Exhibit B
Former Mill E/Koppers Facility
Supplemental Upland Remedial Investigation Work Plan

This Supplemental Upland Remedial Investigation Work Plan (Work Plan) for the Former Mill E/Koppers Facility in Everett, Washington (Site) will support the requirements of the Agreed Order (AO) under the Model Toxics Control Act (MTCA; Chapter 70.105D RCW), which is executed between the Washington State Department of Ecology (Ecology), Weyerhaeuser, and MAP #2. Figure 1 shows the geographic location of the Site, which is within the boundaries of the Everett Smelter Lowland Area. The surrounding properties are shown on Figure 2, and pertinent Site features, including Site piezometers and monitoring wells, are shown on Figure 3.

BACKGROUND

Weyerhaeuser is a former owner and operator of the Site. In 1946, Weyerhaeuser leased a 6.6-acre portion along the west bank of the Snohomish River to American Lumber and Treating Company (and then Koppers Company), who used the Site for wood treatment until 1963. In 1971, Weyerhaeuser constructed Mill E, a small lumber mill, which operated on the Mill E property until 1984; it was dismantled in 1988. Cleanup actions were completed by Weyerhaeuser in 1999, in accordance with the 1998 Cleanup Action Plan (CAP) and Consent Decree No. 98-2-08718-6 (Consent Decree). Weyerhaeuser sold the property to MAP #2 in 2005 and MAP #2 remains the current owner and operator. The Site is currently vacant and is used for light storage.

In its recent correspondence identified above, Ecology identified both Weyerhaeuser and MAP #2 as potentially liable parties (PLPs) for liability outside of the scope of the Consent Decree. In correspondence dated March 28, 2017, Weyerhaeuser accepted status as a PLP for groundwater at the Site outside the barrier wall and outside of the scope of the Consent Decree, with certain reservations as described in that correspondence.[1] This Work Plan provides a summary of activities completed by Weyerhaeuser and MAP #2 at the Site between 2017 and 2018 to address Ecology's concerns regarding barrier wall performance and the origin of discharges from an unknown outfall, designated as LLO-07, which discharges to the Snohomish River from a location on the southern portion of the Site. This Work Plan also provides proposed additional investigation activities at the Site to evaluate elevated concentrations of arsenic in soil and groundwater in the area of the Site outside the barrier wall and outside of the scope of the Consent Decree.

[1] See also Weyerhaeuser correspondence dated October 20, 2017, May 30, 2018, and August 20, 2018, that further discussed its reservations regarding PLP status.

BARRIER WALL EVALUATION

As part of the remedy selected by Ecology in the Consent Decree and CAP, Weyerhaeuser installed a barrier wall at the Site in 1999. The barrier wall surrounds the contained area of contamination in shallow fill material and an Upper Sand Aquifer, which extend to depths of approximately 6 to 10 feet below ground surface (bgs). The barrier wall is embedded in a low permeability Upper Silt Aquitard below this unit. A Lower Sand Aquifer is present beneath the Upper Silt Aquitard. The containment system, which consists of both a subsurface containment barrier wall and an asphalt cap, is shown on Figure 3.

Two cross-sections (A-A’ and B-B’) were prepared based on historical documentation for the Site to show the subsurface geology and hydrogeology relative to the barrier wall construction. Cross-section A-A’ is oriented west to east across the barrier wall, as shown on Figure 4, and cross-section B-B’ is oriented northeast to southeast across the barrier wall, as shown on Figure 5. The locations of the two cross-sections are shown on Figure 3.

Since 1999, Site monitoring has been conducted in accordance with the Performance Compliance Monitoring Plan (PCMP; EMCON 1998) to confirm that the barrier wall is functioning as intended. The purpose of the barrier wall, as outlined in the PCMP, is to hydraulically isolate the major sources of contamination (arsenic, petroleum hydrocarbons, and pentachlorophenol [penta]) in the Upper Sand Aquifer and minimize contaminant migration out of the containment area. The barrier wall was also intended to decrease potential contaminant flux from the Upper Sand Aquifer into the Lower Sand Aquifer and ultimately into the Snohomish River, which is hydraulically connected to the Lower Sand Aquifer.

Weyerhaeuser conducted the PCMP monitoring prior to August 2005, and MAP #2 conducted the monitoring after August 2005. As part of the third 5-year review for the Site (June 2016) and in light of recent data provided in the Everett Smelter Lowland Area *Final Supplemental Remedial Investigation Report* (SRI; GeoEngineers 2016), Ecology indicated that additional data were necessary to confirm that the barrier wall was functioning as intended. In its December 8, 2016, letter, Ecology described additional actions that it believed were necessary to address these concerns; specifically, monitoring of water levels in the Lower Sand Aquifer. Weyerhaeuser developed a PCMP Addendum (Floyd|Snider 2017a) to address Ecology’s concerns regarding the performance of the containment system.

In accordance with the PCMP Addendum, Floyd|Snider completed water level monitoring on a quarterly basis to confirm that vertical hydraulic head differences meet performance criteria throughout the seasons. Water level measurements were collected in September 2017, December 2017, March 2018, June 2018, and September 2018, as reported in the 2017 and 2018 Annual Performance and Monitoring Compliance Reports (Floyd|Snider 2017b, 2018a). These additional data confirmed that the containment system is functioning as designed, consistent with remedial goals and performance standards described in the CAP and PCMP; water levels in the Upper Sand Aquifer inside the barrier wall are stable at a decreased level relative to those in the Upper Sand Aquifer outside the barrier wall, as described below.

The horizontal head differences across the barrier wall and vertical head differences inside and outside the barrier wall are used as the primary indicators of the barrier wall's performance to control the hydraulic movement of contaminants. The groundwater elevation of the Upper Sand Aquifer inside the barrier wall was consistently lower than outside the barrier wall for all three piezometer pair locations (PZ-1A/B, PZ-2A/B, and PZ-3A/B). This indicates a positive horizontal head difference that drives potential groundwater flow inward through the barrier wall, to the extent flow occurs through the barrier. In addition, using water elevation measurements for the Lower Sand Aquifer,[2] the vertical head difference inside the barrier wall was substantially lower (approximately 1 foot) than the vertical head difference outside the barrier wall at all three piezometer pair monitoring locations. These results show that the hydraulic head inside the barrier wall was consistently lower than outside the barrier wall, indicating the barrier wall and asphalt cap are functioning as intended by isolating groundwater horizontally and reducing the downward flux of groundwater and potentially contaminants inside the barrier wall through the Upper Silt Aquitard.

OUTFALL LLO-07 PIPE INVESTIGATION

In its December 8, 2016, and January 27, 2017, letters, Ecology also stated that data collected in 2013 as part of the SRI (GeoEngineers 2016) indicated elevated arsenic concentrations in water discharging from Outfall LLO-07 and elevated concentrations of arsenic and mercury in sediment directly below Outfall LLO-07. The integrity and source of piping discharging at Outfall LLO-07 was not known. As a result, while stating that they were not liable for discharges from Outfall LLO-07, Weyerhaeuser and MAP #2 nevertheless agreed to investigate the unknown source of the outfall.[3]

Weyerhaeuser and Floyd|Snider researched and reviewed available background documents that could provide information about the outfall and its conveyance pipe. Weyerhaeuser reviewed its own property records, and Floyd|Snider reviewed documents from the City of Everett, Snohomish County, Washington state archives, and Sanborn maps. No record of the outfall or its conveyance pipe were found. Visual inspections of the outfall indicated that it was 12 inches in diameter and it was not screened, which allowed river water and debris to enter the pipe during high tides. The stormwater conveyance pipe is located in an area of the Site that is not currently or historically paved and where stormwater currently and historically infiltrates.

Floyd|Snider performed fieldwork at the Site, at the request of Weyerhaeuser, to investigate Outfall LLO-07 and its associated conveyance piping between February and September 2017. Floyd|Snider, along with its subcontractors and MAP #2, investigated the pipe from Outfall LLO-07 using a combination of technologies (refer to Figure 6). The pipe was initially able to be traced 290 feet from where it discharges at Outfall LLO-07, at which point there was an

[2] Using data collected outside the barrier wall is an accurate way to determine the potentiometric surface for the Lower Sand Aquifer inside the wall.

[3] This section provides a summary of Weyerhaeuser and MAP #2's investigation of outfall LLO-07. Please refer to Weyerhaeuser's March 28, 2017, October 20, 2017, May 30, 2018, and August 20, 2018, correspondence for additional information regarding the LLO-07 investigation.

obstruction in the pipe that could not be bypassed. This obstruction was later determined to be a wooden junction box, which was approximately 40 feet from the western property line. Stormwater was observed flowing into the junction box from the upstream conveyance pipe. A stormwater sample was collected for analysis, and the results indicated that arsenic was present at a concentration of 154 micrograms per liter (µg/L). The conveyance pipe was subsequently traced in a westerly direction from inside the junction box to just before the property line. The pipe was exposed via potholing at this location (at the western property boundary) and was confirmed to be intact with no visible signs of damage or obstruction. This was the farthest this pipe could be exposed without crossing the property line or undermining the property line fence. Based upon the visual observation of the pipe, Floyd|Snider concluded there is sufficient evidence to reasonably infer that this pipe crosses the property line intact and drains, or previously drained, an unknown area away from and off of the property. The origin of the pipe remains unknown. Additional details regarding this pipe investigation are provided in a December 2017 technical memorandum, *Revised Pipe Exploration Summary for Storm Drain Associated with Outfall LLO-07* (Floyd|Snider 2017c).

MAP #2 subsequently abandoned the pipe on its property in coordination with Ecology and the adjacent property owner, the Port of Everett, in order to eliminate the inflow of stormwater into the storm drain pipe from an unknown, off-property upland source and to prevent further discharge of stormwater from Outfall LLO-07. In addition, the junction box that was identified on the Site as part of pipe investigation activities was also abandoned at the same time. Three locations along the storm drain pipe alignment were selected to be plugged: (1) at the western property boundary to eliminate inflow of stormwater onto the Site property, (2) at the junction box, and (3) near Outfall LLO-07 to eliminate discharge. Additional details regarding the pipe abandonment are included in a May 2018 technical memorandum, *Storm Drain Pipe Abandonment Associated with Outfall LLO-07 at the Former Mill E/Koppers Facility* (Floyd|Snider 2018b).

EXISTING SITE SOIL AND GROUNDWATER DATA

Remedial investigation activities for the Site were completed in the early 1990s, as summarized in the *Draft Remedial Investigation Report* (EMCON 1994). The barrier wall was installed in 1999 in accordance with the CAP and Consent Decree and is functioning as intended, based on routine PCMP data collection, to provide containment of contaminated soil and groundwater within the wall. More recent data were collected in 2013 in the vicinity of the Site (and on the Site) as part of the SRI for the Everett Smelter Lowland Area (GeoEngineers 2016). The locations of soil and groundwater investigation locations at the Site and in the immediate vicinity of the Site are shown on Figure 7.

Available data show that arsenic concentrations in soil and groundwater outside the barrier wall at the Site exceed MTCA Method A cleanup levels (CULs) in soil for Unrestricted Land Use (WAC 173-340-900, Table 740-1) and MTCA Method A CULs in groundwater (WAC 173-340-900, Table 720-1). Exceedances in some cases are greater than the Site CUL established in the

Consent Decree for inside the barrier wall.[4] Arsenic concentrations in soil are shown on Figure 8, and arsenic concentrations in groundwater are shown on Figure 9 (Upper Sand Aquifer) and Figure 10 (Lower Sand Aquifer).

PROPOSED CURRENT CONDITIONS EVALUATION SAMPLING AND ANALYSIS PLAN

Additional soil and groundwater data collection is proposed to evaluate current conditions outside the barrier wall at the Site, as summarized in Table 1 and described in the sections below. The primary objectives of the proposed investigation are as follows:

- Assess current arsenic concentrations in soil and groundwater in both the Upper and Lower Sand Aquifers outside the barrier wall. This will be accomplished by installing additional Upper and Lower Sand Aquifer monitoring wells and collecting groundwater data from existing and new Site monitoring wells and piezometers and from Everett Smelter Lowland Area monitoring wells in the immediate vicinity of the Site. Additional soil data will be collected as described in the Proposed Soil Quality Evaluation section below to evaluate arsenic concentrations that may be impacting groundwater concentrations or exceeding Mill E Site CULs for soil as defined in the Consent Decree.
- Evaluate current conditions for groundwater in the Upper Sand Aquifer inside the barrier wall, including groundwater sample collection from existing piezometers for arsenic, total petroleum hydrocarbons (TPH), and penta.
- Evaluate current conditions for soil and groundwater in the vicinity of Outfall LLO-07 pipe alignment south of the barrier wall, including groundwater near former monitoring well HC-3.
- Assess Site groundwater flow directions and horizontal gradients for both the Upper and Lower Sand Aquifers, and vertical gradients between the aquifers.
- Collect geochemical parameters from soil and groundwater samples to evaluate arsenic fate and transport and to better understand natural geochemical conditions and determine if naturally reducing conditions are present.

Proposed Monitoring Well Installation

Ecology's December 2016 letter indicated that the 5 µg/L CUL for arsenic in groundwater does not appear to be met at the point of compliance (POC) at the Snohomish River. In order to evaluate arsenic concentrations at the conditional POC (CPOC; where groundwater discharges to

[4] It is important to note that the barrier wall was designed to contain the most significant source of soil contamination (arsenic, petroleum hydrocarbons, and penta) and did not contain all source soil with contamination present at concentrations greater than Site CULs. Arsenic contamination in soil and groundwater greater than the Site CUL remains present outside the barrier wall and is not a new condition. The Site CUL for arsenic defined in the CAP applies only to "within the area of the containment wall."

surface water), a series of shoreline monitoring wells in both the Upper and Lower Sand Aquifers are proposed. Refer to Figure 11 for proposed monitoring well locations.

A total of nine Upper Sand Aquifer monitoring wells are proposed as follows:

- Six monitoring wells (MW-01S through MW-06S) will be installed along the shoreline at the CPOC to evaluate groundwater quality in the Upper Sand Aquifer where groundwater discharges to surface water. Two of these proposed locations (MW-02S and MW-03S) were requested by Ecology and are located between the barrier wall and the bulkhead wall in a possible stagnation zone that may not be representative of Upper Sand Aquifer groundwater discharging through the bulkhead to the Snohomish River. Groundwater in this area may be both isolated from the rest of the Upper Sand Aquifer at the Site and not appreciably discharging to the river, because groundwater flow paths are disrupted by the barrier wall, hydraulic gradients are flat, and flushing from upgradient groundwater flow and precipitation infiltration are significantly reduced.[5]
- Three monitoring wells (MW-05S, MW-07S, and MW-08S) will be installed south of the barrier wall to evaluate groundwater quality in the Upper Sand Aquifer south of the containment system and along the alignment of the LLO-07 conveyance pipe, including along the western property boundary (one of the three, MW-05S, is also a shoreline well as described in the bullet above).
- One monitoring well (MW-09S) will be installed in the northwest portion of the Site, to evaluate groundwater quality in the Upper Sand Aquifer upgradient of piezometer PZ-3B, which had arsenic concentrations ranging from 5.8 to 31 µg/L in 2013.

A total of 10 Lower Sand Aquifer monitoring wells are proposed as follows:

- Six monitoring wells (MW-01D through MW-06D) will be installed along the shoreline at the CPOC to evaluate groundwater quality in the Lower Sand Aquifer where groundwater discharges to surface water.
- One monitoring well (MW-07D) will be installed along the central alignment of the LLO-07 stormwater pipe to evaluate Lower Sand Aquifer groundwater quality and to evaluate vertical and horizontal gradients.
- One monitoring well (MW-08D) will be installed south of the barrier wall along the western property boundary, to evaluate groundwater quality in the Lower Sand Aquifer on the upgradient portion of the Site in this area.
- One monitoring well (MW-09D) will be installed in the northwest portion of the Site, to evaluate groundwater quality in the Lower Sand Aquifer upgradient of

[5] The Upper Sand Aquifer, because of its elevation, occurrence in fill material above the native tideflat, and the shoreline bulkhead, is not strongly connected hydraulically with the Snohomish River, based on limited tidal influence, although it may discharge to seeps that drain to the Snohomish River during low tides. The area between the barrier wall and bulkhead is expected to be a stagnation zone.

Everett Smelter Lowland Site monitoring well LLMW-20D, which had arsenic concentrations ranging from 8.7 to 34 µg/L in 2013.

- One monitoring well (MW-10D) will be installed adjacent to existing Upper Sand Aquifer piezometer PZ-1B in order to provide a closer and onsite compliance monitoring point in the Lower Sand Aquifer for routine PCMP water level monitoring. Everett Smelter Lowland Site monitoring well LLMW-19D, which is approximately 90 feet west of PZ-1B is currently monitored. This monitoring well will also provide groundwater quality data immediately outside the barrier wall and downgradient of LLMW-19D, which had elevated arsenic concentrations (approximately 40 µg/L) in 2013.

Monitoring well construction and development will be performed in accordance with the Floyd|Snider monitoring well construction and development standard guidelines included in Attachment 1. A 2-inch-diameter polyvinyl chloride well with a 5- or 10-foot-long screen will be installed at each proposed location using sonic drilling methods. Soil core will be collected continuously during monitoring well installation and logged to identify the location and thickness of the Upper Silt Aquitard. Soil samples that will be collected for analysis are described in the soil quality evaluation section below.

For Upper Sand Aquifer monitoring well installation, the field geologist will direct the drill rig to be advanced to collect soil core in short (approximately 1 foot) increments as the approximate depth of the contact with the Upper Silt Aquitard, until the aquitard is identified, to minimize penetration of the aquitard. For Lower Sand Aquifer monitoring well installation, appropriate drilling methods will be used to prevent cross-contamination of the Lower Sand Aquifer. If necessary, casing will be advanced into the aquitard to create a seal, and the remainder of the borehole will be drilled through the casing. Upper Sand Aquifer monitoring wells will be constructed with screens set to be consistent with existing Upper Sand Aquifer monitoring wells and extending to approximately at the upper contact of the Upper Sand Aquifer and Upper Silt Aquitard (approximately 5 to 10 feet bgs). Lower Sand Aquifer monitoring wells will be set consistent with existing Lower Sand Aquifer monitoring wells and immediately below the aquitard (approximately 15 to 25 feet bgs). The screened interval will be determined in the field based on field observations (i.e., depth and thickness of the Upper Silt Aquitard) and will be designed to be representative of the targeted aquifer. Wells will be completed with either flush-mounted monuments or standpipes based on their location.

Following installation, monitoring wells will be developed to remove fine-grained material by purging with a submersible pump and surging with the pump or a surge block in order to move water through the sand pack and surrounding soil formation. Wells will be developed until the purge water achieves visual clarity. Existing wells will also be evaluated for the presence of excessive sedimentation (i.e., greater than 0.05 feet of accumulated material) and may be redeveloped if necessary, to remove accumulated fine-grained material prior to groundwater sample collection. Excess soil and purge water will be collected in 55-gallon drums as investigation derived waste (IDW) and will be temporarily stored on site pending waste characterization and offsite disposal.

All new monitoring wells will subsequently be surveyed and tied into the existing network to facilitate evaluation of groundwater elevation and preparation of contour maps.

Proposed Soil Boring Locations

In addition to soil data collection as part of monitoring well installation described above, additional shallow soil borings are proposed to evaluate current soil quality outside the barrier wall and to evaluate if current soil quality may be adversely impacting groundwater quality at the Site. Refer to Figure 11 for proposed soil boring locations.

A total of five soil borings are proposed as follows:

- Four soil borings will be advanced in the soil cap area south of the barrier wall; three north of LLO-07 pipe (SB-101, SB-102, and SB-103) and one south of the pipe (SB-104) to evaluate current soil conditions.
- One soil boring (SB-100) will be advanced northwest of and adjacent to the barrier wall to evaluate current soil conditions immediately outside the barrier wall and in an area where elevated arsenic in the Upper Sand Aquifer has been detected (at location PZ-1B).

Soil borings will be advanced using sonic or direct-push drilling methods, and soil core will be collected continuously until the Upper Silt Aquitard is observed. The field geologist will direct the drill or direct-push rig to be advanced to collect soil core in short (approximately 1 foot) increments as the approximate depth of the contact with the Upper Silt Aquitard, until the aquitard is identified, to minimize penetration of the aquitard. Soil samples will be logged and collected in accordance with Floyd|Snider's standard guidelines included in Attachment 1. Excess soil will be collected in 55-gallon drums as IDW and will be temporarily stored on site pending waste characterization and offsite disposal. All soil boring locations will subsequently be surveyed to document their location.

