Engineering Design Report

South State Street Manufactured Gas Plant
Bellingham, Washington

for
Puget Sound Energy

November 22, 2024

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List of Acronyms and Abbreviations

°C	degrees Celsius
1D	one-dimensional
AC	activated carbon
AO	Agreed Order
ARARs	applicable or relevant and appropriate requirements
ASTM	ASTM International
bgs	below the ground surface
BMC	Bellingham Municipal Code
BMPs	best management practices
BNSF	BNSF Railway Company
CAP	Cleanup Action Plan
CFR	Code of Federal Regulations
City	City of Bellingham
cm	centimeters
cm/d	centimeters per day
Cornwall Site	Cornwall Avenue Landfill cleanup site
cPAHs	carcinogenic PAHs
CQA	construction quality assurance
CQAP	Construction Quality Assurance Plan
CQC	construction quality control
CSWGP	Construction Stormwater General Permit
CSZ	Cascadia Subduction Zone
CWA	Clean Water Act
CY	cubic yards
DNR	Washington State Department of Natural Resources
Ecology	Washington State Department of Ecology
EDR	Engineering Design Report
ENR	enhanced natural recovery
EPA	United States Environmental Protection Agency
EPP	Environmental Protection Plan
ESA	Endangered Species Act

ft^3/lb/hr	cubic feet per pound per hour
ft/ft	feet per foot
GeoEngineers	GeoEngineers, Inc.
GIS	geographic information system
GMD	Glaciomarine Drift
HASP	Health and Safety Plan
HAZWOPER	hazardous waste operations and emergency response
HPAHs	high molecular weight PAHs
HRDPS	high-resolution deterministic prediction system
HTL	high tide line
IDP	Inadvertent Discovery Plan
IHSs	Indicator Hazardous Substances
JARPA	Joint Aquatic Resource Permit Application
kg	kilogram
lbs	pounds
LPAHs	low molecular weight PAHs
mg/L	milligrams per liter
µg/kg	micrograms per kilogram
MGP	manufactured gas plant
MHHW	mean higher high water
MHW	mean high water
MLLW	mean lower low water
MNA	monitored natural attenuation
MNR	monitored natural recovery
MTCA	Model Toxics Control Act
NAPL	non-aqueous phase liquid
NAVD88	North American Vertical Datum of 1988
NEPA	National Environmental Policy Act
NOAA	National Oceanic and Atmospheric Administration
OMMP	Operations, Maintenance, and Monitoring Plan
PAHs	polycyclic aromatic hydrocarbons
PFMs	Passive Flux Meters

PRB	permeable reactive barrier
PRDI	Pre-Remedial Design Investigation
PSE	Puget Sound Energy
PVC	polyvinyl chloride
QAPP	Quality Assurance Project Plan
RCRA	Resource Conservation and Recovery Act
RCW	Revised Code of Washington
RDPS	regional deterministic prediction system
RI/FS	Remedial Investigation/Feasibility Study
ROW	right-of-way
SAP	Sampling and Analysis Plan
SEPA	Washington State Environmental Policy Act
Site	South State Street Manufactured Gas Plant Site
SLR	sea level rise
SMMWW	Stormwater Management Manual for Western Washington
SMS	Sediment Management Standards
SWAC	surface-weighted average concentration
SWPPP	stormwater pollution prevention plan
TESC	temporary erosion and sedimentation control
TEQ	Toxic Equivalent Concentration
TPH	total petroleum hydrocarbons
TPH-D	diesel-range total petroleum hydrocarbons
TPH-G	gasoline-range total petroleum hydrocarbons
TPH-O	oil-range total petroleum hydrocarbons
µg/kg	micrograms per kilogram
USACE	United States Army Corps of Engineers
VOCs	volatile organic compounds
WAC	Washington Administrative Code
WAD	weak acid dissociable
WQC	Water Quality Certification
WQMP	Water Quality Monitoring Plan
ZVI	zero-valent iron

1.0 Introduction

This Engineering Design Report (EDR) describes the preliminary engineering design for the final cleanup action at the South State Street Manufactured Gas Plant Site (Site) in Bellingham, Washington. The Site is generally located at Boulevard Park, south[1] of the downtown business district in Bellingham, Washington as shown in Figure 1-1. Historic lumber mill operations from 1884 to 1925 and manufactured gas plant (MGP) operations from 1890 to 1950, among other potential sources, have resulted in contamination of soil, groundwater, and sediment. Cleanup actions are planned for the Site upland unit and marine unit shown in Figure 1-2 and discussed in Section 1.2. The Site is within the Whatcom Waterway Site and is adjacent to the R.G. Haley International Corp (Haley or Haley Site) and Cornwall Avenue Landfill (Cornwall or Cornwall Site) sites. The relationship between these three sites is shown in Figure 1-3 and described in Section 1.2.2.

Cleanup actions will be completed pursuant to requirements of the Model Toxics Control Act (MTCA), Chapter 70A.305 of the Revised Code of Washington (RCW) and Chapter 173-340 of the Washington Administrative Code (WAC). The cleanup will also comply with the Washington State Sediment Management Standards (SMS; WAC 173-204). Design and permitting activities supporting the cleanup are being conducted under Agreed Order (AO) No. DE 7655 (Ecology 2010, 2017, and 2019) among the Washington State Department of Ecology (Ecology), Puget Sound Energy (PSE) and the City of Bellingham (City).

The following is a summary of general facility information for the Site:

Site Name	South State Street Manufactured Gas Plant
Property Address	South State Street, Bellingham, Washington, 98225
Cleanup Site ID	4606
Facility Site ID	2865
Agreed Order No.	DE 7655
Agreed Order and Amendment Dates	April 30, 2010 (Original), October 10, 2017 (Amendment 1), May 21, 2019 (Amendment 2)
Parties to the Orders	Ecology, City of Bellingham, Puget Sound Energy
Current Property Owners	City of Bellingham, Washington State (managed by the Department of Natural Resources), BNSF Railway Company, Port of Bellingham, Jacqueline J Ogden Rev Living Trust

The upland portion of the Site is currently a public park, Boulevard Park, managed and maintained by the City. The final cleanup action at the Site is designed to be protective of human health and the environment.

1.1 CLEANUP ACTION OBJECTIVES

The cleanup action for the Site is based on the Cleanup Action Plan (CAP; Ecology 2020). The general objective of the cleanup action is to eliminate, reduce, or otherwise control to the extent feasible and practicable, unacceptable risks to human health and the environment posed by hazardous substances in

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[1] All directions are referenced to “project north.” The relationship between project north and true north is shown on the figures.

impacted media. Though not a cleanup action objective, the remedial design also incorporates habitat components that will continue to be refined, as needed, based on continuing design considerations, and input from Ecology and other agencies during the design and permitting phase of the project.

1.1.1 Upland Unit

Potential upland exposure routes and receptors associated with hazardous substances in upland unit soil, soil vapor, and groundwater include:

- People contacting contaminants in soil (dermal contact and incidental ingestion);
- Ecological receptors potentially contacting a polycyclic aromatic hydrocarbon (PAH) hot spot in the upper park (dermal contact and incidental ingestion);
- People being exposed to volatile contaminants resulting from soil vapor migrating to indoor air of potential future buildings (inhalation of indoor air);
- Transport of upland contaminants to marine sediment or surface water via groundwater migration; and
- Erosion of upland contaminated soil and transport to the marine unit.

As described in the RI report (Landau and GeoEngineers 2019), groundwater beneath the Site is classified as non-potable. Therefore, the exposure routes and receptors have not included people contacting contaminants in potable groundwater; however, institutional controls are included in the selected cleanup action that prevent withdrawal of groundwater from the Site for potable and non-potable uses.

The cleanup action for the upland unit includes installing a vegetated soil cap to mitigate the potential direct contact and ingestion exposure pathways described above. Institutional controls will prohibit the addition of any structures with indoor airspace without prior evaluation of potential vapor intrusion risks and mitigation of those risks if present, based on the structure design. Enhanced bioremediation and monitored natural attenuation (MNA) of groundwater will address the transport of upland contaminants in groundwater to marine sediment or surface water. The upland soil cap and the marine sediment cap will be designed to resist erosion.

The upland unit cleanup action is further described in Section 3.1.

1.1.2 Marine Unit

Potential exposure routes and receptors associated with hazardous substances in the marine unit include:

- People contacting contaminants in sediment (dermal contact and incidental ingestion);
- Exposure of aquatic organisms to contaminants in sediment within the biologically active zone (the upper 12 centimeters [cm] of sediment); and
- Exposure of people and higher trophic level ecological receptors (fish, aquatic-dependent birds, and mammals) to contaminants in sediment via the bioaccumulation/seafood ingestion pathway.

Sediment capping and enhanced natural recovery (ENR) are the planned cleanup actions to address contaminants in the marine unit.

Sediment exceeding cleanup levels in portions of the intertidal zone will be capped with sand amended with activated carbon to contain underlying contamination. Other areas requiring capping will be capped with a non-amended conventional sand cap. The capped surfaces will be protected with suitable materials to reduce the risk of erosion.

Sediment within the eelgrass at the northern end of the marine unit has lower concentrations of bioaccumulative contaminants (carcinogenic PAHs [cPAHs]). ENR that includes placement of thin layers of sand will be utilized in this area. Continued (net) sediment deposition that is naturally occurring in the ENR area, and within much of the marine unit, will continue the natural recovery process. However, the sediment cleanup standard will be met in the marine unit upon completion of cleanup construction.

The marine unit cleanup action is further described in Section 3.2.

1.2 SITE BACKGROUND

The following sections describe the Site setting and summarize the Site history, environmental investigation findings, geology and hydrogeology, and environmental conditions. The Remedial Investigation/Feasibility Study (RI/FS; Landau and GeoEngineers 2019), and Pre-Remedial Design Investigation Data Report (GeoEngineers 2023) provide additional detail.

1.2.1 General Site Description

The South State Street MGP was formerly located on what is now Boulevard Park along the eastern shore of Bellingham Bay (Figure 1-1). The Site is divided into an upland unit and marine unit, separated by the mean high tide line (Figure 1-2). The upland unit encompasses the northern portion of Boulevard Park and is further divided into three areas: the upper park, the slope, and the lower park (Figure 1-2). The former MGP was in the upper park area. The marine unit includes aquatic lands of Bellingham Bay. The upland unit includes property owned by the City, Washington State (managed by the Department of Natural Resources [DNR]), Burlington Northern/Santa Fe Railroad (BNSF), and the Jacqueline J Ogden Rev Living Trust (Figure 1-4). The marine unit includes property owned by the City, Washington State (managed by DNR), BNSF, and Port of Bellingham aquatic lands, and platted street right-of-way (ROW).

The Site has been used as a public park since approximately 1980. The area comprising the lower park was constructed by placing fill on tidelands formerly occupied by a historic sawmill. The area comprising the upper park was formerly occupied by the MGP facility. Fill in the lower park includes wood waste associated with former lumber mill and log-rafting operations, and materials from local demolition and construction projects. Pilings associated with the former lumber mill wharf likely remain beneath the lower park. The base of one of the former gas holders remains above-ground in the upper park.

1.2.2 Adjacent MTCA Sites

Twelve cleanup sites located in the general vicinity of the Site are part of the Bellingham Bay Demonstration Pilot Project (Pilot Project). The cleanup sites located closest to the Site are shown in Figure 1-3. The Pilot Project is a coordinated effort by federal, tribal, state, and local governments to clean up contamination around Bellingham Bay.

Portions of the Whatcom Waterway Site overlap with the marine unit of the Site (Figure 1-3). In the area of overlap, the Whatcom Waterway cleanup consists of monitored natural recovery (Whatcom Waterway

Units 7 and 9 in Figure 1-3; Anchor QEA 2015). Unit 7 (Starr Rock) encompasses an area where sediment dredged from Whatcom Waterway and adjacent berthing areas was disposed during the late 1960s. Unit 9 is an area where mercury contamination, not associated with the Site, exists.

The marine unit is also adjacent to the Haley Site and the Cornwall Site. The Haley cleanup action adjacent to the marine unit consists of monitored natural recovery to address dioxin and furan contamination. The Cornwall cleanup action adjacent to the marine unit consists of capping sediment containing landfill debris.

The Site, Whatcom Waterway Site, Haley Site, and Cornwall Site cleanups will be coordinated to assure compatibility.

1.2.3 Site History Summary

A summary of historical information from the RI is presented below.

1.2.3.1 RAILROAD (1890 TO PRESENT)

The mainline of the coastal railroad passes through the Site, as shown in Figure 1-2. The active rail line is operated by BNSF and began operation in 1890. Additional railways historically crossed the Site adjacent to the current rail line. These rail operations included the Bellingham Bay & Eastern/Northern Pacific track, the Northern Pacific/Chicago Milwaukee log dump spur, and the State Street railway.

1.2.3.2 LUMBER MILL (1884 TO 1925)

A former lumber mill, constructed in 1884, operated on piers over aquatic lands adjacent to the Site shoreline. The lumber mill operated for most of its time as either the Bellingham Mill Company or the E.K. Wood Lumber Mill. The facility was located almost exclusively on a wood pile-supported wharf that extended approximately 1,200 feet along the shoreline and 400 feet into Bellingham Bay, encompassing tidelands occupied by the present-day lower park (including a portion of the Site) and waters offshore of the present-day park. The mill was closed after a fire burned it to the ground on September 30, 1925 (Griffin 2007). Over the next 50 years, the wharf was removed and most of the remaining pilings were cut at the mudline or removed entirely, and the area was filled and developed into the present-day lower park (Griffin 2007).

1.2.3.3 MANUFACTURED GAS PLANT (1890 TO 1956)

The Bellingham Bay Gas Company began operating an MGP in December 1890 within the footprint of the present-day upper park (Griffin 2007). Facility operations continued until about 1956. The facility produced gas that was used to heat and light residences and businesses. The facility initially included a coal house bunker, retorts, purifier, barrel sheds, and two gas holders. The facility expanded over the following decades to include an additional gas holder and equipment associated with a propane-air gas manufacturing process. Ownership of the facility changed several times between the early 1900s and mid-1950s with Whatcom County Railway and Light Company having ownership in about 1904, followed by Whatcom Fairhaven Gas Company, Puget Sound Traction & Light & Power Company, Puget Sound Power & Light, Bellingham Gas Company, and finally Cascade Natural Gas Corporation (Griffin 2007 and Herrenkohl 2009).

1.2.3.4 BOULEVARD PARK (1980 TO PRESENT)

The Site has been used solely as a public park since 1980. The park was constructed by placing fill in tidelands formerly occupied by the historic sawmill (lower park) and upland formerly occupied by the MGP facility. Fill in the lower park includes wood waste associated with former lumber mill and log-rafting operations, and materials from local demolition and construction projects. Pilings associated with the former lumber mill wharf likely remain beneath the lower park. The base of one of the former gas holders remains above-ground in the upper park.

The shoreline of Boulevard Park is subject to erosive marine forces. Two projects have been completed to mitigate shoreline erosion. In 2013, the City completed the Boulevard Park Shoreline Improvement project along the west shoreline of Boulevard Park, south of the Site boundary in the lower park. Large debris was removed from the beach, three drift sills were constructed perpendicular to the shoreline, and gravel and sand were placed on the beach. A revetment was constructed at the north end of the project adjacent to the Site boundary.

Another project was completed in 2017 to protect the shoreline from erosion within the Site boundary (lower park shoreline). This work was conducted by the City and PSE in 2017 as a MTCA interim action, under Amendment 1 to the Agreed Order. The interim action generally consisted of placing a riprap revetment along the west shoreline of the Site, stabilizing a concrete bulkhead, and removing a public pier, wood piles and decking. As required by MTCA, the interim action did not preclude the selection of alternatives for the final cleanup action.

1.2.4 Site Investigation Background and Cleanup Activities

The City and PSE have completed several environmental investigations and an interim action at the Site since 2008 that included the following:

- The RI/FS summarizes and evaluates the chemical analytical results associated with environmental investigations completed between 2008 and 2016 (Landau and GeoEngineers 2019).
- An emergency interim action was completed in 2017 following a storm event to prevent potential exposure and migration of contaminated media (Landau and GeoEngineers 2019).
- A Pre-Remedial Design Investigation (PRDI) was completed in 2023 to support the development of this EDR (GeoEngineers 2023). The results of the pre-design upland investigation are summarized in Section 4.0 and the PRDI report is provided in Appendix A.

1.2.5 Geology

The geology of the Site is comprised of a sequence of geological units. From deepest and oldest to shallowest and youngest, the units include the Chuckanut Formation, the Bellingham Drift or Glaciomarine Drift (GMD) unit, and wood debris and fill material as described in the sections below. Figure 1-5 shows the alignment of the geologic cross sections. The conceptual geologic cross sections are presented in Figure 1-6 (A-A’), Figure 1-7 (B-B’), Figure 1-8 (C-C’), and Figure 1-9 (D-D’).

1.2.5.1 CHUCKANUT FORMATION BEDROCK

The bedrock underlying the Site is primarily sandstone and carbonaceous shale, forming the Chuckanut Formation which was formed approximately 55 million years ago in the Eocene epoch. Field samples indicate a range of colors and textures, from red to gray and fine to medium-grained sandstone locally.

The Chuckanut Formation extends across the entire Site at varying depths, with the bedrock surface generally sloping west and northwest. Visible outcrops are present along the upland slopes, particularly in the eastern part of the Site, along the steep slope.

In the upper park, the depth to bedrock varies from the ground surface to 26 feet below ground surface (bgs), with a northward slope. On the steep slope, the bedrock gradient ranges from 0.50 feet per foot (ft/ft) to a maximum of 1.11 ft/ft. The lower park has bedrock at depths ranging from 4.5 feet bgs to 37 feet bgs and sloping northward. In the marine unit, sediment borings reached the bedrock surface in intertidal and subtidal zones. The sediment borings indicate a northwestward slope similar to the lower park.

1.2.5.2 BELLINGHAM DRIFT OR GLACIOMARINE DRIFT (GMD)

Overlying the Chuckanut Formation in portions of the lower park and the marine unit is a layer of glacial marine drift called the Bellingham Drift or GMD generally comprised of unconsolidated material. The Bellingham Drift is composed of unsorted and unstratified, pebbly, sandy silt, and clay materials with occasional marine shells. The unit is referred to as ‘unconsolidated native’ in the cross sections (Figures 1-6, 1-7 and 1-9), These materials were derived from rock debris and deposited on the sea floor by melting glacial ice during rising sea levels.

In the lower portion of the Site, the Bellingham Drift generally has a thickness ranging from 1 to 2 feet, although specific locations have recorded depths of 8 to 9 feet. The thickness tends to increase toward the shoreline and beneath Bellingham Bay, except in the southern part of the Site where unconsolidated native appears to thin towards the bay (Figure 1-6).

1.2.5.3 WOOD DEBRIS AND FILL MATERIAL

Above the Bellingham Drift and Chuckanut Formation, there is a layer of wood debris and fill material. In the upper park, the fill material is primarily comprised of silts, sands, gravels, and various debris, while some areas contain wood and other debris including brick fragments, coal fragments, and clinker.

Throughout most of the lower park, there is a layer of wood debris immediately above the Bellingham Drift or Chuckanut Formation that reaches a thickness of 29 feet (cross section A-A’ in Figure 1-6). The wood debris layer, likely associated with former lumber mill operations, generally thickens toward the west and northwest and consists of fresh to moderately decomposed wood chips and bark. The wood debris extends into Bellingham Bay.

Above the wood debris layer, there is a 2- to 7-foot-thick layer of fill material composed of silts, sands, gravels, and debris such as brick and includes wood fragments.

1.2.5.4 SEISMICITY

Regional seismicity is primarily attributable to the tectonic interaction between the Pacific, Juan de Fuca and North American plates. The Juan de Fuca plate is subducting beneath the North American plate, and it is thought that the resulting deformation and breakup of the Juan de Fuca plate could account for the deep focus earthquakes in the region. Earthquakes commonly occur in the Puget Sound area, with relatively large events occurring in:

- 1946, a Richter magnitude 7.2 earthquake occurred in the Vancouver Island, British Columbia area;
- 1949, a Richter magnitude 7.1 earthquake occurred in the Olympia area;

- 1965, a Richter magnitude 6.5 earthquake occurred between Seattle and Tacoma; and
- 2001, a Richter magnitude 6.8 earthquake occurred near Olympia.

Research has concluded that large magnitude subduction-related earthquakes have occurred along the Washington and Oregon coasts. Geologic and historical evidence suggest that earthquakes with Richter magnitudes of 8 to 9 have occurred in the last 1,500 years, and most recently approximately 300 years ago. No earthquakes of this magnitude have been documented during the more-recent recorded history of the Pacific Northwest. Lower magnitude earthquakes with typically less destructive force occur more commonly and are widespread throughout the region.

1.2.6 Hydrogeology

Hydrogeologic properties and groundwater presence within geologic units vary across the upland unit but shallow groundwater is typically present as an unconfined water-bearing zone within the fill at the Site. Across the upland unit, the bedrock (Chuckanut Formation) is not expected to store or transmit significant quantities of groundwater and acts as an aquitard for shallow groundwater. Groundwater is only present seasonally in the upper park.

The upper park contains seasonal shallow groundwater that is transported downgradient along the contact between the fill and bedrock units. The lower park receives recharge from direct rainfall infiltration and also relies on groundwater inflow from the upper park and steep slope. The combined thickness of fill and the wood debris units in the lower park creates a relatively larger reservoir for the unconfined aquifer compared to the upper park and the slope.

Groundwater was monitored during a dry season and a wet season (September 2021 and February 2022) as part of the PRDI and the depth to water measurements and groundwater elevations are presented in Table 1-1. The depth to groundwater generally ranges from approximately 2 to 13 feet bgs. Groundwater elevations vary by up to 4 feet seasonally and from tidal influence. Groundwater elevations are highest during the wet season and are closest to ground surface in the central lawn area of the lower park. The highest groundwater elevations were observed in the upper park monitoring wells. The direction of groundwater flow during both seasons is generally to the west. Groundwater elevations during the September 2021 dry season monitoring event are shown in Figure 1-10 and the groundwater elevation contours during the February 2022 wet season monitoring event are shown in Figure 1-11.

Tides influence the 14 monitoring wells in the lower park that are west of the railroad tracks. The three lower park wells that are east of the railroad tracks at the base of the steep slope (MW-28, MW-29, and MW-62) and the four wells in the upper park (MW-07, MW-19, MW-24, and MW-44) are not tidally influenced.

The estimated horizontal groundwater gradient of the upper park was measured to be approximately 0.2 ft/ft during the dry season event (September 2021) and 0.3 ft/ft, and during the wet season event (February 2022). The estimated horizontal groundwater gradient of the lower park was measured to be approximately 0.02 ft/ft during a low tide in the dry season event and 0.03 ft/ft during a high tide in the wet season event.

1.2.7 Environmental Conditions

Petroleum hydrocarbons, volatile organic compounds (VOCs), PAHs, cyanide, and metals (selenium and lead) are present exceed screening levels in Site soil, groundwater, and/or sediment. The nature and extent of these contaminants at the Site are described in the RI/FS (Landau and GeoEngineers 2019), CAP (GeoEngineers 2020) and PRDI Data Report (GeoEngineers 2023).

In the upland unit, the most prevalent contaminants are cPAHs, naphthalene, and benzene in soil, and cPAHs, naphthalene, benzene, and cyanide in groundwater. These contaminants are commonly associated with former MGP operations, although some Site contaminants in the upland unit may have originated from historic sources other than the MGP (e.g., fill, treated wood, and historic activities discussed in Section 1.2.3). The highest concentrations of soil and groundwater contamination occur in the upper park and in the lower park near the base of the steep slope. Groundwater is only present seasonally in the upper park. The reduction in contaminant concentrations in groundwater between the upper park and the shoreline indicates that significant natural attenuation occurs between the upper park and the shoreline.

The primary contaminant in the marine unit is cPAHs which require cleanup due to bioaccumulation-based effects on human health and ecological receptors. The boundary of the marine unit coincides with the location where cPAH concentrations in sediment decline to the sediment cleanup level of 229 micrograms per kilogram (µg/kg; Figure 1-2). The cPAH cleanup level for sediment was updated by Ecology in 2021 as described in PRDI Work Plan Addendum No. 1 (GeoEngineers 2021a) to 229 µg/kg toxic equivalent concentration (TEQ), the cPAH concentration protective of the bioaccumulation exposure pathway. The area of cPAH-exceedances of the bioaccumulation-based sediment cleanup level also encompasses a few isolated locations closer to the shoreline where chemicals exceed criteria based on protection of the benthic invertebrate community. Site-related chemicals that most frequently exceed the benthic criteria include total low molecular weight PAHs (LPAHs), high molecular weight PAHs (HPAHs), and some individual PAHs. The planned cleanup action (see Section 3) for the marine unit addresses exceedances of both human health risk-based bioaccumulation and benthic toxicity criteria.

Co-located, potentially bioaccumulative chemicals unrelated to the Site are also present in surface sediment within the marine unit, including metals (arsenic, cadmium, chromium, and mercury) and pentachlorophenol. The South State Street cleanup action will also address these non-Site-related chemicals within (but not beyond) the Site boundary. However, as noted in the CAP (Ecology 2020), the parties performing the Site cleanup action will not be responsible for additional cleanup actions if the non-Site-related chemicals reappear within the Site boundary after the remedy is proved successful.

2.0 Media to be Addressed and Cleanup Standards

Cleanup standards for the Site include (1) cleanup levels for Site media that are protective of human health and the environment; and (2) locations where the cleanup levels must be met (points of compliance). Media-specific cleanup levels for Indicator Hazardous Substances (IHSs) and points of compliance for soil, groundwater, sediment, and air are presented in the following sections. IHSs include:

- Lead and selenium;
- Benzene;
- Naphthalene;
- Cyanide; and
- cPAHs evaluated as TEQ.

Cleanup levels for the Site IHSs are presented in Table 2-1 with the basis for each value. The selected cleanup action addresses other Site contaminants described in the RI/FS in addition to the IHSs.

2.1 SOIL CLEANUP STANDARDS

The soil cleanup levels listed in Table 2-1 are based on the following potential exposure pathways and receptors:

- Direct contact (human health and terrestrial ecological species); and
- Leaching to groundwater, which is discharging to sediment/surface water (human health and benthic/aquatic species).

No cleanup level was needed to protect aquatic resources from upland soil erosion because the selected cleanup action will prevent soil erosion.

The standard point of compliance for soil based on the protection of groundwater is throughout the Site. For the protection of human health via direct contact, the standard point of compliance for soil is from ground surface to 15 feet bgs (WAC 173-340-740(6)(d)). Soil cleanup levels, however, will not be achieved at the standard point of compliance throughout the Site because the selected alternative for the Site includes containment. MTCA recognizes that soil cleanup levels typically are not met at the standard point of compliance for cleanups involving containment and that cleanups involving containment still comply with cleanup standards under certain conditions that are described in WAC 173 340-740(6)(f). The cleanup action selected for the Site meets these conditions.

The point of compliance for soil will be considered to have been met once the Site cleanup actions described in this EDR have been implemented.

2.2 GROUNDWATER CLEANUP STANDARDS

The groundwater cleanup levels listed in Table 2-1 are based on the following exposure pathways and receptors:

- Discharge to sediment (human health and benthic/aquatic species); and
- Discharge to marine surface water (human health and aquatic species).

The standard point of compliance for groundwater under MTCA is throughout the Site. MTCA allows use of a conditional point of compliance at sites where it can be demonstrated that it is not practicable to meet cleanup levels throughout the site within a reasonable restoration time frame, and that all practicable methods of treatment have been used in the cleanup (WAC 173-340-720(8)I). Ecology has determined that the cleanup action selected for the Site meets the regulatory requirements for use of a conditional point of compliance for groundwater. At such sites, the conditional point of compliance must be located as close as technically possible to the source of contamination.

Cap modeling conducted to support design indicates that groundwater will meet cleanup levels after migrating through the cap, which is the chemical isolation and treatment layer placed on top of the source of contamination. The conditional point of compliance for groundwater will be established at a depth of 12 cm (the depth of the biologically active zone) below the surface of the cap.

Ecology has determined that groundwater beneath the Site and other waterfront cleanup sites in Bellingham Bay is non-potable. Therefore, use of groundwater as drinking water did not need to be considered in the development of cleanup levels.

2.3 SEDIMENT CLEANUP STANDARDS

The sediment cleanup level for cPAHs, the only sediment IHS, in Table 2-1 is based on the bioaccumulation exposure pathway (human health and higher trophic level species). The sediment cleanup level is also protective of direct contact with sediment which includes benthic organisms living in sediment and people engaged in beach play, clamming, or net-fishing.

The point of compliance for the protection of human health and higher trophic level species with respect to consumption of seafood is the biologically active zone, which is the upper 12 cm of sediment in Bellingham Bay. This same point of compliance addresses protection of benthic organisms. The point of compliance for protection of human health with respect to direct contact is the upper 45 cm of sediment in the intertidal area.

Compliance with the cPAH cleanup level will be assessed on a surface-weighted average concentration (SWAC) basis.

2.4 AIR CLEANUP STANDARDS

The air cleanup levels for the Site listed in Table 2-1 are based on the protection of human health (inhalation). The standard point of compliance is ambient air throughout the Site. However, inhalation of outdoor air was not identified as a significant exposure pathway in the RI. The air cleanup levels, therefore, are only considered relevant to indoor air if buildings were to be constructed at the Site.

Air cleanup levels were established for benzene and naphthalene. Other VOCs were detected in soil vapor at the Site at concentrations greater than screening levels. However, cleanup levels for these VOCs were not established because of the greater toxicity of benzene relative to the other VOCs and because benzene was detected at the highest concentrations in soil vapor samples.

3.0 Planned Cleanup Action

The cleanup action for the Site includes elements to be completed in the upland unit and the marine unit of the Site. The cleanup action planned for the upland unit involves installation of a vegetated soil cap to eliminate direct contact with contaminated soil, installation of a permeable reactive barrier (PRB) to treat contaminated groundwater upgradient of the pocket beach and monitored natural attenuation (MNA) of contaminants in upland groundwater in other portions of the upland unit. In addition, demolition of remaining former MGP elements will be completed as needed to remove contamination and complete upland capping, including the above-ground concrete tank wall of the remaining gas holder and the electric/generator building adjacent to South State Street. Debris associated with demolished structures will be removed and appropriately disposed of off-site.

The final cleanup action for the Site marine unit includes placing sediment caps to contain contamination and ENR in the northern portion of the marine unit within the existing eelgrass area. Capping methods will include conventional sand caps to isolate contaminated sediment from marine receptors and amended capping methods designed to attenuate contaminants being transported through the cap by groundwater discharging in the upper intertidal area. The marine unit cleanup action will also include habitat restoration and mitigation elements which will be further developed in coordination with Ecology and other permitting agencies. The design and construction of the Site marine cleanup elements will be coordinated with the Cornwall, Haley, and Whatcom Waterway Sites to ensure that the cleanup action objectives are successfully achieved.

Key components of the selected cleanup action are summarized below and shown schematically in Figures 3-1 and 3-2. Section 6.0 presents additional details describing the basis of design, construction considerations, and figures illustrating the cleanup elements.

3.1 UPLAND UNIT CLEANUP ACTION OVERVIEW

3.1.1 Demolition and Disposal of Gas Holder

The remaining gas holder in the upper park, based on previous investigation, contains a combination of MGP residuals, soil, and water. Demolition of the gas holder will require removal of the contents of the tank and demolition of the components of the gas holder structure (asphalt cover and concrete wall).

The asphalt cover and above-ground concrete cylindrical wall of the remaining gas holder in the upper park will be demolished. The residuals including any potential non-aqueous phase liquid (NAPL), soil, and water inside the gas holder will be characterized, managed, and evaluated for disposal or for use as fill if the soil is below Site cleanup levels. The contents of the gas holder will be characterized as part of 60 percent design. The demolished gas holder materials (asphalt and concrete) will be disposed of off-site at a permitted facility.

According to the RI/FS, the remaining gas holder is assumed to have a metal plate bottom (Landau and GeoEngineers 2019). The underground portions of the base of the gas holder, to the extent they exist, will be removed to the extent practicable, to observe whether NAPL is present and warrants removal. Components of the former gas holder that are present below the surrounding grade will be covered by the soil cap similar to the cover that is above the metal bottom of the former northern gas holder. Materials generated by demolition and the removal of the gas holder base will also be disposed of off-site.

3.1.2 Demolition and Disposal of Electrical Building

In the upper park, the small electrical utility building associated with the former MGP will be demolished. The foundation will be demolished to the extent required to allow cap placement. Demolition and disposal will include the following:

- Demolition of the brick and concrete electrical building; and
- Transport to and disposal of demolition debris at a permitted landfill.

3.1.3 Upland Vegetated Soil Caps

Vegetated soil caps will be constructed in the upland unit, including most of the upper and lower park, to contain soil with contaminants exceeding cleanup levels. The raised grade of the cap in the lower park will be tied into the marine unit sediment cap at the shoreline, reducing the risk of coastal inundation from future sea level rise (SLR). The upland unit cap will reduce human health risks from direct contact to park users and park workers and provide a clean soil horizon in which park workers can conduct routine maintenance activities without encountering deeper contaminated soil. The vegetated soil cap will cover approximately 6.9 acres of the Site. The final capped surfaces of the upland areas will be suitable for the current use as a City park.

Site upland unit cap components will consist of the following:

- Where necessary, existing surface soil will be excavated and/or graded to prepare the surface for capping and/or to tie in cap areas with adjacent uncapped areas. Excavated soil will be relocated to areas requiring fill to achieve pre-cap grades;
- A geotextile separation layer will be placed on the graded pre-cap surface below the clean soil cap to separate and demarcate the underlying contaminated soil;
- Clean, imported sandy soil suitable for retaining moisture for vegetation rooting will be used as the initial layer of cap material on top of the geotextile separation and demarcation layer. The thickness of clean, imported sand and underlying clean soil, where present, will be a minimum of 18-inches;
- A minimum 6-inch topsoil layer with grass or other vegetation, or paved surfaces, will be placed on top of the clean, imported sand. The final surfaces will support park use; and
- Where necessary, existing trails, steps, etc., will be rebuilt to restore the existing park function.

Along the shoreline the vegetated soil cap will tie into the upper portion of the nearshore sediment cap. Both the upland and marine unit caps in the shoreline area are designed to resist erosion.

3.1.4 Enhanced Bioremediation of Groundwater

The portion of the upland unit where groundwater impacts are greatest, (upgradient of the pocket beach) will be addressed using enhanced bioremediation (Figure 3-1). This in-situ treatment technology will address lighter organic contaminants (i.e., benzene and naphthalene) and cyanide. Bioremediation will be implemented by constructing a PRB hydraulically upgradient (east) of monitoring wells MW-28, MW-29, and MW-62, which will be used to monitor the treatment effects of the PRB.

The PRB will extend from above the seasonal high-water level to bedrock. It is anticipated that the PRB will be constructed using standard excavator and trench box methods commonly used to install subsurface utilities. The trench backfill will consist of sand mixed with gypsum, and granular zero-valent iron (ZVI).

Over time, the gypsum or ZVI may become depleted, and the barrier would need to be refreshed if continued treatment is needed. The target lifespan for the ZVI is 20 years, while the target lifespan for the gypsum is 15 years. It is anticipated that the gypsum and ZVI components of the PRB would be replenished through injection of gypsum and ZVI slurries along the PRB alignment using direct-push drilling, avoiding replacement of the PRB backfill. The sand matrix of the PRB will allow for effective injection and distribution of the injected slurries.

Aquifer flux measurements and bench testing were completed as part of the EDR as documented in Appendix C and summarized in Section 5.3.

3.1.5 Groundwater Monitored Natural Attenuation

Groundwater in areas of the Site other than where enhanced bioremediation is planned, will be addressed using MNA. Existing groundwater monitoring wells will be preserved, if possible, during upland capping to be used for long-term groundwater monitoring. If existing monitoring wells need to be abandoned to construct the upland cap, new monitoring wells will be installed following cleanup action construction. The monitoring plan for MNA will be developed during design and documented in an operation, maintenance, monitoring plan for the cleanup action. Monitoring activities are described further in Section 3.5.

3.2 MARINE UNIT CLEANUP ACTION OVERVIEW

3.2.1 Sediment Capping

Sediment capping will consist of placement of conventional sand caps and amended caps in the marine unit to isolate and treat contaminants in sediment and porewater. Where necessary, existing riprap armoring and a limited amount of sediment in the upper intertidal (above elevation +5 feet NAVD88) will be removed to create the required pre-cap grade along the shoreline.

Conventional sand caps will be placed over an approximate 6.3-acre area of the marine unit to isolate sediment containing cPAHs at concentrations greater than the sediment cleanup level. The conventional sand caps will consist of a chemical isolation layer of clean sand with a nominal thickness of 2 feet. In some intertidal areas where higher concentrations of contaminants exist in intertidal sediment and porewater and where groundwater discharge increases the potential for contaminant migration, an amended cap design will be used that incorporates amendment mixed with clean sand to treat contaminants that may migrate through the cap with the flow of groundwater. Amended sand caps will be placed over an approximate 0.55-acre area.

An additional layer of erosion protection material will be placed on top of the chemical isolation layer to prevent erosion of cap material. The material used for erosion protection will be selected based on coastal engineering described in Section 5.2 and will range from armor rock in higher energy nearshore areas to gravelly cobble and gravelly sand size rock mixes in deeper areas.

The armored surface of the sediment cap in the nearshore area will be designed to connect with the soil cap in the lower park. Shoreline protection consisting of armor rock or gravelly cobble will be required waterward of the upland and both the upland and marine unit caps in the shoreline area will be designed to resist coastal erosion. The upper elevation of the sediment cap armor and shoreline erosion protection will be designed with consideration of SLR. The required upper elevation of the marine unit elements will inform the design of the lower park upland cap at the edge of the upland unit.

3.2.2 Sediment Natural Recovery

ENR will be used within the eelgrass area at the northern end of the marine unit which has lower concentrations of cPAHs.

ENR will involve the placement of approximately 4 inches of clean sand on the sediment surface. The clean sand will be placed in two 2-inch lifts, separated by at least 3 months to allow natural consolidation to occur and to reduce damage to eelgrass in the ENR area. The clean sand placed on the surface will mix with contaminated surface sediment through natural processes, reducing the contaminant concentration at the surface as part of the natural recovery process. The placement of additional clean sand accelerates or "enhances" the natural recovery process in ENR areas.

Continued (net) sediment deposition that is naturally occurring in the ENR area, and within much of the marine unit, will continue the natural recovery process. However, the sediment cleanup standard will be met at the time of construction and therefore, additional natural recovery will not be required to meet the cleanup standard.

3.3 ENGINEERING JUSTIFICATION FOR DESIGN

The following sections summarize engineering criteria and other considerations addressing MTCA requirements described in WAC 173-340-400, Implementation of the Cleanup Action. These criteria include the following:

- Design criteria, assumptions, and calculations for the components of the cleanup action;
- Expected treatment, destruction, immobilization, or containment efficiencies and how determined; and
- Demonstration that the cleanup action will achieve compliance with cleanup requirements.

Subsequent sections of the EDR provide additional detail and engineering analysis that support the basis of design and construction approach.

3.3.1 Design Criteria

General design objectives and key criteria for the upland and marine cleanup action components are summarized below. Additional discussion of the site constraints, engineering considerations, design life and construction considerations are presented in Section 6.0.

3.3.2 Upland Unit Cleanup Action Components

- Demolition and Disposal of Gas Holder
    - ☐ Demolish and remove gas holder and excavate and segregate contaminated soil and/or NAPL-impacted soil to remove potential contamination source; and
    - ☐ Manage debris, contaminated soil, and NAPL-impacted soil (if present) for offsite transportation and disposal in accordance with applicable regulations.

- Demolition and Disposal of Electrical Building
    - Demolish the electrical building to facilitate placement of the vegetative soil cap; and
    - Manage debris in accordance with applicable regulations.
- Vegetative Soil Caps
    - Excavate and grade existing ground surface as needed to place upland caps;
    - Install soil caps to prevent direct contact with underlying soil;
    - Vegetate soil caps to create suitable surface for continued park use and help preserve cap integrity and performance;
    - Achieve post-construction grading and drainage to transition smoothly with the existing park and shoreline areas; and
    - Provide for cap integrity and functionality as sea level rises.
- Enhanced Bioremediation of Groundwater
    - Install a PRB hydraulically upgradient of monitoring wells MW-28, MW-29, and MW-62 to reduce groundwater concentrations of lighter organic contaminants (i.e., benzene and naphthalene) and cyanide upgradient of the pocket beach.
- Groundwater MNA
    - Establish an MNA groundwater monitoring well network using existing monitoring wells, if possible, or install new monitoring wells following cleanup action construction; and
    - Complete groundwater monitoring in accordance with monitoring plan that will be developed during design and documented in an operation, maintenance, monitoring plan for the cleanup action.

3.3.3 Marine Unit Cleanup Action Components

- Sediment Caps
    - Cap contaminated marine areas to protect the benthic community (on a point-by-point basis) and protect human and ecological health from bioaccumulative chemicals (based on area-weighted average);
    - Determine cap thicknesses and appropriate amendment material including activated carbon (AC) based on cap performance modeling;
    - Estimate anticipated settlement and stability under static and seismic loading including weight of overlying armor; and
    - Establish stable final cap grades.
- Sediment Cap Erosion Protection
    - Identify design criteria considering current and tidal effects, SLR, storm wind direction and force, storm surge, wave runup and bank overtopping based on a design lifespan of 100 years for the cleanup action;
    - Identify appropriate types and sizes of erosion protection material, placement areas, and layer thicknesses;
    - Consider changes to seafloor and habitat conditions; and
    - Transition from shoreline smoothly to the upland vegetated soil cap.

- Sediment Cap Habitat Layers
  - Identify design criteria considering current and tidal effects, storm wind direction and force, storm surge, wave runup and bank overtopping, based on a design lifespan of 10 years for the habitat materials required for mitigation purposes;
  - Identify appropriate types and sizes of habitat materials, placement areas, and layer thicknesses; and
  - Transition from shoreline smoothly to the upland vegetated soil cap.
- ENR
  - Evaluate coastal engineering considerations for long-term stability after placement of ENR material; and
  - ENR will be completed within the eelgrass beds at the northern end of the marine unit by placing two, 2-inch lifts of clean sand across the ENR area. The second lift of sand placement will be at least 3 months following the initial placement.

3.3.4 Effectiveness of the Cleanup Action and Compliance with Cleanup Standards

The cleanup action complies with MTCA requirements and will achieve cleanup standards when completed in accordance with the requirements of WAC 173-340-400, the CAP, and standard engineering practices. The cleanup action will protect human health and the environment, comply with cleanup standards, comply with applicable federal, state, and local regulations, and provide for compliance monitoring and operations and maintenance. Remaining contaminated media with concentrations exceeding cleanup levels will be addressed using institutional controls. Institutional controls will provide notification regarding the presence of residual contamination and limit or prohibit activities that may interfere with or impair the integrity of the cleanup action, its maintenance or monitoring, or any other activity necessary to ensure protection of human and environmental health. The cleanup action uses permanent solutions to the maximum extent practicable, provides for a reasonable restoration time frame, and considers public concerns.

3.3.5 Controls to Prevent Hazardous Material Releases

The following controls will be used to prevent releases of hazardous materials during implementation of the cleanup action:

- Installing and maintaining temporary erosion and sedimentation control (TESC) structures and implementation of best management practices (BMPs) during construction of the cleanup action;
- Covering and securing loads during off-site hauling of impacted materials;
- Decontaminating all construction equipment and haul trucks prior to exiting the Site;
- Handling contaminated materials to prevent cross contamination with clean materials;
- Installing floating debris containment and oil absorbent booms during shoreline and in-water work,
- Monitoring surface water quality during in-water construction;
- Other measures, as needed, to prevent release of contaminated media beyond the Site boundaries and achieve water quality standards established for in-water construction; and
- Developing an emergency response plan for unintended release events and maintaining emergency response materials on-Site.

Additional control measures to prevent or minimize contaminant releases are described in Section 6.0.

3.3.6 Protection of Worker and Public Safety

It is expected that standard safety practices will mitigate potential risks to site workers and the public. A site-specific Health and Safety Plan (HASP) will be implemented during construction and the environmental controls listed above will be used to prevent releases of hazardous materials. The components of the cleanup action design are expected to be protective of the long-term safety of the public and park workers and will be verified by post-construction confirmational monitoring described in Section 8.0.

3.4 PERMITTING AND REGULATORY REQUIREMENTS

Applicable or relevant and appropriate requirements (ARARs), permitting and other regulatory requirements for the Site cleanup action are described in the following sections.

3.4.1 ARARs

Cleanup actions at the Site must comply with MTCA requirements described in WAC 173-340-710 including all state and federal laws that have jurisdiction over the cleanup (i.e., are applicable) or that Ecology determines may apply to the cleanup (i.e., are relevant and appropriate). Collectively these laws, implementing regulations, standards, limitations, or other requirements are referred to as applicable or relevant and appropriate requirements (ARARs). ARARs regulate specific components of the cleanup including, but not limited to, standards for cleanup of soil, groundwater, and sediment; disposal of waste materials including debris and soil, and management of stormwater during construction.

Federal statutes and implementing regulations for the cleanup include:

- Clean Water Act (CWA) Section 401, with respect to water quality criteria for surface water (Bellingham Bay) and in-water work associated with sediment excavation, capping, and erosion protection;
- CWA Section 402, with respect to stormwater discharges to Bellingham Bay;
- Dredge and fill requirements under Code of Federal Regulations (CFR) 320-330 implementing Section 404 of the CWA, and Section 10 of the Rivers and Harbors Act, with respect to sediment excavation, capping, and erosion protection;
- Resource Conservation and Recovery Act (RCRA) and Subtitle C regulations (40 CFR 260 and 261);
- Endangered Species Act (ESA) (16 USC §1361 et seq. 50 CFR 216), due to listing of Puget Sound Chinook and Coastal/Puget Sound bull trout; and
- National Historic Preservation Act (16 USC 470 et seq. Section 106).

State statutes and implementing regulations for the cleanup include:

- Washington State Shoreline Management Act with Shorelines Master Program procedures and guidelines implemented through Chapter 173-26, with respect to construction activities during the cleanup action;
- Washington State Water Pollution Control Act implemented by the Water Quality Standards for Surface Waters of the State of Washington (Chapter 173-201A WAC);
- Washington State Sediment Management Standards (Chapter 173-204 WAC);
- Washington Hazardous Waste Management Act implemented by the Dangerous Waste Regulations (Chapter 173-303);

- Washington State Model Toxics Control Act implemented by Chapter 173-340 WAC; and
- Washington State Hydraulic Code Rules under implemented by Chapter 220-110 WAC.

The National Environmental Policy Act (NEPA) (42 USC Chapter 55 § 4321 et seq.; 40 CFR Chapter V, Parts 1500-1508) and the Washington State Environmental Policy Act (SEPA) implemented by Chapters 197-11 and 173-802 are additional ARARs for the Site cleanup. In 2020 Ecology completed SEPA review of the Site cleanup action and made a Determination of Non-Significance as the SEPA lead agency. The NEPA review will be completed by the United States Army Corps of Engineers (USACE) through the Section 404 permit process.

3.4.2 Permits and Other Regulatory Requirements

Most of the requirements associated with ARARs are specified as regulatory permit conditions; however, cleanup actions conducted under a MTCA Order or Consent Decree are exempt from the procedural requirements of most state and local permits including the Washington State Solid and Hazardous Waste Management Act, Hydraulic Code Rules, Water Pollution Control Act, and local regulations. Although cleanup actions conducted under an order or consent decree are exempt from the procedural requirements, all cleanup actions must meet the substantive requirements of the subject regulations and permits. State and local agencies will be consulted to identify the substantive requirements following completion of 60 percent design.

Permits administered by the State of Washington but granted authority under federal regulations pursuant to the CWA/NPDES must still be obtained, as do all federally required permits. Requirements governing cleanup of sediment under federal regulation will be addressed through the Joint Aquatic Resource Permit Application (JARPA). The JARPA coordinates information applicable to the USACE-issued CWA Section 10 and Section 404 permits and Ecology-issued CWA Section 401 Water Quality Certifications. A state issued NPDES permit may be required for any on-site water treatment or discharge of stormwater from the cleanup site during implementation of the remedy. A DNR Use Authorization for State-Owned Aquatic Lands may also be required.

The federal permitting process includes review of issues relating to wetlands, Tribal Treaty rights, threatened and endangered species, habitat impacts and other factors. The USACE will consult with natural resource trustees regarding potential project impacts on species and habitats protected under the ESA and related requirements. In addition, the State Historic Preservation Office will be consulted to determine the effects of the cleanup under Section 106 of the National Historic Preservation Act.

Bellingham Municipal Code (BMC) requirements and Whatcom County building and construction permits, including demolition, grading, and drainage approvals, are not required because of the MTCA exemption from the procedural requirements. However, the substantive requirements of the BMC and local permits must be met including accommodation of long-term SLR per BMC Chapter 16.30 Planned Actions.

3.5 OPERATION AND MAINTENANCE OF THE CLEANUP ACTION

Long-term operation and maintenance of the cleanup action is necessary to ensure continued protection of human health and the environment following construction. A draft post-construction operation and maintenance plan for the cleanup action will be developed prior to or concurrent with construction-level documents and will be finalized when construction is complete.

4.0 Pre-remedial Design Investigation Results

This section summarizes the activities and results of the PRDI completed at the Site. PRDI activities were completed to provide additional information to support preparation of the remedial design. PRDI activities were completed between May 2021 and March 2022. The work was completed in accordance with the PRDI Work Plan and addenda (GeoEngineers 2020, 2021a, 2021b, 2022a, and 2022b) prepared by GeoEngineers, Inc. and approved by Ecology. PRDI activities included evaluating the following:

- The extent of soil contamination in the upper park requiring capping;
- Soil and groundwater conditions where enhanced, in-situ bioremediation is to be performed for treatment of groundwater;
- The extent of the nearshore intertidal capping and components of the cap needed to protect sediment and surface water;
- The extent of the marine unit based on the revised cPAH TEQ sediment cleanup level of 229 µg/kg; and
- Coastal marine processes.

PRDI results that affect the cleanup action design are summarized below. The complete PRDI Data Report is included in Appendix A.

4.1 UPPER PARK SOIL CAPPING

The cleanup action includes placement of soil caps in the upper park. The primary objective of the soil caps is to provide a 2-foot barrier of clean soil between park users and contaminants in underlying soil exceeding the direct contact cleanup level for cPAHs. Surface soil samples (from 0 to 1 foot bgs and from 1 to 2 feet bgs) were collected during the PRDI to refine the area to be capped in the upper park.

Carcinogenic PAH soil concentrations were compared to the MTCA Method B direct contact cleanup level of 190 µg/kg TEQ and the park user remediation level of 430 µg/kg TEQ. The park user remediation level is based on child and adult exposure to shallow soil 2 days per week (or 104 days per year) for a combined 30 years. During preparation of the PRDI Data Report, a park worker remediation level of 9,000 µg/kg was developed. The park worker remediation level is based on adult exposure to shallow soil 2 days per week for 8 months (or 69 days per year) for 25 years. Therefore, the park user remediation level is also protective of park workers. The remediation level calculations are included in Appendix B.

The surface soil data indicate that cPAH soil concentrations are less than the MTCA Method B direct contact cleanup level or the park user remediation level in a large section of the central portion of the upper park and near the northern park entrance along South State Street (see Appendix A, Figure 11).

Chemical analytical results for the surface soil samples are also included in Appendix A, Table 1 and were used to refine the upper park soil caps shown on Figure 3-1.

4.2 IN-SITU GROUNDWATER BIOREMEDIATION AND MONITORED NATURAL ATTENUATION

The cleanup action includes enhanced, in-situ bioremediation and MNA to address groundwater contamination. Enhanced, in-situ bioremediation will be used to address the portion of the lower park where groundwater impacts are greatest, upgradient of the pocket beach. The enhanced, in-situ bioremediation will address lighter organic contaminants (i.e., benzene and naphthalene) and cyanide in groundwater. MNA will be used to address contaminants in groundwater in other parts of the lower park.

4.2.1 Site-Wide Groundwater and Porewater Results to Evaluate Spatial Trends and Temporal Trends

Two Site-wide groundwater monitoring events were completed following installation and development of the new monitoring wells and re-development of the existing wells to evaluate spatial and temporal trends of groundwater contaminants. Porewater samples were collected as part of the intertidal sediment investigation (see Section 4.3).

Petroleum-Related Contaminants: The groundwater results show that petroleum-related contaminants, including gas- and diesel-range hydrocarbons as well as individual petroleum-related groundwater IHSs benzene and naphthalene, attenuate to below cleanup or screening levels before groundwater reaches the shoreline. Except for in one isolated area in the vicinity of location PRDI-2, porewater was demonstrated to not exceed cleanup or screening levels for petroleum-related contaminants.

Cyanide: Porewater cyanide concentrations were only detected at locations PRDI-4 and PRDI-12 at concentrations greater than the groundwater cleanup level.

The Site-wide groundwater and porewater monitoring analytical results are presented in Appendix A, Tables 3 and 7, respectively, and are shown in Appendix A, Figures 15 through 17. The Site-wide groundwater and porewater data were used to support the design of the intertidal sediment cap shown in Figure 3-1.

4.2.2 Soil and Groundwater Results to Support Bioremediation

Soil and grab groundwater sampling was completed using direct-push borings at the base of the slope area in the lower park to further characterize the lateral and vertical extent of contamination. Figure 1-5 presents the direct-push boring locations (GP-58 through GP-75). The sampling was completed to characterize the saturated thickness of soil above bedrock and contaminants in groundwater near the base of the slope between the upper and lower park areas to support the design for enhanced, in-situ bioremediation of groundwater.

The soil and groundwater results and the observations from the direct-push borings documented in the boring logs in Appendix A were used to propose an approximately 130-foot-long PRB from GP-58/GP-70 at the north end to GP-64/MW-29 at the south end (see Figure 3-1 and Appendix C, Figure 3).

Appendix A, Table 2 presents the subsurface soil sample analytical results and Appendix A, Table 4 provides the groundwater grab sample analytical results from direct push borings GP-58 through GP-75. These soil and groundwater results, along with the aquifer flux testing and bench study results presented in Appendix C, were used to support design of the PRB shown on Figure 3-1.

4.2.3 Soil and Groundwater Results to Support Natural Attenuation

Soil and groundwater samples were also collected for the purpose of evaluating the geochemical conditions that support natural attenuation of contaminants in soil and groundwater. In soil, iron and copper are known to attenuate cyanide and total organic carbon informs the potential for attenuation of organic contaminants. In groundwater, sulfate, nitrate, dissolved iron, total iron, and alkalinity are indicators of natural attenuation mechanisms.

Petroleum-Related Contaminants: The groundwater results show that petroleum-related contaminants attenuate to below cleanup or screening levels before groundwater reaches the shoreline (see Appendix A, Figures 15 and 16). Except for one isolated area in the vicinity of location PRDI-2, porewater was demonstrated to not exceed cleanup or screening levels for petroleum-related contaminants. Geochemical conditions in the lower park support the use of natural attenuation to address petroleum-related contamination.

Cyanide: Cyanide concentrations in groundwater appear to degrade along the flow path toward the marine area where groundwater discharges to surface water. Weak acid dissociable (WAD) cyanide was only detected at two out of 11 intertidal porewater sampling locations (PRDI-4 and PRDI-12) at concentrations greater than the groundwater cleanup level, indicating that, although there is elevated WAD cyanide in upland groundwater, the WAD cyanide concentrations generally attenuate before reaching surface water (see Appendix A, Figure 17). In addition, the detected concentration of cyanide in porewater sample PRDI-12 is not clearly linked to groundwater concentrations upgradient of the porewater sample location as groundwater concentrations of WAD cyanide upgradient of PRDI-12 in monitoring well MW-59 were less than the groundwater cleanup level during both the dry and wet season monitoring events. Geochemical conditions support the use of natural attenuation to address cyanide.

Upland subsurface soil analytical results are presented in Appendix A, Table 2. The site-wide groundwater and porewater monitoring analytical results are presented in Appendix A, Tables 3 and 7, respectively, and are shown in Appendix A, Figures 15 through 17. The site-wide groundwater and porewater data were used to show that natural recovery is occurring for petroleum-related contaminants and cyanide. The geochemical conditions data indicate that natural attenuation is expected to continue.

4.3 NEARSHORE INTERTIDAL SEDIMENT CAPPING

The cleanup action includes placement of cap material on nearshore intertidal sediment. The nearshore intertidal zone is expected to have the highest groundwater flux from the upland to the marine unit and therefore, requires evaluation of additional cap design considerations to address attenuation of contaminants. The nearshore intertidal sediment cap will protect human health and the environment from exposure (via bioaccumulation and direct contact pathways) to cPAH concentrations greater than the sediment cleanup level and protect surface water and sediment from contaminants in groundwater.

4.3.1 Intertidal Shallow Sediment Results to Refine the Lateral Extent of the Intertidal Cap

Sediment samples were collected from PRDI-9 through PRDI-12 to characterize sediment from the bioaccumulation compliance interval (0 to 12 cm) and the direct contact compliance interval (0 to 45 cm) along the shoreline, west and south of the pocket beach. Samples were collected from PRDI-9 through PRDI-12 to determine if additional capping is required west and south of the pocket beach for the remedy to be protective.

cPAHs were detected in sediment at concentrations greater than the cleanup level of 229 µg/kg TEQ at PRDI-9 in the bioaccumulation compliance interval (370 µg/kg TEQ) and direct contact compliance interval (502 µg/kg TEQ). Additionally, cPAHs were detected at a concentration greater than the cleanup level at PRDI-11 in the direct contact compliance interval (309 µg/kg TEQ).

Intertidal sediment analytical results are presented in Appendix A, Table 5 and are shown in Appendix A, Figure 23. The data from PRDI-9 through PRDI-12 were used to refine the extent of intertidal capping shown on Figure 3-1.

4.3.2 Intertidal Sediment and Porewater Results to Support Cap Design

Near surface (0 to 15 cm) and shallow subsurface (15 to 60 cm) sediment samples and porewater samples (~30 cm below mudline) were collected at locations PRDI-1 through PRDI-12 to inform the design thickness and need for the use of cap amendments for the intertidal nearshore cap to protect surface water and sediment from groundwater IHSs.

Cyanide was only detected in the sediment samples collected from 15 to 60 cm at locations PRDI-4 and PRDI-5 at concentrations just above the reporting limit. Gasoline-range hydrocarbons and naphthalene were not detected in the 0 to 15 cm and 15 to 60 cm sediment samples collected from PRDI-1 through PRDI-12. Total diesel/oil and benzene were detected in most or all the 24 near surface and shallow subsurface samples at concentrations less than MTCA Method A soil cleanup levels, which were used for comparative purposes since there are no sediment cleanup levels for total diesel/oil and benzene.

Porewater results for petroleum-related contaminants and cyanide were discussed previously in Section 4.2.1.

Near surface and shallow subsurface sediment analytical results are presented in Appendix A, Table 5. Porewater analytical results are presented in Appendix A, Table 7 and are shown in Appendix A, Figures 15 through 17. The porewater results were used in the cap modeling (see Section 5.1) to evaluate the need for cap amendments (activated carbon and/or zero valent iron).

4.3.3 Seepage Velocity Results to Support Cap Modeling

Groundwater seepage velocity was measured to provide empirical data for use in cap modeling. Seepage velocity measurement locations are shown in Appendix A, Figure 10. Field measurements and calculations of seepage velocities are summarized in Appendix A, Table 9.

The range of seepage velocities measured represents near maximum seepage velocities in the intertidal area. The seepage velocities were considered, along with groundwater flux measurements from monitoring wells MW-28 and MW-29 (see Appendix C), for use in cap modeling presented in Appendix D and summarized in Section 5.1.

4.4 LOWER INTERTIDAL AND SUBTIDAL RESULTS TO REFINE THE LATERAL EXTENT OF THE SEDIMENT CAPPING AREA

Surface sediment samples (0 to 12 cm) were collected to define the extent of contamination and to support refining the limits of where different elements of the cleanup action (e.g., capping, enhanced natural recovery) would be applied as part of the cleanup action. Nine intertidal and 36 subtidal surface sediment samples were collected as part of the PRDI and analyzed for cPAHs. The intertidal and subtidal surface sediment cPAH results are presented in Appendix A, Tables 5 and 10, respectively and are shown in Appendix A, Figure 24.

Figure 24 in Appendix A shows the cPAH surface sediment results compared to the cPAH sediment cleanup level of 229 µg/kg TEQ. The marine unit boundary (see Figure 1-2) is based on geographic information system (GIS) interpolation of the cPAH surface sediment data (using inverse distance weighting) and also incorporates the intertidal cPAH sediment cleanup level exceedance at location PRDI-11 and the intertidal WAD cyanide porewater cleanup level exceedances at location PRDI-12. The active remedy areas shown in Figure 3-1 (i.e., capping and enhanced natural recovery) were delineated in the EDR based on hill-topping[2] of the cPAH surface sediment data to meet a SWAC of 229 µg/kg TEQ, engineering design considerations, and coastal geomorphology data and information discussed in Section 5.2.

4.5 COASTAL MARINE PROCESSES TO SUPPORT CLEANUP ACTION DESIGN

The objective of investigating coastal marine processes was to support the design of sediment caps and shoreline erosion protection to be placed as part of the cleanup action and to identify where ENR and/or MNR can be applied. The investigation of coastal marine processes included an assessment of coastal geomorphology and the parameters that affect coastal engineering design for capping and shoreline protection to be performed as part of the cleanup action.

Sediment cores were collected at locations PRDI-35 through PRDI-41 (Appendix A, Figure 9) to evaluate sediment erosion and accretion at the Site. Sediment core samples were submitted for radiocarbon and/or radioisotope analysis and for grain size analysis. Sediment accretion rates for the seven cores ranged from 0.77 to 1.8 cm/year with an average of 1.2 cm/year.

The grain size results show that sediment sizes range from coarse sand to fine cobble in the intertidal area, transitioning to finer materials offshore. A comparison of the sediment accretion rates, and grain size results show that the areas with finer surface sediment grain sizes correspond to higher sediment accretion rates.

Coastal MetOcean conditions and a geomorphologic assessment prepared as part of the PRDI are presented in Appendix H of the PRDI Data Report which is provided in Appendix A of this report.

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[2] In hill-topping, grid cell concentrations in the marine unit are ranked from highest to lowest and the highest concentrations are iteratively removed from the dataset and replaced with the natural background TEQ.

5.0 Modeling and Testing Results Supporting Remedial Design

Several design elements for the Site cleanup action required testing or modeling to determine design parameters that will ensure that these cleanup elements are protective over their required lifespan. The sections below describe the results of the testing and modeling conducted to support remedial design.

5.1 SEDIMENT CAP MODELING

Sediment cap performance modeling was completed to support selection of sediment capping elements and configurations that meet the objectives of the cleanup action. The objective of cap performance modeling was to identify design sediment cap profiles for containing contaminants present in underlying sediment and porewater to meet cleanup levels at applicable points of compliance. Further details on cap modeling procedures and results are presented in Appendix D.

A one-dimensional transient model was used to evaluate contaminant transport within cap material under selected cap design scenarios. Analyses were performed using the transient numerical modeling program CapSim© (Version 4.2) developed by Dr. Danny Reible and associates (Texas Tech University 2023). The CapSim program is a well-accepted model that is commonly used to evaluate the contaminant isolation capability of sediment caps. Application of the CapSim model also addresses cap design considerations for chemical containment described in the United States Environmental Protection Agency (EPA) and USACE guidance for contaminated sediment capping (Palermo et al. 1998).

For modeling purposes, concentrations of constituents in porewater entering the cap from below were conservatively assumed to remain fixed over the 100-year design life that was modeled. This assumption simulates an infinite source of contamination to the overlying sediment cap. The primary drivers of this cap design are benzene and cyanide due to their prevalence and relative mobility in the aqueous phase, as well as the velocity of the groundwater entering the cap. Groundwater flux was estimated to be approximately 750 cm/year as calculated based on the study conducted by Landau (Landau 2023). Conservative concentrations of benzene, cyanide, and naphthalene were selected from the PRDI porewater data set and were used as input values in CapSim. The following porewater concentrations were used for modeling[3]:

- Benzene: 6.07 µg/L
- Cyanide: 15.0 µg/L
- Naphthalene: 3.87 µg/L

Results of the cap modeling informed and optimized configuration of chemical isolation layers consisting of sand with AC amendments determined to be necessary to contain contaminants in sediment and porewater. Cap modeling results indicated that the AC amendments would be needed to meet cleanup levels in nearshore areas of the marine unit. Modeling showed that AC effectively attenuates all three IHSs: benzene, cyanide, and naphthalene over a 100-year design life modeled. Contaminant containment can be achieved by capping the area using a 1 foot chemical containment horizon utilizing 1 percent (by weight) AC.

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[3] Benzene and naphthalene porewater concentrations detected at location PRDI-2 were not repeatable and were not considered for the cap modeling. The follow-up PRDI porewater sampling that was completed to confirm the porewater results at PRDI-2 is discussed in Appendix A, Section 3.5.2 and the associated results are discussed in Appendix A, Section 5.1.1.

Following the cap modeling for benzene, cyanide, and naphthalene, a sensitivity analysis was performed to confirm that the proposed cap amendment will also contain cPAHs. Benzo(a)pyrene was used as a surrogate for cPAH TEQ because benzo(a)pyrene is the most toxic cPAH and is the basis for the cPAH TEQ calculation. The sensitivity analysis results indicate that AC effectively attenuates cPAHs over a 100-year design life modeled.

The sediment caps within the marine unit (see Figure 6-9) of the Site will consist of three layers (listed from bottom to top): 1 foot of amended sand cap, 1 foot of sand, and 2 feet of armoring. The amended cap consists of sand with 1 percent activated carbon by weight. The cap will be placed to reduce the porewater concentrations of benzene, cyanide, and naphthalene to below the Site cleanup levels.

5.2 COASTAL DYNAMICS EVALUATION

The nearshore area of the Site is subject to significant wave exposure and energy because of its location on Bellingham Bay. Coastal dynamics and future climate change are key considerations for the design, performance, and maintenance of the marine unit cleanup action. As a result, coastal processes were analyzed and modeled based on available data and design criteria as established in Section 3.3, and the design water level, wind and wave conditions established for coastal engineering design. Furthermore, a conceptual level design integrating contaminant containment and habitat mitigation has been evaluated with modeling tools to confirm the stability of proposed design elements to protect the subtidal seabed, intertidal beach, and shoreline areas that are susceptible to wave-induced erosion. The Coastal Conditions Assessment and Modeling report is provided in Appendix E of this EDR, that presents coastal data analysis and modeling approaches, input data, assumptions, and the established design criteria.

The coastal modeling evaluated storm wave generation and transformation, wave runup, potential overtopping of the shoreline slope, and beach morphological change under both extreme low and high design water level conditions and taking SLR into account. The coastal modeling establishes an environmental basis of design that is consistent with recommendations described in Ecology’s Sustainable Remediation: Climate Change Resiliency and Green Remediation (Sustainable Remediation) guidance (Ecology 2023). As noted in Section 3.3, the 10-year design life for the low-risk habitat mitigation design and 100-year design life for the high-risk contamination capping design have been adopted as a primary part of the design basis for this project. Key assumptions and results from design storm and wave erosion modeling in compliance with Ecology’s Sustainable Remediation guidance are summarized below.

5.2.1 Storm Wind Conditions

Storm winds over Bellingham Bay are the direct driving force of wind waves, which is the governing factor for the design of coastal engineering elements at the Site. The effect of tidal currents on design was found to be negligible (PRDI Coastal Study Report, CGS 2023). Therefore, more storm wind analyses were performed with acquisition of additional short-term measured wind data from in-water buoys and upland sites, as well as the newly acquired long-term regional deterministic prediction system (RDPS) and high-resolution deterministic prediction system (HRDPS) modeled wind data from Canadian operational climate hindcast models (pan-Canadian Deterministic Prediction System, Milbrandt et al. 2016 and Fillion et al. 2010).

Wind data from the different sources were first compared against one another for quality assurance through proper calibration and verification procedures. The short-term measured wind data from the in-water buoys and upland sites provided a good means to calibrate and verify the long-term RDPS and HRDPS wind data. The main finding from this process was that the combined RDPS+HRDPS hindcast wind data is a more reliable long-term (44-year continuous) wind data, compared to the over-land wind observation data from Bellingham Airport, which was used during the PRDI. It is also more representative for the wind field over the Bellingham Bay region for the purpose of modeling wave generation and propagation into the Site.

