18.1' <50% core recovery, very well sorted, gray, coarse-grained sand w/<10% silt, wet, compact (*photo 8294*) | ☒ | 16.1-18.1' |
| 18 | Bottom of hole | | |

# Photo Log – Boring AGT429

Top

#8279

#8280

#8281

#8286

#8291

Bottom

# Photo Log – Boring AGT429 (cont.)

Top

Bottom

#8292

#8294

# Soil Boring and Sample Log

| | | | |
|---|---|---|---|
| Project: Little Squalicum Park | Boring #: AGT430 | Date: 9/25/2012 | Logged by: C. Pitz/P. Marti |
| Driller: Cascade | Drilling Method: Direct push | LAT DD: 48.765414 LONG DD: 122.516400 | NAD83HARN |
| Ground surface elevation: 19.35 feet | Vertical Datum: NAVD88 | | |

| Depth BGS (feet) | Formation Description (color, grain size, moisture content, density, %fines) | Sample Interval | Sample Info |
|---|---|---|---|
| 0 | 0.0-1.0' no core retrieved | | |
| 1 | 1.0-1.8' dry, brown sandy gravelly soil, gravel <1", roots (*photo 8301*) | | |
| 2 | 1.8-2.2' gray gravelly sand to sandy gravel, <1", <15% silt<br>2.2-2.9' dry to slightly moist, dark gray gravelly sand w/ roots, gravel <1", minor iron oxidation staining (*photo 8301*) | | |
| 3 | 3.3-4.0' wet, brown to gray sandy gravel to gravelly sand, <15% silt, <1.5", no odor detected (*photo 8301*) | ☒ | 3.0-4.0' |
| 4 | 4.0-5.0' no core recovery (hit rock) | | |
| 5 | 5.0-10.0' ~30% core recovery – saturated gravel, rust brown w/ <10% silt, <15% sand, gravel rounded, well sorted, ~0.5-1" (*photo 8307*) | | |
| 6 | | | |
| 7 | | | |
| 8 | | ☒ | 8.0-9.5' |
| 9 | | | |
| 10 | 10.0-13.4' ~80% core recovery- saturated, loose, silty sandy gravel – brown to rust brown, silt <20%, gravel rounded, <1.25" (*photo 8314*) | | |
| 11 | | ☒ | 11.0-12.5' |
| 12 | | | |
| 13 | | | 13.4' to estuary surface |
| 14 | 13.4-15.4' very well sorted, gray, compact medium to coarse-grained sand, no gravel, <5% silt, saturated (*photo 8317*) | ☒ | 13.4-15.4' |
| 15 | | | |
| 16 | Bottom of hole | | |

# Photo Log – Boring AGT430

Top

#8301

#8307

#8314

#8317

Bottom

# Soil Boring and Sample Log

Project: Little Squalicum Park
Boring #: AGT431
Date: 9/26/2012
Logged by: C. Pitz/P. Marti
Driller: Cascade
Drilling Method: Direct push
LAT DD: 48.765466
LONG DD: 122.516639
NAD83HARN
Ground surface elevation: 19.09 feet
Vertical Datum: NAVD88

| Depth BGS (feet) | Formation Description (color, grain size, moisture content, density, %fines) | Sample Interval | Sample Info |
|---|---|---|---|
| 0 | 0.0-2.0' limited core recovery | | |
| 1 | 2.0-2.6' – dry, light brown gravelly, sandy soil, gravel <1", roots | | |
| 2 | 2.6-3.8' dry to damp, dark brown gravelly sandy silt (*photo 5017*) | | |
| 3 | | ☒ | 3.0-4.0' |
| 4 | 3.8-4.5' dark gray silty sand (fill?) with minor large gravel <2" | | |
| 5 | 4.5-6.0' increasing silt content, transitioning to moist to wet clayey silt w/ ~20% sand and gravel, no evidence of odor (*photo 5016*) | | |
| 6 | 6.0-6.6' wet to saturated, light gray to gray, sandy silty gravel, sand coarse, gravel <1.5", silt <15%, compact (*photo 5016*) | | |
| 7 | 6.6-9.1' same as above, but less silt, gravel <2", sand coarser, gray to brown, loose (*photo 5015*) | | |
| 8 | | ☒ | 7.3-8.8' |
| 9 | 9.1-10.0' gravelly sand, brown, gravel <2", w/~15-20% silt, ~5% clay? compact, moist (*photo 5015*) | | |
| 10 | 10.0-11.1' well sorted brown sand w/~10-15% silt, ~5% small gravel compact, moist (*photo 5013*) | | |
| 11 | 11.1-13.1' ~75% recovery – medium to coarse grained well sorted brown to rusty brown sand w/ <10% silt, no gravel, iron ox. staining, grading to well sorted unstained gray coarse sand at base of interval (*photo 5012*) | ☒ | 11.1' to estuary surface |
| 12 | | | 11.1-13.1' |
| 13 | | | |