Proposed Soil Quality Evaluation

Existing data indicate that the majority of arsenic detected in soil outside the barrier wall is less than the Site CUL for arsenic of 200 milligrams per kilogram specified in the CAP (refer to Figure 8).

Additional soil arsenic data will be collected during the installation of Upper Sand Aquifer monitoring wells and soil borings south of the barrier wall and along the Outfall LLO-07 pipe alignment and northwest of the barrier wall to evaluate arsenic levels in soil around the containment system and in the vicinity of the pipe. Field investigation activities indicated that the conveyance pipe is located between 5.5 and 8 feet bgs as it traverses the Site west to east (it is deepest just before the outfall). There was also a minimum of 1 foot of clean soil placed outside the barrier wall during remedial construction activities in 1999 (refer to soil cap area on Figure 3). Many previous test pits and soil borings that were sampled for arsenic were generally very shallow (i.e., less than 3 feet bgs), and additional data are necessary to evaluate the vertical extent of arsenic in soil outside the barrier wall. Therefore, additional soil data will be collected between 2 and 10 feet bgs to evaluate arsenic concentrations in shallow soils.

Soil samples will be collected from the continuously collected soil core in 2-foot intervals from the ground surface to the upper contact with the Upper Silt Aquitard or 10 feet bgs, whichever comes first. Soil samples will initially be selected for arsenic analysis from selected intervals of the Upper Sand Aquifer based on the location and surrounding data density and depths to fill in data gaps. Soil samples that are not selected for initial laboratory analysis of arsenic will be archived at the laboratory in the event that additional data are needed to define the vertical extent of arsenic in soil. Additional analyses will be performed as needed based on the initial results.

Soil samples will also be collected for analyses of iron, manganese, sulfide, and total organic carbon to evaluate the variability in aquifer minerals that affect fate and transport of arsenic.

Proposed Groundwater Quality Evaluation

The proposed groundwater quality evaluation will consist of the collection and laboratory analyses of groundwater samples as follows:

- Existing Site Upper Sand Aquifer piezometers located inside the barrier wall (PZ-1A, PZ-2A, and PZ-3A) for arsenic (total and dissolved), TPH by NWTPH-Gx and NWTPH-Dx, and penta by USEPA Method 8270.
- Existing Site Upper Sand Aquifer piezometers located outside the barrier wall (PZ-1B, PZ-2B, and PZ-3B) for arsenic (total and dissolved).
- Existing Site Lower Sand Aquifer piezometer located outside the barrier wall (PZ-2D) for arsenic (total and dissolved).
- Existing Everett Smelter Lowland Site Upper Sand Aquifer monitoring wells (LLMW-18S and LLMW-21S) for arsenic (total and dissolved).
- Existing Everett Smelter Lowland Site Lower Sand Aquifer monitoring wells (LLMW-18D, LLMW-19D, LLMW-20D, and LLMW-21D) for arsenic (total and dissolved).
- New proposed Upper and Lower Sand Aquifer monitoring wells for arsenic (total and dissolved).

Groundwater samples will be collected using standard low-flow sampling methods in accordance with the Floyd|Snider standard guidelines (included in Attachment 1), and field measurements for pH, temperature, dissolved oxygen, oxygen reduction potential, and specific conductivity will be collected.

The depth to groundwater will be recorded at each location prior to groundwater sample collection. Two comprehensive groundwater monitoring events are proposed to evaluate seasonal data variability and flow patterns, one during the wet season (October through April) and one during the dry season (May through September). Groundwater samples will be collected from the Lower Sand Aquifer monitoring wells during a low tide to minimize tidal interference[6] and collect samples representative of groundwater discharging to surface water. Refer to Figure 11 for proposed soil and groundwater investigation locations.

Groundwater samples will also be collected for analyses of major cations (calcium, magnesium, potassium, and sodium), major anions (bromide, chloride, fluoride, and sulfate), alkalinity (dissolved), major ions (ortho-phosphate), nitrate, nitrite, iron (dissolved), manganese (dissolved), sulfide (dissolved), and organic carbon (total and dissolved) to evaluate potential natural variability of geochemical conditions that affect fate and transport of arsenic.

Quality Assurance Project Plan

The Quality Assurance Project Plan included in Attachment 2 describes the analytical program to be conducted for each sample selected for chemical analysis, as well as the laboratory quality assurance objectives and quality control procedures required to be met to achieve technically sound and useable data.

Contingency Discussion

Weyerhaeuser has proposed the installation of 19 additional monitoring wells (9 in the Upper Sand Aquifer and 10 in the Lower Sand Aquifer) as part of this Work Plan and believes the additional data collection will provide sufficient information to evaluate groundwater quality at the Site.

The Lower Sand Aquifer groundwater flow is not restricted by the barrier wall (the barrier wall is keyed into the Upper Silt Aquitard above the Lower Sand Aquifer), and, therefore, collection of groundwater data immediately adjacent to and outside the wall can provide adequate information regarding the nature and extent of arsenic in the Lower Sand Aquifer. In particular, the proposed data collection program includes several locations along the shoreline to assess groundwater prior to the point of discharge to the Snohomish River (the groundwater POC). If data gaps remain after the completion of additional investigation activities described in this Work Plan, then they would be addressed in a Supplemental Remedial Investigation/Focused Feasibility Study Work Plan (SRI/FFS Work Plan) that would be developed to address these data gaps, after consultation with Ecology.

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[6] Floyd|Snider conducted a baseline groundwater level evaluation in 2017 to determine the tidal influence in the vicinity of the barrier wall. All accessible locations were measured for a full tide cycle. Tidal influence was noted in all measured Lower Sand Aquifer monitoring wells and was not noted in Upper Sand Aquifer piezometers. Transducers will be used in selected wells as part of this proposed investigation to supplement existing data to determine which wells will require sample collection at low tide.

Lastly, analyses of geochemical parameters in soil and groundwater are proposed as part of this Work Plan to provide a better understanding of site-specific subsurface geochemical conditions and will be used to evaluate fate and transport of arsenic at the Site. If the additional data collected as part of this Work Plan warrant additional geochemical analyses or arsenic speciation to better understand fate and transport, then it would be addressed as Phase 2 in the SRI/FFS Work Plan that would be submitted after consultation with Ecology.

NEXT STEPS

The proposed field investigation would be initiated within 30 days of the effective date of the AO, per Exhibit C of the AO.

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LIST OF ATTACHMENTS

Table

Table 1
Proposed Supplemental Upland Field Investigation

Location ID [1]	Purpose/Objectives	Sample Collection [2]	Laboratory Analysis [3,4,5,6]
Proposed Groundwater Monitoring Wells			
MW-01S through MW-06S	• Evaluate groundwater quality in the Upper Sand Aquifer along the shoreline	• Groundwater (wet and dry season) • Soil	• Arsenic • Geochemical parameters
MW-05S, MW-07S, MW-08S	• Evaluate groundwater quality in the Upper Sand Aquifer south of the containment system and along the alignment of the LLO-07 conveyance pipe, including along the western property boundary	• Groundwater (wet and dry season) • Soil	• Arsenic • Geochemical parameters
MW-09S	• Evaluate groundwater quality in the Upper Sand Aquifer upgradient of piezometer PZ-3B	• Groundwater (wet and dry season) • Soil	• Arsenic • Geochemical parameters
MW-01D through MW-06D	• Evaluate groundwater quality in the Lower Sand Aquifer along the shoreline	• Groundwater (wet and dry season)	• Arsenic • Geochemical parameters
MW-07D	• Evaluate groundwater quality in the Lower Sand Aquifer and evaluate vertical and horizontal gradients	• Groundwater (wet and dry season)	• Arsenic • Geochemical parameters
MW-08D	• Evaluate groundwater quality in the Lower Sand Aquifer on the upgradient portion of the Site along the western property boundary	• Groundwater (wet and dry season)	• Arsenic • Geochemical parameters
MW-09D	• Evaluate groundwater quality in the Lower Sand Aquifer upgradient of Everett Smelter Lowland Site monitoring well LLMW-20D	• Groundwater (wet and dry season)	• Arsenic • Geochemical parameters
MW-10D	• Provide a closer and onsite compliance monitoring point in the Lower Sand Aquifer for routine PCMP water level monitoring	• Groundwater (wet and dry season) • Soil	• Arsenic • Geochemical parameters
Existing Groundwater Monitoring Wells			
PZ-1A, PZ-2A, PZ-3A	• Evaluate current groundwater quality in the Upper Sand Aquifer inside the barrier wall	• Groundwater (wet and dry season)	• Arsenic • TPH by NWTPH-Gx and NWTPH-Dx • Penta by USEPA Method 8270 • Geochemical parameters
PZ-1B, PZ-2B, PZ-3B, LLMW-18S, LLMW-21S	• Evaluate current groundwater quality of the Upper Sand Aquifer outside the barrier wall	• Groundwater (wet and dry season)	• Arsenic • Geochemical parameters
PZ-2D, LLMW-18D, LLMW-19D, LLMW-20D, LLMW-21D	• Evaluate current quality of the Lower Sand Aquifer outside the barrier wall	• Groundwater (wet and dry season)	• Arsenic • Geochemical parameters
Proposed Soil Borings			
SB-101 through SB-104	• Evaluate current soil conditions in the soil cap area south of the barrier wall	• Soil, between 2 and 10 feet bgs	• Arsenic • Geochemical parameters
SB-100	• Evaluate current soil conditions immediately outside the barrier wall and in an area where elevated arsenic in the Upper Sand Aquifer has been detected	• Soil, between 2 and 10 feet bgs	• Arsenic • Geochemical parameters

Notes:

1 Refer to Figure 11 for proposed locations.
2 All groundwater samples will be analyzed for both total and dissolved arsenic.
3 Refer to the QAPP in Attachment 2 for additional information regarding sample collection.
4 Arsenic analysis by USEPA Method 200.8 for groundwater and USEPA Method 6020 for soil.
5 Geochemical parameters for groundwater include major cations (calcium, magnesium, potassium, and sodium), major anions (bromide, chloride, fluoride, and sulfate), alkalinity (dissolved), major ions (ortho-phosphate), nitrate, nitrite, iron (dissolved), manganese (dissolved), sulfide (dissolved), and organic carbon (total and dissolved).
6 Geochemical parameters for soil include iron, manganese, sulfide, and total organic carbon.

Abbreviations:

bgs Below ground surface
PCMP Performance Compliance Monitoring Plan
Penta Pentachlorophenol
QAPP Quality Assurance Project Plan
TPH Total petroleum hydrocarbons
USEPA U.S. Environmental Protection Agency

Figures

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Former Mill E/Koppers Facility
Everett, Washington

Figure 1
Site Location

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Figure 2
Site and Surrounding Properties

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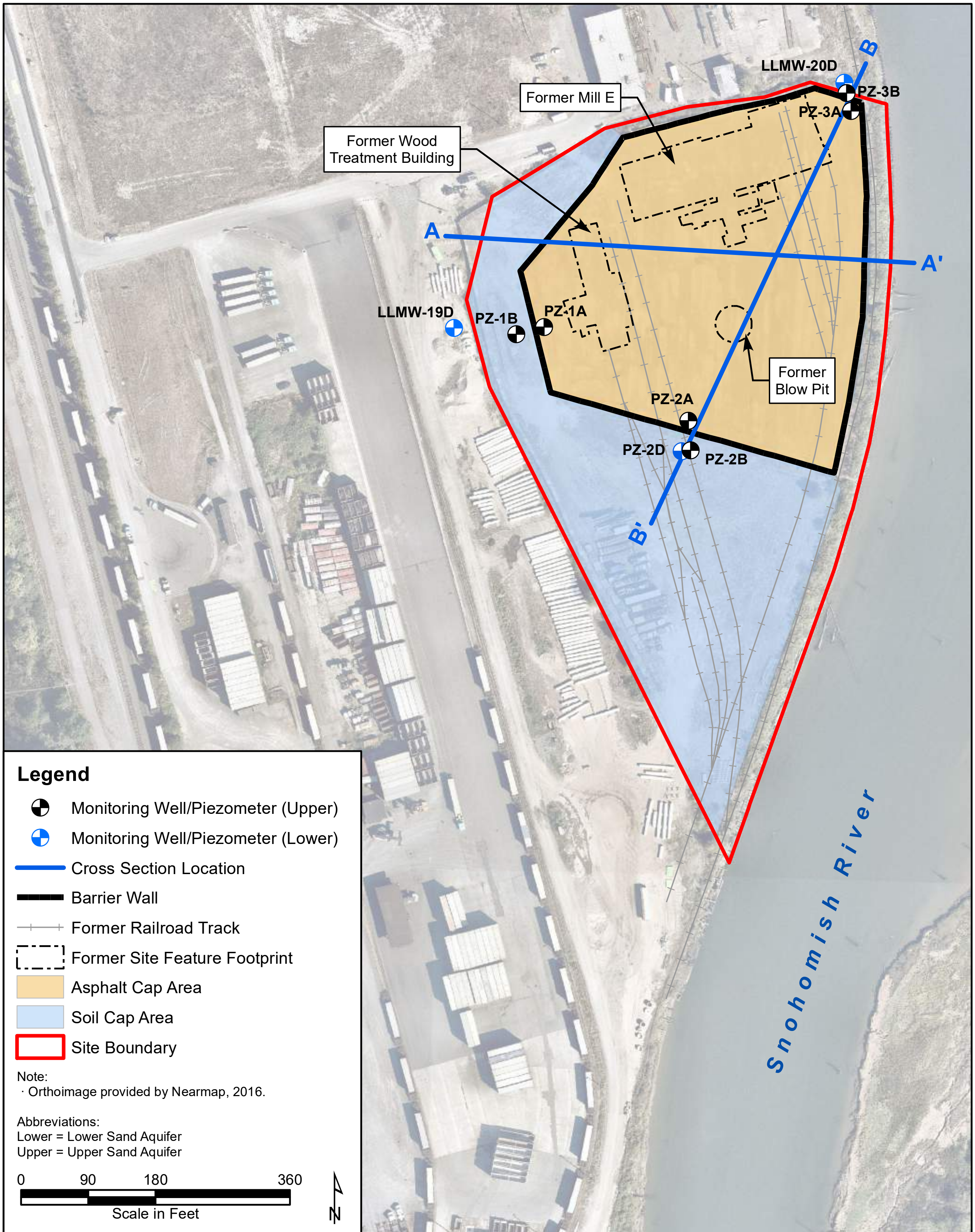
4/9/2020



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Former Mill E/Koppers Facility
Everett, Washington

Figure 3
Site Features and
Site Monitoring Network

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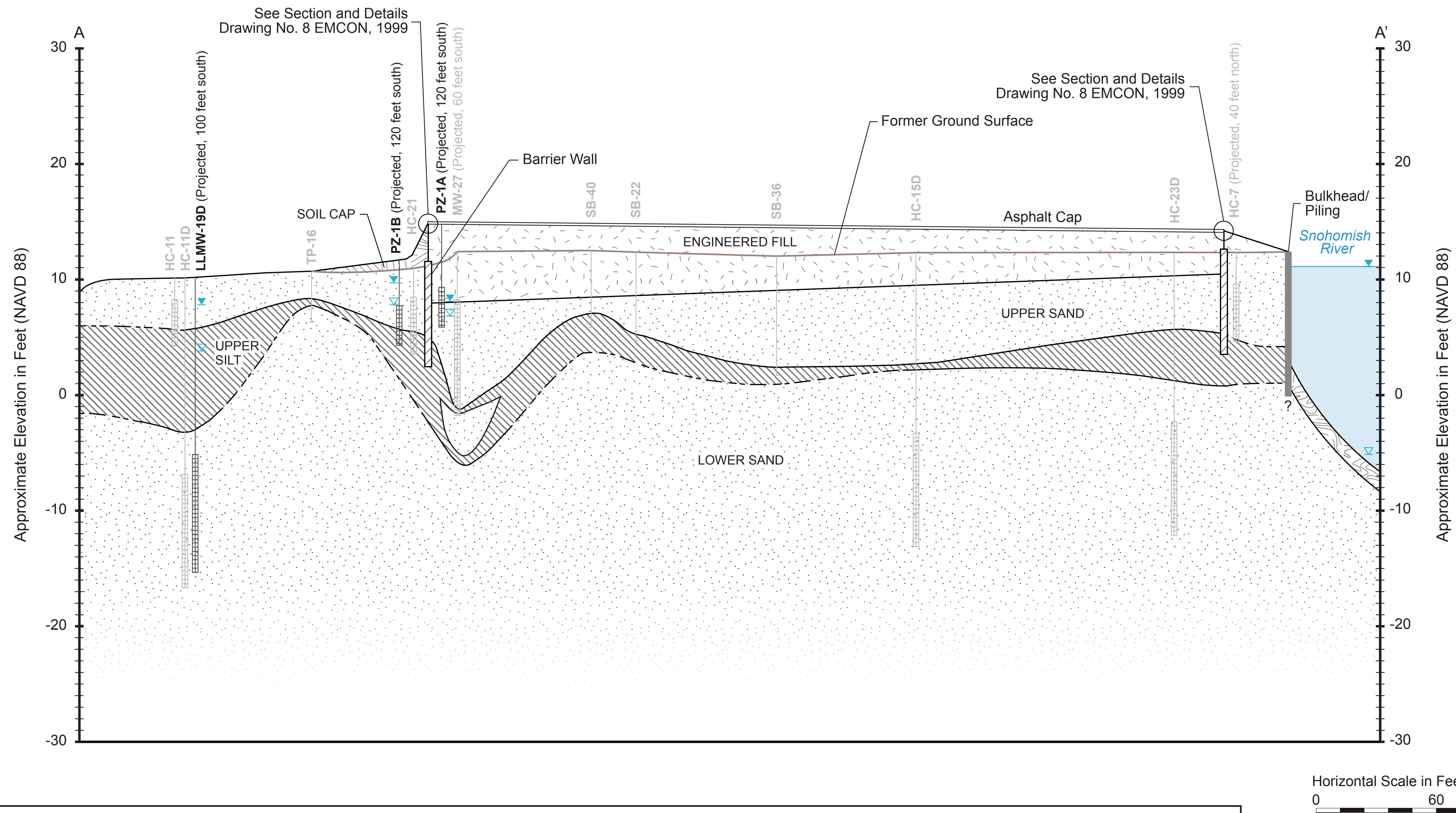
4/9/2020



Legend

- Boring
- Highest observed water level (2015–2018)
- Lowest observed water level (2015–2018)
- Existing monitoring well
- Decommissioned monitoring well
- Contact boundary between lithologies (dashed where inferred)

Note:
- Elevations in NAVD 88.

Abbreviation:
NAVD 88 = North American Vertical Datum of 1988

References:

EMCON. 1999. *Former Mill "E"/Koppers Site Remediation*. Weyerhaeuser Everett Mill. Everett, Washington. September.
Hart Crowser. 1989. *Site Characterization Report*. Weyerhaeuser Old Machine Shop. Everett Mill E Site. Everett, Washington. October.
Hart Crowser. 1991. *Phase I Site Characterization Report*. Weyerhaeuser-Everett Mill E Site. Everett, Washington. March.
NOAA. 2019. Station 9447659 Everett, WA. https://tidesandcurrents.noaa.gov/noaatideannual.html?id=9447659. Last accessed July 5, 2019.