As such, the extremal analysis was carried out using the combined (and calibrated) RDPS and HRDPS wind data. The 100-year, 30-year, and 10-year return period design winds from three governing directions (SSW, SW, and W) were determined for designs of cleanup actions and habitat mitigation. In addition, a representative storm condition, a storm that occurred in December 2018, and a likely return period of over 30 years, was selected to determine the impact of a large storm event on site conditions. Measured wind data from a buoy in Bellingham Bay was used to define the representative storm wind conditions.

5.2.2 Design Water Levels

Design water levels for the Site were derived during PRDI (Appendix A) which were based on published return period water levels at the long-term National Oceanic and Atmospheric Administration (NOAA) tidal station on Friday Harbor and corrected for both tidal and storm surge differences between Friday Harbor and Bellingham stations.

Both high and low water levels are considered as the governing conditions for erosion protection and mitigation designs, as a higher water level corresponds to higher wave energy approaching higher elevation beach and shore bank and an extreme lower tide leaves the subtidal seabed (which is associated with eelgrass mitigation zone) more susceptible to wave erosion. Representative design water levels were selected for both low tide and high tide conditions, corresponding to both 100-year design life (long-term high risk) and 10-year design life (low risk) design scenarios. The selection takes into account the joint probability of extreme storms and more likely governing water levels for the two design life scenarios. The selected water level scenarios include the following:

- Two low water scenarios: Mean lower low water (MLLW) – 2 feet (extreme low water) and MLLW
- Two High water scenarios: Mean higher high water (MHHW) and MHHW + 2 feet (with storm surge)

5.2.3 Sea Level Rise (SLR)

In compliance with Ecology's guidelines, SLR due to climate change has also been considered and modeled in combination with a high tide scenario (MHHW + 2 feet) for future design conditions. The SLR scenarios can be represented as:

- For 100-year design life, consider a Year 2120 high water scenario: MHHW + 2 feet + SLR
- For 10-year design life, consider a Year 2050 high water scenario: MHHW + 2 feet + SLR

A potential SLR of up to 50 inches over the next 100 years (Year 2120) was used based on substantive requirements of BMC, Chapter 16.30 Planned Actions.

The 50-inch SLR criterion represents a likelihood of occurrence of less than 5 percent in 2120, as presented on the Washington Coastal Hazards Resilience Network Website (https://wacoastalnetwork.com/chrn/research/sea-level-rise/). The City has adopted this SLR criterion for municipal planning and review of shoreline and building permits for commercial development projects, and has determined that applying the 50-inch SLR criteria for South State Street Site remediation is appropriate for meeting the substantive requirements of the BMC.

5.2.4 Modeling of Design Wave

Wave modeling was performed using the Delft SWAN wave model to establish the design wave conditions for both existing conditions prior to the project and for the post-project conditions based on the proposed design concept. Descriptions of the wave modeling as well as the basis of design for each coastal element are presented in the Coastal Report provided in Appendix E.

For erosion protection design, the following potential governing scenarios, considered to represent a reoccurrence probability of one in 100-years, were modeled to meet the 100-year design life criteria:

- 100-year design wind coupled with 4 tidal scenarios, MLLW, MHHW, MHHW + 2 feet, and MHHW + 2 feet + SLR
- 30-year design wind coupled with an extreme low water, MLLW – 2 feet

For habitat mitigation design, the following potential governing scenarios, considered to represent a reoccurrence probability of one in 30-years, were modeled to meet the 10-year design life criteria:

- 30-year design wind coupled with MLLW, MHHW, MHHW + 2 feet, and MHHW + 2 feet + SLR
- 10-year design wind coupled with an extreme low water, MLLW – 2 feet
- The 30-year return period storm conditions were selected for the 10-year design life criterion because the probability of a 30-year return period storm occurring is at 29 percent in the next 10 years.

Modeled design wave conditions for the above scenarios were extracted along cross sections A through F which represent six geographic and dynamic zones that are related to different wave action and contamination levels and distributions. Cross sections A through F locations and section details are shown in Figure 6-9 and Figure 6-10. Design wave conditions were extracted at the deepwater end of each cross section, which were used as the incident wave conditions for modeling the one-dimensional (1D) morphodynamic beach response to design storm conditions (as presented in Section 5.2.6). Design wave conditions were also extracted nearshore at the approximate bed elevation of -5 feet NAVD88. These wave conditions were used for determining governing design waves to be used for designing and sizing potential erosion protection materials including armor rock for shore protection or toe stability structures (as presented in Section 5.2.5). The derived design wave conditions were detailed in Appendix E.

5.2.5 Modeling of Groin Effect

After evaluating initial model results of wave conditions nearshore, a rock structure groin was proposed to be perpendicular to the shore along cross section B (Figure 6-9 and Figure 6-12) where the shoreline curves around toward the existing pocket beach. The purpose of the groin is two-fold:

- To protect shoreline capping from wave scour in the pocket beach area including the gravelly cobble erosion protection that is proposed to be used in the intertidal portion of the pocket beach; and

- Contain gravelly cobble beach habitat material overlying the armor rock to the south of the groin by intercepting longshore transport to the north.

The proposed groin has a minimum crest elevation of 12 feet NAVD88 that can block or minimize wave transmission (through overtopping), thereby adequately containing habitat material placed south of the groin and reducing wave energy on the north side of the groin.

SWAN wave modeling with the groin was conducted for comparison with the existing condition run to assess the impact of the proposed groin on wave attenuation in the intertidal area of the pocket beach on the north side of the groin. For the 100-year westerly wave and the highest water level scenario, the SWAN model results (Appendix E, Figure 15) show that without the groin, there is a large lower intertidal area in the pocket beach where wave height would still exceed 3.5 feet, meaning that armor rock would likely be required for erosion protection. With the proposed rock groin, the wave height in the entire intertidal area within the pocket beach falls below 3.5 feet. Use of the groin would obviate the need for armor rock capping in the pocket beach, allowing for the placement of smaller grain size, habitat-suitable material instead.

5.2.6 Morphodynamic Modeling

Morphodynamic modeling was conducted using the Delft Xbeach-1D model for two selected representative 1D cross sections A and D in the project area. The primary purpose is to evaluate the stability of proposed gravelly cobble and gravelly sand material, to be placed either as erosion protection (remedial cap) or for habitat mitigation (eelgrass substrate). The Xbeach modeling adopted the SWAN model output at the offshore end of cross sections A and D as incident wave conditions for the same 100-year or 30-year design storm conditions, respectively, which include different return period wave and water level combinations for different purposes. Both existing and proposed design beach profiles were modeled. Morphodynamic modeling provided a basis for evaluating material sizing, beach slopes, and cap material transitioning as design concepts evolved for different zones or profiles over the course of EDR development.

Simulation of the existing beach profile at cross section A was performed as a model verification process. Existing condition modeling revealed that including the effects of eelgrass and infiltration/exfiltration of water from breaking waves into and out of the porous sediment layer played a large role in accurately modeling wave dissipation on beaches and, therefore, a more accurate prediction of beach response to extreme waves.

Beach responses to design storm conditions were modeled for cross section A, with the proposed gravelly cobble habitat material in the intertidal zone and gravelly sand in the subtidal zone.

Model results for the subtidal zone show only very small, localized erosion of up to 2 inches at the toe of the proposed cobble berm downslope of the proposed armor rock toe berm and adjacent to the estimated final limits of existing habitat. Such localized erosion is likely due to wave induced scour at the interface or transition zone between two largely different grain size materials. A smoother and stable transition profile is expected to form after mixing and initial adjustment between two materials.

The other location subject to scour is similarly at the toe of the gravelly cobble habitat material in the intertidal zone where the armor stone toe berm is proposed to contain the gravelly cobble material. Model results show an erosion depth of up to 10 inches in the cobble beach. The cobble beach is designed to dynamically adjust in the event of a large storm, and after the storm. Large waves tend to push cobble up slope creating a steeper berm that stops beach material from moving further up. Typically, post-storm recovery is expected. On the shoreline south of the proposed groin however, the recovery process can be affected by longshore transport caused by southwesterly or westerly waves as cobble material moves north exposing armor rock erosion protection material. Net deficit transport may result in exposure of the armor rock layer on the southern intertidal beach. Additional evaluation of the cobble beach mitigation shall be performed during 60 percent design to minimize scour or erosion south of the proposed groin.

The response to extreme storm conditions in the subtidal area along cross section D shows a similar response to cross section A with erosion of about 2 inches at the transition between the gravelly cobble to berm and the gravelly sand habitat material. The intertidal area shows less erosion than the subtidal area at cross section D as waves attenuate more compared to cross section A as waves are approaching closer to shore. It also shows that the upper intertidal beach area adjacent to the existing BNSF revetment is flatter, which would make the gravelly cobble beach more stable.

For the representative December 2018 storm, the response of gravelly cobble beach in the intertidal area along cross sections A and D are very similar to the results for the 100-year design wind event at MHHW + 2 feet. The subtidal gravelly sand area had no erosion as the peak of the storm occurred during high tide, and winds had already attenuated when water levels were low.

The morphodynamic modeling confirmed likely stable sizes for gravelly cobble and gravelly sand that were proposed for areas represented by cross sections A through F.

5.2.7 Tsunami Considerations

In addition to coastal modeling, a tsunami impact assessment for the Site was performed with the main findings summarized in Appendix F. In the tsunami assessment the potential tsunami impacts to and the proposed cleanup action and habitat mitigation design were evaluated based on the most recent tsunami hazard modeling study for the Bellingham area published by DNR (Dolcimascolo et al. 2021). The DNR study considered an extreme tsunami scenario generated by an extended L1 (a magnitude of 9.0) Cascadia Subduction Zone (CSZ) earthquake, which was estimated to have a recurrence interval of over 2,500 years. The model calculates tsunami wave induced coastal inundation and associated flow velocities at specified time intervals assuming tsunami waves are impacting the Site while the local tide is at mean high water (MHW).

As reported in the DNR study, the extended L1 earthquake scenario closely approximates design requirements for critical facilities in the Washington State building code for seismic hazards and is more conservative (with greater inundation) relative to the Puget Sound Region by assuming a full-length rupture of the CSZ fault, as compared to any previously published tsunami modeling reports (such as Eungard et al. 2018). Therefore, the tsunami scenario represents the worst considered tsunami event that the Site may be subjected to and has a 4 percent occurrence likelihood in 100 years.

The DNR model predicts that a tsunami would result in a peak water level of approximately 10 feet above MHW in the project vicinity. The lower park would be inundated by approximately 2 to 6 feet of water. Peak surging water velocity associated with the tsunami waves is modeled to be between 0 and 3 knots for the inundated areas of the lower park, but higher localized velocity (greater than 3 knots) is likely due to flow constriction affected by local topography. According to the DNR model prediction, the first tsunami impact wave would arrive at the Site in about 2 hours and 15 minutes after a reported earthquake event in the

CSZ. Tsunami waves are projected to potentially continue to reach the Site vicinity for at least 8 hours after the earthquake event.

5.2.8 Site Resiliency

The tsunami impact on the proposed project is assessed mainly based on the wave velocity predicted by the DNR model. At a velocity of 0 to 3 knots, cleanup action components including the groin structure and armor rock in the intertidal area are expected to survive the tsunami impact. The impact to sediment capping areas in the subtidal and intertidal areas is likely to be more significant, but the level of damage will depend on the level and the intensity of the tsunami event. Some studies have suggested that the next earthquake event will be about two-thirds the size of the Extended L1 scenario that DNR modeled and that is referenced here, creating a smaller tsunami than the one DNR modeled (Witter et al. 2011).

Overall, the potential future tsunami impact to this project is believed to be manageable and the risk level is considered low due to low probability of occurrence.

5.3 PRB DESIGN TESTING RESULTS AND RECOMMENDATIONS

In April through September 2023, Landau Associates, Inc. (Landau) performed testing for evaluation and design of a PRB as the proposed remedial approach for the portion of the upland where groundwater impacts are greatest, upgradient of the pocket beach. Testing included aquifer flux tests using Passive Flux Meters™ (PFMs; EnviroFlux, LLC, Gainesville, Florida) and bench tests to evaluate proposed PRB backfill material properties. Design testing results and recommendations are detailed in Appendix C.

5.3.1 Aquifer Flux Testing Results

Groundwater flux and contaminant flux through the target treatment zone was measured using PFMs deployed in two monitoring wells at the Site. The PFMs measure groundwater flux and contaminant flux (total petroleum hydrocarbons [TPH], benzene, and cyanide) using a combination of specialized resins and activated carbon. PFMs were installed in monitoring wells MW-28 and MW-29 (Appendix C, Figure 2) near opposite ends of the planned PRB in April 2023 to measure wet season flux and in September 2023 to measure dry season flux.

Groundwater flux is also referred to as specific discharge, Darcy flux, or Darcy velocity and is presented in units of distance per unit time. Groundwater flux measured by the PFMs ranged from 1.6 to 2.6 centimeters per day (cm/d) during the wet season and from 0.7 to 2.0 cm/d during the dry season.

Average groundwater seepage velocity (i.e., average linear velocity) is estimated by dividing groundwater flux by the effective porosity. Assuming an effective porosity of 30 percent for the sandy fill along the PRB alignment (ITRC 2011), average groundwater seepage velocities ranged from 5.2 to 8.5 cm/d (0.17 to 0.28 feet/day) during the wet season and from 2.2 to 6.8 cm/d (0.07 to 0.22 feet/day) during the dry season.

Low-flow groundwater sampling was performed at MW-28 and MW-29 immediately following retrieval of PFMs in April 2023 (wet season) and in September 2023 (dry season). All samples were analyzed for gasoline-range total petroleum hydrocarbons (TPH-G), diesel-range total petroleum hydrocarbons (TPH-D), oil-range total petroleum hydrocarbons (TPH-O), total and WAD cyanide, benzene, and sulfate at Analytical Resources, LLC in Tukwila, Washington. Consistent with prior results, groundwater sampling results show higher TPH-G and benzene concentrations at monitoring well MW-28 than MW-29 and higher total and WAD cyanide at monitoring well MW-29 than MW-28. Both wells have similar TPH-D concentrations as well as dissolved oxygen, ferrous iron, and pH measurements. However, sulfate concentrations are significantly higher at MW-29 than MW-28. Because these wells are located adjacent to the Bellingham Bay shoreline, this suggests that MW-29 is more affected by seawater intrusion than MW-28. As TPH-G results are also lower at monitoring well MW-29, this suggests that the elevated sulfate at this location may be stimulating biodegradation of the TPH-G, demonstrating that the proposed method of bioremediation is feasible at the Site. These conclusions are also supported by monitoring well data from nearby and upgradient monitoring wells.

5.3.2 PRB Material Testing Results and Recommendations

Proposed PRB construction materials were evaluated for various physical and chemical characteristics using column tests. All tests were performed in horizontal columns constructed using 4-foot-long sections of clear, 2-inch-diameter polyvinyl chloride (PVC) pipe. Groundwater or tap water was pumped through the columns using peristaltic chemical metering pumps.

Three column tests were performed using gypsum mixed with sand to evaluate the sulfate concentrations produced, longevity, and potential settling/compaction issues for three gypsum products. The three gypsum products, consisting of pulverized gypsum, pelleted gypsum, and mined gypsum (obtained from USA Gypsum, Denver, Pennsylvania) were mixed with 12/20 sand at a ratio of 30 percent by weight in each test. Tap water was passed through the columns, as the primary objective was to evaluate the rate of gypsum dissolution, not to evaluate contaminant treatment. The primary observations made during the gypsum tests were general effluent water quality (color, odor, etc.), effluent sulfate concentration, and settling/compaction of fill material.

All three products produced similar sulfate concentrations near the maximum sulfate concentration (1,451 milligrams per liter [mg/L]) calculated based on the gypsum solubility limit. Dissolved sulfate in water produced by gypsum products is more than adequate to enhance TPH treatment within, and downgradient of, the planned PRB. Settling/compaction of the gypsum columns ranged from 28 to 42 percent. The pelleted gypsum, which contains a lignin binder, produced effluent that was dark brown and smelled of soil and wood; for this reason, the product was eliminated from further consideration. As the pulverized, recycled gypsum is least expensive and performs similar to mined, unprocessed gypsum, the recycled product is the recommended material for the PRB.

Four tests were performed using ZVI products (Ferox Flow and Ferox PRB obtained from Hepure Technologies, Hillsborough, New Jersey) mixed with sand. The difference between influent and effluent concentrations of cyanide (mass absorbed/reacted by the ZVI) was used to develop reaction rates, as literature values for ZVI treatment of cyanide in groundwater are limited. ZVI was mixed with 12/20 sand at various ratios to determine if the amount of ZVI significantly reduced the amount of cyanide in the column effluent. Site groundwater was used as the influent for testing, as the primary objective was to evaluate treatment of cyanide-contaminated groundwater through the columns. Results for the four tests are summarized as follows:

- <u>Ferox Flow, 15 percent by weight</u>: Average free cyanide reduction = 69 percent.
- <u>Ferox PRB, 15 percent by weight</u>: Average free cyanide reduction = 68 percent.

- Ferox PRB, 20 percent by weight: Average free cyanide reduction = 75 percent.
- Ferox PRB, 25 percent by weight: Average free cyanide reduction = 76 percent.

Both ZVI products showed similar free cyanide reduction. With some contaminants, the Ferox Flow product may provide higher reactivity (i.e., improved concentration reduction) due to smaller particle size with greater surface area, but this was not demonstrated for cyanide in these column tests. As presented above, the cyanide concentration reduction for 15 percent by weight Ferox Flow and Ferox PRB were approximately the same at 69 and 68 percent, respectively. The Ferox PRB product is recommended for use in the PRB because its larger particle size will result in greater treatment longevity.

Data from the four tests were used to calculate the reaction rate for cyanide with ZVI. Influent and effluent free cyanide concentrations were used in a first-order reaction equation to calculate average reaction rates for each column test. The average first-order reaction rates, k, and the average mass-based first-order reaction rates, k_{mass}, were approximately the same for all four column tests, regardless of product or percent weight in the column. Using data from all four tests, the average k for cyanide with ZVI is 0.068 per hour (1/hr) and the average k_{mass} is 0.004 cubic feet per pound per hour (ft^3/lb/hr).

6.0 Engineering Design Considerations and Construction Approach

The Site cleanup action consists of demolition, grading, soil capping, and groundwater bioremediation in the upland unit and demolition, grading, sediment capping, and ENR in the marine unit. Institutional controls will be a required element of the cleanup action in the upland and marine units as contaminants will remain at the Site following completion of the cleanup action. Site-specific design and construction considerations, design details, and the general approaches for construction of the cleanup action are presented in this section. Supporting figures with additional design details for specific cleanup action elements are presented in Figures 6-1 to 6-17.

6.1 SITE-SPECIFIC CONSIDERATIONS AFFECTING CLEANUP ACTION DESIGN, CONSTRUCTION, AND OPERATION

Site conditions and other considerations for the basis of design discussed in Section 6.2 and approaches for construction discussed in Section 6.3 are summarized in the following sections.

6.1.1 Site Setting

The general Site setting, and associated topography/bathymetry, physical features, and extent of contamination are described in Section 1.

Site setting considerations for design include the following:

- The upland portion of the Site is geographically and topographically divided into two separate areas, the upper park area adjacent to South State Street and the lower park area adjacent to the marine unit. A steep slope is present on the western portion of the upper park. The upper and lower park areas are also separated by the BNSF railroad tracks (Figure 6-1).
- Two structures remaining in the upper park associated with the former manufactured gas plant require demolition: a remaining gas holder and a former electrical building.
- The complex topography of the upper park will require complex grading prior to placing the soil cap.
- Construction in the upper park at and adjacent to the top of the steep slope will require consideration of using smaller equipment and setbacks for grading and placing the soil cap to prevent destabilizing the slope.
- The lower park has a relatively flat surface for placing the soil cap.
- Eelgrass is present in the lower intertidal and shallow subtidal zones generally between -2 and -10 feet NAVD88. The eelgrass bed is shown on Figure 3-2 (see the “Approximate Limits of Aquatic Vegetation”).
- The Washington Department of Fish and Wildlife (WDFW) has documented surf smelt spawning on the beach along the western boundary of the Upland Unit, south of the pocket beach (WDFW 2024).
- The cleanup action design needs to include evaluation and incorporation of a SLR of 50 inches over the lifespan of the cleanup action.
- Wave and current dynamics, combined with anticipated SLR over the lifespan of the cleanup action (see Section 5.2) result in erosive conditions requiring bank and sediment cap protection measures as well as consideration for the final elevation of the lower park upland cap.

- Utilities within the upland cap areas require coordination with the City.
- Existing structures in the lower park will require modification to adjust the building elevations to fit the upland cap elevations.

Site setting considerations for construction include the following:

- The upper park is primarily accessible from South State Street and is not accessible from the lower park by vehicles.
- The lower park and land-based work in the marine unit will require access through the Boulevard Park parking area.
- Upland work restrictions and authorization will be required to work adjacent to BNSF railroad property and/or ROW.
- Tidal conditions constrain construction methods, aquatic access, and vessel size and type and affect the ability to complete construction activities near the shoreline or upper intertidal areas using water-based equipment.
- The presence of large revetment rock, wood debris, and pilings, will affect bank and intertidal sediment grading and capping.
- Removal of mature trees will be required in the upper and lower park areas to allow grading to support capping. Selected mature trees will be protected from damage from grading and/or capping.

6.1.2 Permitting Requirements

The Site cleanup is being performed pursuant to MTCA and must comply with the substantive requirements of permits and other regulatory requirements listed in Section 3.4. The cleanup design must address permit requirements affecting construction means and methods, materials management, demolition and grading, and resource and worker protection. Project construction will also be subject to the in-water work window which is typically August 1 to February 15 in Bellingham Bay.

6.1.3 Weather

Weather conditions can affect construction and potentially impede progress during periods of heavy precipitation, high winds, and freezing/snowy conditions. Cold weather and excessive precipitation can hinder upland earthwork, including excavation and fill placement and compaction. Subsurface drainage structures and other utilities should be installed below the 12-inch frost depth typically used for construction projects in Bellingham. In the marine unit, high winds and large waves can hinder material placement. Site safety planning for construction must consider potential temperature extremes, icing, wind hazards, visibility, and other weather-related conditions for Site workers and other personnel.

6.1.4 Flooding, Sea Level Rise, and Tsunami

The upland cap for the upper park and lower park areas will be designed to allow infiltration. Additionally, the upland cap design will consider the need for surface flow during heavy rain events to prevent the ponding of stormwater on the surface of the park.

Section 5.2 summarizes the results of coastal engineering analyses that considered a projected SLR of up to 50 inches over the 100-year project design life, which is a substantive requirement for the City for new shoreline development projects. Design considerations for SLR include protecting sediment caps and shoreline areas from anticipated changes in wave and current energy and impacts from changes in the elevation of surface water. The seaward edge of the upland cap must also be protected from potential wave run-up and erosion during storm surge conditions.

Section 5.2 also summarizes tsunami considerations based on current Washington Geologic Survey/DNR and American Society of Civil Engineers hazard modeling and inundation maps for Bellingham Bay. The lower park area of the Site is projected to experience inundation depths of 2 to 6 feet above the existing ground surface relative to MHW tidal conditions during an approximate 2,500-year tsunami event. The ability of the cleanup components to withstand tsunami impacts depends on the magnitude of the tsunami event, the energy and forces associated with those events, wave frequency, entrained debris, and other factors.

6.1.5 Geotechnical Stability

Geotechnical conditions in the upland unit and marine unit are expected to affect the design of capping elements due to the presence of compressible materials in the soil and sediment being capped, seismic conditions, and the presence of steep slopes near potential areas of construction activities. Following completion of the EDR, geotechnical analysis and evaluation will be completed to assess settlement and stability of the upland and sediment caps and existing underlying soil and sediment under static and seismic (pseudo-static) conditions. The geotechnical analysis will inform the design, constructability, construction sequencing, and consideration of potential future maintenance and repair and will include the following:

- Evaluation of the presence and characteristics of compressible sawdust and other wood debris and fine-grained material in surface and subsurface upland soil and marine sediment. The additional load from upland and sediment capping materials may cause settlement of the caps. Potential settlement of upland and marine caps will be evaluated to ensure that required isolation thicknesses and final elevations (i.e., final top of bank based on SLR) are preserved over the lifespan of the caps and that differential settlement does not result in reduced cap thickness or preferential pathways for groundwater discharge, particularly in nearshore sediment cap areas using amended capping.
- Evaluation of seismic conditions at the Site, based on a high Richter magnitude event associated with a 2,475-year return period consistent with typical building code practice for comparative purposes. The evaluation results are expected to indicate that the sediment caps would move under this scenario. The ability of the caps to withstand potential damage from seismic events depends on the magnitude and duration of such events, associated energy and destructive forces, and other factors.

6.1.6 Rail Traffic Vibrations

Vibrations from rail traffic are expected to have minor, if any, effect on the construction and performance of the cleanup action components. Settlement impacts on newly placed fill from repetitious vibratory loads typically occur within the first few cycles of vibration with diminishing impacts from each subsequent cycle. Potential settlement caused by rail traffic vibrations is anticipated to be more prevalent during upland cap placement in the lower park and marine cap placement adjacent to the railroad tracks and would dissipate markedly with distance from the tracks. It is unlikely that rail traffic vibrations will promote post-construction settlement concerns.

6.1.7 Existing and Future Site Use

The Site is part of the City's Boulevard Park. As described above, the lower park falls within the portion of Boulevard Park on the Bellingham Bay waterfront and the upper park is located adjacent to South State Street. Following construction of the cleanup action, the City plans to continue the current use of the Site as a public park. The City's Parks, Recreation and Open Space plan includes a future pile-supported over walk walkway structure to connect Boulevard Park to Salish Landing Park on the Cornwall Site. To the extent possible, the areas of Boulevard Park affected by the cleanup action will be restored for public use. Coordination with the City will continue through design and construction so that the park can be operated for public use, in consideration of the following:

- Prevention of potential damage to upland and sediment caps including institutional controls to prevent damage from excavation/digging in the capped areas.
- Protection of the upland cap from future park activities, including restrictions on plantings that may result in roots extending below the clean cap layers and reaching separation geotextiles placed on existing contaminated soil.
- Maintaining or restoring existing utilities and irrigation serving the park.
- Providing access for long-term monitoring and maintenance for monitoring wells and other cleanup action components.

6.1.8 Coordination with Haley, Cornwall, and Whatcom Waterway Site Cleanups

Cleanup actions are being conducted at adjacent sites including the Whatcom Waterway, Haley, and Cornwall Sites (see Figure 1-3). Specifically, the marine unit of the Site is adjacent to the marine portions of the Haley and Cornwall Sites and overlaps the Whatcom Waterway Site. Design of the Site cleanup action and cleanup construction will be coordinated with cleanup actions at the Haley, Cornwall, and Whatcom Waterway Sites to ensure that cleanup action objectives for each site are met.

6.1.8.1 HALEY AND CORNWALL SITES

The southern extent of the marine units of the Haley and Cornwall Sites are adjacent to the marine unit of the Site. Sediment capping and creation of a habitat mitigation area are components of the Cornwall cleanup action and MNR is a component of the Haley cleanup action in the area adjacent to the Site marine unit where placement of thin layers of sand is planned to enhance the natural recovery of sediment with cPAHs greater than the cleanup level. Additionally, the design for the Salish Landing Park, a new City of Bellingham park that is being constructed on the Haley and Cornwall Sites at the north end of the South State Street Site, includes a marine element that overlaps approximately 9,700 square feet of the Site marine unit. Filling is proposed on the portion of the Site marine unit adjacent to where shoreline capping is being performed on the Cornwall Site as part of park construction to extend a beach area and enhance shoreline habitat.

The planned construction activities associated with the Cornwall cleanup action and Salish Landing Park are currently being designed. As design progresses for the Cornwall cleanup and Salish Landing Park projects, the City will coordinate with PSE with respect to the City's actions at the Cornwall cleanup action and Salish Landing Park so that the Site cleanup action design can meet cleanup objectives in the area where the Site marine unit and the Salish Landing Park project overlap.

6.1.8.2 WHATCOM WATERWAY SITE

The Site cleanup action will be coordinated with cleanup of Phase 2 Areas of the Whatcom Waterway Site. Areas planned for sediment capping as part of the Site cleanup action overlap with areas of MNR that are part of the Whatcom Waterway cleanup. Sediment capping methods planned for the Site cleanup action are compatible with the overlapping Whatcom Waterway cleanup actions.

6.2 DESIGN DETAILS

6.2.1 Upland Structure Demolition

Several structures within the upland unit of the Site will be demolished or modified to allow construction of upland caps. Two of the structures are historical gas plant features that will be permanently demolished with the associated demolition debris hauled off-site for disposal or recycling. The historical gas plant structures include the last remaining gas holder and a small electrical service building, both of which are in the upper park. In addition, two existing park structures will be modified and may need to be temporarily relocated for the purpose of cap placement. The two park structures include a covered stage structure and a former restroom building both of which are in the lower park. These structures are identified in Figure 6-1 and described further in the following sections.

6.2.1.1 GAS HOLDER DEMOLITION

The existing gas holder shown in Figure 6-1 that is to be demolished is the last of three MGP gas holders that were present at the Site and is in a sloped portion of the upper park. The remaining gas holder consists of an above-ground concrete cylindrical wall and is covered with a 2-inch layer of asphalt covered with plastic. According to the RI/FS, the remaining gas holder is assumed to have a metal plate bottom (Landau and GeoEngineers 2019). The contents of the gas holder include soil, water, and MGP residuals that potentially includes NAPL.

Demolition of the remaining gas holder structure will be completed prior to completing upland capping in the upper park. The demolition of the gas holder will consist of removing the asphalt and plastic cover from the gas holder, then removing material present within the gas holder. The material within the gas holder will be further characterized as part of 60 percent design to identify appropriate management and disposal or if any of the soil can remain on Site.

The concrete walls of the structure will be cut off as far below the existing grade as determined to be safe. Further evaluation of the stability of the concrete wall of the gas holder and soil placed against the wall, particularly on the uphill (eastern) portion of the gas holder, will be completed during 60 percent design. The underground portions of the base of the gas holder, to the extent they exist, will be removed to the extent practicable to observe if NAPL is present and warrants removal. Components of the former gas holder not accessible for removal without excavating existing soil beyond the footprint of the gas holder, will be documented, and left in place below the soil cap to be constructed in the upper park. The demolished gas holder materials (asphalt, plastic, and concrete) will be disposed of off-Site.

6.2.1.2 ELECTRICAL BUILDING DEMOLITION

A small electrical utility building associated with the former MGP that is unused and not known to be currently connected to utilities is in the easternmost portion of the upper park, adjacent to South State Street (Figure 6-1). Demolition of the electrical building will be completed prior to completing upland capping in the upper park. The electrical building is a brick and concrete structure that will be demolished using standard demolition methods. The design of the concrete foundation of the electrical building is not known. The foundation will be demolished to the extent needed to allow cap placement within and surrounding the building footprint. Debris generated from the electrical building demolition will be disposed of off-Site as demolition debris.

6.2.1.3 LOWER PARK STRUCTURE RELOCATION AND DEMOLITION

Two existing park structures are present in the lower park as shown on Figure 6-1 that will require modification because soil capping will increase the surface elevation to accommodate for SLR considerations.

An existing covered stage is present in the lower park; it is a timber framed open structure constructed on a concrete base. Electrical utilities are not connected to this structure. This structure will be salvaged by disconnecting the timber-framed elements from the concrete base as a whole or in pieces and either temporarily raising the structure or temporarily relocating the structure to a different part of the park during upland capping. The concrete base will require modification to account for the increased surface elevation resulting from capping. Alternatively, the concrete base may be demolished and reconstructed. Following modification or reconstruction of the concrete base and upland soil capping, the timber-framed stage structure will be reconstructed on the concrete base. Power will be reconnected to the structure.

An existing restroom building is present in the lower park that is inoperable. Similar to the stage structure, the restroom structure will be salvaged, and the foundation will require modification due to the increased surface elevation resulting from capping in the lower park. The restroom building is a wood-framed structure on a deep pile supported structural concrete cap foundation. Utilities connected to this building are limited to underground power. Utilities connected to the restroom have previously included water and sanitary sewer. However, the water and sewer connections to the restroom building have been disconnected. This structure will be salvaged by disconnecting the wood-framed elements from the concrete base as a whole and either temporarily raising the structure or temporarily relocating the structure to a different part of the park during upland capping. The foundation will be raised or rebuilt to accommodate the increased surface elevation and the wood-framed structure will be reconstructed on the concrete base. Water and sewer utilities will not be reconnected to the structure, but power will be maintained. The City plans to repurpose the building for a future use that does not require water or sewer.

Existing irrigation and water connections to the lower park area will be reconstructed and located in the clean cap.

Coordination with the City will be conducted during the 60 percent design to determine the degree of modification and reconstruction required for the existing park structures. The design of the structure modifications will be incorporated into the upland cap design for the lower park at that time.

6.2.2 Clearing, Grubbing, and Incidental Demolition

Areas of the upper park and lower park where grading and capping will be performed will require removal of trees and smaller vegetation, paved surfaces, and other surface features that would impede cap placement. In the upper park numerous trees will require removal prior to grading and upland capping. Multiple trees will also require removal in the lower park prior to capping. The general location of the trees requiring removal are shown in Figure 6-1. Trees present within the area proposed for capping, even if excavation is not needed prior to capping, are assumed to require removal. The placement of cap material within the root zone of trees is expected to damage the tree, causing the eventual death of the tree, which may cause damage to the cap or present a safety hazard to park users. Tree felling will be completed during other demolition activities, prior to initiating earthwork for capping. Debris and logs generated by tree removal will be hauled off-Site for recycling. Stumps and roots from large trees will be removed during clearing and grubbing activities and transported offsite for disposal.

Smaller vegetation will also be cleared and grubbed during grading prior to capping. Debris generated by clearing and grubbing will be transported off-Site for disposal.

Existing asphalt and concrete paved surfaces, and miscellaneous hardscapes located within planned cap areas will be broken up and removed to facilitate drainage under the cap. The asphalt and concrete demolition debris will be hauled off-Site for disposal or recycling.

6.2.3 Upland Capping

Upland soil capping is planned in the upper park and lower park portions of the upland unit to provide 2 feet of soil with contaminant concentrations less than direct-contact cleanup levels at the park surface. A soil cap consisting of a minimum 2-foot layer of clean soil, separated from the existing soil by a geotextile, will be constructed to cover the majority of the existing soil surface including the entire lower park portion of the upland unit.

In the upper park, data collected during the PRDI identified that a significant portion of the upper park has at least 2 feet of soil with contaminant concentrations less than direct-contact cleanup levels at the park surface. The PRDI also identified that there are two areas where the top 1 foot of surface soil has contaminant concentrations less than direct-contact cleanup levels and therefore, only requires 1 foot of additional soil cap to achieve 2 feet of soil with contaminant concentrations less than direct-contact cleanup levels at the park surface.

The soil caps in the upper park and lower park will be permeable and will allow precipitation to infiltrate. The edges of the soil cap surfaces will tie into the existing ground surface. Excavation and grading of existing surface soil will be performed to prepare the ground surface for placement of cap material.

The upland caps will be designed in consideration of the Site’s use as a City park so that Site use does not adversely affect the cap function and performance. Underground conduit for power will be reconstructed as part of the project.

6.2.3.1 PRE-CAP GRADING

Figure 6-2 presents the grading plan for the upper park. The majority of the pre-cap excavation and grading is planned for the upper park, where the complex topography requires excavation in some areas to allow the cap surface to support park use and to tie into the adjacent areas not being capped. The majority of the pre-cap grading in the upper park involves excavating 2 feet or less of material along some of the cap edges to allow transition to a full cap thickness. One area on the southern portion of the upper park requires excavation of greater than 4 feet of existing soil to remove a small ridge that is not suitable for capping.

Limited pre-cap grading is anticipated in the lower park due to the thickness of cap material that will be required to achieve final elevations that account for SLR. Excavation of existing soil at some edges of the cap will be required to allow the cap surface to transition to the existing surface elevations and maintain a full 2-foot-thick cap.

Existing soil removed to achieve desired pre-cap grades will be redistributed to other areas of the upper park or lower park where fill can be used to build up the pre-cap surface elevation. If excess soil is generated by the grading, the soil will be characterized and transported off-site for disposal. Site soil generated by pre-cap grading activities will be managed appropriately to prevent off-site contaminant migration or exposure to workers and the environment. All accessible pathways and access points will be reconstructed to meet or exceed current park uses.

6.2.3.2 ESTIMATED CUT AND FILL QUANTITIES

Estimated cut and fill quantities associated with the Site cleanup action are summarized in Table 6-1. The estimated in-place excavation volume of upland soil needed to achieve the required pre-cap grades is 300 cubic yards (CY). An estimated 10,700 CY of clean, imported fill soil for the upland cap cover will be placed in the upper park and lower park areas.

TABLE 6-1: SUMMARY OF UPLAND EARTHWORK AREAS (SF) AND VOLUMES (CY)

UPLAND EXCAVATION AND FILL VOLUMES		
CONSTRUCTION ELEMENT	EARTHWORK AREA (SF)	IN-PLACE VOLUME (CY)
Upper Park - soil excavation	13,200	300
Upper Park – Import clean cap material	26,600	2,800
Lower Park - soil excavation	7,100	Incidental
Lower Park – Import clean cap material	64,100	7,900

6.2.3.3 UPLAND CAP STABILITY

As described in Section 6.1.5, geotechnical analysis to evaluate potential settlement and slope stability under loading is planned for the 60 percent design. Geotechnical analysis is planned to include evaluation of long-term static and seismic (pseudo-static) conditions for upland grading and capping areas in the upper park and lower park.

6.2.3.4 UPLAND CAP PROFILE

The upland cap in both the lower park and upper park areas will consist of two to three distinct layers to prevent exposures to underlying contaminated soil.

After the existing soil surface is graded and prepared for capping, including relocation of any excavated soil, a geotextile will be placed over the area to separate contaminated soil from the clean imported soil cap material. The geotextile will function as a physical barrier and keep the imported fill and underlying contaminated soil from mixing. The geotextile will have the following minimum properties:

- Grab tensile strength of 160 pounds (lbs) or greater;
- Puncture resistance of 310 lbs or greater; and
- Water permittivity of 0.4 sec^{-1} or greater.

Once the geotextile is installed, clean, imported cap soil will be placed over the cap areas and graded to the design surface elevation. The upland cap soil will be imported from an off-Site source and will meet the specifications developed as part of the design. The cap soil profile will consist of a minimum of 6 inches of topsoil at the surface with the balance of the cap material made up of a sandy fill soil. The topsoil will be vegetated with grass turf, shrubs, and bushes. For capped areas planned for revegetation with shrubs and bushes the topsoil portion of the cap will be increased to up to 100 percent of the cap thickness, to support plant growth. Several locations will have an additional depth of topsoil to allow for planting of shallow rooted trees to replace trees that were removed to construct the upland cap. Planting of trees that will grow to become larger, deep-rooted trees to replace larger trees that were removed to construct the upland cap will be limited to areas outside the cap limits to prevent tree roots from penetrating the geotextile underlying the cap material. These trees may be planted in areas of Boulevard Park outside the Site limits as needed to achieve mitigation requirements for tree removal. Revegetation will be coordinated with the City during the 60 percent design.

Straw, mulch and/or tackifiers will be used, as needed, to stabilize the topsoil surface and reduce erosion following placement. Further coordination of appropriate plant types and required topsoil thickness and mixes will be completed during the design.

Where the surface is a gravel or paved trail section, the topsoil layer will be eliminated and replaced with an appropriate trail construction profile based on City's current Design Standards for Park and Trail Development (City of Bellingham 2018, with updates). The trail profile will consist of a base course of clean imported crushed rock and top course of either crushed rock or asphalt, The specific requirements for trail construction will be developed as part of the 60 percent design.

6.2.3.5 PARK UTILITY MODIFICATION OR REPLACEMENT

Water, sanitary sewer, and electrical utilities are located throughout the upper park and lower park portions of the Site and are expected to be preserved, and modified, if necessary, for the restoration of the park function as part of cleanup action construction.

In the upper park and lower park, existing irrigation water lines will need to be modified to account for the upland cap placement. Within the footprint of the capped areas, the irrigation lines will be re-routed to within the cap profile, above the underlying geotextile. This will allow maintenance of the irrigation lines without encountering contaminated soil under the cap. New sprinklers, control boxes, low-voltage wiring, etc. will be installed within the cap profile to match the function of the existing irrigation system.

In addition to the irrigation water lines, below ground electrical power circuits feed lights along the pathway. This electrical circuit is expected to require modification during construction of the caps in the upper and lower park. The locations and elevations of the trail lights are planned to be modified along with the trail itself. Where applicable, the existing below ground electrical line may be rerouted to within the cap profile.

The lower and upper park currently have below-ground power serving the site lighting, restroom facility and the stage structure. The utility lines up to the structures are not expected to be modified during cleanup action. However, the connection to the buildings will require modification depending on the degree of modification required for the structures themselves.

6.2.4 Groundwater Bioremediation

Groundwater bioremediation will be performed by installation of a PRB in the area upgradient of the pocket beach as shown in Figure 6-7. The proposed PRB is 130 feet long, 12 feet deep, and 5 feet wide and will include sand mixed with amendments to treat contaminated groundwater. Based on column study results described in Section 5.3 and Appendix C, the following products, or equivalent products, will be used in the PRB:

- Pulverized gypsum (USA Gypsum, Denver, Pennsylvania, or local equivalent recycled drywall)
- Ferox PRB (Hepure Technologies, Hillsborough, New Jersey).

The PRB would use approximately 116,600 lbs of gypsum to achieve a 15-year treatment longevity for treatment of organic contaminants in groundwater. This represents 18 percent by weight in the total PRB composition (gypsum, ZVI, and sand). This design is based on gypsum solubility (2,600 mg/L at 25 degrees Celsius [°C]; Lebedev and Kosorukov 2017) and the wet season average groundwater seepage velocity derived from Site PFM measurements described in Section 5.3.1. The longevity of the gypsum within the PRB is calculated from the required number of pore volume flushes to dissolve all the gypsum. Use of 18 percent gypsum is expected to result in 1 to 2 feet of settlement within the 12-foot vertical interval of the PRB reactive backfill over 15 years. To account for this settlement, reactive PRB material (i.e., sand containing gypsum and ZVI) will extend a minimum of 2 feet above the anticipated seasonal high groundwater elevation. Periodic filling will likely be needed at the surface of the PRB as settlement is observed. Replenishing of the gypsum in the PRB after 15 years, if needed, can be performed through direct push injection of a gypsum slurry.

The PRB would also use approximately 89,700 lbs of Ferox PRB ZVI to achieve a 20-year longevity for treatment of cyanide in groundwater. This represents 14 percent by weight of the total PRB reactive backfill. The first-order reaction equation, reaction rate relationships, and flow parameter relationships were used to derive the mass of ZVI required in the PRB, as described in Appendix C. The mass of ZVI required for the PRB consists of both natural demands calculated for naturally occurring elements and minerals in Site groundwater that compete for ZVI reaction sites and the mass required to reduce WAD cyanide concentrations at the Site. Using vendor-provided reaction constants and historic monitoring well data, the additional ZVI demand from competing species is approximately 45,400 lbs. The ZVI mass required to treat cyanide is approximately 44,300 lbs. Replenishing of the ZVI in the PRB after 20 years, if needed, can be performed through direct push injection of a ZVI slurry.

6.2.5 Shoreline Demolition

Shoreline demolition will be required to prepare surfaces for placement of sediment cap and erosion protection materials. The structures or material requiring demolition consist of remnant piling and the existing riprap armor along the shoreline including the revetment constructed as an interim action in 2017.

Remnant piling in the intertidal and shoreline portion of the Site will be cut off at the pre-cap surface. The pilings are generally close to the existing shoreline in areas where grading is required prior to cap placement. The pilings in areas with planned excavation/grading prior to capping may be initially cut off at the existing surface to facilitate grading, followed by cutting the piles off again at the final pre-cap grade. The cut-off piling will be transported off-Site for disposal.

The riprap revetment that was constructed as an interim action will be removed as an element of the cleanup action construction. The riprap rock will be removed prior to completing grading activities along the shoreline and stockpiled on Site for reuse. The rock used for the riprap revetment is expected to be suitable for the primary armor stone in the proposed wave attenuation groin. Rock removed from the shoreline that is determined to not be suitable for reuse on Site will be transported off-Site for disposal.

6.2.6 Shoreline and Intertidal Sediment Grading

The upper intertidal area of the Site marine unit will require grading up to the existing top of bank to prepare a surface for sediment capping and placement of erosion protection materials. A significant volume of the material requiring removal is associated with the rock revetment constructed as part of the interim action, which is included as a demolition element described in Section 6.2.5 above. The area requiring grading generally falls between existing elevation +5 feet NAVD88 and the top of slope and is limited to the shoreline areas west and south of the pocket beach at the northwest corner of the lower park. Within the pocket beach, and in the shoreline areas farther north, grading of the existing surface is not planned prior to placement of cap and erosion protection material.

Sediment, rocks, and debris generated by excavation and grading west and south of the pocket beach will be stockpiled on Site and tested for waste characterization. The stockpiled material is expected to be transported off-Site for disposal at a Subtitle D landfill.

6.2.7 Sediment Capping

Design analyses for sediment cap engineering were performed consistent with EPA and USACE guidance for contaminated sediment capping (Palermo et al. 1998). The following design criteria were considered to determine the composition and thicknesses of the sediment cap components:

- Chemical isolation and containment of contaminants considering contaminant locations/ concentrations, contaminant mobility, and the estimated rate of groundwater flux through underlying sediment;
- Bioturbation;
- Erosion; and
- Cap stability considering potential consolidation and settlement including loading from the erosion protection layer.

6.2.7.1 SEDIMENT CAP CHEMICAL CONTAINMENT LAYER DESIGN

The containment of contaminants in sediment is the primary purpose of sediment capping and the chemical containment layer is the primary layer of the cap design for achieving containment. The chemical containment layer is designed to isolate and prevent erosion and mobilization of the contaminated sediment, prevent mobile contaminants in sediment and/or groundwater/porewater from migrating through the cap into sediment and porewater at the top of the cap and overlying surface water, and prevent human and ecological receptor exposure to the sediment contamination.

The distribution of the sediment cap in the marine unit is designed to achieve cleanup standards (Table 2-1) based on the protection of benthic organisms, humans, and higher trophic level ecological species, as described in Section 2.3. The areas of the marine unit where sediment capping is proposed are shown in Figure 6-9. Compliance with the sediment cleanup level for cPAHs, the only sediment IHS, is evaluated based on a SWAC across the entire marine unit. The marine unit SWAC was calculated for cPAHs for conditions immediately following construction based on the proposed sediment capping plan presented in Figure 6-9. The calculated post-construction SWAC for cPAHs is 226 µg/kg. Therefore, the Site marine unit will meet the cPAH cleanup level of 229 µg/kg upon completion of the cleanup action construction.

The chemical containment layer for areas requiring capping for containment of cPAHs will consist of a 2-foot-thick layer of a clean sand material. The chemical containment layer will be placed directly on the existing sediment surface except in intertidal areas where the cap material will be placed on a geogrid designed to reduce differential setting due to the loading associated with cap and erosion protection material. A geogrid material will be placed below the chemical containment layer in areas above existing elevation -2 feet NAVD88, where the overall cap and erosion protection layer thickness will be greater, and the existing sediment surface has a large amount of wood debris that may increase the potential for settlement. Further evaluation of geotechnical stability and the need for mitigation methods will be completed during the 60 percent design phase.

In intertidal areas where groundwater discharges at the mudline and existing porewater concentrations of South State Street IHSs exceed cleanup levels, the chemical containment layer will be modified to include amendments that will attenuate contaminants within the cap. These areas will consist of a 1-foot layer of clean sand amended with 1 percent, by weight, activated carbon, overlain by a 1-foot layer of clean sand. Section 5.1 describes the modeling process used to confirm the performance of the selected amended cap design. The areas where the chemical containment layer consists of an amended sand cap are shown in Figure 6-9.

6.2.7.2 CAP EROSION PROTECTION

The chemical containment layer of the sediment cap must be protected from the erosive forces of wave action and current energy. Coastal modeling and engineering was performed to support the design of cap erosion protection materials that will remain stable and protect the chemical containment layer over a 100-year design life. EDR Section 5.2 summarizes the coastal modeling process, with additional details presented in Appendix E. Coastal modeling evaluated the effects of a 100-year storm event and associated wind-driven waves, the proposed bathymetry of capped surfaces, and a SLR of 50 inches. Wave heights and related modeling outputs were used to analyze erosion protection for the caps and shoreline area.

The stability analysis yielded design recommendations for erosion protection material presented in Table 6-3 based on the bottom elevation and slope angle. The D50 material designation represents the median particle size of the material which means 50 percent of the material (by weight) will be larger and 50 percent will be smaller than D50 value. Each type of material and its extent and function is described below. The distribution of the different erosion protection materials at the Site is shown in Figure 6-9, with erosion protection layer thicknesses shown on the sediment cap cross sections presented in Figures 6-11 through 6-17.

As described in Appendix E, the erosion protection strategy for the marine unit includes the construction of a groin structure offshore of the northwest corner of the lower park as shown in Figure 6-9. The groin structure serves two purposes; (1) shelter the pocket beach area to the east from higher waves originating from the southwest protecting the shoreline cap and allowing for the use of smaller material for erosion protection and habitat mitigation and restoration, and (2) retain habitat materials placed on the surfaces in the area to the south of the groin. The groin structure is proposed to be constructed primarily of armor stone, with a top elevation ranging from +14 feet NAVD88 at the landward extent to +10 feet NAVD88 at the waterward extent.

Generally, the erosion protection materials required to protect the cap material are delineated by the proposed wave attenuation groin. In the area south of the groin, where the surfaces are expected to be impacted more directly by waves from the southwest, larger erosion protection materials will be used, ranging from armor rock to gravelly cobble. North and east of the groin, and within the pocket beach, the erosion protection material will be smaller than south of the groin, ranging from gravelly cobble to gravelly sand. North of the pocket beach, along the BNSF revetment and outside the protection of the groin, larger armor rock will be used at higher elevations. Table 6-3 below outlines the material types used for erosion protection in these zones.

TABLE 6-3 STABLE EROSION PROTECTION MATERIAL SIZE

MARINE CAP ZONE	ELEVATION RANGE (NAVD88)	MATERIAL TYPE	MATERIAL SIZE D50	MATERIAL THICKNESS
South of Groin	Max = 15.5 feet (final) Min = -2 feet (existing)	Armor Rock	1 foot	2 feet (plus 6-inch bedding)
	Max = -6 feet (existing) Min = -30 feet (existing)	Gravelly Sand	0.4 inches	1 foot
North of Groin / Pocket Beach	Max = 14 feet (final) Min = -5 feet (existing)	Gravelly Cobble	1.75 inches	1.5 feet
	Max = -5 feet (existing) Min = -20 feet (existing)	Gravelly Sand	0.4 inches	1 foot
North of Pocket Beach	Max = 2.5 feet (final) Min = -4 feet (existing)	Armor Rock	1 foot	2 feet (plus 6-inch bedding)
	Max = -4 feet (existing) Min = -6 feet (existing)	Gravelly Cobble	1.75 inches	1 foot
	Max = -6 feet (existing) Min = -20 feet (existing)	Gravelly Sand	0.4 inches	1 foot

Armor Rock – Where needed, armor rock used in the upper intertidal zone will be a graded mixture of angular rock with a D50 particle size of 1 foot. The armor rock will protect intertidal capped surfaces above elevation 0 feet NAVD88 and the shoreline bank from wave runup. The armor rock layer will have a minimum thickness of 2 feet and will be underlain by a gravel bedding layer of 6 inches and geotextile fabric to prevent piping of materials and further protect the underlying chemical containment horizon.

Gravelly Cobble Mix – The gravelly cobble mix will be a graded mixture of round rock with a D50 particle size of 1.5 inches. The gravelly cobble mix will be used to protect capped surfaces transitioning between lower intertidal and subtidal conditions and will be 1.5-feet thick without the need for a bedding layer.

Gravelly Sand Mix – The gravelly sand mix will be a graded mixture with a D50 of 0.4 inches to protect cap surfaces in subtidal areas. The gravelly sand mix will be 1-foot thick and will be placed directly on the surface of the chemical containment layer in subtidal areas as listed in Table 6-3 above.

6.2.7.3 SEDIMENT CAP HABITAT MATERIAL

The sediment cap will also consist of a habitat substrate layer placed on top of the erosion protection layer that will support habitat restoration and mitigation by providing material suitable to restore and enhance intertidal and eelgrass habitat and retain suitability for forage fish spawning. Eelgrass suitable substrate will be placed offshore to offset impact to existing eelgrass due to the cap placement and provide additional substrate above the cap erosion protection layers to allow planting eelgrass without penetrating the underlying cap material. The habitat material will range from gravelly sand to a larger gravelly cobble mix used in higher energy areas. Figure 6-10 shows the distribution of habitat materials across the marine unit.

Coastal modeling and engineering was performed to support the selection of habitat substrate material that will remain stable over a 10-year design life. EDR Section 5.2 summarizes the coastal modeling process with additional details presented in Appendix E. The size of the material used for habitat substrate generally corresponds to the relative size of the erosion protection materials upon which it is placed. The larger gravelly cobble mix is planned to be used as a habitat material where the erosion protection layer consists of armor rock. This is generally in the higher energy intertidal areas south of the proposed groin and along the shoreline revetment north of the pocket beach. In all other marine cap areas where habitat material is to be placed, gravelly sand material will be used. This includes lower energy intertidal areas north of the groin where gravelly cobble is used for erosion protection as well as offshore cap areas where additional material thickness is desired for eelgrass planting. The habitat substrate layers are presented on marine cross sections A through F in Figures 6-11 through 6-17 along with the marine unit cap layers. Table 6-4 below outlines the material types used for habitat substrate the various zones and elevation ranges. These areas generally correspond to the areas for erosion protection listed in Table 6-3.

TABLE 6-4 HABITAT SUBSTRATE MATERIAL SIZE

MARINE CAP ZONE	ELEVATION RANGE (NAVD88)	MATERIAL TYPE	MATERIAL SIZE D50	MATERIAL THICKNESS
South of Groin	Max = 17 feet (final) Min = 2 feet (final)	Gravelly Cobble	1.5 inches	Min. 1.5 feet
	Max = -6 feet (final) Min = -13 feet (final)	Gravelly Sand	0.4 inches	1 foot
North of Groin / Pocket Beach	Max = 15.5 feet (final) Min = -3 feet (final)	Gravelly Sand	0.4 inches	1.5 feet
	Max = -3 feet (final) Min = -13 feet (final)	Gravelly Sand	0.4 inches	Min. 1 foot
North of Pocket Beach	Max = 2.5 feet (final) Min = -1.5 feet (final)	Gravelly Cobble	1.5 inches	Min. 1.5 feet
	Max = -1.5 feet (final) Min = -13 feet (final)	Gravelly Sand	0.4 inches	Min. 1 foot

6.2.7.4 MARINE CAP STABILITY

As described in Section 6.1.5, geotechnical analysis to evaluate potential settlement and slope stability under loading during capping is planned for the 60 percent design. Geotechnical analysis is planned to include scenarios for long-term static and seismic (pseudo-static) conditions for marine capping. The analysis is expected to indicate the potential for differential settlement in upper intertidal areas where several feet of cap, erosion protection, and habitat materials are to be placed. A geogrid is expected to be required to be placed at the base of the cap profile on the sediment surface in the zone above approximate existing elevation -2 feet NAVD88. The geogrid will resist cap thinning or shearing via differential settlement. Further evaluation of geotechnical conditions and the need for geotextiles of various types will be completed during 60 percent design.

6.2.7.5 ENHANCED NATURAL RECOVERY

Based on evaluations completed during the RI/FS (Landau and GeoEngineers 2019), ENR was identified for areas where contaminant concentrations are relatively low and eelgrass is present. The use of ENR is intended to reduce contaminant concentrations in the biologically active zone through the placement of thin layers of clean sand that will mix with existing surface sediment through bioturbation. Placement of sand in multiple thin layers is expected to allow the sand to accumulate on the sediment surface without damaging eelgrass. Two placement events, each consisting of approximately 2 inches of clean sand, would be separated by several months to increase the likelihood of eelgrass survival in the placement area. A total of 4 inches of clean sand would be placed in the ENR area, resulting in an approximately 33 percent reduction of the contaminant concentration within the biologically active zone. Additional natural recovery of sediment quality as a result of ongoing sediment accumulation is expected in this area but is not required to achieve compliance with the cPAH cleanup level based on the SWAC.

6.3 CONSTRUCTION APPROACH

This section describes general sequencing and constructability considerations for the cleanup action components in the Site upland and marine units.

6.3.1 Construction Work Windows and Sequencing

Specific work activities must be carefully planned and sequenced based on the construction means and methods chosen by the selected contractor. Construction work must also consider in-water work windows and other timing constraints. General sequencing and planning considerations are discussed in the following sections.

6.3.1.1 WORK WINDOWS AND HOURS OF OPERATION

A primary consideration for coordinating and planning work in the marine unit and shoreline bank area is the annual in-water work window for Bellingham Bay between August 1 and February 15. This constraint primarily affects shoreline and intertidal demolition and grading and placement of marine capping and habitat materials. The design assumes that all work below the high tide line (HTL) must be completed within the in-water work window. Upland work will ideally occur during the dry season between about May 1 and September 30 to reduce construction stormwater volumes and optimize conditions for soil compaction.

General work hours will be determined prior to construction, but construction noise potentially affecting residential areas is subject to the City's noise ordinance limiting work to the hours of 7:00 am to 10:00 pm unless otherwise necessary (BMC 10.24.120 Public Disturbance Noise). Work during evening low-tide periods could potentially be needed outside these working hours. The selected contractor will be required to coordinate these periods with the City, including obtaining any required noise ordinance variances, or meeting City substantive requirements.

The contractor will determine the overall scheduling and sequencing of construction based on equipment and labor availability, work window constraints, seasonal conditions, noise limitations, traffic flow/vehicle movement restrictions, marine access, and other factors. Constraints on construction timing and sequencing will be further identified in the contract plans and specifications including contract performance and scheduling requirements.

6.3.1.2 GENERAL CONSTRUCTION SEQUENCING

The anticipated sequence of construction is to first complete shoreline demolition and grading as needed to complete intertidal sediment capping, followed by placement of marine cap material, including construction of the proposed wave attenuation groin and placement of habitat material. Upland capping in the lower park is expected to be completed following completion of the upper portion of the sediment capping and habitat material placement, to allow the two surfaces to join. Construction of the upper park cap can be completed when needed to fit the contractor's project sequencing.

6.3.1.3 SHORELINE AND MARINE DEMOLITION AND GRADING

Shoreline and marine demolition and grading will include the following:

- Mobilizing and establishing secure work and staging areas and installing stormwater erosion control and management features/facilities.
- Demolition of incidental structures along the shoreline within the footprint of the shoreline capping and habitat material placement.
- Removing existing riprap revetment material along the shoreline and stockpiling for reuse.
- Cut off pilings as needed to complete demolition and pre-cap grading.
- Excavating the shoreline and upper intertidal sediment as needed to achieve adequate pre-cap grades and stockpiling excavated material for characterization and off-site disposal.

6.3.1.4 MARINE CAPPING AND HABITAT MATERIAL PLACEMENT

Marine capping and habitat material placement will include the following:

- Placing quarry spall bedding and armor stone to construct the proposed wave attenuation groin. Armor stone for the groin may consist of rock generated by the removal of the existing revetment.
- Constructing the marine cap in the intertidal area (above existing elevation 0 feet NAVD88) by placing a polyester geogrid on the graded sediment surface, followed by placement of the sand chemical containment layer, including activated carbon-amended sand where applicable, and erosion protection material.
- Placing capping material, including erosion protection material, and ENR material in subtidal areas.
- Placing habitat substrate where needed across the cap areas.

6.3.1.5 UPLAND DEMOLITION AND GRADING

Upland demolition and grading will include the following:

- Mobilizing and establishing secure work and staging areas and installing stormwater erosion control and management features/facilities.
- Clearing and grubbing vegetation and demolishing concrete and asphalt pavement and incidental structures as needed to complete grading and capping.
- Demolishing the remaining gas holder in the upper park. Walls of the gas holder will be demolished as needed to match proposed pre-cap grade. The contents of the gas holder will be removed and either transported off-Site for disposal or reused on-site if determined to be less than the cleanup levels.
- Modifying, as necessary, the two structures located within the lower park upland cap area to allow for cap placement.
- Decommissioning and abandoning existing groundwater monitoring wells that would likely be damaged during grading and capping.

- Excavating surface soil as needed to create the desired pre-cap elevations across the lower and upper park areas. Excavated soil will be relocated to areas requiring fill or will be transported off-Site for disposal.

6.3.1.6 UPLAND CAPPING

Upland capping will include the following:

- Completing construction of upland cap elements in the upper park and lower park areas.
- Restoring utilities, pathways, and trails within the cap area.
- Vegetating the cap surface with grass, shrubs, bushes and trees and planting vegetation on the shoreline bank.

6.3.2 Mobilization, Site Preparation, and Temporary Facilities

Mobilization and Site preparation will generally consist of securing the Site to prevent uncontrolled access and establishing staging areas and other temporary support facilities. Site control elements will be applied separately for the upper park and the combined lower park and marine unit as the construction period in the two areas may not completely overlap. Stormwater control measures, utility checks, and other preparatory activities will also be completed before transporting equipment and materials to the Site to construct the cleanup action components.

6.3.2.1 CONSTRUCTION ACCESS, HAUL ROUTES, AND SITE SECURITY

Access to the upper park portion of the Site for construction vehicles is only from South State Street, east of the Site. An existing small parking lot associated with Boulevard Park is expected to be the access point for construction in the upper park, including delivery of construction equipment as well as importing and exporting materials. Currently, there are multiple entry points to the park for public access and limited fencing exists along the perimeter of the upper park. A temporary perimeter fence with lockable gates will need to be constructed to secure the work area during construction.

The lower park and adjacent areas of the marine unit are accessible from the upland by Bayview Drive which is the access road for Boulevard Park and includes perpendicular parking spaces for park users along the entire length. The upland cap in the lower park extends to Bayview Drive. A portion of the roadway and parking is likely going to require closure for use by construction vehicles. The only upland haul route for equipment and materials will be along Bayview Drive through the Park. The contractor will provide traffic control and determine traffic flow patterns as needed to support construction activities.

The majority of the lower park is unfenced and open to the public. A security fence currently lines the western property boundary along the BNSF railway which is expected to be left in place during construction. Additional temporary fencing will be installed by the contractor around the perimeter of the lower park construction area to isolate the construction area from the remainder of Boulevard Park, which is expected to remain open to the public during construction.

6.3.2.2 UTILITIES CHECKS

Underground public and private utilities will be located and marked with paint prior to construction. The contractor will be responsible for field-locating all utilities using appropriate methods. Utility checks will also be completed for potential offshore utilities including contacting telecommunications companies regarding marine cables.

Existing water, sewer, stormwater, gas, and power utilities are present in the upper and lower park. Existing utilities will be protected during construction. Existing utilities located within the areas of planned grading and/or capping will be modified as needed to maintain necessary cover over the utility. Utilities with surface features, such as electrical junction boxes, storm drains, or water valves, will be modified as needed to restore the surface feature following placement of cap material.

Two outfalls are currently located along the shoreline of the lower park within the area of marine capping. One 4-inch diameter PVC outfall is present on the western shoreline that is the end of a 37-foot-long storm drain fed by a single catch basin on a park pathway near the shoreline. The catch basin may not be necessary after the lower park is re-graded and capped. One 8-inch diameter PVC outfall is on the northern shoreline near the pocket beach. This outfall is the end of a 315-foot-long drain fed by two catch basins located at the northern limit of the parking lot and circular vehicle turnaround. Further discussion with the City will be conducted during the 60 percent design to determine if the outfalls need to be preserved or modified or can be abandoned.

6.3.2.3 CLEARING AND GRUBBING

Vegetation within areas proposed for grading and capping will be cleared and grubbed to prepare ground surfaces for construction activities. Trees and vegetation removed during clearing will be stockpiled and hauled off-site for disposal.

6.3.2.4 STORMWATER MANAGEMENT

Standard construction stormwater BMPs will be established with the goal, at a minimum, of preventing stormwater with visual turbidity or sheen entering surface waters of Bellingham Bay. Stormwater management will be implemented in accordance with substantive requirements of City's stormwater management regulations (Chapter 15.42) and Ecology's Construction Stormwater General Permit (CSWGP). A stormwater pollution prevention plan will be developed for the project by the selected contractor or other party. BMPs will be consistent with the current version of Ecology's Stormwater Management Manual for Western Washington (SMMWW) in effect at the time of the work. Management of Site stormwater will transition to the City's MS4 program after completion of construction.

6.3.2.5 STAGING AREAS AND TEMPORARY SERVICES

The contractor will establish areas for employee parking, construction vehicle and equipment staging, storage for clean and contaminated materials, supplies, temporary offices, and emergency spill response and first aid materials. The contractor will provide and maintain temporary electrical, lighting, water, sanitary, office waste management, and telecommunications services needed for the duration of the project.

6.3.2.6 DEMOLITION

Surface structures in the portions of the upland unit requiring grading and capping will be removed prior to initiating earthwork. In the upper park area, demolition will include the electrical utility building and the removal of the walls and contents of the remaining gas holder. The walls of the gas holder will be demolished to the elevation of the adjacent pre-cap grade. The debris from demolition of the electrical building and gas holder walls will be transported off-Site for disposal. The contents of the gas holder will also be removed during demolition and either transported off-site for disposal or reused on-Site if the soil within the gas holder is less than cleanup levels. Demolition of the gas holder may require temporary shoring prior to filling to avoid collapse of the adjacent soil.

Structures and material present along the shoreline will require demolition and removal prior to grading and capping. The existing rock revetment will be removed prior to grading for placement of marine cap material in the upper intertidal and shoreline areas. The revetment material will be stockpiled on Site for reuse. Remnant piling present along the shoreline and in the upper intertidal area will be cut off at the pre-cap grades during demolition and prior to capping. The cut off piling will be hauled off-Site for disposal.

6.3.2.7 GROUNDWATER MONITORING WELLS

Many of the existing groundwater monitoring wells are within areas of grading and capping and will be decommissioned prior to the start of work. Existing groundwater monitoring wells that require removal will be decommissioned by a Washington-licensed driller in accordance with Ecology requirements (WAC 173-160-460). Selected wells in the upland capping areas may be protected during capping, if practical, for use in compliance monitoring after the cleanup action is completed. Any wells that are retained will need to be modified to extend the well casing to the upland cap surface and to provide a new protective well monument. Any modification of the existing wells will be performed by a Washington-licensed driller in accordance with Ecology requirements (WAC 173-160-460). Figure 6-1 identifies monitoring wells that are to be decommissioned and wells that are to be protected during cleanup action construction.

Additional groundwater monitoring wells are expected to be installed to support compliance monitoring after the remedy is constructed. New wells will be installed after upland capping has been completed. The compliance monitoring plan that will identify groundwater wells to be used for post-cleanup action monitoring will be developed as part of the Operations, Maintenance, and Monitoring Plan (OMMP).

6.3.3 Upland Capping

This section presents information for construction of the upland cap to be constructed in the upper and lower park portions of the upland unit. The planned cap surface elevations are presented in Figure 6-3 for the upper park and Figure 6-5 for the lower park. For cap construction, typical land-based construction equipment will be suitable for grading, fill placement, and compaction. The final grading and fill sequence will be determined by the contractor; however, the following sections provide information to be considered during planning and construction.

6.3.3.1 PRE-CAP GRADING

Prior to constructing the upland cap in the upper and lower park areas, excavation and grading will be required to prepare the pre-cap surfaces to allow the cap to be placed and tie into the existing park surface. Due to the complex topography of the upper park within the proposed capping limits, substantial grading of the existing surface is needed to prepare the pre-cap surface. The pre-cap grading limits and elevations for the upper park are presented on Figure 6-3.

The lower park area will require less pre-cap grading relative to the upper park, primarily due to the thickness of the cap needed to raise the final surface elevation to account for SLR. Limited excavation and grading will be needed in the lower park at the limits of the cap to tie in the cap to the uncapped surface of the park. This includes the paved roadway and parking area, and the eastern limit of the lower park adjacent to the BNSF property rail line.

Soil generated by pre-cap grading will be relocated to areas requiring fill or will be transported off-Site for disposal. In cap areas requiring a significant fill volume to be placed prior to capping, excavated soil will be used for fill beneath the cap.

The final pre-cap surface will be rolled with a smooth drum roller before placing cap material.