Bottom of hole

# Photo Log – Boring AGT431

Top

#5017

#5016

Bottom

#5015

#5013

#5012

# Soil Boring and Sample Log

| | | | |
|---|---|---|---|
| Project: Little Squalicum Park | Boring #: AGT432 | Date: 9/26/2012 | Logged by: C. Pitz/P. Marti |
| Driller: Cascade | Drilling Method: Direct push | LAT DD: 48.765454 | LONG DD: 122.516518 NAD83HARN |
| Ground surface elevation: 19.35 feet | Vertical Datum: NAVD88 | | |

| Depth BGS (feet) | Formation Description (color, grain size, moisture content, density, %fines) | Sample Interval | Sample Info |
|---|---|---|---|
| 0 | 0.0-1.0' no core retrieved | | |
| 1 | 1.0-2.9' 90% recovery, light brown silty gravelly sand/soil w/ roots, gravel <1.5", very dry, silt content increasing to base of interval, some woody debris (fill?) (*photo 5010*) | | **Static water level**<br>9/26/2012 @1350: 4.16' BGS |
| 2 | @2.9' fresher gray well sorted fine to medium sand w/<10% gravel/silt (*photo 5010*) | | |
| 3 | 3.0-3.3' dark brown to black woody debris – organic odor, but not petroleum | ☒ | 2.9-3.9' |
| 4 | 3.3-4.1' well sorted fine to medium grained sand, gray, fining downward (*photo 5010*) ▽ | | |
| 5 | @4.5' iron ox. surface<br>4.5-10.2' medium to coarse grained, well sorted sand, brown to gray, w/ <15% silt/gravel, good recovery, wet to saturated, occasional iron ox. staining (*photo 5009, 5008*) | | |
| 6 | | | |
| 7 | | ☒ | 7.0-9.0' (duplicate) |
| 8 | | | |
| 9 | | | |
| 10 | 10.2-11.4' light gray to gray, very plastic clay, no sand or gravel, damp (*photo 5007*) | | 10.8' to estuary surface |
| 11 | 11.4-12.8 decreasing clay, increasing sand/silt, sand fine to very fine grained, gray, fresh, unstained, moist (*photo 5006*) | ☒ | 10.8-12.8' |
| 12 | | | |
| 13 | Bottom of hole | | |

# Photo Log – Boring AGT432

Top

#5010

#5009

Bottom

#5008

#5007

#5006

# Appendix D. Lab Results for Soil Samples Collected Below the Proposed Estuary Surface

Table D-1. Summary of Lab Results for Soil Samples Collected Below the Proposed Estuary Surface.