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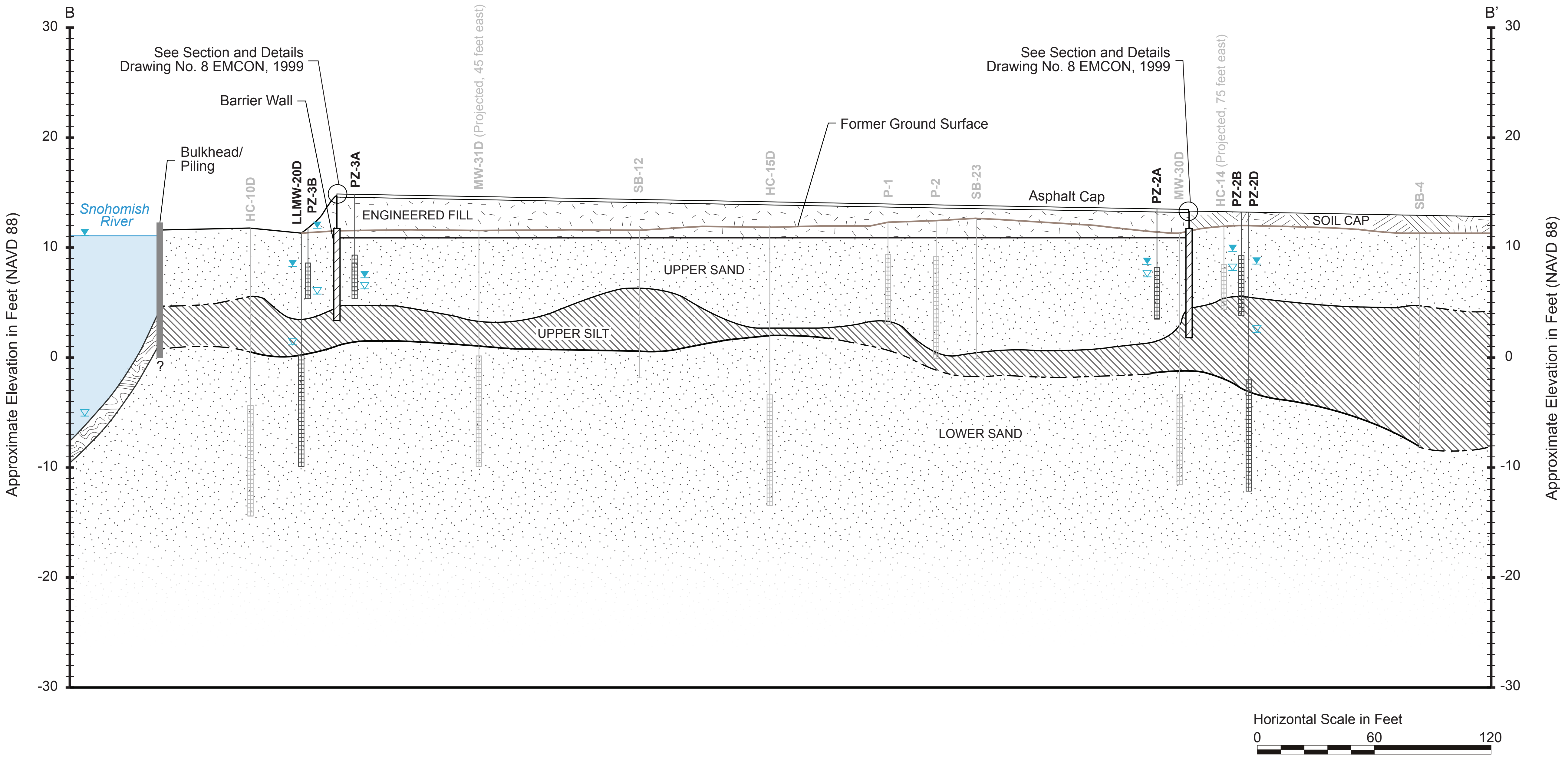
Former Mill E/Koppers Facility
Everett, Washington

Figure 4
Cross-Section A-A'

I:\GIS\Projects\WEYER_MILL_E\AI\Cross-Sections\Figure 4 Cross-Section A-A'_2020-0410.ai
04/10/2020



Legend

- Boring
- Highest observed water level (2015–2018)
- Lowest observed water level (2015–2018)
- Existing monitoring well
- Decommissioned monitoring well
- Contact boundary between lithologies (dashed where inferred)

Note:
- Elevations in NAVD 88.

Abbreviation:
NAVD 88 = North American Vertical Datum of 1988

References:

EMCON. 1999. *Former Mill "E"/Koppers Site Remediation*. Weyerhaeuser Everett Mill. Everett, Washington. September.

Hart Crowser. 1989. *Site Characterization Report*. Weyerhaeuser Old Machine Shop. Everett Mill E Site. Everett, Washington. October.

Hart Crowser. 1991. *Phase I Site Characterization Report*. Weyerhaeuser-Everett Mill E Site. Everett, Washington. March.

NOAA. 2019. Station 9447659 Everett, WA. https://tidesandcurrents.noaa.gov/noaatideannual.html?id=9447659. Last accessed July 5, 2019.

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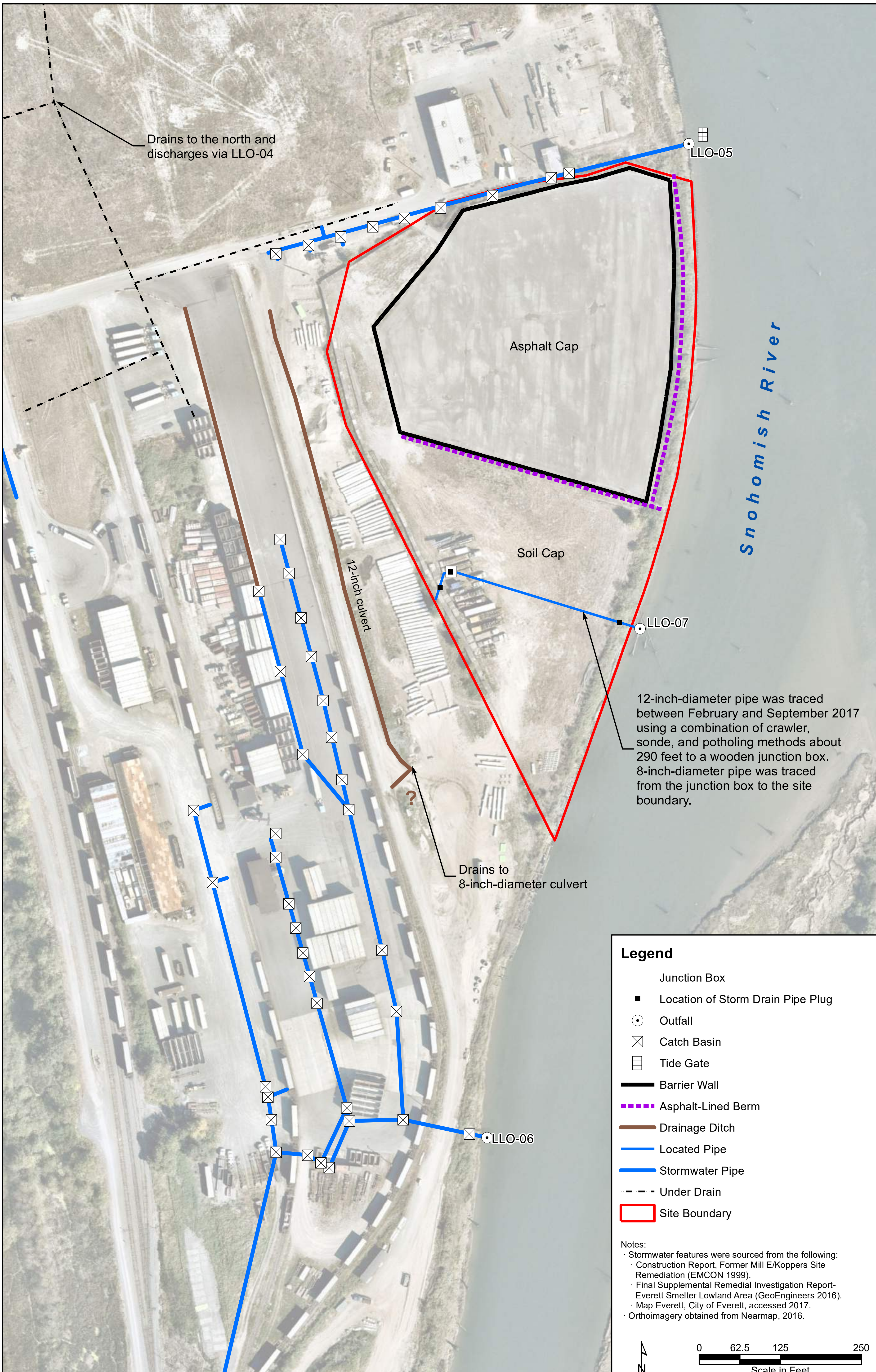
Figure 5
Cross-Section B-B'



FLOYD | SNIDER strategy ▪ science ▪ engineering	**Supplemental Upland Remedial Investigation Work Plan Former Mill E/Koppers Facility Everett, Washington**	Figure 6 Stormwater Features and LLO-07 Pipe Investigation Details

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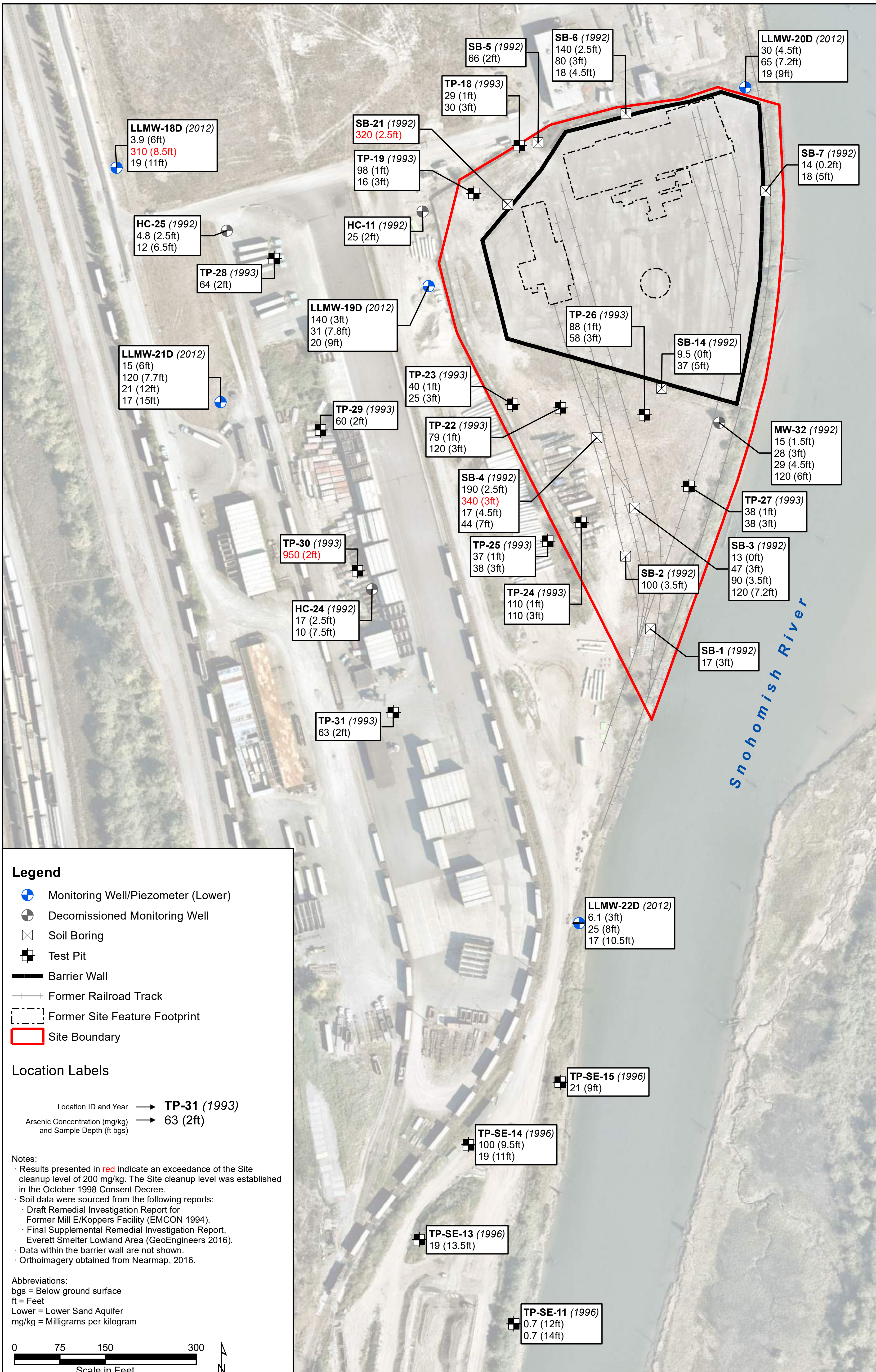
Former Mill E/Koppers Facility
Everett, Washington

Figure 7
Soil and Groundwater Investigation Locations



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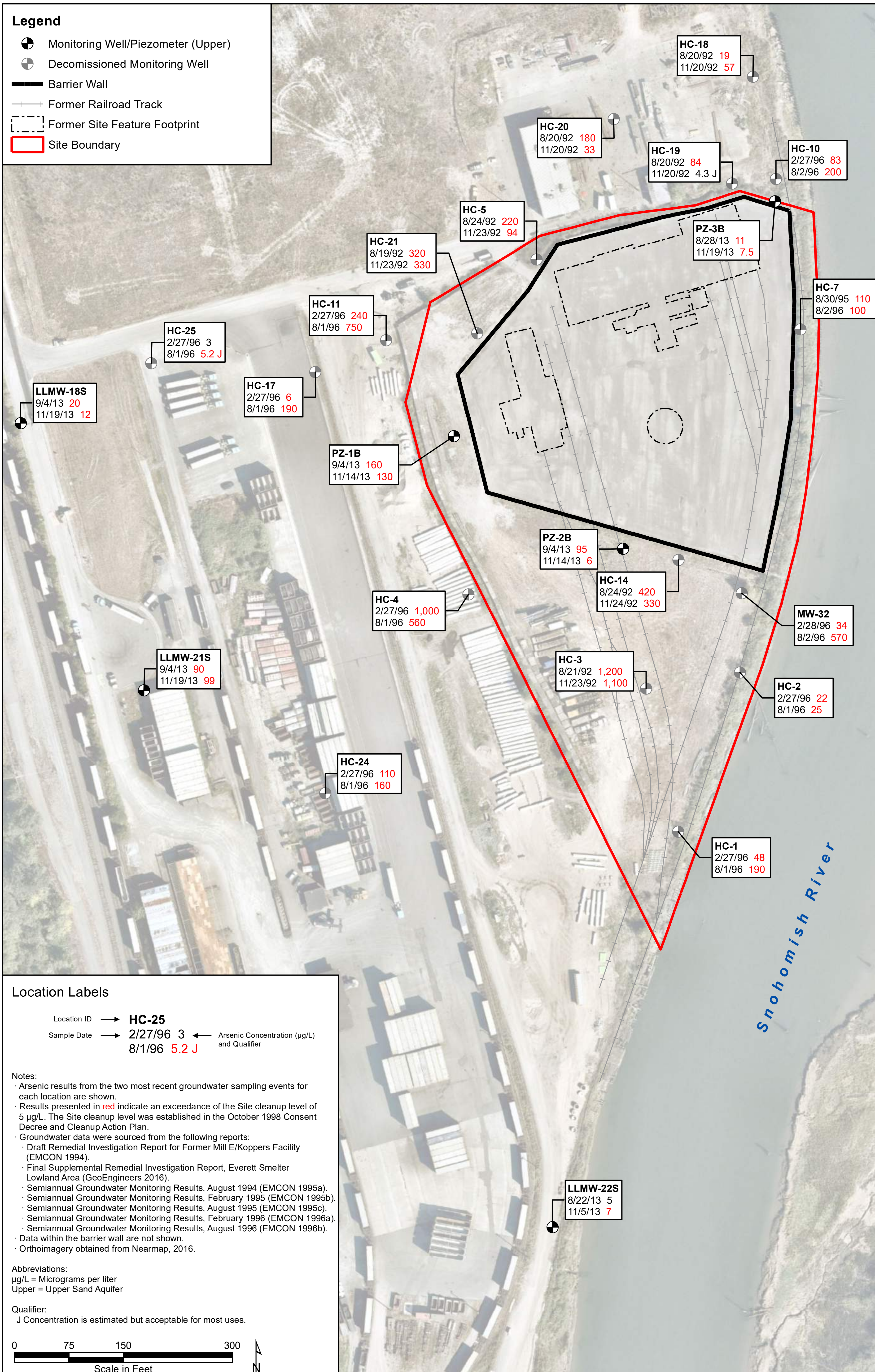
Everett, Washington

Figure 8
Arsenic in Soil

I:\GIS\Projects\WEYER_MILL_E\MXD\Agreed Order\Revised Memo_Aug19\Figure 8 Arsenic in Soil.mxd
4/9/2020



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Former Mill E/Koppers Facility
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Figure 9
Arsenic in Groundwater—Upper Sand Aquifer

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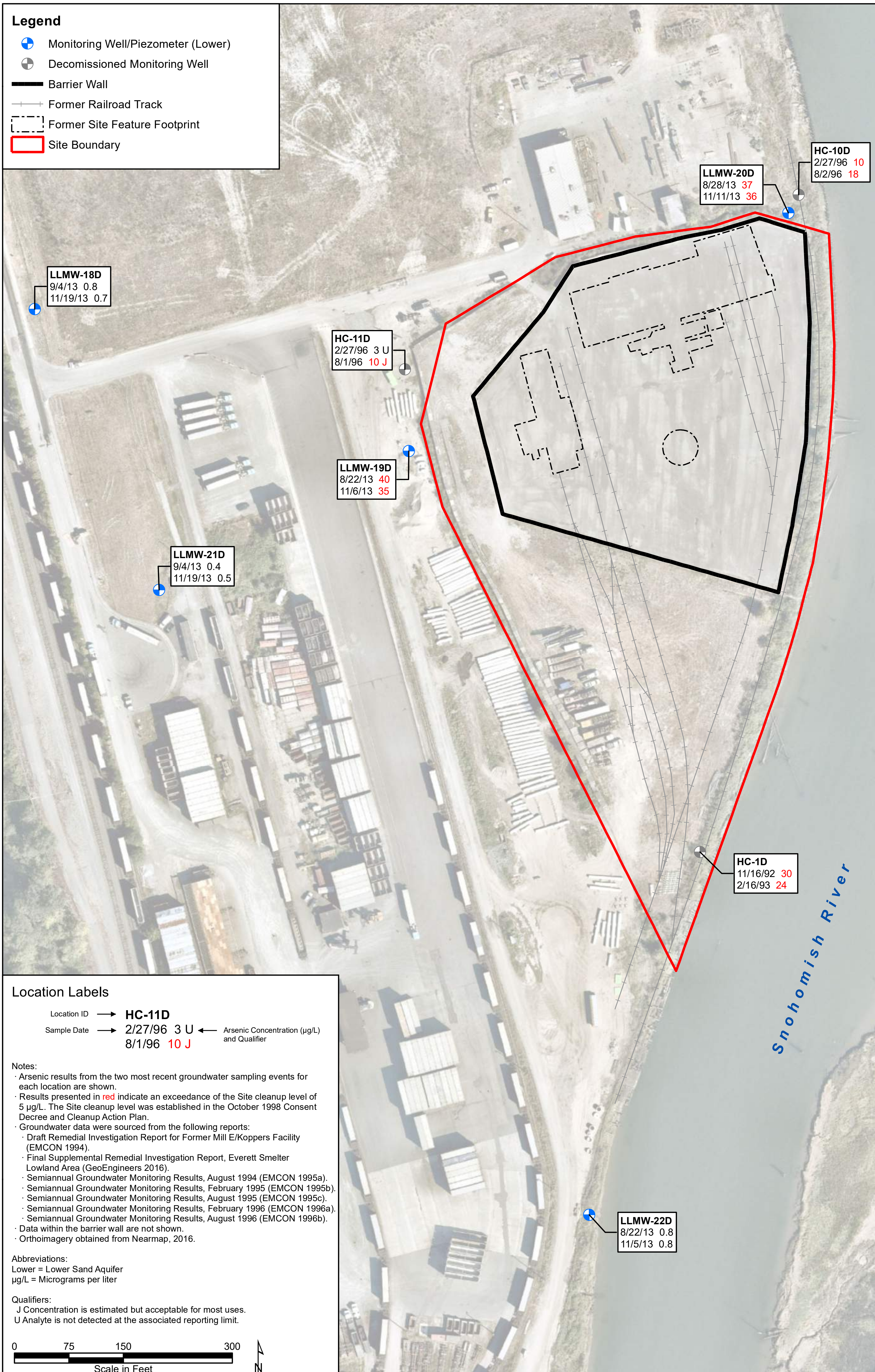

Notes:
- Arsenic results from the two most recent groundwater sampling events for each location are shown.
- Results presented in red indicate an exceedance of the Site cleanup level of 5 µg/L. The Site cleanup level was established in the October 1998 Consent Decree and Cleanup Action Plan.
- Groundwater data were sourced from the following reports:
  - Draft Remedial Investigation Report for Former Mill E/Koppers Facility (EMCON 1994).
  - Final Supplemental Remedial Investigation Report, Everett Smelter Lowland Area (GeoEngineers 2016).
  - Semiannual Groundwater Monitoring Results, August 1994 (EMCON 1995a).
  - Semiannual Groundwater Monitoring Results, February 1995 (EMCON 1995b).
  - Semiannual Groundwater Monitoring Results, August 1995 (EMCON 1995c).
  - Semiannual Groundwater Monitoring Results, February 1996 (EMCON 1996a).
  - Semiannual Groundwater Monitoring Results, August 1996 (EMCON 1996b).
- Data within the barrier wall are not shown.
- Orthoimagery obtained from Nearmap, 2016.

Abbreviations:
Lower = Lower Sand Aquifer
µg/L = Micrograms per liter

Qualifiers:
J Concentration is estimated but acceptable for most uses.
U Analyte is not detected at the associated reporting limit.