6.3.3.2 UPLAND CAP PLACEMENT

After the pre-cap surface has been prepared, the upland cap will be constructed as shown in Figures 6-3 through 6-6. A geotextile separation layer will be placed on the graded and rolled surface followed by placement of cap material. The cap material will be placed in 12-inch lifts and compacted using a smooth drum roller to 90 percent of the maximum dry density in general accordance with ASTM International (ASTM) D1557. The surface of the cap will consist of topsoil and will not be compacted. Grass, shrubs, bushes, and trees will be planted on the surface of the cap. Plants and trees will be selected with shallow root systems so that the roots remain within the cap.

6.3.4 Upland Groundwater Bioremediation

This section discusses construction of the groundwater bioremediation PRB to be constructed in the lower park. The PRB is planned to be constructed within or near the pathway at the base of the sloped area separating the upper and lower park areas as shown on Figure 6-7. Generally, the PRB will be constructed using common trenching methods and by placing a mixture of reactive material and clean sand across the target reactive zone of the PRB. The PRB will be completed by backfilling the remainder of the trench with clean fill and restoring the ground surface.

An excavator will be used to advance the excavation of the PRB trench from the ground surface down to bedrock, approximately 16 feet bgs. Trench boxes, or alternative shoring method, will be required because the excavation will extend approximately 6 to 8 feet below the wet season water table and 4 feet below the dry season water table in sandy fill of unknown compaction (Figure 6-8). Approximately 300 CY of existing subsurface material will be removed to install the PRB. The excavated material will be stockpiled onsite, profiled for waste disposal, and then transported and disposed of at an appropriate upland landfill.

The PRB components (sand, ZVI, and Gypsum) will be mixed above-ground prior to placement in the PRB trench. PRB components would typically be laid out in rows next to the trench and mixed to visual uniformity with the excavator. The lack of space near the proposed PRB alignment may require that the PRB material be mixed in another portion of the lower park and stockpiled as a mixture prior to placement in the PRB. The trench will be backfilled with the prepared PRB mixture as the trench box advances along the length of the PRB to avoid open sections of the trench which could slough below the water table.

6.3.5 Sediment Capping

This section summarizes the approach and methods for constructing the sediment caps in the areas shown in Figure 6-9. Figure 6-10 presents the plan for habitat material to be placed on the sediment caps and erosion protection material to restore habitat and achieve mitigation goals. Figures 6-11 through 6-17 present cross-sectional views of the sediment capping plan at section locations shown on Figures 6-9 and 6-10.

6.3.5.1 CAP SURFACE GRADING AND PREPARATION

Sediment capping within the intertidal zone will require preparation of a smooth graded surface prior to placement of cap materials. Demolition within the intertidal area, as described in Sections 6.2.5 and 6.3.2, will remove pilings and large rock from the existing shoreline revetment from the shoreline. Following demolition, additional debris removal, sediment excavation, and grading will be performed to prepare the sediment surface for cap placement.

Limited removal of shallow sediment will be required in some areas of the upper intertidal cap to achieve the required grades for cap placement. Sediment removal and grading will be within the area above the approximate existing elevation of +5 feet NAVD88 and will be conducted in the dry during low-tide periods using land-based excavation equipment. The sediment surface will be graded to the required slope for cap placement, typically a 12- to 14-percent slope (approximately 1v:8h to 1v:7h). The planned slope grades are shown in cross-section in Figures 6-11 through 6-17. Remnant piling will be cut off at the existing mudline to facilitate grading. Outside the footprint of the required grading, the upper intertidal (above elevation +0 feet NAVD88) cap placement will first require removal of loose surface debris prior to capping. Excavated sediment and debris will be transferred to the upland, stockpiled for characterization, and transported off-site for disposal.

Typical marine construction BMPs will be implemented for water quality protection during debris removal, grading, or any other construction work near or below the HTL.

6.3.5.2 SEDIMENT CAP MATERIAL TYPES AND AREAS

Engineered caps of several designs will be placed over specific intertidal and subtidal areas of the marine unit as shown in Figure 6-9. As described in Section 6.2.7, the sediment cap designs consist of a chemical containment layer to contain contaminants in underlying sediment and groundwater/porewater and an erosion protection layer to provide long-term protection of the chemical containment layer from wave action and other disturbance. Most cap areas will utilize a chemical containment layer consisting of a conventional 2-foot-thick, clean sand cap. Where mobile contaminants are present in groundwater entering the cap, the cap chemical containment layer will include activated carbon as an amendment to attenuate groundwater contaminants. The amended cap will consist of a 1-foot-thick layer of sand mixed with a 1-percent, by weight, dosage of activated carbon overlain by 1-foot-thick layer of clean sand. The amended cap areas are limited to the intertidal area offshore of the western portion of the lower park and the intertidal area of the pocket beach.

All cap areas will require erosion protection to ensure long-term protection of the chemical containment layer. The erosion protection materials include armor rock, gravelly cobble aggregate mix, and a gravelly sand aggregate mix. The erosion protection materials were selected based on coastal engineering summarized in Section 5.2 and Appendix E. Figure 6-9 shows the areas where the different erosion protection materials are used.

In the higher subtidal areas in the northern portion of the marine unit where sediment is impacted by moderate contaminant concentrations, ENR is used to reduce bioavailable contaminant concentrations and to avoid destruction of existing eelgrass. As shown in Figure 6-9, ENR will be applied to a band of impacted sediment at approximate elevation -3 to -13 feet NAVD88. ENR application will consist of the placement of two thin layers of clean sand, separated by several months to allow recovery of eelgrass between applications. Each layer of sand will be approximately 2-inches thick, applied by spreading the sand at/near the surface of the water and allowing the sand to slowly settle and accumulate on the eelgrass area.

6.3.5.3 MARINE HABITAT MATERIAL TYPES AND AREAS

All the cap surfaces will be covered by a layer of habitat material, placed on top the erosion protection layer. The habitat substrate will provide for habitat restoration when placed on larger erosion protection material, particularly angular armor rock, in intertidal areas and will provide additional material thickness in subtidal areas for re-establishing eelgrass. The habitat substrate material will consist of either a gravelly cobble which will be used in intertidal areas south of the groin to cover areas of armor rock erosion protection material or a gravelly sand which will be used in low energy areas to enhance intertidal and forage fish habitat and in subtidal areas for eelgrass substrate. Figure 6-10 presents a plan view of the habitat material placement. Cross-sectional views of the habitat placement are presented on Figures 6-11 through 6-17.

6.3.5.4 CAPPING MATERIALS PREPARATION

To prepare for placement, clean, imported cap materials will be blended and sized to meet specified mix proportions and grain size gradations. Sand, gravel, cobble, and rock materials for capping are expected to be available from local sources. Cap amendments will be sourced from vendors based on the availability of materials meeting the specifications. Capping materials will be delivered to the Site by truck or barge, with sizing and blending occurring either on- or off-Site. Materials temporarily stored in the upland unit will be protected from potential cross contamination and erosion.

6.3.5.5 CAP PLACEMENT METHODS

Placement methods for capping materials will depend on the location and bathymetry of the placement location shown in Figure 6-9 and Figure 6-10 and described below.

- Wave Attention Groin – The groin material will be placed prior to construction of adjacent caps to allow the adjacent cap material to be placed up against the groin material. The construction of the groin will consist of placement of a geogrid on the prepared sediment surface, placement of a 1-foot-thick quarry spall bedding layer, and placement of the armor stone making up the groin. Where possible, the materials will be placed in the dry during low-tide periods using land-based methods.
- Western Intertidal Cap South of the Groin – The sediment cap adjacent to the western portion of the lower park and south of the wave attenuation groin will be capped using land-based equipment following completion of demolition and grading in the shoreline and upper intertidal area. The prepared sediment surface will be covered with a polyester geogrid before placing the amended sand containment layer. A second geotextile layer will be placed to separate the top of the amended sand layer from an armor rock gravel bedding layer and armor rock. Placement of the erosion protection layer in this area will be completed immediately following placement of amended sand. The erosion protection layer will consist of a 6-inch gravel bedding layer and 2-foot layer of armor rock.
- East of Groin and Pocket Beach – The intertidal sediment cap east of the wave attenuation groin and adjacent to the northern portion of the lower park, through the pocket beach, will be capped using land-based equipment following completion of demolition and grading in the shoreline and upper intertidal area. The prepared sediment surface will be covered with a polyester geogrid before placing the overlying sand chemical containment layer. Within the pocket beach, as shown in Figure 6-9, the chemical containment layer will be amended with activated carbon. Placement of the erosion protection

layer in this area will be completed immediately following placement of the chemical containment layer and will consist of placement of a 1.5-foot layer of a gravelly cobble material.

- Northern Intertidal, Rail Revetment – Construction of the intertidal portion of the sediment cap in the area north of the pocket beach will likely be performed from the water due to the limited access available for construction equipment along the revetment. The prepared sediment surface will be covered with a polyester geogrid before placing the overlying sand containment layer. A second geotextile layer will be placed to separate the top of the sand layer and an armor rock gravel bedding layer and armor rock. Placement of the erosion protection layer in this area will be completed immediately following placement of the sand layer. The erosion protection layer will consist of a 6-inch gravel bedding layer and 2-foot layer of armor rock. The erosion protection layer will transition to a gravelly cobble material below approximate existing elevation -2 feet NAVD88, as shown in Figure 6-14.
- Lower Intertidal and Subtidal Cap Areas – The deeper intertidal and subtidal areas have water depths up to approximately 30 feet where capping will be completed through the water column using barge-based equipment. A crane-operated clamshell, fixed-arm hydraulic excavator, or tremie method will be used to place the sand chemical containment layer material in a controlled fashion to achieve the designed distribution and thickness. Erosion protection material ranging from armor rock and gravelly cobble in the lower intertidal zone to gravelly sand in subtidal areas will be placed as designed with a clamshell, excavator bucket, or skip-box. The contractor may propose alternative methods but will need to demonstrate the efficacy if alternative methods are proposed.
- ENR Area – Placement of clean sand for ENR as shown in Figure 6-9 between approximately elevation -3 to -13 feet NAVD88 will require barge-based equipment and placement methods. The ENR sand will be placed slowly in two separate 2-inch lifts using barge-mounted spreader equipment that evenly distributes the sand across a large area to prevent damaging existing eelgrass within the area of placement. Placement of each of the two lifts of the ENR material will be separated by several months.
- Habitat Material – Habitat material will be placed following completion of all capping, including all erosion protection material placement. Habitat material will be placed using the same methods used to place cap and erosion protection materials. Placement of habitat material in intertidal areas will be completed using land-based methods. In inaccessible intertidal areas, such as along the rail line revetment to the north, and in subtidal areas, material placement will be completed using water-based methods.

Material will generally be placed in lifts no greater than 1-foot thick to promote even coverage and reduce differential settlement except for the armor stone. The groin armor stone material has a D50 significantly larger than 1-foot in diameter and erosion protection armor rock has a D50 of 1-foot and will have individual rocks greater than 1-foot in diameter. The contractor will determine the specific areas, number of passes, and overall sequence for placement of the capping components. Erosion protection material will require careful placement to prevent disturbance of the underlying containment layers and seafloor.

Construction quality assurance will generally consist of confirming the acceptability of the capping material blends and grain sizes before placement, the placement areas, and thicknesses. The upper surfaces of the containment and erosion protection layers will be surveyed to confirm that the top-of-cap surface elevations and design thicknesses have been achieved. The post-placement bathymetry will also provide a baseline for future comparison.

7.0 Construction Requirements

This section summarizes general contracting considerations, construction quality assurance (CQA) and construction quality control (CQC) requirements, and construction documentation for the South State Street cleanup action. The general construction requirements are presented in order of when they are to be performed and include pre-construction, during construction, and post-construction time periods.

In accordance with WAC 173 340 400(6)(b)(i), construction will be performed under the supervision of a professional engineer registered in the State of Washington or a qualified technician under the direct supervision of the professional engineer registered in the State of Washington.

7.1 PRE-CONSTRUCTION REQUIREMENTS

This section includes the pre-construction requirements to be completed by PSE and the City to prepare for construction including:

- Construction Planning and Coordination.
- Plans and Specifications.
- Construction Quality Assurance Plan.
- Water Quality Monitoring Plan.
- Cultural Resources.

7.1.1 Construction Planning and Coordination

Construction planning and coordination will be performed to facilitate completion of the cleanup action at the Site while the City operates and the public uses Boulevard Park. Construction will require contractor access through and to portions of the park to complete the cleanup action. Park use will not be allowed in the areas of the park undergoing cleanup action construction. Areas undergoing cleanup action will be returned to park use after final acceptance of the completed cleanup action and approval by Ecology.

7.1.2 Plans and Specifications

Cleanup action design plans and specifications will be prepared at the 60 percent, 90 percent, and 100 percent (final) design phases in accordance with the Amended AO. Construction level plans and specifications (Contract Documents) will be prepared based on the final cleanup action design and will include supporting drawings and related information needed for contracting. The draft Contract Documents are anticipated to be developed following 90 percent design and when permitting has progressed sufficiently so that major design modifications are not anticipated. The Contract Documents will be finalized following 100 percent (final) design. The Contract Documents will describe the scope of work to be completed and related details of the cleanup action. The Contract Documents will also include applicable permits, and approvals and associated conditions, including substantive requirements of exempted permits.

The Contract Documents will describe the project and associated activities and performance objectives consistent with WAC 173-340-400 (4)(b). The Contract Documents will include:

- General description of the work to be performed and location/facilities maps.

- Description of required contractor submittals for construction planning and scheduling, construction CQA/CQC, health and safety, environmental protection, cultural resource protection, surveying, progress reporting and deliverables, and construction and environmental monitoring.
- Detailed plans, procedures, material specifications and other performance requirements for the contractor to complete construction activities.
- Permits, approvals, and other substantive requirement provisions that must be followed during construction.
- Public and worker health and safety provisions.
- Environmental protections and site security requirements.
- Quality control organization, CQA and CQC responsibilities, and minimum contractor staff qualifications.
- Requirements for quality control tests, frequency, and acceptability criteria.
- Corrective action requirements and protocols.
- Construction documentation and tracking including progress reports, CQC reports, meetings, material characterization and testing results, constructed conditions, and completion reports.
- An inadvertent discovery plan (IDP) meeting the requirements of WAC 173-340-815.
- Any additional elements deemed necessary to assure conformance of the work in accordance with the Contract Documents and permit requirements.

7.1.3 Construction Quality Assurance Plan

The Construction Quality Assurance Plan (CQAP) describing CQA activities needed to demonstrate the adequacy of the work completed will be prepared in conjunction with the contract documents following 90 percent design and when permitting has progressed sufficiently so that major design modifications are not anticipated. The CQAP will include CQC verification steps to document that performance objectives and other Contract Document requirements are met. The CQAP will address the following:

- Quality assurance/quality control organization and project CQA/CQC responsibilities.
- Programmatic CQA requirements and CQA criteria for construction.
- CQA activities and procedures.
- Construction monitoring and tracking including progress reports, CQA reports, meetings, and completion reports.
- Corrective action requirements and protocols, in conjunction with the contractor’s CQC Plan corrective actions.
- CQA documentation.
- Any additional elements deemed necessary to assure conformance of the work in accordance with the contract documents and permit requirements.

7.1.4 Water Quality Monitoring Plan

A Water Quality Monitoring Plan (WQMP) will be developed by PSE and the City to describe the scope, frequency, and documentation requirements for monitoring surface water quality during in-water construction activities. The water quality monitoring requirements will be included in the application for the

USACE permit and 401 Water Quality Certification (WQC) required for marine construction work and will likely be elements required by the permit/certification. The WQMP is expected to include conditions for visual and instrumented monitoring, BMPs to protect surface water quality during in-water construction, compliance criteria, and reporting requirements. Requirements will also include spill prevention, contingency response actions, and corrective measures should exceedances of applicable water quality criteria occur. The WQMP will be submitted to Ecology and other permitting agencies (as required) for review and included in the final Contract Documents.

7.1.5 Cultural Resources

An IDP will be prepared to describe procedures in the event of discovering archaeological materials or human remains during construction. The IDP will be prepared in accordance with applicable state and federal laws and requirements of the Washington State Department of Archaeology and Historic Preservation. The IDP will be developed using Ecology's template, or equivalent, and implemented during all ground-disturbing activities. The IDP will be submitted to Ecology for review and included in the final Contract Documents.

7.2 DURING CONSTRUCTION REQUIREMENTS

This section includes the requirements to be completed during construction. The requirements generally include actions completed once the construction Contractor has been selected including:

- Contractor Pre-Construction Submittals.
- Contractor Quality Assurance Monitoring.
- Construction Documentation and Meetings.
- Environmental Protection Monitoring.
- Site Health and Safety.

7.2.1 Contractor Pre-Construction Submittals

This section includes pre-construction submittals that will be required to be completed by the selected construction contractor. Additional pre-construction submittals will be identified during design and development of the construction plans and specifications.

7.2.1.1 CONSTRUCTION QUALITY CONTROL PLAN

Prior to construction, the contractor will prepare a CQC Plan as a required deliverable to present a system for demonstrating that the work activities and constructed elements meet project performance objectives and other requirements of the Contract Documents and permit conditions. The CQC Plan will describe how the contractor will implement and achieve quality control for work activities. The CQC Plan will identify key personnel, roles, and responsibilities, CQC inspections and frequencies, equipment maintenance/servicing and calibration, review and approval check points, quantities and dimensions including progress surveys, documentation forms for the CQC system, and submittal and record keeping procedures. A key function of the CQC Plan is also to provide contractor procedures for identifying deficiencies, corrective actions, and outcomes and resolutions. Additional construction documentation will include requests for interpretation, change documentation, and PSE and City responses.

7.2.1.2 ENVIRONMENTAL PROTECTION PLAN

Prior to construction, the contractor will submit an Environmental Protection Plan (EPP) describing measures to be implemented to prevent releases of contaminated media and impacts to the environment during construction in accordance with requirements of the Contract Documents. The EPP will identify management protocols and procedures to control contaminated media associated with each construction element. Environmental controls must address associated permit and other regulatory requirements for materials handling, stormwater, surface water quality, and air quality. Construction will also be subject to permit conditions for protection of biological species that may potentially be affected. Shoreline and in-water BMPs may include debris/petroleum containment booms and a silt curtain.

Monitoring of stormwater, surface water, and air quality will be incorporated into the EPP including the WQMP provided in the Construction Documents and a stormwater pollution prevention plan (SWPPP) prepared by the contractor. The contractor will develop a SWPPP in accordance with requirements of Ecology's CSWGP or an individual stormwater permit to be issued by Ecology. Key considerations for the SWPPP are protection of adjacent surface waters of Bellingham Bay and prevention of cross contamination of groundwater and other media. The SWPPP will describe stormwater collection, management, and treatment procedures along with BMPs for drainage and erosion control (such as silt fencing and wattles), off-site tracking prevention, spill prevention, and other environmental protection measures. The SWPPP will also describe the required stormwater monitoring to be conducted by the contractor.

The EPP will also describe collection, temporary storage, pretreatment, and off-Site disposal at the City's wastewater treatment facility or other permitted disposal of construction water including dewatering water, water generated as part of equipment decontamination, and contaminated stormwater. Additional environmental controls will be described for equipment and personnel decontamination, and spill prevention and response. Spill prevention and response will address proper handling and storage of fuels, equipment maintenance, contingency measures for containing potential releases of these materials and contaminated media, and spill notifications and documentation.

7.2.1.3 IMPORT MATERIAL QUALITY

Prior to the import of materials to the Site, the contractor will submit documentation verifying that the materials meet the requirements of the Contract Documents. The submittals will include documentation that the materials conform with specified material types, gradations and meet criteria for conventional and chemical parameters and is free from other deleterious substances.

7.2.1.4 HEALTH AND SAFETY PLAN

Prior to construction, the contractor will prepare a Site HASP to be implemented during construction. The HASP will incorporate standard environmental remediation construction methods and safety practices to mitigate potential risks to Site workers (including subcontractors), other project personnel, and the public. The HASP will comply with applicable state and federal regulatory requirements including requisite hazardous waste operations training. Site safety will also include maintenance of security fencing and vehicle and personnel entry control.

7.2.2 Construction Quality Assurance Monitoring

The Contractor will conduct regular reviews, inspections, and monitoring during construction to determine and document that the work performed conforms with project requirements. PSE's and the City's representative will review submittals from the contractor to confirm that quality assurance requirements are achieved, and that the contractor has provided appropriate documentation and deliverables in accordance with the construction plans and specifications. Construction confirmation will include review of information submitted by the contractor including work progress/completion reports, capping material quantities and progress surveys, as well as additional observations, inspections, testing, and other actions independent from, or in addition to the contractor's information. The PSE and City representative will also determine and document the nature of defects, deviations, and causes for rejection, as applicable, confirm suitable corrective actions, and confirm completion of corrective actions taken.

Planned CQA monitoring activities for the upland unit include:

- Topographic surveys of the pre-construction site conditions and constructed caps and features will be conducted under the supervision of a licensed professional land surveyor in the State of Washington and include:
  - Upper and lower park existing topography and surface features, including the shoreline bank area above HTL;
  - Location of groundwater bioremediation PRB;
  - Post-grading surface of the upper park and lower park prior to placement of cap material, including shoreline bank area above existing HTL;
  - Surface of the completed upland cap in the upper park and lower park and location of reconstructed pathways and structures;
  - Location and elevation of the surface of each sediment cap material that extends into the existing upland (above existing HTL);
  - Location and elevation of groundwater monitoring well monuments and casings; and
  - Utilities.
- Groundwater bioremediation mix proportions, and hydraulic conductivity performance testing results.
- Import fill and other cap construction material characteristics and quality.

Planned CQA monitoring activities for the marine unit include:

- Bathymetric survey and topographic survey of the pre-construction site conditions and constructed caps and features will be conducted under the supervision of a licensed professional land surveyor in the State of Washington and include:
  - Pre-construction sediment surface and visible piling and debris locations;
  - Top of sediment cap containment horizon(s) and thicknesses;
  - Top of erosion protection surfaces and thicknesses; and
  - Top of habitat substrate surfaces and thicknesses.
- Sediment cap amendments and other cap construction material characteristics and quality.
- Sediment cap amendment proportions and mixing test results.

Additional CQA items for both the upland and marine units include:

- Erosion and sediment controls, and stormwater and surface water quality monitoring and protection measures.
- Contaminated materials management and containment measures, air quality, and other environmental controls.
- Debris removal and management.
- Habitat monitoring, protection, and restoration/mitigation measures.
- Other permit-driven QA requirements.

7.2.3 Construction Documentation and Meetings

Contractor construction documentation will consist of reports and other documentation to track project progress and CQC activities and results. Separate CQA records will be prepared and maintained by the CQA representative(s). Meetings will be performed on a regular basis to discuss construction progress and activities.

7.2.3.1 CONTRACTOR REPORTS

Contractor reports will consist of daily, weekly, and other progress reports as needed to document the activities in progress or completed. Routine reports will include associated records for quality control monitoring, checks, progress surveys, materials testing, and other CQC items along with defects and corrective actions. Contractor documentation will also include meeting minutes, requests for interpretation as needed, and requests for payment.

7.2.3.2 CONSTRUCTION MEETINGS

Weekly construction meetings including PSE, City, and contractor representative(s) are anticipated to discuss progress, planning, quality and environmental controls, and upcoming scheduled work along with any problems and solutions. Contractor meetings also include daily health and safety and work planning meetings prior to the start of the work shift.

7.2.3.3 CQA REPORTING

CQA documentation will include field notes, forms, reports and work products, checklists, and approvals, with supporting photographs and testing data, and other information as needed. CQA monitoring and related activities will be documented in daily and weekly CQA reports.

7.2.4 Environmental Protection Monitoring

The Contractor will implement the requirements of the EPP throughout the duration of construction. The contractor will inspect and maintain all necessary BMPs and protection measures specified in the EPP including stormwater management, surface water runoff control, TESC measures, spill prevention measures, dust and air emissions controls. Monitoring, documentation and reporting for stormwater and surface water will be in accordance with the permit requirements, SWPPP and WQMP.

Other water quality BMPs will be implemented such as silt fencing for upland stormwater and sediment control, and floating booms to contain debris and oil, if present. A debris boom with a silt curtain will be deployed during sediment capping where needed to minimize transport of turbidity.

Site grading and excavation work could generate airborne dust requiring water misting or other control measures to limit dust generation. Short-term air emissions from construction equipment engine exhaust will be controlled by maintaining the equipment in good working order and by limiting idling when equipment is not actively working. As an additional BMP, foaming agents or other odor control measures could also be needed during completion of the groundwater bioremediation trench if petroleum materials encountered during the work create odors or fumes adversely affecting air quality.

Monitoring of the BMPs will include regular inspections and documentation using checklists and daily field reports.

7.2.5 Site Health and Safety

Human health will be protected during the cleanup action through implementation of a Site HASP. Cleanup-related construction activities will be performed in accordance with the requirements of the Washington Industrial Safety and Health Act (RCW 49.17) and the Federal Occupational Safety and Health Act (29 CFR 1910, 1926). These regulations include requirements for worker protection from physical hazards and exposure to contaminants. Workers will be required to have current hazardous waste operations and emergency response (HAZWOPER) training. The contractor will monitor and document health and safety parameters as required in the HASP and state and federal requirements. Site safety requirements will also apply to visitors and will be protective of adjacent public and residential uses.

7.3 POST-CONSTRUCTION REQUIREMENTS

7.3.1 Construction Completion Report

Upon completion of the cleanup action, a construction completion report will be prepared in accordance with MTCA requirements listed in WAC 173-340-400(6)(b)(ii). The construction completion report will include the following:

- A statement that the construction has been performed under the oversight of a professional engineer registered in the State of Washington or a qualified technician under the direct supervision of a professional engineer registered in the State of Washington.
- Text describing construction work performed to complete the cleanup action including construction means and methods, materials used, waste management, and documentation of tests and measurements. Daily field reports, photographs, key CQA/CQC records will be provided as supporting documentation and reference information to document the details of the work completed.
- Description of modifications to approved construction plans and specifications.
- Monitoring well decommissioning and installation logs and records.
- As-built drawings documenting all aspects of the completed cleanup action.
- A statement from the engineer as to whether the cleanup action has been constructed in substantial compliance with the plans, specifications, and related documents.

7.3.2 Performance Monitoring

Performance monitoring is required to confirm that the cleanup action has attained cleanup standards and other performance standards such as quality control or monitoring to demonstrate compliance with permit(s) and/or substantive requirements. Cleanup standards for the Site include protection of human health and the environment from contaminated media as discussed in Section 2.0.

Performance monitoring includes demonstration that the work meets the permit and Contract Document requirements including criteria established in the project plans and specifications and other CQA/CQC requirements. The Construction Completion Report will document how the cleanup action met the permit requirements and requirements established in Contract Documents. The constructed features must conform to specified dimensions and configurations, material specifications and other quality criteria, unless otherwise modified during construction. Any modifications made during construction will be documented in the Construction Completion Report. Post-construction topographic and bathymetric surveys will be completed as required by Contract Documents and will be reported as part of the Construction Completion Report to document post-construction baseline conditions throughout the Site.

Upland and sediment capping are designed to meet the cleanup levels at the points of compliance immediately following completion of cleanup action construction.

Marine capped sediment surface and cap porewater will be sampled immediately following construction to document compliance with cleanup standards and the baseline post-construction sediment conditions.

8.0 Operations, Maintenance and Monitoring

This section presents a general description of operations, maintenance, and monitoring following construction for the Site cleanup action. A draft OMMP fulfilling requirements of WAC 173-340-400(4)(c) will be developed based on the 90 percent design and submitted to Ecology for review. The final OMMP will be prepared after construction is completed. The OMMP will describe the required inspection, monitoring, and maintenance activities for the cleanup action. The OMMP will describe compliance and confirmational monitoring to address requirements of WAC 173-340-410 and -820 including a Sampling and Analysis Plan (SAP) and Quality Assurance Project Plan (QAPP) for the media to be monitored.

8.1 OPERATIONS, MAINTENANCE, AND MONITORING PLAN

A draft OMMP will be prepared based on the 90 percent design construction plans and specifications. The OMMP will then be finalized based on as-built conditions following construction. In accordance with WAC 173-340-400(4)(c) the OMMP will include:

- Roles and responsibilities for OMMP activities.
- Contact information for responsible individuals.
- Cleanup action description and operating principles.
- Description of the compliance monitoring that will be performed for each component of the clean action (i.e., caps in the upland unit, caps in the marine unit, PRB, etc.).
- Inspection and maintenance procedures for upland unit and marine unit caps.
- SAP and QAPP meeting the requirements of WAC 173-340-820.
- Procedures and forms for monitoring, operation, and maintenance records.
- Materials sources/suppliers.
- Monitoring and maintenance schedules and recommendations.
- Contingency procedures for maintenance and repairs.
- Health and safety provisions, contaminant action levels and contingency plans.
- An IDP meeting the requirements of WAC 173-340-815.
- Status reports and record keeping.

Conditions triggering contingency response actions and corrective measures will be identified in the OMMP. Criteria for contingency actions will also consider potential SLR conditions affecting the erosion protection systems or other constructed features. The OMMP will include other information as required by Ecology and as needed for successful long-term operations, maintenance, and monitoring.

8.1.1 Inspections

The scope and schedule for the inspection program and other aspects of long-term operations, maintenance, and monitoring will be specified in the OMMP. Site inspections will document physical conditions of upland and shoreline cap areas, functionality of the constructed features, maintenance activities completed, and conditions warranting corrective actions or other follow-up efforts as needed.

8.1.2 Groundwater Monitoring

Groundwater compliance monitoring will be performed to evaluate MNA and enhanced groundwater bioremediation components of the cleanup action. The scope of and schedule for confirmation groundwater monitoring will be proposed in the draft OMMP and confirmed in the final OMMP to be completed after construction.

Selected wells in the upland cap areas may be protected during earthwork, if practical, for use in confirmation monitoring after the remedy is constructed. Wells that are retained will need to be modified to extend the well casing to the upland cap surface and will need a new protective well monument. Additionally, new wells will likely need to be installed to support confirmation monitoring after the remedy is constructed. New wells will be installed after capping is completed. The wells that are to be decommissioned and retained, as well as the new wells to be installed will be identified in the OMMP.

Ecology has determined that the Site cleanup action meets the regulatory requirements for a conditional point of compliance for groundwater as described in Section 2.0. Groundwater will meet cleanup levels after migrating through the cap. The conditional point of compliance for groundwater is established at a depth of 12 cm below the surface of the cap. Groundwater will also be monitored in wells installed within the upland to evaluate upland site conditions over time. Compliance with groundwater cleanup standards is planned to be evaluated using monitoring data from sediment cap porewater collected from the depth of 12 cm.

The results of the groundwater monitoring will be reviewed to assess changes in groundwater quality and evaluate the extent of contaminant degradation over time.

8.1.3 Sediment Monitoring

Sediment monitoring will include physical monitoring to confirm that the cap components remain structurally sound and chemical monitoring of sediment and porewater to confirm the caps remain functional for long-term contaminant containment.

The thickness and integrity of the cap components will be monitored through direct measurements and using bathymetric surveys and topographic surveys of the shoreline area. Bathymetric and topographic surveys will also be used in conjunction with direct measurements of sediment accumulation to assess patterns of sediment deposition or erosion, if occurring, over time.

Chemical quality monitoring of the sediment will be conducted at the point of compliance in the upper 12 cm of the sediment caps representing the biologically active zone in Bellingham Bay. The upper 12 cm also addresses protection of humans and higher trophic level ecological receptors with respect to consumption of seafood gathered from subtidal areas. Monitoring will include sampling habitat material and sediment deposited on top of the erosion protection materials or accumulating in the interstices of erosion protection materials. The result of sediment sampling and analysis will be compared to the sediment cleanup levels established for the Site.

Porewater sampling will be performed at the base of the biologically active zone within the area of amended sand capping. Porewater sampling will be performed to evaluate contaminant concentrations in groundwater after passing through the amended sand cap prior to becoming porewater within the biologically active zone or surface water. The result of porewater sampling and analysis will be compared to the groundwater cleanup levels established for the Site.

8.1.4 Habitat Mitigation Monitoring

Requirements for monitoring the performance of habitat mitigation associated with the cleanup at the Site will be determined as part of permitting. The requirements for monitoring will be specified in the future habitat mitigation plan developed to support the Corps of Engineers permit and will be based on review by natural resource agencies.

8.1.5 OMMP Revisions

The OMMP will be revised as needed based on Site conditions including future public park use. The OMMP may be further updated during periodic reviews by PSE, the City, and Ecology to ensure that the cleanup action remains effective for protecting human health and the environment over the long-term. Maintenance activities, monitoring parameters, and the frequency of inspections and monitoring may also be modified in the future.

8.2 INSTITUTIONAL CONTROLS

Institutional controls will be developed for the Site to provide notifications regarding the presence of contaminated media remaining at the Site following completion of cleanup action construction, limitations or prohibitions on activities that may compromise the integrity of the cleanup action, and other activities necessary to ensure protection of human health and the environment. Institutional controls and environmental covenant provisions will be presented in the OMMP to be prepared for Ecology review and approval. Easements to construct cleanup elements on property owned by Washington State, BNSF, and the Jacqueline J Ogden Rev Living Trust will also be needed.

MTCA restrictive covenants or alternate approach(es) acceptable to Ecology will be established in accordance with WAC 173-340-440 for City-owned property, BNSF-owned property, state-owned property, and Jacqueline J Ogden Rev Living Trust-owned property (see Figure 1-4 for parcel ownership). Restrictive covenants will be developed in accordance with the Uniform Environmental Covenants Act (Chapter 64.70 RCW) and will be filed with Whatcom County subject to Ecology's approval. Alternatively, an 'effective alternative system' meeting the requirements of WAC 173-340-440(8)(b) for restrictive covenants may be developed, as acceptable to Ecology and other parties.

The restrictive covenants or acceptable alternative system will list restrictions on property use and conveyance and will be binding on the property owners. The restrictions will also provide for unimpeded monitoring and operations and maintenance and require property owners to notify lessees and purchasers of the restrictions placed on the property. DNR's mapping system and index plates will be updated to document remediation and associated encumbrances for state-owned parcels. Restrictive covenants will be required per WAC 173-340-440(8)(b)(ii) and related MTCA requirements if Site parcel ownerships are transferred in the future.

Institutional controls for the upland unit will place restrictions on activities that could result in releases of hazardous substances or exposure to maintenance workers, the public, and/or other parties. The restrictions will be based on the planned future park use and will focus on prohibiting activities that could compromise the integrity of the upland capping containment structures. Institutional controls will also protect the groundwater bioremediation system and upper shoreline bank armor from disturbance that would adversely affect their function. Additional institutional controls will be established to protect groundwater wells and prevent use of groundwater.

Institutional controls for the marine unit will include prohibitions on activities that could damage the sediment caps including the erosion protection material and shoreline armoring. Prohibited activities will include digging and shellfish collection in the engineered cap areas and vessel anchoring. Institutional controls will also be needed for protection of habitat mitigation areas.

8.3 REPORTING AND RECORD KEEPING

As described in Section 7.3.1, upon completion of the cleanup action, a construction completion report will be prepared describing cleanup construction, providing key CQA/CQC records including pertinent progress surveys and as-built information and other supporting documentation. The construction completion report will serve as a comparative baseline for subsequent monitoring, inspections and operations and maintenance activities. Reports documenting post-construction inspections, operations, and maintenance activities, and confirmational monitoring will be prepared and submitted to Ecology for review. The OMMP will further specify record-keeping requirements for Site monitoring, inspections, and operations and maintenance including repairs and other modifications.

In accordance with WAC 173-34-420, periodic status reports summarizing post-construction activities and general site conditions will be submitted to Ecology on a 5-year frequency or as determined with Ecology. The status report will generally include the following topics on the activities and/or changes at the Site:

- Previous 5-year issues and resolutions.
- Land use changes.
- Summary of groundwater monitoring, stormwater control, sediment cap monitoring, upland cap monitoring and habitat mitigation monitoring for the following:
    - System or monitoring changes.
    - Accidents or upsets to the cleanup element.
    - Monitoring analytical results.
    - Changes planned for the next five years.
- Other features that have changes at the Site (e.g., landscaping, fencing, structures, etc.).

9.0 Schedule for Design, Permitting and Construction

A planning schedule for design, permitting and construction of the cleanup action has been developed as part of the EDR and to meet the requirements of MTCA Site Cleanup and Monitoring (WAC 173-340-400(4)(a)(vi)). The design, permitting and construction schedule is provided in Appendix G.

The schedule in Appendix G presents the current plan for design, permitting and construction of the Site cleanup action. However, the schedule may be affected by permitting agency review and/or other factors. As a result, the schedule provided in Appendix G should be considered preliminary. Scheduling for construction of the Site cleanup action will be developed prior to construction and in accordance with requirements of a future Consent Decree.

10.0 References

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Tables

Table 1-1

Dry and Wet Season Groundwater Elevations

South State Street EDR
Bellingham, Washington

Well[1]	Depth to Water (ft bgs)	Total Depth of Well (ft bgs)	TOC Elevation[2] (ft NAVD88)	Groundwater Elevation (ft NAVD88)	Date
MW-07	12.04	12.28	52.94	40.90	9/20/2021
	8.86	12.29	52.94	44.08	2/7/2022
MW-19	12.71	13.25	57.67	44.96	9/20/2021
	8.73	13.25	57.67	48.94	2/7/2022
MW-24	11.85	15.19	53.34	41.49	9/20/2021
	7.96	15.2	53.34	45.38	2/7/2022
MW-28	10.95	14.69	18.9	7.95	9/20/2021
	7.09	14.69	18.9	11.81	2/7/2022
MW-29	11.51	14.8	19.12	7.61	9/20/2021
	9.66	14.84	19.12	9.46	2/7/2022
MW-31	8.14	10.15	14.4	6.26	9/20/2021
	7.64	10.2	14.4	6.76	2/7/2022
MW-34	4.80	13.9	9.89	5.09	9/20/2021
	3.53	13.85	9.89	6.36	2/7/2022
MW-36	7.02	23.35	10.63	3.61	9/20/2021
	4.09	23.24	10.63	6.54	2/7/2022
MW-38	6.24	24.7	11.3	5.06	9/20/2021
	5.30	24.7	11.3	6.00	2/7/2022
MW-40	5.53	31.6	10.27	4.74	9/20/2021
	3.71	31.53	10.27	6.56	2/7/2022
MW-42	5.98	34.59	9.25	3.27	9/20/2021
	2.84	34.55	9.25	6.41	2/7/2022
MW-44	12.47	12.69	54.04	41.57	9/20/2021
	12.22	12.7	54.04	41.82	2/7/2022
MW-45	10.01	11.68	15.51	5.50	9/20/2021
	9.55	16.71	15.51	5.96	2/7/2022
MW-46	3.25	10.95	8.93	5.68	9/20/2021
	2.34	10.96	8.93	6.59	2/7/2022
MW-53	6.89	11.41	15.08	8.19	9/20/2021
	7.40	12	15.08	7.68	2/7/2022
MW-54	6.93	13.9	12.08	5.15	9/20/2021
	6.18	13.92	12.08	5.90	2/7/2022
MW-55	5.31	36.68	10.41	5.10	9/20/2021
	4.35	36.68	10.41	6.06	2/7/2022

Well[1]	Depth to Water (ft bgs)	Total Depth of Well (ft bgs)	TOC Elevation[2] (ft NAVD88)	Groundwater Elevation (ft NAVD88)	Date
MW-58	13.15	14.02	19.81	6.66	9/20/2021
	6.78	13.04	19.81	13.03	2/7/2022
MW-59	5.39	13.3	10.1	4.71	9/20/2021
	3.45	13.57	10.1	6.65	2/7/2022
MW-60	6.10	14.22	9.47	3.37	9/20/2021
	2.99	14.22	9.47	6.48	2/7/2022
MW-61	7.10	14.67	13.57	6.47	2/7/2022
MW-62	11.31	14.93	19.26	7.95	9/20/2021
	7.69	14.95	19.26	11.57	2/7/2022

Notes:

[1] Monitoring well locations are plotted on Figure 1-5.

[2] Top of casing elevation was surveyed by Larry Steele & Associates, a licensed surveyor, on September 2, 2021.

bgs = below ground surface

NAVD88 = North American Vertical Datum 1988

Table 2-1

Summary of Cleanup Levels

South State Street MGP Site
Bellingham, Washington

Indicator Hazardous Substance	Soil		Groundwater	Sediment	Indoor Air	Basis for Cleanup Level
	Vadose	Saturated				
Metals						
Selenium	7.4 mg/kg	0.5 mg/kg	71 µg/L	na	na	**Soil**: Protection of groundwater as surface water (based on toxicity to aquatic organisms), adjusted up to the PQL only for saturated soil. **GW**: Protection of surface water (based on toxicity to aquatic organisms).
Lead	250 mg/kg	250 mg/kg	na	na	na	**Soil**: Human health - based on direct contact.
VOCs						
Benzene	0.009 mg/kg	0.005 mg/kg	1.6 µg/L	na	0.32 µg/m^3	**Soil:** Protection of groundwater as surface water (based on fish consumption by people), adjusted up to the PQL only for saturated soil. **GW:** Protection of surface water (based on fish consumption by people). **Air:** Human health - based on inhalation of indoor air.
PAHs						
Naphthalene	2.3 mg/kg	0.12 mg/kg	83 µg/L	na	0.074 µg/m^3	**Soil:** Protection of benthic organisms in sediment via the groundwater pathway. **GW:** Protection of benthic organisms in sediment. **Air:** Human health - based on inhalation of indoor air.
cPAH TEQ	6.6 µg/kg	6.6 µg/kg	0.02 µg/L	229 µg/kg dw	na	**Soil**: Protection of groundwater as surface water (based on fish consumption by people), adjusted up to the derived PQL. **GW**: Protection of surface water (based on fish consumption by people); adjusted up to the derived PQL. **Sed**: Human and ecological health - bioaccumulative risks to people and ecological receptors (risk-based SCO).
Other						
Cyanide	0.57 mg/kg	0.1 mg/kg	0.005 mg/L	na	na	**Soil**: Protection of groundwater as surface water (based on toxicity to aquatic organisms), adjusted up to the PQL only for saturated soil. **GW**: Protection of surface water (based on toxicity to aquatic organisms), adjusted up to the PQL.

Notes:

cPAH = carcinogenic polycyclic aromatic hydrocarbon
CSL = cleanup screening level
dw = dry weight
GW = groundwater
mg/kg = milligram per kilogram
na = compound is not an indicator hazardous substance for this medium, therefore, no cleanup level is needed.
PAH = polycyclic aromatic hydrocarbons
PQL = practical quantitation limit
SMS = Sediment Management Standards
TEQ = toxic equivalent concentration
µg/kg = microgram per kilogram
µg/L = microgram per liter
µg/m^3 = microgram per cubic meter
VOC = volatile organic compound

Figures

Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Data Source: Open Street Map, 2023

Projection: NAD 1983 StatePlane Washington North FIPS 4601 Feet

Vicinity Map

South State Street MGP Site
Bellingham, Washington

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Figure 1-1

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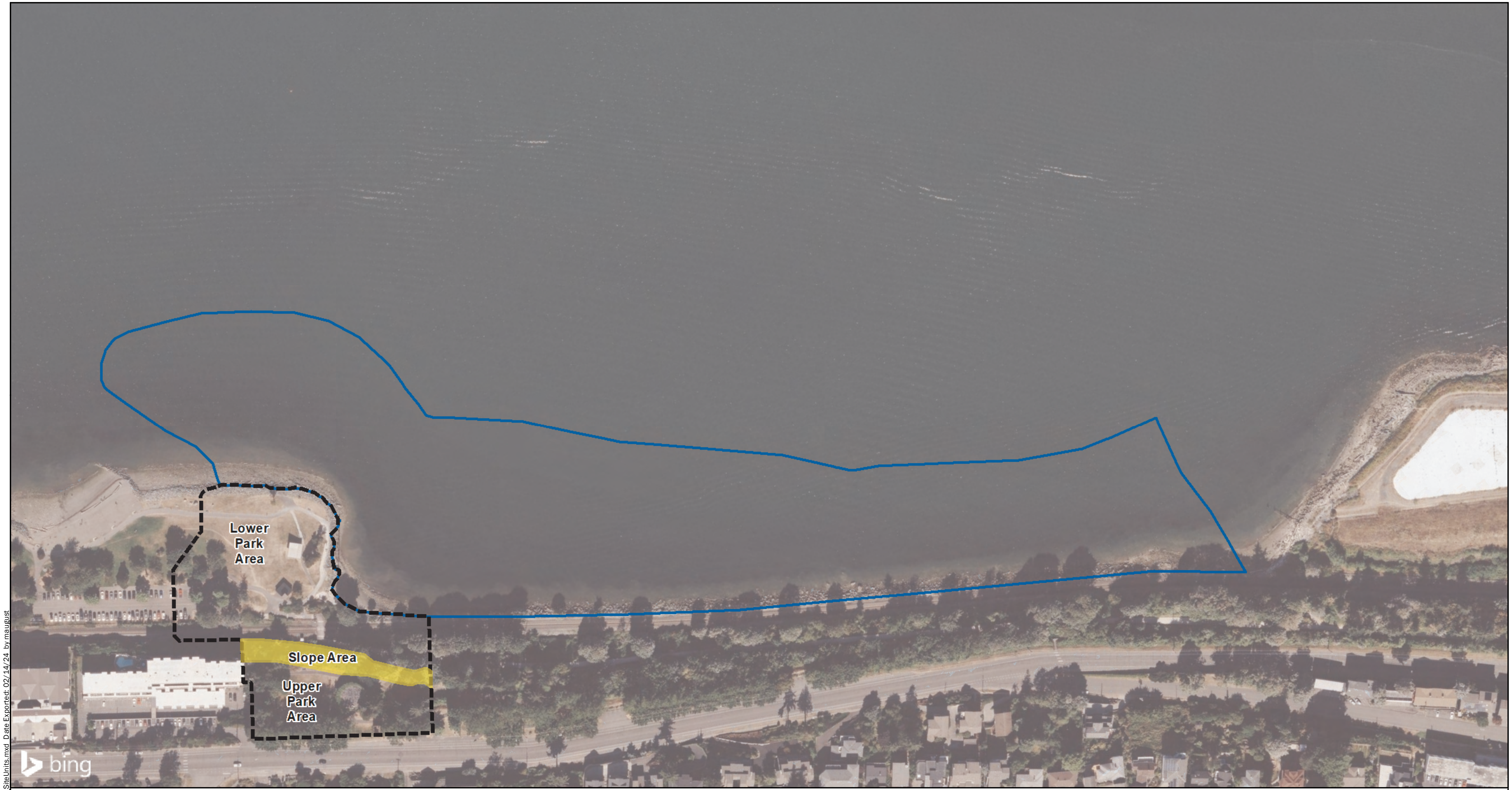


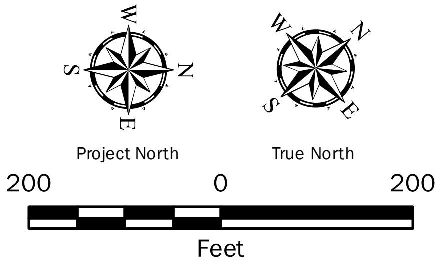
Notes:
1. The locations of all features shown are approximate.
2. Mean High Tide defines the boundary between the Upland Unit and Marine Unit.
3. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Data Source: DEAM 2023, Larry Steele and Associates 2021.
Survey data from David Evans and Associates, 2021.

Projection: NAD83 WA State Plane, N Zone, US Foot
Vertical Datum: NAVD88

Legend

▭ Upland Unit Boundary
▭ Marine Unit Boundary
🟨 Slope Area



Site Units

South State Street MGP Site
Bellingham, Washington

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Figure 1-2

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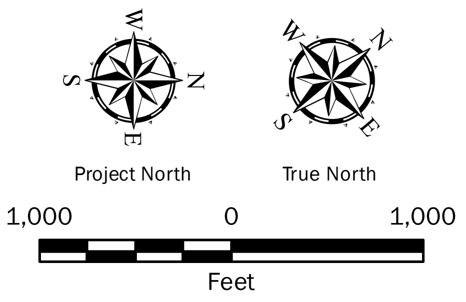
Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Data Source: Aerial imagery provided by ESRI.

Projection: NAD 1983 StatePlane Washington North FIPS 4601 Feet

Legend

🟧	South State Street MGP Site
🟦	Whatcom Waterway MTCA Cleanup Site Unit
☐	Other MTCA Cleanup Site



MTCA Cleanup Sites in Bellingham Bay

SSS MGP Site
Bellingham, Washington

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Figure 1-3

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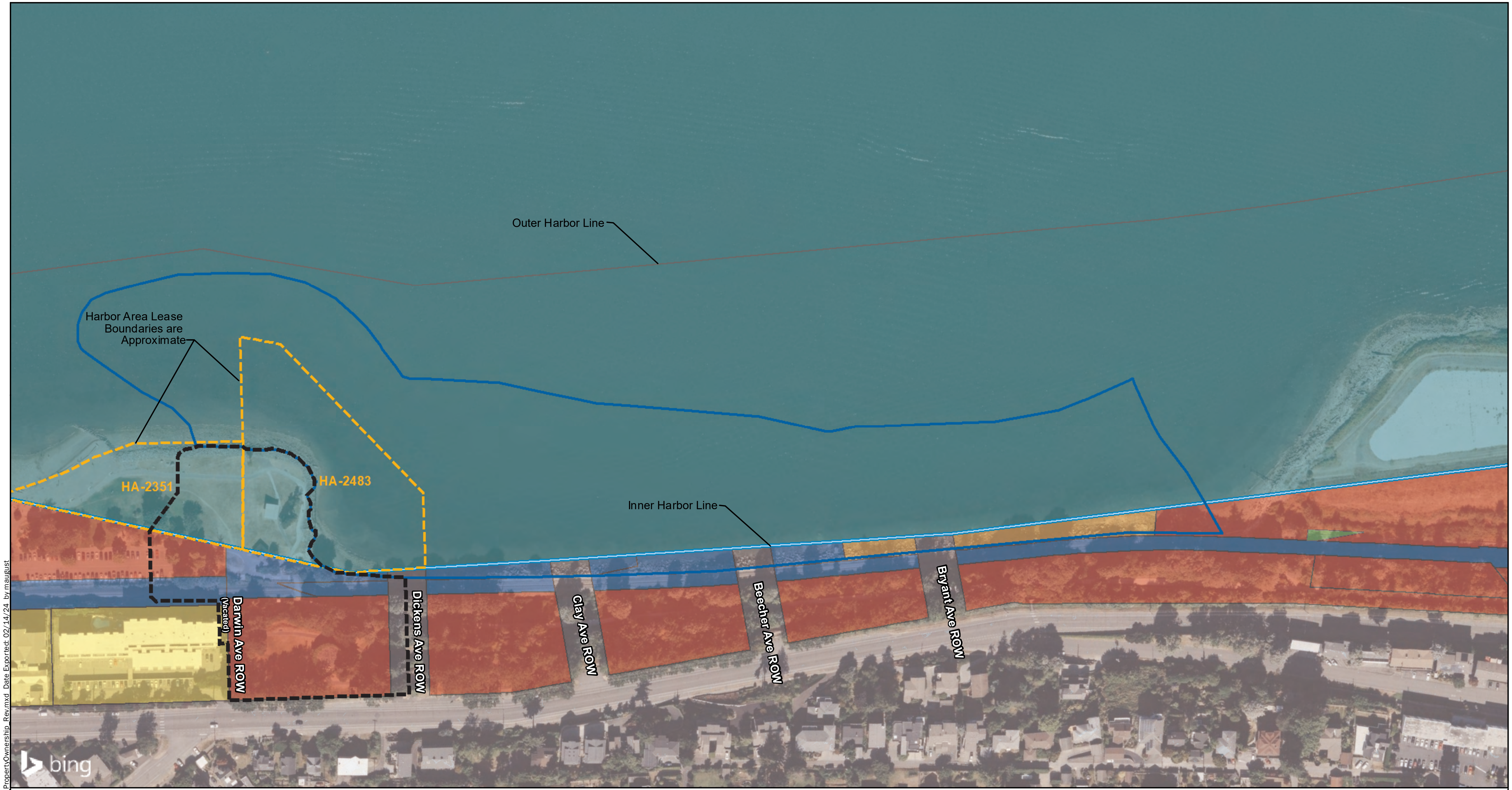


Notes:
1. The locations of all features shown are approximate.
2. Mean High Tide defines the boundary between the Upland Unit and Marine Unit.
3. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

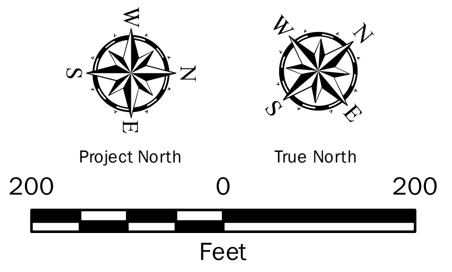
Data Source: Base data from City of Belligham, .
City of Bellingham - DNR Harbor Lease No. HA-2483, October 1978 & HA-2351, June 1975.
Projection: NAD83 WA State Plane, N Zone, US Foot
Vertical Datum: NAVD88

Legend

- ⬚ Upland Unit Boundary
- ▭ Marine Unit Boundary
- ⬚ Harbor Area Lease Boundary

Owner

- 🟦 BNSF Railway
- 🟥 City of Bellingham
- 🟧 Port of Bellingham
- 🟨 Private Residence
- ▨ State Owned Aquatic Lands
- 🟩 Whatcom County
- ☐ ROW



South State Street MGP Site and Property Ownership

South State Street MGP Site
Bellingham, Washington

GeoEngineers

Figure 1-4

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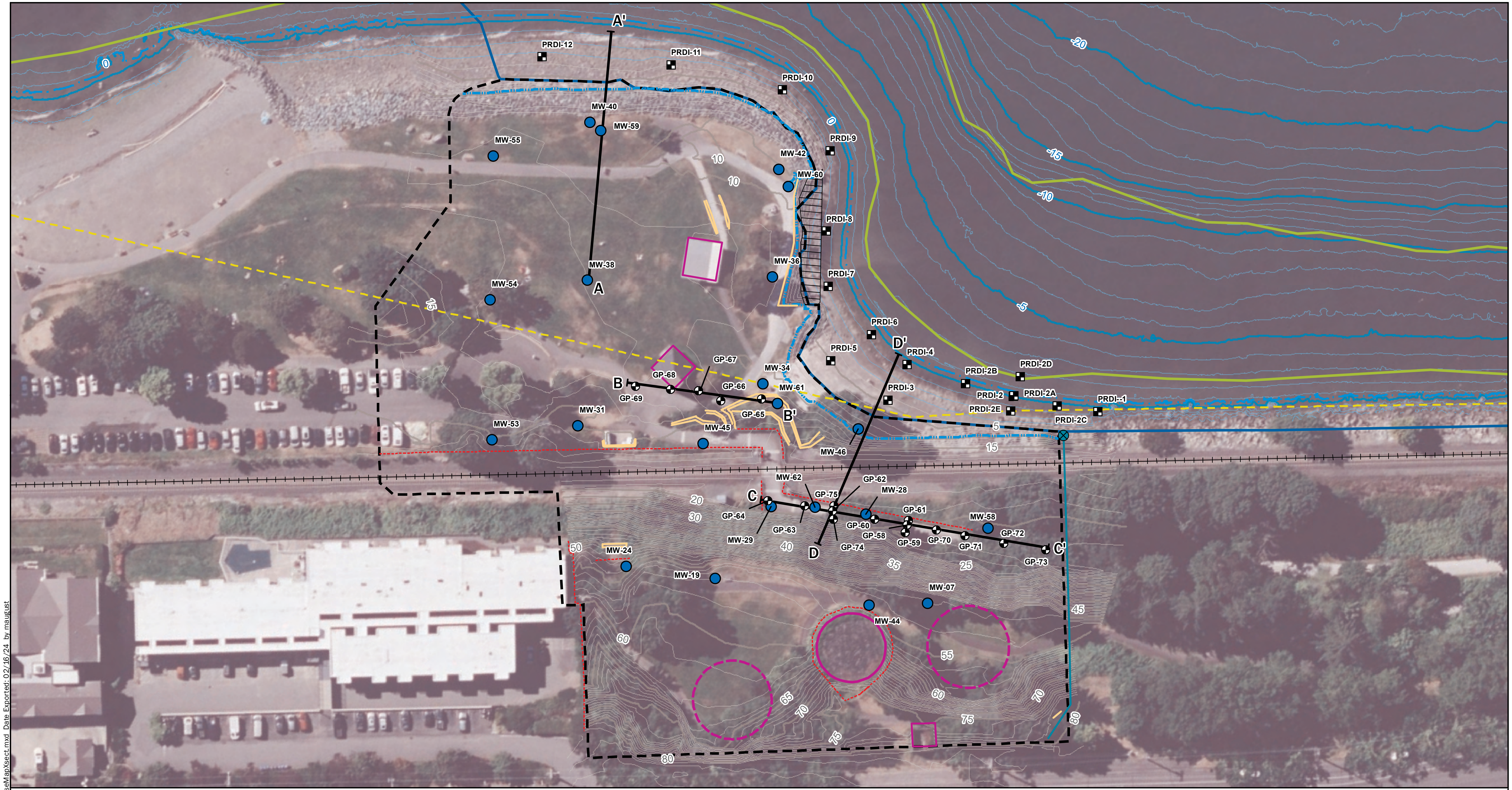

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Notes:
1. The locations of all features shown are approximate.
2. Mean High Tide defines the boundary between the Upland Unit and Marine Unit.
3. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Data Source: Base upland survey from Larry Steel Associates, 2022. Base bathymetric survey from David Evands and Assocates, 2021. Aerial from Bing.

Projection: NAD83 WA State Plane, N Zone, US Foot
Vertical Datum: NAVD88

Legend

- Direct Push Soil Boring
- Monitoring Well
- Intertidal Sediment and Porewater Sample Location
- Stormwater Outfall
- Stormwater Pipe
- Approximate Limits of Aquatic Vegetation
- Fence
- Retaining Wall
- BNSF Centerline
- Inner Harbor Line
- OHWM (9.70' NAVD88)
- MLLW (el. 0.48' NAVD88)
- Wood Pilings Area
- Site Structures
- Former Gas Holder
- Marine Unit Boundary
- Upland Unit Boundary

Bathymetry Contours
- 1-Foot Contour
- 5-foot Contour

Upland Contours
- 1-Foot Contour
- 5-foot Contour

Project North
True North

75 0 75
Feet

Geologic Cross Section Alignment

South State Street MGP Site
Bellingham, Washington

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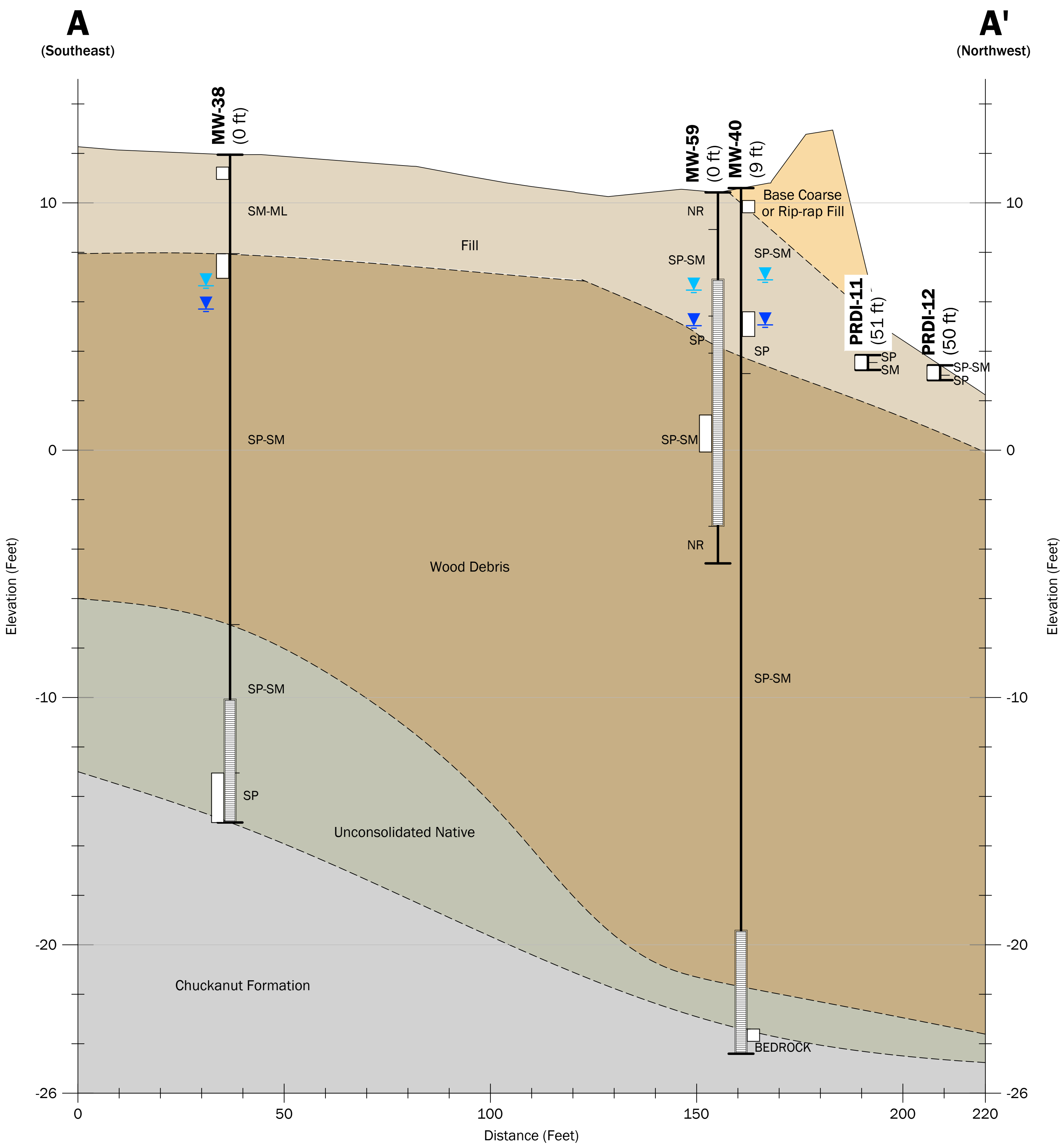
Figure 1-5



Legend

Boring ID (Offset)

- Boring
- Inferred Soil Contact
- SM Soil Classification
- Groundwater Measured February 2022
- Groundwater Measured September 2021
- Well Screen
- Soil Sample Interval Collected for Analysis (See Data Tables)
- ▨ Base Coarse or Rip-rap Fill
- ▨ Fill with Debris
- ▨ Wood Debris
- ▨ Fill
- ▨ Unconsolidated Native (Glaciomarine Drift Unit)
- ▨ Chuckanut Formation

Notes:

1. The subsurface conditions shown are based on interpolation between widely spaced explorations and should be considered approximate; actual subsurface conditions may vary from those shown.
2. This figure is for informational purposes only. It is intended to assist in the identification of features discussed in a related document. Data were compiled from sources as listed in this figure. The data sources do not guarantee these data are accurate or complete. There may have been updates to the data since the publication of this figure. This figure is a copy of a master document. The hard copy is stored by GeoEngineers, Inc. and will serve as the official document of record.

Datum: NAVD 88, unless otherwise noted.

30 0 30
Horizontal Scale in Feet
5 0 5
Vertical Scale in Feet
Vertical Exaggeration: 6X

Geologic Cross Section A-A'

South State Street MGP Site
Bellingham, Washington

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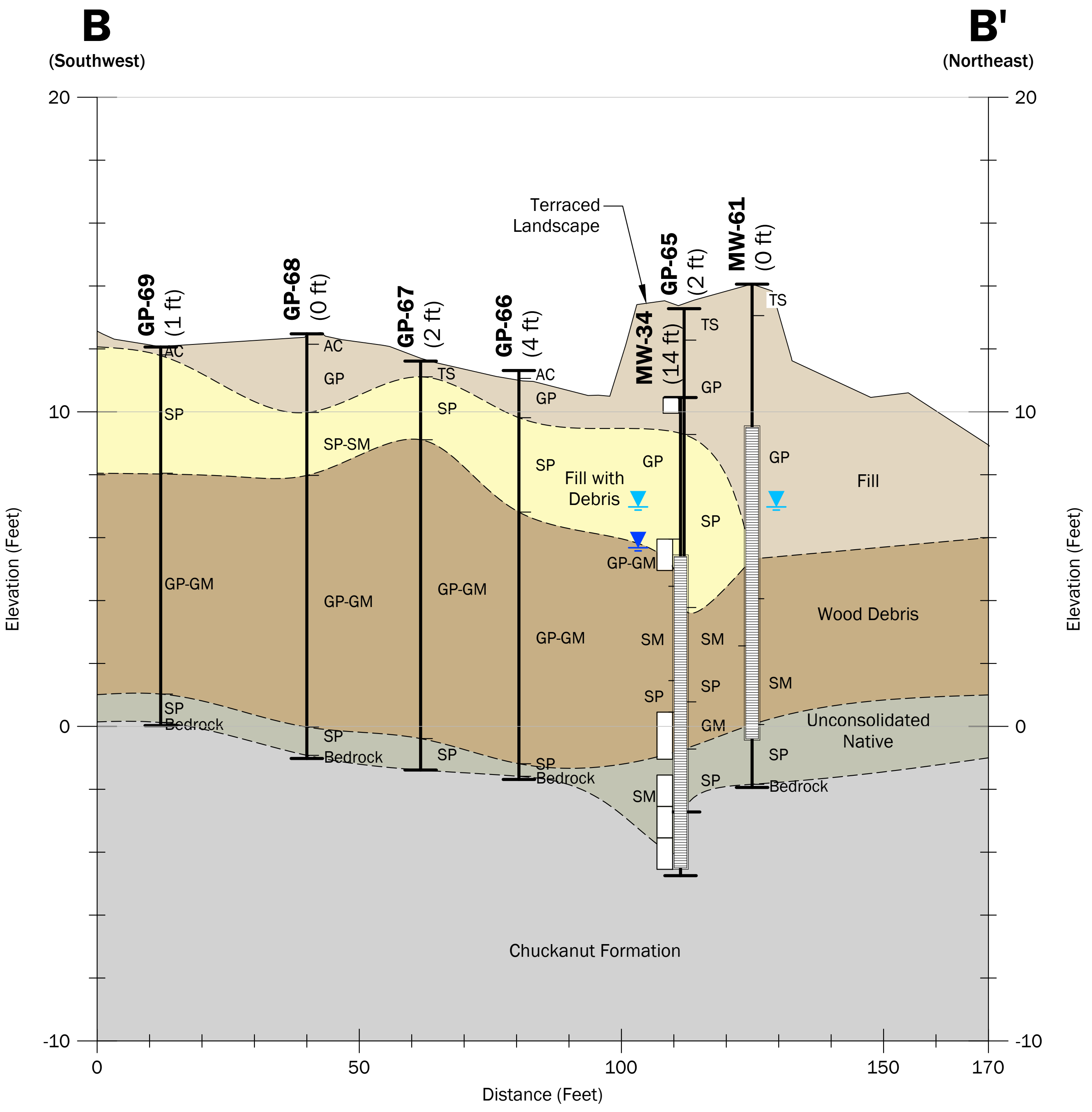
Figure 1-6

\\geoengineers.com\WAN\Projects\0\0186890\CAD\04\EDR Figures\0186890004_F1-6-F1-9_Cross-Sections.dwg TAB:1-6 Date Exported: 01/25/24 - 12:25 by mwoods



Legend

- Boring ID (Offset) — Boring
- Inferred Soil Contact
- SM — Soil Classification
- Groundwater Measured February 2022
- Groundwater Measured September 2021
- Well Screen
- Soil Sample Interval Collected for Analysis (See Data Tables)

- 🟧 Base Coarse or Rip-rap Fill
- 🟨 Fill with Debris
- 🟫 Wood Debris
- ⬜ Fill
- 🟩 Unconsolidated Native (Glaciomarine Drift Unit)
- ⬜ Chuckanut Formation

Notes:

1. The subsurface conditions shown are based on interpolation between widely spaced explorations and should be considered approximate; actual subsurface conditions may vary from those shown.
2. This figure is for informational purposes only. It is intended to assist in the identification of features discussed in a related document. Data were compiled from sources as listed in this figure. The data sources do not guarantee these data are accurate or complete. There may have been updates to the data since the publication of this figure. This figure is a copy of a master document. The hard copy is stored by GeoEngineers, Inc. and will serve as the official document of record.

Datum: NAVD 88, unless otherwise noted.