| | Marine Sediment SQS | Marine Sediment AET SCO | AGT425 (12.9-14.9' BGS) | AGT426 (7.9-9.6' BGS) | AGT427 (14.2-15.2' BGS) | AGT428 (9.4-11.4' BGS) | AGT429 (16.1-18.1' BGS) | AGT430 (13.4-15.4' BGS) | AGT431 (11.1-13.1' BGS) | AGT432 (10.8-12.8' BGS) |
|---|---|---|---|---|---|---|---|---|---|---|
| **Total Organic Carbon (TOC) (%)** | | | | | | | | | | |
| TOC @ 104°C | NA | NA | 0.10 U | 0.10 U | 0.19 | 0.10 U | 0.10 U | 0.15 | 0.10 U | 0.19 |
| TOC @70°C | NA | NA | 0.10 U | 0.10 U | 0.19 | 0.10 U | 0.10 U | 0.15 | 0.10 U | 0.19 |
| **Percent Solids (%)** | | | | | | | | | | |
| | NA | NA | 82.2 | 82.4 | 72.1 | 80.7 | 83.1 | 81.2 | 81.6 | 80.2 |
| **TPH-Dx Diesel Range Organics (mg/Kg dry weight)** | | | | | | | | | | |
| | NA | NA | 5.6 U | 6.0 U | 1300* | 5.8 U | NS | 440* | 450* | 6.0 U |
| **TPH-Dx Lube Oil Range Organics (mg/Kg dry weight)** | | | | | | | | | | |
| | NA | NA | 14 U | 15 U | 17 U | 15 U | NS | 15 U | 16 U | 15 U |
| **Metals (mg/Kg dry weight)** | | | | | | | | | | |
| Arsenic | **57** | **57** | 2.13 | 1.91 | 5.02 | 4.09 | 3.4 | 3.85 | 4.22 | 4.83 |
| Cadmium | **5.1** | **5.1** | 0.154 | 0.085 | 0.186 | 0.116 | 0.142 | 0.242 | 0.094 | 0.179 |
| Chromium | **260** | **260** | 31.4 | 31.5 | 55.7 | 30.9 | 29 | 29.4 | 31.3 | 37.2 |
| Copper | **390** | **390** | 16.7 | 16.3 | 38 | 19.6 | 15.5 | 21.4 | 16.3 | 26.6 |
| Lead | **450** | **450** | 2.23 | 2.15 | 6.72 | 3.01 | 2 | 2.74 | 2.15 | 4.34 |
| Mercury | **0.41** | **0.41** | 0.0165 | 0.0179 | 0.0573 | 0.0187 | NS | 0.0258 | 0.0115 | 0.0329 |
| Silver | **6.1** | **6.1** | 0.069 | 0.061 | 0.106 | 0.087 | 0.069 | 0.096 | 0.056 | 0.084 |
| Zinc | **410** | **410** | 39.9 | 34.1 | 74.7 | 47 | 36.1 | 50 | 36.9 | 54.3 |
| **Organic Chemicals (ug/Kg dry weight)** | | | | | | | | | | |
| 2,4-dimethylphenol | (A) | **29** | 150 U | 150 U | 170 U | 150 U | 140 U | 150 U | 150 U | 150 U |
| 2-Methylphenol | (A) | **63** | 150 U | 150 U | 170 U | 150 U | 140 U | 150 U | 150 U | 150 U |
| 4-Methylphenol | (A) | **670** | 150 U | 150 U | 170 U | 150 U | 140 U | 150 U | 150 U | 150 U |
| Benzoic Acid | (A) | **650** | REJ | REJ | REJ | REJ | REJ | REJ | REJ | REJ |
| Benzyl Alcohol | (A) | **57** | 150 U | 150 U | 170 U | 150 U | 140 U | 150 U | 150 U | 150 U |
| Dibenzofuran | (A) | **540** | 30 U | 30 U | 34 U | 30 U | 29 U | 30 U | 30 U | 31 U |
| Phenol | (A) | **420** | 60 U | 60 U | 69 U | 59 U | 58 U | 60 U | 61 U | 62 U |
| N-nitrosodiphenylamine | (A) | **28** | 30 U | 30 U | 34 U | 30 U | 29 U | 30 U | 30 U | 31 U |
| **Phthalates (ug/Kg dry weight)** | | | | | | | | | | |
| bis(2-Ethylhexyl)phthalate | (A) | **1300** | 60 U | 60 U | 69 U | 59 U | 58 U | 60 U | 61 U | 62 U |
| butylbenzyl phthalate | (A) | **63** | 60 U | 60 U | 69 U | 59 U | 58 U | 60 U | 61 U | 62 U |
| Diethyl phthalate | (A) | **200** | 30 U | 30 U | 34 U | 30 U | 29 U | 30 U | 30 U | 31 U |
| Dimethyl phthalate | (A) | **71** | 30 U | 30 U | 34 U | 30 U | 29 U | 30 U | 30 U | 31 U |
| Di-N-Butylphthalate | (A) | **1400** | 15 U | 15 U | 17 U | 15 U | 14 U | 15 U | 15 U | 15 U |
| Di-N-Octyl Phthalate | (A) | **6200** | 300 UJ | 300 UJ | 340 UJ | 300 UJ | 290 UJ | 300 UJ | 300 UJ | 310 UJ |
| **PAHs (ug/Kg dry weight)** | | | | | | | | | | |
| Naphthalene | (A) | **2100** | 30 U | 30 U | 34 U | 30 U | 29 U | 30 U | 30 U | 31 U |
| Acenaphthylene | (A) | **1300** | 15 U | 15 U | 17 U | 15 U | 14 U | 15 U | 15 U | 15 U |
| Acenaphthene | (A) | **500** | 15 U | 15 U | 17 U | 15 U | 14 U | 15 U | 15 U | 15 U |