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Former Mill E/Koppers Facility
Everett, Washington

Figure 10
Arsenic in Groundwater—Lower Sand Aquifer

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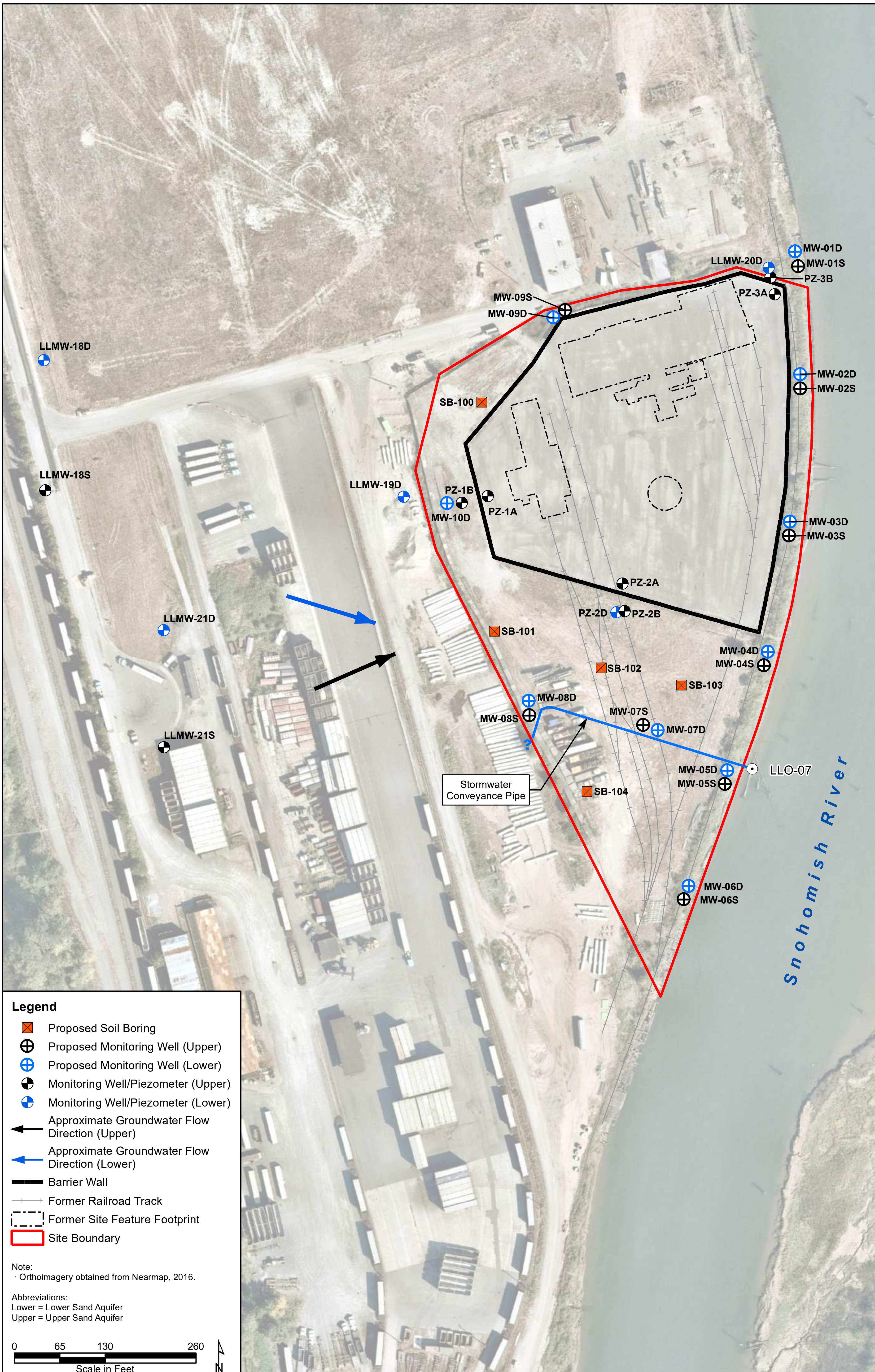

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Former Mill E/Koppers Facility
Everett, Washington

Figure 11
Proposed Soil and Groundwater Investigation Locations

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4/9/2020

Attachment 1
Floyd|Snider Standard Guidelines

F|S STANDARD GUIDELINE

Well Construction

DATE/LAST UPDATE: May 2015

These procedures should be considered standard guidelines and are intended to provide useful guidance when in the field, but are not intended to be step-by-step procedures, as some steps may not be applicable to all projects.

All field staff should be sufficiently trained in the standard guidelines and should review and understand these procedures prior to going in the field. It is the responsibility of the field staff to review the standard guidelines with the field manager or project manager and identify any deviations from these guidelines prior to field work. When possible, the project-specific Sampling and Analysis Plan should contain any expected deviations and should be referenced in conjunction with these standard guidelines.

1.0 Scope and Purpose

This standard guideline presents commonly used procedures for the installation of resource protection wells, in accordance with applicable sections of the Washington State Minimum Standards for Construction and Maintenance of Wells (Washington Administrative Code [WAC] 173-160, Part Two) and ASTM Standard Practice for Design and Installation of Groundwater Monitoring Wells (ASTM D5092-04[2010]e1). These wells may include groundwater monitoring wells, piezometers, groundwater extraction wells, injection wells, or vapor extraction wells. The guideline is intended to be used by field staff who are overseeing well drilling and construction.

2.0 Equipment and Supplies

Well Installation Equipment and Tools:

- Tape measure or measuring wheel
- Weighted tape or leadline
- Water level meter
- Hand-held Global Positioning System (GPS; optional)
- Camera
- Trash bags

- Well construction materials including polyvinyl chloric (PVC) screen and riser, sandpack, bentonite and well monument will be provided by the drilling subcontractor.

Paperwork:

- Work Plan and/or Sampling and Analysis Plan (SAP)/Quality Assurance Project Plan (QAPP)
- Health and Safety Plan (HASP)
- Copies of figures showing previous boring locations and boring logs from previous investigations and historical depth to water levels, if available
- Well installation forms (printed on Rite in the Rain paper)
- Permanent markers and pencils

Personal Equipment:

- Steel-toed boots
- Hard hat
- Safety vest
- Safety glasses
- Nitrile gloves
- Ear plugs
- Rain gear
- Work gloves

3.0 Standard Procedures

3.1 PREPARATION

First, before going into the field, it is important to discuss the project needs with the Project Manager (PM). These include the appropriate aquifer for well screening (especially if it is not the shallowest aquifer), soil sampling interval (if applicable to drilling method), screen length and placement (especially important at tidally influenced sites), well construction materials (i.e., screen slot size and grain size of the filter pack), surface completion of the wells, and any other important construction details. Any non-standard materials needed for well construction should also be communicated to the drilling firm when the work is scheduled, or a minimum of two weeks prior to the field event. Select a boring log template that is appropriate for the project needs.

Next, review the work plan and existing materials such as cross-sections, historical depth to water levels, or boring logs from previous investigations (if available) to familiarize yourself with the site geology. In addition to site-specific information (or alternatively if other information is not available), a geologic map of the area from a reputable source such as the U.S. Geological Survey (USGS) may also be reviewed.

Finally, check the area of the site where drilling will occur for underground objects. A OneCall locate request should be made at least one week and no less than three days prior to commencement of drilling in order to give public utility locators time to mark known, buried utility lines. All planned boring locations should be marked on the ground with white spray paint prior to making a locate request. In almost all cases, site maintenance managers or equivalent should be consulted for site selection and a private utility locator should clear any underground objects using electromagnetic techniques from the drilling area. If drilling in close proximity to buried utilities, field staff may need to request authorization for use of an air knife or vacuum extraction to clear the borehole to a depth below the utility lines.

3.2 DRILLING

1. Mark the desired well location using coordinates pre-loaded into a handheld GPS, or by measuring from known Site features. It is best to use both methods, if possible.
2. Before drilling begins, record the following information on each log:
    a. Operator's name and company, equipment make/model, equipment measurements (i.e., sampler length and diameter, hammer weight and stroke if using hollow stem auger, boring diameter).
    b. Your name, date, project, boring name, and approximate descriptive location relative to existing site features. Include a description of the ground surface and whether or not concrete coring was necessary; if so, include core diameter, concrete thickness, and subcontractor information.
    c. A small hand drawn map showing your location with measurements to a stationary reference point, or GPS coordinates (or ideally, both). This is also a good place to note if you have had to move a boring location because of underground utilities, access issues, etc. It is important to record the reason for relocation and the direction and distance moved (i.e., moved 10 feet to the north due to presence of subsurface water line).
3. If you are using a hollow stem auger, it is important to communicate to the driller how often you would like a split spoon sample collected. Typically this would be continuous or every 5 feet but may be different depending on the project needs. Usually this is established before the driller issues a quote. Any changes will affect the cost of the work and should be discussed with the PM.
    a. Record any feedback from the driller about the drilling conditions. This may include difficult drilling or rig chatter (usually caused by hard materials), heaving sands (usually caused by hydrostatic pressure on the borehole), caving, or hole instability.

4. For split spoon samples, record the number of hammer blows (blow counts) necessary to drive the sampler each 6-inch increment, as reported by the driller. If more than 50 blows are needed, record the distance that the sampler was driven in 50 blows (i.e., 2-inches in 50 blows). This is referred to as the standard penetration test (SPT).
5. For all drilling methods, create a log of the soils encountered according to the Floyd|Snider Soil Logging Standard Guideline. Pay particular attention to the moisture content of the soils, making careful notation of the water table where free water is first encountered. After drilling has been completed to the desired depth, confirm the depth to the water table using a water level meter.

3.3 WELL DESIGN AND CONSTRUCTION

1. Determine the length and placement of the well screen based on the observed depth to the water table, the specifics of the work plan, and the observed lithology. The well screen is typically set across the water table of shallow aquifers for monitoring wells and piezometers. However, the screened interval may be fully submerged for groundwater extraction wells, sites with very shallow groundwater, or wells installed in deeper aquifers below confining units. If an area is tidally influenced, note the tide elevation during well completion; if the tide is at a high or low at the time of drilling the well screen may need to be lowered or raised accordingly so that the screen spans the water table when the tide is at zero. The hydraulic conductivity of the aquifer material will also factor into well screen placement. For example, wells screened in tight silts may not produce enough water to adequately develop and sample. In this case, it may be preferable to screen the well in a more transmissive unit. Include the length of any required bottom caps or sumps below the well casing when determining the total depth of the boring required to place the well screen at the desired interval. The Washington State minimum standards also require that the diameter of the well screen relative to the diameter of the borehole (annual space) be small enough to allow placement of a filter pack that is 4 inches in diameter larger than the screen. For example, a 2-inch diameter monitoring well should be completed within a borehole that has a minimum 6-inch diameter.
2. Determine the filter pack material. The purpose of the filter pack is to prevent fine-grained aquifer material from entering the well while still allowing groundwater to flow through. Filter pack is composed of clean, rounded, relatively uniform silica sand. The choice of sand for the filter pack will depend on the grain size range of the aquifer material, with emphasis on the finest aquifer material. Filter pack material should be approximately 10 to 15 times the grain size of the surrounding aquifer material. The particle size ranges of fine, medium, and coarse sand, and the particle size ranges of common filter pack materials are given in the two tables below. As indicated in these tables, suitable filter pack choices for an aquifer with appreciable fine sand would include a range from 20-40 to 10-20 sand. For aquifers where the smallest particle size is medium sand, a filter pack of 2-12 sand or similar may be appropriate. More precise filter pack designs are possible based on grain size curves (see Driscoll 1986, Blair 2006).

Unified Soil Classification System (USCS) Classification	U.S. Sieve Size	Grain Size (inches)	Grain Size (millimeters)
Fine Sand	40 to 200	.003 to 0.16	.074 to .42
Medium Sand	10 to 40	.016 to .06	.42 to 1.68
Coarse Sand	10 to 4	.06 to 0.19	1.68 to 4.76

Example Sand Pack Gradations (U.S. Sieve Sizes)	Grain Size (inches)	Grain Size (millimeters)
32-40	.016 to .02	.42 to .55
20-40	.016 to .03	.42 to .84
16-30	.05 to .02	.59 to 1.2
10-20	.03 to .08	.84 to 2
2-12	.06 to .3	1.7 to 8

3. Determine the screen slot diameter. The purpose of the well screen is to allow groundwater to flow into and through the well screen for sample collection. Monitoring well casings are typically constructed of PVC (Washington State minimum standards require Schedule 40 or thicker-walled PVC for borings up to 200 feet deep); however, materials such as stainless steel may be used for the purposes of longevity, heat, specific chemical resistance, or other site-specific concerns. The screened interval of the well consists of a series of slots that are commonly 0.01 inch or 0.02 inch in width. Similar to filter pack material, narrower slots allow less fine-grained material and also less groundwater to pass through them. The screen slot size should be selected to retain approximately 90% or greater of the filter pack material. The largest screen slot size practical should be selected.

4. Once the driller has assembled the well casing of the appropriate length, oversee placement of the casing and filter pack. The casing should be centered in the borehole and level. When using a hollow stem auger, the sand is typically poured from the surface while the augers are being lifted from the borehole. When using sonic drilling or other methods where the drill rods are removed prior to sand placement, it is preferable to use a Tremie tube lowered to the bottom of the borehole to deliver the sand, which helps to ensure that the sand has actually reached the bottom of the borehole. As the driller is pouring sand into the annular space, monitor the height of the sand in the borehole using a weighted tape or leadline to ensure that the space is being filled evenly. If possible, use a surge block to force water from the well out into the sand pack periodically to eliminate any bridges or gaps in the sand. The sand pack

placement is complete when it has reached a height minimum of 1 foot (but no more the 5 feet) above the top of the well screen.

5. A bentonite seal must be placed above the sand pack to isolate the screened interval of the aquifer and to prevent the annular space from acting as a preferential pathway for surface water, water above the screen zone, or other liquid (i.e., free product). The purpose of the bentonite plug is to prevent downward migration inside the borehole, which has the potential to cause groundwater contamination. Monitor the placement of the bentonite plug above the sand pack. The bentonite plug is typically composed of dehydrated bentonite chips, which are poured into the annual space from the surface; or a bentonite slurry, which is pumped into the space via a Tremie tube. A bentonite chip seal is still recommended (but not necessary) immediately above the sand pack when using bentonite slurry to minimize migration of the slurry into the sandpack. Pumping is preferable in situations where bentonite will be placed below the water table. The U.S. Environmental Protection Agency (USEPA) recommends that the bentonite seal consist of a minimum of 2 feet of bentonite placed above the sand pack. If using a bentonite chip seal, hydrate the chips with clean water so that they expand to seal the borehole.
6. Communicate the desired surface completion to the driller (i.e., an aboveground well monument or a monument flush with the ground surface) if you have not already done so. Verify that the well monument has been installed correctly. For flush-mounted wells, ensure that the well is level with the surrounding grade, especially in areas with pedestrian or vehicle traffic. In areas with frequent or heavy vehicle traffic, heavy-duty traffic-rated monuments or manholes should be used. For aboveground well monuments (i.e., stand pipes), ensure that the monument is level, anchored in a minimum of 2 feet of concrete, and protected by steel bollards, unless otherwise specified in the work plan. The concrete surrounding any well monument should seal the borehole at the ground surface.

4.0 Decontamination

All reusable equipment that comes into contact with soil and groundwater should be decontaminated as follows prior to moving to the next sampling location.

Split spoons, stainless steel bowls and spoons, the water level tape, and any other tools used for well drilling and installation must be decontaminated between boring locations. If collecting soils samples for chemical analysis, split spoons and any tools used for sample processing will be decontaminated between each sample; alternatively, disposable bowls and spoons may be used. Equipment decontamination will consist of a tap water rinse to remove soil particles, followed by scrubbing with brushes and an alconox (or similar)/clean water solution, and a final rinse with distilled or deionized water.

5.0 Investigation-Derived Waste

Unless otherwise specified in the project work plan, waste soils, liquids, and other drilling materials generated during well drilling and installation will be contained in accordance with applicable laws, and stored in a designated area until transported off-site for disposal.

The approach to handling and disposal of these materials is as follows. For investigation-derived waste (IDW) that is contained, such as waste soils, 55-gallon drums approved by the Washington State Department of Transportation (WSDOT) will be supplied by the driller and used for temporary storage pending profiling and disposal. Each container holding IDW will be sealed and labeled with its contents (e.g., “soil cuttings”), the date(s) on which the wastes were placed in the container, the owner’s name, contact information for the field person who generated the waste, and the site name.

IDW contained within drums will be characterized relative to applicable waste criteria using data from the sampling locations whenever possible. Material that is designated for off-site disposal will be transported to an off-site facility permitted to accept the waste. Manifests will be used as appropriate for disposal.

Disposable sampling materials and incidental trash such as paper towels and personal protective equipment (PPE) used in sample processing will be placed in heavy-duty garbage bags or other appropriate containers and disposed of as solid waste in the municipal collection system (i.e., site dumpster).

6.0 Field Documentation

All observations should be recorded on a soil boring/well completion form appropriate for the drilling method or in a bound field notebook. Field staff should record as much detail as possible in the field log (including well construction materials, Ecology well ID tag number, and surface completions) and note any anomalies or details that varied from the SAP. After the field work is complete, a set of final well construction logs (usually electronic) that serve as the record for the project will be completed in consultation with the project manager or field manager.

F|S STANDARD GUIDELINE

Well Development

DATE/LAST UPDATE: May 2015

These procedures should be considered standard guidelines and are intended to provide useful guidance when in the field, but are not intended to be step-by-step procedures, as some steps may not be applicable to all projects.

All field staff should be sufficiently trained in the standard guidelines and should review and understand these procedures prior to going in the field. It is the responsibility of the field staff to review the standard guidelines with the field manager or project manager and identify any deviations from these guidelines prior to field work. When possible, the project-specific Sampling and Analysis Plan should contain any expected deviations and should be referenced in conjunction with these standard guidelines.

1.0 Scope and Purpose

This Standard Guideline for Well Development presents commonly used procedures for monitoring well development for newly installed monitoring wells and/or existing wells that may require redevelopment. Monitoring well development restores hydraulic conductivity with the surrounding formations that were disturbed during the drilling process. Development removes residual fines from well filter pack materials and the borehole wall and reduces the turbidity of the water, which provides more representative groundwater samples. These wells may include groundwater monitoring wells, piezometers, or groundwater extraction wells. This guideline describes the purge and surge method of development and is intended to be used by field staff who are overseeing or completing well development. Often, the drilling subcontractors are asked to complete well development activities subsequent to new well installations, in which case, Floyd|Snider staff would oversee the development. Other development methods, such as jetting, are not described herein, but may be used if specified in the project-specific Work Plan or Sampling and Analysis Plan (SAP).

Well development shall be completed by continuous pumping at a steady rate using a portable pump and polyethylene tubing, with regular surging (e.g., using a surge block) to force water through the filter pack and surrounding formation. Wells should ideally be developed either during installation (following sand placement but prior to sealing) or soon after installation, unless otherwise specified in the work plan, using the described methodologies or equivalents. For wells that are completed using a grout or concrete seal, if development does not take place prior to sealing, it should be completed within 48 hours following well installation in order allow for grout and concrete to cure.

2.0 Equipment and Supplies

Well Development Equipment and Tools:

- Appropriate high volume pump (centrifugal, submersible, etc.) and correct diameter tubing, or bailer
- Hose clamps (optional)
- Power source (generator, 12-volt battery, or car battery) and appropriate power adapter for pump
- Water quality meter or turbidity meter (if needed)
- 2-, 4-, or 6-inch surge block (typically provided by the driller)
- Water level meter
- Washington State Department of Transportation (WSDOT)-approved 55-gallon drums
- Equipment decontamination supplies including:
  - Scrub brushes
  - Alconox or other soap
  - Distilled or deionized water
  - Paper towels
- Trash bags
- Camera

Paperwork:

- Work Plan and/or SAP/Quality Assurance Project Plan (QAPP)
- Bound field notebook or appropriate field forms
- Well development form (printed on Rite in the Rain paper)
- Health and Safety Plan (HASP)
- Well installation forms (printed on Rite in the Rain paper)

Personal Equipment:

- Steel-toed boots
- Safety vest
- Safety glasses
- Nitrile gloves
- Rain gear
- Work gloves

3.0 Standard Procedures

3.1 OFFICE PREPARATION

Meet with the project manager to identify key information and goals of the well development, including how long after construction the wells should be developed. Determine if Floyd|Snider or the driller will be doing the development.