30 0 30
Horizontal Scale in Feet
5 0 5
Vertical Scale in Feet
Vertical Exaggeration: 6X

Geologic Cross Section B-B'

South State Street MGP Site
Bellingham, Washington

GeoEngineers

Figure 1-7

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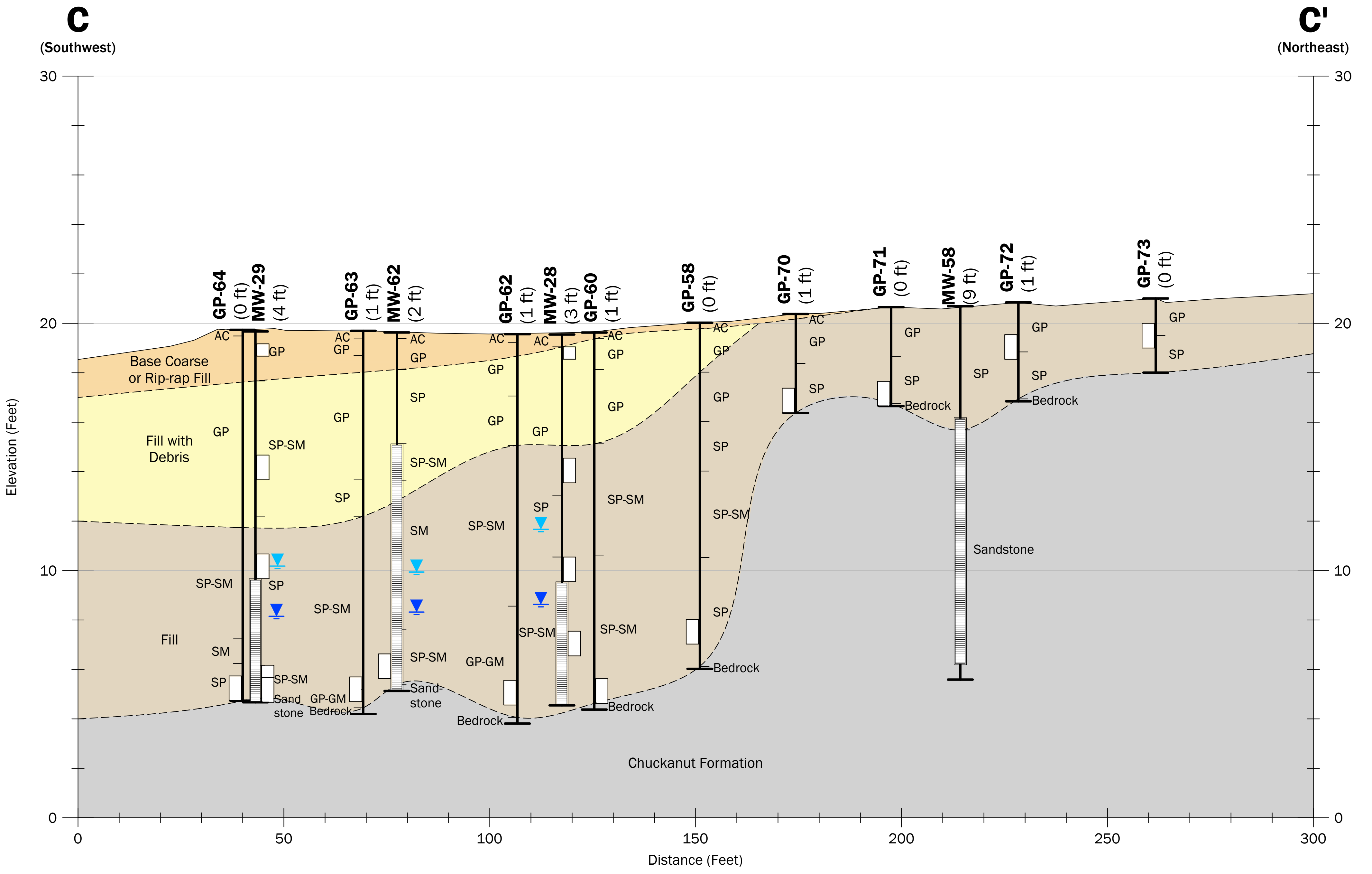

Legend

Boring ID (Offset)

Boring

Inferred Soil Contact

SM Soil Classification

▼ Groundwater Measured February 2022

▼ Groundwater Measured September 2021

▨ Well Screen

☐ Soil Sample Interval Collected for Analysis (See Data Tables)

🟧 Base Coarse or Rip-rap Fill

🟨 Fill with Debris

🟫 Wood Debris

▨ Fill

▨ Unconsolidated Native (Glaciomarine Drift Unit)

▨ Chuckanut Formation

Notes:

1. The subsurface conditions shown are based on interpolation between widely spaced explorations and should be considered approximate; actual subsurface conditions may vary from those shown.
2. This figure is for informational purposes only. It is intended to assist in the identification of features discussed in a related document. Data were compiled from sources as listed in this figure. The data sources do not guarantee these data are accurate or complete. There may have been updates to the data since the publication of this figure. This figure is a copy of a master document. The hard copy is stored by GeoEngineers, Inc. and will serve as the official document of record.

Datum: NAVD 88, unless otherwise noted.

30 0 30
Horizontal Scale in Feet
5 0 5
Vertical Scale in Feet
Vertical Exaggeration: 6X

Geologic Cross Section C-C'

South State Street MGP Site
Bellingham, Washington

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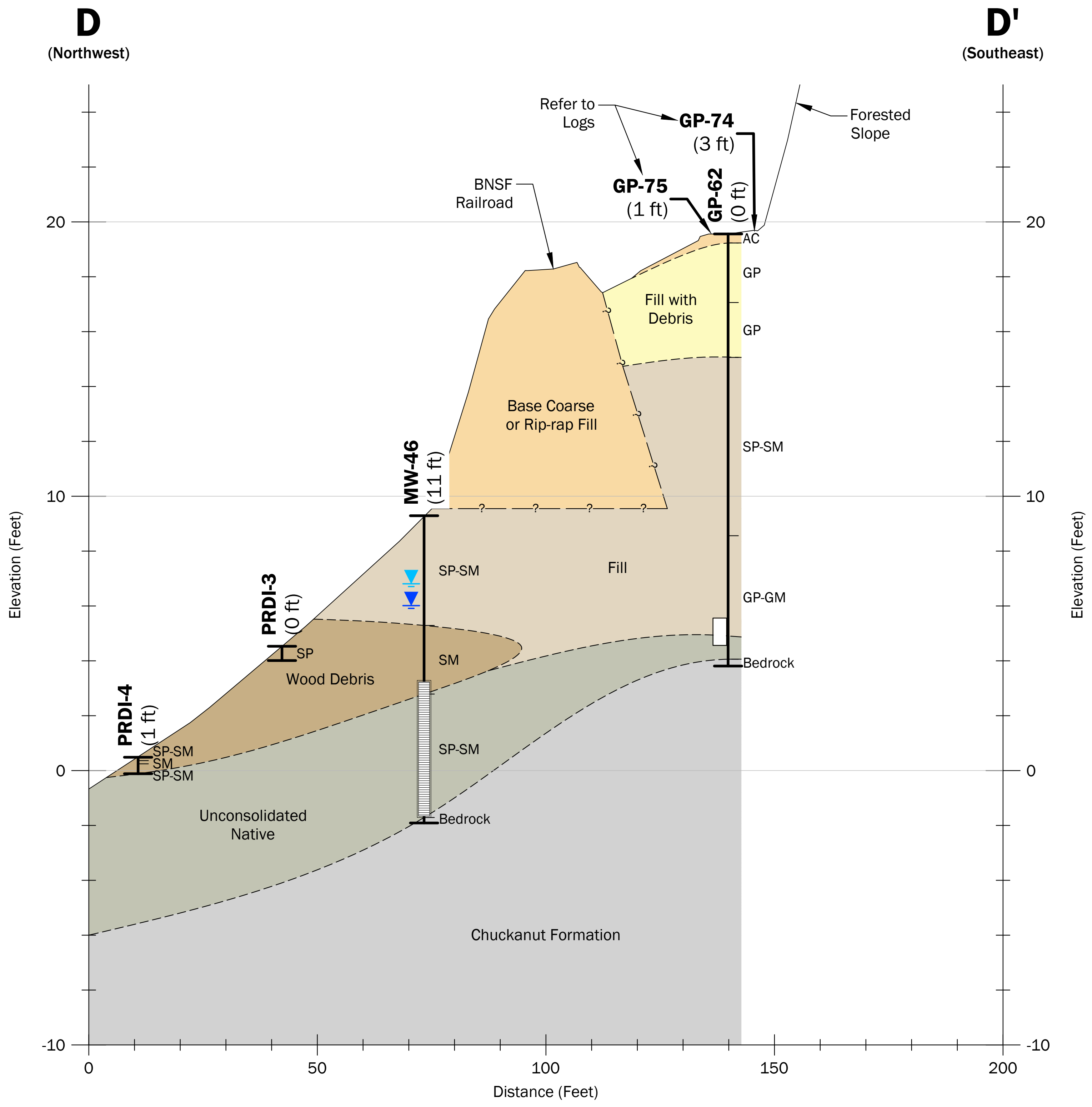
Figure 1-8

\\geoengineers.com\WAN\Projects\0\0186890\CAD\04\EDR Figures\0186890004_F1-6-F1-9_Cross-Sections.dwg TAB:1-8 Date Exported: 01/25/24 - 12:26 by mwoods



Legend

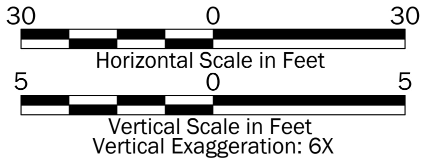
Boring ID (Offset)
Boring
Inferred Soil Contact
SM Soil Classification
▼ Groundwater Measured February 2022
▼ Groundwater Measured September 2021
▥ Well Screen
☐ Soil Sample Interval Collected for Analysis (See Data Tables)

▭	Base Coarse or Rip-rap Fill
▭	Fill with Debris
▭	Wood Debris
▭	Fill
▭	Unconsolidated Native (Glaciomarine Drift Unit)
▭	Chuckanut Formation

Notes:

1. The subsurface conditions shown are based on interpolation between widely spaced explorations and should be considered approximate; actual subsurface conditions may vary from those shown.
2. This figure is for informational purposes only. It is intended to assist in the identification of features discussed in a related document. Data were compiled from sources as listed in this figure. The data sources do not guarantee these data are accurate or complete. There may have been updates to the data since the publication of this figure. This figure is a copy of a master document. The hard copy is stored by GeoEngineers, Inc. and will serve as the official document of record.

Datum: NAVD 88, unless otherwise noted.



Vertical Exaggeration: 6X

Geologic Cross Section D-D'

South State Street MGP Site
Bellingham, Washington

GEOENGINEERS

Figure 1-9

Notes:
1. The locations of all features shown are approximate.
2. Mean High Tide defines the boundary between the Upland Unit and Marine Unit.
3. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.
4. MW-58 groundwater elevation not used because the well screen is located in bedrock and does not represent actual aquifer groundwater elevation.

Data Source: Base upland survey from Larry Steel Associates, 2022. Base bathymetric survey from David Evands and Assocates, 2021. Aerial from Bing.
Projection: NAD83 WA State Plane, N Zone, US Foot
Vertical Datum: NAVD88

Legend

◍	Monitoring Well and Elevation in ft NAVD88
⊗	Stormwater Outfall
—	Groundwater Contour 1ft
– –	Inferred Groundwater Contour
- - -	Inner Harbor Line
-··-	OHWM (9.70' NAVD88)
-·-	MLLW (el. 0.48' NAVD88)
⬚	Upland Unit Boundary
▭	Marine Unit Boundary
🟧	Slope Area
➔	Groundwater Flow Direction

Project North

True North

75 0 75

Feet

Groundwater Elevation Contour Map
Dry Season

South State Street MGP Site
Bellingham, Washington

GEOENGINEERS

Figure 1-10

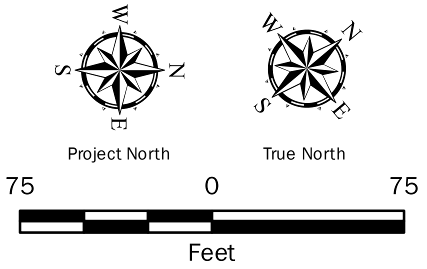
P:\0\0186890\GIS\MXDs\018689001_F1-11_GW_WetSeason.mxd Date Exported: 02/16/24 by maugust

Notes:
1. The locations of all features shown are approximate.
2. Mean High Tide defines the boundary between the Upland Unit and Marine Unit.
3. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.
4. MW-58 groundwater elevation not used because the well screen is located in bedrock and does not represent actual aquifer groundwater elevation.

Data Source: Base upland survey from Larry Steel Associates, 2022. Base bathymetric survey from David Evands and Assocates, 2021. Aerial from Bing.
Projection: NAD83 WA State Plane, N Zone, US Foot
Vertical Datum: NAVD88

Legend

⊕	Monitoring Well and Elevation in ft NAVD88
⊗	Stormwater Outfall
—	Groundwater Contour 1ft
– –	Inferred Groundwater Contour
- -	Inner Harbor Line
-··-	OHWM (9.70' NAVD88)
-·-	MLLW (el. 0.48' NAVD88)
⬚	Upland Unit Boundary
▭	Marine Unit Boundary
🟧	Slope Area
➚	Groundwater Flow Direction

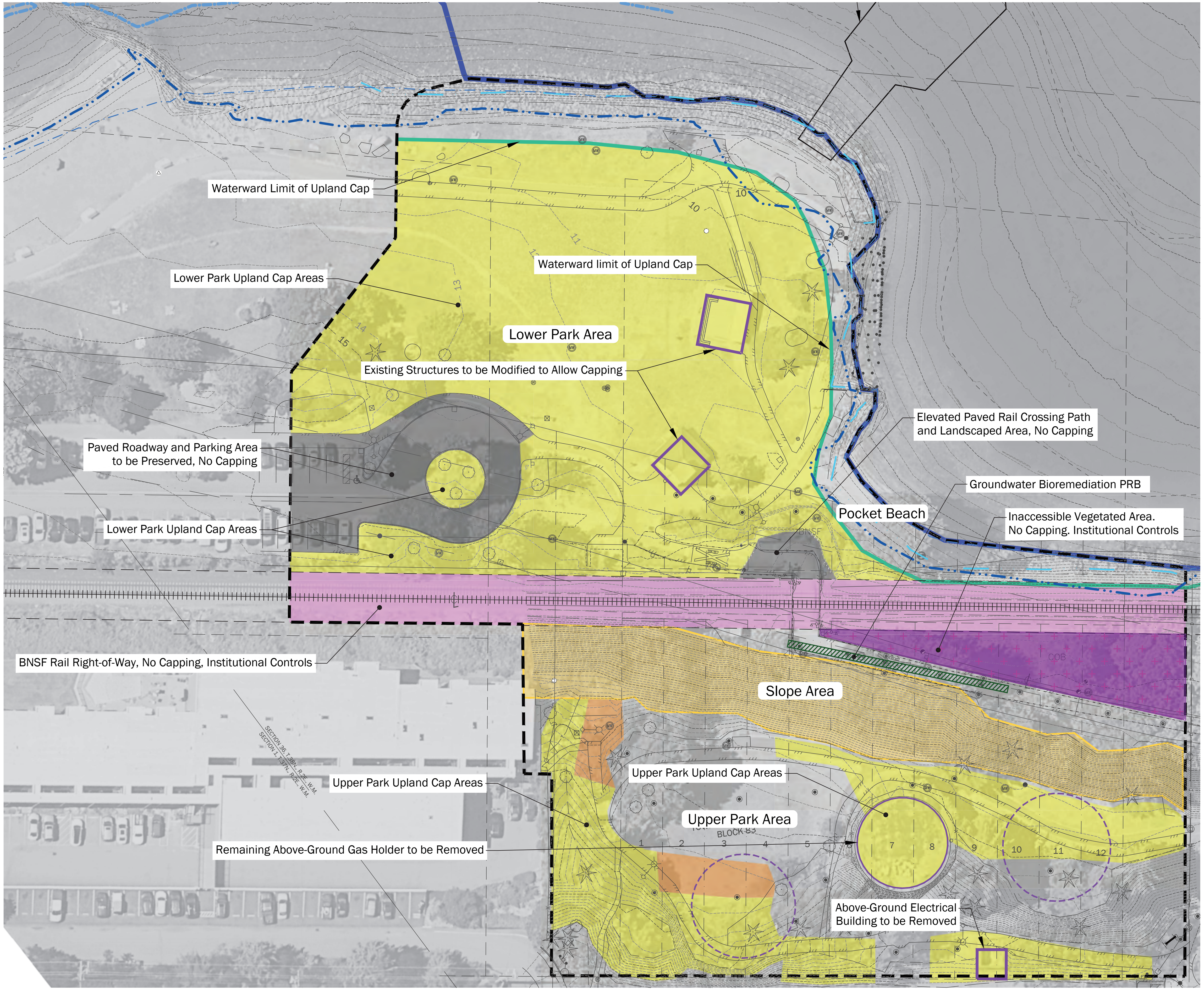


Groundwater Elevation Contour Map
Wet Season

South State Street MGP Site
Bellingham, Washington

GEOENGINEERS

Figure 1-11



Source(s):

- Aerial from Google Earth Pro, dated 7/31/22

Projection: Washington State Plane, North Zone, NAD83, US Foot

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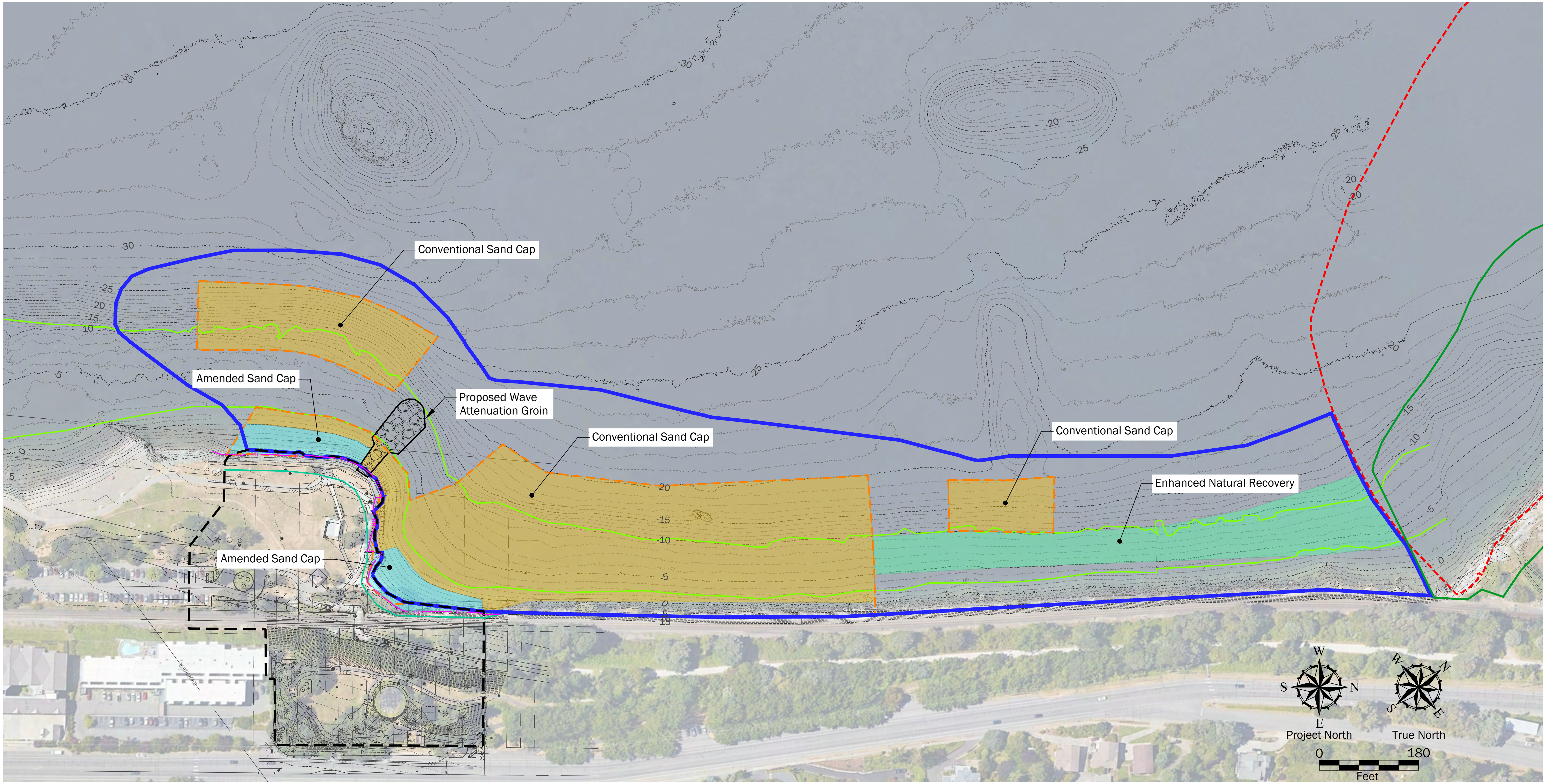
Cleanup Action - Upland Unit

South State Street MGP Site
Bellingham, Washington

GEOENGINEERS

Figure 3-1

\\geoengineers.com\WAN\Projects\0\0186890\CAD\04\EDR Figures\0186890004_F3-1_Cleanup Action Upland Unit.dwg 3-1 Date Exported:11/20/2024 11:19 AM - by Michael R. Woods



Note(s):

1. Elevations on this plan reference the North American Vertical Datum of 1988 (NAVD88).
2. Sample location data was collected during sediment sampling with GPS mounted on research vessel.

Source(s):

- Survey data from David Evans and Associates, 2021
- Aerial from Google Earth Pro, dated 7/31/22
- Cornwall 60% Design from Landau Associates, 2021

Projection: Washington State Plane, North Zone, NAD83, US Foot

Legend

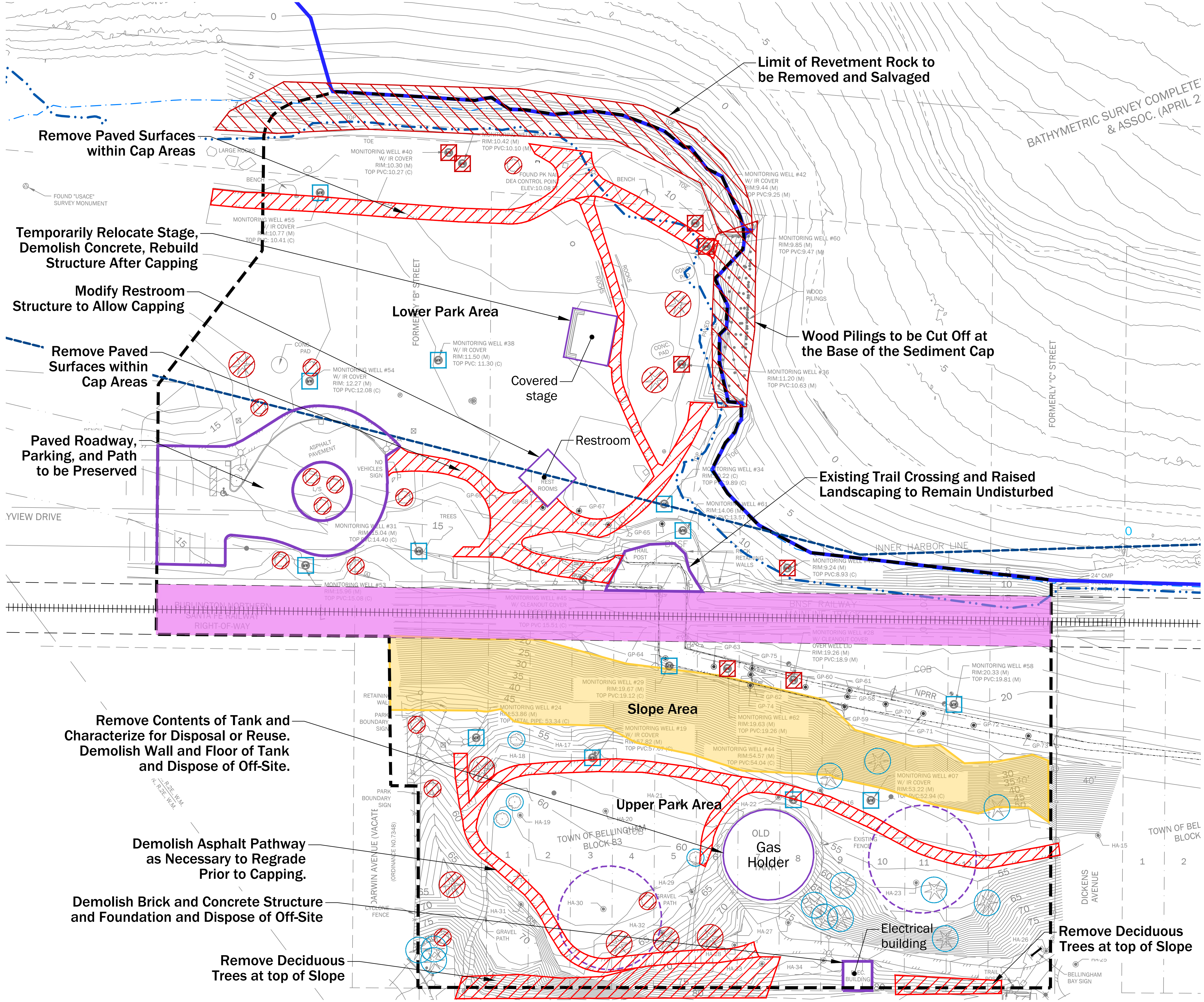
┅	Upland Unit Boundary
━	Marine Unit Boundary
┅	Haley Marine Unit Boundary
━	Cornwall Sediment Cap and Shoreline Stabilization Boundary (60% Design)
━	Approximate Limits of Aquatic Vegetation
HTL	Existing High Tide Level
🟨	Conventional Sand Cap (2-foot sand layer, erosion protection layer, and habitat substrate)
🟦	Amended Sand Cap (2-foot activated carbon amended sand layer, erosion protection layer, and habitat substrate)
🟩	ENR (4-in sand layer placed in 2 lifts to preserve eelgrass)
▨	Armor Stone Groin Structure (armor stone on 1-foot quarry spalls bedding layer)

Cleanup Action - Marine Unit

South State Street MGP Site
Bellingham, Washington

GeoEngineers

Figure 3-2



Legend

- ▭ Slope Area
- ▨ Railroad Right-of-Way
- ○ Existing Site Structures
- ◌ Former Gas Holder
- ◌ Gravel Path
- Existing Elevation Contour (Feet, NAVD88)
- High Tide Line (HTL) (el. 9.30-ft NAVD88)
- Ordinary High Water (OHW) (el. 9.99-ft NAVD88)
- Inner Harbor Line
- Upland Unit Boundary
- Marine Unit Boundary
- ▨ Marine (below HTL) Elements to be Demolished or Removed
- ▨ Upland (above HTL) Elements to be Demolished or Removed
- ☐ Existing Monitoring Well to be Protected During Construction
- ☒ Existing Monitoring Well to be Decommissioned During Construction
- ⊘ Deciduous tree to be removed
- ○ Deciduous tree to be preserved
- ⊘ Conifer tree to be removed
- ☆ Conifer tree to be preserved

Notes:

1. The locations of all features shown are approximate.
2. Mean High Tide defines the boundary between the Upland Unit and Marine Unit.
3. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Data Source: Survey data from Larry Steele and Assoc., 2012.

Projection: NAD83 WA State Planes, N Zone, US Foot
Vertical Datum: Mean Lower Low Water (MLLW)

W S N E
Project North

W N S E
True North

60 0 60
Feet

Demolition Plan

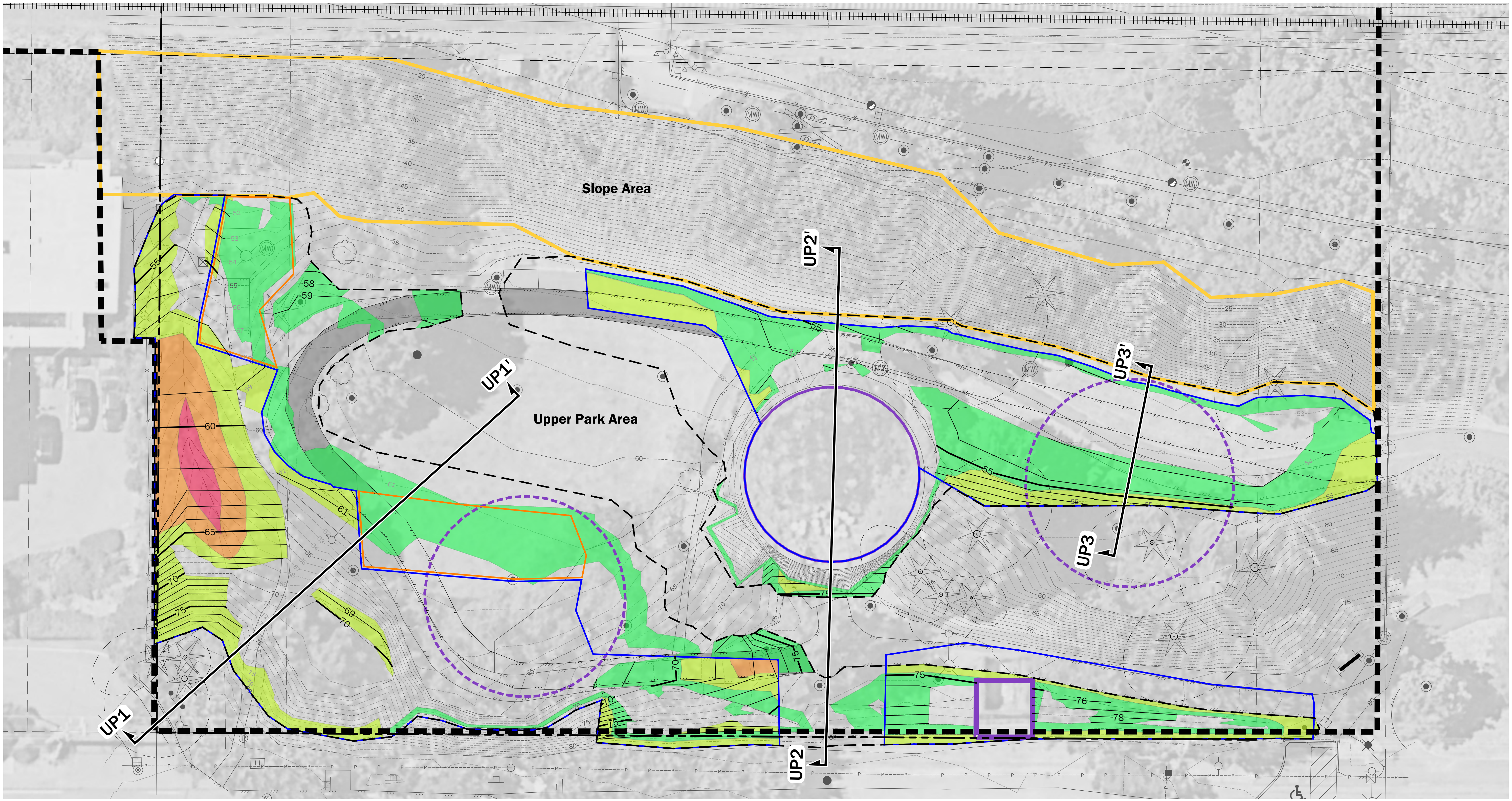
SSS MGP Site
Bellingham, Washington

GeoEngineers

Figure 6-1

\\geoengineers.com\WAN\Projects\0\0186890\CAD\04\EDR Figures\018689004_F6-1_Demolition Plan.dwg TAB:6-1 Date Exported: 08/09/24 - 14:26 by mwoods

\\geoengineers.com\WAN\Projects\0\0186890\CAD\04\EDR Figures\018689004_F6-2_Upper Park Grading Plan.dwg F06-2 Date Exported:2/15/2024 8:10 PM - by Michael R. Woods



Source(s):

- Aerial from Google Earth Pro, dated 7/31/22

Projection: Washington State Plane, North Zone, NAD83, US Foot

Legend

Existing Elevation Contour (Feet, NAVD88)
Elevation of Excavated Surface (Feet, NAVD88)
Railroad Right-of-Way Institutional Controls
Existing Site Structure
Former Gas Holder
Tree Trunk and Drip Line (field collected)
Upland Unit Boundary
Limits of Grading
Rerouted Paved Path
Targeted 1-foot Cap Area
Targeted 2-foot Cap Area
A A' Cross Section Location
🟥 Excavate ≥ 4 ft
🟧 Excavate 2 to 4 ft
🟨 Excavate 1 to 2 ft
🟩 Excavate ≤ 1 ft

W S N E Project North

W N S E True North

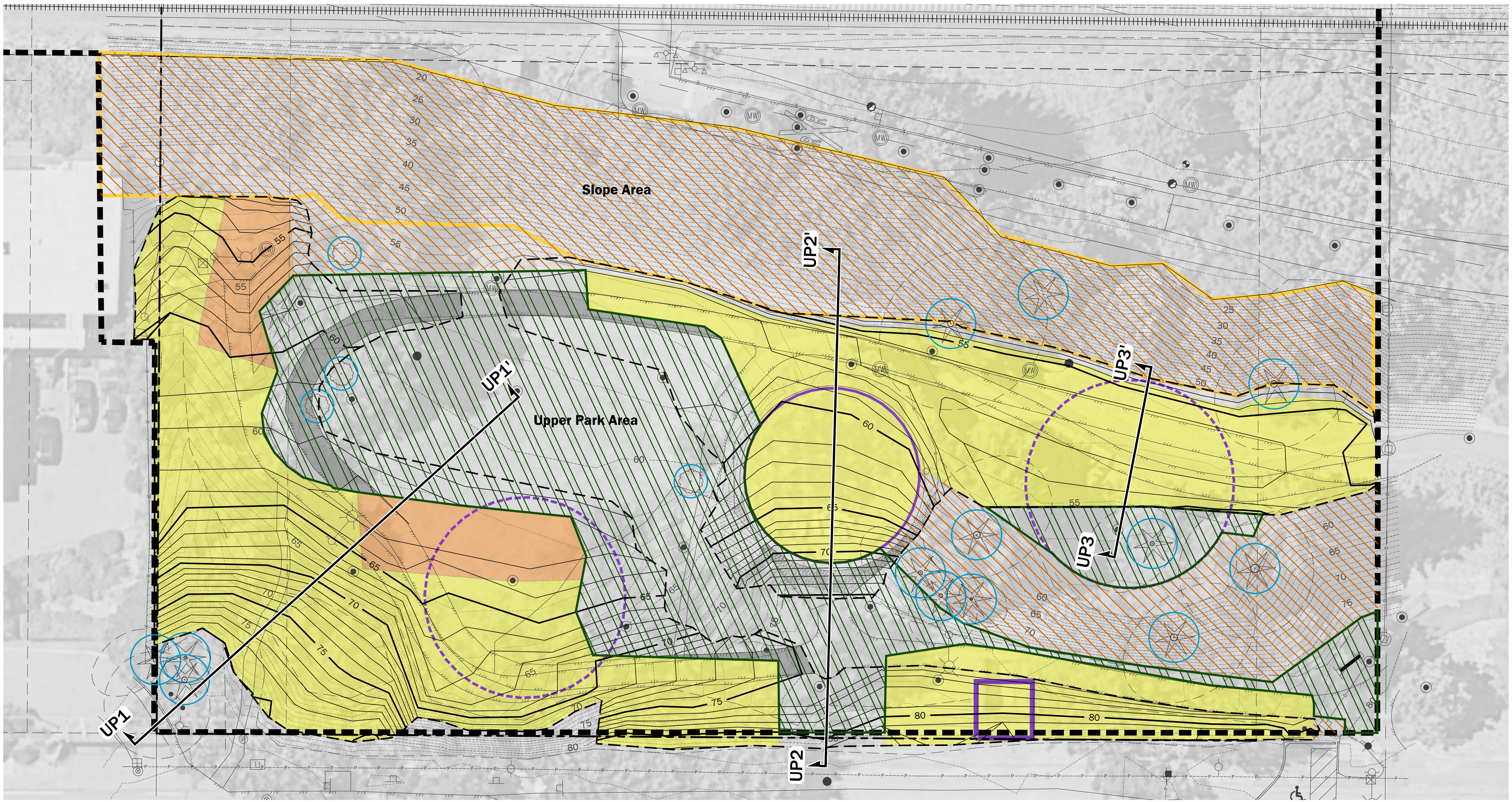
0 30 Feet

Upper Park Grading Plan

South State Street MGP Site
Bellingham, Washington

GeoEngineers

Figure 6-2



\\geoengineers.com\WAN\Projects\0\0186890\CAD\04\EDR Figures\018689004_F6-3_Upper Park Capping Plan.dwg F06-3 Date Exported:2/15/2024 8:08 PM - by Michael R. Woods

Source(s):
- Aerial from Google Earth Pro, dated 7/31/22

Projection: Washington State Plane, North Zone, NAD83, US Foot

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Legend

Existing Elevation Contour (Feet, NAVD88)
Final Elevation Contour (Feet, NAVD88)
Railroad Right-of-Way Institutional Controls
Existing Site Structure
Former Gas Holder
Tree Trunk and Drip Line (field collected)
▨ Vegetated Slopes - No Cap
▨ Areas Below Cleanup Levels or Existing Asphalt
Deciduous tree to be preserved
Conifer tree to be preserved
Rerouted Paved Path
Targeted 1 foot cap Areas
Targeted 2 foot Cap Areas
A A' Cross Section Location

W S N E
Project North

W N S E
True North

0 30
Feet

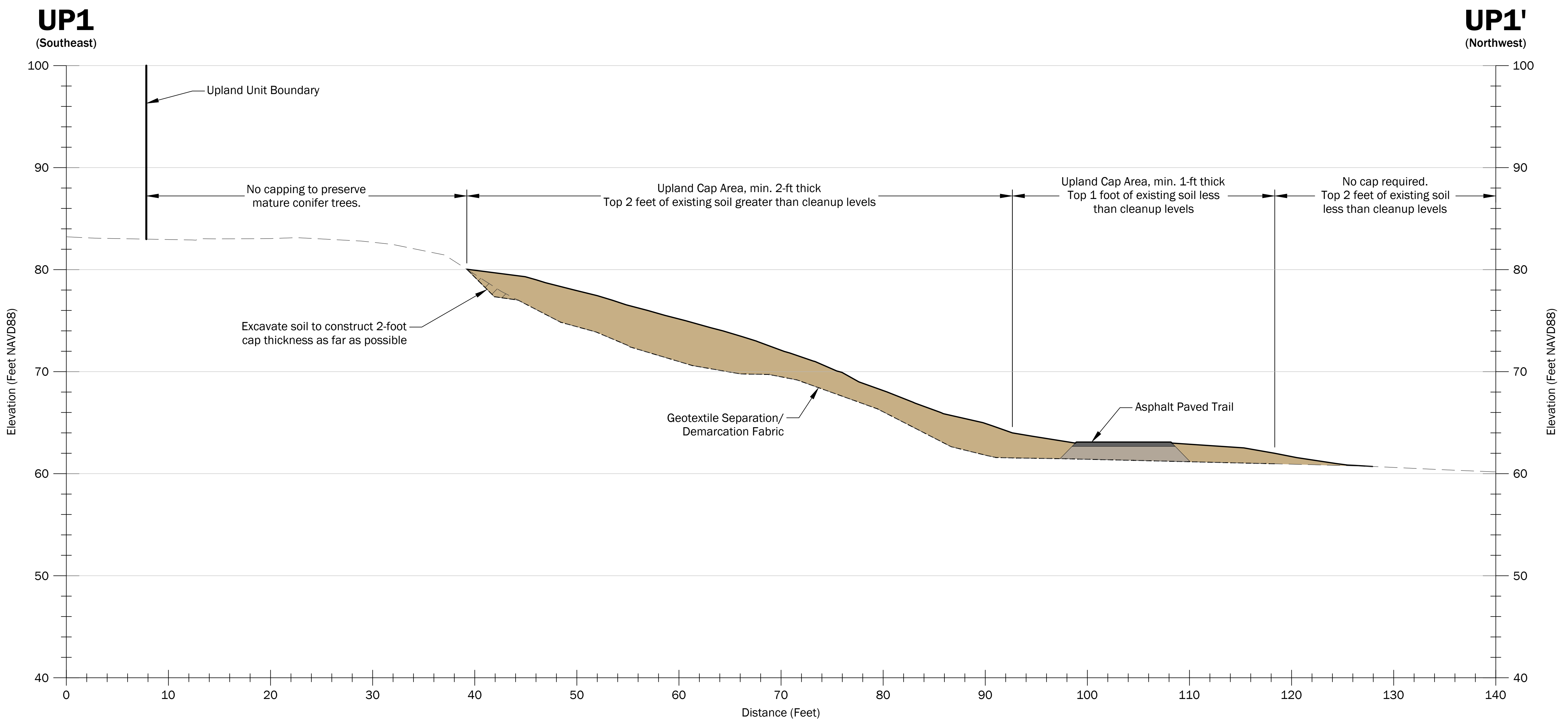
Upper Park Capping Plan

South State Street MGP Site
Bellingham, Washington

GeoEngineers

Figure 6-3

\\geoengineers.com\WAN\Projects\0\0186890\CAD\04\EDR Figures\018689004_F6-4_Upper Park Capping Sections.dwg F06-4-1 Date Exported:2/13/2024 5:28 PM - by Michael R. Woods



Notes:

1. The subsurface conditions shown are based on interpolation between widely spaced explorations and should be considered approximate; actual subsurface conditions may vary from those shown.
2. This figure is for informational purposes only. It is intended to assist in the identification of features discussed in a related document. Data were compiled from sources as listed in this figure. The data sources do not guarantee these data are accurate or complete. There may have been updates to the data since the publication of this figure. This figure is a copy of a master document. The hard copy is stored by GeoEngineers, Inc. and will serve as the official document of record.

Datum: NAVD 88, unless otherwise noted.

Legend

— — —	Existing Ground Surface
———	Cap Final Surface
- - - - -	Geotextile Separation/ Demarcation Fabric
▨	Pre-Cap Excavation
🟫	Topsoil Upland Cap Material
🟨	Clean Fill Upland Cap Material
🟪	Excavated Soil Relocated for use as Fill
▬	Asphalt Paved Trail and Gravel Base Course

10 0 10
Horizontal Scale in Feet

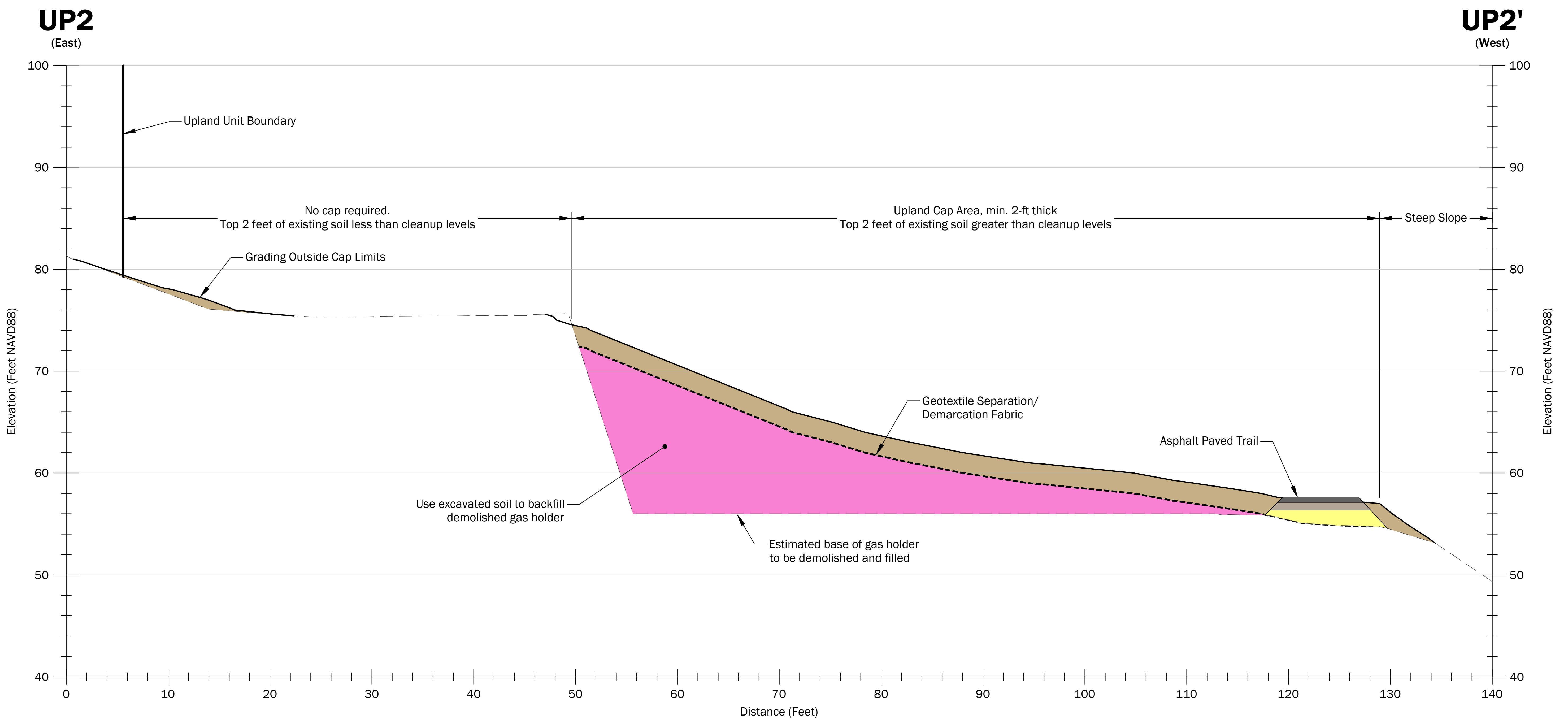
10 0 10
Vertical Scale in Feet
Vertical Exaggeration = 1X

Upper Park Capping Section UP1 -UP1'

South State Street MGP Site
Bellingham, Washington

GeoEngineers

Figure 6-4A



Notes:

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Datum: NAVD 88, unless otherwise noted.

Legend

— — — Existing Ground Surface

—— Cap Final Surface

- - - - Geotextile Separation/ Demarcation Fabric

▨ Pre-Cap Excavation

🟫 Topsoil Upland Cap Material

🟨 Clean Fill Upland Cap Material

🟪 Excavated Soil Relocated for use as Fill

▬ Asphalt Paved Trail and Gravel Base Course

10 0 10
Horizontal Scale in Feet
10 0 10
Vertical Scale in Feet
Vertical Exaggeration = 1X

Upper Park Capping Section UP2 -UP2'

South State Street MGP Site
Bellingham, Washington

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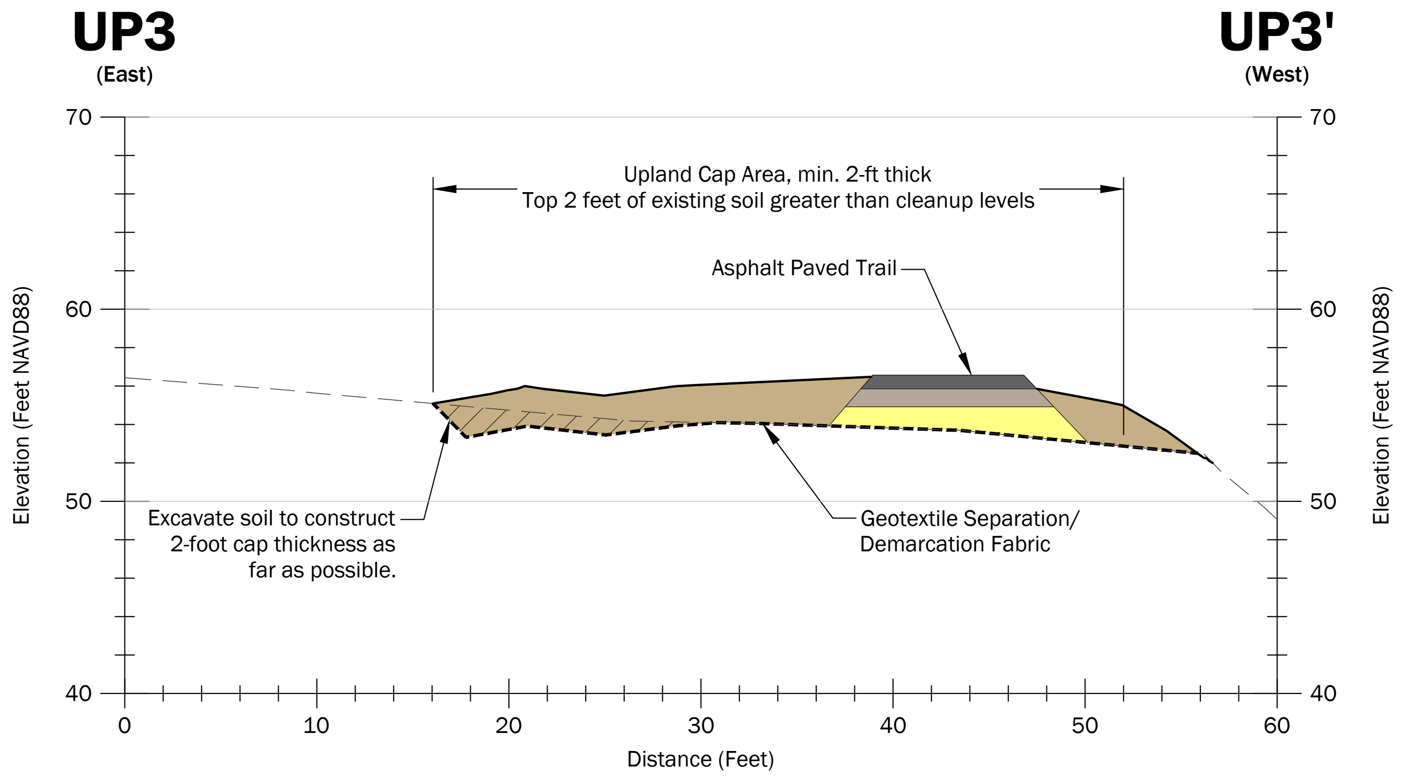
Figure 6-4B

\\geoengineers.com\WAN\Projects\0\0186890\CAD\04\EDR Figures\018689004_F6-4_Upper Park Capping Sections.dwg F06-4-2 Date Exported:2/13/2024 5:28 PM - by Michael R. Woods



Notes:

1. The subsurface conditions shown are based on interpolation between widely spaced explorations and should be considered approximate; actual subsurface conditions may vary from those shown.
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Datum: NAVD 88, unless otherwise noted.

Legend

- – – – Existing Ground Surface
- —— Cap Final Surface
- - - - - Geotextile Separation/ Demarcation Fabric
- ▨ Pre-Cap Excavation
- 🟫 Topsoil Upland Cap Material
- 🟨 Clean Fill Upland Cap Material
- 🟪 Excavated Soil Relocated for use as Fill
- ▬ Asphalt Paved Trail and Gravel Base Course

10 0 10
Horizontal Scale in Feet
10 0 10
Vertical Scale in Feet
Vertical Exaggeration = 1X

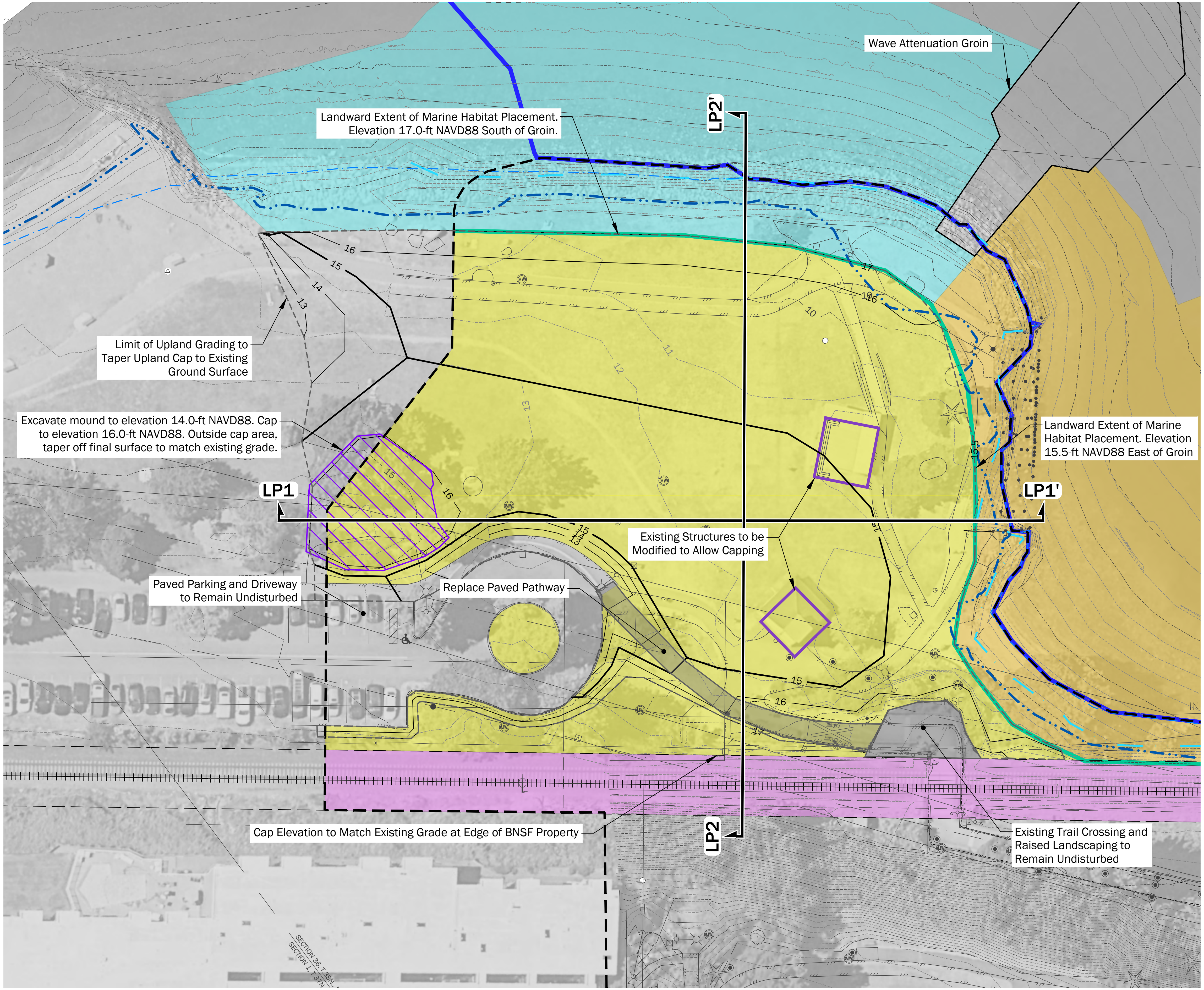
Upper Park Capping Section UP3 -UP3'

South State Street MGP Site
Bellingham, Washington

GeoEngineers

Figure 6-4C

\\geoengineers.com\WAN\Projects\0\0186890\CAD\04\EDR Figures\018689004_F6-4_Upper Park Capping Sections.dwg F06-4-3 Date Exported:2/15/2024 8:21 PM - by Michael R. Woods



Source(s):

- Aerial from Google Earth Pro, dated 7/31/22

Projection: Washington State Plane, North Zone, NAD83, US Foot

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Lower Park Capping Plan

South State Street MGP Site
Bellingham, Washington

GEOENGINEERS

Figure 6-5

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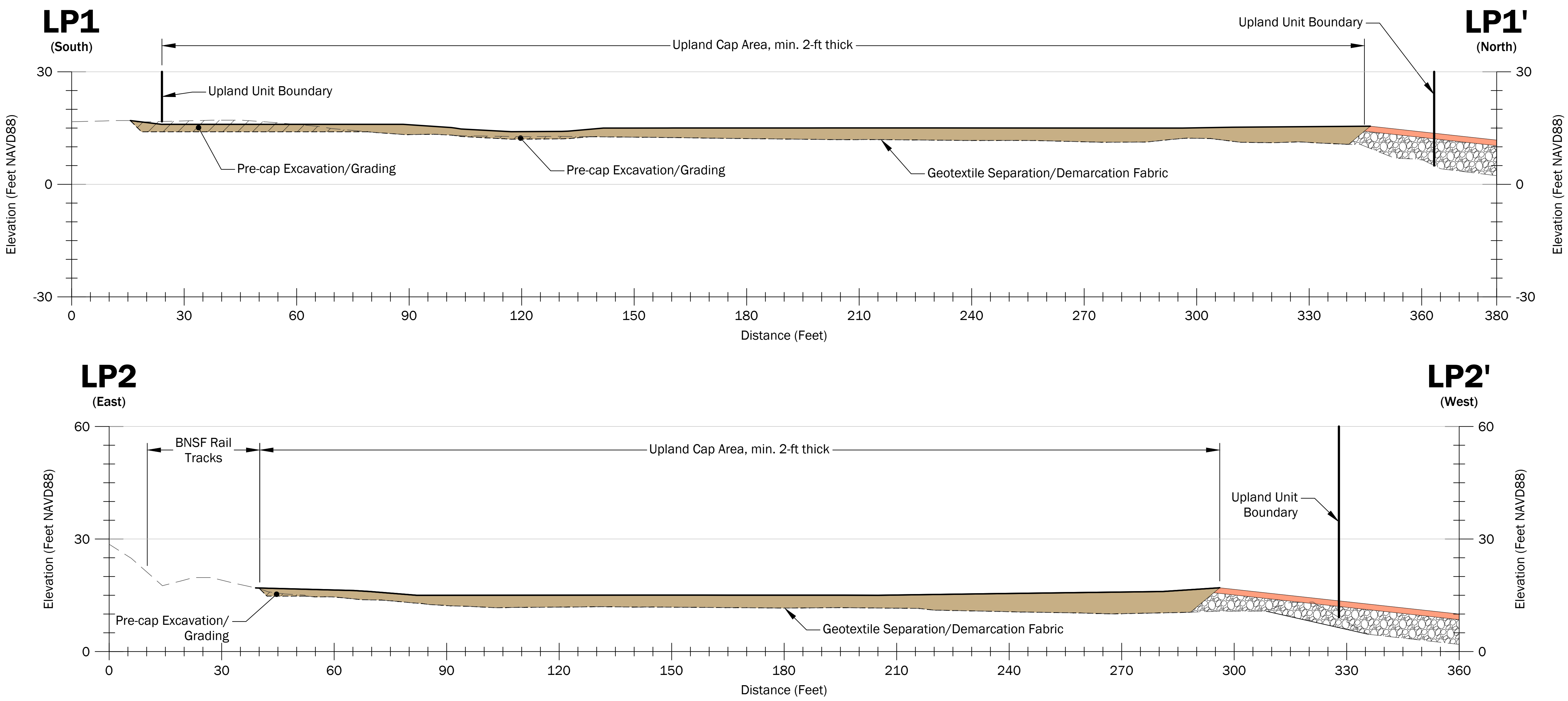

Notes:

1. The subsurface conditions shown are based on interpolation between widely spaced explorations and should be considered approximate; actual subsurface conditions may vary from those shown.
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Datum: NAVD 88, unless otherwise noted.

Legend

- – – – Existing Ground Surface
- ── Cap Final Surface
- - - - - Geotextile Separation/ Demarcation Fabric
- ▨ Pre-Cap Excavation
- ■ Topsoil Upland Cap Material

30 0 30
Horizontal Scale in Feet
30 0 30
Vertical Scale in Feet
Vertical Exaggeration = 1X

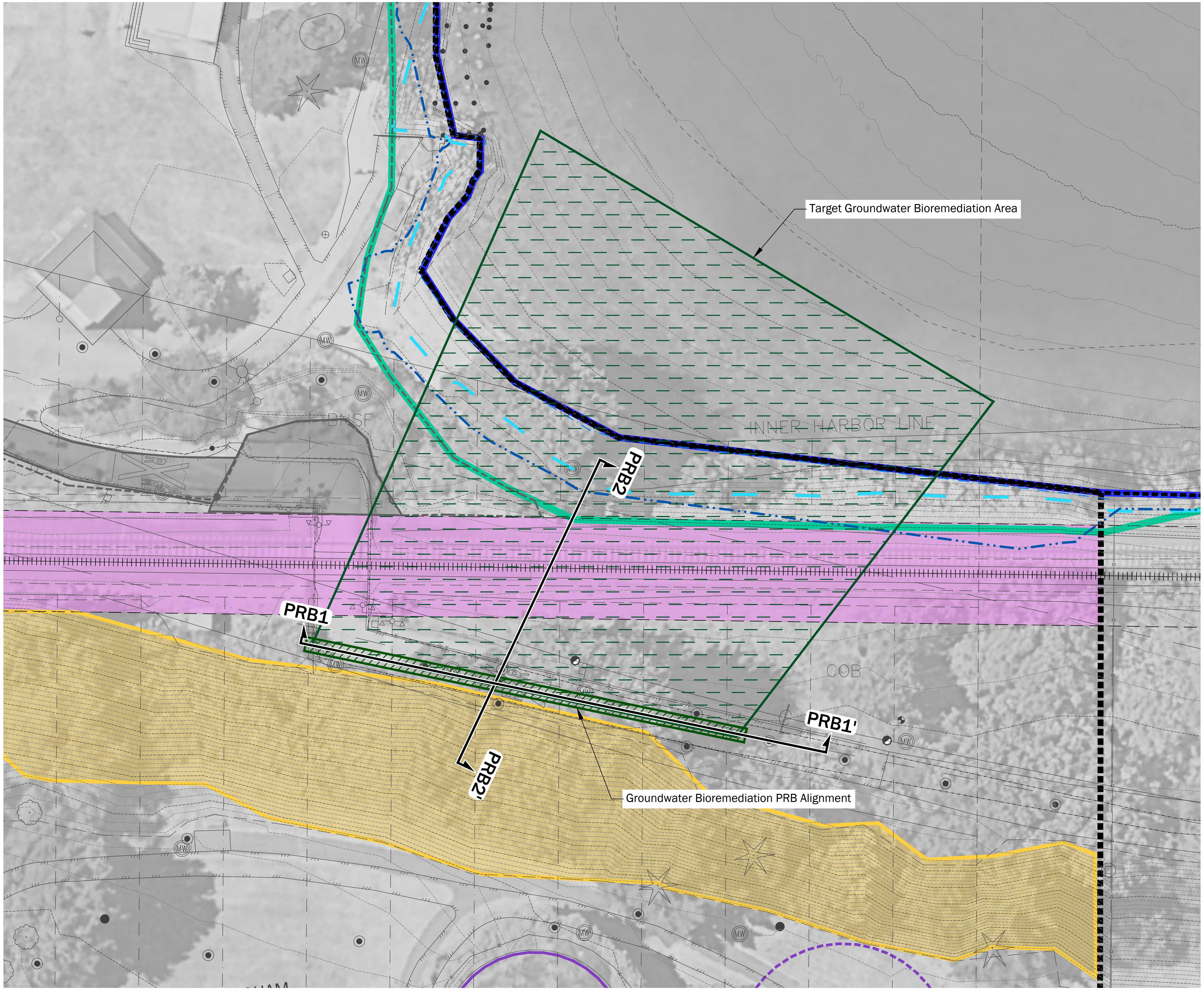
Lower Park Upland Cap Sections

South State Street MGP Site
Bellingham, Washington

GeoEngineers

Figure 6-6

\\geoengineers.com\WAN\Projects\0\0186890\CAD\04\EDR Figures\0186890004_F6-6_Lower Park Capping Sections.dwg 6-6 Date Exported:2/13/2024 6:11 PM - by Michael R. Woods



Legend

- Existing Elevation Contour (Feet, NAVD88)
- Final Elevation Contour (Feet, NAVD88)
- Railroad Right-of-Way Institutional Controls
- Existing Site Structure
- Gravel Path
- Ordinary High Water (OHW) (el. 9.99-ft NAVD88)
- High Tide Line (HTL) (el. 9.30-ft NAVD88)
- Upland Unit Boundary
- Marine Unit Boundary
- Slope Area - Monitor Vegetation and Slope Stability
- Targeted Groundwater Bioremediation Area
- Groundwater Bioremediation PRB Alignment
- A A' Cross Section Location

Source(s):

- Aerial from Google Earth Pro, dated 7/31/22

Projection: Washington State Plane, North Zone, NAD83, US Foot

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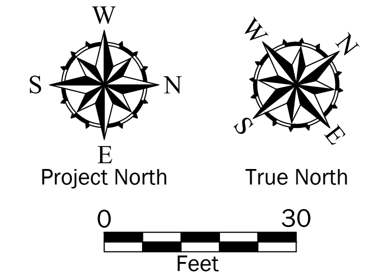


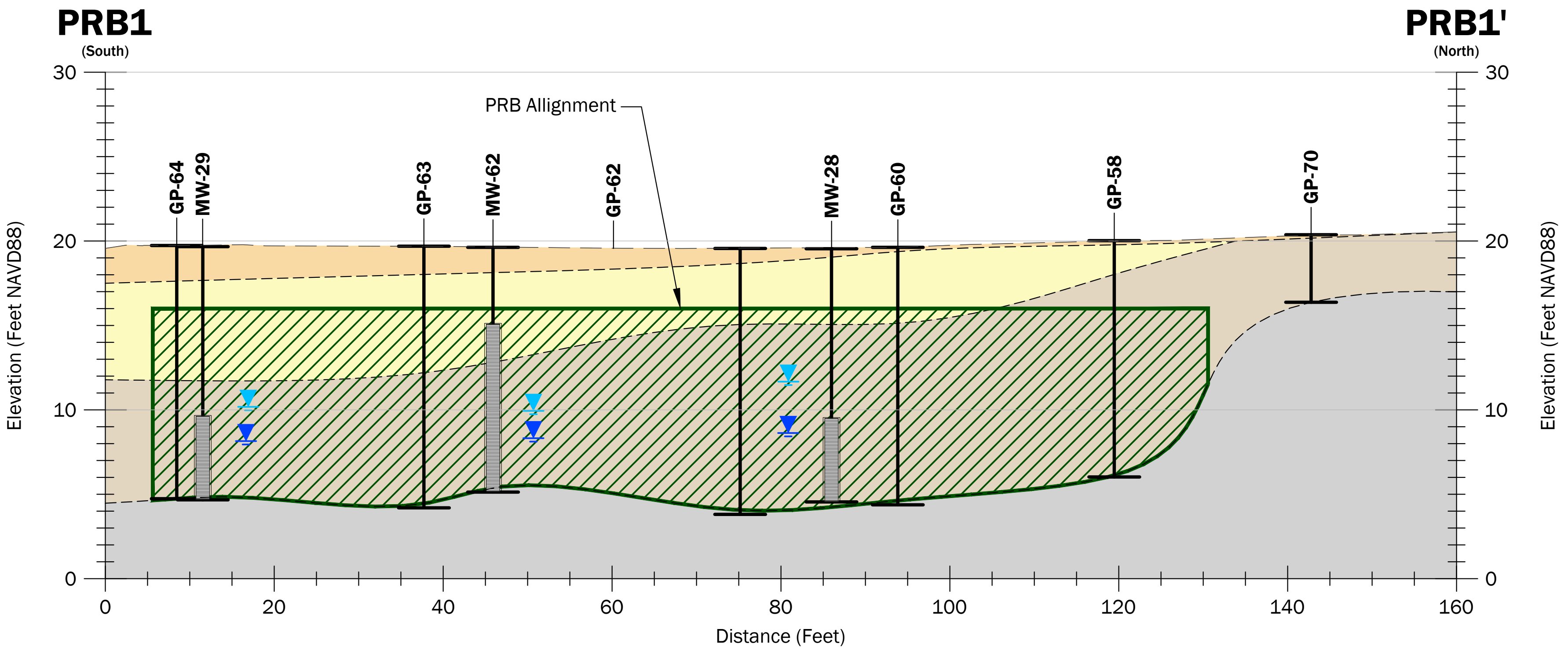
Groundwater Enhanced Bioremediation Plan

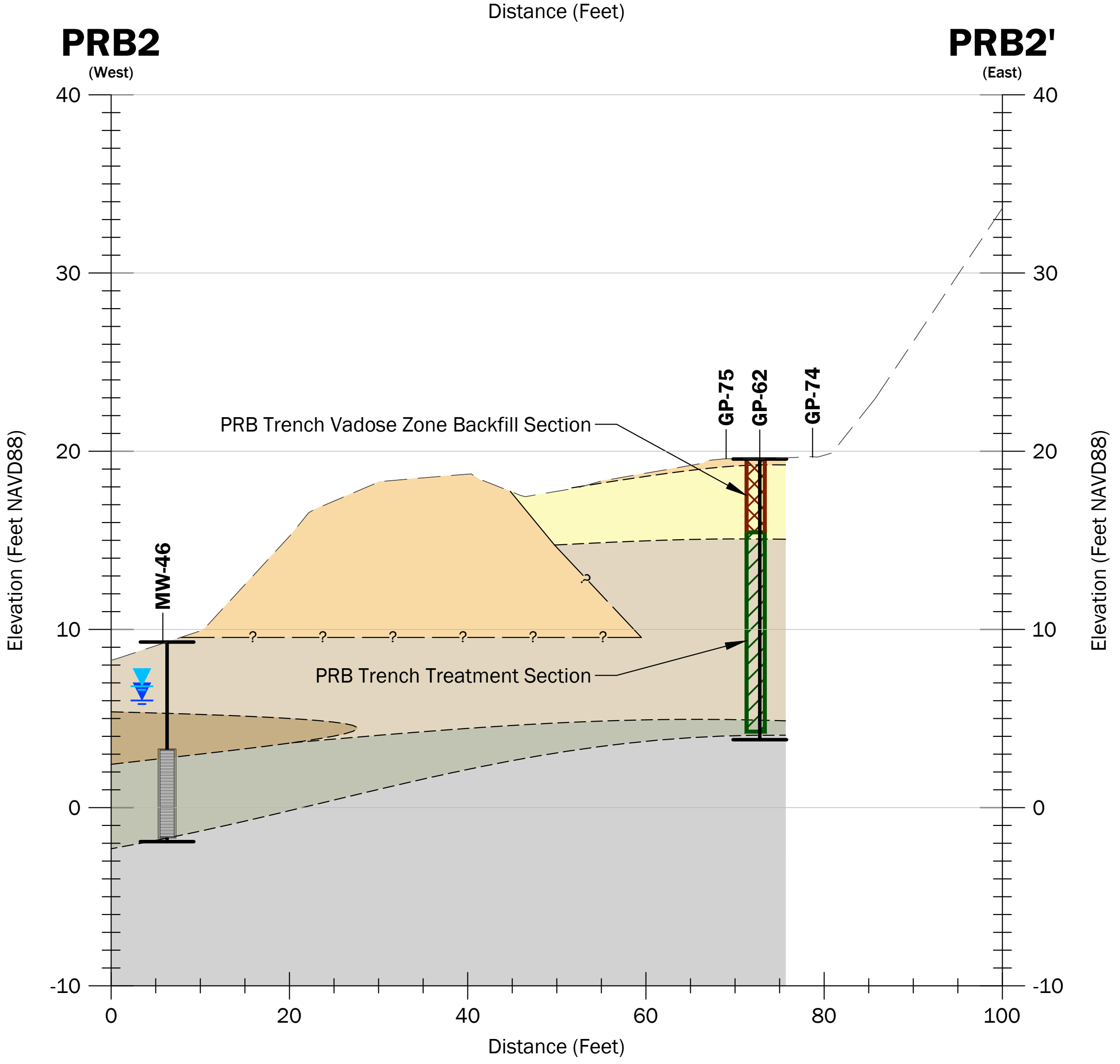
South State Street MGP Site
Bellingham, Washington

GeoEngineers

Figure 6-7

\\geoengineers.com\WAN\Projects\0\0186890\CAD\04\EDR Figures\018689004_F6-7_Groundwater Enhanced Bioremediation Plan.dwg F06-7 Date Exported:2/13/2024 6:15 PM - by Michael R. Woods





Legend

Boring ID (Offset)

Boring

Inferred Soil Contact

Groundwater Measured February 2022

Groundwater Measured September 2021

Well Screen

🟧 Base Coarse or Rip-rap Fill

🟨 Fill with Debris

🟫 Wood Debris

⬜ Fill

🟩 Unconsolidated Native

⬜ Chuckanut Formation

Notes:

1. The subsurface conditions shown are based on interpolation between widely spaced explorations and should be considered approximate; actual subsurface conditions may vary from those shown.
2. This figure is for informational purposes only. It is intended to assist in the identification of features discussed in a related document. Data were compiled from sources as listed in this figure. The data sources do not guarantee these data are accurate or complete. There may have been updates to the data since the publication of this figure. This figure is a copy of a master document. The hard copy is stored by GeoEngineers, Inc. and will serve as the official document of record.