|  | Marine Sediment SQS | Marine Sediment AET SCO | AGT425 (12.9-14.9' BGS) | AGT426 (7.9-9.6' BGS) | AGT427 (14.2-15.2' BGS) | AGT428 (9.4-11.4' BGS) | AGT429 (16.1-18.1' BGS) | AGT430 (13.4-15.4' BGS) | AGT431 (11.1-13.1' BGS) | AGT432 (10.8-12.8' BGS) |
|---|---|---|---|---|---|---|---|---|---|---|
| Fluorene | (A) | **540** | 15 U | 15 U | 17 U | 15 U | 14 U | 15 U | 15 U | 15 U |
| Phenanthrene | (A) | **1500** | 30 U | 30 U | 34 U | 30 U | 29 U | 14 J | 30 U | 10 J |
| Anthracene | (A) | **960** | 30 U | 30 U | 34 U | 30 U | 29 U | 30 U | 30 U | 31 U |
| LPAH | (A) | **5200** | 30 U | 30 U | 34 U | 30 U | 29 U | 14 J | 30 U | 10 J |
| 2-Methylnaphthalene | (A) | **670** | 30 U | 30 U | 8.1 J | 30 U | 29 U | 30 U | 30 U | 31 U |
| Fluoranthene | (A) | **1700** | 30 U | 30 U | 34 U | 30 U | 29 U | 30 U | 30 U | 31 U |
| Pyrene | (A) | **2600** | 30 U | 30 U | 34 U | 30 U | 29 U | 30 U | 30 U | 31 U |
| Benz[a]anthracene | (A) | **1300** | 30 U | 30 U | 34 U | 30 U | 29 U | 30 U | 30 U | 31 U |
| Chrysene | (A) | **1400** | 30 U | 30 U | 34 U | 30 U | 29 U | 30 U | 30 U | 31 U |
| Total benzofluoranthenes | (A) | **3200** | 15 U | 15 U | 17 U | 15 U | 14 U | 15 U | 15 U | 15 U |
| Benzo[a]pyrene | (A) | **1600** | 15 U | 15 U | 17 U | 15 U | 14 U | 15 U | 15 U | 15 U |
| Indeno(1,2,3-cd)pyrene | (A) | **600** | 15 U | 15 U | 17 U | 15 U | 14 U | 15 U | 15 U | 15 U |
| Dibenzo[a,h]anthracene | (A) | **230** | 30 UJ | 30 UJ | 34 UJ | 30 UJ | 29 U | 30 UJ | 30 UJ | 31 UJ |
| Benzo[ghi]perylene | (A) | **670** | 30 U | 30 U | 34 U | 30 U | 29 U | 30 U | 30 U | 31 U |
| HPAH | (A) | **12000** | 30 UJ | 30 UJ | 34 UJ | 30 UJ | 29 U | 30 UJ | 30 UJ | 31 UJ |
| **Chlorinated Organics (ug/Kg dry weight)** |  |  |  |  |  |  |  |  |  |  |
| 1,2-Dichlorobenzene | (A) | **31** | 60 U | 60 U | 69 U | 59 U | 58 U | 60 U | 61 U | 62 U |
| 1,2,4-Trichlorobenzene | (A) | **35** | 30 U | 30 U | 34 U | 30 U | 29 U | 30 U | 30 U | 31 U |
| 1,4-Dichlorobenzene | (A) | **110** | 60 U | 60 U | 69 U | 59 U | 58 U | 60 U | 61 U | 62 U |
| Hexachlorobutadiene | (A) | **22** | 60 U | 60 U | 69 U | 59 U | 58 U | 60 U | 61 U | 62 U |
| Hexachlorobenzene | (A) | **11** | 15 U | 15 U | 17 U | 15 U | 14 U | 15 U | 15 U | 15 U |
| Pentachlorophenol | **360** | **360** | 150 UJ | 150 UJ | 170 UJ | 150 UJ | 140 UJ | 150 UJ | 150 UJ | 150 UJ |