3.2 WELL DEVELOPMENT PROCEDURES

The following procedures are general guidelines for monitoring well development. These same procedures are also appropriate for extraction wells, injection wells, and/or piezometers. Specific instructions provided in individual work plans shall supersede these procedures in the event there are discrepancies.

Visually inspect all well development equipment for damage; repair as necessary.

1. Decontaminate all hoses, surge blocks, and/or submersible pump by scrubbing with brush and alconox or other soap solution and rinsing with deionized water.
2. Prior to development, use a water level meter to measure the depth in each well to the static water level and total depth to a reference mark on the top of the well casing.
3. Attach a length of clean or disposable tubing, approximately 5 feet longer than the well casing, to the outlet of the submersible pump.
4. Each well development cycle consists of surging followed by well evacuation (pumping). Surging may be accomplished with a surge block sized to fit snugly inside the well casing, or with the submersible pump. Surging using a pump increases the hydraulic gradient and velocity of groundwater near the well by drawing the water level down and moving more fine-grained soil particles into the well casing. Surging using a pump is only effective if the well produces enough water for continuous pumping and the pump is of a large enough diameter relative to the well casing. If

pumping must be stopped to allow the well to recharge, a surge block is preferable for surging. If using a surge block, connect polyvinyl chloride (PVC) pipe or other rods longer than the well casing to the surge block. Lower the surging device into the well to a depth within the screened interval. A bailer can be used to surge in situations when a surge block is not available and the well has insufficient recharge for the submersible pump.

5. During development, it is important to note the color and clarity of the water and any other visual or olfactory observations on the field form or in the field notebook. Note any significant changes as development progresses.
6. Surging should consist of a minimum of ten consecutive surges (i.e., quickly raise and lower surge block or pump in well) with an appropriately sized surge block or pump over the full length of the screen. For long well screens (greater than 10 feet), surging should be done in short intervals of 2 to 3 feet at a time. In cases where the screen extends to above the water table, clean water may have to be added to the well to develop the top of the filter pack.
7. After surging, water is purged from well until the pumped stream starts to run clear. At that point, stop pumping and initiate another surge cycle. If a well has more hydraulic head than the pump is able to overcome, or if an insufficient volume of water for pumping is present, a disposable bailer may also be used for purging.
8. Repeat this procedure until evacuated water is visibly clear and essentially free of sediment. Perform a minimum of three surge and pump cycles.
9. Well development will be terminated when the variation in the turbidity Nephelometric Turbidity Units (NTUs) readings is less than 10 percent or until the discharge is visibly clear and free of sediment after a minimum of three surge and purge cycles. As an alternative, periodic water samples can be collected for field measurements of temperature, specific conductivity, and pH; well development should continue until field parameters stabilize to within ±5 percent on three consecutive measurements or 10 well volumes have been purged. If it is not possible reduce the turbidity further, the well should be purged up to a maximum of four hours or as determined sufficient by the field geologist or project manager.
10. Report field observations and volume of water removed on the standard well development form (attached). Take final water level measurements and record then on the field form or in the field notebook.
11. Contain the purged water and manage in accordance with the project-specific SAP or Section 5.0 below. Prior to developing the next well or after the completion of development activities, decontaminate all reusable equipment used in development in accordance with Section 4.0 below.
12. If feasible, it is best to wait at least two weeks after development to sample the wells. Wells can be sampled a minimum of 48 hours after the completion of development if

the project schedule requires a quick turnaround. However, the groundwater sample will be more representative of static conditions in the aquifer if allowed to stabilize for at least one to two weeks after development.

4.0 Decontamination

All reusable equipment that comes into contact with groundwater should be decontaminated as follows prior to moving to the next sampling location.

Water level meter and surge block: The water level indicator and tape will be decontaminated between sampling locations and at the end the day by spraying the entire length of tape that came in contact with groundwater with an Alconox (or similar)/clean water solution followed by a thorough rinse with distilled or deionized water. Surge block decontamination will consist of a tap water rinse to remove soil particles, followed by scrubbing with brushes and an alconox (or similar)/clean water solution and a final rinse with distilled or deionized water.

Submersible Pump: Decontaminating the pump requires running the pump in three progressively cleaner grades of water. Place the pump and the length of the power cord that was in contact with water into a bucket containing approximately four gallons of an Alconox (or similar)/clean water solution. Run the pump for approximately two minutes or until the volume of water in the bucket has been exhausted. Next, place the pump and cord into a second bucket containing approximately four gallons of clean water and run the pump for approximately two minutes or until the volume of water in the bucket is exhausted. Lastly, place the pump and power cord into a third bucket containing approximately four gallons of distilled or deionized water and run the pump for approximately two minutes or until the volume of water in the bucket is exhausted. The soap/water solution and rinse water may be re-used. When done for the day, dry the exterior of the pump and power cord with clean paper towels to the extent practical prior to storage. All decontamination water and rinse water (including soapy solution) should be managed in accordance with Section 5.0 below.

5.0 Investigation-Derived Waste

Unless otherwise specified in the project work plan, well development and decontamination water generated during development and any drilling materials will be contained and stored in a designated area until transported off-site for disposal in accordance with applicable laws.

The approach to handling and disposal of these materials is as follows. For investigation-derived waste (IDW) that is contained, such as well development water, WSDOT-approved 55-gallon drums will be supplied by the driller and used for temporary storage pending profiling and disposal. Each container holding IDW will be sealed and labeled as to its contents (e.g., "MW-1 Well development water"), the date(s) on which the wastes were placed in the container, the owner's name, contact information for the field person who generated the waste, and the site name.

IDW contained within drums will be characterized relative to applicable waste criteria using data from the sampling locations whenever possible. Material that is designated for off-site disposal will be transported to an off-site facility permitted to accept the waste. Manifests will be used as appropriate for disposal.

Disposable sampling materials and incidental trash such as paper towels and personal protective equipment (PPE) used in sample processing will be placed in heavy duty garbage bags or other appropriate containers and disposed of as trash in the municipal collection system (i.e., site dumpster).

6.0 Field Documentation

Well development procedures will be documented on the well development field form (attached) or a bound field notebook. Information recorded will at a minimum include date, personnel present (including subcontractors), purpose of field event, weather conditions, depth of water, well construction details for the well(s) being developed (i.e., diameter, total depth, screen interval), water quality field measurements (if collected), amount of purged water generated, and any deviations from the SAP.

Enclosure: Well Development Field Form

WELL DEVELOPMENT FIELD FORM

FLOYD | SNIDER

Project Name:______________________________ Date: ______________

Project Number:______________________________ Field Personnel: ______________________________

Driller (if applicable): ______________________________

Purge Data

Well ID:	Total Well Depth:	Well Condition/Damage Description:
Well Casing Type/Diameter/Screened Level:	One Casing Volume (gal):	
Method of Development (Circle): Surge Block Pump Surge Bailer	Equipment Used (type of pump, etc.):	

Begin Purge (time):	
End Purge (time):	
Gallons Purged (time):	
Purge Water Disposal Method (circle): On-site Storage Tank On-site Treatment Drum Other:	

Volume of Schedule 40 PVC Pipe

Diameter	O.D.	I.D.	Volume (Gal/Linear Ft.)	Weight of Water (Lbs/Lineal Ft.)
1 ¼″	1.660″	1.380″	0.08	0.64
2″	2.375″	2.067″	0.17	1.45
3″	3.500″	3.068″	0.38	3.2
4″	4.500″	4.026″	0.66	5.51
6″	6.625″	6.065″	1.5	12.5

Time	Depth to Water (feet)	Vol. Purged (gallons)	Rate (gpm)	pH	Conductivity	Turbidity	Temp	Comments
			--	--	--	--	--	Prior to purging

Notes:

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strategy ▪ science ▪ engineering

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F|S STANDARD GUIDELINE

Soil Logging

DATE/LAST UPDATE: August 2018

These procedures should be considered standard guidelines and are intended to provide useful guidance when in the field, but are not intended to be step by step procedures, as some steps may not be applicable to all projects.

All field staff should be sufficiently trained in the standard guidelines and should review and understand these procedures prior to going in the field. It is the responsibility of the field staff to review the standard guidelines with the field manager or project manager and identify any deviations from these guidelines prior to field work. When possible, the project-specific Sampling and Analysis Plan should contain any expected deviations and should be referenced in conjunction with these standard guidelines.

1.0 Scope and Purpose

These soil logging standard guidelines should be used by the field staff performing subsurface investigations, such as a direct push or roto-sonic soil boring, installation of a monitoring well via hollow stem auger, or roto-sonic or mud rotary drilling. While many projects will not necessarily have a Licensed Geologist (LG) or Hydrogeologist (LHG) who reviews and stamps every boring log, it is important that the field staff discusses the soil logging needs for a particular investigation with the project geologist, the project manager, or whoever will ultimately be responsible for interpreting the findings of the field investigation. This discussion is in addition to field training and general knowledge about soil logging, and should happen prior to entering the field, with additional follow-up before drafting a final set of electronic logs, after the investigation is complete.

2.0 Equipment and Supplies

Logging Equipment and Tools:

- 100-foot tape measure or measuring wheel
- Handheld Global Positioning System (GPS; optional)
- Unified Soil Classification System (USCS) Soil Classification Field Guide

- Soil logging kit containing:
  - Stainless steel spoons
  - Paint scraper or trowel
  - Small Ziploc bags
  - Small stainless steel bowls or black mining pans for sheen testing
  - Spray bottle filled with water
  - Paper towels (preferably white)
  - Engineers tape
  - Note cards
  - Optional items include:
    - Empty VOA vials or small glass jars
    - Munsell color chart
    - Sieves
    - White and grayscale color cards for photographs
- Plastic sheeting and duct tape or clamps to cover the sampling table
- Camera
- Trash bags
- Coolers
- Jars
- Labels
- Ice

Paperwork:

- Work Plan and/or Sampling and Analysis Plan (SAP)/Quality Assurance Project Plan (QAPP)
- Health and Safety Plan (HASP)
- Copies of figures showing previous boring locations and boring logs from previous investigations, if available
- Boring log forms appropriate for drilling method, printed in Rite in the Rain paper and/or bound field notebook
- Permanent markers and pencils

Personal Equipment:

- Steel-toed boots
- Hard hat

- Safety vest
- Safety glasses
- Nitrile gloves
- Ear plugs
- Rain gear
- Work gloves

3.0 Standard Procedures

3.1 OFFICE PREPARATION

First, meet with the project manager or field manager to identify the key information and goals of the soil boring investigation. These may include fill history, known or suspected sources of contamination and potential field indications of these contaminants, identification of specific units, or important geotechnical measurements. If possible, select a boring log template that is appropriate for the project needs.

Next, review the work plan and all available existing materials such as cross-sections or boring logs from previous investigations to familiarize yourself with the site geology. In addition (or alternatively if other information is not available), you may also review a geologic map of the area from a reputable source such as United States Geological Survey (USGS).

Finally, check the area of the site where drilling will occur for underground objects. At minimum, a OneCall locate request should be made at least one week in advance of drilling in order to give public utility locators time to mark known buried utility lines. All planned boring locations should be marked on the ground with white spray paint prior to making a locate request. In almost all cases, a private utility locator should also clear the area of drilling any underground objects using electromagnetic techniques. If drilling is to occur in close proximity to buried utilities, the work plan may specify use of an air knife or vacuum to clear the borehole to a depth below the utility lines.

3.2 COLLECTING SOIL SAMPLES FOR CLASSIFICATION

1. Before beginning drilling, record the following information on each log:
   a. Operator's name and company, equipment make/model, equipment measurements (i.e., sampler length and diameter, hammer weight and stroke if using hollow stem auger, boring diameter)
   b. Your name, date, project, boring name and approximate descriptive location (i.e., where is the soil boring relative to known site features). Include a description of the ground surface and whether or not coring was necessary, if coring was necessary, include core diameter, concrete thickness, and subcontractor information.

   c. A small hand drawn map showing your location with measurements to a stationary reference point, or GPS coordinates (ideally, both). This is also a good place to note if you have had to move a boring location because of underground utilities, access issues, etc. It is important to note the reason for relocation and the direction and distance moved (i.e., moved 10 feet to the north due to presence of subsurface water line).

2. If you are using a hollow stem auger drilling method, it is important to communicate to the driller how often you would like a split spoon sample collected. Typically this would be continuous or every 5 feet but may be different depending on the project needs.
3. Note any feedback from the driller about the drilling conditions. This may include difficult drilling or rig chatter (usually caused by hard materials), heaving sands (usually caused by hydrostatic pressure on the borehole), caving, or hole instability.
4. For split spoon samples, record the number of hammer blows (blow counts) necessary to drive the sampler each 6-inch increment, as reported by the driller. If more than 50 blows are needed, record the distance that the sampler was driven in 50 blows (i.e., 2-inches in 50 blows). This is referred to as the standard penetration test.
5. Cover the sampling table with plastic sheeting. Lay an engineer's tape lengthwise across the sampling table. Once a sample has been collected, orient it on the table so that the top is aligned with the 0-foot mark on the tape.
6. Split open the sampler, core barrel liner, or sample collection bag. Record the depth interval that the sampler was driven and the depth interval of soil that was recovered. For split spoons or single-cased core barrels, such as Geoprobe direct-push rods, determine whether any loose 'slough' soil has been dislodged by the drilling equipment and deposited at the top of your core (AMS direct push rods are double cased and do not create slough). Do not include slough in the measurement of the soil recovered. Often the core will be filled with an uninterrupted column of soil that is shorter in length than the total drive interval. In such cases, record the recovery interval as it is situated in the core unless you are able to determine the actual depth where the soil sample originated. For the purposes of recording soil observations and collecting samples for analysis, assume that the recovered column of soil has been evenly compressed unless you are able to determine the interval(s) in which compression has occurred. Decompress the recovered soil when making further observations (e.g., if the recovered soil column is 80 percent of the length of the drive interval, assume 0.8 feet of recovered soil represent 1 foot of soil in situ).
7. Before further disturbing the soil, take volatile organic compound (VOC) measurements with a photoionization detector (PID), if using. Take measurements by making crevices in the soil with a spoon or scraper and inserting the PID probe into these openings. Alternatively, collect small spoonfuls of soil into Ziploc bag(s), seal the bag(s), gently shake the bag(s), and insert the PID probe through the top of the bag(s) and into the headspace once the soil vapor has been allowed to equilibrate with the

surrounding air (headspace method). The bag headspace screening method is typically more accurate and is useful at sites with low concentrations of VOCs, whereas the in-situ method is a faster and more qualitative method, best used at sites with higher VOC concentrations. If sampling for VOCs by the U.S. Environmental Protection Agency (USEPA) Method 5035, these soil samples should also be collected prior to disturbing the core. Soil sampling procedures using USEPA Method 5035 are described in detail in the Soil Sample Collection Standard Guideline.

8. Use a straight edge to scrape the soil level and expose the center of the core. Photograph the core alongside the measuring tape and an index card displaying the soil boring location/ID and depth interval.

3.3 SOIL CLASSIFICATION

Soils are described using the following characteristics: Color, consistency, MAJOR CONSTITUENT, minor constituent, geotechnical properties, moisture content, other observations (e.g. visual or olfactory indications of contamination). The USCS field guide is included in this guidance for reference. The steps below should help guide the logger in classifying soils according to the USCS.

1. Record the color of the soil. A descriptive color (i.e., light brown) or a color identified using the Munsell color chart are both valid.
2. Determine whether organic matter influences the properties of the material. If so, record as an organic soil.
3. If the soil is predominantly inorganic, identify whether the major constituent is coarse- or fine-grained. Coarse-grained soils include sands and gravels; fine-grained soils include silts and clays.
    a. For coarse grained soils, determine:
        i. Grain size(s) present including fine, medium, or coarse, and grain size distribution including well-graded (a mixture of fine to coarse grains) or poorly-graded (uniform in size). The USCS guide is helpful for determining grain sizes. If the major constituent is gravel, note its angularity using “rounded,” “sub-angular” or “angular.”
        ii. Minor constituent(s). If a minor constituent represents less than approximately 15% of the sample, note this as “with [minor constituent]” and optionally, whether it is “trace” (<5%) or “few” (5-15%). If a minor constituent represents more than 15% of the sample, use “[minor constituent]-y.” For example, a sand with 5% silt would be classified as a “SAND with trace silt” and sand with 30% silt would be classified as a “SILTY SAND.” For coarse-grained soils with fines between 5% and 15%, the USCS includes several dashed classifications, such as SW-SM. It is often helpful to record an estimated percentage for soil constituents to aid in classification according to the USCS.

b. For fine-grained soils, determine:

   i. Major constituent. To determine whether a material is silt or clay, a simple settling test may be performed in a glass vial or gloved hand by spraying a small amount of the sample with water. Silt particles will settle out of suspension in water within a few minutes, whereas clay particles will remain suspended for a longer period of time.

   ii. Minor constituent(s). As described above, determine the approximate percentage and record as "with [minor constituent]" or "[minor constituent]-y" as appropriate. It is often helpful to record an estimated percentage to aid in classification according to the USCS.

   iii. Geotechnical properties. Depending on project data needs, geotechnical properties may be optional but often provide helpful information. Geotechnical properties include plasticity (ranging from "non-plastic" to "highly plastic" as determined by a thread test) and consistency (ranging from "loose" to "very dense" for coarse-grained soils and "soft" to "hard" for fine-grained soils). When using split spoon samplers, blow counts recorded during the standard penetration test (also referred to as N-values) are used to determine consistency; when using direct-push or sonic drilling, consistency is described qualitatively.

4. Using the USCS guide and the description of the soil, determine the appropriate USCS symbol and record it on the log. If it is difficult to distinguish the major constituent of a soil, a borderline "/" symbol may be used to denote the two potential major constituents present. This is not the same as the USCS classifications that utilize a dash, such as SW-SM.

5. Determine whether contacts between stratigraphic units are abrupt, or gradational. Note abrupt contacts using a solid line and gradational contacts using a dotted line. If the contact between units is not visible and was missed between sample depths, a dashed line is used.

6. If the site or area geology is known, and you are confident in your identification of a specific stratum, note the geologic unit. At a site where the geology is uncertain, you may make some more general notes about the depositional environment, such as identifying probable estuarine deposits, colluvium, glacial till, etc.

7. Note the moisture content of the soil, using "dry," "moist," "wet," or "saturated." Mark the water table at the time of drilling on the log at the depth where saturated soil is first observed.

3.4 OTHER OBSERVATIONS

1. Record other materials observed in the sample. These may include minor amounts of rootlets or other plant matter, evidence of organisms such as shell fragments, and/or anthropogenic debris such as brick fragments, plastic, or metal debris.
2. Record potential indications of contamination. These may include odors, colored or black staining on soils, colored crystals, hydrocarbon sheens, or non-aqueous phase liquid (NAPL) product.
    a. To test for hydrocarbon sheen, put a small amount of soil in a bowl, saturate with water and swirl, noting whether a rainbow sheen appears on the surface of the water. Alternatively, place a small amount of water in the bottom of the bowl and a small amount of soil along the side, then tilt the bowl so that the water slowly touches the soil. If observed, note the color of the sheen and describe as slight (discontinuous on the water surface), moderate (continuous but spreading slowly) or high (rainbow sheen covering entire surface water).
    b. To test for the presence of NAPL, use a clean paper towel to blot the surface of the core and note the proportion of the towel that is saturated with oil (be sure to allow the towel to dry when blotting moist to wet soils to distinguish between saturation due to NAPL and due to water).
3. Note the final depth of the boring and any reasons for early termination of the boring (i.e., refusal).
4. If monitoring wells will be installed, follow the Standard Guidelines for monitoring well construction and well development.

4.0 Decontamination

All reusable equipment that comes into contact with soil should be decontaminated as follows prior to moving to the next sampling location.

Split spoons, stainless steel bowls and spoons, and any other tools used for soil classification must be decontaminated between boring locations. If collecting soil samples for chemical analysis, split spoons and any tools used for sample processing must be decontaminated between each sample; alternatively, disposable bowls and spoons may be used. Equipment decontamination will consist of a tap water rinse to remove soil particles, followed by scrubbing with brushes and an alconox (or similar)/clean water solution and a final rinse with distilled or deionized water.

5.0 Investigation-Derived Waste

Unless otherwise specified in the project work plan, waste soils and other drilling materials generated during soil boring activities will be contained, transported, disposed of in accordance with applicable laws, and stored in a designated area until transported off-site for disposal.

The approach to handling and disposal of these materials is as follows. For investigation-derived waste (IDW) that is contained, such as waste soils, 55-gallon drums approved by the Washington State Department of Transportation (WSDOT) will be supplied by the driller and used for temporary storage pending profiling and disposal. Each container holding IDW will be sealed and labeled as to its contents (e.g., "soil cuttings"), the dates on which the wastes were placed in the container, the owner's name, contact information for the field person who generated the waste, and the site name.