Datum: NAVD 88, unless otherwise noted.

20 0 20
Horizontal Scale in Feet
10 0 10
Vertical Scale in Feet
Vertical Exaggeration = 2X

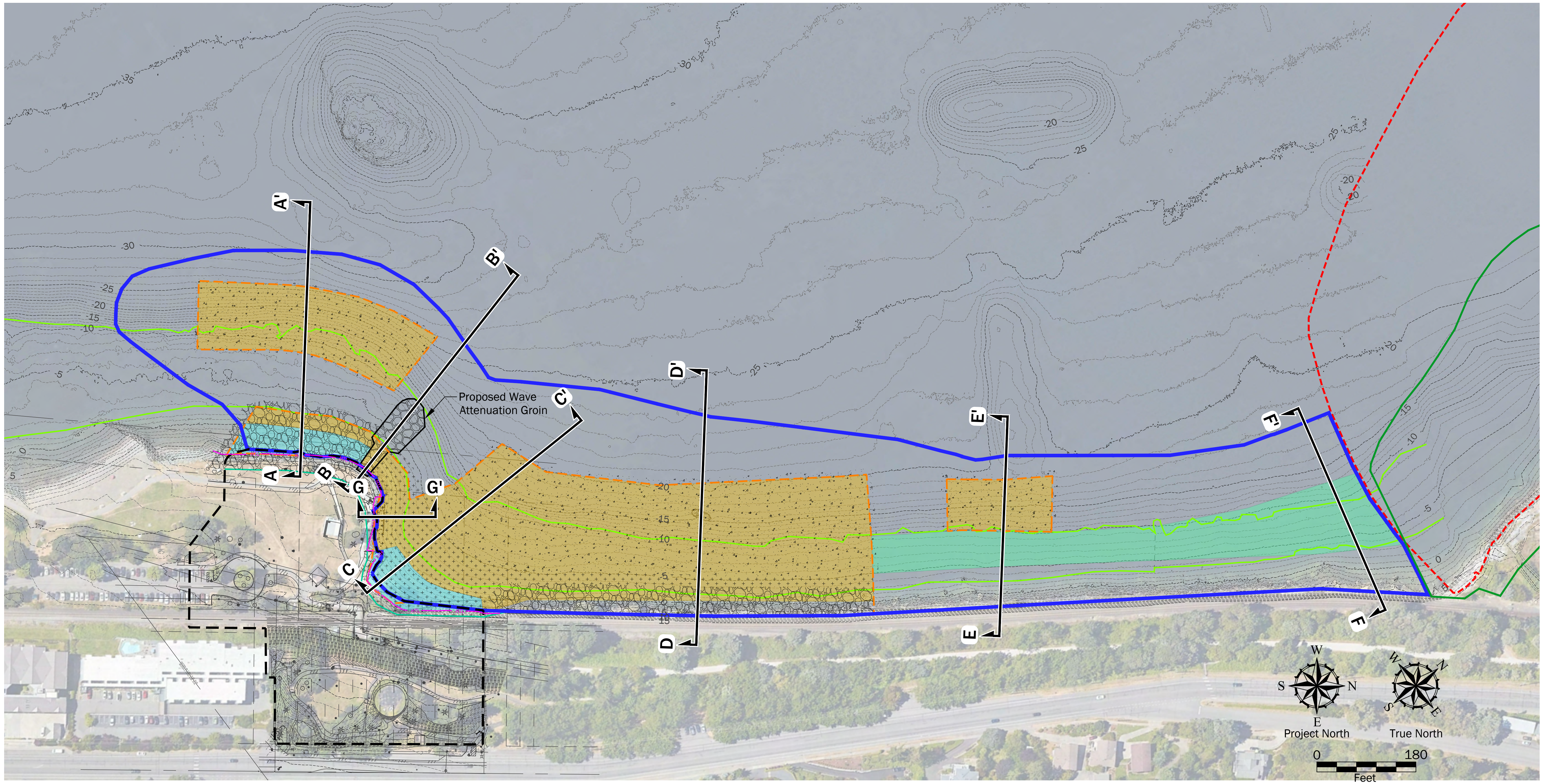
Groundwater Enhanced Bioremediation Sections

South State Street MGP Site
Bellingham, Washington

GEOENGINEERS

Figure 6-8

\\geoengineers.com\WAN\Projects\0\0186890\CAD\04\EDR Figures\018689004_F6-8_Groundwater Enhanced Bioremediation Sections.dwg 6-8 Date Exported:2/13/2024 6:25 PM - by Michael R. Woods



Note(s):

1. Elevations on this plan reference the North American Vertical Datum of 1988 (NAVD88).
2. Sample location data was collected during sediment sampling with GPS mounted on research vessel.

Source(s):

- Survey data from David Evans and Associates, 2021
- Aerial from Google Earth Pro, dated 7/31/22
- Cornwall 60% Design from Landau Associates, 2021

Projection: Washington State Plane, North Zone, NAD83, US Foot

Legend

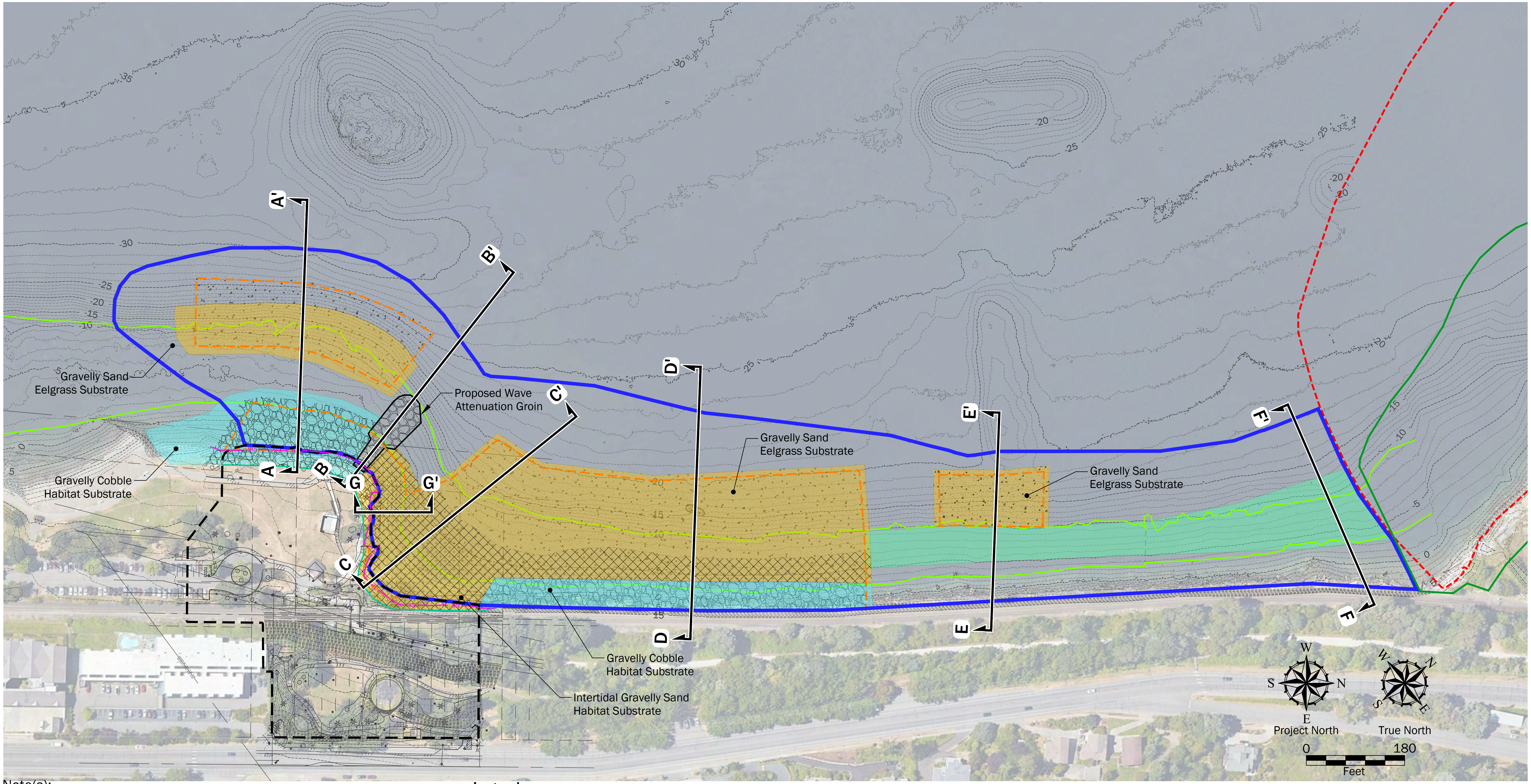
- Upland Unit Boundary
- Marine Unit Boundary
- Haley Marine Unit Boundary
- Cornwall Sediment Cap and Shoreline Stabilization Boundary (60% Design)
- Approximate Limits of Aquatic Vegetation
- HTL Existing High Tide Level
- 🟨 Conventional Sand Cap (2-foot sand layer, erosion protection layer, and habitat substrate)
- 🟦 Amended Sand Cap (2-foot activated carbon amended sand layer, erosion protection layer, and habitat substrate)
- 🟩 ENR (4-in sand layer placed in 2 lifts to preserve eelgrass)
- A A' Cross Section Location
- ▨ Armor Stone Groin Structure (armor stone on 1-foot quarry spalls bedding layer)
- ▨ Armor Rock Erosion Protection Layer (2-foot layer of D50=1-foot rock on 6 inches of bedding)
- ▨ Gravelly Cobble Erosion Protection Layer (1.5-foot layer of D50=1.5-inch aggregate)
- ▨ Gravelly Sand Erosion Protection Layer (1.5-foot layer of D50=0.4-inch aggregate)

Sediment Capping Plan

South State Street MGP Site
Bellingham, Washington

GEOENGINEERS

Figure 6-9



Note(s):

1. Elevations on this plan reference the North American Vertical Datum of 1988 (NAVD88).
2. Sample location data was collected during sediment sampling with GPS mounted on research vessel.

Source(s):

- Survey data from David Evans and Associates, 2021
- Aerial from Google Earth Pro, dated 7/31/22
- Cornwall 60% Design from Landau Associates, 2021

Projection: Washington State Plane, North Zone, NAD83, US Foot

Legend

- Upland Unit Boundary
- Marine Unit Boundary
- Haley Marine Unit Boundary
- Cornwall Sediment Cap and Shoreline Stabilization Boundary (60% Design)
- Approximate Limits of Aquatic Vegetation
- HTL Existing High Tide Level
- Gravelly Sand Eelgrass Habitat Substrate
- Intertidal Gravelly Sand Habitat Substrate
- Gravelly Cobble Intertidal Habitat Substrate
- Sand Cap Areas
- ENR (4-in sand layer placed in 2 lifts to preserve eelgrass)
- Armor Stone Groin Structure (armor stone on 1-foot quarry spalls bedding layer)
- Armor Rock Erosion Protection Layer (2-foot layer of D50=1-foot rock on 6 inches of bedding)
- Gravelly Cobble Erosion Protection Layer (1.5-foot layer of D50=1.5-inch aggregate)
- Gravelly Sand Erosion Protection Layer (1.5-foot layer of D50=0.4-inch aggregate)
- A A' Cross Section Location

Marine Habitat Plan

South State Street MGP Site
Bellingham, Washington

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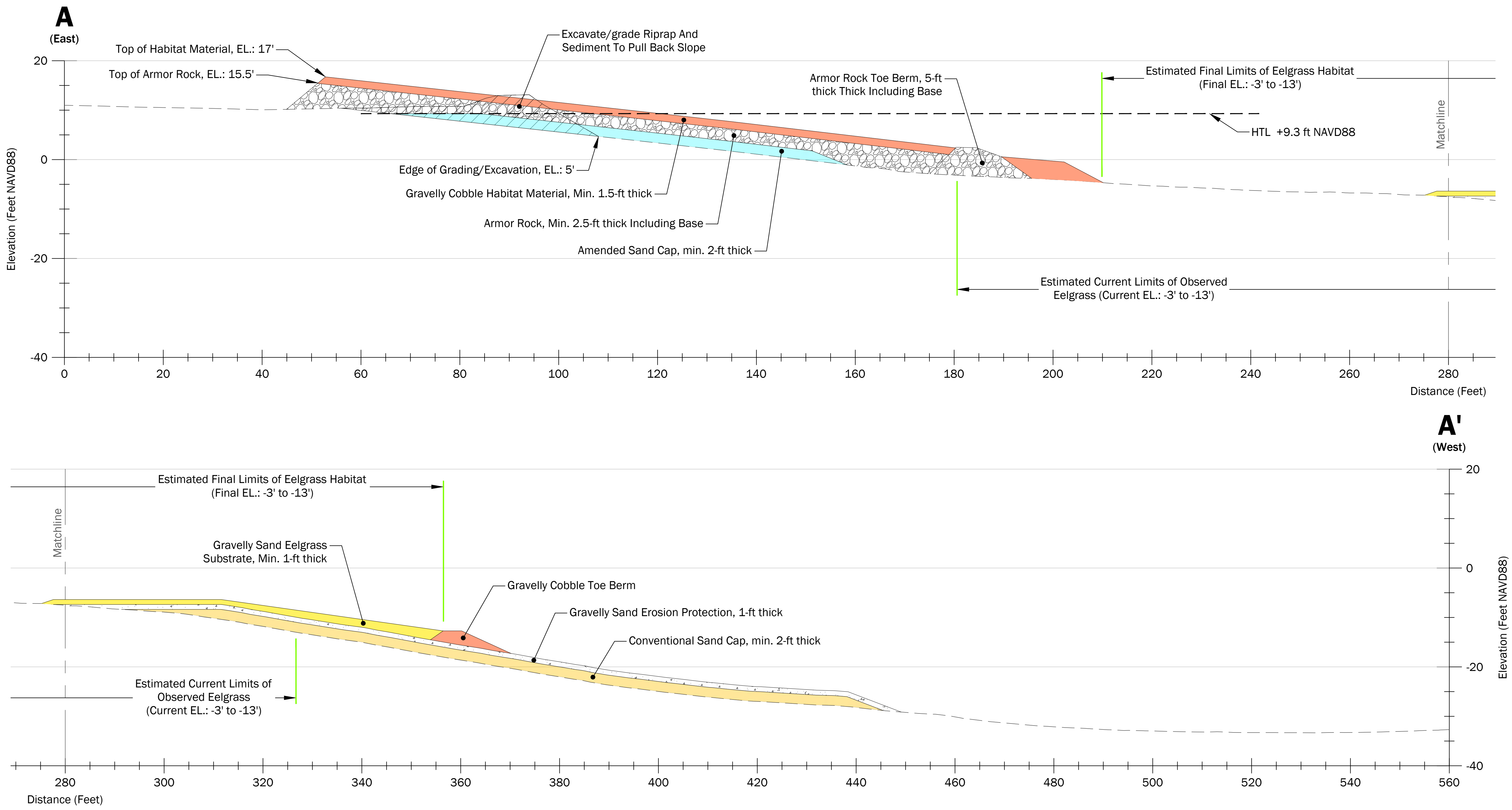
Figure 6-10



Notes:

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Datum: NAVD 88, unless otherwise noted.

Legend

- – – – Existing Ground Surface
- 🟧 Conventional Sand Cap
- 🟦 Amended Sand Cap
- 🟥 Gravelly Cobble Habitat Substrate
- 🟨 Gravelly Sand Habitat Substrate
- ▨ Armor Rock Erosion Protection (including 6-in Gravelly Sand Bedding Layer)
- ▨ Gravelly Cobble Erosion Protection
- ▨ Gravelly Sand Erosion Protection
- ▨ Excavation Area

20 0 20
Horizontal Scale in Feet
20 0 20
Vertical Scale in Feet
Vertical Exaggeration = 1X

Cross Section A-A'

South State Street MGP Site
Bellingham, Washington

GeoEngineers

Figure 6-11

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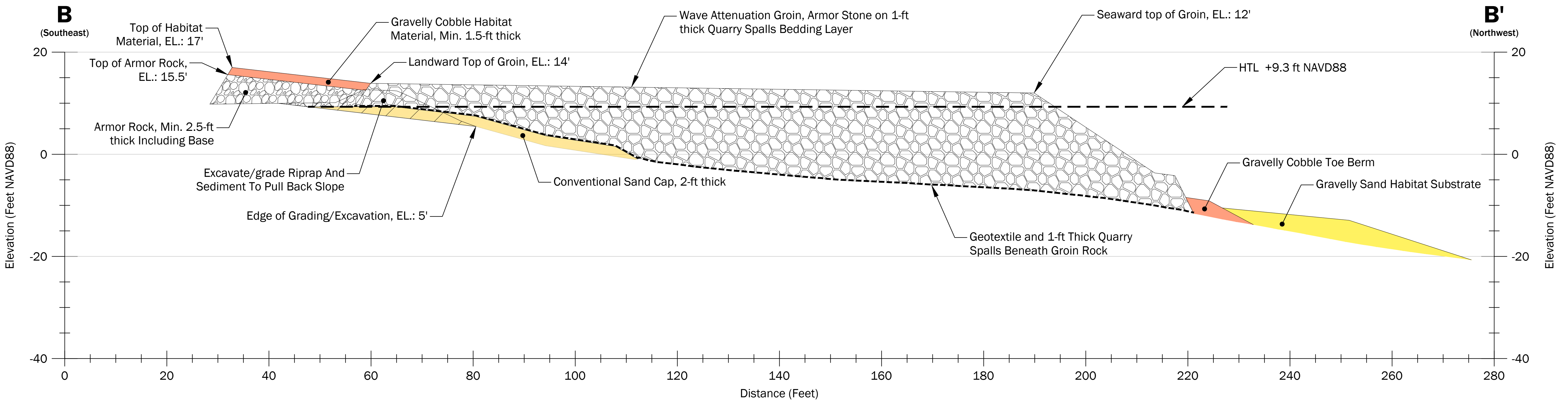

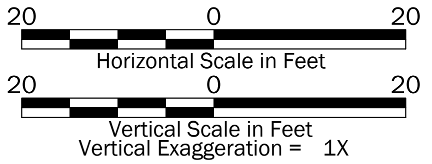

Legend

- – – – – Existing Ground Surface
- ▭ Conventional Sand Cap
- ▭ Amended Sand Cap
- ▭ Gravelly Cobble Habitat Substrate
- ▭ Gravelly Sand Habitat Substrate
- - - - - - Geotextile and 1-ft Thick Quarry Spalls Beneath Groin Rock
- ▦ Armor Stone Groin Structure (armor stone on 1-ft quarry spalls bedding layer)
- ▦ Armor Rock Erosion Protection
- ▦ Gravelly Cobble Erosion Protection
- ▦ Gravelly Sand Erosion Protection
- ▨ Excavation Area

Notes:

1. The subsurface conditions shown are based on interpolation between widely spaced explorations and should be considered approximate; actual subsurface conditions may vary from those shown.
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Cross Section B-B'

South State Street MGP Site
Bellingham, Washington

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Figure 6-12

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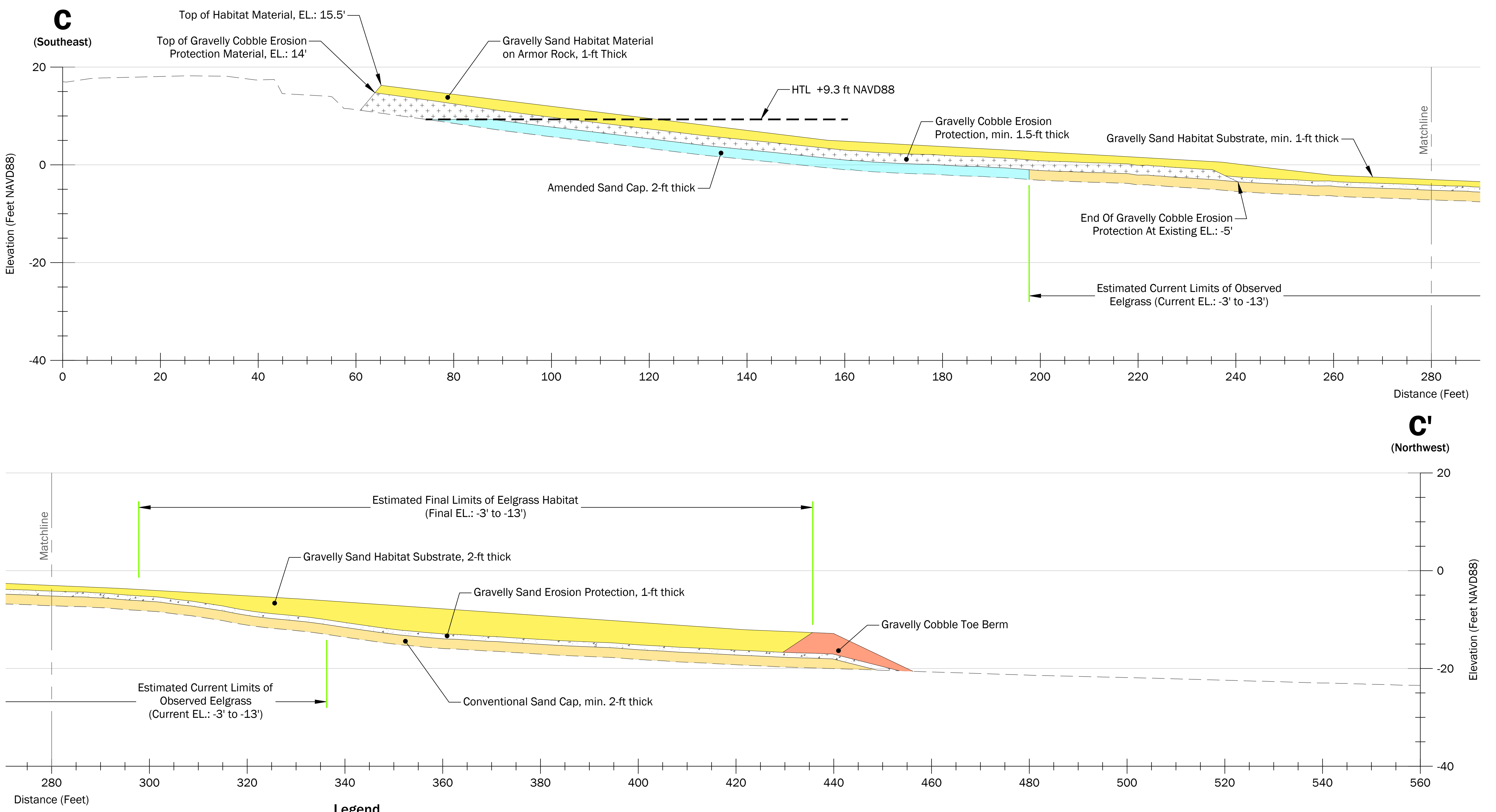

Notes:

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2. This figure is for informational purposes only. It is intended to assist in the identification of features discussed in a related document. Data were compiled from sources as listed in this figure. The data sources do not guarantee these data are accurate or complete. There may have been updates to the data since the publication of this figure. This figure is a copy of a master document. The hard copy is stored by GeoEngineers, Inc. and will serve as the official document of record.

Datum: NAVD 88, unless otherwise noted.

Legend

- – – Existing Ground Surface
- 🟧 Conventional Sand Cap
- 🟦 Amended Sand Cap
- 🟥 Gravelly Cobble Habitat Substrate
- 🟨 Gravelly Sand Habitat Substrate
- ▨ Armor Rock Erosion Protection (including 6-in Gravelly Sand Bedding Layer)
- ▨ Gravelly Cobble Erosion Protection
- ▨ Gravelly Sand Erosion Protection
- ▨ Excavation Area

20 0 20
Horizontal Scale in Feet
20 0 20
Vertical Scale in Feet
Vertical Exaggeration = 1X

Cross Section C-C'

South State Street MGP Site
Bellingham, Washington

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Figure 6-13

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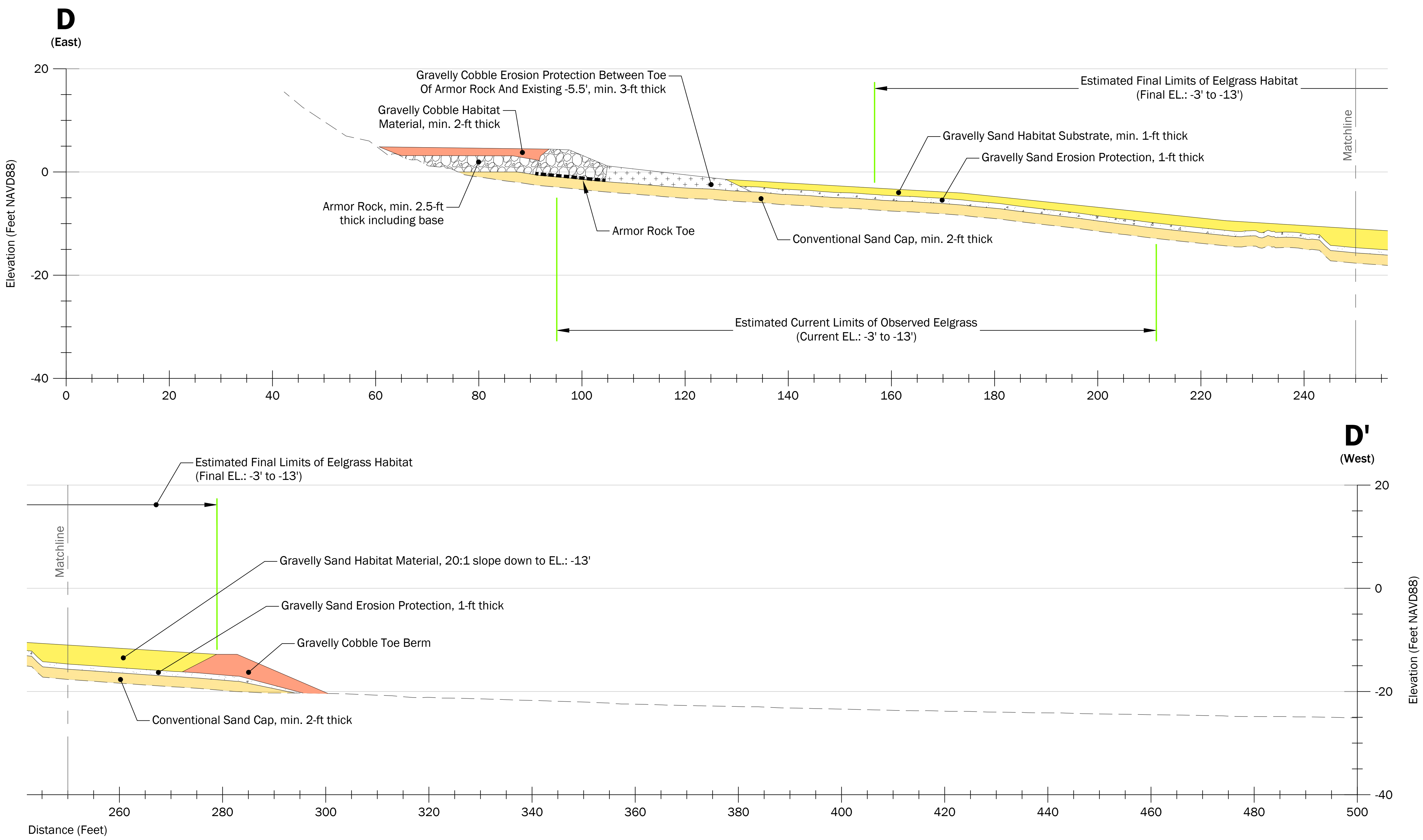

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Legend

— — —	Existing Ground Surface
🟨	Conventional Sand Cap
🟦	Amended Sand Cap
🟥	Gravelly Cobble Habitat Substrate
🟨	Gravelly Sand Habitat Substrate
- - - - - - -	Geotextile
▨	Armor Rock Erosion Protection (including 6-in Gravelly Sand Bedding Layer)
▨	Gravelly Cobble Erosion Protection
▨	Gravelly Sand Erosion Protection
▨	Excavation Area

20 0 20
Horizontal Scale in Feet
20 0 20
Vertical Scale in Feet
Vertical Exaggeration = 1X

Cross Section D-D'

South State Street MGP Site
Bellingham, Washington

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Figure 6-14

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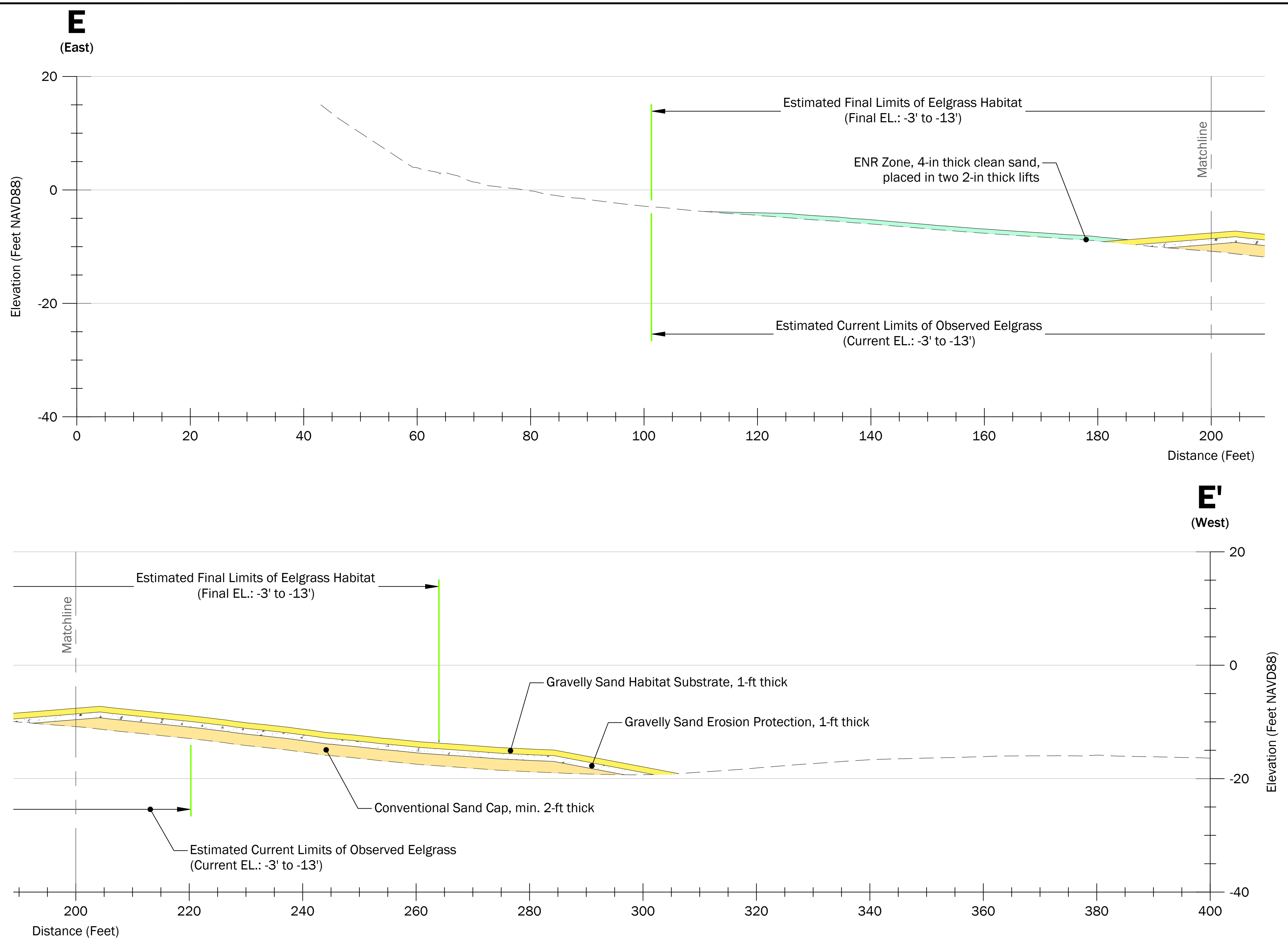

Notes:

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Datum: NAVD 88, unless otherwise noted.

Legend

- — — — Existing Ground Surface
- 🟧 Conventional Sand Cap
- 🟦 Amended Sand Cap
- 🟥 Gravelly Cobble Habitat Substrate
- 🟨 Gravelly Sand Habitat Substrate
- 🟩 ENR Zone (Clean Sand Placed in 2 Lifts 2-in Thick)
- ▨ Armor Rock Erosion Protection (Including 6-in Gravelly Sand Bedding Layer)
- ▨ Gravelly Cobble Erosion Protection
- ▨ Gravelly Sand Erosion Protection
- ▨ Excavation Area

20 0 20
Horizontal Scale in Feet

20 0 20
Vertical Scale in Feet
Vertical Exaggeration = 1X

Cross Section E-E'

South State Street MGP Site
Bellingham, Washington

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Figure 6-15

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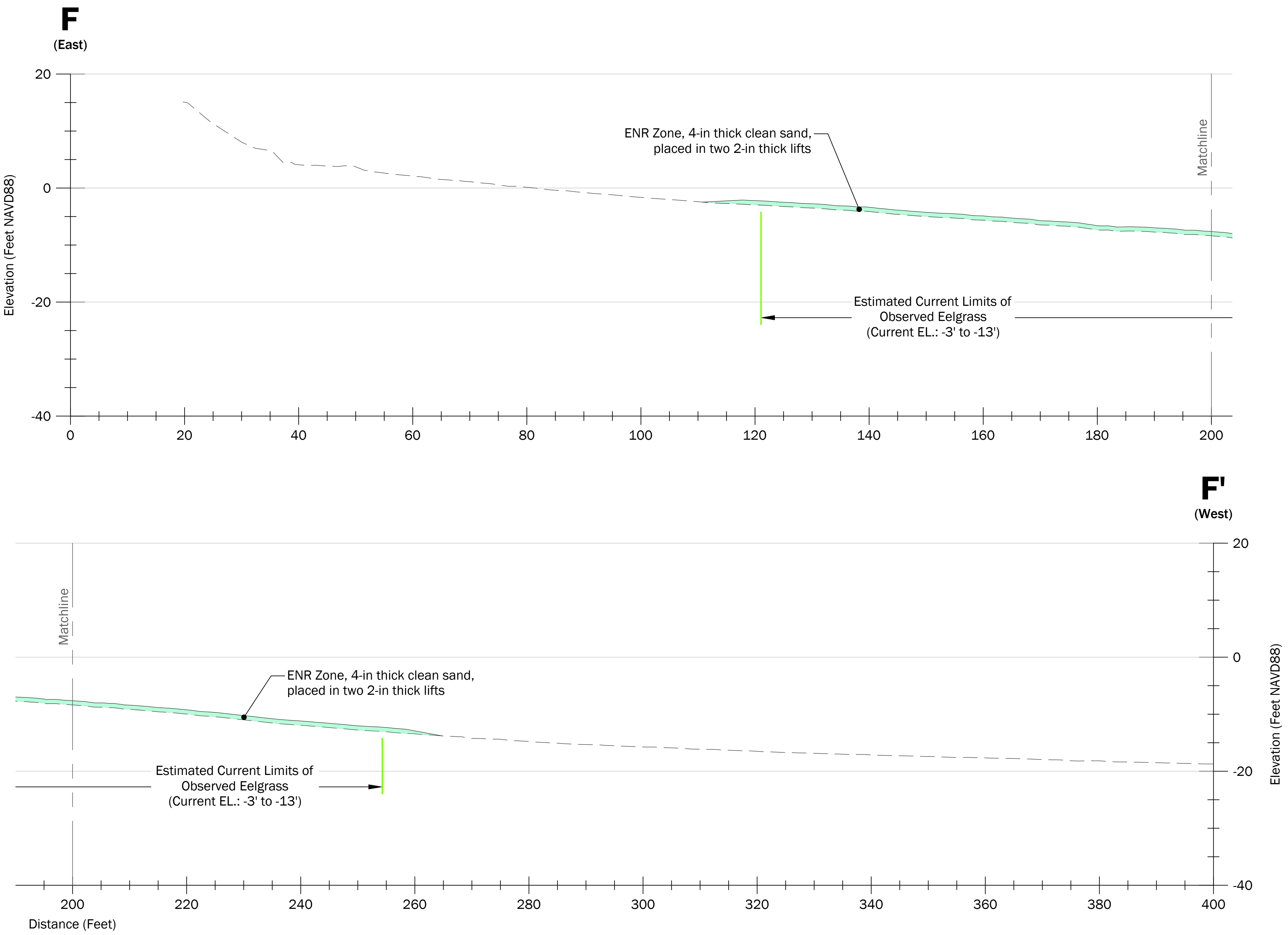

Notes:
1. The subsurface conditions shown are based on interpolation between widely spaced explorations and should be considered approximate; actual subsurface conditions may vary from those shown.
2. This figure is for informational purposes only. It is intended to assist in the identification of features discussed in a related document. Data were compiled from sources as listed in this figure. The data sources do not guarantee these data are accurate or complete. There may have been updates to the data since the publication of this figure. This figure is a copy of a master document. The hard copy is stored by GeoEngineers, Inc. and will serve as the official document of record.

Datum: NAVD 88, unless otherwise noted.

Legend

– – –	Existing Ground Surface
🟨	Conventional Sand Cap
🟦	Amended Sand Cap
🟧	Gravelly Cobble Habitat Substrate
🟨	Gravelly Sand Habitat Substrate
🟩	ENR Zone (Clean Sand Placed in 2 Lifts 2-in Thick)
▦	Armor Rock Erosion Protection (including 6-in Gravelly Sand Bedding Layer)
⁘	Gravelly Cobble Erosion Protection
░	Gravelly Sand Erosion Protection
▨	Excavation Area

20 0 20
Horizontal Scale in Feet
20 0 20
Vertical Scale in Feet
Vertical Exaggeration = 1X

Cross Section F-F'

South State Street MGP Site
Bellingham, Washington

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Figure 6-16

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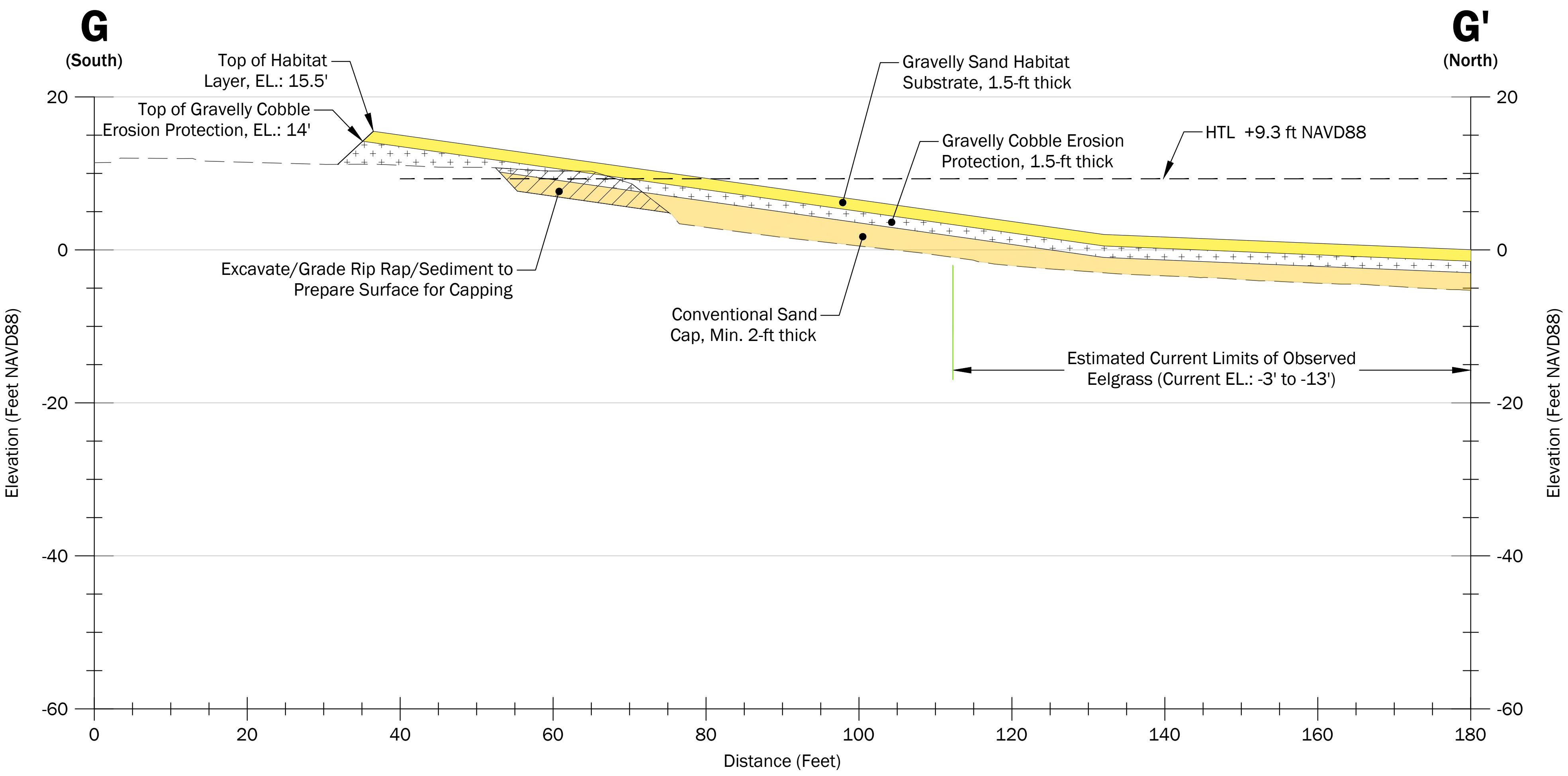

20 0 20
Horizontal Scale in Feet
20 0 20
Vertical Scale in Feet
Vertical Exaggeration = 1X

Legend

- — — — Existing Ground Surface
- 🟨 Conventional Sand Cap
- 🟦 Amended Sand Cap
- 🟥 Gravelly Cobble Habitat Substrate
- 🟨 Gravelly Sand Habitat Substrate
- ▨ Armor Rock Erosion Protection (including 6-in Gravelly Sand Bedding Layer)
- ▨ Gravelly Cobble Erosion Protection
- ▨ Gravelly Sand Erosion Protection
- ▨ Excavation Area

Notes:

1. The subsurface conditions shown are based on interpolation between widely spaced explorations and should be considered approximate; actual subsurface conditions may vary from those shown.
2. This figure is for informational purposes only. It is intended to assist in the identification of features discussed in a related document. Data were compiled from sources as listed in this figure. The data sources do not guarantee these data are accurate or complete. There may have been updates to the data since the publication of this figure. This figure is a copy of a master document. The hard copy is stored by GeoEngineers, Inc. and will serve as the official document of record.

Datum: NAVD 88, unless otherwise noted.

Cross Section G-G'

South State Street MGP Site
Bellingham, Washington

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Figure 6-17

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Appendices

Appendix A

PRDI Data Report

Appendix A.
PRDI Data Report

The PRDI Data report can be found on Washington State Department of Ecology's South State Street Manufactured Gas Plant project website at https://apps.ecology.wa.gov/cleanupsearch/site/4606.

Appendix B

Soil Remediation Levels

Table B-1

Park User (Child/Adult) Soil Remediation Level Calculations Based on Direct Contact (Ingestion and Dermal Contact) - cPAHs

South State Street MGP Site
Bellingham, Washington

Analyte	Park User - Remediation Level (mg/kg)		
	Ingestion	Dermal Contact	Combined - Ingestion and Dermal Contact
Benzo(a)pyrene	0.610	1.51	0.43

Cancer - Mutagenic (Ingestion - Child/Adult)

Carcinogenic Formula (Equation 740-2; modified for modified for early life exposure)

$$\textbf{Soil Cleanup Level (mg/kg)} = \frac{\textbf{RISK x AT x UCF}}{\textbf{CPFo x AB1 x EF x ELESIR}_{\textbf{child/adult-adj}}}$$

Where:

$$\text{ELESIR}_{\text{child/adult-adj}} = (\text{SIR}_{0\text{-}2} \text{ x ADAF}_{0\text{-}2} \text{ x ED}_{0\text{-}2} \text{ x } 1/\text{ABW}_{0\text{-}2}) +$$
$$(\text{SIR}_{2\text{-}6} \text{ x ADAF}_{2\text{-}6} \text{ x ED}_{2\text{-}6} \text{ x } 1/\text{ABW}_{2\text{-}6}) +$$
$$(\text{SIR}_{6\text{-}16} \text{ x ADAF}_{6\text{-}16} \text{ x ED}_{6\text{-}16} \text{ x } 1/\text{ABW}_{6\text{-}16}) +$$
$$(\text{SIR}_{16\text{-}30} \text{ x ADAF}_{16\text{-}30} \text{ x ED}_{16\text{-}30} \text{ x } 1/\text{ABW}_{16\text{-}30})$$

Method B Cancer Mutagenic (Child/Adult)

Acceptable cancer risk level (RISK) (1 in 1,000,000) untiless = 1.00E-06
Child/Adult Soil Ingestion Early Life Exposure Adjustment Factor (ELESIR$_{\text{child/adult-adj}}$) (mg-year/kg-day) = 431.4
Age-Dependent Adjustment Factor - 0 - 2 years old (ADAF$_{0\text{-}2}$) = 10
Age-Dependent Adjustment Factor - 2 - 6 years old (ADAF$_{2\text{-}6}$) = 3
Age-Dependent Adjustment Factor - 6 - 16 years old (ADAF$_{6\text{-}16}$) = 3
Age-Dependent Adjustment Factor - 16 - 30 years old (ADAF$_{16\text{-}30}$) = 1
Average body weight (ABW$_{0\text{-}2}$) (kg) = 16
Average body weight (ABW$_{2\text{-}6}$) (kg) = 16
Average body weight (ABW$_{6\text{-}16}$) (kg) = 70
Average body weight (ABW$_{16\text{-}30}$) (kg) = 70
Averaging Time (AT) (years) = 75
Unit conversion factor (UCF) (mg/kg) = 1.00E+06
Carcinogenic Potency Factor (CPFo) (kg-day/mg) = 1
Soil ingestion rate - 0 - 2 years (SIR$_{0\text{-}2}$) (mg/day) = 200
Soil ingestion rate - 2 - 6 years (SIR$_{2\text{-}6}$) (mg/day) = 200
Soil ingestion rate - 6 - 16 years (SIR$_{6\text{-}16}$) (mg/day) = 50
Soil ingestion rate - 16 - 30 years (SIR$_{16\text{-}30}$) (mg/day) = 50
Gastrointestinal absorption fraction (AB1) (unitless) = 1
Exposure duration (ED$_{0\text{-}2}$) (years) = 2
Exposure duration (ED$_{2\text{-}6}$) (years) = 4
Exposure duration (ED$_{6\text{-}16}$) (years) = 10
Exposure duration (ED$_{16\text{-}30}$) (years) = 14
Exposure Frequency (EF) (unitless) = 0.28

Cancer - Mutagenic (Dermal Contact - Child/Adult)

Carcinogenic Formula (Equation 740-2; modified for modified for early life exposure)

$$\textbf{Soil Cleanup Level (mg/kg)} = \frac{\textbf{RISK x AT x UCF}}{\textbf{CPFd x ABS x EF x ELESA}_{\textbf{child/adult-adj}}}$$

Where:

$$\text{ELESA}_{\text{child/adult-adj}} = (\text{SA}_{0\text{-}2} \text{ x ADAF}_{0\text{-}2} \text{ x AF}_{0\text{-}2} \text{ x ED}_{0\text{-}2} \text{ x } 1/\text{ABW}_{0\text{-}2}) +$$
$$(\text{SIR}_{2\text{-}6} \text{ x ADAF}_{2\text{-}6} \text{ x AF}_{2\text{-}6} \text{ x ED}_{2\text{-}6} \text{ x } 1/\text{ABW}_{2\text{-}6}) +$$
$$(\text{SIR}_{6\text{-}16} \text{ x ADAF}_{6\text{-}16} \text{ x AF}_{2\text{-}6} \text{ x ED}_{6\text{-}16} \text{ x } 1/\text{ABW}_{6\text{-}16}) +$$
$$(\text{SIR}_{16\text{-}30} \text{ x ADAF}_{16\text{-}30} \text{ x AF}_{16\text{-}30} \text{ x ED}_{16\text{-}30} \text{ x } 1/\text{ABW}_{16\text{-}30})$$

Method B Cancer Mutagenic (Child/Adult)

Acceptable cancer risk level (RISK) (1 in 1,000,000) untiless = 1.00E-06
Child/Adult Soil Ingestion Early Life Exposure Adjustment Factor (ELESIR$_{\text{child/adult-adj}}$) (mg-year/kg-day) = 1194.3
Age-Dependent Adjustment Factor - 0 - 2 years old (ADAF$_{0\text{-}2}$) = 10
Age-Dependent Adjustment Factor - 2 - 6 years old (ADAF$_{2\text{-}6}$) = 3
Age-Dependent Adjustment Factor - 6 - 16 years old (ADAF$_{6\text{-}16}$) = 3
Age-Dependent Adjustment Factor - 16 - 30 years old (ADAF$_{16\text{-}30}$) = 1
Average body weight (ABW$_{0\text{-}2}$) (kg) = 16
Average body weight (ABW$_{2\text{-}6}$) (kg) = 16
Average body weight (ABW$_{6\text{-}16}$) (kg) = 70
Average body weight (ABW$_{16\text{-}30}$) (kg) = 70
Averaging Time (AT) (years) = 75
Unit conversion factor (UCF) (mg/kg) = 1.00E+06
Carcinogenic Potency Factor (CPFd) (kg-day/mg) = 1.12
Surface Area - 0 - 2 years (SA$_{0\text{-}2}$) (cm^2) = 2,200
Surface Area - 2 - 6 years (SA$_{2\text{-}6}$) (cm^2) = 2,200
Surface Area - 6 - 16 years (SA$_{6\text{-}16}$) (cm^2) = 2,500
Surface Area - 16 - 30 years (SA$_{16\text{-}30}$) (cm^2) = 2,500
Adherence Factor (AF) (mg/cm^2-day) = 0.2
Dermal absorption fraction (ABS) (unitless) = 0.13
Exposure duration (ED$_{0\text{-}2}$) (years) = 2
Exposure duration (ED$_{2\text{-}6}$) (years) = 4
Exposure duration (ED$_{6\text{-}16}$) (years) = 10
Exposure duration (ED$_{16\text{-}30}$) (years) = 14
Exposure Frequency (EF) (unitless) = 0.28

Notes and Sources:

[a] WAC 173-340-745, Equation 740-4 or Equation 740-4

[a] Exposure frequency is a site-specific value. Assumes park user exposure to shallow soil 2 days per week (or 104 days per year) for 30 years.

[c] CLARC Master Spreadsheet dated August 2023.

cm^2 = square centimeters

kg = kilograms

mg = milligrams

Table B-2

Park Worker (Adult) Soil Remediation Level Calculations Based on Direct Contact (Ingestion and Dermal Contact) - cPAHs

South State Street MGP Site
Bellingham, Washington

Constants[a]

Parameter	Unit	Park Worker Adult	
		Cancer	Noncancer
Cancer Risk/Hazard Quotient (CR/HQ) [a]	unitless	1E-06	1E+00
Fractional Intake or Gastrointestinal Absorption Fraction (AB/AB1) [a]	unitless	1	1
Body Weight (ABW/BW) [a]	kg	70	70
Averaging Time (AT) [a]	days	27,375	9,125
Exposure Frequency (EF) [b]	days/year	69	69
Exposure Duration (ED) [b]	years	25	25
Soil/Sediment Ingestion Rate (SIR/IR) [a]	mg/day	50	50
Dermal Surface Area (SA) [a]	cm^2	2,500	2,500
Adherence Factor (AF) [a]	mg/cm^2-day	0.2	0.2
Unit Conversion Factor (UCF)	mg/kg	1.00E+06	1.00E+06

Calculated Soil Remediation Levels

Analyte	Oral Cancer Potency Factor (CPFo) [c]	Oral Reference Dose (RfDo) [c]	Dermal Absorption Factor (ABS) [c]	GI Absorption Factor [c]	Dermal Cancer Potency Factor (CPFd) [a]	Dermal Reference Dose (RfDd) [a]	Remediation Level Park Worker Adult	
	$(mg/kg\text{-}day)^{-1}$	mg/kg-day	unitless	unitless	$(mg/kg\text{-}day)^{-1}$	mg/kg-day	Cancer - mg/kg	Noncancer - mg/kg
cPAH TEQ	1	--	0.13	0.89	1.12	--	9.029	--

Notes:

[a] Values are from WAC 173-340-745, Equation 745-4 or Equation 745-5

[a] Site-specific value. Assumes park worker exposure to shallow soil 2 days per week for 8 months (or 69 days per year) for 25 years.

[c] Values are from CLARC Master Spreadsheet dated August 2023.

cm^2 = square centimeters

kg = kilograms

mg = milligrams

Appendix C

Design Testing Results and Recommendations, Permeable Reactive Barrier

TECHNICAL MEMORANDUM

TO: Neil Morton, GeoEngineers, Inc.

FROM: Jenny Green, EIT and Clint Jacob, PE, LG

DATE: December 21, 2023

RE: Design Testing Results and Recommendations
Permeable Reactive Barrier
Former South State Street Manufactured Gas Plant Site
Bellingham, Washington
Landau Project No. 0611004.030

INTRODUCTION

This technical memorandum was prepared by Landau Associates, Inc. (Landau) to present a summary of testing performed for evaluation and design of a permeable reactive barrier (PRB) at the former South State Street Manufactured Gas Plant (SSSMGP) in Bellingham, Washington (Site). A vicinity map is shown on Figure 1 and a site plan is shown on Figure 2. This report describes aquifer flux testing results, bench testing results, and recommendations for full-scale implementation of a PRB performed as described in the work plan (Landau 2022) provided in Appendix G of the Pre-Remediation Design Investigation (PRDI) report (GeoEngineers 2023).

REMEDIAL APPROACH AND CONCEPTUAL DESIGN

The Site consists of two main cleanup areas: the upland unit and the marine unit (Figure 2). The approved cleanup action for the portion of the upland unit where groundwater impacts are greatest is enhanced bioremediation (Washington State Department of Ecology [Ecology] 2020). As presented in the work plan (Landau 2022), the proposed remedial approach is construction of a PRB to stimulate bioremediation and degrade/absorb target contaminants, which include benzene, naphthalene, gasoline-range total petroleum hydrocarbons (TPH-G), diesel-range TPH (TPH-D), and cyanide in groundwater, prior to discharge to marine surface water.

The proposed PRB consists of a trench that is oriented perpendicular to groundwater flow, which is backfilled with a mixture of sand and reactive media (described below) that treats contaminated groundwater as it flows through the trench. The PRB will be located east of the railroad tracks and pedestrian footpath, at the foot of the bedrock outcrop, to intercept and treat contaminated groundwater flowing from the upland area before it is discharged to Bellingham Bay at the pocket beach. The target treatment zone, in plan and profile views, is shown on Figures 2 and 3, respectively.

The proposed PRB will be approximately 130 feet (ft) long and extend from a location between GP-59/GP-61 and GP-70 to MW-29. It will be located hydraulically upgradient (generally east) of monitoring wells MW-28, MW-29, and MW-62, which will be used to monitor the treatment effects of the PRB (Figure 2).

The proposed PRB will extend from above the seasonal high water table to bedrock. The highest groundwater level observed during the Remedial Investigation (RI; Landau 2019) was approximately 6 ft below ground surface (bgs; elevation 14 ft), and the bedrock was encountered at elevation 4 or 5 ft (approximately 16 ft bgs). It is anticipated that the PRB will be constructed from 4 to 16 ft bgs (between elevations 4 to 16 ft), as shown in profile on Figure 3.

The proposed backfill material for the PRB consists of mixed sand, gypsum, and granular zero-valent iron (ZVI). Sand is required to maintain the hydraulic conductivity of the PRB and to prevent excessive settling of backfill as the gypsum dissolves over time. Gypsum and ZVI are the reactive media. Gypsum (calcium sulfate dihydrate; $CaSO_4{\cdot}2H_2O$) will provide a slow release of sulfate, as the electron acceptor, to enhance biodegradation of TPH within and downgradient of the PRB. ZVI is known to immobilize cyanide through adsorption and through precipitation of insoluble iron-cyanides (commonly known as Turnbull's Blue and Prussian Blue; Adams 1992, Dzombak et al. 2005, Ghosh et al. 1999).

AQUIFER FLUX TESTING

Groundwater flux and contaminant flux through the target treatment zone was measured using Passive Flux Meters™ (PFMs; EnviroFlux, LLC, Gainesville, Florida) deployed in permanent monitoring wells at the Site. Groundwater flux (q) is an apparent velocity, representing the velocity (v) at which water would move through an aquifer if the aquifer were an open conduit (Fetter 2001). Groundwater flux, also referred to as specific discharge, Darcy flux, or Darcy velocity, is defined as the groundwater volumetric flow rate (Q) divided by the cross-sectional area for flow (A) and has units of distance per unit time (Equation 1).

(Eqn. 1)

$$v = \frac{Q}{A} = q$$

Groundwater flux is related to average groundwater seepage velocity (v_x), or average linear velocity, through effective porosity (n_e). The groundwater flux is divided by the effective porosity to account for the actual open space available for flow through the aquifer pore spaces (Equation 2; Fetter 2001).

(Eqn. 2)

$$v_x = \frac{Q}{n_e A} = \frac{q}{n_e}$$

Similarly, contaminant flux (J), or mass flux, is defined as the mass of a contaminant that passes through a defined cross-sectional area over a period of time. It combines two key features of a contaminant plume: how much contaminant is in the groundwater and how fast the water is moving through a defined cross-sectional area (i.e., the contaminant concentration [C] and the groundwater flux (Interstate Technology & Regulatory Council [ITRC] 2010). Contaminant flux has units of mass per unit area per unit time (Equation 3; ITRC 2010).

(Eqn. 3)

$$J = qC$$

Summaries of the construction and deployment of the PFMs and the results provided by EnviroFlux are provided in the following subsections.

Flux Meter Design and Deployment

The PFMs provided and analyzed by EnviroFlux were designed to measure groundwater flux and contaminant flux (TPH, benzene, and cyanide) using a combination of specialized resins and activated carbon. Each PFM was 5 ft long and featured two sampling intervals consisting of three absorbent layers per sampling interval. One absorbent layer was made of a specialized resin used for volatile organic compounds; this layer was used to measure TPH-G, TPH-D, and benzene flux. Another absorbent layer was made of granular activated carbon and impregnated with tracer; the loss of tracer during the period of deployment allows for estimation of groundwater flux. The final absorbent layer was made of a different specialized resin used to measure cyanide flux.

PFMs were installed in monitoring wells MW-28 and MW-29 near opposite ends of the planned PRB (Figure 2) in April 2023 to measure wet season flux and in September 2023 to measure dry season flux. Wet season flux was used to represent the shortest (worst case) residence time in the PRB for treatment, while dry season flux was used to represent the longest residence time. The PFMs were deployed for 19 to 21 days at the bottom of each well within the screened interval (10 to 15 ft bgs). Upon retrieval, the absorbent materials in the PFMs were sampled and analyzed by EnviroFlux. The analytical results were processed by EnviroFlux using its propriety modeling software and a summary was provided to Landau for review and evaluation.

Concurrent Groundwater Sampling

Low-flow groundwater sampling was performed at MW-28 and MW-29 immediately following retrieval of PFMs in April 2023 (wet season) and in September 2023 (dry season). All samples were analyzed for TPH-G, TPH-D, oil-range TPH (TPH-O), total and weak acid dissociable (WAD) cyanide, benzene, and sulfate at Analytical Resources, LLC in Tukwila, Washington. Results are compared to contaminant concentrations calculated from flux results in Table 1 and presented in detail in Table 2. Laboratory data packages are provided as Attachment 1.

Groundwater Flux Results and Average Seepage Velocity

The groundwater flux results from the PFMs are summarized in Table 1; the full data package provided by EnviroFlux is included as Attachment 2. Measured groundwater flux ranged from 1.6 to 2.6 centimeters per day (cm/d) during the wet season and from 0.7 to 2.0 cm/d during the dry season.

Assuming an effective porosity of 30 percent for the sandy fill along the PRB alignment (ITRC 2011), average groundwater seepage velocities ranged from 5.2 to 8.5 cm/d (0.17 to 0.28 feet per day [ft/d]) during the wet season and from 2.2 to 6.8 cm/d (0.07 to 0.22 ft/d) during the dry season (Table 1).

Comparison of Groundwater Sample Results to Calculated Values

Using the measured contaminant flux values and the measured groundwater flux values from the PFMs, theoretical groundwater concentrations at the time of deployment were calculated. These "calculated" groundwater concentrations were then compared to the groundwater concentrations measured in groundwater samples collected at the time flux meters were recovered.

Table 2 presents the results of groundwater sampling and includes recent sampling during the PRDI. The 2023 results and PRDI results consistently show higher TPH-G and benzene concentrations at monitoring well MW-28 than MW-29. TPH-G at MW-28 has ranged from 4,470 to 32,500 micrograms per liter (µg/L) since 2021 compared to 484 to 1,350 µg/L at MW-29, and benzene at MW-28 has ranged from 1,110 to 4,890 µg/L compared to 1.48 to 9.78 µg/L at MW-29. Results also consistently show higher total and WAD cyanide at monitoring well MW-29 than MW-28. WAD cyanide, which is the species compared to cleanup levels, ranged from 0.025 to 0.340 milligrams per liter (mg/L) at MW-29 since 2021 compared to 0.008 to 0.033 mg/L at MW-28.

Both wells have similar TPH-D concentrations as well as dissolved oxygen, ferrous iron, and pH measurements. However, sulfate concentrations differ significantly between the two monitoring wells; sulfate has ranged from 0.203 to 10.6 (estimated) mg/L at MW-28 but has ranged from 37.3 to 95.5 mg/L at MW-29. Because these wells are located adjacent to the Bellingham Bay shoreline, this suggests that MW-29 is more affected by seawater intrusion than MW-28. As TPH-G results are also lower at monitoring well MW-29, this suggests that the elevated sulfate at this location may be stimulating biodegradation of TPH-G from the upper portion of the site. These conclusions are also supported by monitoring well data from nearby and upgradient monitoring wells. As presented in the pre-remedial design investigation data report (GeoEngineers 2023), sulfate concentrations at monitoring wells in the upper park area (MW-7, MW-19, and MW-24; located east and upslope of MW-28 and MW-29) ranged from 14 to 34 mg/L in 2022, similar to sulfate at MW-28 during the same period. By contrast, sulfate concentrations at MW-29 were two to three times higher, likely influenced by intruding seawater, which contains approximately 2,700 mg/L sulfate. In 2022, TPH-G concentrations at monitoring wells in the upper park area located immediately upgradient of MW-29 (MW-19 and MW-24) ranged from 1.0 to 50 mg/L in 2022, similar to TPH-G concentrations at MW-28. By contrast, TPH-G concentrations at MW-29 were less than 0.5 mg/L. Treatment of TPH-G from intruding seawater at MW-29 is strongly supported by these observations and provides evidence that the proposed method to further stimulate bioremediation through sulfate addition to the PRB will be effective at the Site.

In general, there was not good agreement between groundwater concentrations calculated from the PFM results and the groundwater sampling results. Results by both methods are presented for benzene, TPH-G, TPH-D, and total cyanide in Table 1; groundwater samples were not analyzed for toluene, ethylbenzene, and xylenes. Instances of good agreement are as follows:

- During the wet season event, the benzene flux (21 milligrams per square meter per day [mg/m^2/d] at MW-28) and calculated groundwater concentration (1,377 micrograms per liter [µg/L] at MW-28) agreed well with the groundwater sample result of 1,440 µg/L at MW-28.

- During the dry season event, the TPH-D flux and calculated groundwater concentrations at both MW-28 and MW-29 agreed well with the groundwater sample results.

Landau confirmed with EnviroFlux that the correct contaminant absorbents were used in the PFMs and there are no major competing species at the Site to interfere with the results. Calculated flux meter values were not consistently higher or lower than sample results. The lack of agreement likely reflects variable contaminant concentrations during the 20-day flux meter soak period, which are averaged by that method.

PRB MATERIAL COLUMN TESTING

Proposed PRB construction materials were evaluated for various physical and chemical characteristics using column tests. Test design and results are described in the following subsections.

All tests were performed in horizontal columns constructed using a 4-ft-long section of clear, 2-inch-diameter polyvinyl chloride (PVC) pipe. Fluid was pumped through the columns using peristaltic chemical metering pumps. The lowest achievable flow was 4.5 ft/d, which is approximately 54 times the maximum wet season groundwater flux of 0.08 ft/d estimated from the flux meters. Sampling ports were located along the length of each column and at the outlet of each column. Mesh screens were installed at each end of the columns to prevent material from being washed out. As the simulated flow rates through the columns were low, the columns were situated at a slight reverse slope to ensure that the PRB material being tested remained completely saturated during pumping.