NA: Not applicable
NS: not sampled
SQS: Sediment Quality Standard; Ecology, 1995
AET: Apparent Effects Threshold (see Ecology Publication No. 12-09-057)
SCO: Sediment Cleanup Objective
BGS: Below ground surface
PAHs: Polycyclic Aromatic Hydrocarbons, PAH concentrations in boxes indicate detection.
LPAH: Low molecular weight polycyclic aromatic hydrocarbons. Value shown is the sum of naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, and anthracene. Only detected values are used to calculate the sum. If all chemicals in the group were undetected, the highest individual detection limit is reported (Ecology, 2012).
Total benzofluoranthenes: represents the sum of the concentrations of the b and k isomers of benzofluoranthenes.
HPAH: High molecular weight polycyclic aromatic hydrocarbons. Value shown is the sum of fluoranthene, pyrene, benz[a]anthracene, chrysene, total benzofluoranthenes, benzo[a]pyrene, indeno[1,2,3-cd]pyrene, Dibenzo[a,h]anthracene, and benzo(ghi)perylene. Only detected values are used to calculate the sum. If all chemicals in the group were undetected, the highest individual detection limit is reported (Ecology, 2012)
REJ: Analytical results rejected by lab
U: The analyte was analyzed for, but was not detected at or above the reported quantitation limit.
J: The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample
UJ: The analyte was not detected above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately measure the analyte in the sample.
(A) Sample TOC is below recommended range for TOC normalization, criteria do not apply (see Ecology, 2012).
*See Footnote 4 on page 20 regarding diesel-range-organic designation.

# Appendix E. Glossary, Acronyms, and Abbreviations

## Glossary

**Downgradient:** The direction of flow, as defined by the hydraulic gradient.

**Dissolved oxygen (DO):** A measure of the amount of oxygen dissolved in water.

**Groundwater:** Water in the subsurface that saturates the rocks and sediment in which it occurs. The upper surface of groundwater saturation is commonly termed the water table.

**Hydrogeology:** The study of the distribution, characterization, and movement of groundwater in the soil and rocks below the earth's surface.

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

**pH:** A measure of the acidity or alkalinity of water. A low pH value (0 to 7) indicates that an acidic condition is present, while a high pH (7 to 14) indicates a basic or alkaline condition. A pH of 7 is considered to be neutral. Since the pH scale is logarithmic, a water sample with a pH of 8 is ten times more basic than one with a pH of 7.

**Specific conductance:** A measure of water's ability to conduct an electrical current. Specific conductance is related to the concentration and charge of dissolved ions in water.

**Stormwater:** The portion of precipitation that does not naturally percolate into the ground or evaporate but instead runs off roads, pavement, and roofs during rainfall or snow melt. Stormwater can also come from hard or saturated grass surfaces such as lawns, pastures, playfields, and from gravel roads and parking lots.

**Turbidity:** A measure of the amount of suspended sediment or organic matter in water.

**Upgradient:** In hydrology, an *upgradient* location is one that exhibits a larger hydraulic head in comparison to a *downgradient* location. Water flows from areas of high hydraulic head to areas of low hydraulic head. Hydraulic head is the total pressure exerted by a water mass at any given point. Total hydraulic head is the sum of elevation head, pressure head, and velocity head.

## Acronyms and Abbreviations

Following are acronyms and abbreviations used frequently in this report.

| | |
|---|---|
| AET | Apparent Effects Threshold |
| BNA | Base Neutral Acid semivolatiles |
| CGS | Coastal Geologic Services |
| E&E | Ecology and Environment, Inc. |
| Ecology | Washington State Department of Ecology |
| EPA | U.S. Environmental Protection Agency |
| MEL | Manchester Environmental Laboratory |

| | |
|---|---|
| MLLW | Mean Lower Low Water |
| MTCA | Model Toxics Control Act |
| NAD83 | North American Datum, 1983 |
| NAVD88 | North American Vertical Datum, 1988 |
| PAH | Polycyclic Aromatic Hydrocarbon |
| PCP | Pentachlorophenol |
| RPD | Relative percent difference |
| SCO | Sediment Cleanup Objective |
| SMS | Sediment Management Standards |
| SQS | Sediment Quality Standard |
| TOC | Total Organic Carbon |
| TPH-Dx | Total Petroleum Hydrocarbons – Diesel Range Organics |

*Metals*

| | |
|---|---|
| Ag | Silver |
| As | Arsenic |
| Cd | Cadmium |
| Cr | Chromium |
| Cu | Copper |
| Hg | Mercury |
| Pb | Lead |
| Zn | Zinc |

*Units of Measurement*

| | |
|---|---|
| °C | degrees centigrade |
| dw | dry weight |
| ft | feet |
| kg | kilograms, a unit of mass equal to 1,000 grams |
| mg | milligram |
| mg/Kg | milligrams per kilogram (parts per million) |
| mg/L | milligrams per liter (parts per million) |
| mL | milliliters |
| NTU | nephelometric turbidity units |
| ug/Kg | micrograms per kilogram (parts per billion) |
| ug/L | micrograms per liter (parts per billion) |
| uS/cm | microsiemens per centimeter, a unit of conductivity |