Whenever possible, IDW contained within drums will be characterized relative to applicable waste criteria using data from the sampling locations. Material that is designated for off-site disposal will be transported to an off-site facility that is permitted to accept the waste. Manifests will be used as appropriate for disposal.

Disposable sampling materials and incidental trash such as paper towels and personal protective equipment (PPE) used in sample processing will be placed in heavy duty garbage bags or other appropriate containers and disposed of as solid waste in the municipal collection system (i.e., site dumpster).

6.0 Field Documentation

All observations should be recorded on a soil boring form appropriate for the drilling method or in a bound field notebook. Field staff should make an effort to record as much detail as possible in the field log. After the field work is complete, a set of final logs (usually electronic) that serve as the record for the project will be completed in consultation with the project manager or field manager.

Enclosure: USCS Soil Classification Field Guide

USCS SOIL CLASSIFICATION FIELD GUIDE

FIELD GUIDE FOR SOIL AND STRATIGRAPHIC ANALYSIS v.2

midwest GEOSCIENCES group
www.midwestgeo.com

START HERE

DENSITY OR CONSISTENCY

COARSE GRAINED DEPOSITS N-VALUE		FINE GRAINED DEPOSITS N-VALUE	q_u (tsf)	
0-4	► VERY LOOSE	0-2	<0.25	► VERY SOFT
5-10	► LOOSE	3-4	0.25-0.50	► SOFT
11-29	► MEDIUM DENSE	5-8	0.50-1.0	► MEDIUM
30-49	► DENSE	9-15	1.0-2.0	► STIFF
>50	► VERY DENSE	16-30	2.0-4.0	► VERY STIFF
		>30	>4.0	► HARD

COLOR
Use Standard Munsell Color Notation

IS THE COLOR A MATRIX COLOR?
- YES → MATRIX COLOR: List in sequence, dominant first
- NO → IS THE COLOR FROM A COATING OR CONCENTRATION?
  - YES → COATING or CONCENTRATION: Note frequency, color, and size
  - NO → MOTTLE: Note contrast, color, and size

CLASSIFICATION
Unified Soil Classification System - adopted ASTM D2488

STEP 1: IS SEDIMENT COARSE GRAINED OR FINE GRAINED?

COARSE-GRAINED DEPOSITS (>50% coarse-grained sediments, <50% fines)

STEP 2: DETERMINE SAND VS. GRAVEL RATIO

INCREASING GRAIN SIZE

SAND: FINE | MEDIUM | COARSE — GRAVEL: SMALL | LARGE

0.075 MM | 0.425 MM | 2.0 MM | 4.75 MM | 19.0 MM | 75.0 MM

STEP 3: CONTINUE WITH SAND OR GRAVEL ON FLOW CHART (REVERSE)

FINE-GRAINED DEPOSITS (>50% fines, <50% coarse-grained sediments) (organic and inorganic)

STEP 2: DETERMINE PLASTICITY AND ASSIGN USCS GROUP SYMBOL

INCREASING PLASTICITY

NON PLASTIC | LOW PLASTICITY | MEDIUM PLASTICITY | HIGH PLASTICITY

ML | CL | CH

STEP 3: CONTINUE WITH GROUP SYMBOL ON FLOW CHART (REVERSE)

MOISTURE

- MOISTURE ABSENT ► DRY
- DAMP ► MOIST
- VISIBLE WATER ► WET

FOR NON-PLASTIC FINES:
- WATER RISES TO SURFACE SLOWLY ► SLOW DILATENCY
- WATER RISES TO SURFACE QUICKLY ► RAPID DILATENCY

PLASTICITY (Use with CLASSIFICATION)

- WILL NOT SUPPORT 6mm DIAMETER ROLL IF HELD ON END ► NON-PLASTIC
- 6mm DIA. ROLL CAN BE REPEATEDLY ROLLED AND SUPPORTS ITSELF, 4mm DIA. ROLL DOES NOT ► LOW PLASTICITY
- 4mm DIA. ROLL CAN BE REPEATEDLY ROLLED AND SUPPORTS ITSELF, 2mm DIA. ROLL DOES NOT ► MEDIUM PLASTICITY
- 2mm DIA. ROLL CAN BE REPEATEDLY ROLLED AND SUPPORTS ITSELF ► HIGH PLASTICITY

6mm | 4 | 2

COHESIVENESS

- 6mm DIAMETER ROLL CANNOT BE FORMED ► NONCOHESIVE
- 6mm DIAMETER ROLL CAN BE FORMED ► COHESIVE

SEDIMENTARY STRUCTURE

- UNIFORM ► MASSIVE
- BEDS >30cm ► THICKLY BEDDED
- BEDS 3cm to 30cm ► BEDDED
- BEDS 0.5cm to 3cm ► THINLY BEDDED
- BEDS <0.5cm ► LAMINATED

SECONDARY SOIL STRUCTURE (IN SOLUM ONLY)
- Spheroidal peds or granules usually packed loosely ► GRANULAR
- Irregular, roughly cubelike peds with planar faces (angular or subangular) ► BLOCKY
- Flat and horizontal peds ► PLATY
- Vertical, pillarlike peds with flat tops ► PRISMATIC
- Vertical, pillarlike peds with curved tops (which are commonly "bleached") ► COLUMNAR

WEATHERING ZONE ABBREVIATION

MODIFIER SYMBOL (if present)		1st SYMBOL		2nd SYMBOL		LAST SYMBOL (if present)	
MOTTLED	► M	OXIDIZED	► O	LEACHED	► L	SECONDARY CARBONATE	► 2
JOINTED	► J	REDUCED	► R	UNLEACHED	► U		
		UNOXIDIZED	► U				

EXAMPLE: solum, OJL, MOJL, MOJL2, MOJU — MRJU, RJU, RU, UU

SECONDARY GRAIN SIZE INFORMATION

- < 5% ► TRACE
- 6% to 15% ► LITTLE
- 16% to 30% ► FEW
- 31% to 49% ► SOME

- ► UNIFORM (poorly graded)
- ► NON-UNIFORM (well graded)

- ► FINE SAND
- ► MEDIUM-GRAINED SAND
- ► COARSE-GRAINED SAND
- ► FINE GRAVEL
- ► COARSE GRAVEL

FOR GLACIAL DIAMICTONS ► CLAST FRACTION ► CLAST LITHOLOGY

DEPOSITIONAL ENVIRONMENT

VARIOUS DEPOSITIONAL ENVIRONMENTS (interpretation) ► EOLIAN (LOESS) ► FLUVIAL ► ALLUVIAL ► LACUSTRINE ► COASTAL ► RESEDIMENTED

GLACIAL DEPOSITIONAL PROCESSES ► SUBGLACIAL ► GLACIOFLUVIAL ► GLACIOLACUSTRINE ► RESEDIMENTED

GENERALIZED RESEDIMENTATION PROCESSES ► MASS SLUMP ► SEDIMENT FLOW ► COLLUVIUM

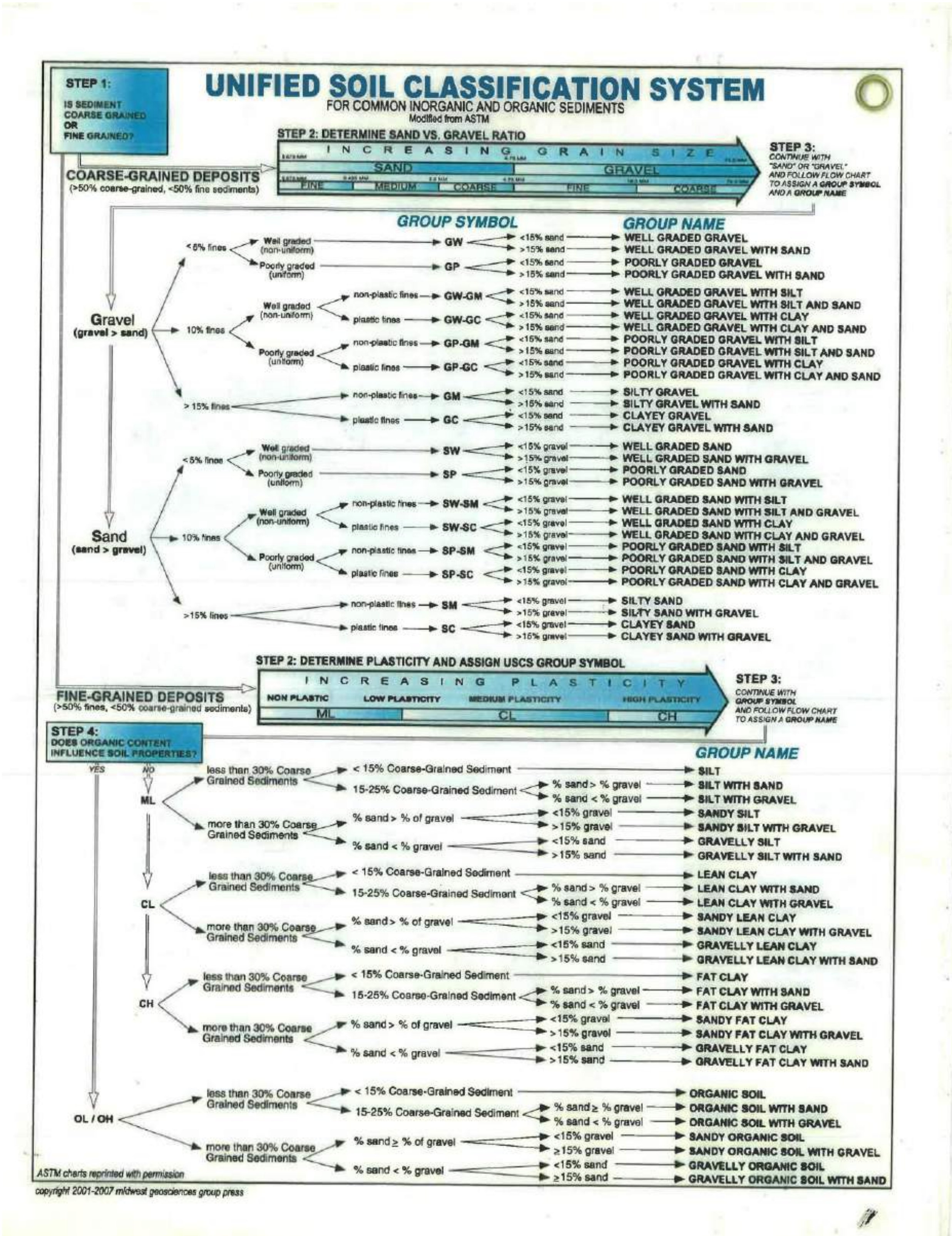
STRATIGRAPHIC NAME

USE FORMAL STATE GEOLOGICAL SURVEY NOMENCLATURE WHEN POSSIBLE;
IF NOT POSSIBLE, ASSIGN SITE-SPECIFIC UNIT NAME ACCORDING TO DEPOSITIONAL ENVIRONMENT / FACIES ASSEMBLAGE

STRATIGRAPHIC CONTACT

- < 10 cm ► SHARP (or ABRUPT for pedogenic alternation)
- > 10 cm (Note transition interval) ► GRADATIONAL (or TRANSITIONAL for weathering zone change)

010106



UNIFIED SOIL CLASSIFICATION SYSTEM
FOR COMMON INORGANIC AND ORGANIC SEDIMENTS
Modified from ASTM
STEP 1:
IS SEDIMENT COARSE GRAINED OR FINE GRAINED?
STEP 2: DETERMINE SAND VS. GRAVEL RATIO
INCREASING GRAIN SIZE
SAND
GRAVEL
FINE
MEDIUM
COARSE
FINE
COARSE
STEP 3:
CONTINUE WITH "SAND" OR "GRAVEL" AND FOLLOW FLOW CHART TO ASSIGN A GROUP SYMBOL AND A GROUP NAME
COARSE-GRAINED DEPOSITS
(>50% coarse-grained, <50% fine sediments)
GROUP SYMBOL
GROUP NAME
Gravel
(gravel > sand)
<5% fines
Well graded (non-uniform)
Poorly graded (uniform)
GW
<15% sand
WELL GRADED GRAVEL
>15% sand
WELL GRADED GRAVEL WITH SAND
GP
<15% sand
POORLY GRADED GRAVEL
>15% sand
POORLY GRADED GRAVEL WITH SAND
10% fines
non-plastic fines
plastic fines
GW-GM
WELL GRADED GRAVEL WITH SILT
WELL GRADED GRAVEL WITH SILT AND SAND
GW-GC
WELL GRADED GRAVEL WITH CLAY
WELL GRADED GRAVEL WITH CLAY AND SAND
GP-GM
POORLY GRADED GRAVEL WITH SILT
POORLY GRADED GRAVEL WITH SILT AND SAND
GP-GC
POORLY GRADED GRAVEL WITH CLAY
POORLY GRADED GRAVEL WITH CLAY AND SAND
>15% fines
GM
SILTY GRAVEL
SILTY GRAVEL WITH SAND
GC
CLAYEY GRAVEL
CLAYEY GRAVEL WITH SAND
Sand
(sand > gravel)
SW
<15% gravel
WELL GRADED SAND
>15% gravel
WELL GRADED SAND WITH GRAVEL
SP
POORLY GRADED SAND
POORLY GRADED SAND WITH GRAVEL
SW-SM
WELL GRADED SAND WITH SILT
WELL GRADED SAND WITH SILT AND GRAVEL
SW-SC
WELL GRADED SAND WITH CLAY
WELL GRADED SAND WITH CLAY AND GRAVEL
SP-SM
POORLY GRADED SAND WITH SILT
POORLY GRADED SAND WITH SILT AND GRAVEL
SP-SC
POORLY GRADED SAND WITH CLAY
POORLY GRADED SAND WITH CLAY AND GRAVEL
SM
SILTY SAND
SILTY SAND WITH GRAVEL
SC
CLAYEY SAND
CLAYEY SAND WITH GRAVEL
STEP 2: DETERMINE PLASTICITY AND ASSIGN USCS GROUP SYMBOL
INCREASING PLASTICITY
NON PLASTIC
LOW PLASTICITY
MEDIUM PLASTICITY
HIGH PLASTICITY
ML
CL
CH
STEP 3:
CONTINUE WITH GROUP SYMBOL AND FOLLOW FLOW CHART TO ASSIGN A GROUP NAME
FINE-GRAINED DEPOSITS
(>50% fines, <50% coarse-grained sediments)
STEP 4:
DOES ORGANIC CONTENT INFLUENCE SOIL PROPERTIES?
YES
NO
GROUP NAME
ML
less than 30% Coarse Grained Sediments
< 15% Coarse-Grained Sediment
SILT
15-25% Coarse-Grained Sediment
% sand > % gravel
SILT WITH SAND
% sand < % gravel
SILT WITH GRAVEL
more than 30% Coarse Grained Sediments
% sand > % of gravel
<15% gravel
SANDY SILT
>15% gravel
SANDY SILT WITH GRAVEL
% sand < % gravel
<15% sand
GRAVELLY SILT
>15% sand
GRAVELLY SILT WITH SAND
CL
LEAN CLAY
LEAN CLAY WITH SAND
LEAN CLAY WITH GRAVEL
SANDY LEAN CLAY
SANDY LEAN CLAY WITH GRAVEL
GRAVELLY LEAN CLAY
GRAVELLY LEAN CLAY WITH SAND
CH
FAT CLAY
FAT CLAY WITH SAND
FAT CLAY WITH GRAVEL
SANDY FAT CLAY
SANDY FAT CLAY WITH GRAVEL
GRAVELLY FAT CLAY
GRAVELLY FAT CLAY WITH SAND
OL / OH
% sand ≥ % gravel
ORGANIC SOIL
ORGANIC SOIL WITH SAND
ORGANIC SOIL WITH GRAVEL
% sand ≥ % of gravel
≥15% gravel
SANDY ORGANIC SOIL
SANDY ORGANIC SOIL WITH GRAVEL
≥15% sand
GRAVELLY ORGANIC SOIL
GRAVELLY ORGANIC SOIL WITH SAND
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F|S STANDARD GUIDELINE

Soil Sample Collection

DATE/LAST UPDATE: May 2015

These procedures should be considered standard guidelines and are intended to provide useful guidance when in the field, but are not intended to be step by step procedures, as some steps may not be applicable to all projects.

All field staff should be sufficiently trained in the standard guidelines for the sampling method they intend to use and should review and understand these procedures prior to going into the field. It is the responsibility of the field staff to review the standard guidelines with the field manager or project manager and identify any deviations from these guidelines prior to field work. When possible, the project-specific Sampling and Analysis Plan should contain any expected deviations and should be referenced in conjunction with these standard guidelines.

1.0 Scope and Purpose

This standard guideline presents commonly used procedures for collection of soil samples for characterization and laboratory analysis. The methods presented in this guideline apply to the collection of soil samples during the following characterization activities: soil borings via drilling, manual collection of shallow soil samples, test pit excavation, excavation confirmation, and stockpile characterization. Specific details regarding the collection of discrete and composite samples, and special sampling techniques for volatile organic compounds (VOCs) are also included. The guideline is intended to be used by staff who collect soil samples in the field.

It is important that the field staff completing the soil sample collection discusses the specific needs for a particular investigation with the project geologist, the project manager, or whoever will ultimately be responsible for interpreting the findings of the field investigation. This discussion is in addition to field training and general knowledge about soil sampling, and should happen prior to entering the field, with additional follow-up before finalizing the field forms, after the investigation is complete.

2.0 Equipment and Supplies

Soil Sampling Equipment and Tools:

- Tape measure or measuring wheel
- Stainless steel bowls and spoons
- Graduated plunger and collection tubes for VOC samples (if needed)
- Trash bags
- Decontamination tools including:
    - Paper towels
    - Spray bottles of alconox (or similar) solution
    - Deionized or distilled water
- Adhesive drum labels, or paint or grease pen
- Washington State Department of Transportation- (WSDOT) approved drums for investigation-derived waste (IDW) disposal, if needed (if drilling, to be provided by driller)
- Camera
- Hand-held global position system (GPS; optional)
- Coolers, sample jars, labels, ice

Paperwork:

- Work Plan and/or Sampling and Analysis Plan/Quality Assurance Project Plan (SAP/QAPP)
- Health and Safety Plan (HASP)
- Sample collection forms printed in Rite in the Rain paper, or Rite in the Rain field notebook

Personal Equipment:

- Steel-toed boots
- Safety vest
- Safety glasses
- Nitrile gloves
- Rain gear
- Work gloves

3.0 Standard Procedures

3.1 OFFICE PREPARATION

Prior to going into the field, review the SAP/QAPP tables to become familiar with the desired sample intervals, nomenclature, field Quality Assurance (QA) samples, analytes, sample containers, and holding times for each analytical method.

At least one week prior to sampling, coordinate with the laboratory specified in the SAP/QAPP to get coolers and appropriate sample containers. Familiarize yourself with the volume requirements and container types, preservation methods, and holding times for each class of analytes.

3.2 GENERAL SOIL SAMPLE COLLECTION PROCEDURES

1. Locate the desired sample location and depth interval using a handheld GPS or by taking field measurements from known site features. Note the soil type and any other observations or indications of contamination on a soil boring log, soil sample collection form or field notebook, as described in the Soil Logging Standard Guideline. Note the location and depth of the sample and take a photograph, if possible.
2. Refer to subsections 3.2.1 through 3.2.4 for the appropriate soil collection procedures for drilling, shallow soil, test pit excavation, excavation confirmation, and stockpiles. If collecting samples for VOC analysis by the U.S. Environmental Protection Agency (USEPA) Method 5035, refer to Section 3.3 for specific sample collection procedures for this method. If composite soil sampling is recommended, refer to Section 3.4 for details.
3. Once soil has been collected from the desired depth or interval, mix thoroughly until the sample is homogenous in color, texture, and moisture.
4. Fill the required laboratory-provided jars, taking care not to overfill. If large gravels (diameter greater than ~ 1 inch) are encountered, these should be discarded to ensure that an adequate soil volume is collected for analysis. If necessary, use a clean paper towel to remove soil particles from the threaded mouth of the jar before securing lids to ensure a good seal.
5. Label each jar with the sample name, date, time, field staff initials and required analyses. If collecting a field duplicate, use the sample nomenclature specified in the work plan and note the field duplicate name and sample time in the sample log. If extra volume for matrix spike/matrix spike duplicate (MS/MSD) analysis is being collected, use the same name on all jars. Soil samples should be protected from moisture by placing the filled sample jars into separate sealed Ziploc bags before placing them into a cooler.

6. Complete a chain-of-custody form for all samples, including sample names, date and time of collection, number of containers, and required analyses and methods. Keep samples on ice to maintain temperatures of 4-6 degrees Celsius (°C) and transport to the laboratory under chain-of-custody procedures.