Gypsum Column Test Design and Results

Three column tests were performed using gypsum mixed with sand to evaluate, for each gypsum product, the sulfate concentrations produced, the longevity, and observe potential settling/compaction issues. Three gypsum products were mixed with 12/20 sand at a ratio of 30 percent by weight in each test, as described below. Tap water was passed through the columns, as the primary objective was to evaluate the rate of gypsum dissolution, not to evaluate contaminant treatment. A summary of test designs and results is presented in Table 3. Effluent sulfate concentration plots for all three tests are shown on Figure 4.

The first product tested was pulverized gypsum (USA Gypsum, Denver, Pennsylvania) made from recycled dry wall, with particle sizes of 1/4-inch and smaller. The pulverized gypsum column was operated over 50 days. During this time, material in the column settled/compacted by approximately 33 percent. The effluent was pale yellow with a slight odor of potting soil. The average sulfate concentration in the effluent was 1,142 ± 235 mg/L (95 percent confidence interval [CI]).

The second product tested was pelleted gypsum (USA Gypsum, Denver, Pennsylvania). This product contains a lignin binder to create the pellets and ranges in size from 1/8-inch to 1/4-inch. The pelleted gypsum column was operated for approximately 47 days, during which the material in the column settled/compacted by about 42 percent. The effluent was dark brown and smelled of soil and wood. The average sulfate concentration in the effluent was 1,199 ± 175 mg/L (95 percent CI).

The third product tested was mined gypsum (USA Gypsum, Denver, Pennsylvania), unprocessed and direct from the mine. Particle sizes are 1/2-inch and smaller. The mined gypsum column was operated for more than 50 days, during which the material in the column settled/compacted by approximately 28 percent. The effluent was pale yellow with little or no odor and an average sulfate concentration of 1,390 ± 101 mg/L (95 percent CI).

All three products produced similar dissolved sulfate concentrations near the maximum sulfate concentration (1,451 mg/L) calculated based on the gypsum solubility limit. Dissolved sulfate in water produced by the gypsum products is more than adequate to enhance TPH treatment within, and downgradient of, the planned PRB. Because the water produced by the pelleted gypsum column had such a strong color and odor, this material was not considered for the full-scale design. The cost of the mined gypsum ($0.13 per pound) is nearly double the cost of the pulverized product ($0.08 per pound). Therefore, the pulverized gypsum is the selected material for the PRB based on performance and price and has the added benefit of being a sustainable (recycled) product.

ZVI Column Test Design and Results

Four tests were performed using ZVI mixed with sand. The difference between influent and effluent concentrations of cyanide (mass absorbed/reacted by the ZVI) was used to develop reaction rates, as literature values for ZVI treatment of cyanide in groundwater are limited. ZVI was mixed with 12/20 sand at various ratios to determine if the amount of ZVI significantly reduced the amount of cyanide in the column effluent. A summary of test designs and results is presented in Table 4. Influent and effluent concentration bar charts for all four tests are shown on Figure 5.

Site groundwater was used as the influent for testing, as the primary objective was to evaluate treatment of cyanide-contaminated groundwater through the columns. Influent cyanide concentrations across the four tests varied, due to use of groundwater from two different monitoring wells (MW-29 and MW-62). Monitoring well MW-29 was chosen as the source of groundwater because it has had higher total and WAD cyanide concentrations than MW-28 (Table 2). However, MW-29 had very low groundwater recharge during the summer dry season period when column testing was performed. Therefore, groundwater was also obtained from nearby well MW-62 in order to complete the tests (see GeoEngineers 2023 for recent data). MW-62 is located approximately halfway between MW-28 and MW-29 within the proposed PRB alignment (Figure 2). The meter used to monitor free cyanide concentrations during the column test (Hanna® Cyanide Photometer, Model HI97714) indicated adequate cyanide in groundwater from both wells (0.064 mg/L at MW-29 and 0.094 mg/L at MW-62) to be used for the tests.

The first test was conducted using the Ferox Flow ZVI product (Hepure Technologies, Hillsborough, New Jersey) at 15 percent by weight. This product has an average particle size of 125 microns. The 15 percent Ferox Flow column was operated for 8 days and had an average free cyanide concentration in the effluent of 0.020 ± 0.007 mg/L (95 percent CI), which represents a concentration reduction of 69 percent through the column.

The other three tests were conducted using the Ferox PRB ZVI product (Hepure Technologies, Hillsborough, New Jersey) at 15 percent, 20 percent, and 25 percent by weight, respectively. This product has an average particle size of 325 microns. Test results are summarized as follows:

- The 15 percent Ferox PRB column was operated for 8 days and had an average free cyanide concentration in the effluent of 0.020 ± 0.011 mg/L (95 percent CI). This represents an average reduction in concentration of 68 percent.
- The 20 percent Ferox PRB column was operated for 7 days. The average free cyanide concentration in the effluent from this column was 0.024 ± 0.009 mg/L (95 percent CI); this is an average reduction of 75 percent.
- The 25 percent Ferox PRB column was operated for 7 days. The effluent free cyanide concentration from this column was 0.022 ± 0.008 mg/L, which represents an average reduction of 76 percent.

As both ZVI products reduced free cyanide to similar concentrations (Table 4), Ferox PRB is selected for use in the PRB. Ferox PRB is the product typically specified by the vendor for PRB applications. With some contaminants, Ferox Flow may provide higher reactivity (i.e., improved concentration reduction) due to smaller particle size with greater surface area, but this was not demonstrated for cyanide in these column tests. As described above, the cyanide concentration reduction for 15 percent by weight Ferox Flow and Ferox PRB were approximately the same at 69 and 68 percent, respectively. Therefore, Ferox PRB is the preferred product because of greater longevity resulting from larger particle size.

Data from the four tests were used to calculate reaction rates for cyanide with ZVI. Influent and effluent free cyanide concentrations were used in the first-order reaction equation (Equation 4) to calculate an average first-order reaction rate, *k*, and an average mass-based first-order reaction rate, k_{mass}, for each column test.

(Eqn. 4)

$$C = C_0 e^{-kt}$$

As shown in Table 5, the average *k and* k_{mass} were approximately the same for all four column tests, regardless of product or percent weight in the column. The overall average first-order reaction rate, *k*, for cyanide with ZVI based on all test results is 0.068 per hour (1/hr). The overall average mass-based first-order reaction rate, k_{mass}, is 0.004 cubic feet per pound per hour (ft^3/lb/hr). These calculations and results were confirmed by the vendor. Reaction rate calculations are summarized in Table 5; results are shown on Figure 5.

CONCLUSIONS AND RECOMMENDATIONS

Based on this evaluation, the following products are recommended for use in the PRB:

- Pulverized gypsum (USA Gypsum, Denver, Pennsylvania or local equivalent recycled drywall)
- Ferox PRB (Hepure Technologies, Hillsborough, New Jersey).

Column testing provided valuable information regarding the desired percent weight of gypsum and ZVI in the PRB. The following discussion provides recommendations for each component balancing required treatment, longevity, and cost and considering settlement of the PRB backfill materials.

Pulverized Gypsum

Substantial settlement (28 to 42 percent) was observed in the pulverized gypsum column due to gypsum softening and compaction. Therefore, a mass fraction of less than 30 percent gypsum is desired to avoid substantial settling of the PRB backfill if adequate longevity can be demonstrated.

Sulfate effluent concentrations in the column effluent indicated that gypsum was dissolved near its solubility limit, despite a shorter residence time in the columns than expected for the PRB.[1] Therefore, the theoretical solubility of gypsum (calcium sulfate dihydrate) can be used to calculate the percent gypsum required in the PRB for a desired longevity. Gypsum solubility at 25 degrees Celsius (°C) is 2,600 mg/L (Lebedev and Kosorukov 2017), with a corresponding maximum sulfate concentration of 1,451 mg/L. As presented in Table 6, the longevity of the gypsum within the PRB is calculated from the required number of pore volume flushes to dissolve all the gypsum. The time required is based on the wet season average groundwater seepage velocity derived from Site PFM measurements. **Based on this estimation and a target lifespan of 15 years, approximately 116,600 pounds (lbs) of gypsum would be required. This represents 18 percent by weight in the total PRB composition (i.e., gypsum, ZVI, and sand).**

However, as observed in the column test, softening and compaction of the gypsum, and eventual dissolution, is expected to result in settlement over the lifespan of the PRB. Based on approximately half as much gypsum in the PRB (18 percent) as the column test (30 percent) and the 12-ft vertical interval of the PRB reactive backfill (Figure 3), this could result in approximately 1.5 to 2.5 ft of settlement. As an additional consideration, although a reduction in flow was not observed in the column tests, softening and compaction of a high concentration of gypsum in the barrier would fill some of the sand pore spaces and could reduce the hydraulic conductivity of the barrier. To account for this settlement, the recommended height of the PRB reactive material extends 2 ft above the historic seasonal high groundwater elevation. To avoid development of a surface depression over time above the PRB alignment, we recommend that the non-reactive backfill starting at 4 ft bgs extend 1 to 2 ft above grade, or that plans be made to periodically fill and regrade the ditch over the PRB. Given the length of the PRB and connection to the Chuckanut Formation bedrock, it is unlikely that a reduction in the PRB effective porosity due to gypsum softening and compaction would result in groundwater being diverted around or beneath the PRB.

Ferox PRB ZVI

The mass fraction range of ZVI used during column testing (15 to 25 percent) did not significantly affect the amount of reduction of free cyanide. The mass fraction was determined using the calculated reaction rate (described above) and iron demand of competing species in Site groundwater. As with the gypsum calculations, conservative design parameters were used.

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[1] Flow through the columns was approximately 54 times the maximum wet season groundwater flux.

The first-order reaction equation (Equation 4), reaction rate relationships, and flow parameter relationships were used to derive an equation for the mass of iron required in the PRB (Equation 5). This equation and its derivation were confirmed by the vendor.

(Eqn. 5)

$$W = F\left(\frac{Anu}{k_{mass}}\right)\ln\left(\frac{C_0}{C}\right)$$

The mass of ZVI required in the PRB consists of both the mass required to reduce WAD cyanide concentrations at the Site (Table 7) and to account for natural demand due to naturally occurring elements and minerals in Site groundwater that compete for ZVI reaction sites (Table 8). Based on assumptions presented in Table 7 and summarized below, the ZVI mass required to treat cyanide is approximately 44,300 lbs. Key assumptions include:

- Effective porosity of the barrier = 0.40
  - Effective porosity determined in bench-scale column tests and field observations in a PRB containing 100 percent ZVI range from 45 to 55 percent (ITRC 2011).
  - As the PRB at the Site will have a ZVI fraction of much less than 100 percent, it is appropriate to reduce the effective porosity used in the design (ITRC 2011).
  - The effective porosity of 40 percent used for calculations is higher than the 30 percent effective porosity assumed for Site fill. This value of 40 percent is also consistent with published ranges for clean sand (Woessner and Poeter 2020), which will be specified as the structural fill component in the PRB.
- Influent WAD cyanide concentration = 0.640 mg/L
  - Equivalent to twice the maximum concentration detected in Site groundwater as a design factor of safety.
- Target lifespan = 20 years
- Average seepage velocity through the barrier = 6.4 cm/d (0.21 ft/d)
  - This is the maximum wet season groundwater flux divided by the assumed barrier porosity of 0.40.

Using vendor-provided reaction constants and maximum detections for the various water quality parameters obtained from historic data for three Site monitoring wells located nearest the planned PRB (MW-28, MW-29, and MW-62), the additional ZVI demand from competing species is approximately 45,400 lbs (Table 8).

The total weight of ZVI to address both cyanide and natural demand is 89,700 lbs (Table 7). This represents 14 percent by weight in the total PRB composition (gypsum, ZVI, and sand).

Table 7 also compares the calculated quantity of required ZVI mass to screening criteria and typical values provided by Hepure. The percent of ZVI relative to the other materials in the PRB (14 percent) is within the typical range of 10 to 50 percent. The ZVI percent of frontal area (57 pounds per square foot [lb/ft^2]) is within the typical range of 40 to 200 lb/ft^2; this is a measure of how likely it is that a drop of water containing cyanide will encounter ZVI within the face of the PRB for treatment to occur.

The composition of the full-scale PRB based on use of 18 percent gypsum to maximize TPH treatment longevity is as follows.[2]

Component	Weight (lbs)	Volume (ft^3)	Fraction
Pulverized gypsum	116,629	3,332	18.1%
Ferox PRB	89,677	492	13.9%
Sand	437,337	3,976	67.9%
TOTAL	**643,643**	**7,800**	**100.0%**

Discussion with Hepure has confirmed Landau's expectations for the method of PRB construction. An excavator and trench box will be used to advance the excavation to bedrock. A trench box will be required because the excavation will extend approximately 8 to 10 ft below the wet season water table and 6 ft below the dry season water table in sandy fill of unknown compaction (Figure 3). PRB components are typically laid out in windrows next to the trench and mixed to visual uniformity with the excavator. The trench is backfilled with the mixture as the trench box advances along the length of the PRB to avoid open sections of the trench which would slough below the water table.

USE OF THIS TECHNICAL MEMORANDUM

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[2] A lower design lifespan of 15 years was used for the gypsum component of the PRB. Injection of additional gypsum may be necessary to prolong TPH treatment for the entire 20-year target lifespan of the PRB.

LANDAU ASSOCIATES, INC.

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JKG/CLJ/ljl
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Attachments

Figure 1	Vicinity Map
Figure 2	Site Plan
Figure 3	Target Treatment Zone Cross Section C-C’
Figure 4	Gypsum Column Study Effluent Sulfate Results
Figure 5	ZVI Column Study Results
Table 1	Passive Flux Meter™ Results Summary
Table 2	Groundwater Analytical Results Summary
Table 3	Gypsum Column Study Results Summary
Table 4	ZVI Column Study Results Summary
Table 5	ZVI-Cyanide Reaction Rates
Table 6	Gypsum Demand Calculations
Table 7	ZVI Demand Calculations
Table 8	Competing Species Demand on ZVI
Attachment 1	Laboratory Data Packages
Attachment 2	EnviroFlux Data Packages

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Data Source: Esri.

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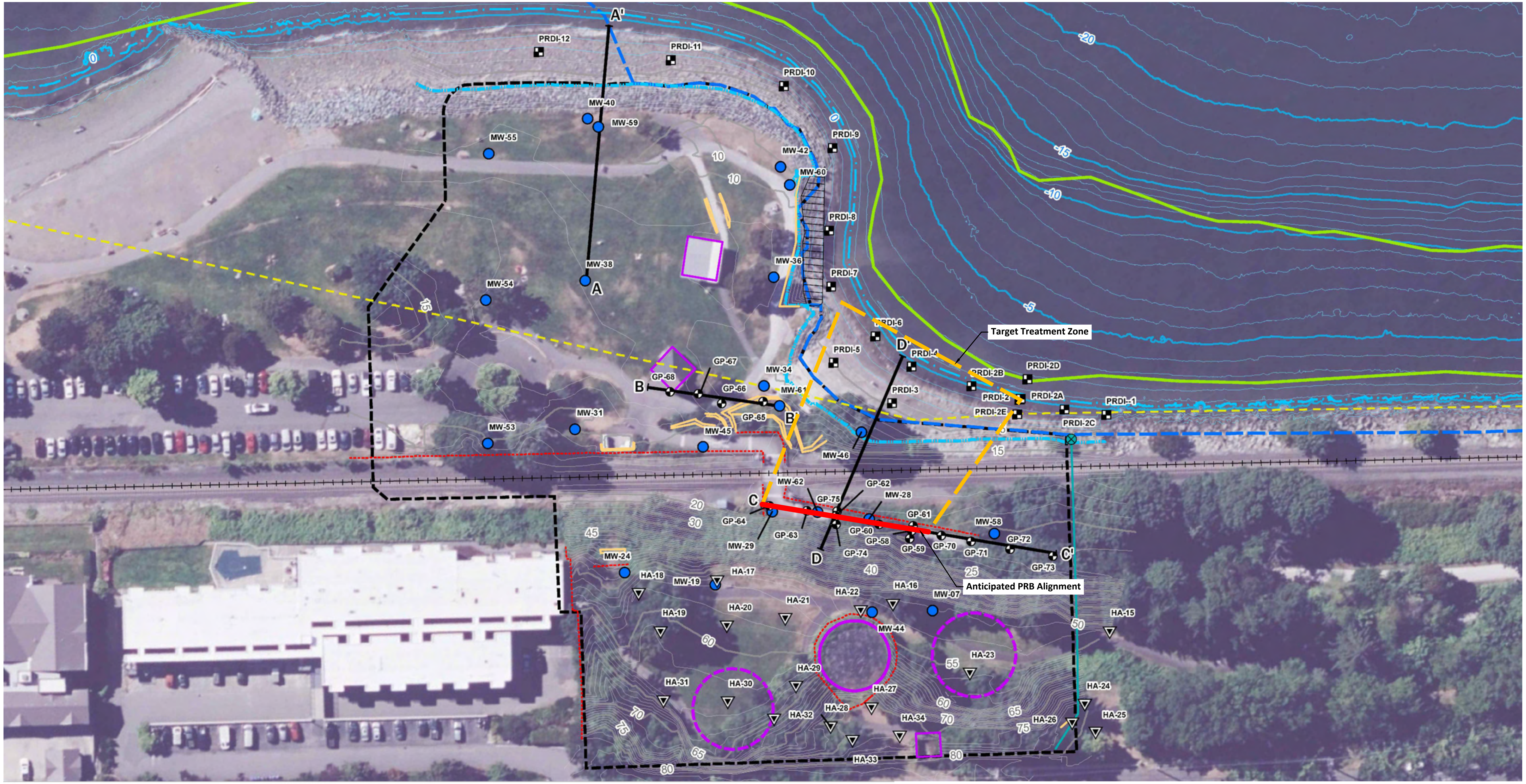
Former South State Street MGP
Bellingham, Washington

Vicinity Map

Figure
1



Notes:
1. The locations of all features shown are approximate.
2. Mean High Tide defines the boundary between the Upland Unit and Marine Unit.
3. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Data Source: Base upland survey from Larry Steel Associates, 2022. Base bathymetric survey from David Evands and Assocates, 2021. Aerial from Bing.

Projection: NAD83 WA State Plane, N Zone, US Foot
Vertical Datum: NAVD88

Legend

⊕	Direct Push Soil Boring
▽	Shallow Hand Auger Soil Sample
●	Monitoring Well
▞	Intertidal Sediment and Porewater Sample Location
⊗	Stormwater Outfall
—	Stormwater Pipe
—	Approximate Limits of Aquatic Vegetation
- - -	Fence
—	Retaining Wall
—+—	BNSF Centerline
- -	Inner Harbor Line
-··-	OHWM (9.70' NAVD88)
- · -	MLLW (el. 0.48' NAVD88)
▨	Wood Pilings Area
□	Site Structures
□	Former Gas Holder
□	Marine Unit Boundary
□	Upland Unit Boundary

Bathymetry Contours

—	1-Foot Contour
—	5-foot Contour

Upland Contours

—	1-Foot Contour
—	5-foot Contour

Source: PRDI (GeoEngineers 2023)

Former South State Street MGP
Bellingham, Washington

Site Plan

Figure
2

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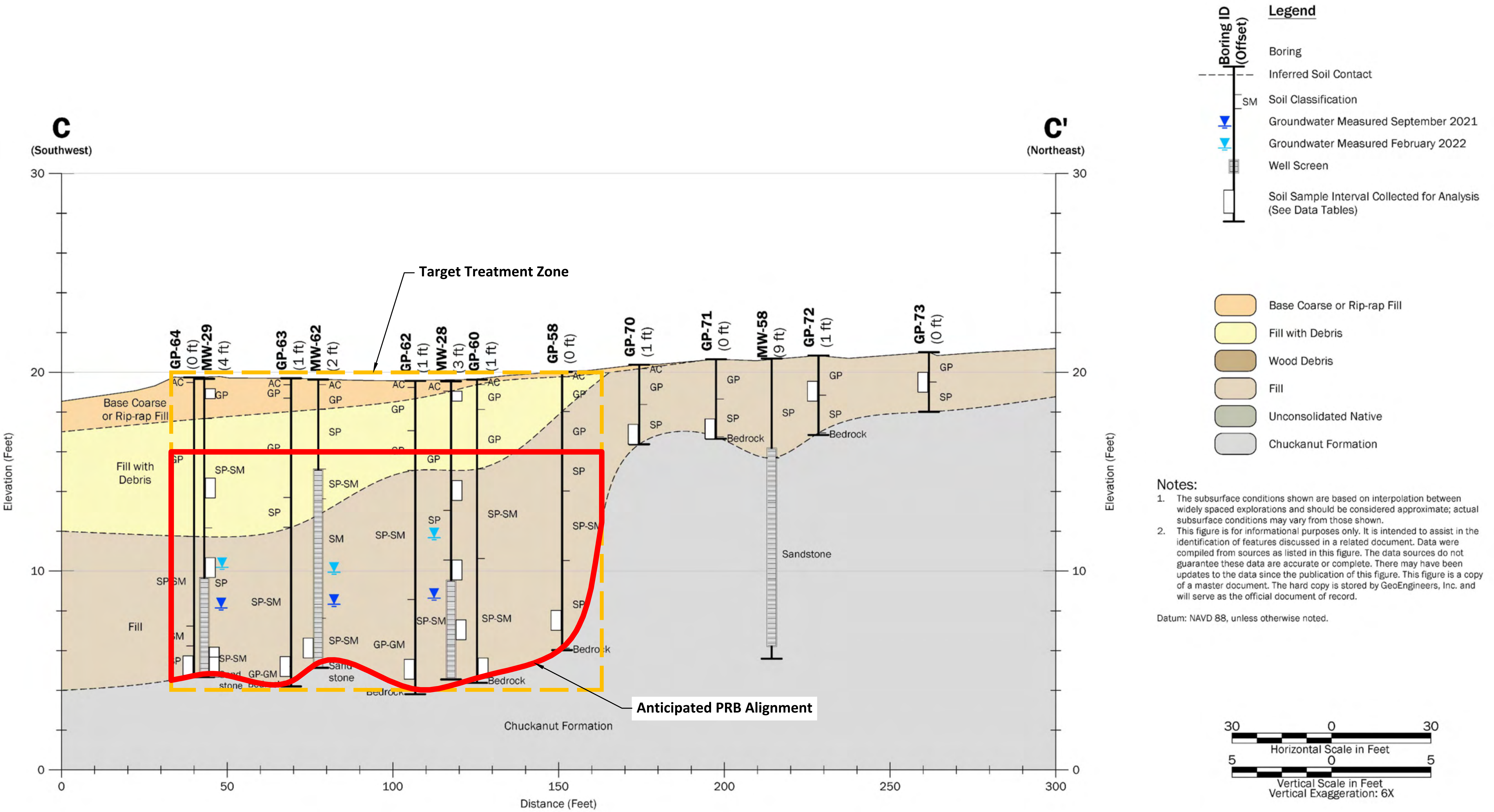

Notes:

1. The subsurface conditions shown are based on interpolation between widely spaced explorations and should be considered approximate; actual subsurface conditions may vary from those shown.
2. This figure is for informational purposes only. It is intended to assist in the identification of features discussed in a related document. Data were compiled from sources as listed in this figure. The data sources do not guarantee these data are accurate or complete. There may have been updates to the data since the publication of this figure. This figure is a copy of a master document. The hard copy is stored by GeoEngineers, Inc. and will serve as the official document of record.

Datum: NAVD 88, unless otherwise noted.

Source: PRDI (GeoEngineers 2023)

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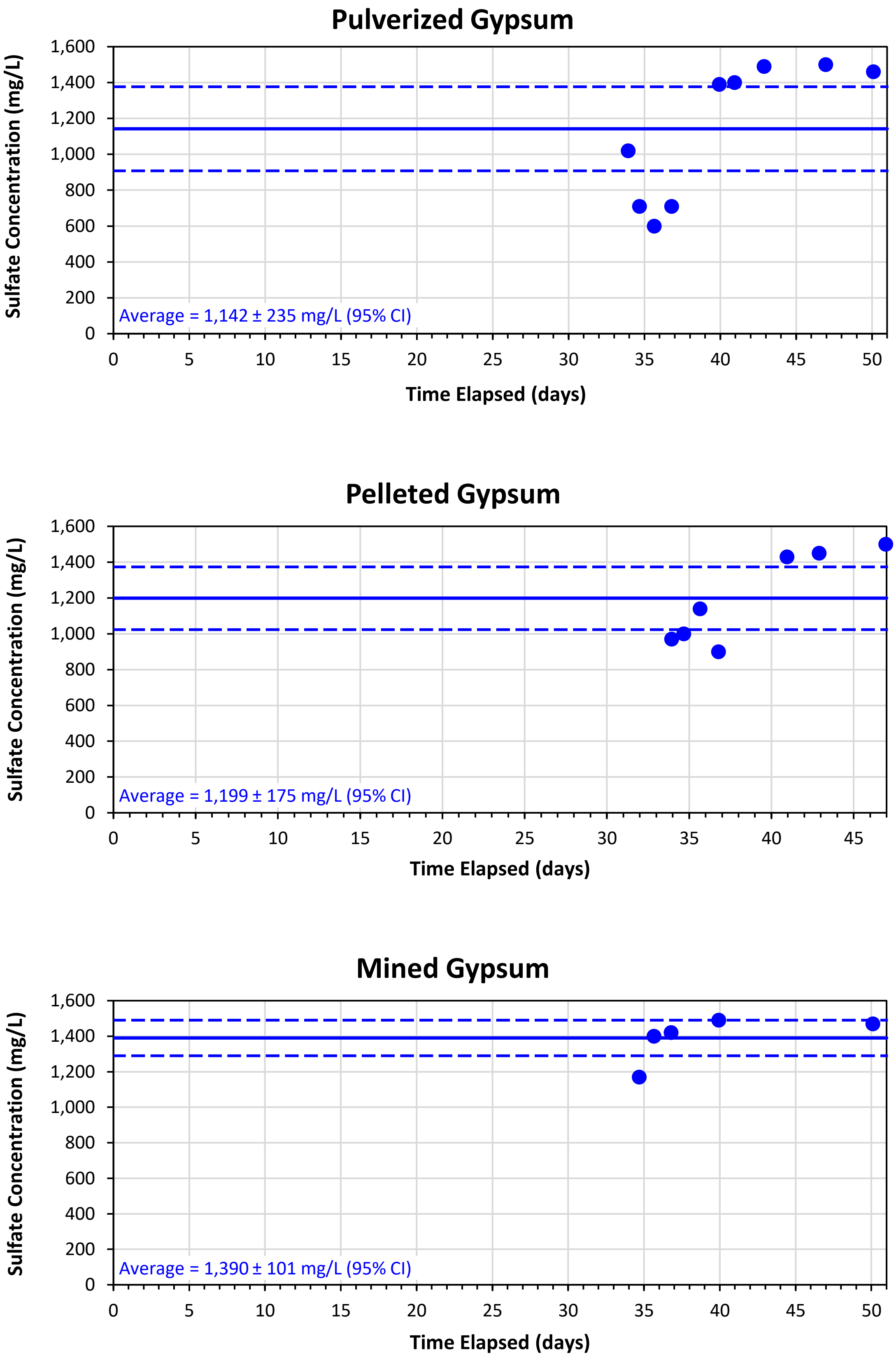
Former South State Street MGP Bellingham, Washington	**Target Treatment Zone Cross Section C-C'**	Figure 3



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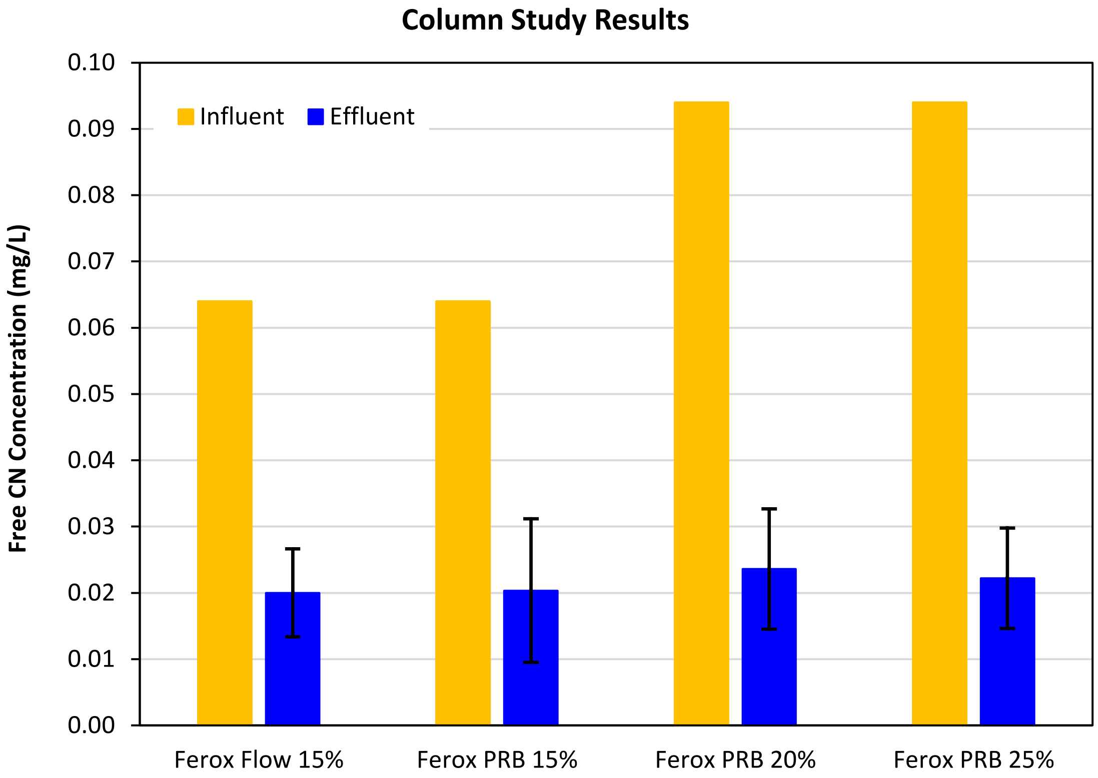
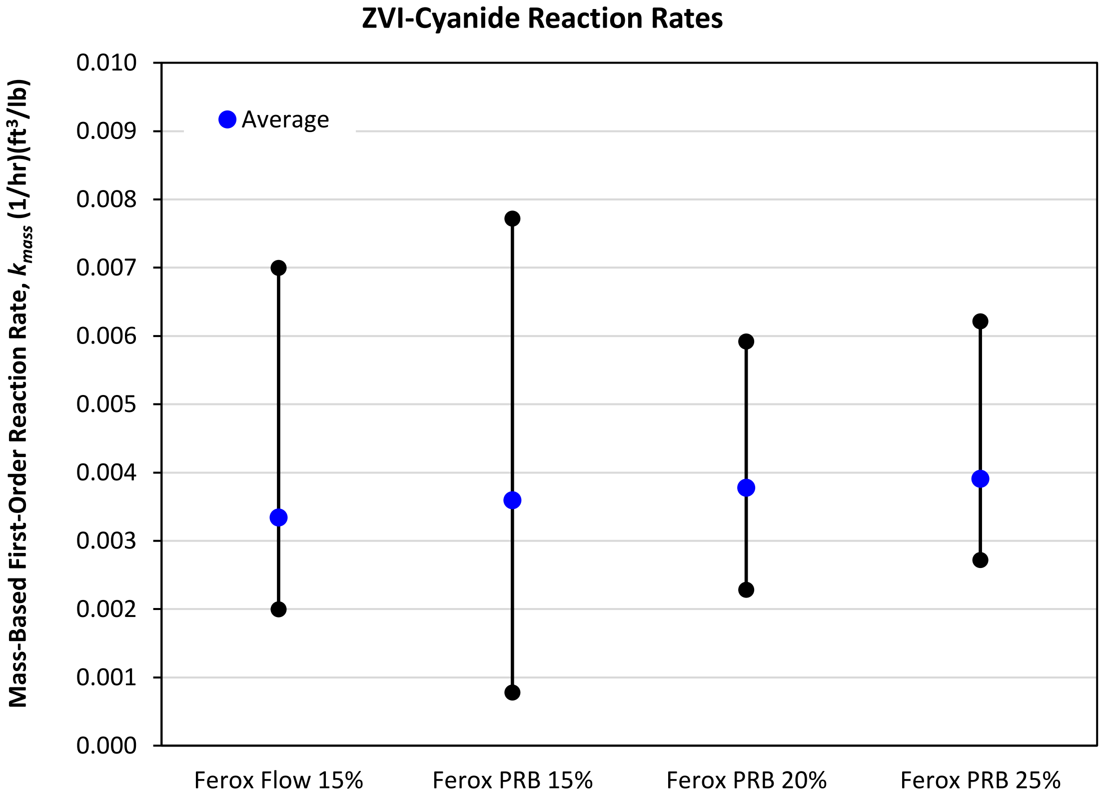
Former SSSMGP Site
Bellingham, Washington

Gypsum Column Study
Effluent Sulfate Results

Figure
4





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Former SSSMGP Site
Bellingham, Washington

ZVI Column Study Results

Figure
5

Table 1
Passive Flux Meter$^{\text{TM}}$ Results Summary
Former SSSMGP Site
Bellingham, Washington

Monitoring Location:	MW-28		MW-29	
Sampling Date:	**4/25/2023**	**9/28/2023**	**4/25/2023**	**9/28/2023**
Flow Characteristics Through Site Soil				
Average Groundwater Flux (cm/d)	1.55	2.04	2.56	0.67
Effective Porosity, Site Soil (a)	0.30	0.30	0.30	0.30
Average Seepage Velocity (cm/d)	5.2	6.8	8.5	2.2
Average Seepage Velocity (ft/d)	0.17	0.22	0.28	0.07
Flow Characteristics Through Barrier				
Effective Porosity, Barrier (b)	0.40	0.40	0.40	0.40
Average Seepage Velocity (cm/d)	3.9	5.1	6.4	1.7
Average Seepage Velocity (ft/d)	0.13	0.17	0.21	0.05
Benzene				
Average Flux (mg/m^2/d)	21.4	114	ND (<0.002)	4.10
Calculated GW Concentration (µg/L) (c)	1,377	5,586	ND	612
Measured GW Concentration (µg/L) (d)	1,440	1,110	ND (<0.05)	51.2
Toluene				
Average Flux (mg/m^2/d)	1.80	4.04	0.23	1.31
Calculated GW Concentration (µg/L) (c)	116	198	9.04	196
Measured GW Concentration (µg/L) (d)	NM	NM	NM	NM
Ethylbenzene				
Average Flux (mg/m^2/d)	1.23	6.62	ND (<0.02)	6.24
Calculated GW Concentration (µg/L) (c)	79.2	324	ND	930
Measured GW Concentration (µg/L) (d)	NM	NM	NM	NM
m,p-Xylene				
Average Flux (mg/m^2/d)	0.42	ND (<0.16)	ND (<0.02)	ND (<0.16)
Calculated GW Concentration (µg/L) (c)	26.7	ND	ND	ND
Measured GW Concentration (µg/L) (d)	NM	NM	NM	NM
o-Xylene				
Average Flux (mg/m^2/d)	1.53	1.87	ND (<0.02)	0.55
Calculated GW Concentration (µg/L) (c)	98.5	91.7	ND	82.5
Measured GW Concentration (µg/L) (d)	NM	NM	NM	NM
Gasoline-Range Total Petroleum Hydrocarbons				
Average Flux (mg/m^2/d)	0.33	0.19	0.14	0.07
Calculated GW Concentration (µg/L) (c)	21.0	9.30	5.33	10.9
Measured GW Concentration (µg/L) (d)	10,700	4,470	ND (<100)	1,350
Diesel-Range Total Petroleum Hydrocarbons				
Average Flux (mg/m^2/d)	1,089	36.6	ND (<13.3)	7.31
Calculated GW Concentration (µg/L) (c)	70,196	1,789	ND	1,090
Measured GW Concentration (µg/L) (d)	1,400	1,360	1,730	1,060
Total Cyanide				
Average Flux (mg/m^2/d)	ND (<3.2)	ND (<2.9)	26.3	13.4
Calculated GW Concentration (mg/L) (c)	ND	ND	1.03	1.99
Measured GW Concentration (mg/L) (d)	0.060	0.019	4.80	0.35

Notes:

(a) Mid-range value for "most aquifer materials." From *Permeable Reactive Barrier: Technology Update* by The Interstate Technology & Regulatory Council, June 2011.

(b) Mid-range value for a "PRB containing 100% ZVI." From *Permeable Reactive Barrier: Technology Update* by The Interstate Technology & Regulatory Council, June 2011.

(c) Calculated by dividing the average flux measured by the flux meter by the average Darcy flux measured by the flux meter.

(d) Concentration detected (or not detected) during groundwater monitoring event performed immediately following flux meter retrieval.

Blue shading indicates calculated and measured GW concentrations that are comparable.

Abbreviations and Acronyms:

µg = micrograms
cm = centimeter
d = day
ft = feet
GW = groundwater
L = liter
m^2 = square meters
mg = milligrams
ND = not detected
NM = not measured

Table 2
Groundwater Analytical Results Summary
Former SSSMGP Site
Bellingham, Washington

		Petroleum Hydrocarbons			Cyanide		Volatiles	Aquifer Redox Conditions					
	Sample Date	GRO (µg/L)	DRO (µg/L)	ORO (µg/L)	Total Cyanide (mg/L)	WAD Cyanide (mg/L)	Benzene (µg/L)	DO (mg/L)	ORP (mV)	Iron II (mg/L)	Sulfate (mg/L)	pH	Groundwater Elevation (ft NAVD88)
Sampling Location	**Cleanup Level (b):**	**800 (c)**	**500 (c)**	**500 (c)**	**---**	**0.005**	**1.6**	**---**	**---**	**---**	**---**	**---**	**---**
MW-28	9/20/2021 (a)	**22,600**	**2,840**	<200	**0.155**	**0.033**	**4,890**	0.64	-84.6	---	5.40	6.54	7.95
	2/9/2022 (a)	**32,500**	---	---	**0.106**	**0.016**	**3,720**	1.80	-38.7	---	10.6 J	6.64	11.81
	4/6/2022 (a)	---	**2,500**	<200	---	---	---	0.22	178.0	---	---	6.47	11.33
	4/25/2023	**10,700**	**1,400**	<200	**0.060**	**0.033**	**1,440**	0.80	-84.4	6.9	2.45	6.52	9.86
	9/28/2023	**4,470**	**1,360**	<240	**0.019**	**0.008**	**1,110**	0.84	-71.1	7.0	0.203	7.13	7.84
MW-29	9/21/2021 (a)	<100	**521**	**229**	**1.14**	**0.073**	**1.48**	0.87	195.0	---	95.5	6.83	7.61
	2/8/2022 (a)	**484**	**2,530**	**724**	**0.955**	**0.091**	**9.78**	0.57	177.0	---	72.6	6.36	9.46
	4/25/2023	<100	**1,730**	**626**	**4.80**	**0.340**	<0.05	2.92	52.9	0.0	45.8	6.50	9.25
	9/28/2023	**1,350**	**1,060**	**614**	**0.352**	**0.025**	**51.2**	2.70	19.5	7.2	37.3	6.64	6.91

Notes:

(a) Sampling performed by GeoEngineers, Inc.

(b) Cleanup levels determined in the Cleanup Action Plan (Washington State Department of Ecology 2020).

(c) GRO, DRO, and ORO are not groundwater contaminants of concern. MTCA Method A criteria are used as screening levels.

Bold = Concentration detected above laboratory reporting limit.

Blue shading indicates concentration above applicable screening/cleanup level.

--- = Not measured/not applicable

Abbreviations and Acronyms:

µg/L = micrograms per liter

DO = dissolved oxygen

DRO = diesel-range organics

ft = feet

GRO = gasoline-range organics

ORO = oil-range organics

mg/L = milligrams per liter

MTCA = Model Toxics Control Act

mV = millivolts

NAVD88 = North American Vertical Datum of 1988

ORP = oxidation reduction potential

WAD = weak acid dissociable

Table 3
Gypsum Column Study Results Summary
Former SSSMGP Site
Bellingham, Washington

Column ID	Product	Particle Size	Composition		Test Duration			Sulfate Concentration (mg/L)		Settling/Compaction		
			Gypsum	Sand	Start Date	End Date	Run Time (days)	Average Effluent	Effluent 95% CI	Starting Length (ft)	Ending Length (ft)	Change
G1	Pulverized gypsum	1/4" or smaller	30%	70%	7/26/23	9/14/23	50.1	1,142	± 235	5.00	3.34	33%
G2	Pelleted gypsum	1/8" to 1/4"	30%	70%	7/26/23	9/11/23	47.0	1,199	± 175	5.00	2.88	42%
G3	Mined gypsum	1/2" or smaller	30%	70%	7/26/23	9/14/23	50.1	1,390	± 101	5.00	3.58	28%

Abbreviations and Acronyms:

% = percent
CI = confidence interval
ft = feet
ID = identification
mg/L = milligrams per liter

Table 4
ZVI Column Study Results Summary
Former SSSMGP Site
Bellingham, Washington

Column ID	Product	Particle Size	Composition		Test Duration			Free CN Concentration (mg/L)			Removal Efficiency		
			ZVI	Sand	Start Date	End Date	Run Time (days)	Influent	Average Effluent	Effluent 95% CI	Minimum	Maximum	Average
ZF15	Ferox Flow	125 microns	15%	85%	9/12/23	9/20/23	8.0	0.064	0.020	± 0.007	55%	94%	69%
ZP15	Ferox PRB	325 microns	15%	85%	9/12/23	9/20/23	8.0	0.064	0.020	± 0.011	27%	95%	68%
ZP20	Ferox PRB	325 microns	20%	80%	9/29/23	10/6/23	7.0	0.094	0.024	± 0.009	60%	90%	75%
ZP25	Ferox PRB	325 microns	25%	75%	9/29/23	10/6/23	7.0	0.094	0.022	± 0.008	66%	91%	76%

Abbreviations and Acronyms:

% = percent
CI = confidence interval
CN = cyanide
ID = identification
mg/L = milligrams per liter
ZVI = zero-valent iron

Table 5
ZVI-Cyanide Reaction Rates
Former SSSMGP Site
Bellingham, Washington

Ferox Flow, 15%

Time Elapsed	Res. Time	Res. Time	ZVI Ratio	Influent, C_0	Effluent, C	C/C_0	$\ln(C/C_0) = -kt$	k	k_{mass}	
d	d	hrs	lb/ft^3	mg/L	mg/L	---	---	1/hr	$ft^3/lb/hr$	
1.1	0.9	21	18.7	0.064	0.023	0.359	-1.023	0.048	0.003	
2.2	0.9	21	18.7	0.064	0.016	0.250	-1.386	0.065	0.003	
5.1	0.9	21	18.7	0.064	0.004	0.063	-2.773	0.131	0.007	
5.9	0.9	21	18.7	0.064	0.029	0.453	-0.792	0.037	0.002	
7.0	0.9	21	18.7	0.064	0.021	0.328	-1.114	0.053	0.003	
8.0	0.9	21	18.7	0.064	0.027	0.422	-0.863	0.041	0.002	
								0.037	0.002	**Minimum**
								0.131	0.007	**Maximum**
								0.062	0.003	**Average**

Ferox PRB, 15%

Time Elapsed	Res. Time	Res. Time	ZVI Ratio	Influent, C_0	Effluent, C	C/C_0	$\ln(C/C_0) = -kt$	k	k_{mass}	
d	d	hrs	lb/ft^3	mg/L	mg/L	---	---	1/hr	$ft^3/lb/hr$	
1.1	0.9	21	18.7	0.064	0.003	0.047	-3.060	0.144	0.008	
2.2	0.9	21	18.7	0.064	0.022	0.344	-1.068	0.050	0.003	
5.1	0.9	21	18.7	0.064	0.015	0.234	-1.451	0.068	0.004	
5.9	0.9	21	18.7	0.064	0.047	0.734	-0.309	0.015	0.001	
7.0	0.9	21	18.7	0.064	0.013	0.203	-1.594	0.075	0.004	
8.0	0.9	21	18.7	0.064	0.022	0.344	-1.068	0.050	0.003	
								0.015	0.001	**Minimum**
								0.144	0.008	**Maximum**
								0.067	0.004	**Average**

Ferox PRB, 20%

Time Elapsed	Res. Time	Res. Time	ZVI Ratio	Influent, C_0	Effluent, C	C/C_0	$\ln(C/C_0) = -kt$	k	k_{mass}	
d	d	hrs	lb/ft^3	mg/L	mg/L	---	---	1/hr	$ft^3/lb/hr$	
3.0	0.9	21	18.7	0.094	0.022	0.234	-1.452	0.068	0.004	
4.0	0.9	21	18.7	0.094	0.032	0.340	-1.078	0.051	0.003	
4.9	0.9	21	18.7	0.094	0.038	0.404	-0.906	0.043	0.002	
6.0	0.9	21	18.7	0.094	0.017	0.181	-1.710	0.081	0.004	
7.0	0.9	21	18.7	0.094	0.009	0.096	-2.346	0.111	0.006	
								0.043	0.002	**Minimum**
								0.111	0.006	**Maximum**
								0.071	0.004	**Average**

Table 5
ZVI-Cyanide Reaction Rates
Former SSSMGP Site
Bellingham, Washington

Ferox PRB, 25%

Time Elapsed	Res. Time	Res. Time	ZVI Ratio	Influent, C_0	Effluent, C	C/C_0	$\ln(C/C_0) = -kt$	*k*	*k* $_{mass}$	
d	d	hrs	lb/ft^3	mg/L	mg/L	---	---	1/hr	ft^3/lb/hr	
3.0	0.9	21	18.7	0.094	0.032	0.340	-1.078	0.051	0.003	
4.0	0.9	21	18.7	0.094	0.008	0.085	-2.464	0.116	0.006	
4.9	0.9	21	18.7	0.094	0.017	0.181	-1.710	0.081	0.004	
6.0	0.9	21	18.7	0.094	0.026	0.277	-1.285	0.061	0.003	
7.0	0.9	21	18.7	0.094	0.028	0.298	-1.211	0.057	0.003	
								0.051	0.003	**Minimum**
								0.116	0.006	**Maximum**
								0.073	0.004	**Average**

Overall

k	*k* $_{mass}$	
1/hr	ft^3/lb/hr	
0.015	0.001	**Minimum**
0.144	0.008	**Maximum**
0.068	**0.004**	**Average**

Abbreviations and Acronyms:

% = percent

C = concentration at time t

C_0 = influent concentration

d = days

ft^3 = cubic feet

hr = hour

k = first-order reaction rate

k $_{mass}$ = mass-based first-order reaction rate

L = liters

lb = pounds

mg = milligrams

PRB = permeable reactive barrier

t = time

Table 6
Gypsum Demand Calculations
Former SSSMGP Site
Bellingham, Washington

Parameter	Value	Units	Comments
Gypsum solubility limit	0.0026	g/mL	Calcium sulfate dihydrate at 25°C
	2,600	mg/L	Convert to mg/L
Gypsum molar mass	172.17	mg/mmol	
Sulfate molar mass	96.06	mg/mmol	
Ratio of sulfate:gypsum	0.56		
Sulfate concentration at gypsum solubility limit	1,451	mg/L	Maximum theoretical sulfate concentration
Weight of Gypsum Required for Each Barrier Flush			
Barrier length	130	ft	
Barrier width	5	ft	
Barrier depth	12	ft	
Barrier volume	7,800	ft^3	
	220,871	L	
Effective Porosity, Barrier	0.40		100% ZVI barrier; conservative estimate
Water within barrier pore space	88,348	L	
Weight of gypsum in barrier at solubility limit	229,705,882	mg	
	506	lbs	
Number of Barrier Flushes during Lifespan			
Average Groundwater Seepage velocity through barrier	6.4	cm/d	Linear velocity through barrier; max wet season
	0.21	ft/d	Convert to ft/d
Residence time in barrier	23.8	d	
Barrier lifespan	15	yr	
	5,475	d	Convert to days
Number of barrier flushes in lifespan	230	flushes	Equal to the lifespan divided by residence time
Weight of Gypsum Required for Lifespan of Barrier			
Weight of gypsum required for lifespan	**116,629**	**lbs**	
Volume of gypsum required for lifespan	3,332	ft^3	
Volume of soil required	3,976	ft^3	See Table 7
Weight of soil required	437,337	lbs	See Table 7
Weight of ZVI required	89,677		See Table 7
Fraction of total barrier composition	**18.1%**	**by wt**	

Abbreviations and Acronyms:

% = percent
°C = degrees Celsius
by wt = by weight
cm = centimeters
d = days
ft = feet
g = grams
L = liters
lbs = pounds
mg = milligrams
mL = milliliters
mmol = millimoles
wt = weight
yr = years
ZVI = zero-valent iron

Table 7
ZVI Demand Calculations
Former SSSMGP Site
Bellingham, Washington

$$W = F\left(\frac{Anu}{k_{mass}}\right)\ln\left(\frac{C_0}{C}\right)$$

Variable	Description	Value	Units	Comments
F	Factor of Safety	6		
u	Average groundwater seepage velocity	6.4	cm/d	through barrier; max wet season
		0.009	ft/hr	Converted to ft/hr
n	Effective Porosity, Barrier	0.40		100% ZVI barrier; conservative estimate
L	Length of barrier	130	ft	
H	Depth of barrier	12	ft	
A	Cross-sectional area	1,560	ft^2	
k_{mass}	Mass reaction rate	0.004	ft^3/lb-hr	Average from column study
C_0	Influent concentration	0.680	mg/L	Twice the maximum detected WAD cyanide concentration
C	Effluent concentration	0.005	mg/L	Cleanup level
z	Width of barrier	5	ft	
W	Weight of ZVI needed	44,285	lbs	
Additional ZVI Demand from Competing Species in Groundwater				
W_c	Additional ZVI demand	45,392	lbs	See Table 8
$\mathbf{W_z}$	**Total weight of ZVI**	**89,677**	**lbs**	
Determine Barrier Composition				
ρ_z	Density of ZVI	182	lb/ft^3	From vendor for Ferox PRB
V_z	Volume of ZVI	492	ft^3	
V_b	Volume of barrier	7,800	ft^3	
V_g	Volume of gypsum	3,332	ft^3	See Table 4
ρ_s	Density of gypsum	35	lb/ft^3	For vendor for pulverized gypsum
W_g	Weight of gypsum	116,629	lbs	
V_s	Volume of PRB sand	3,976	ft^3	
ρ_s	Density of PRB sand	110	lb/ft^3	For 12/20 sand
W_s	Weight of PRB sand	437,337	lbs	
Barrier Screening Criteria				
ZVI Percent of total barrier mass		**13.9%**	**by wt**	**Typical = 10-50%**
ZVI Percent of frontal area		57	lb/ft^2	Typical = 40-200 lb/ft^2

Abbreviations and Acronyms:

% = percent
cm = centimeters
d = days
ft = feet
ft^2 = square feet
ft^3 = cubic feet
hr = hours
L = liters
lb = pounds
mg = milligrams
PRB = permeable reactive barrier
wt = weight
ZVI = zero-valent iron

Table 8
Competing Species Demand on ZVI
Former SSSMGP Site
Bellingham, Washington

Parameter	Value	Units	Comments
Barrier length	130	ft	
Barrier width	5	ft	
Barrier depth	12	ft	
Average groundwater seepage velocity	0.009	ft/hr	Through barrier; max wet season
Effective Porosity, Barrier	0.40		100% ZVI barrier; conservative estimate
Lifespan	20	years	Target
Ferox PRB reactivity	2.28		Proprietary, from vendor (Hepure)

Calculation of Ferrox PRB ZVI Demand:

Competing Species	Molecular Weight	Theor. Demand	Concentration (a)	Static Demand	Flow Demand	Total Demand	Adj. Demand
		mol/mol	mg/L	lbs	lbs	lbs	lbs
Dissolved oxygen (O_2)	31.998	2	0.87	0	91	91	208
Nitrate (NO_3^-)	62.004	2.5	0.05	0	3	3	8
Sulfate (SO_4^{2-})	96.061	4	95.50	5	6,660	6,664	15,225
Chloride (Cl^-)	35.453	1	276.76	13	13,074	13,087	29,897
Calcium (Ca^{2+})	40.078	1	0.00	0	0	0	0
Magnesium (Mg)	24.305	1	0.00	0	0	0	0
Antimony (Sb)	121.76	1	0.00	0	0	0	0
Arsenic (As)	74.922	3	0.00	0	0	0	0
Chromium (Cr)	51.996	3	0.00	0	0	0	0
Selenium (Se)	78.960	2	0.56	0	24	24	54
Cadmium (Cd)	112.41	1	0.00	0	0	0	0
Lead (Pb)	207.20	1	0.00	0	0	0	0
			Totals:	**18**	**19,852**	**19,870**	**45,392**

Notes:

(a) Maximum of concentrations measured during pre-remedial design investigation at MW-28, MW-29, and MW-61 (September 20, 2021).

Abbreviations and Acronyms:

ft = feet
ft/hr = feet per hour
lbs = pounds
mg/L = milligrams per liter
mol = moles
PRB = permeable reactive barrier
ZVI = zero-valent iron

ATTACHMENT 1

Laboratory Data Packages

Analytical Resources, LLC
Analytical Chemists and Consultants
Tukwila, WA

12 May 2023

Clint Jacob
Landau Associates, Inc.
130 2nd Avenue S.
Edmonds, WA 98020

RE: SSSMGP (0611004.020.023)

Please find enclosed sample receipt documentation and analytical results for samples from the project referenced above.

Sample analyses were performed according to ARI's Quality Assurance Plan and any provided project specific Quality Assurance Plan. Each analytical section of this report has been approved and reviewed by an analytical peer, the appropriate Laboratory Supervisor or qualified substitute, and a technical reviewer.

Should you have any questions or problems, please feel free to contact us at your convenience.

Associated Work Order(s)	Associated SDG ID(s)
23D0602	N/A

I certify that this data package is in compliance with the terms and conditions of the contract, both technically and for completeness, for other than the conditions detailed in the enclose Narrative. ARI, an accredited laboratory, certifies that the report results for which ARI is accredited meets all the requirements of the accrediting body. A list of certified analyses, accreditations, and expiration dates is included in this report.

Release of the data contained in this hardcopy data package has been authorized by the Laboratory Manager or his/her designee, as verified by the following signature.

Analytical Resources, LLC

Kelly Bottem, Client Services Manager

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

ACCREDITED IN ACCORDANCE WITH nelac
Cert# 100006-012

2300602

LANDAU ASSOCIATES

Chain-of-Custody Record

☒ **North Seattle** (206) 631-8660
☐ **Tacoma** (253) 926-2493
☐ **Olympia** (360) 791-3178
☐ **Spokane** (509) 327-9737
☐ **Portland** (503) 542-1080
☐ ____________

Date 4/25/23
Page 1 of 1

Turnaround Time:
Standard X
Accelerated ____________

Project Name Former SSSMGP
Project No. 0611004.020.023
Project Location/Event Bellingham, WA / PRB Design Testing
Sampler's Name Jenny Green, Adam Torocsik
Project Contact Clint Jacob, Jenny Green
Send Results To Landau Data, C. Jacob, J. Green

Testing Parameters

Sample I.D.	Date	Time	Matrix	No. of Containers	TPH-G (NWTPH-Gx)	Benzene (8260)	TPH-Dx (NWTPH-Dx)	Sulfate (EPA 300.0)	Total/WAD CN (4500-CN)		TPH-G (NWTPH-Gx)✱	Benzene (8260)✱				
MW-28-042523	4/25/23	1319	AQ	8	X	X	X	X	X							
MW-29-042523	4/25/23	1320	AQ	12	X	X	X	X	X		X	X				
TB-042523	—	—	AQ	4	X	X										

WARNING:
CYANIDE IN SAMPLES
AND APPARENT
REACTION OF HCL
WITH CYANIDE IN
MW-29 SAMPLES
(TURNED BLUE)

Special Handling Requirements:
____

Shipment Method: drop off
Stored on ice: [✓ Yes] / No
2.8°C

Observations/Comments

__ Allow water samples to settle, collect aliquot from clear portion ☐

__ NWTPH-Dx - Acid wash cleanup ☐
- Silica gel cleanup ☐

__ Dissolved metal samples were field filtered

Other ____________

✱ Collected in HCl vials rinsed with DI water due to apparent reaction of samples with HCl.

NOTE SHORT HOLD TIME ON UNPRESERVED VIALS FOR GX AND BENZ.
↑
7 DAYS

Relinquished by
Signature
Printed Name Jenny Green
Company Landau Assoc.
Date 4/26/23 Time 959

Received by
Signature Phillip
Printed Name Philip Bates
Company AR
Date 4/26/23 Time 9:59

Relinquished by
Signature ____________
Printed Name ____________
Company ____________
Date ____________ Time ____________

Received by
Signature ____________
Printed Name ____________
Company ____________
Date ____________ Time ____________

WHITE COPY - Laboratory YELLOW COPY - Project File PINK COPY - Client Representative

10/2018

Landau Associates, Inc.	Project: SSSMGP	
130 2nd Avenue S.	Project Number: 0611004.020.023	**Reported:**
Edmonds WA, 98020	Project Manager: Clint Jacob	12-May-2023 18:24

ANALYTICAL REPORT FOR SAMPLES

Sample ID	Laboratory ID	Matrix	Date Sampled	Date Received
MW-28-042523	23D0602-01	Water	25-Apr-2023 13:19	26-Apr-2023 09:59
MW-29-042523	23D0602-02	Water	25-Apr-2023 13:20	26-Apr-2023 09:59
MW-29-042523	23D0602-03	Water	25-Apr-2023 13:20	26-Apr-2023 09:59
TB-042523	23D0602-04	Water	25-Apr-2023 13:19	26-Apr-2023 09:59

Landau Associates, Inc.
130 2nd Avenue S.
Edmonds WA, 98020

Project: SSSMGP
Project Number: 0611004.020.023
Project Manager: Clint Jacob

Reported:
12-May-2023 18:24

Work Order Case Narrative

Gasoline by NWTPH-g (GC/MS)

The sample(s) were analyzed within the recommended holding times.

Initial and continuing calibrations were within method requirements.

Internal standard areas were within limits.

The surrogate percent recoveries were within control limits.

The method blank(s) were clean at the reporting limits.

The blank spike and blank spike duplicate (BS/LCS and BSD/LCSD) spike recoveries and relative percent difference (RPD) were within control limits.

Volatiles - EPA Method SW8260D

The sample(s) were analyzed within the recommended holding times.

Initial and continuing calibrations were within method requirements.

Internal standard areas were within limits.

The surrogate percent recoveries were within control limits.

The method blank(s) were clean at the reporting limits.

The blank spike and blank spike duplicate (BS/LCS and BSD/LCSD) spike recoveries and relative percent difference (RPD) were within control limits.

Wet Chemistry

The sample(s) were prepared and analyzed within the recommended holding times.

Initial and continuing calibrations were within method requirements.

The method blank(s) were clean at the reporting limits.

The blank spike (BS/LCS) percent recoveries were within control limits.

Diesel/Heavy Oil Range Organics - WA-Ecology Method NW-TPHDx

The sample(s) were extracted and analyzed within the recommended holding times.

Initial and continuing calibrations were within method requirements.

The surrogate percent recoveries were within control limits.

The method blank(s) were clean at the reporting limits.

The blank spike (BS/LCS) percent recoveries were within control limits.

Printed: 4/26/2023 10:53:01AM

WORK ORDER

23D0602

Samples will be discarded 90 days after submission of a final report unless other instructions are received

Client: Landau Associates, Inc.

Project Manager: Kelly Bottem

Project: SSSMGP

Project Number: 0611004.020.023

Preservation Confirmation

Container ID	Container Type	pH
23D0602-01 A	HDPE NM, 500 mL	
23D0602-01 B	HDPE NM, 500 mL	<12 fail
23D0602-01 C	Glass NM, Amber, 500 mL	
23D0602-01 D	Glass NM, Amber, 500 mL	
23D0602-01 E	VOA Vial, Clear, 40 mL, HCL	
23D0602-01 F	VOA Vial, Clear, 40 mL, HCL	
23D0602-01 G	VOA Vial, Clear, 40 mL, HCL	
23D0602-01 H	VOA Vial, Clear, 40 mL, HCL	
23D0602-02 A	HDPE NM, 500 mL	
23D0602-02 B	HDPE NM, 500 mL	<12 fail
23D0602-02 C	Glass NM, Amber, 500 mL	
23D0602-02 D	Glass NM, Amber, 500 mL	
23D0602-02 E	VOA Vial, Clear, 40 mL, HCL	
23D0602-02 F	VOA Vial, Clear, 40 mL, HCL	
23D0602-02 G	VOA Vial, Clear, 40 mL, HCL	
23D0602-02 H	VOA Vial, Clear, 40 mL, HCL	
23D0602-03 A	VOA Vial, Clear, 40 mL	
23D0602-03 B	VOA Vial, Clear, 40 mL	
23D0602-03 C	VOA Vial, Clear, 40 mL	
23D0602-03 D	VOA Vial, Clear, 40 mL	
23D0602-04 A	VOA Vial, Clear, 40 mL, HCL	
23D0602-04 B	VOA Vial, Clear, 40 mL, HCL	
23D0602-04 C	VOA Vial, Clear, 40 mL, HCL	
23D0602-04 D	VOA Vial, Clear, 40 mL, HCL	

PEB
Preservation Confirmed By

4/26/23
Date

Reviewed By

Date

Analytical Resources, LLC
Analytical Chemists and Consultants

Cooler Receipt Form

ARI Client: Landau Seattle

COC No(s): ______ [✓ NA]

Assigned ARI Job No: 23D0602

Project Name: Former SSSMGP

Delivered by: Fed-Ex UPS Courier [✓ Hand Delivered] Other: ______

Tracking No: ______ [✓ NA]

Preliminary Examination Phase:

Were intact, properly signed and dated custody seals attached to the outside of the cooler? YES [✓ NO]

Were custody papers included with the cooler? ……………… [✓ YES] NO

Were custody papers properly filled out (ink, signed, etc.) ……………… [✓ YES] NO

Temperature of Cooler(s) (°C) (recommended 2.0-6.0 °C for chemistry)

Time 9:59 2.8

If cooler temperature is out of compliance fill out form 00070F

Temp Gun ID#: 5009708

Cooler Accepted by: PIB Date: 4/26/23 Time: 9:59

Complete custody forms and attach all shipping documents

Log-In Phase:

Was a temperature blank included in the cooler? ……………… YES [✓ NO]

What kind of packing material was used? … [✓ Bubble Wrap] [✓ Wet Ice] Gel Packs Baggies [✓ Foam Block] Paper Other: ______

Was sufficient ice used (if appropriate)? ……………… NA [✓ YES] NO

How were bottles sealed in plastic bags? ……………… Individually Grouped [✓ Not]

Did all bottles arrive in good condition (unbroken)? ……………… [✓ YES] NO

Were all bottle labels complete and legible? ……………… [✓ YES] NO

Did the number of containers listed on COC match with the number of containers received? ……………… [✓ YES] NO

Did all bottle labels and tags agree with custody papers? ……………… [✓ YES] NO

Were all bottles used correct for the requested analyses? ……………… [✓ YES] NO

Do any of the analyses (bottles) require preservation? (attach preservation sheet, excluding VOCs) ... NA [✓ YES] NO

Were all VOC vials free of air bubbles? ……………… NA [✓ YES] NO

Was sufficient amount of sample sent in each bottle? ……………… [✓ YES] NO

Date VOC Trip Blank was made at ARI……………… NA 4/21/23

Were the sample(s) split by ARI? [✓ NA] YES Date/Time: ______ Equipment: ______ Split by: ______

Samples Logged by: PIB Date: 4/26/23 Time: ~~10:23~~ PIB 4/26 10:46 Labels checked by: PIB

***** Notify Project Manager of discrepancies or concerns *****

Sample ID on Bottle	Sample ID on COC	Sample ID on Bottle	Sample ID on COC

Additional Notes, Discrepancies, & Resolutions:

Client provided two sets for VOCs for sample MW-29-042523 because of a reaction with the HCL. one set is preserved the other set is unpreserved.