3.2.1 Soil Sample Collection via Drilling

These procedures should be used for drilling via direct-push, hollow stem auger, or roto-sonic methods where a pre-designated sample interval (i.e. 0 to 5 feet below ground surface [bgs]) is retrieved from the subsurface using a split spoon sampling device, lined core, or bag sampler.

1. Ensure that reusable sampling equipment has been thoroughly decontaminated prior to sampling.
2. Use a stainless steel spoon or trowel, or disposable scoop to remove an equal volume of soil across the targeted depth interval from the sampler.
    a. If using a split spoon sampler or other reusable sampler, avoid collecting the soil that is touching the sides of the sampler to the extent practical.
    b. If the soil touching a reusable sampler must be collected to obtain adequate volume for analysis, notify the PM and record in the field logbook.

3.2.2 Manual Collection of Shallow Soil Samples

These procedures should be used for shallow soil sampling via scoop, trowel, shovel, or hand auger.

1. Dig or auger to the bottom depth of the shallowest sample to be collected, using a tool that has been cleaned and decontaminated. Verify that the target depth has been reached using a measuring tape.
2. If using a scoop or trowel, collect the soil directly into a decontaminated stainless steel bowl.
3. If using a shovel, the soil may either be collected in bowls or set as aside on plastic sheeting in favor of collecting the sample from the sidewall of the hole. If sampling the sidewall, use a decontaminated or disposable scoop or trowel to collect soil from the target depth, or scrape along the sidewall to collect soil across a target depth interval. Transfer soil to a decontaminated stainless steel bowl, repeating until a sufficient volume has been collected.
4. If using a hand auger, empty the cylinder of the auger directly into a decontaminated stainless steel bowl. It may be necessary to empty the hand auger onto plastic sheeting or into a bowl in order to reach the target depth without overflowing the sampler.
5. Any soil from depth intervals that are not targeted for sampling should be set aside on plastic sheeting and returned to the hole after sampling.

3.2.3 Sample Collection from Test Pits or Limited Soil Excavations

These procedures should be used for collecting samples from test pit explorations excavated using a back hoe or excavator. These same general procedures should also be followed for post-excavation soil samples used to confirm that an excavation has removed contaminated material or to document post-excavation conditions after target excavation limits have been reached.

1. Measure the length, width, and depth of the test pit or excavation area to verify that the target extents have been reached. The lateral spacing of the test pit or excavation confirmation samples, or exact location of samples should be specified in the work plan and typically depend on the size of the excavation area but can vary significantly from project to project.
2. If not specified in the work plan, sidewall samples may be collected either midway between the ground surface and base of the excavation, or incrementally along the entire height of the sidewall. Both sidewall and base (bottom) samples should penetrate a minimum of 6 inches beyond the excavated surface.
3. If the test pit or excavation is less than 4 feet deep, or has been benched to accommodate safe entry, a sample may be collected directly from the sidewall(s). To collect soil from a sidewall, use a decontaminated or disposable scoop, trowel, or shovel to obtain soil from the desired depth or depth interval directly into a decontaminated stainless steel bowl.
4. If a test pit or excavation cannot be safely entered, instruct the excavator operator to scoop sidewall material from the target depth or depth interval. Collect the soil sample from the excavator bucket using a decontaminated stainless steel spoon, trowel, or disposal scoop, avoiding material that has come into contact with the teeth or sides of the bucket. Place an adequate volume of soil into a decontaminated stainless steel bowl. If necessary, follow the compositing procedures in Section 3.4.

3.2.4 Stockpile Sampling

These procedures should be used for classifying stockpiled soil, including excavated soil and imported backfill material.

1. Where potentially contaminated soils have been previously excavated and stockpiled on site, Washington State Department of Ecology (Ecology) guidance recommends using a decontaminated or disposable scoop or trowel, penetrating 6 to 12 inches beneath the surface of the pile at several locations until sufficient volume for analysis is achieved. A decontaminated shovel may also be used to facilitate collection of soil from large piles. The locations for soil collection should be where contamination is most likely to be present based on field screening (i.e. staining, odor, sheen, or elevated photoionization detector [PID] readings). If there are not field indications of contamination, the locations should be distributed evenly around the stockpile.

2. The stockpile may need to be broken up into sections for sample collection depending on the size of the pile (i.e., segregate the pile in half or quarters). If this is necessary, it is important to document where each set of samples were collected from (i.e., north quadrant) and create a field sketch of the pile for reference.
3. If a sampling frequency is not specified in the work plan, the general rule of thumb for contaminated soil stockpile profiling is to collect and submit 3 analytical samples (these samples can be multi-point composites or grabs) for stockpiles less than 100 cubic yards (CY), 5 samples for stockpiles between 100 and 500 CY, 7 samples for stockpiles 500 to 1,000 CY, 10 samples for stockpiles 1,000 to 2,000 CY, and 10 samples for stockpiles larger than 2,000 CY with an additional sample collected for every 500 CY of material. This rule of thumb is consistent with Ecology guidance for site remediation.
4. Samples for characterization of stockpiles of imported backfill or other presumed clean material should also be collected as described above. If not described in the work plan, the typical sample frequency for imported or clean material characterization is one sample per 500 CY.

3.3 SOIL SAMPLE COLLECTION FOR VOC ANALYSIS

If collecting soil samples for VOC analysis by USEPA Method 5035, collect these samples first before disturbing the soil. This method uses a soil volume gauge fitted with a disposable soil sampling plunger tube to collect a soil plug that can be discharged directly to a VOA vial, limiting the loss of volatiles during sampling. The collection of VOC samples using the 5035 method specifies use of an airtight VOA vial with a septum lid. Ecology's interpretation of the USEPA 5035 method allows for field preservation of the sample with methanol or sodium bisulfate, or laboratory preservation (i.e. field collection into an un-preserved vial). It is important to note that if laboratory preservation is the selected method, samples must be received at the laboratory within 48-hours of sample collection. The method of sample preservation for the 5035 method will vary for each site and is dependent on site-specific conditions. Preservation method selection should be coordinated with the laboratory and specified in the sampling plan.

1. Note the volume of soil needed for analysis as specified by the laboratory (commonly 5 or 10 grams). Raise the handle of the soil volume gauge to the slot in the gauge body corresponding to the desired volume and turn clockwise until the tabs in the handle lock into the slot.
2. Insert a sample tube at the open end of the gauge body and turn clockwise until the tabs on the tube lock into the "0 gram" slot. Remove the cap from the sample tube and press directly (where possible) into the shallow soil, soil core/sampler, excavation base or sidewall, or stockpile.
3. Continue pressing the sample tube until the plunger is stopped by the sample volume gauge. If a depth interval (for example 9 to10 feet) is targeted for VOC sampling, collect small volumes of soil across this interval until the sample tube is filled

4. Twist counterclockwise to disengage the sample tube, then depress the plunger to eject the soil plug directly into a laboratory-provided VOA vial. If multiple vials per sample are required, the same plunger may be re-used to fill the remaining vials.

3.4 COMPOSITE SAMPLE COLLECTION

For this guideline, composites are considered to be samples that are collected across more than one location, or multiple depth intervals at a single location. Samples collected over continuous depth intervals within a sampling device (i.e. split spoon) are addressed for each sampling method in Section 3.2 above.

Compositing of sample material may be performed in the field, or by the analytical laboratory. To collect a field composite sample, identify the locations and depth(s) that will comprise the composite. Collect soil from the first target sub-sample depth or depth interval and hold in a decontaminated stainless steel bowl, covered with aluminum foil to prevent cross contamination and label with the location and depth. Continue to collect and hold individual sub-samples until all components of the composite have been collected, then transfer an equal amount of each sub-sample to a clean bowl and homogenize. Fill necessary sample jars from homogenized composite. In some cases, project plans may require that each individual sample that comprised the composite be collected in jars and submitted to the laboratory in the event that individual sample analysis is desired, or if laboratory compositing is requested in addition to field compositing as a field quality control measure. In this case, label each individual jar, but indicate HOLD on the chain-of-custody, and note that the sample is part of composite XYZ.

To collect a laboratory composite sample, collect, and label each sub-sample using the procedures described above in Section 3.2. Record each sub-sample on the chain-of-custody form, and indicate on this form which samples should be composited by the laboratory and the desired name of the composite sample. It is important to communicate to the laboratory if discrete samples will also require analysis (in some cases) or only the composite sample.

4.0 Decontamination

All reusable equipment that comes into contact with soil should be decontaminated prior to moving to the next sampling location.

Stainless steel bowls and spoons, and any tools used for sample processing will be decontaminated between each sample; alternatively, disposable bowls and spoons may be used. Equipment decontamination will consist of a tap water rinse to remove soil particles, followed by scrubbing with brushes and an alconox (or other soap)/clean water solution and a final rinse with distilled or deionized water.

5.0 Investigation-Derived Waste

Unless otherwise specified in the project work plan, waste soils will be contained, transported, disposed of in accordance with applicable laws, and stored in a designated area until transported off-site for disposal.

The approach to handling and disposal of these materials is as follows. For IDW that is containerized, such as waste soils, 55-gallon drums approved by WSDOT will be used for temporary storage pending profiling and disposal. Each container holding IDW will be sealed and labeled as to its contents (e.g., “soil”), the dates on which the wastes were placed in the container, the owner’s name and contact information for the field person who generated the waste, and the site name.

IDW that is placed into drums for temporary storage will be characterized relative to applicable waste criteria using data from the sampling locations whenever possible. Material that is designated for off-site disposal will be transported to an off-site facility permitted to accept the waste. Manifests will be used, as appropriate for disposal.

Disposable sampling materials and incidental trash such as paper towels and personal protective equipment (PPE) used in sample processing will be placed in heavy duty garbage bags or other appropriate containers and disposed of as solid waste in the municipal collection system (i.e., site Dumpster).

6.0 Field Documentation

All observations including sample collection locations, soil descriptions, sample depths, collection times, analyses, and field QC samples should be recorded on a boring log, soil sample collection form, or bound field notebook. Information recorded should additionally include personnel present (including subcontractors), purpose of field event, weather conditions, sample collection date and times, sample analytes, and any deviations from the SAP.

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F|S STANDARD GUIDELINE

Low-Flow Groundwater Sample Collection

DATE/LAST UPDATE: August 2015

These procedures should be considered standard guidelines and are intended to provide useful guidance when in the field, but are not intended to be step-by-step procedures, as some steps may not be applicable to all projects.

All field staff should be sufficiently trained in the standard guidelines for the sampling method they intend to use and should review and understand these procedures prior to going into the field. It is the responsibility of the field staff to review the standard guidelines with the field manager or project manager and identify any deviations from these guidelines prior to field work. When possible, the project-specific Sampling and Analysis Plan should contain any expected deviations and should be referenced in conjunction with these standard guidelines.

1.0 Scope and Purpose

This standard guideline provides details necessary for collecting representative groundwater samples from monitoring wells using low-flow methods. These guidelines are designed to meet or exceed guidelines set forth by the Washington State Department of Ecology (Ecology). Low-Flow sampling provides a method to minimize the volume of water that is purged and disposed from a monitoring well, and minimizes the impact that purging has on groundwater chemistry during sample collection.

2.0 Equipment and Supplies

Groundwater Sampling Equipment and Tools:

- For wells with head less than 25 feet:
  - Peristaltic pump with fully-charged internal battery or standalone battery and appropriate connectors

- For wells with head greater than 25 feet:
  - Bladder pump and controller, as well as an air cylinder, or air compressor (with extension cord if near an electrical outlet; with battery and appropriate connectors or generator if not near an outlet)

    OR
  - Low-flow submersible pump and controller (with extension cord if near an electrical outlet; with battery and appropriate connectors or generator if not near an outlet)
- Multi-parameter water quality meter
- Water level meter
- Poly tubing
- Silicone tubing
- Filters (if field filtering)
- Tools for opening wells (1/2-inch, 9/16-inch, and 5/8-inch sockets, ratchet, screwdriver)
- Well keys
- Tube cutters, razor blade, or scissors
- 5-gallon buckets and clamp
- Paper towels
- Bailer or pump to drain well box if full of stormwater
- Hammer
- Alconox (or similar decontamination solution), deionized water, spray bottles
- Tape measure
- Trash bags

Lab Equipment:

- Sample jars/bottles
- Coolers
- Chain-of-Custody Forms
- Labels
- Ice
- Ziploc bags

Paperwork:

- Field notebook with site maps
- Table of well construction details and/or well logs, if available
- Sampling forms
- Purge water plan
- Rite-in-the-Rain pens, paper, and permanent markers
- Site-Specific Health and Safety Plan (HASP)
- Sampling and Analysis Plan (SAP) and/or Quality Assurance Project Plan (QAPP) (including tables of analytes and bottle types)

Personal Protective Equipment (PPE):

- Boots/waders
- Safety vest
- Safety glasses
- Rain gear
- Nitrile gloves
- Work gloves

3.0 Standard Procedures

Low-Flow groundwater sampling consists of purging groundwater within the well casing at a rate equal to or less than the flow rate of representative groundwater from the surrounding aquifer into the well screen. The flow rate will depend on the hydraulic conductivity of the aquifer and the drawdown, with the goal of minimizing drawdown within the monitoring well. Field parameters are monitored during purging and groundwater samples are collected after field parameters have stabilized. Deviations from these procedures should be approved by the Project Manager and fully documented.

3.1 CALIBRATION OF WATER QUALITY METERS

All multi-parameter water quality meters to be used will be calibrated prior to each sampling event. Calibration procedures are outlined in each instrument's specific user manual.

3.2 MONITORING, MAINTENANCE, AND SECURITY

Prior to sampling, depth to water and total depth measurements will be collected and recorded for accessible monitoring wells onsite (or an appropriate subset for larger sites). Check for an existing measuring point (notch or visible mark on top of casing). If a measuring point is not observed, a measuring point should be established on the north side of the casing. The conditions of the well box and bolts will also be observed and deficiencies will be recorded on the sampling forms or logbook (i.e., missing or stripped bolt). The following should also be recorded:

- Condition of the well box, lid, bolts, locks, and gripper cap, if deficiencies
- Condition of gasket if deficient and if water is present in the well box
- Note any obstructions or kinks in the well casing
- Note any equipment in the well casing, such as transducers, bailers, or tubing
- Condition of general area surrounding the well, such as subsidence, potholes, or if the well is submerged within a puddle.

Replace any missing or stripped bolts, and redevelop wells if needed.

3.3 LOW-FLOW PURGING METHOD AND SAMPLING PROCEDURES

Groundwater samples will be collected using low-flow purging and sampling procedures consistent with Ecology guidelines and the U.S. Environmental Protection Agency (USEPA) standard operating procedures (USEPA 1996). The following describes the Low-Flow purging and sampling procedures for collecting groundwater samples using a peristaltic pump. If the water level is greater than 20 feet below ground surface (bgs), Grundfos or Geotech submersible pumps or bladder pumps can be used since their pumping rates can be adjusted to low-flow levels.

- Place the peristaltic pump and water quality equipment near the wellhead. Slowly lower new poly tubing down into the well casing approximately to the middle of the well screen. If the depth of the well screen is not known, lower the tubing to the bottom of the well, making sure that the tubing has not been caught on the slotted well casing, and then raise the tubing 3 to 5 feet off the bottom of the casing. Document the estimated depth of the tubing placement within the well. Connect the tubing to the peristaltic pump using new flex tubing and connect the discharge line to the flow-through cell of the water quality meter. The discharge line from the flow cell should be directed to a bucket to contain the purged water.
- If using a low-flow submersible pump, connect the pump head to dedicated or disposable tubing. If using a bladder pump, connect both the air intake and water discharge ports to decontaminated or disposable tubing, using the manufacturer's instructions to ensure a secure connection. Lower the pump with tubing into the well as described above and connect the water discharge tubing directly to the flow-through cell.
- Measure the depth to water to the nearest 0.01 foot with a decontaminated water level meter and record the information on a sampling form.
- Start pumping the well at a purge rate of 0.1 to 0.2 liters per minute and slowly increase the rate. Purge rate is adjusted using a speed control knob or arrows on peristaltic and low-flow submersible pumps. The purge rate for bladder pumps is controlled by the air compressor, which first pressurizes the pump chamber in order

to compress the flexible bladder and force water through the discharge line, and then vents the chamber in order to allow the bladder to refill with water.

  - A good rule of thumb is to pressurize to 10 psi + 0.5 psi/foot of tubing depth and begin with 4 discharge/refill cycles per minute; using greater air pressure and accelerating the pump cycles will increase the purge rate.

- Check the water level. If the water level is dropping, lower the purge rate. Maintain a steady flow with no or minimal drawdown (less than 0.33 feet according to USEPA 2002). Maintaining a drawdown of less than 0.33 feet may not be feasible depending on hydrogeological conditions. If possible, measure the discharge rate of the pump with a graduated cylinder or use a stopwatch when filling sampling jars (500 milliliters [mL] polyethylene or glass ambers) to estimate the rate. When purging water through a flow cell, the maximum flow rate for accurate water quality readings is about 0.5 liters per minute (L/minute).

- Monitor and record water quality parameters every three to five minutes after one tubing volume (including the volume of water in the flow cell) has been purged.

  - One foot of ¼-inch interior diameter tubing holds about 10 mL of water, and flow-through cells typically hold less than 200 mL of water; one volume should be purged after about 5 minutes at a flow rate of 0.1 L/minute.

- Water-quality indicator parameters that will be monitored and recorded during purging include:

  - pH
  - Specific conductivity
  - Dissolved oxygen
  - Temperature
  - Turbidity
  - Oxidation reduction potential (ORP)

- Purging will continue until temperature, pH, turbidity, and specific conductivity are approximately stable (when measurements are within 10 percent) for three consecutive readings, or 30 minutes have elapsed. Because these field parameters (especially dissolved oxygen and ORP) may not reach the stabilization criteria, collection of the groundwater sample will be based on the professional judgment of field personnel at the time of sampling.

- The water sample can be collected once the criteria above have been met.

- If drawdown in the well cannot be maintained at 0.33 feet or less, reduce the flow or turn off the pump for 15 minutes and allow for recovery. If the water quality parameters have stabilized, and if at least two tubing volumes and the flow cell volume have been purged, then sample collection can proceed when the water level has recovered and the pump is turned back on. This should be noted on the sampling form.

- To collect the water sample, maintain the same pumping rate. After the well has been purged and the sample bottles have been labeled, the groundwater sample will be collected by directly filling the laboratory-provided bottles from the pump discharge line prior to passing through the flow cell. All sample containers should be filled with minimum disturbance by allowing the water to flow down the inside of the bottle or vial. When collecting a volatile organic compound (VOC) sample, fill to the top to form a meniscus over the mouth of the vial prior to placing the cap to eliminate air bubbles. Be careful not to overflow preserved bottles/pre-cleaned Volatile Organic Analyte (VOA) vials.
- If sampling for filtered metals, collect these samples last and fit an in-line filter at the end of the discharge line. Take note of the flow direction arrow on the filter prior to fitting. A minimum of 0.5 to 1 liter of groundwater must pass through the filter prior to collecting the sample.
- Sample labels will clearly identify the project name, sampler's initials, sample location and unique sample id, analysis to be performed, date, and time. After collection, samples will be placed in a cooler maintained at a temperature of approximately 4 to 6 degrees Celsius (°C) using ice. Chain-of-Custody Forms will be completed. Upon transfer of the samples to the laboratory, the Chain-of-Custody Form will be signed by the persons transferring custody of the sample containers to document change in possession.
- When sample collection is complete at a designated location, remove and properly dispose of the non-dedicated tubing. In most cases, this waste is considered solid waste and can be disposed of as refuse. Close and lock the well.

4.0 Decontamination

All reusable equipment that comes into contact with groundwater should be decontaminated using the processes described in this section prior to moving to the next sampling location.

Water Level Meter: The water level indicator and tape will be decontaminated between sampling locations and at the end the day by spraying the entire length of tape that came in contact with groundwater with an Alconox (or similar)/clean water solution followed by a thorough rinse with distilled or deionized water.

Water Quality Sensors and Flow-Through Cell: Distilled water or deionized water will be used to rinse the water quality sensors and flow-through cell. No other decontamination procedures are recommended since they are sensitive equipment. After the sampling event, the water quality meters will be cleaned and maintained according to the specific manual.

Submersible Pump (if applicable: Decontaminating the pump requires running the pump in three progressively cleaner grades of water.

1. Fill a bucket with approximately 4 gallons or more to sufficiently cover the pump of an Alconox (or similar)/clean water solution. Place the pump and the length of the

power cord (if applicable) that was in contact with water into the bucket and run the pump for approximately two minutes or until the volume of water in the bucket has been exhausted.

2. Fill a second bucket containing approximately 4 gallons or more to sufficiently cover the pump of clean water. Place the pump and cord into this bucket and run the pump for approximately two minutes or until the volume of water in the bucket has been exhausted.
3. Fill a third bucket with approximately 4 gallons or more to sufficiently cover the pump of distilled or deionized water. Place the pump and cord into this bucket and run the pump for approximately two minutes or until the volume of water in the bucket has been exhausted.

Bladder Pump: Clean the inside and outside of the pump body with an Alconox (or similar)/clean water solution, followed by a thorough rinse with distilled or deionized water. The outside of the air supply line that came in contact with groundwater may also be cleaned with Alconox (or similar) solution and re-used; bladders and water discharge lines must be replaced after each sample is collected.

5.0 Investigation-Derived Waste (IDW)

Unless otherwise specified in the project work plan, water generated during groundwater sampling activities will be contained, transported, disposed of in accordance with applicable laws, and stored in a designated area until transported off-site for disposal.

The approach to handling and disposal of these materials for a typical cleanup site is as follows. For IDW that is containerized, such as purge water, 55-gallon drums (or other smaller sized drums) approved by the Washington State Department of Transportation will be used for temporary storage pending profiling and disposal. Each container holding IDW will be sealed and labeled as to its contents (e.g., “purge water”), the dates on which the wastes were placed in the container, the owner’s name and contact information for the field person who generated the waste, and the site name.

IDW containerized within drums will be characterized relative to applicable waste criteria using data from the sampling locations whenever possible. Material that is designated for off-site disposal will be transported to an off-site facility permitted to accept the waste. Manifests will be used, as appropriate for disposal.

Disposable sampling materials and incidental trash such as paper towels and PPE used in sample processing will be placed in heavy-duty garbage bags or other appropriate containers and disposed of as trash in the municipal collection system.

6.0 Field Documentation

Groundwater sampling activities will be documented in field sampling forms and/or field notebooks, and Chain-of-Custody Forms. Information recorded will, at a minimum, include personnel present (including subcontractors or client representatives), purpose of field event, weather conditions, sample collection date and times, sample analytes, depths to water, water quality parameters, well box/lid conditions, amount of purged water generated, and any deviations from the SAP. Photographs of damaged well casings or well boxes should be taken.

7.0 References

USEPA. 1996. Low-Stress (low flow) Purging and Sampling Procedure for the Collection of Groundwater Samples from Monitoring Wells, Revision 2. Region 1. July 30, 1996.

_____. 2002. Groundwater Sampling Guidelines for Superfund and CAR Project Managers. Office of Solid Waste and Emergency Response. EPA 542.S-02-001. May 2002.

Attachment 2
Quality Assurance Project Plan

Former Mill E/Koppers Facility

Quality Assurance Project Plan

Prepared for

The Weyerhaeuser Company
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April 2020

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LIMITATIONS

This report has been prepared for the exclusive use of Weyerhaeuser, their authorized agents, and regulatory agencies. It has been prepared following the described methods and information available at the time of the work. No other party should use this report for any purpose other than that originally intended, unless Floyd|Snider agrees in advance to such reliance in writing. The information contained herein should not be utilized for any purpose or project except the one originally intended. Under no circumstances shall this document be altered, updated, or revised without written authorization of Floyd|Snider.

Table of Contents

List of Tables

List of Acronyms and Abbreviations

Acronym/ Abbreviation	Definition
LCS	Laboratory control sample
LCSD	Laboratory control sample duplicate
MDL	Method detection limit
MS	Matrix spike
MSD	Matrix spike duplicate
PQL	Practical quantitation limit
QA	Quality assurance
QAPP	Quality Assurance Project Plan
QC	Quality control
RPD	Relative percent difference
USEPA	U.S. Environmental Protection Agency

1.0 Quality Assurance Project Plan

This Quality Assurance Project Plan (QAPP) describes the analytical program to be conducted for each sample, as well as the laboratory quality assurance (QA) objectives and quality control (QC) procedures required to be met to achieve technically sound and useable data. Analytical methods were selected to ensure that reporting limits are less than the applicable cleanup level criterion, where feasible.

1.1 CHEMICAL LABORATORY ANALYSES PROGRAM

Soil and groundwater samples will be submitted to Fremont Analytical in Seattle, Washington. Soil samples will be analyzed for arsenic using U.S. Environmental Protection Agency (USEPA) Method 6020. Groundwater samples will be analyzed for both total and dissolved arsenic using USEPA Method 200.8. A subset of groundwater samples will also be analyzed for total petroleum hydrocarbons (TPH) by NWTPH-Gx and NWTPH-Dx, and pentachlorophenol (penta) by USEPA Method 8270.

Sample containers and preservation requirements are presented in Table 1.1.

Table 1.1
Analytical Requirements, Methods, Preservation, Bottle Type, and Holding Times

Analyte	Analytical Method	Bottle Type	Preservative	Holding Time
Soil				
Arsenic	USEPA Method 6020	One 4-oz WMG	None, cool to <6 °C	6 months
Groundwater				
Arsenic	USEPA Method 200.8	One 250-mL HDPE (1)	HNO_3 to pH<2 (2)	6 months
Penta	USEPA Method 8270	Two 500-mL amber glass	None, cool to <6 °C	7 days to extract, then 40 days to analyze
TPH	NWTPH-Gx	Three 40-mL VOA	Cool to <6 °C, HCl to pH<2, no headspace	14 days
	NWTPH-Dx	One 500-mL amber glass	None, cool to <6 °C	7 days to extract, then 40 days to analyze

Notes:
1 One container is needed for total arsenic and one container is needed for dissolved arsenic.
2 The sample collected for dissolved arsenic should be filtered in the field using a 0.45-micrometer filter prior to preservation.

Abbreviations:
°C Degrees Celsius
HDPE High-density polyethylene
VOA Volatile organic analysis
WMG Wide-mouth glass jar

1.1.1 Reporting Limits

The analytical method identified in Table 1.1 results in method detection limits (MDLs) and practical quantitation limits (PQLs) that are less than the relevant arsenic cleanup level criteria for soil and groundwater. The target MDLs and PQLs for arsenic are summarized in Table 1.2.

Table 1.2
Analytical Methods, Detection Limits, and Reporting Limits

Analyte	Analytical Method	Units	Method Detection Limit	Practical Quantitation Limit
Soil				
Arsenic	USEPA Method 6020	mg/kg	0.078	0.25
Groundwater				
Arsenic	USEPA Method 200.8	µg/L	0.234/0.589 (1)	0.5/1.75 (1)
Penta	USEPA Method 8270	µg/L	0.058	2.0
TPH	NWTPH-Gx and NWTPH-Dx	µg/L	Gasoline: 11 Diesel: 5.4 Oil: 52	Gasoline: 100 Diesel: 50 Oil: 250

Note:
1 Values are for total and dissolved arsenic, respectively.

Abbreviations:
µg/L Micrograms per liter
mg/kg Milligrams per kilogram

These PQLs are goals only, insofar as instances may arise where high sample concentrations, heterogeneity of samples, or matrix interferences preclude achieving the desired reporting limit and associated QA/QC criteria. In such instances, the laboratory will report the reason for any deviation from these reporting limits.

1.2 GEOCHEMICAL ANALYSIS

Soil and groundwater samples will also be analyzed for geochemical parameters to evaluate fate and transport of arsenic. Soil samples will be collected for analyses of iron, manganese, sulfide, and total organic carbon. Groundwater samples will be collected for analyses of major cations (calcium, magnesium, potassium, and sodium), major anions (bromide, chloride, fluoride, and sulfate), alkalinity (dissolved), major ions (ortho-phosphate), nitrate, nitrite, iron (dissolved), manganese (dissolved), sulfide (dissolved), and organic carbon (total and dissolved). The analytical methods and target MDLs and PQLs are summarized in Table 1.3.

Table 1.3
Geochemical Parameters

Analyte [1]	Analytical Method	Units	Method Detection Limit	Practical Quantitation Limit
Soil				
Iron	USEPA Method 6020	mg/kg	1.0	5.0
Manganese	USEPA Method 6020	mg/kg	1.0	5.0
Sulfide	USEPA Method 9034	mg/kg	2.4	5.0
Total organic carbon	USEPA Method 9060	mg/kg	44.4	2,000
Groundwater				
Major Cations				
Calcium	USEPA Method 6010C	mg/L	0.0230	1.10
Magnesium		mg/L	0.133	1.10
Potassium		mg/L	0.146	3.30
Sodium		mg/L	0.550	2.0
Major Anions				
Bromide	USEPA Method 300.0	mg/L	0.060	0.50
Chloride		mg/L	0.040	0.50
Fluoride		mg/L	0.030	0.20
Sulfate		mg/L	0.260	1.20
Other Analytes				
Alkalinity (dissolved)	SM2320B	mg/L	5.00	5.0
Major ions (ortho-phosphate)	USEPA Method 365.1	mg/L	0.030	0.10
Nitrite as N	USEPA Method 300.0	mg/L	0.080	0.40
Nitrate as N	USEPA Method 300.0	mg/L	0.020	0.20
Iron (dissolved)	USEPA Method 6020A	µg/L	29.0	200.0
Manganese (dissolved)	USEPA Method 6020A	µg/L	1.8	10.0
Sulfide (dissolved)	SM4500 S2 D	mg/L	0.0	0.1
Organic carbon (total and dissolved)	SM5310B	mg/L	0.05	0.5

Notes:

1 Analysis is being performed to develop the geochemical conceptual site model and understand fate and transport of arsenic at the Site. Not considered a constituent of concern for the Site.

1.3 LABORATORY DATA QUALITY OBJECTIVES

Laboratory QA/QC objectives include obtaining data that are technically sound and properly documented, having been evaluated against established criteria for the principle data quality indicators (i.e., precision, accuracy, representativeness, completeness, and comparability) as defined in Ecology and USEPA guidance (Ecology 2016 and USEPA 2002). Specific data QA criteria for the method are presented in Table 1.4.

Table 1.4
Data Quality Assurance Criteria

Analyte	Precision (1)	Accuracy	Completeness	Reference
Soil				
Arsenic	±20% RPD	80–120%	95%	USEPA Method 6020
Groundwater				
Arsenic	±20% RPD	80–120%	95%	USEPA Method 6020
Penta	±30% RPD	20–137%	95%	USEPA Method 8270
TPH	±30% RPD	50–150%	95%	NWTPH-Gx and NWTPH-Dx

Note:
1 Precision criteria apply to analytical precision only. Field duplicate precision will be screened against an RPD of 75%.

Abbreviation:
RPD Relative percent difference

1.3.1 Precision

Precision measures the reproducibility of measurements under a given set of conditions. Specifically, precision is a quantitative measure of the variability of a group of measurements compared to their average values. Analytical precision is measured by matrix spike (MS)/matrix spike duplicate (MSD) samples for organic analyses and by laboratory duplicate samples for inorganic analyses.

Analytical precision measurements will be carried out on project-specific samples at a minimum laboratory duplicate frequency of one per laboratory analysis group or 1 in 20 samples, whichever is more frequent per matrix analyzed, as practical. Laboratory precision will be evaluated against quantitative RPD performance criteria.

Field precision will be evaluated by the collection of field duplicates at a minimum frequency of one per laboratory analysis group or 1 in 20 samples. Currently, no performance criteria have been established for field duplicates. Field duplicate precision will, therefore, be screened against an RPD of 75 percent for all samples. However, data will not be qualified based solely on field duplicate precision.

Precision measurements can be affected by the nearness of a chemical concentration to the method detection limit, where the percent error (expressed as RPD) increases. The equation used to express precision is as follows:

$$RPD = \frac{(C_1 - C_2) \times 100\%}{(C_1 + C_2)/2}$$

Where:

C_1 = Larger of the two observed values
C_2 = Smaller of the two observed values

1.3.2 Accuracy

Accuracy is an expression of the degree to which a measured or computed value represents the true value. Analytical accuracy may be assessed by analyzing "spiked" samples with known standards (surrogates, laboratory control samples [LCSs], and/or MS samples) and measuring the percent recovery. Accuracy measurements on MS samples will be carried out at a minimum frequency of 1 in 20 samples per matrix analyzed. Because MSs/MSDs measure the effects of potential matrix interferences of a specific matrix, the laboratory will perform MSs/MSDs only on samples from this investigation and not from other projects. Surrogate recoveries will be determined for samples analyzed for organic compounds.

Laboratory accuracy will be evaluated against quantitative LCS, MS, and surrogate spike recoveries using limits for each applicable analyte. Accuracy can be expressed as a percentage of the true or reference value, or as a percent recovery in those analyses where reference materials are not available and spiked samples are analyzed. The equation used to express accuracy is as follows:

$$\%R = 100\% \times (S - U)/C_{sa}$$

Where:

%R = Percent recovery
S = Measured concentration in the spiked aliquot
U = Measured concentration in the unspiked aliquot
C_{sa} = Actual concentration of spike added

1.3.3 Representativeness

Representativeness expresses the degree to which sample data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, or an environmental condition. Care will be taken in the design of the sampling program to ensure that sample locations are properly selected, sufficient numbers of samples are collected to accurately reflect conditions at the location(s), and samples are representative of the sampling location(s). A sufficient volume of sample will be collected at each sampling location to minimize bias or errors associated with sample particle size and heterogeneity.

1.3.4 Comparability

Comparability is a qualitative parameter expressing the confidence with which one dataset can be compared to another. In order to ensure that results are comparable, samples will be analyzed using standard USEPA methods and protocols. Calibration and reference standards will be traceable to certified standards, and standard data reporting formats will be used. Data will also be reviewed to verify that precision and accuracy criteria were achieved and, if not, that data were appropriately qualified.

1.3.5 Completeness

Completeness is a measure of the amount of data that is determined to be valid in proportion to the amount of data collected. Completeness will be calculated as follows:

$$C = \frac{\text{(Number of acceptable data points) x 100}}{\text{(Total number of data points)}}$$

The data quality objective for completeness for all components of this project is 95 percent. Data that were qualified as estimated because the QC criteria were not met will be considered valid for the purpose of assessing completeness. Data that were qualified as rejected will not be considered valid for the purpose of assessing completeness.

1.4 LABORATORY AND FIELD QUALITY ASSURANCE/QUALITY CONTROL PROCEDURES

The quality of analytical data generated is assessed by both the implementation of field QC procedures, and by the frequency and type of internal laboratory QA/QC checks developed for analysis type and method. Field QC is evaluated through the analysis of trip blanks and field duplicates. Field duplicates are collected to evaluate the efficiency of field decontamination procedures, variability from sample handling, and sample heterogeneity. Laboratory results will be evaluated by reviewing analytical results of method blanks, MS/MSD, field duplicate samples, LCS, calibrations, performance evaluation samples, and interference checks as specified by the specific analytical methods.

Results of the QA/QC samples from each laboratory analysis group will be reviewed by the laboratory analyst immediately after a laboratory analysis group has been analyzed. The QA/QC sample results will then be evaluated to determine whether control limits were exceeded. If control limits are exceeded in the laboratory analysis group, corrective action (e.g., method modifications followed by reprocessing the affected samples) will be initiated prior to processing a subsequent group of samples.

All primary chemical standards and standard solutions used in this project will be traceable to documented and reliable commercial sources. Standards will be validated to determine their accuracy by comparison with an independent standard. Any impurities identified in the standard will be documented.

The procedures that will be used to assess data quality throughout sample analysis are summarized in the following sections.

1.4.1 Laboratory Duplicates

Analytical duplicates provide information on the precision of the analysis and are useful in assessing potential sample heterogeneity and matrix effects. Analytical duplicates are subsamples of the original sample that are prepared and analyzed as a separate sample. A minimum of one duplicate will be analyzed per laboratory analysis group. When there are fewer than 20 samples, a laboratory duplicate will still be analyzed.

1.4.2 Matrix Spikes and Matrix Spike Duplicates

Analysis of MS samples provides information on the extraction efficiency of the method on the sample matrix. By performing MSD analyses, information on the precision of the method is also provided for organic analyses. A minimum of one MS/MSD will be analyzed for every laboratory analysis group for which MS/MSD sample analysis is applicable. MS/MSD analyses will be performed on project-specific samples. When there are fewer than 20 samples, a MS/MSD will still be analyzed.

1.4.3 Laboratory Control Samples and Laboratory Control Sample Duplicates

An LCS is a method blank sample carried throughout the same process as the samples to be analyzed, with a known amount of standard added. The blank spike compound recovery assesses analytical accuracy in the absence of any sample heterogeneity or matrix effects. All LCS and LCS duplicate (LCSD) data for metals and organic compounds will be reported. The LCS/LCSD will be performed once per laboratory analysis group.

1.4.4 Surrogate Spike

All project samples analyzed for organic compounds will be spiked with appropriate surrogate compounds as defined in the analytical methods. Surrogate recoveries will be reported by the laboratories; however, no sample result will be corrected for recovery using these values.

1.4.5 Method Blanks

Method blanks are analyzed to assess possible laboratory contamination at all stages of sample preparation and analysis. A minimum of one method blank will be analyzed for every extraction batch.

1.5 DATA REDUCTION AND REPORTING

The laboratory will be responsible for internal checks on data reporting and will correct errors identified during the QA review. Close contact will be maintained with the laboratories to resolve any QC problems in a timely manner. The analytical laboratories will be required, where applicable, to report the following:

- **Project Narrative.** This summary, in the form of a cover letter, will discuss problems, if any, encountered during any aspect of analysis. This summary should discuss, but not be limited to, QC, sample shipment, sample storage, and analytical difficulties.

Any problems encountered (actual or perceived) and their resolutions will be documented in as much detail as necessary.

- **Sample IDs.** Records will be produced that clearly match all field duplicate QA samples with laboratory sample IDs.
- **Chain-of-Custody Records.** Legible copies of the custody forms will be provided as part of the data package. This documentation will include the time of receipt and condition of each sample received by the laboratory. Additional internal tracking of sample custody by the laboratory will also be documented.
- **Sample Results.** The data package will summarize the results for each sample analyzed. The summary will include the following information when applicable:
  - Field sample identification code and the corresponding laboratory identification code:
    - Sample matrix
    - Date of sample extraction
    - Date and time of analysis
    - Weight and/or volume used for analysis
    - Final dilution volumes or concentration factor for the sample
    - Percent moisture in solid samples
    - Identification of the instrument used for analysis
    - Method reporting and quantitation limits
  - Analytical results reported with reporting units identified
  - All data qualifiers and their definitions
  - Electronic data deliverables
- **Quality Assurance/Quality Control Summaries.** This section will contain the results of all QA/QC procedures. Each QA/QC sample analysis will be documented with the same information required for the sample results (refer to previous bullet). No recovery or blank corrections will be made by the laboratory. The required summaries are listed below; additional information may be requested:
  - **Method Blank Analysis.** The method blank analyses associated with each sample and the concentration of all compounds of interest identified in these blanks will be reported.
  - **Surrogate Spike Recovery.** All surrogate spike recovery data for organic compounds will be reported. The name and concentration of all compounds added, percent recoveries, and range of recoveries will be listed.
  - **Matrix Spike Recovery.** All MS recovery data for metals and organic compounds will be reported. The name and concentration of all compounds added, percent recoveries, and range of recoveries will be listed. The RPD for all duplicate analyses will be reported.

- **Matrix Duplicate.** The RPD for all matrix duplicate analyses will be reported.
- **Field Duplicates.** Field duplicates will be reported in the same format as any other sample. RPDs will be calculated for duplicate samples and evaluated as part of the data quality review.

1.6 DATA VALIDATION

Once data are received from the laboratory, a number of QC procedures will be followed to provide an accurate evaluation of the data quality. Specific procedures will be followed to assess data precision, accuracy, and completeness.

A data quality review of the analytical data will follow USEPA National Functional Guidelines in accordance with the QAPP limits (USEPA 2017a and 2017b). All chemical data will be reviewed with regard to the following:

- Chain of custody/documentation
- Sample preservation and holding times
- Instrument performance (calibration, tuning, sensitivity)
- Method blanks
- Method reporting limits
- Surrogate recoveries
- MS/MSD recoveries
- LCS recoveries
- Laboratory and field duplicate RPD

A Level II summary validation will be performed on all data.

2.0 References

U.S. Environmental Protection Agency (USEPA). 2002. *Guidance on Environmental Data Verification and Data Validation, EPA QA/G-8*. Publication No. EPA/240/R-02/004. Office of Environmental Information. Washington, DC. November.

_____. 2017a. *National Functional Guidelines for Organic Superfund Methods Data Review*. EPA-540-R-2017-002/OLEM 9355.0-136. Office of Superfund Remediation and Technology Innovation. Washington, D.C. January.

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