By: PIB Date: 4/26/23

0016F
01/17/2018

Cooler Receipt Form

Revision 014A

Analytical Resources, LLC
Analytical Chemists and Consultants

Printed: 4/26/2023 10:53:01AM

WORK ORDER

23D0602

Samples will be discarded 90 days after submission of a final report unless other instructions are received

Client: Landau Associates, Inc.
Project Manager: Kelly Bottem
Project: SSSMGP
Project Number: 0611004.020.023

Preservation Confirmation

Container ID	Container Type	pH
23D0602-01 A	HDPE NM, 500 mL	
23D0602-01 B	HDPE NM, 500 mL	<12 fail ①
23D0602-01 C	Glass NM, Amber, 500 mL	
23D0602-01 D	Glass NM, Amber, 500 mL	
23D0602-01 E	VOA Vial, Clear, 40 mL, HCL	
23D0602-01 F	VOA Vial, Clear, 40 mL, HCL	
23D0602-01 G	VOA Vial, Clear, 40 mL, HCL	
23D0602-01 H	VOA Vial, Clear, 40 mL, HCL	
23D0602-02 A	HDPE NM, 500 mL	
23D0602-02 B	HDPE NM, 500 mL	<12 fail ①
23D0602-02 C	Glass NM, Amber, 500 mL	
23D0602-02 D	Glass NM, Amber, 500 mL	
23D0602-02 E	VOA Vial, Clear, 40 mL, HCL	
23D0602-02 F	VOA Vial, Clear, 40 mL, HCL	
23D0602-02 G	VOA Vial, Clear, 40 mL, HCL	
23D0602-02 H	VOA Vial, Clear, 40 mL, HCL	
23D0602-03 A	VOA Vial, Clear, 40 mL	
23D0602-03 B	VOA Vial, Clear, 40 mL	
23D0602-03 C	VOA Vial, Clear, 40 mL	
23D0602-03 D	VOA Vial, Clear, 40 mL	
23D0602-04 A	VOA Vial, Clear, 40 mL, HCL	
23D0602-04 B	VOA Vial, Clear, 40 mL, HCL	
23D0602-04 C	VOA Vial, Clear, 40 mL, HCL	
23D0602-04 D	VOA Vial, Clear, 40 mL, HCL	

PEB
Preservation Confirmed By

4/26/23
Date

① Both samples tested negative for Cl and S^2. Preserved w/2ml (6N) NaOH to pH >12.0. 4-26-23 17:26

Reviewed By

Date

Landau Associates, Inc.	Project: SSSMGP	
130 2nd Avenue S.	Project Number: 0611004.020.023	**Reported:**
Edmonds WA, 98020	Project Manager: Clint Jacob	12-May-2023 18:24

MW-28-042523

23D0602-01 (Water)

Volatile Organic Compounds

Method: EPA 8260D — Sampled: 04/25/2023 13:19

Instrument: NT2 Analyst: LH — Analyzed: 04/26/2023 12:38

Analysis by: Analytical Resources, LLC

Sample Preparation: Preparation Method: EPA 5030C (Purge and Trap) — Extract ID: 23D0602-01 E

Preparation Batch: BLD0705 — Sample Size: 10 mL

Prepared: 04/26/2023 — Final Volume: 10 mL

Analyte	CAS Number	Dilution	Detection Limit	Reporting Limit	Result	Units	Notes
Benzene	71-43-2	1	0.05	0.20	175	ug/L	E
Surrogate: 1,2-Dichloroethane-d4				*80-129 %*	*105*	*%*	
Surrogate: Toluene-d8				*80-120 %*	*96.8*	*%*	
Surrogate: 4-Bromofluorobenzene				*80-120 %*	*95.8*	*%*	
Surrogate: 1,2-Dichlorobenzene-d4				*80-120 %*	*103*	*%*	

Landau Associates, Inc.	Project: SSSMGP	
130 2nd Avenue S.	Project Number: 0611004.020.023	**Reported:**
Edmonds WA, 98020	Project Manager: Clint Jacob	12-May-2023 18:24

MW-28-042523

23D0602-01 (Water)

Volatile Organic Compounds

Method: NWTPHg — Sampled: 04/25/2023 13:19

Instrument: NT2 Analyst: LH — Analyzed: 04/26/2023 12:38

Analysis by: Analytical Resources, LLC

Sample Preparation: Preparation Method: EPA 5030C (Purge and Trap) — Extract ID: 23D0602-01 E

Preparation Batch: BLD0705 — Sample Size: 10 mL

Prepared: 04/26/2023 — Final Volume: 10 mL

Analyte	CAS Number	Dilution	Reporting Limit	Result	Units	Notes
Gasoline Range Organics (Tol-Nap)	GRO	1	100	5870	ug/L	E
Surrogate: Toluene-d8			*80-120 %*	*96.8*	*%*	
Surrogate: 4-Bromofluorobenzene			*80-120 %*	*95.8*	*%*	

Landau Associates, Inc.
130 2nd Avenue S.
Edmonds WA, 98020

Project: SSSMGP
Project Number: 0611004.020.023
Project Manager: Clint Jacob

Reported:
12-May-2023 18:24

MW-28-042523

23D0602-01 (Water)

Petroleum Hydrocarbons

Method: NWTPH-Dx
Instrument: FID4 Analyst: AA

Sampled: 04/25/2023 13:19
Analyzed: 05/12/2023 06:34

Analysis by: Analytical Resources, LLC

Sample Preparation:
Preparation Method: EPA 3510C SepF
Preparation Batch: BLD0737
Prepared: 05/01/2023
Sample Size: 500 mL
Final Volume: 1 mL
Extract ID: 23D0602-01 C 01

Analyte	CAS Number	Dilution	Reporting Limit	Result	Units	Notes
Diesel Range Organics (C12-C24)	DRO	1	0.100	1.40	mg/L	
HC ID: DIESEL						
Motor Oil Range Organics (C24-C38)	RRO	1	0.200	ND	mg/L	U
Surrogate: o-Terphenyl			*50-150 %*	*78.0*	*%*	

Landau Associates, Inc.	Project: SSSMGP	
130 2nd Avenue S.	Project Number: 0611004.020.023	**Reported:**
Edmonds WA, 98020	Project Manager: Clint Jacob	12-May-2023 18:24

MW-28-042523

23D0602-01 (Water)

Wet Chemistry

Method: EPA 300.0 — Sampled: 04/25/2023 13:19

Instrument: IC930 Analyst: BF — Analyzed: 05/01/2023 20:51

Analysis by: Analytical Resources, LLC

Sample Preparation:
Preparation Method: No Prep Wet Chem
Preparation Batch: BLE0044
Prepared: 05/01/2023
Sample Size: 10 mL
Final Volume: 10 mL
Extract ID: 23D0602-01 A

Analyte	CAS Number	Dilution	Detection Limit	Reporting Limit	Result	Units	Notes
Sulfate	14808-79-8	1	0.100	0.100	2.45	mg/L	

Landau Associates, Inc.	Project: SSSMGP	
130 2nd Avenue S.	Project Number: 0611004.020.023	**Reported:**
Edmonds WA, 98020	Project Manager: Clint Jacob	12-May-2023 18:24

MW-28-042523

23D0602-01 (Water)

Wet Chemistry

Method: SM 4500-CN$^-$ E-99
Sampled: 04/25/2023 13:19
Instrument: UV1800-2 Analyst: RMS
Analyzed: 04/28/2023 17:00

Analysis by: Analytical Resources, LLC

Sample Preparation: Preparation Method: No Prep Wet Chem
Preparation Batch: BLD0764
Prepared: 04/27/2023
Sample Size: 50 mL
Final Volume: 50 mL
Extract ID: 23D0602-01 B

Analyte	CAS Number	Dilution	Detection Limit	Reporting Limit	Result	Units	Notes
Cyanide, Total	57-12-5	1	0.0050	0.0050	0.0600	mg/L	

Landau Associates, Inc.	Project: SSSMGP	
130 2nd Avenue S.	Project Number: 0611004.020.023	**Reported:**
Edmonds WA, 98020	Project Manager: Clint Jacob	12-May-2023 18:24

MW-28-042523

23D0602-01 (Water)

Wet Chemistry

Method: SM 4500-CN¯ I-97 Sampled: 04/25/2023 13:19

Instrument: UV1800-2 Analyst: RMS Analyzed: 04/28/2023 16:05

Analysis by: Analytical Resources, LLC

Sample Preparation: Preparation Method: SM 4500-CN¯ I-99 Extract ID: 23D0602-01 B

Preparation Batch: BLD0792 Sample Size: 50 mL

Prepared: 04/27/2023 Final Volume: 50 mL

Analyte	CAS Number	Dilution	Detection Limit	Reporting Limit	Result	Units	Notes
Cyanide, Weak Acid Dissociable	57-12-5	1	0.005	0.005	0.033	mg/L	

Landau Associates, Inc.	Project: SSSMGP	
130 2nd Avenue S.	Project Number: 0611004.020.023	**Reported:**
Edmonds WA, 98020	Project Manager: Clint Jacob	12-May-2023 18:24

MW-28-042523

23D0602-01RE1 (Water)

Volatile Organic Compounds

Method: EPA 8260D

Instrument: NT2   Analyst: LH

Sampled: 04/25/2023 13:19

Analyzed: 04/26/2023 14:30

Analysis by: Analytical Resources, LLC

Sample Preparation: Preparation Method: EPA 5030C (Purge and Trap)

Preparation Batch: BLD0705

Prepared: 04/26/2023

Sample Size: 1 mL

Final Volume: 10 mL

Extract ID: 23D0602-01RE1 F

Analyte	CAS Number	Dilution	Detection Limit	Reporting Limit	Result	Units	Notes
Benzene	71-43-2	1	0.53	2.00	939	ug/L	E
Surrogate: 1,2-Dichloroethane-d4				*80-129 %*	*109*	*%*	
Surrogate: Toluene-d8				*80-120 %*	*97.7*	*%*	
Surrogate: 4-Bromofluorobenzene				*80-120 %*	*94.3*	*%*	
Surrogate: 1,2-Dichlorobenzene-d4				*80-120 %*	*100*	*%*	

Landau Associates, Inc.	Project: SSSMGP	
130 2nd Avenue S.	Project Number: 0611004.020.023	**Reported:**
Edmonds WA, 98020	Project Manager: Clint Jacob	12-May-2023 18:24

MW-28-042523

23D0602-01RE1 (Water)

Volatile Organic Compounds

Method: NWTPHg — Sampled: 04/25/2023 13:19

Instrument: NT2 Analyst: LH — Analyzed: 04/26/2023 14:30

Analysis by: Analytical Resources, LLC

Sample Preparation: Preparation Method: EPA 5030C (Purge and Trap) — Extract ID: 23D0602-01RE1 F

Preparation Batch: BLD0705 — Sample Size: 1 mL

Prepared: 04/26/2023 — Final Volume: 10 mL

Analyte	CAS Number	Dilution	Reporting Limit	Result	Units	Notes
Gasoline Range Organics (Tol-Nap)	GRO	1	1000	10700	ug/L	
Surrogate: Toluene-d8			*80-120 %*	*97.7*	*%*	
Surrogate: 4-Bromofluorobenzene			*80-120 %*	*94.3*	*%*	

Landau Associates, Inc.	Project: SSSMGP	
130 2nd Avenue S.	Project Number: 0611004.020.023	**Reported:**
Edmonds WA, 98020	Project Manager: Clint Jacob	12-May-2023 18:24

MW-28-042523

23D0602-01RE2 (Water)

Volatile Organic Compounds

Method: EPA 8260D — Sampled: 04/25/2023 13:19

Instrument: NT2 Analyst: LH — Analyzed: 04/27/2023 09:39

Analysis by: Analytical Resources, LLC

Sample Preparation: Preparation Method: EPA 5030C (Purge and Trap) — Extract ID: 23D0602-01RE2 E

Preparation Batch: BLD0759 — Sample Size: 0.4 mL

Prepared: 04/27/2023 — Final Volume: 10 mL

Analyte	CAS Number	Dilution	Detection Limit	Reporting Limit	Result	Units	Notes
Benzene	71-43-2	1	1.33	5.00	1440	ug/L	
Surrogate: 1,2-Dichloroethane-d4				*80-129 %*	*107*	*%*	
Surrogate: Toluene-d8				*80-120 %*	*100*	*%*	
Surrogate: 4-Bromofluorobenzene				*80-120 %*	*94.8*	*%*	
Surrogate: 1,2-Dichlorobenzene-d4				*80-120 %*	*99.4*	*%*	

Landau Associates, Inc.	Project: SSSMGP	
130 2nd Avenue S.	Project Number: 0611004.020.023	**Reported:**
Edmonds WA, 98020	Project Manager: Clint Jacob	12-May-2023 18:24

MW-29-042523

23D0602-02 (Water)

Volatile Organic Compounds

Method: EPA 8260D — Sampled: 04/25/2023 13:20

Instrument: NT2 Analyst: LH — Analyzed: 04/27/2023 09:16

Analysis by: Analytical Resources, LLC

Sample Preparation: Preparation Method: EPA 5030C (Purge and Trap) — Extract ID: 23D0602-02 E

Preparation Batch: BLD0759 — Sample Size: 10 mL

Prepared: 04/27/2023 — Final Volume: 10 mL

Analyte	CAS Number	Dilution	Detection Limit	Reporting Limit	Result	Units	Notes
Benzene	71-43-2	1	0.05	0.20	ND	ug/L	U
Surrogate: 1,2-Dichloroethane-d4				*80-129 %*	*108*	*%*	
Surrogate: Toluene-d8				*80-120 %*	*101*	*%*	
Surrogate: 4-Bromofluorobenzene				*80-120 %*	*91.9*	*%*	
Surrogate: 1,2-Dichlorobenzene-d4				*80-120 %*	*99.9*	*%*	

Landau Associates, Inc.	Project: SSSMGP	
130 2nd Avenue S.	Project Number: 0611004.020.023	**Reported:**
Edmonds WA, 98020	Project Manager: Clint Jacob	12-May-2023 18:24

MW-29-042523

23D0602-02 (Water)

Volatile Organic Compounds

Method: NWTPHg — Sampled: 04/25/2023 13:20

Instrument: NT2 Analyst: LH — Analyzed: 04/27/2023 09:16

Analysis by: Analytical Resources, LLC

Sample Preparation: Preparation Method: EPA 5030C (Purge and Trap) — Extract ID: 23D0602-02 E

Preparation Batch: BLD0759 — Sample Size: 10 mL

Prepared: 04/27/2023 — Final Volume: 10 mL

Analyte	CAS Number	Dilution	Reporting Limit	Result	Units	Notes
Gasoline Range Organics (Tol-Nap)	GRO	1	100	ND	ug/L	U
Surrogate: Toluene-d8			*80-120 %*	*101*	*%*	
Surrogate: 4-Bromofluorobenzene			*80-120 %*	*91.9*	*%*	

MW-29-042523

23D0602-02 (Water)

Petroleum Hydrocarbons

Method: NWTPH-Dx
Instrument: FID4 Analyst: AA

Sampled: 04/25/2023 13:20
Analyzed: 05/12/2023 06:53

Analysis by: Analytical Resources, LLC

Sample Preparation:
Preparation Method: EPA 3510C SepF
Preparation Batch: BLD0737
Prepared: 05/01/2023
Sample Size: 500 mL
Final Volume: 1 mL
Extract ID: 23D0602-02 C 01

Analyte	CAS Number	Dilution	Reporting Limit	Result	Units	Notes
Diesel Range Organics (C12-C24)	DRO	1	0.100	1.73	mg/L	
HC ID: DRO						
Motor Oil Range Organics (C24-C38)	RRO	1	0.200	0.626	mg/L	
HC ID: MOTOR OIL						
Surrogate: o-Terphenyl			*50-150 %*	*79.2*	*%*	

Landau Associates, Inc.	Project: SSSMGP	
130 2nd Avenue S.	Project Number: 0611004.020.023	**Reported:**
Edmonds WA, 98020	Project Manager: Clint Jacob	12-May-2023 18:24

MW-29-042523

23D0602-02RE1 (Water)

Wet Chemistry

Method: EPA 300.0 Sampled: 04/25/2023 13:20
Instrument: IC930 Analyst: BF Analyzed: 05/02/2023 13:11

Analysis by: Analytical Resources, LLC

Sample Preparation: Preparation Method: No Prep Wet Chem Extract ID: 23D0602-02RE1 A
Preparation Batch: BLE0044 Sample Size: 10 mL
Prepared: 05/01/2023 Final Volume: 10 mL

Analyte	CAS Number	Dilution	Detection Limit	Reporting Limit	Result	Units	Notes
Sulfate	14808-79-8	11	1.10	1.10	45.8	mg/L	D

Landau Associates, Inc.
130 2nd Avenue S.
Edmonds WA, 98020

Project: SSSMGP
Project Number: 0611004.020.023
Project Manager: Clint Jacob

Reported:
12-May-2023 18:24

MW-29-042523

23D0602-02RE1 (Water)

Wet Chemistry

Method: SM 4500-CN^- I-97
Instrument: UV1800-2 Analyst: RMS

Sampled: 04/25/2023 13:20
Analyzed: 04/28/2023 16:52

Analysis by: Analytical Resources, LLC

Sample Preparation:
Preparation Method: SM 4500-CN^- I-99
Preparation Batch: BLD0792
Prepared: 04/27/2023

Sample Size: 50 mL
Final Volume: 50 mL

Extract ID: 23D0602-02RE1 B

Analyte	CAS Number	Dilution	Detection Limit	Reporting Limit	Result	Units	Notes
Cyanide, Weak Acid Dissociable	57-12-5	5	0.025	0.025	0.340	mg/L	D

Landau Associates, Inc.	Project: SSSMGP	
130 2nd Avenue S.	Project Number: 0611004.020.023	**Reported:**
Edmonds WA, 98020	Project Manager: Clint Jacob	12-May-2023 18:24

MW-29-042523

23D0602-02RE2 (Water)

Wet Chemistry

Method: SM 4500-CN¯ E-99 Sampled: 04/25/2023 13:20

Instrument: UV1800-2 Analyst: RMS Analyzed: 04/28/2023 17:43

Analysis by: Analytical Resources, LLC

Sample Preparation: Preparation Method: No Prep Wet Chem Extract ID: 23D0602-02RE2 B
Preparation Batch: BLD0764 Sample Size: 50 mL
Prepared: 04/27/2023 Final Volume: 50 mL

Analyte	CAS Number	Dilution	Detection Limit	Reporting Limit	Result	Units	Notes
Cyanide, Total	57-12-5	50	0.250	0.250	4.80	mg/L	D

Landau Associates, Inc.	Project: SSSMGP	
130 2nd Avenue S.	Project Number: 0611004.020.023	**Reported:**
Edmonds WA, 98020	Project Manager: Clint Jacob	12-May-2023 18:24

MW-29-042523

23D0602-03 (Water)

Volatile Organic Compounds

Method: EPA 8260D
Sampled: 04/25/2023 13:20
Instrument: NT2 Analyst: LH
Analyzed: 04/27/2023 09:59

Analysis by: Analytical Resources, LLC

Sample Preparation: Preparation Method: EPA 5030C (Purge and Trap)
Extract ID: 23D0602-03 B
Preparation Batch: BLD0759
Sample Size: 10 mL
Prepared: 04/27/2023
Final Volume: 10 mL

Analyte	CAS Number	Dilution	Detection Limit	Reporting Limit	Result	Units	Notes
Benzene	71-43-2	1	0.05	0.20	0.63	ug/L	
Surrogate: 1,2-Dichloroethane-d4				*80-129 %*	*105*	*%*	
Surrogate: Toluene-d8				*80-120 %*	*101*	*%*	
Surrogate: 4-Bromofluorobenzene				*80-120 %*	*94.0*	*%*	
Surrogate: 1,2-Dichlorobenzene-d4				*80-120 %*	*101*	*%*	

Landau Associates, Inc.	Project: SSSMGP	
130 2nd Avenue S.	Project Number: 0611004.020.023	**Reported:**
Edmonds WA, 98020	Project Manager: Clint Jacob	12-May-2023 18:24

MW-29-042523

23D0602-03 (Water)

Volatile Organic Compounds

Method: NWTPHg Sampled: 04/25/2023 13:20

Instrument: NT2 Analyst: LH Analyzed: 04/27/2023 09:59

Analysis by: Analytical Resources, LLC

Sample Preparation: Preparation Method: EPA 5030C (Purge and Trap) Extract ID: 23D0602-03 B

Preparation Batch: BLD0759 Sample Size: 10 mL

Prepared: 04/27/2023 Final Volume: 10 mL

Analyte	CAS Number	Dilution	Reporting Limit	Result	Units	Notes
Gasoline Range Organics (Tol-Nap)	GRO	1	100	ND	ug/L	U
Surrogate: Toluene-d8			*80-120 %*	*101*	*%*	
Surrogate: 4-Bromofluorobenzene			*80-120 %*	*94.0*	*%*	

Landau Associates, Inc. 130 2nd Avenue S. Edmonds WA, 98020	Project: SSSMGP Project Number: 0611004.020.023 Project Manager: Clint Jacob	**Reported:** 12-May-2023 18:24

TB-042523

23D0602-04 (Water)

Volatile Organic Compounds

Method: EPA 8260D | Sampled: 04/25/2023 13:19
Instrument: NT2 Analyst: LH | Analyzed: 04/26/2023 12:18

Analysis by: Analytical Resources, LLC

Sample Preparation: Preparation Method: EPA 5030C (Purge and Trap) | Extract ID: 23D0602-04 B
Preparation Batch: BLD0705 | Sample Size: 10 mL
Prepared: 04/26/2023 | Final Volume: 10 mL

Analyte	CAS Number	Dilution	Detection Limit	Reporting Limit	Result	Units	Notes
Benzene	71-43-2	1	0.05	0.20	ND	ug/L	U
Surrogate: 1,2-Dichloroethane-d4				*80-129 %*	*107*	*%*	
Surrogate: Toluene-d8				*80-120 %*	*101*	*%*	
Surrogate: 4-Bromofluorobenzene				*80-120 %*	*90.5*	*%*	
Surrogate: 1,2-Dichlorobenzene-d4				*80-120 %*	*101*	*%*	

Landau Associates, Inc.	Project: SSSMGP	
130 2nd Avenue S.	Project Number: 0611004.020.023	**Reported:**
Edmonds WA, 98020	Project Manager: Clint Jacob	12-May-2023 18:24

TB-042523

23D0602-04 (Water)

Volatile Organic Compounds

Method: NWTPHg
Sampled: 04/25/2023 13:19
Instrument: NT2 Analyst: LH
Analyzed: 04/26/2023 12:18

Analysis by: Analytical Resources, LLC

Sample Preparation: Preparation Method: EPA 5030C (Purge and Trap)
Extract ID: 23D0602-04 B
Preparation Batch: BLD0705
Sample Size: 10 mL
Prepared: 04/26/2023
Final Volume: 10 mL

Analyte	CAS Number	Dilution	Reporting Limit	Result	Units	Notes
Gasoline Range Organics (Tol-Nap)	GRO	1	100	ND	ug/L	U
Surrogate: Toluene-d8			*80-120 %*	*101*	*%*	
Surrogate: 4-Bromofluorobenzene			*80-120 %*	*90.5*	*%*	

Landau Associates, Inc.	Project: SSSMGP	
130 2nd Avenue S.	Project Number: 0611004.020.023	**Reported:**
Edmonds WA, 98020	Project Manager: Clint Jacob	12-May-2023 18:24

Analysis by: Analytical Resources, LLC

Volatile Organic Compounds - Quality Control

Batch BLD0705 - NWTPHg

Instrument: NT2 Analyst: LH

QC Sample/Analyte	Result		Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Blank (BLD0705-BLK1)					Prepared: 26-Apr-2023	Analyzed: 26-Apr-2023 08:27					
Gasoline Range Organics (Tol-Nap)	ND		100	ug/L							U
Surrogate: Toluene-d8	5.02			ug/L	*5.00*		*100*	*80-120*			
Surrogate: 4-Bromofluorobenzene	4.58			ug/L	*5.00*		*91.6*	*80-120*			
Blank (BLD0705-BLK2)					Prepared: 26-Apr-2023	Analyzed: 26-Apr-2023 08:27					
Benzene	ND	0.05	0.20	ug/L							U
Surrogate: 1,2-Dichloroethane-d4	5.44			ug/L	*5.00*		*109*	*80-129*			
Surrogate: Toluene-d8	5.02			ug/L	*5.00*		*100*	*80-120*			
Surrogate: 4-Bromofluorobenzene	4.58			ug/L	*5.00*		*91.6*	*80-120*			
Surrogate: 1,2-Dichlorobenzene-d4	5.04			ug/L	*5.00*		*101*	*80-120*			
LCS (BLD0705-BS1)					Prepared: 26-Apr-2023	Analyzed: 26-Apr-2023 06:44					
Gasoline Range Organics (Tol-Nap)	1010		100	ug/L	1000		101	72-128			
Surrogate: Toluene-d8	5.25			ug/L	*5.00*		*105*	*80-120*			
Surrogate: 4-Bromofluorobenzene	4.74			ug/L	*5.00*		*94.9*	*80-120*			
LCS (BLD0705-BS2)					Prepared: 26-Apr-2023	Analyzed: 26-Apr-2023 07:05					
Benzene	10.6	0.05	0.20	ug/L	10.0		106	80-120			
Surrogate: 1,2-Dichloroethane-d4	5.29			ug/L	*5.00*		*106*	*80-129*			
Surrogate: Toluene-d8	5.13			ug/L	*5.00*		*103*	*80-120*			
Surrogate: 4-Bromofluorobenzene	4.90			ug/L	*5.00*		*97.9*	*80-120*			
Surrogate: 1,2-Dichlorobenzene-d4	4.94			ug/L	*5.00*		*98.8*	*80-120*			
LCS Dup (BLD0705-BSD1)					Prepared: 26-Apr-2023	Analyzed: 26-Apr-2023 07:26					
Gasoline Range Organics (Tol-Nap)	1070		100	ug/L	1000		107	72-128	6.49	30	
Surrogate: Toluene-d8	5.26			ug/L	*5.00*		*105*	*80-120*			
Surrogate: 4-Bromofluorobenzene	4.79			ug/L	*5.00*		*95.9*	*80-120*			
LCS Dup (BLD0705-BSD2)					Prepared: 26-Apr-2023	Analyzed: 26-Apr-2023 07:46					
Benzene	10.7	0.05	0.20	ug/L	10.0		107	80-120	0.73	30	
Surrogate: 1,2-Dichloroethane-d4	5.31			ug/L	*5.00*		*106*	*80-129*			
Surrogate: Toluene-d8	5.23			ug/L	*5.00*		*105*	*80-120*			
Surrogate: 4-Bromofluorobenzene	4.68			ug/L	*5.00*		*93.7*	*80-120*			

Analysis by: Analytical Resources, LLC

Volatile Organic Compounds - Quality Control

Batch BLD0705 - EPA 8260D

Instrument: NT2 Analyst: LH

QC Sample/Analyte	Result	Detection Limit	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
LCS Dup (BLD0705-BSD2)					Prepared: 26-Apr-2023	Analyzed: 26-Apr-2023 07:46					
Surrogate: 1,2-Dichlorobenzene-d4	5.01			ug/L	*5.00*		*100*	*80-120*			

Landau Associates, Inc.
130 2nd Avenue S.
Edmonds WA, 98020

Project: SSSMGP
Project Number: 0611004.020.023
Project Manager: Clint Jacob

Reported:
12-May-2023 18:24

Analysis by: Analytical Resources, LLC

Volatile Organic Compounds - Quality Control

Batch BLD0759 - NWTPHg

Instrument: NT2 Analyst: LH

QC Sample/Analyte	Result		Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Blank (BLD0759-BLK1)					Prepared: 27-Apr-2023 Analyzed: 27-Apr-2023 08:55						
Gasoline Range Organics (Tol-Nap)	ND		100	ug/L							U
Surrogate: Toluene-d8	5.02			ug/L	*5.00*		*100*	*80-120*			
Surrogate: 4-Bromofluorobenzene	4.68			ug/L	*5.00*		*93.7*	*80-120*			
Blank (BLD0759-BLK2)					Prepared: 27-Apr-2023 Analyzed: 27-Apr-2023 08:55						
Benzene	ND	0.05	0.20	ug/L							U
Surrogate: 1,2-Dichloroethane-d4	5.41			ug/L	*5.00*		*108*	*80-129*			
Surrogate: Toluene-d8	5.02			ug/L	*5.00*		*100*	*80-120*			
Surrogate: 4-Bromofluorobenzene	4.68			ug/L	*5.00*		*93.7*	*80-120*			
Surrogate: 1,2-Dichlorobenzene-d4	4.93			ug/L	*5.00*		*98.7*	*80-120*			
LCS (BLD0759-BS1)					Prepared: 27-Apr-2023 Analyzed: 27-Apr-2023 07:13						
Gasoline Range Organics (Tol-Nap)	999		100	ug/L	1000		99.9	72-128			
Surrogate: Toluene-d8	5.23			ug/L	*5.00*		*105*	*80-120*			
Surrogate: 4-Bromofluorobenzene	4.86			ug/L	*5.00*		*97.3*	*80-120*			
LCS (BLD0759-BS2)					Prepared: 27-Apr-2023 Analyzed: 27-Apr-2023 07:33						
Benzene	10.6	0.05	0.20	ug/L	10.0		106	80-120			
Surrogate: 1,2-Dichloroethane-d4	5.21			ug/L	*5.00*		*104*	*80-129*			
Surrogate: Toluene-d8	5.19			ug/L	*5.00*		*104*	*80-120*			
Surrogate: 4-Bromofluorobenzene	4.77			ug/L	*5.00*		*95.5*	*80-120*			
Surrogate: 1,2-Dichlorobenzene-d4	5.06			ug/L	*5.00*		*101*	*80-120*			
LCS Dup (BLD0759-BSD1)					Prepared: 27-Apr-2023 Analyzed: 27-Apr-2023 07:54						
Gasoline Range Organics (Tol-Nap)	983		100	ug/L	1000		98.3	72-128	1.62	30	
Surrogate: Toluene-d8	5.25			ug/L	*5.00*		*105*	*80-120*			
Surrogate: 4-Bromofluorobenzene	4.81			ug/L	*5.00*		*96.2*	*80-120*			
LCS Dup (BLD0759-BSD2)					Prepared: 27-Apr-2023 Analyzed: 27-Apr-2023 08:14						
Benzene	10.3	0.05	0.20	ug/L	10.0		103	80-120	2.40	30	
Surrogate: 1,2-Dichloroethane-d4	5.17			ug/L	*5.00*		*103*	*80-129*			
Surrogate: Toluene-d8	5.16			ug/L	*5.00*		*103*	*80-120*			
Surrogate: 4-Bromofluorobenzene	4.84			ug/L	*5.00*		*96.7*	*80-120*			

Analysis by: Analytical Resources, LLC

Volatile Organic Compounds - Quality Control

Batch BLD0759 - EPA 8260D

Instrument: NT2 Analyst: LH

QC Sample/Analyte	Result	Detection Limit	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
LCS Dup (BLD0759-BSD2)					Prepared: 27-Apr-2023	Analyzed: 27-Apr-2023 08:14					
Surrogate: 1,2-Dichlorobenzene-d4	5.04			ug/L	*5.00*		*101*	*80-120*			

Landau Associates, Inc.	Project: SSSMGP	
130 2nd Avenue S.	Project Number: 0611004.020.023	**Reported:**
Edmonds WA, 98020	Project Manager: Clint Jacob	12-May-2023 18:24

Analysis by: Analytical Resources, LLC

Petroleum Hydrocarbons - Quality Control

Batch BLD0737 - NWTPH-Dx

Instrument: FID4   Analyst: AA

QC Sample/Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Blank (BLD0737-BLK1)				Prepared: 01-May-2023 Analyzed: 12-May-2023 03:16						
Diesel Range Organics (C12-C24)	ND	0.100	mg/L							U
Motor Oil Range Organics (C24-C38)	ND	0.200	mg/L							U
Surrogate: o-Terphenyl	0.170		mg/L	*0.225*		*75.5*	*50-150*			
LCS (BLD0737-BS1)				Prepared: 01-May-2023 Analyzed: 12-May-2023 03:36						
Diesel Range Organics (C12-C24)	2.40	0.100	mg/L	3.00		80.0	56-120			
Surrogate: o-Terphenyl	0.168		mg/L	*0.225*		*74.7*	*50-150*			
LCS Dup (BLD0737-BSD1)				Prepared: 01-May-2023 Analyzed: 12-May-2023 03:55						
Diesel Range Organics (C12-C24)	1.95	0.100	mg/L	3.00		65.0	56-120	20.60	30	
Surrogate: o-Terphenyl	0.135		mg/L	*0.225*		*60.0*	*50-150*			

Analysis by: Analytical Resources, LLC

Wet Chemistry - Quality Control

Batch BLD0764 - SM 4500-CN¯ E-99

Instrument: UV1800-2 Analyst: RMS

QC Sample/Analyte	Result	Detection Limit	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Blank (BLD0764-BLK1)					Prepared: 27-Apr-2023 Analyzed: 28-Apr-2023 16:08						
Cyanide, Total	ND	0.0050	0.0050	mg/L							U
LCS (BLD0764-BS1)					Prepared: 27-Apr-2023 Analyzed: 28-Apr-2023 16:09						
Cyanide, Total	0.141	0.0050	0.0050	mg/L	0.150		94.0	75-125			

Landau Associates, Inc.	Project: SSSMGP	
130 2nd Avenue S.	Project Number: 0611004.020.023	**Reported:**
Edmonds WA, 98020	Project Manager: Clint Jacob	12-May-2023 18:24

Analysis by: Analytical Resources, LLC

Wet Chemistry - Quality Control

Batch BLD0792 - SM 4500-CN$^-$ I-97

Instrument: UV1800-2   Analyst: RMS

QC Sample/Analyte	Result	Detection Limit	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Blank (BLD0792-BLK1)					Prepared: 27-Apr-2023 Analyzed: 28-Apr-2023 15:23						
Cyanide, Weak Acid Dissociable	ND	0.005	0.005	mg/L							U
LCS (BLD0792-BS1)					Prepared: 27-Apr-2023 Analyzed: 28-Apr-2023 15:24						
Cyanide, Weak Acid Dissociable	0.159	0.005	0.005	mg/L	0.150		106	75-125			

Analysis by: Analytical Resources, LLC

Wet Chemistry - Quality Control

Batch BLE0044 - EPA 300.0

Instrument: IC930 Analyst: BF

QC Sample/Analyte	Result	Detection Limit	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Blank (BLE0044-BLK1)					Prepared: 01-May-2023 Analyzed: 01-May-2023 19:51						
Sulfate	ND	0.100	0.100	mg/L							U
LCS (BLE0044-BS1)					Prepared: 01-May-2023 Analyzed: 01-May-2023 20:11						
Sulfate	5.19	0.100	0.100	mg/L	5.00		104	90-110			

Certified Analyses included in this Report

Analyte	**Certifications**
EPA 300.0 in Water	
Sulfate	DoD-ELAP,WADOE,WA-DW,NELAP
EPA 8260D in Water	
Benzene	DoD-ELAP,ADEC,NELAP,WADOE
NWTPH-Dx in Water	
Diesel Range Organics (C12-C2	DoD-ELAP,NELAP,WADOE
Motor Oil Range Organics (C24-	DoD-ELAP,NELAP,WADOE
NWTPHg in Water	
Gasoline Range Organics (Tol-N	WADOE,DoD-ELAP
SM 4500-CN^- E-99 in Water	
Cyanide, Total	WADOE,WA-DW,NELAP,DoD-ELAP
SM 4500-CN^- I-97 in Water	
Cyanide, Weak Acid Dissociable	NELAP,WADOE

Code	Description	Number	Expires
ADEC	Alaska Dept of Environmental Conservation	17-015	03/28/2025
DoD-ELAP	DoD-Environmental Laboratory Accreditation Program, PJLA Testing	66169	02/28/2025
NELAP	ORELAP - Oregon Laboratory Accreditation Program	WA100006-012	05/12/2023
WADOE	WA Dept of Ecology	C558	06/30/2023
WA-DW	Ecology - Drinking Water	C558	06/30/2023

Notes and Definitions

*	Flagged value is not within established control limits.
D	The reported value is from a dilution
D1	Surrogate was not detected due to sample extract dilution
E	The analyte concentration exceeds the upper limit of the calibration range of the instrument established by the initial calibration (ICAL)
J	Estimated concentration value detected below the reporting limit.
Q	Indicates a detected analyte with an initial or continuing calibration that does not meet established acceptance criteria (<20% RSD, <20% drift or minimum RRF)
U	This analyte is not detected above the reporting limit (RL) or if noted, not detected above the limit of detection (LOD).
DET	Analyte DETECTED
ND	Analyte NOT DETECTED at or above the reporting limit
NR	Not Reported
dry	Sample results reported on a dry weight basis
RPD	Relative Percent Difference
[2C]	Indicates this result was quantified on the second column on a dual column analysis.

Analytical Resources, LLC
Analytical Chemists and Consultants
Tukwila, WA

25 October 2023

Clint Jacob
Landau Associates, Inc.
130 2nd Avenue S.
Edmonds, WA 98020

RE: SSSMGP (611004.030.031)

Please find enclosed sample receipt documentation and analytical results for samples from the project referenced above.

Sample analyses were performed according to ARI's Quality Assurance Plan and any provided project specific Quality Assurance Plan. Each analytical section of this report has been approved and reviewed by an analytical peer, the appropriate Laboratory Supervisor or qualified substitute, and a technical reviewer.

Should you have any questions or problems, please feel free to contact us at your convenience.

Associated Work Order(s)	Associated SDG ID(s)
23I0924	N/A

I certify that this data package is in compliance with the terms and conditions of the contract, both technically and for completeness, for other than the conditions detailed in the enclose Narrative. ARI, an accredited laboratory, certifies that the report results for which ARI is accredited meets all the requirements of the accrediting body. A list of certified analyses, accreditations, and expiration dates is included in this report.

Release of the data contained in this hardcopy data package has been authorized by the Laboratory Manager or his/her designee, as verified by the following signature.

Analytical Resources, LLC

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Kelly Bottem

Kelly Bottem, Client Services Manager

ACCREDITED IN ACCORDANCE WITH nelac
Cert# 100006-012

23I0924

LANDAU ASSOCIATES

Chain-of-Custody Record

☑ **North Seattle** (206) 631-8660
☐ **Tacoma** (253) 926-2493
☐ **Olympia** (360) 791-3178
☐ **Spokane** (509) 327-9737
☐ **Portland** (503) 542-1080
☐ ______

Date 9/28/23
Page 1 of 1

Turnaround Time:
Standard X
Accelerated ______

Project Name Former SSSMGP
Project No. 611004.030.031
Project Location/Event Bellingham, WA / PRB Design Testing
Sampler's Name Kalpana Prasad, Adam Torocsik
Project Contact Clint Jacob, Jenny Green
Send Results To " " " " Landau Data

Testing Parameters

Sample I.D.	Date	Time	Matrix	No. of Containers	TPH-G(NWTPH-Gx)*	Benzene (8260)*	TPH-Dx(NWTPH-Dx)	Sulfate (EPA 300.0)	Total/WAD CN (4500-CN)•							
MW-28-230928	9/25/23	1150	AQ	8	X	X	X	X	X							
MW-29-230928	↓	1200	↓	AT ~~8~~ 7	X	X	X	X	X							
Trip Blanks		—	↓	4	X	X										

Special Handling Requirements: ______

Shipment Method: drop off

Stored on ice: [✓ Yes] / No

Observations/Comments

__ Allow water samples to settle, collect aliquot from clear portion ☐

__ NWTPH-Dx - Acid wash cleanup ☐
- Silica gel cleanup ☐

__ Dissolved metal samples were field filtered

Other
* Non preserved VOAs, 7 day hold
• 48 hr hold CN

Relinquished by	**Received by**	**Relinquished by**	**Received by**
Signature	Signature	Signature	Signature
Printed Name Adam Torocsik	Printed Name Jacobwalte	Printed Name	Printed Name
Company LAI	Company AR, LLC	Company	Company
Date 9/29/2023 Time 1147	Date 09/29/23 Time 1147	Date Time	Date Time

WHITE COPY - Laboratory YELLOW COPY - Project File PINK COPY - Client Rep

Landau Associates, Inc.
130 2nd Avenue S.
Edmonds WA, 98020

Project: SSSMGP
Project Number: 611004.030.031
Project Manager: Clint Jacob

Reported:
25-Oct-2023 14:54

ANALYTICAL REPORT FOR SAMPLES

Sample ID	Laboratory ID	Matrix	Date Sampled	Date Received
MW-28-230928	23I0924-01	Water	28-Sep-2023 11:50	29-Sep-2023 11:47
MW-29-230928	23I0924-02	Water	28-Sep-2023 12:00	29-Sep-2023 11:47
Trip Blanks	23I0924-03	Water	28-Sep-2023 11:50	29-Sep-2023 11:47

Landau Associates, Inc.	Project:	SSSMGP	
130 2nd Avenue S.	Project Number:	611004.030.031	**Reported:**
Edmonds WA, 98020	Project Manager:	Clint Jacob	25-Oct-2023 14:54

Work Order Case Narrative

Gasoline by NWTPH-g (GC/MS)

The sample(s) were analyzed within the recommended holding times.

Initial and continuing calibrations were within method requirements.

Internal standard areas were within limits.

The surrogate percent recoveries were within control limits.

The method blank(s) were clean at the reporting limits.

Volatiles - EPA Method SW8260D

The sample(s) were analyzed within the recommended holding times.

Initial and continuing calibrations were within method requirements.

Internal standard areas were within limits.

The surrogate percent recoveries were within control limits.

The method blank(s) were clean at the reporting limits.

Wet Chemistry

The sample(s) were prepared and analyzed within the recommended holding times.

Initial and continuing calibrations were within method requirements.

The method blank(s) were clean at the reporting limits.

The blank spike (BS/LCS) percent recoveries were within control limits.

Diesel/Heavy Oil Range Organics - WA-Ecology Method NW-TPHDx

The sample(s) were extracted and analyzed within the recommended holding times.

Initial and continuing calibrations were within method requirements.

The surrogate percent recoveries were within control limits.

The method blank(s) contained a positive hit in the motor oil range. Samples that contain motor oil have been flagged with a "B" qualifer.

The blank spike (BS/LCS) percent recoveries were within control limits.

Analytical Resources, LLC
Analytical Chemists and Consultants

Cooler Receipt Form

ARI Client: Landau Associates

Project Name: Former SSSMGP

COC No(s): [✓ NA]

Delivered by: Fed-Ex UPS Courier [✓ Hand Delivered] Other:

Assigned ARI Job No: 23I0924

Tracking No: [✓ NA]

Preliminary Examination Phase:

Were intact, properly signed and dated custody seals attached to the outside of the cooler? YES [✓ NO]

Were custody papers included with the cooler? [✓ YES] NO

Were custody papers properly filled out (ink, signed, etc.) [✓ YES] NO

Temperature of Cooler(s) (°C) (recommended 2.0-6.0 °C for chemistry)

Time 1147 4.8

If cooler temperature is out of compliance fill out form 00070F

Temp Gun ID#: JC009708

Cooler Accepted by: Date: 09/29/23 Time: 1147

Complete custody forms and attach all shipping documents

Log-In Phase:

Was a temperature blank included in the cooler? YES [✓ NO]

What kind of packing material was used? ... Bubble Wrap [✓ Wet Ice] Gel Packs Baggies Foam Block Paper Other:

Was sufficient ice used (if appropriate)? NA [✓ YES] NO

How were bottles sealed in plastic bags? Individually Grouped [✓ Not]

Did all bottles arrive in good condition (unbroken)? [✓ YES] NO

Were all bottle labels complete and legible? [✓ YES] NO

Did the number of containers listed on COC match with the number of containers received? [✓ YES] NO

Did all bottle labels and tags agree with custody papers? [✓ YES] NO

Were all bottles used correct for the requested analyses? [✓ YES] NO

Do any of the analyses (bottles) require preservation? (attach preservation sheet, excluding VOCs) ... [✓ NA] YES NO

Were all VOC vials free of air bubbles? NA [✓ YES] NO

Was sufficient amount of sample sent in each bottle? [✓ YES] NO

Date VOC Trip Blank was made at ARI NA 9/26/23

Were the sample(s) split by ARI? NA YES Date/Time: Equipment: Split by:

Samples Logged by: Date: 9/29/23 Time: 16:38 Labels checked by:

***** Notify Project Manager of discrepancies or concerns *****

Sample ID on Bottle	Sample ID on COC	Sample ID on Bottle	Sample ID on COC

Additional Notes, Discrepancies, & Resolutions:

By: Date:

Printed: 9/30/2023 8:55:30AM

WORK ORDER

23I0924

Samples will be discarded 90 days after submission of a final report unless other instructions are received

Client: **Landau Associates, Inc.**

Project Manager: **Kelly Bottem**

Project: **SSSMGP**

Project Number: **611004.030.031**

Preservation Confirmation

Container ID	Container Type	pH	
23I0924-01 A	HDPE NM, 500 mL		
23I0924-01 B	HDPE NM, 500 mL	<12	Fail
23I0924-01 C	Glass NM, Amber, 1000 mL		
23I0924-01 D	Glass NM, Amber, 1000 mL		
23I0924-01 E	VOA Vial, Clear, 40 mL		
23I0924-01 F	VOA Vial, Clear, 40 mL		
23I0924-01 G	VOA Vial, Clear, 40 mL		
23I0924-01 H	VOA Vial, Clear, 40 mL		
23I0924-02 A	HDPE NM, 500 mL		
23I0924-02 B	HDPE NM, 500 mL	<12	Fail
23I0924-02 C	Glass NM, Amber, 1000 mL		
23I0924-02 E	VOA Vial, Clear, 40 mL		
23I0924-02 F	VOA Vial, Clear, 40 mL		
23I0924-02 G	VOA Vial, Clear, 40 mL		
23I0924-02 H	VOA Vial, Clear, 40 mL		
23I0924-03 A	VOA Vial, Clear, 40 mL, HCL		
23I0924-03 B	VOA Vial, Clear, 40 mL, HCL		
23I0924-03 C	VOA Vial, Clear, 40 mL, HCL		
23I0924-03 D	VOA Vial, Clear, 40 mL, HCL		

JJ~ for LB
Preservation Confirmed By

09/30/23
Date

Reviewed By

Date

Analytical Resources, LLC
Analytical Chemists and Consultants

Printed: 9/30/2023 8:55:30AM

9/26

WORK ORDER

23I0924

Samples will be discarded 90 days after submission of a final report unless other instructions are received

Client: Landau Associates, Inc.

Project Manager: Kelly Bottem

Project: SSSMGP

Project Number: 611004.030.031

Preservation Confirmation

Container ID	Container Type	pH	
23I0924-01 A	HDPE NM, 500 mL		
23I0924-01 B	HDPE NM, 500 mL	<12	Fail ①
23I0924-01 C	Glass NM, Amber, 1000 mL		
23I0924-01 D	Glass NM, Amber, 1000 mL		
23I0924-01 E	VOA Vial, Clear, 40 mL		
23I0924-01 F	VOA Vial, Clear, 40 mL		
23I0924-01 G	VOA Vial, Clear, 40 mL		
23I0924-01 H	VOA Vial, Clear, 40 mL		
23I0924-02 A	HDPE NM, 500 mL		
23I0924-02 B	HDPE NM, 500 mL	<12	Fail ①
23I0924-02 C	Glass NM, Amber, 1000 mL		
23I0924-02 E	VOA Vial, Clear, 40 mL		
23I0924-02 F	VOA Vial, Clear, 40 mL		
23I0924-02 G	VOA Vial, Clear, 40 mL		
23I0924-02 H	VOA Vial, Clear, 40 mL		
23I0924-03 A	VOA Vial, Clear, 40 mL, HCL		
23I0924-03 B	VOA Vial, Clear, 40 mL, HCL		
23I0924-03 C	VOA Vial, Clear, 40 mL, HCL		
23I0924-03 D	VOA Vial, Clear, 40 mL, HCL		

JJ for LB
Preservation Confirmed By

09/30/23
Date

① Tested Neg for S^- & Cl.
Preserved with 2ml
~~4N~~ cna (6N) NaOH to pH >12.0.
at 9-29-23
18:12
cna

9-30-23 cna
No pres sheet at time
of testing. Notes loged
directly on bottles.

Reviewed By

Date

Landau Associates, Inc.	Project: SSSMGP	
130 2nd Avenue S.	Project Number: 611004.030.031	**Reported:**
Edmonds WA, 98020	Project Manager: Clint Jacob	25-Oct-2023 14:54

MW-28-230928

23I0924-01 (Water)

Volatile Organic Compounds

Method: EPA 8260D — Sampled: 09/28/2023 11:50

Instrument: NT3 Analyst: TWC — Analyzed: 09/29/2023 22:19

Sample Preparation: Preparation Method: EPA 5030C (Purge and Trap) — Extract ID: 23I0924-01 E

Preparation Batch: BLI0930 — Sample Size: 10 mL

Prepared: 09/29/2023 — Final Volume: 10 mL

Analyte	CAS Number	Dilution	Detection Limit	Reporting Limit	Result	Units	Notes
Benzene	71-43-2	1	0.05	0.20	414	ug/L	E
Surrogate: 1,2-Dichloroethane-d4				*80-129 %*	*111*	*%*	
Surrogate: Toluene-d8				*80-120 %*	*99.5*	*%*	
Surrogate: 4-Bromofluorobenzene				*80-120 %*	*99.7*	*%*	
Surrogate: 1,2-Dichlorobenzene-d4				*80-120 %*	*104*	*%*	

Landau Associates, Inc.	Project: SSSMGP	
130 2nd Avenue S.	Project Number: 611004.030.031	**Reported:**
Edmonds WA, 98020	Project Manager: Clint Jacob	25-Oct-2023 14:54

MW-28-230928

23I0924-01 (Water)

Volatile Organic Compounds

Method: NWTPHg — Sampled: 09/28/2023 11:50

Instrument: NT3 Analyst: TWC — Analyzed: 09/29/2023 22:19

Sample Preparation: Preparation Method: EPA 5030C (Purge and Trap) — Extract ID: 23I0924-01 E

Preparation Batch: BLI0930 — Sample Size: 10 mL

Prepared: 09/29/2023 — Final Volume: 10 mL

Analyte	CAS Number	Dilution	Reporting Limit	Result	Units	Notes
Gasoline Range Organics (Tol-Nap)	GRO	1	100	4470	ug/L	
Surrogate: Toluene-d8			*80-120 %*	*99.5*	*%*	
Surrogate: 4-Bromofluorobenzene			*80-120 %*	*99.7*	*%*	

Landau Associates, Inc.	Project: SSSMGP	
130 2nd Avenue S.	Project Number: 611004.030.031	**Reported:**
Edmonds WA, 98020	Project Manager: Clint Jacob	25-Oct-2023 14:54

MW-28-230928

23I0924-01 (Water)

Petroleum Hydrocarbons

Method: NWTPH-Dx
Sampled: 09/28/2023 11:50
Instrument: FID4 Analyst: NRB
Analyzed: 10/21/2023 00:37

Sample Preparation:
Preparation Method: EPA 3510C SepF
Extract ID: 23I0924-01 C 01
Preparation Batch: BLJ0114
Sample Size: 500 mL
Prepared: 10/05/2023
Final Volume: 1 mL

Analyte	CAS Number	Dilution	Reporting Limit	Result	Units	Notes
Diesel Range Organics (C12-C24)	DRO	1	0.100	1.36	mg/L	
HC ID: DIESEL						
Motor Oil Range Organics (C24-C38)	RRO	1	0.200	0.240	mg/L	B
HC ID: MOTOR OIL						
Surrogate: o-Terphenyl			*50-150 %*	*69.1*	*%*	

Landau Associates, Inc.	Project: SSSMGP	
130 2nd Avenue S.	Project Number: 611004.030.031	**Reported:**
Edmonds WA, 98020	Project Manager: Clint Jacob	25-Oct-2023 14:54

MW-28-230928

23I0924-01 (Water)

Wet Chemistry

Method: EPA 300.0 Sampled: 09/28/2023 11:50
Instrument: IC930 Analyst: BF Analyzed: 10/20/2023 23:23

Sample Preparation: Preparation Method: No Prep Wet Chem Extract ID: 23I0924-01 A
Preparation Batch: BLJ0663 Sample Size: 10 mL
Prepared: 10/20/2023 Final Volume: 10 mL

Analyte	CAS Number	Dilution	Detection Limit	Reporting Limit	Result	Units	Notes
Sulfate	14808-79-8	1	0.100	0.100	0.203	mg/L	

Landau Associates, Inc.	Project: SSSMGP	
130 2nd Avenue S.	Project Number: 611004.030.031	**Reported:**
Edmonds WA, 98020	Project Manager: Clint Jacob	25-Oct-2023 14:54

MW-28-230928

23I0924-01 (Water)

Wet Chemistry

Method: SM 4500-CN¯ E-99 Sampled: 09/28/2023 11:50

Instrument: UV1800-2 Analyst: KOTT Analyzed: 10/13/2023 09:56

Sample Preparation: Preparation Method: SM 4500-CN¯ C-99 Extract ID: 23I0924-01 B

Preparation Batch: BLJ0416 Sample Size: 50 mL

Prepared: 10/12/2023 Final Volume: 50 mL

Analyte	CAS Number	Dilution	Detection Limit	Reporting Limit	Result	Units	Notes
Cyanide, Total	57-12-5	1	0.0050	0.0050	0.0190	mg/L	

MW-28-230928

23I0924-01 (Water)

Wet Chemistry

Method: SM 4500-CN¯ I-97
Instrument: UV1800-2   Analyst: KOTT

Sampled: 09/28/2023 11:50
Analyzed: 10/13/2023 16:01

Sample Preparation:
Preparation Method: SM 4500-CN¯ I-99
Preparation Batch: BLJ0392
Prepared: 10/12/2023
Sample Size: 50 mL
Final Volume: 50 mL
Extract ID: 23I0924-01 B

Analyte	CAS Number	Dilution	Detection Limit	Reporting Limit	Result	Units	Notes
Cyanide, Weak Acid Dissociable	57-12-5	1	0.005	0.005	0.008	mg/L	

Landau Associates, Inc.	Project: SSSMGP	
130 2nd Avenue S.	Project Number: 611004.030.031	**Reported:**
Edmonds WA, 98020	Project Manager: Clint Jacob	25-Oct-2023 14:54

MW-28-230928

23I0924-01RE1 (Water)

Volatile Organic Compounds

Method: EPA 8260D — Sampled: 09/28/2023 11:50
Instrument: NT3 Analyst: TWC — Analyzed: 10/03/2023 22:18

Sample Preparation: Preparation Method: EPA 5030C (Purge and Trap) — Extract ID: 23I0924-01RE1 G
Preparation Batch: BLJ0024 — Sample Size: 0.1 mL
Prepared: 10/03/2023 — Final Volume: 10 mL

Analyte	CAS Number	Dilution	Detection Limit	Reporting Limit	Result	Units	Notes
Benzene	71-43-2	1	5.31	20.0	1110	ug/L	
Surrogate: 1,2-Dichloroethane-d4				*80-129 %*	*102*	*%*	
Surrogate: Toluene-d8				*80-120 %*	*97.3*	*%*	
Surrogate: 4-Bromofluorobenzene				*80-120 %*	*94.0*	*%*	
Surrogate: 1,2-Dichlorobenzene-d4				*80-120 %*	*103*	*%*	

Landau Associates, Inc.	Project: SSSMGP	
130 2nd Avenue S.	Project Number: 611004.030.031	**Reported:**
Edmonds WA, 98020	Project Manager: Clint Jacob	25-Oct-2023 14:54

MW-29-230928

23I0924-02 (Water)

Volatile Organic Compounds

Method: EPA 8260D
Sampled: 09/28/2023 12:00
Instrument: NT3 Analyst: TWC
Analyzed: 09/29/2023 22:41

Sample Preparation:
Preparation Method: EPA 5030C (Purge and Trap)
Extract ID: 23I0924-02 E
Preparation Batch: BLI0930
Sample Size: 10 mL
Prepared: 09/29/2023
Final Volume: 10 mL

Analyte	CAS Number	Dilution	Detection Limit	Reporting Limit	Result	Units	Notes
Benzene	71-43-2	1	0.05	0.20	51.2	ug/L	
Surrogate: 1,2-Dichloroethane-d4				*80-129 %*	*109*	*%*	
Surrogate: Toluene-d8				*80-120 %*	*102*	*%*	
Surrogate: 4-Bromofluorobenzene				*80-120 %*	*102*	*%*	
Surrogate: 1,2-Dichlorobenzene-d4				*80-120 %*	*102*	*%*	

Landau Associates, Inc.
130 2nd Avenue S.
Edmonds WA, 98020

Project: SSSMGP
Project Number: 611004.030.031
Project Manager: Clint Jacob

Reported:
25-Oct-2023 14:54

MW-29-230928

23I0924-02 (Water)

Volatile Organic Compounds

Method: NWTPHg
Instrument: NT3 Analyst: TWC

Sampled: 09/28/2023 12:00
Analyzed: 09/29/2023 22:41

Sample Preparation: Preparation Method: EPA 5030C (Purge and Trap)
Preparation Batch: BLI0930
Prepared: 09/29/2023
Sample Size: 10 mL
Final Volume: 10 mL
Extract ID: 23I0924-02 E

Analyte	CAS Number	Dilution	Reporting Limit	Result	Units	Notes
Gasoline Range Organics (Tol-Nap)	GRO	1	100	1350	ug/L	
Surrogate: Toluene-d8			*80-120 %*	*102*	*%*	
Surrogate: 4-Bromofluorobenzene			*80-120 %*	*102*	*%*	

Landau Associates, Inc.	Project: SSSMGP	
130 2nd Avenue S.	Project Number: 611004.030.031	**Reported:**
Edmonds WA, 98020	Project Manager: Clint Jacob	25-Oct-2023 14:54

MW-29-230928

23I0924-02 (Water)

Petroleum Hydrocarbons

Method: NWTPH-Dx — Sampled: 09/28/2023 12:00

Instrument: FID4 Analyst: NRB — Analyzed: 10/21/2023 00:57

Sample Preparation: Preparation Method: EPA 3510C SepF — Extract ID: 23I0924-02 C 01

Preparation Batch: BLJ0114 — Sample Size: 500 mL

Prepared: 10/05/2023 — Final Volume: 1 mL

Analyte	CAS Number	Dilution	Reporting Limit	Result	Units	Notes
Diesel Range Organics (C12-C24)	DRO	1	0.100	1.06	mg/L	
HC ID: DIESEL						
Motor Oil Range Organics (C24-C38)	RRO	1	0.200	0.614	mg/L	B
HC ID: MOTOR OIL						
Surrogate: o-Terphenyl			*50-150 %*	*69.2*	*%*	

Landau Associates, Inc.	Project: SSSMGP	
130 2nd Avenue S.	Project Number: 611004.030.031	**Reported:**
Edmonds WA, 98020	Project Manager: Clint Jacob	25-Oct-2023 14:54

MW-29-230928

23I0924-02 (Water)

Wet Chemistry

Method: SM 4500-CN¯ I-97 Sampled: 09/28/2023 12:00

Instrument: UV1800-2 Analyst: KOTT Analyzed: 10/13/2023 16:04

Sample Preparation: Preparation Method: SM 4500-CN¯ I-99 Extract ID: 23I0924-02 B

Preparation Batch: BLJ0392 Sample Size: 50 mL

Prepared: 10/12/2023 Final Volume: 50 mL

Analyte	CAS Number	Dilution	Detection Limit	Reporting Limit	Result	Units	Notes
Cyanide, Weak Acid Dissociable	57-12-5	1	0.005	0.005	0.025	mg/L	

Landau Associates, Inc.	Project: SSSMGP	
130 2nd Avenue S.	Project Number: 611004.030.031	**Reported:**
Edmonds WA, 98020	Project Manager: Clint Jacob	25-Oct-2023 14:54

MW-29-230928

23I0924-02RE1 (Water)

Wet Chemistry

Method: EPA 300.0 Sampled: 09/28/2023 12:00
Instrument: IC930 Analyst: BF Analyzed: 10/21/2023 11:42

Sample Preparation: Preparation Method: No Prep Wet Chem Extract ID: 23I0924-02RE1 A
Preparation Batch: BLJ0663 Sample Size: 10 mL
Prepared: 10/20/2023 Final Volume: 10 mL

Analyte	CAS Number	Dilution	Detection Limit	Reporting Limit	Result	Units	Notes
Sulfate	14808-79-8	17	1.70	1.70	37.3	mg/L	D

Landau Associates, Inc.	Project: SSSMGP	
130 2nd Avenue S.	Project Number: 611004.030.031	**Reported:**
Edmonds WA, 98020	Project Manager: Clint Jacob	25-Oct-2023 14:54

MW-29-230928
23I0924-02RE1 (Water)

Wet Chemistry

Method: SM 4500-CN¯ E-99 — Sampled: 09/28/2023 12:00
Instrument: UV1800-2 Analyst: KOTT — Analyzed: 10/13/2023 10:00

Sample Preparation: Preparation Method: SM 4500-CN¯ C-99 — Extract ID: 23I0924-02RE1 B
Preparation Batch: BLJ0416 — Sample Size: 50 mL
Prepared: 10/12/2023 — Final Volume: 50 mL

Analyte	CAS Number	Dilution	Detection Limit	Reporting Limit	Result	Units	Notes
Cyanide, Total	57-12-5	2	0.0100	0.0100	0.352	mg/L	D

Landau Associates, Inc.	Project: SSSMGP	
130 2nd Avenue S.	Project Number: 611004.030.031	**Reported:**
Edmonds WA, 98020	Project Manager: Clint Jacob	25-Oct-2023 14:54

Trip Blanks

23I0924-03 (Water)

Volatile Organic Compounds

Method: EPA 8260D — Sampled: 09/28/2023 11:50

Instrument: NT3 Analyst: TWC — Analyzed: 09/29/2023 21:57

Sample Preparation: Preparation Method: EPA 5030C (Purge and Trap) — Extract ID: 23I0924-03 A

Preparation Batch: BLI0930 — Sample Size: 10 mL

Prepared: 09/29/2023 — Final Volume: 10 mL

Analyte	CAS Number	Dilution	Detection Limit	Reporting Limit	Result	Units	Notes
Benzene	71-43-2	1	0.05	0.20	ND	ug/L	U
Surrogate: 1,2-Dichloroethane-d4				*80-129 %*	*97.8*	*%*	
Surrogate: Toluene-d8				*80-120 %*	*100*	*%*	
Surrogate: 4-Bromofluorobenzene				*80-120 %*	*97.7*	*%*	
Surrogate: 1,2-Dichlorobenzene-d4				*80-120 %*	*102*	*%*	

Landau Associates, Inc.	Project: SSSMGP	
130 2nd Avenue S.	Project Number: 611004.030.031	**Reported:**
Edmonds WA, 98020	Project Manager: Clint Jacob	25-Oct-2023 14:54

Trip Blanks

23I0924-03 (Water)

Volatile Organic Compounds

Method: NWTPHg — Sampled: 09/28/2023 11:50

Instrument: NT3 Analyst: TWC — Analyzed: 09/29/2023 21:57

Sample Preparation: Preparation Method: EPA 5030C (Purge and Trap) — Extract ID: 23I0924-03 A

Preparation Batch: BLI0930 — Sample Size: 10 mL

Prepared: 09/29/2023 — Final Volume: 10 mL

Analyte	CAS Number	Dilution	Reporting Limit	Result	Units	Notes
Gasoline Range Organics (Tol-Nap)	GRO	1	100	ND	ug/L	U
Surrogate: Toluene-d8			*80-120 %*	*100*	*%*	
Surrogate: 4-Bromofluorobenzene			*80-120 %*	*97.7*	*%*	

Analysis by: Analytical Resources, LLC

Volatile Organic Compounds - Quality Control

Batch BLI0930 - NWTPHg

Instrument: NT3 Analyst: TWC

QC Sample/Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Blank (BLI0930-BLK1)				Prepared: 29-Sep-2023 Analyzed: 29-Sep-2023 13:26						
Gasoline Range Organics (Tol-Nap)	ND	100	ug/L							U
Surrogate: Toluene-d8	4.97		ug/L	*5.00*		*99.4*	*80-120*			
Surrogate: 4-Bromofluorobenzene	4.79		ug/L	*5.00*		*95.9*	*80-120*			

Landau Associates, Inc.	Project: SSSMGP	
130 2nd Avenue S.	Project Number: 611004.030.031	**Reported:**
Edmonds WA, 98020	Project Manager: Clint Jacob	25-Oct-2023 14:54

Analysis by: Analytical Resources, LLC

Volatile Organic Compounds - Quality Control

Batch BLI0930 - EPA 8260D

Instrument: NT3 Analyst: TWC

QC Sample/Analyte	Result	Detection Limit	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Blank (BLI0930-BLK2)					Prepared: 29-Sep-2023 Analyzed: 29-Sep-2023 13:26						
Benzene	ND	0.05	0.20	ug/L							U
Surrogate: 1,2-Dichloroethane-d4	4.99			ug/L	*5.00*		*99.8*	*80-129*			
Surrogate: Toluene-d8	4.97			ug/L	*5.00*		*99.4*	*80-120*			
Surrogate: 4-Bromofluorobenzene	4.79			ug/L	*5.00*		*95.9*	*80-120*			
Surrogate: 1,2-Dichlorobenzene-d4	5.04			ug/L	*5.00*		*101*	*80-120*			

Landau Associates, Inc.
130 2nd Avenue S.
Edmonds WA, 98020

Project: SSSMGP
Project Number: 611004.030.031
Project Manager: Clint Jacob

Reported:
25-Oct-2023 14:54

Analysis by: Analytical Resources, LLC

Volatile Organic Compounds - Quality Control

Batch BLI0930 - NWTPHg

Instrument: NT3   Analyst: TWC

QC Sample/Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
LCS (BLI0930-BS1)				Prepared: 29-Sep-2023	Analyzed: 29-Sep-2023 11:32					
Gasoline Range Organics (Tol-Nap)	1090	100	ug/L	1000		109	72-128			
Surrogate: Toluene-d8	4.91		ug/L	*5.00*		*98.2*	*80-120*			
Surrogate: 4-Bromofluorobenzene	4.89		ug/L	*5.00*		*97.7*	*80-120*			

Analysis by: Analytical Resources, LLC

Volatile Organic Compounds - Quality Control

Batch BLI0930 - EPA 8260D

Instrument: NT3   Analyst: TWC

QC Sample/Analyte	Result	Detection Limit	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
LCS (BLI0930-BS2)					Prepared: 29-Sep-2023	Analyzed: 29-Sep-2023 11:55					
Benzene	10.3	0.05	0.20	ug/L	10.0		103	80-120			
Surrogate: 1,2-Dichloroethane-d4	5.08			ug/L	*5.00*		*102*	*80-129*			
Surrogate: Toluene-d8	5.04			ug/L	*5.00*		*101*	*80-120*			
Surrogate: 4-Bromofluorobenzene	4.85			ug/L	*5.00*		*97.0*	*80-120*			
Surrogate: 1,2-Dichlorobenzene-d4	5.07			ug/L	*5.00*		*101*	*80-120*			

Landau Associates, Inc.	Project: SSSMGP	
130 2nd Avenue S.	Project Number: 611004.030.031	**Reported:**
Edmonds WA, 98020	Project Manager: Clint Jacob	25-Oct-2023 14:54

Analysis by: Analytical Resources, LLC

Volatile Organic Compounds - Quality Control

Batch BLI0930 - NWTPHg

Instrument: NT3 Analyst: TWC

QC Sample/Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
LCS Dup (BLI0930-BSD1)				Prepared: 29-Sep-2023 Analyzed: 29-Sep-2023 12:17						
Gasoline Range Organics (Tol-Nap)	1040	100	ug/L	1000		104	72-128	4.48	30	
Surrogate: Toluene-d8	4.88		ug/L	*5.00*		*97.6*	*80-120*			
Surrogate: 4-Bromofluorobenzene	4.93		ug/L	*5.00*		*98.6*	*80-120*			

Landau Associates, Inc.	Project: SSSMGP	
130 2nd Avenue S.	Project Number: 611004.030.031	**Reported:**
Edmonds WA, 98020	Project Manager: Clint Jacob	25-Oct-2023 14:54

Analysis by: Analytical Resources, LLC

Volatile Organic Compounds - Quality Control

Batch BLI0930 - EPA 8260D

Instrument: NT3 Analyst: TWC

QC Sample/Analyte	Result	Detection Limit	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
LCS Dup (BLI0930-BSD2)					Prepared: 29-Sep-2023 Analyzed: 29-Sep-2023 12:39						
Benzene	11.2	0.05	0.20	ug/L	10.0		112	80-120	8.35	30	
Surrogate: 1,2-Dichloroethane-d4	5.19			ug/L	*5.00*		*104*	*80-129*			
Surrogate: Toluene-d8	5.05			ug/L	*5.00*		*101*	*80-120*			
Surrogate: 4-Bromofluorobenzene	4.83			ug/L	*5.00*		*96.5*	*80-120*			
Surrogate: 1,2-Dichlorobenzene-d4	5.08			ug/L	*5.00*		*102*	*80-120*			

Landau Associates, Inc.	Project: SSSMGP	
130 2nd Avenue S.	Project Number: 611004.030.031	**Reported:**
Edmonds WA, 98020	Project Manager: Clint Jacob	25-Oct-2023 14:54

Analysis by: Analytical Resources, LLC

Volatile Organic Compounds - Quality Control

Batch BLI0930 - EPA 8260D

Volatile Organic Compounds - Quality Control

Batch BLJ0024 - EPA 8260D

Instrument: NT3 Analyst: TWC

QC Sample/Analyte	Result	Detection Limit	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Blank (BLJ0024-BLK1)					Prepared: 03-Oct-2023 Analyzed: 03-Oct-2023 16:31						
Benzene	ND	0.05	0.20	ug/L							U
Surrogate: 1,2-Dichloroethane-d4	4.59			ug/L	*5.00*		*91.7*	*80-129*			
Surrogate: Toluene-d8	4.83			ug/L	*5.00*		*96.6*	*80-120*			
Surrogate: 4-Bromofluorobenzene	4.81			ug/L	*5.00*		*96.1*	*80-120*			
Surrogate: 1,2-Dichlorobenzene-d4	5.08			ug/L	*5.00*		*102*	*80-120*			

Landau Associates, Inc.	Project: SSSMGP	
130 2nd Avenue S.	Project Number: 611004.030.031	**Reported:**
Edmonds WA, 98020	Project Manager: Clint Jacob	25-Oct-2023 14:54

Analysis by: Analytical Resources, LLC

Volatile Organic Compounds - Quality Control

Batch BLJ0024 - EPA 8260D

Instrument: NT3 Analyst: TWC

QC Sample/Analyte	Result	Detection Limit	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
LCS (BLJ0024-BS1)					Prepared: 03-Oct-2023 Analyzed: 03-Oct-2023 15:24						
Benzene	9.26	0.05	0.20	ug/L	10.0		92.6	80-120			
Surrogate: 1,2-Dichloroethane-d4	5.15			ug/L	*5.00*		*103*	*80-129*			
Surrogate: Toluene-d8	4.88			ug/L	*5.00*		*97.6*	*80-120*			
Surrogate: 4-Bromofluorobenzene	5.20			ug/L	*5.00*		*104*	*80-120*			
Surrogate: 1,2-Dichlorobenzene-d4	4.93			ug/L	*5.00*		*98.6*	*80-120*			

Analysis by: Analytical Resources, LLC

Volatile Organic Compounds - Quality Control

Batch BLJ0024 - EPA 8260D

Instrument: NT3   Analyst: TWC

QC Sample/Analyte	Result	Detection Limit	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
LCS Dup (BLJ0024-BSD1)						Prepared: 03-Oct-2023	Analyzed: 03-Oct-2023 15:47				
Benzene	10.4	0.05	0.20	ug/L	10.0		104	80-120	11.90	30	
Surrogate: 1,2-Dichloroethane-d4	4.80			ug/L	*5.00*		*96.0*	*80-129*			
Surrogate: Toluene-d8	4.87			ug/L	*5.00*		*97.4*	*80-120*			
Surrogate: 4-Bromofluorobenzene	5.16			ug/L	*5.00*		*103*	*80-120*			
Surrogate: 1,2-Dichlorobenzene-d4	5.01			ug/L	*5.00*		*100*	*80-120*			

Analysis by: Analytical Resources, LLC

Volatile Organic Compounds - Quality Control

Batch BLJ0024 - EPA 8260D

Analysis by: Analytical Resources, LLC

Petroleum Hydrocarbons - Quality Control

Batch BLJ0114 - NWTPH-Dx

Instrument: FID4 Analyst: NRB

QC Sample/Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Blank (BLJ0114-BLK1)				Prepared: 05-Oct-2023 Analyzed: 20-Oct-2023 18:31						
Diesel Range Organics (C12-C24)	ND	0.100	mg/L							U
Motor Oil Range Organics (C24-C38)	0.246	0.200	mg/L							
Surrogate: o-Terphenyl	0.168		mg/L	*0.225*		*74.8*	*50-150*			

Landau Associates, Inc.
130 2nd Avenue S.
Edmonds WA, 98020

Project: SSSMGP
Project Number: 611004.030.031
Project Manager: Clint Jacob

Reported:
25-Oct-2023 14:54

Analysis by: Analytical Resources, LLC

Petroleum Hydrocarbons - Quality Control

Batch BLJ0114 - NWTPH-Dx

Instrument: FID4 Analyst: NRB

QC Sample/Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
LCS (BLJ0114-BS1)				Prepared: 05-Oct-2023		Analyzed: 20-Oct-2023 18:52				
Diesel Range Organics (C12-C24)	2.09	0.100	mg/L	3.00		69.8	56-120			
Surrogate: o-Terphenyl	0.164		mg/L	*0.225*		*72.8*	*50-150*			

Analysis by: Analytical Resources, LLC

Petroleum Hydrocarbons - Quality Control

Batch BLJ0114 - NWTPH-Dx

Instrument: FID4 Analyst: NRB

QC Sample/Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
LCS Dup (BLJ0114-BSD1)				Prepared: 05-Oct-2023 Analyzed: 20-Oct-2023 19:12						
Diesel Range Organics (C12-C24)	2.40	0.100	mg/L	3.00		80.0	56-120	13.60	30	
Surrogate: o-Terphenyl	0.185		mg/L	*0.225*		*82.3*	*50-150*			

Analysis by: Analytical Resources, LLC

Petroleum Hydrocarbons - Quality Control

Batch BLJ0114 - NWTPH-Dx

Analysis by: Analytical Resources, LLC

Wet Chemistry - Quality Control

Batch BLJ0392 - SM 4500-CN¯ I-97

Instrument: UV1800-2 Analyst: KOTT

QC Sample/Analyte	Result	Detection Limit	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Blank (BLJ0392-BLK1)				Prepared: 12-Oct-2023 Analyzed: 13-Oct-2023 15:59							
Cyanide, Weak Acid Dissociable	ND	0.005	0.005	mg/L							U
LCS (BLJ0392-BS1)				Prepared: 12-Oct-2023 Analyzed: 13-Oct-2023 16:00							
Cyanide, Weak Acid Dissociable	0.131	0.005	0.005	mg/L	0.150		87.3	75-125			
Duplicate (BLJ0392-DUP1)		**Source: 23I0924-01**		Prepared: 12-Oct-2023 Analyzed: 13-Oct-2023 16:02							
Cyanide, Weak Acid Dissociable	0.008	0.005	0.005	mg/L		0.008			0.00		
Matrix Spike (BLJ0392-MS1)		**Source: 23I0924-01**		Prepared: 12-Oct-2023 Analyzed: 13-Oct-2023 16:03							
Cyanide, Weak Acid Dissociable	0.135	0.005	0.005	mg/L	0.150	0.008	84.6	75-125			

Recovery limits for target analytes in MS/MSD QC samples are advisory only.

Analysis by: Analytical Resources, LLC

Wet Chemistry - Quality Control

Batch BLJ0416 - SM 4500-CN$^-$ E-99

Instrument: UV1800-2 Analyst: KOTT

QC Sample/Analyte	Result	Detection Limit	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Blank (BLJ0416-BLK1)					Prepared: 12-Oct-2023 Analyzed: 13-Oct-2023 09:38						
Cyanide, Total	ND	0.0050	0.0050	mg/L							U
LCS (BLJ0416-BS1)					Prepared: 12-Oct-2023 Analyzed: 13-Oct-2023 09:39						
Cyanide, Total	0.152	0.0050	0.0050	mg/L	0.150		101	75-125			

Landau Associates, Inc.	Project: SSSMGP	
130 2nd Avenue S.	Project Number: 611004.030.031	**Reported:**
Edmonds WA, 98020	Project Manager: Clint Jacob	25-Oct-2023 14:54

Analysis by: Analytical Resources, LLC

Wet Chemistry - Quality Control

Batch BLJ0663 - EPA 300.0

Instrument: IC930 Analyst: BF

QC Sample/Analyte	Result	Detection Limit	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Blank (BLJ0663-BLK1)					Prepared: 20-Oct-2023 Analyzed: 20-Oct-2023 18:03						
Sulfate	ND	0.100	0.100	mg/L							U
LCS (BLJ0663-BS1)					Prepared: 20-Oct-2023 Analyzed: 20-Oct-2023 18:23						
Sulfate	5.16	0.100	0.100	mg/L	5.00		103	90-110			

Landau Associates, Inc.	Project: SSSMGP	
130 2nd Avenue S.	Project Number: 611004.030.031	**Reported:**
Edmonds WA, 98020	Project Manager: Clint Jacob	25-Oct-2023 14:54

Certified Analyses included in this Report

Analyte	Certifications
EPA 300.0 in Water	
Sulfate	DoD-ELAP,WADOE,WA-DW,NELAP
EPA 8260D in Water	
Benzene	DoD-ELAP,ADEC,NELAP,WADOE
NWTPH-Dx in Water	
Diesel Range Organics (C12-C2	DoD-ELAP,NELAP,WADOE
Motor Oil Range Organics (C24-	DoD-ELAP,NELAP,WADOE
NWTPHg in Water	
Gasoline Range Organics (Tol-N	WADOE,DoD-ELAP
SM 4500-CN¯ E-99 in Water	
Cyanide, Total	WADOE,WA-DW,NELAP,DoD-ELAP
SM 4500-CN¯ I-97 in Water	
Cyanide, Weak Acid Dissociable	NELAP,WADOE

Code	Description	Number	Expires
ADEC	Alaska Dept of Environmental Conservation	17-015	03/28/2025
DoD-ELAP	DoD-Environmental Laboratory Accreditation Program, PJLA Testing	66169	02/28/2025
NELAP	ORELAP - Oregon Laboratory Accreditation Program	WA100006-012	05/12/2024

Notes and Definitions

*	Flagged value is not within established control limits.
B	This analyte was detected in the method blank.
D	The reported value is from a dilution
E	The analyte concentration exceeds the upper limit of the calibration range of the instrument established by the initial calibration (ICAL)
J	Estimated concentration value detected below the reporting limit.
U	This analyte is not detected above the reporting limit (RL) or if noted, not detected above the limit of detection (LOD).
DET	Analyte DETECTED
ND	Analyte NOT DETECTED at or above the reporting limit
NR	Not Reported
dry	Sample results reported on a dry weight basis
RPD	Relative Percent Difference
[2C]	Indicates this result was quantified on the second column on a dual column analysis.

ATTACHMENT 2

EnviroFlux Data Packages

Landau	
Project name:	Former SSSMGP
Project Manager	Clint Jacob
Installation Date	4/6/2023
Sampling Date	4/25/2023
Reporting Date	5/15/2023

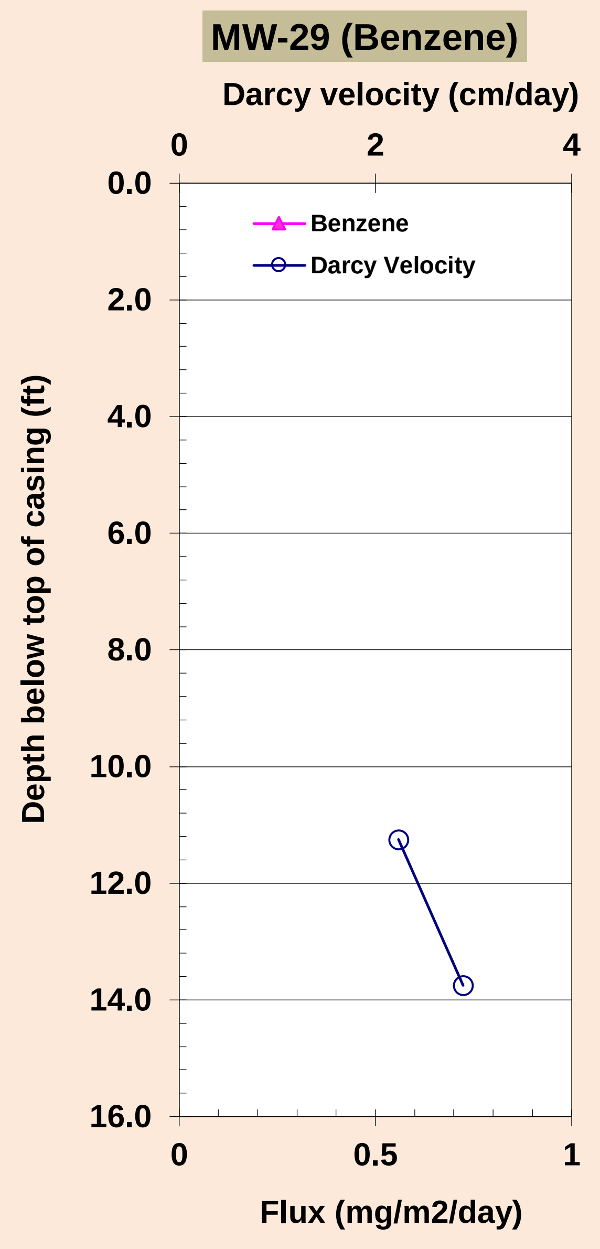
Table 1. Summary of flux values for each well

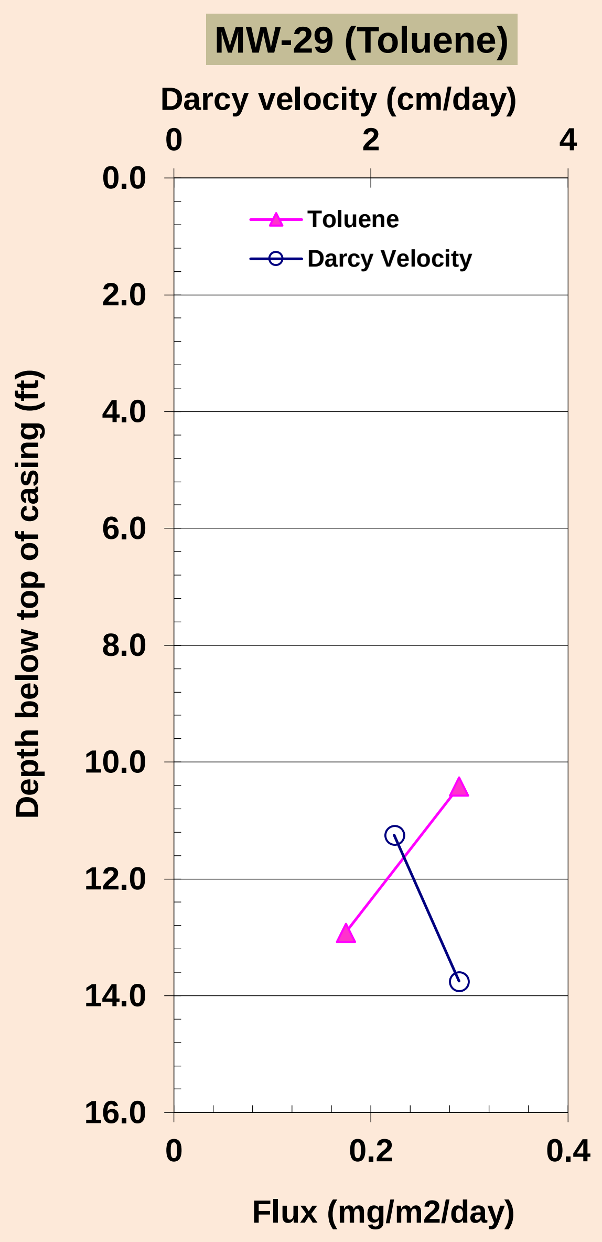
Well_ID	Sample_ID	Depth below top of well casing (ft)	Darcy Velocity (cm/day)	Benzene flux (mg/m^2/day)	Toluene flux (mg/m^2/day)	Ethylbenzene flux (mg/m^2/day)	M,P-xylene flux (mg/m^2/day)	O-xylene flux (mg/m^2/day)	TPH-g flux (mg/m^2/day)	TPH-d flux (mg/m^2/day)	Cyanide flux (mg/m^2/day)
MW-29	**PFM-1-1-1-042523**	10.4	-	ND (<0.002)	0.29	ND (<0.02)	ND (<0.02)	ND (<0.02)	ND (<0.08)	ND (<13.3)	-
	PFM-1-2-1-042523	11.3	2.2						-	-	-
	PFM-1-3-1-042523	12.1	-	-	-	-	-	-	-	-	23.7
	PFM-1-1-2-042523	12.9	-	ND (<0.002)	0.17	ND(<0.02)	ND(<0.02)	ND(<0.02)	0.14	ND (<13.3)	-
	PFM-1-2-2-042523	13.8	2.9						-	-	-
	PFM-1-3-2-042523	14.6	-	-	-	-	-	-	-	-	28.9
MW-28	**PFM-2-1-1-042523**	10.4	-	20.40	2.07	1.19	0.43	1.49	ND (<0.08)	65.0	-
	PFM-2-2-2-042523	11.3	1.1						-	-	-
	PFM-2-1-2-042523	12.1	-	-	-	-	-	-	-	-	ND (<3.17)
	PFM-2-1-2-042523	12.9	-	22.33	1.53	1.27	0.40	1.57	0.33	2113.8	-
	PFM-2-2-1-042523	13.8	2.0						-	-	-
	PFM-2-3-2-042523	14.6	-	-	-	-	-	-	-	-	ND(<3.24)

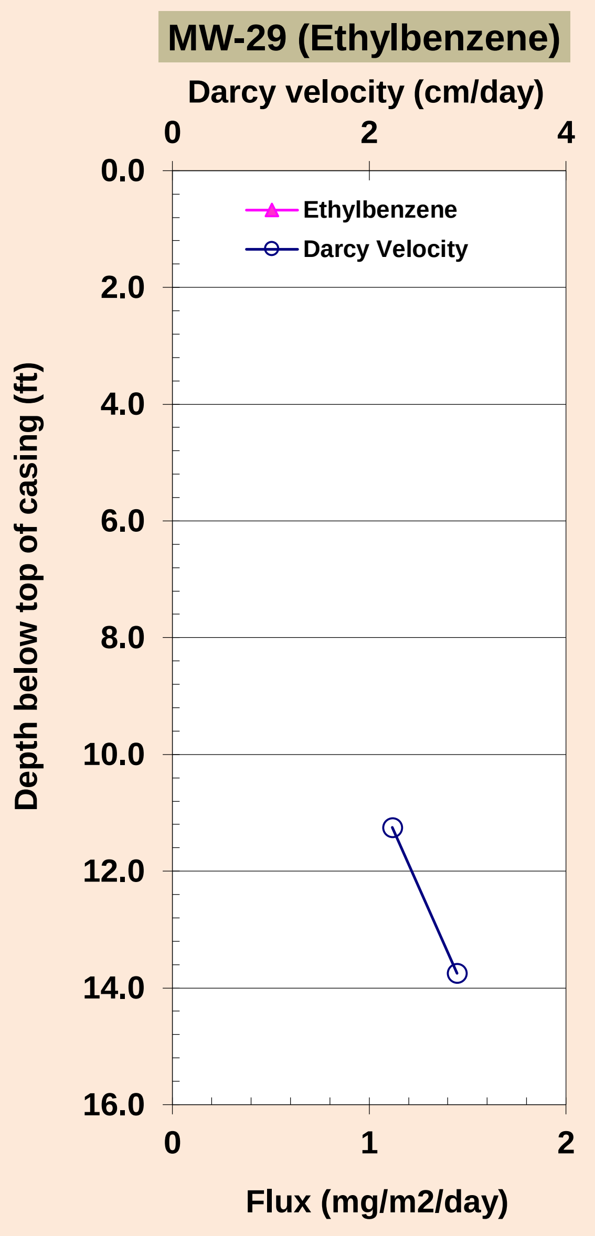
Table 2. Summary of flux average contaminant concentration

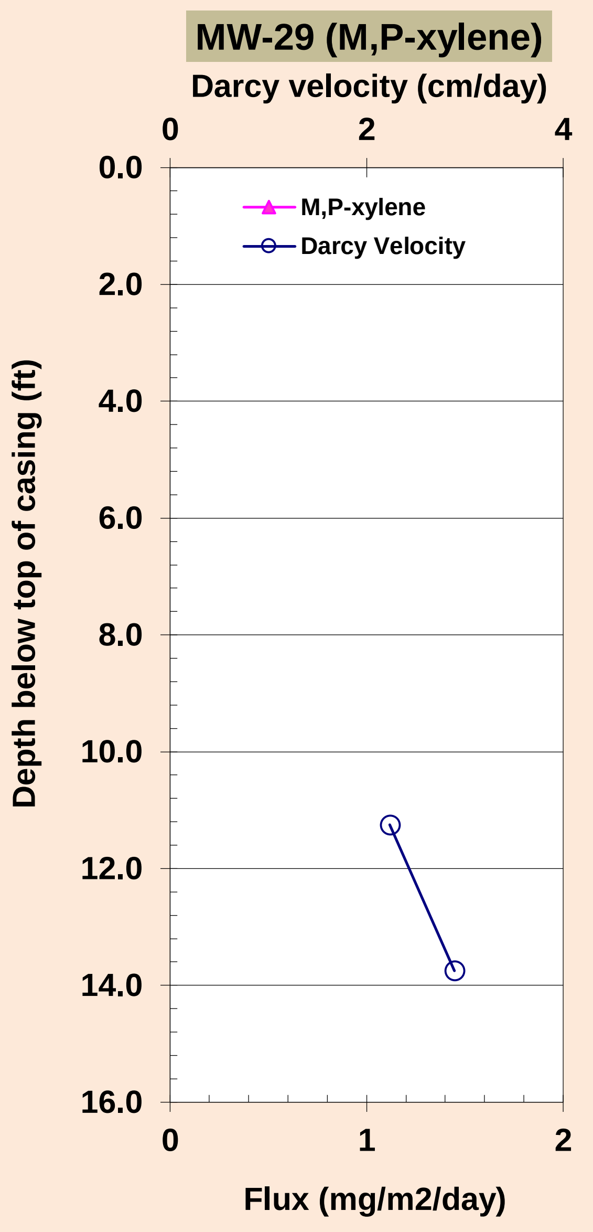
Well_ID	Sample_ID	Depth below top of well casing (ft)	Darcy Velocity (cm/day)	Benzene (ug/L)	Toluene (ug/L)	Ethylbenzene (ug/L)	M,P-xylene (ug/L)	O-xylene (ug/L)	TPH-g (mg/L)	TPH-d (mg/L)	Total Cyanide (mg/L)
MW-29	**PFM-1-1-1-042523**	10.4	-	ND	13	ND	ND	ND	ND	ND	-
	PFM-1-2-1-042523	11.3	2.2						-	-	-
	PFM-1-3-1-042523	12.1	-	-	-	-	-	-	-	-	1.1
	PFM-1-1-2-042523	12.9	-	ND	6	ND	ND	ND	0.005	ND	-
	PFM-1-2-2-042523	13.8	2.9						-	-	-
	PFM-1-3-2-042523	14.6	-	-	-	-	-	-	-	-	1.0
MW-28	**PFM-2-1-1-042523**	10.4	-	1782	181	104	38	130	ND	6	-
	PFM-2-2-2-042523	11.3	1.1						-	-	-
	PFM-2-1-2-042523	12.1	-	-	-	-	-	-	-	-	ND
	PFM-2-1-2-042523	12.9	-	1140	78	65	20	80	0	108	-
	PFM-2-2-1-042523	13.8	2.0						-	-	-
	PFM-2-3-2-042523	14.6	-	-	-	-	-	-	-	-	ND

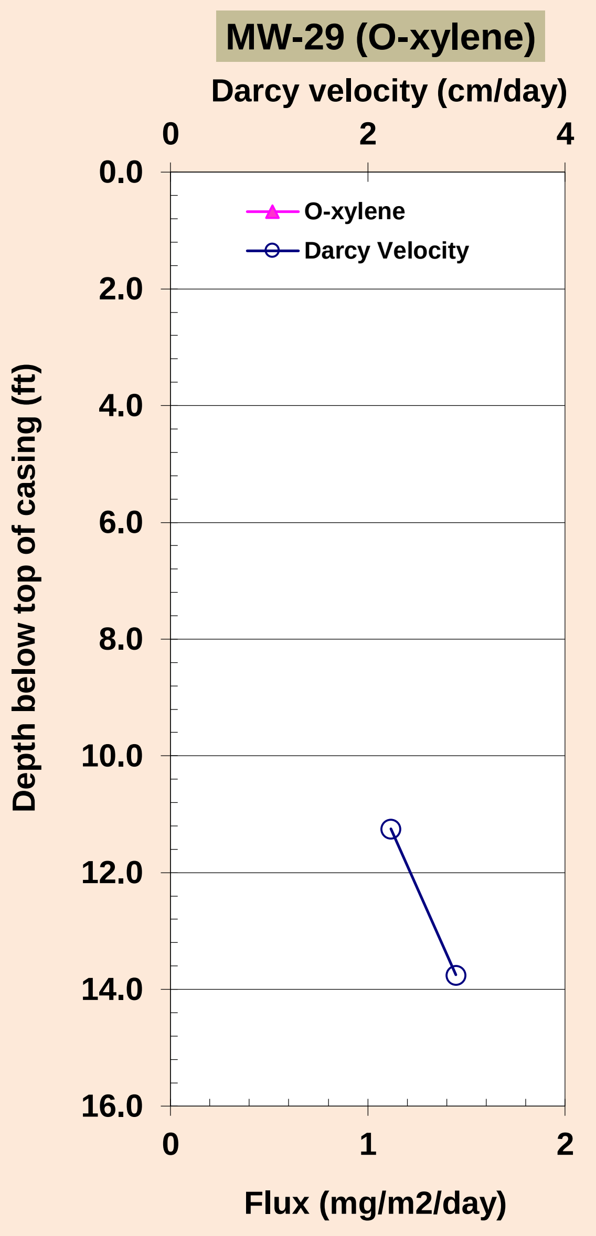
Landau	
Project name:	Former SSSMGP
Project Manager	Clint Jacob
Installation Date	4/6/2023
Sampling Date	4/25/2023
Reporting Date	5/15/2023

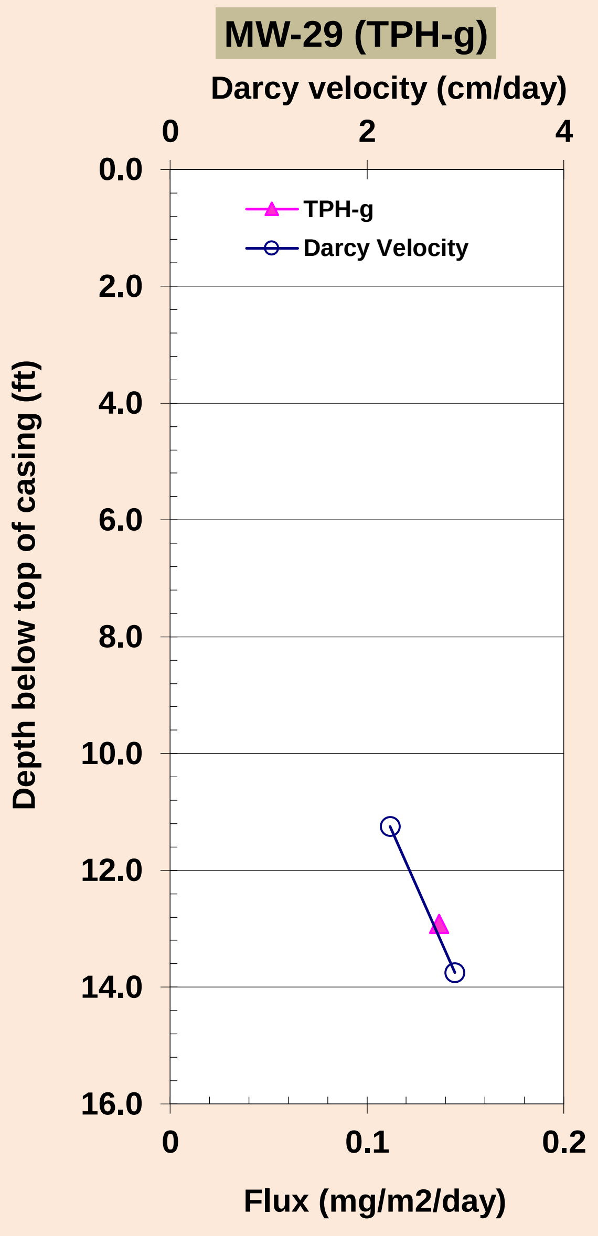


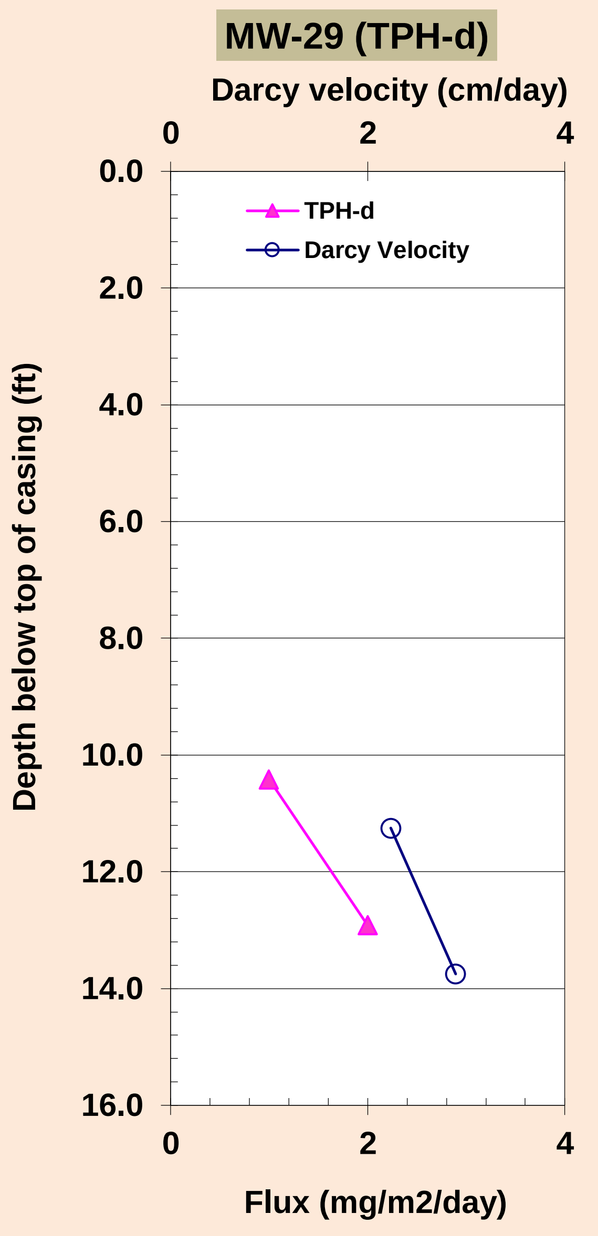


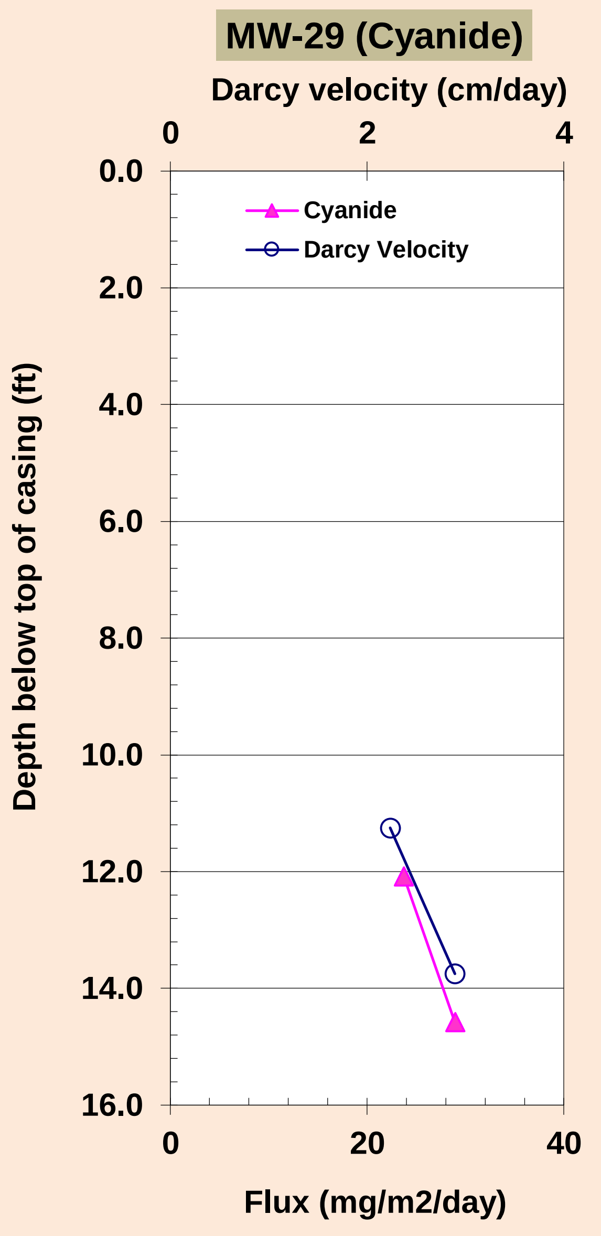


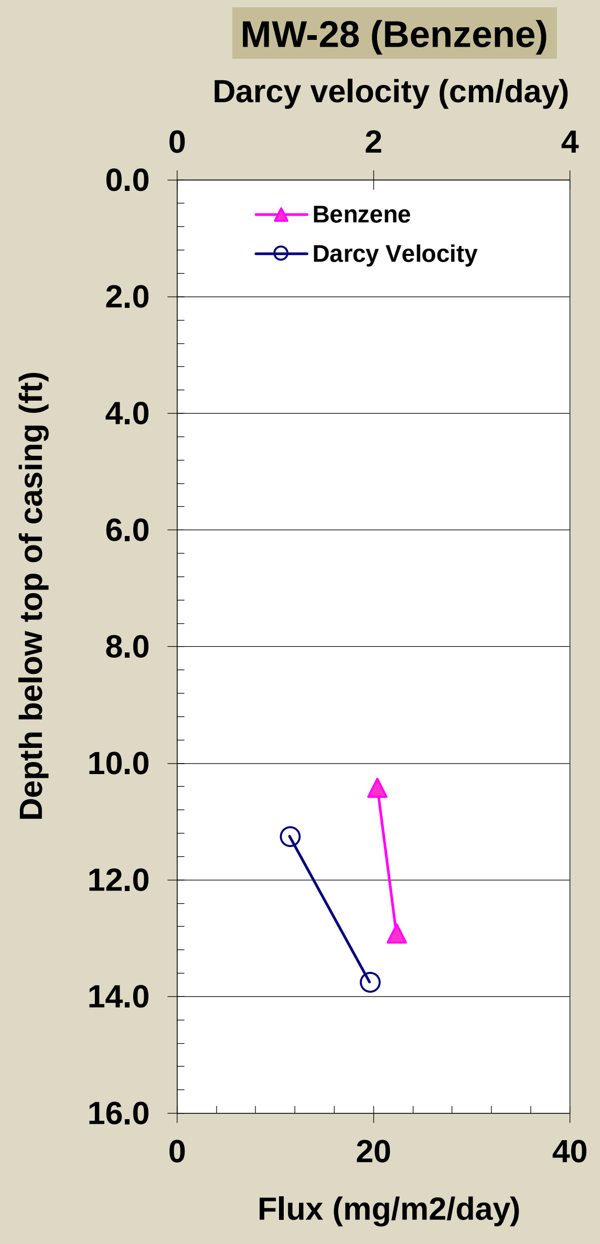


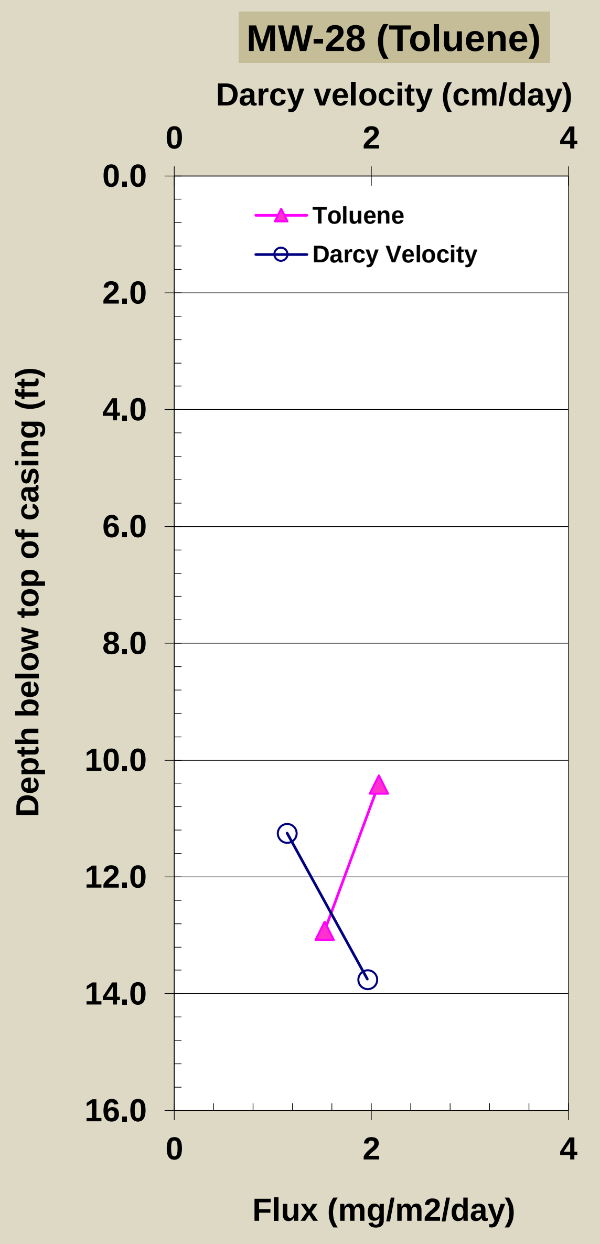


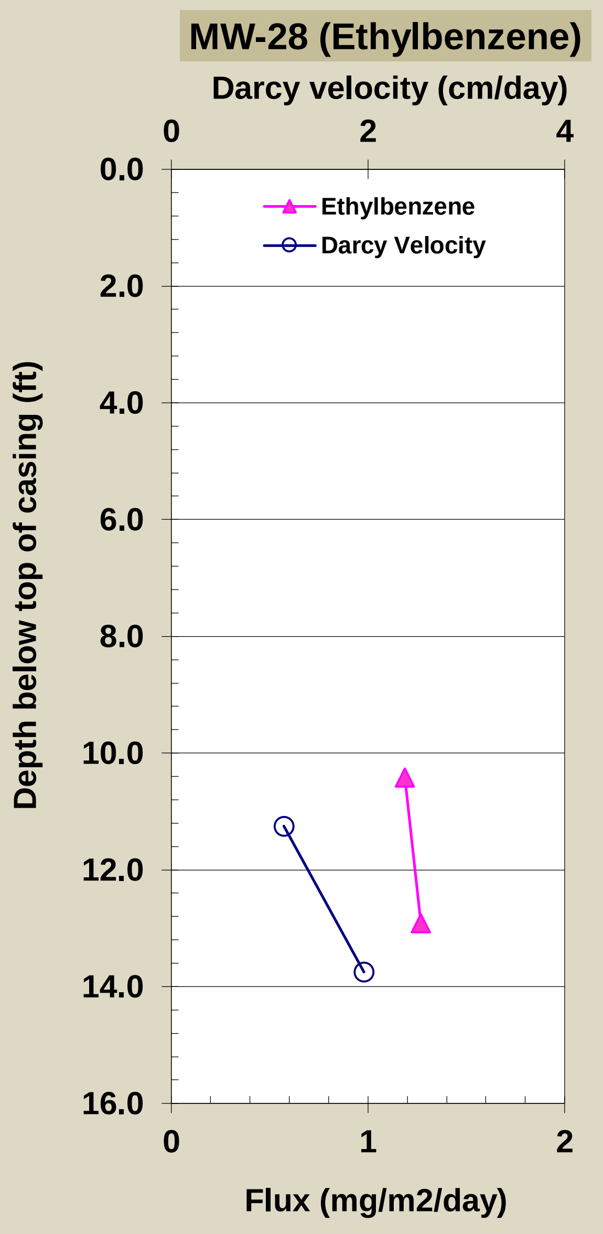


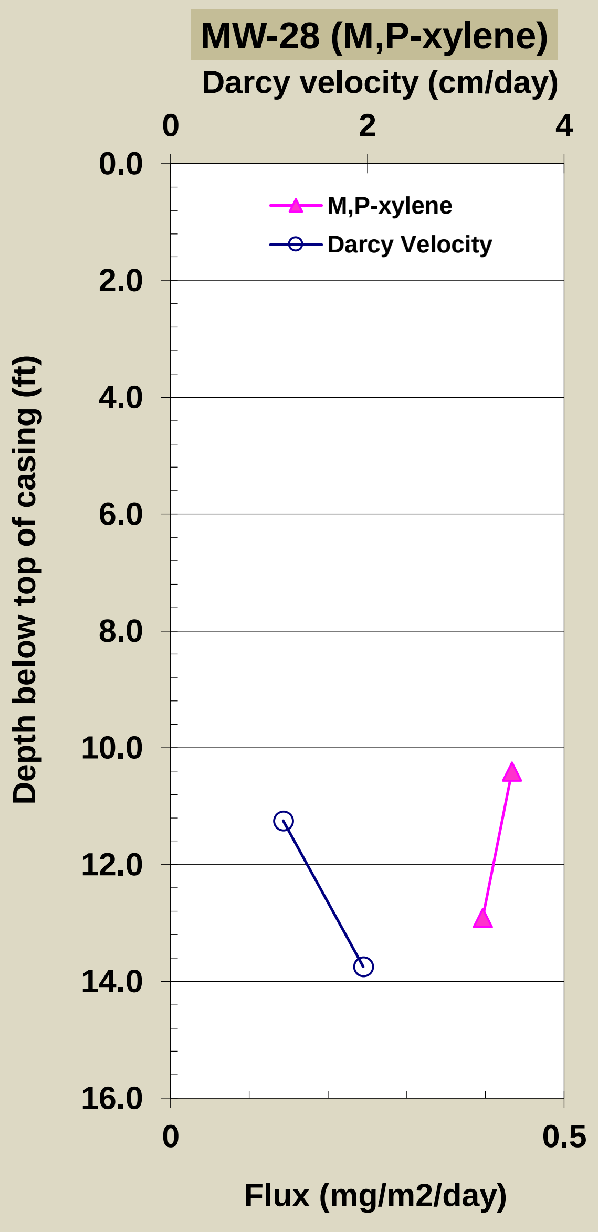


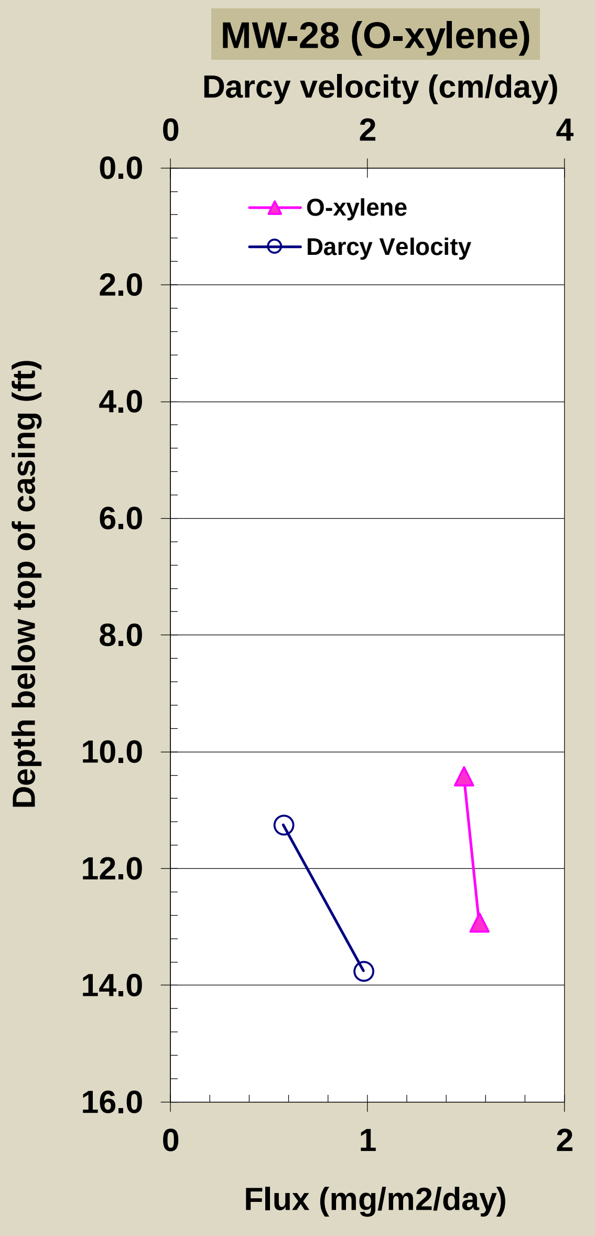


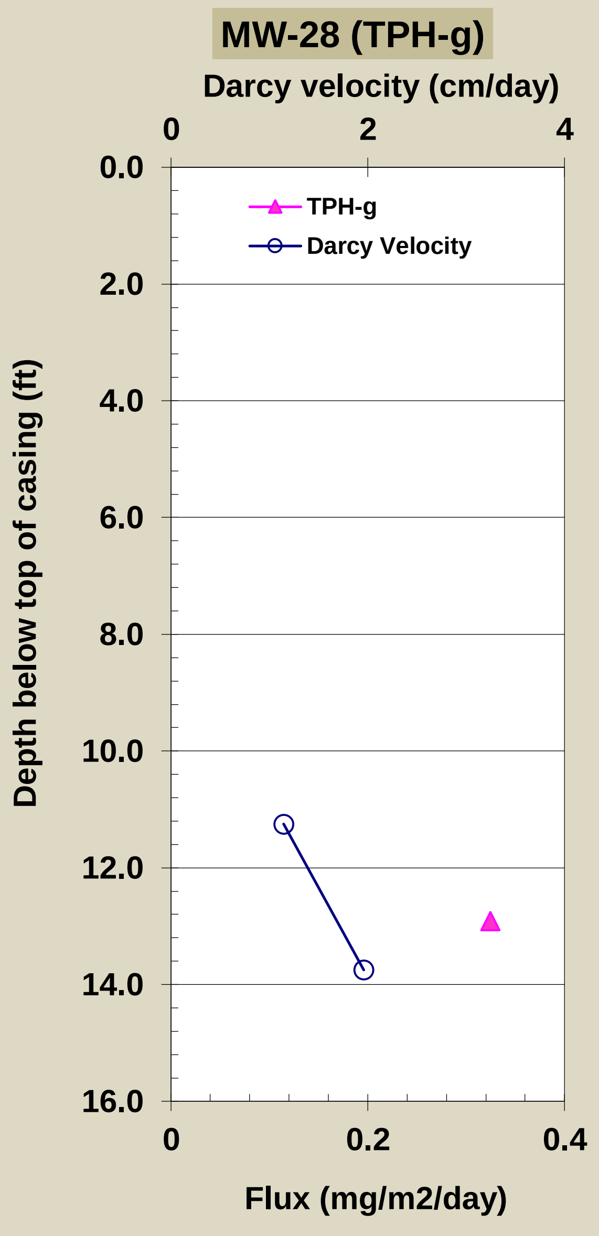


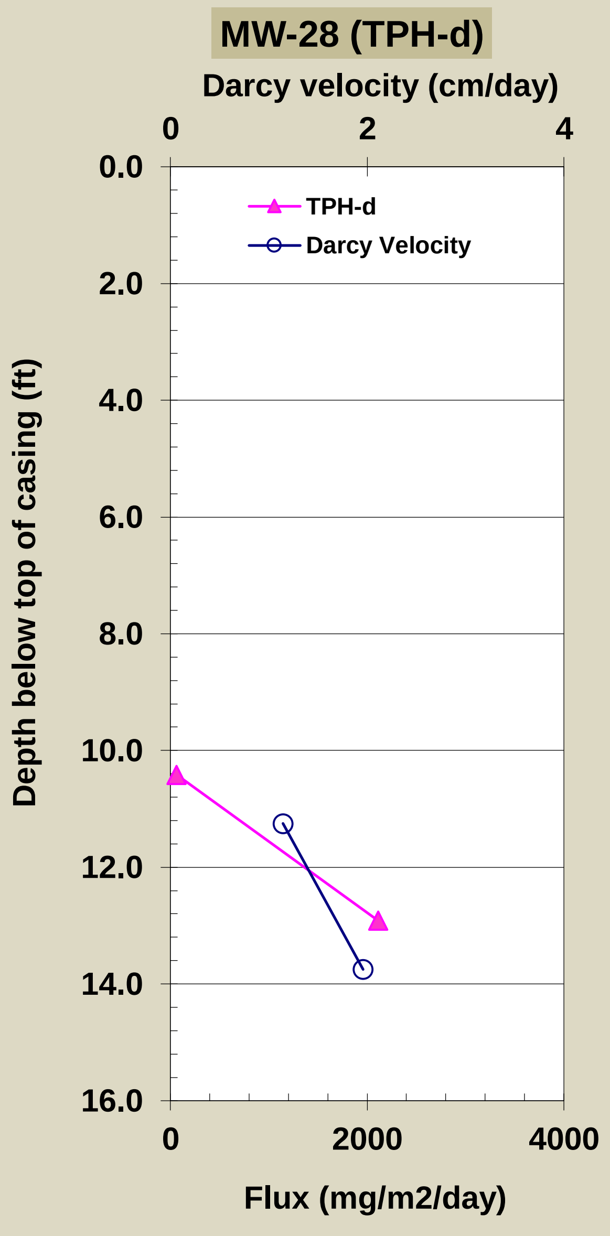


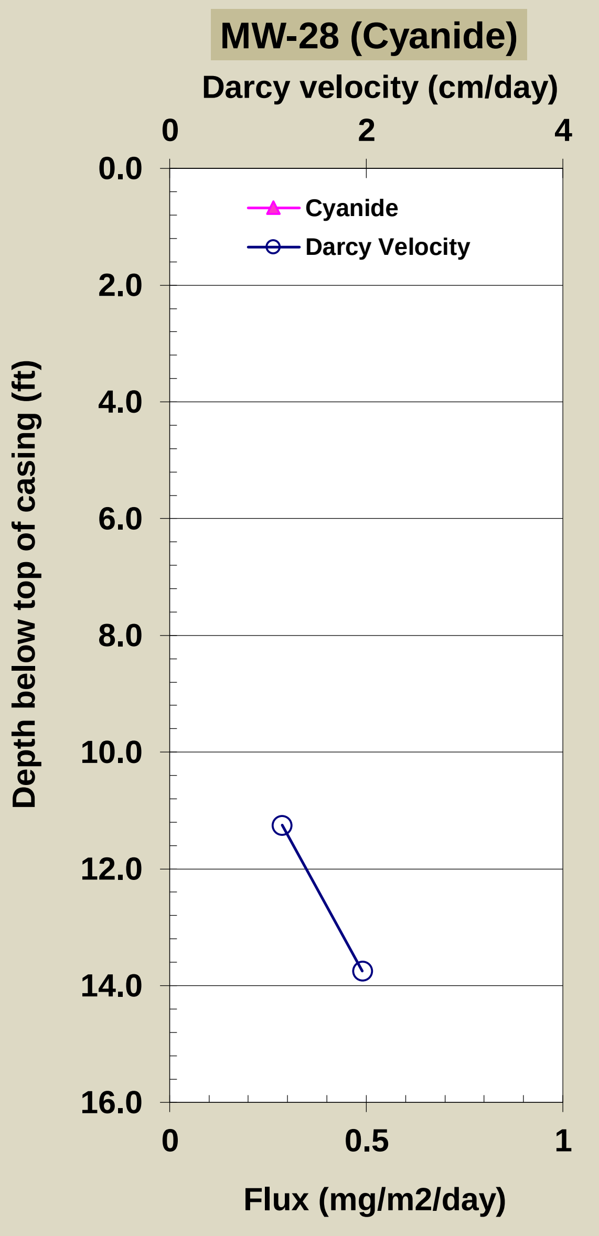












Landau	
Project name:	Former SSSMGP
Project Manager	Clint Jacob
Installation Date	4/6/2023
Sampling Date	4/25/2023
Reporting Date	5/15/2023

Table 3. Mass discharge per unit width for aquifer of each well

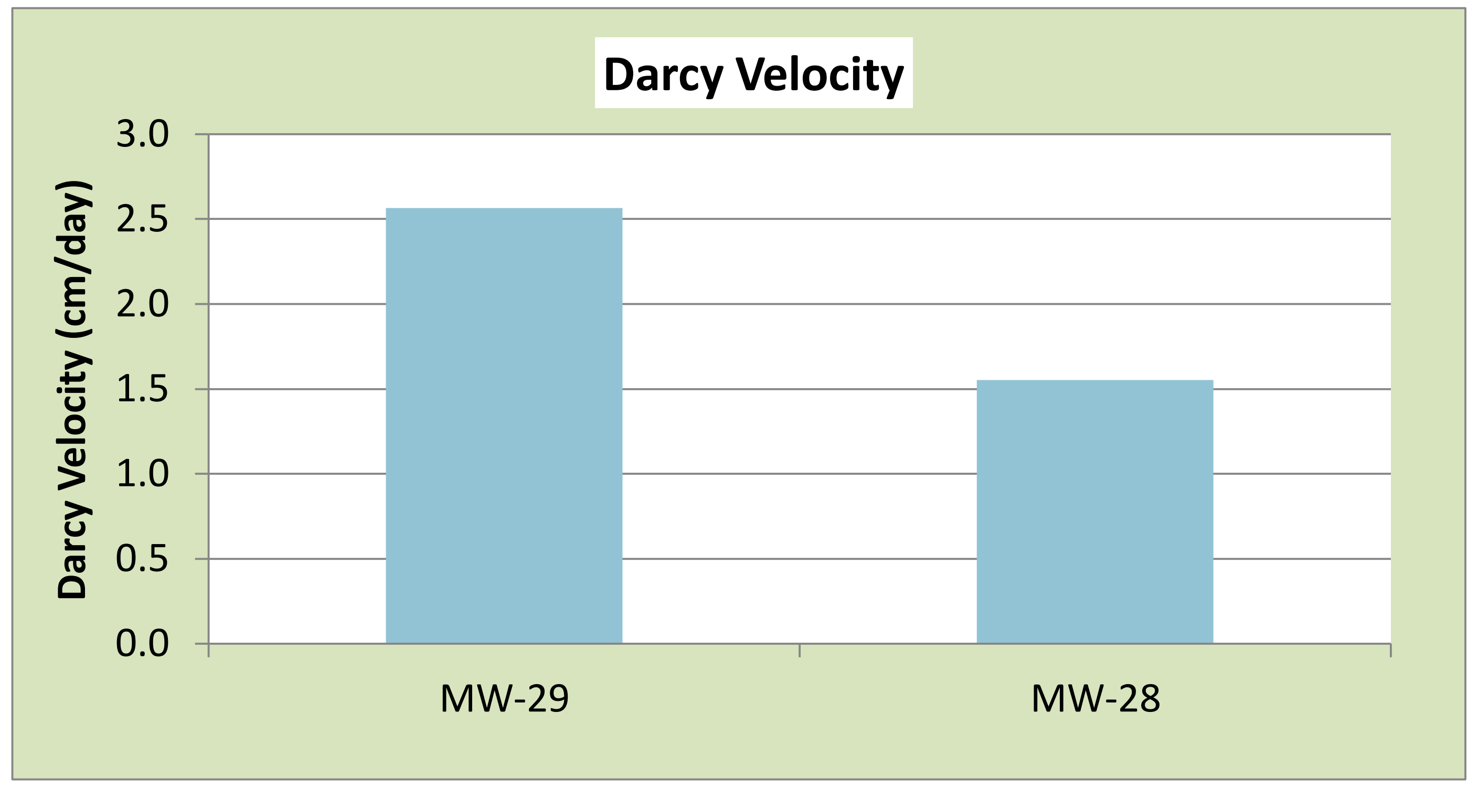
Well	Darcy Velocity (cm/day)	Benzene discharge (mg/m/day)	Toluene discharge (mg/m/day)	Ethylbenzene discharge (mg/m/day)	M,P-xylene discharge (mg/m/day)	O-xylene discharge (mg/m/day)	TPH-g discharge (mg/m/day)	TPH-d discharge (mg/m/day)	Cyanide discharge (mg/m/day)
MW-29	2.6	ND	0.28	ND	ND	ND	0.08	ND	32.1
MW-28	1.6	26.0	2.2	1.50	0.51	1.86	0.20	1328.2	ND

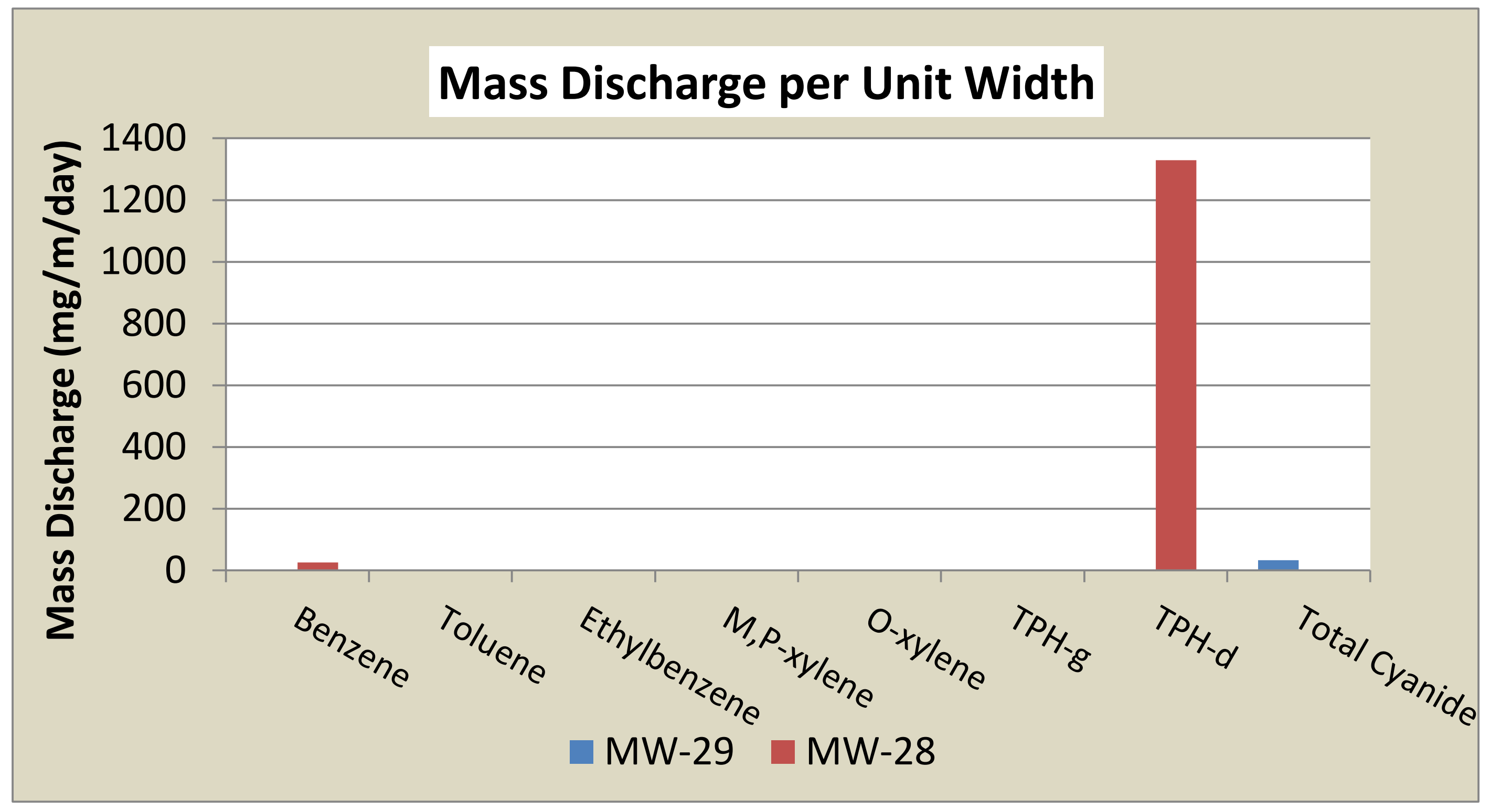
Table 4. Well average values of mass flux based on PFMs

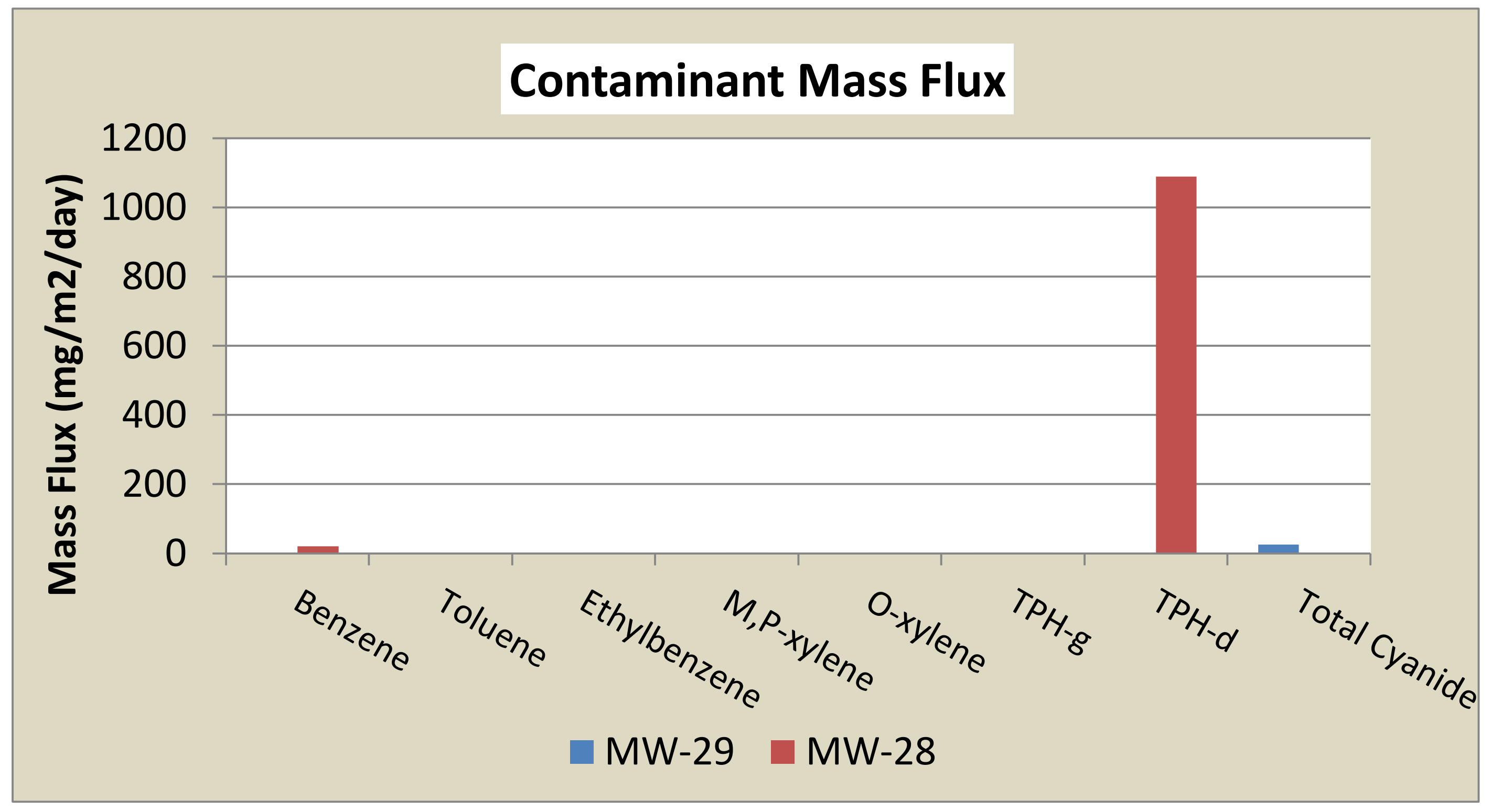
Well	Darcy Velocity (cm/day)	Benzene flux (mg/m^2/day)	Toluene flux (mg/m^2/day)	Ethylbenzene flux (mg/m^2/day)	M,P-xylene flux (mg/m^2/day)	O-xylene flux (mg/m^2/day)	TPH-g flux (mg/m^2/day)	TPH-d flux (mg/m^2/day)	Cyanide flux (mg/m^2/day)
MW-29	2.6	ND(<0.002)	0.23	ND(<0.02)	ND(<0.02)	ND(<0.02)	0.14	ND (<13.3)	26.3
MW-28	1.6	21.36	1.80	1.23	0.42	1.53	0.33	1089.4	ND (<3.2)

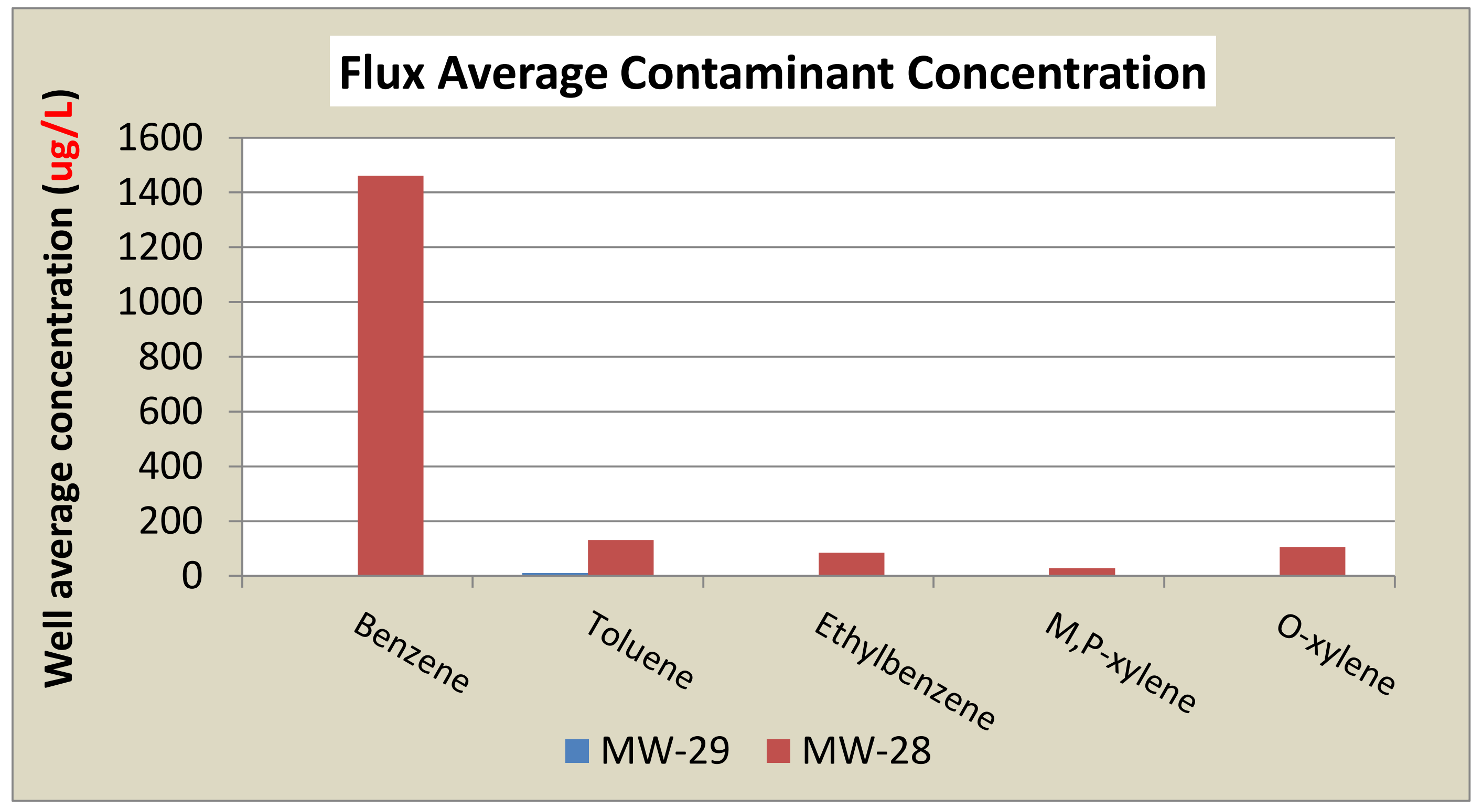
Table 5. Flux average contaminant concentration on PFMs

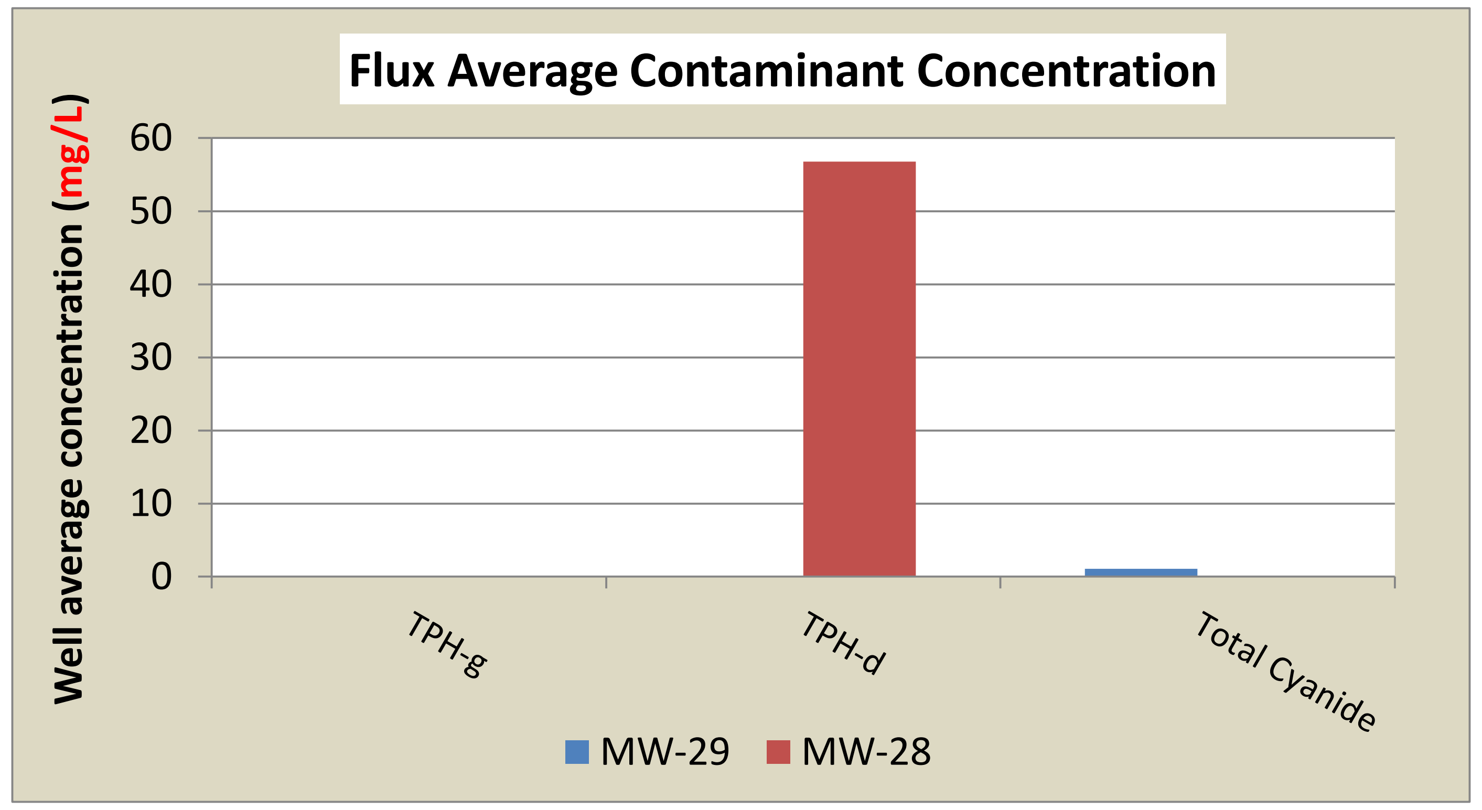
Well	Darcy Velocity (cm/day)	Benzene (ug/L)	Toluene (ug/L)	Ethylbenzene (ug/L)	M,P-xylene (ug/L)	O-xylene (ug/L)	TPH-g (mg/L)	TPH-d (mg/L)	Total Cyanide (mg/L)
MW-29	2.6	ND	9.5	ND	ND	ND	0.005	ND	1.03
MW-28	1.6	1460.8	129.5	84.3	29.1	105.0	0.017	56.8	ND











Landau	
Project name:	Former SSSMGP
Project Manager	Clint Jacob
Installation Date	9/7/2023
Sampling Date	9/28/2023
Reporting Date	10/27/2023

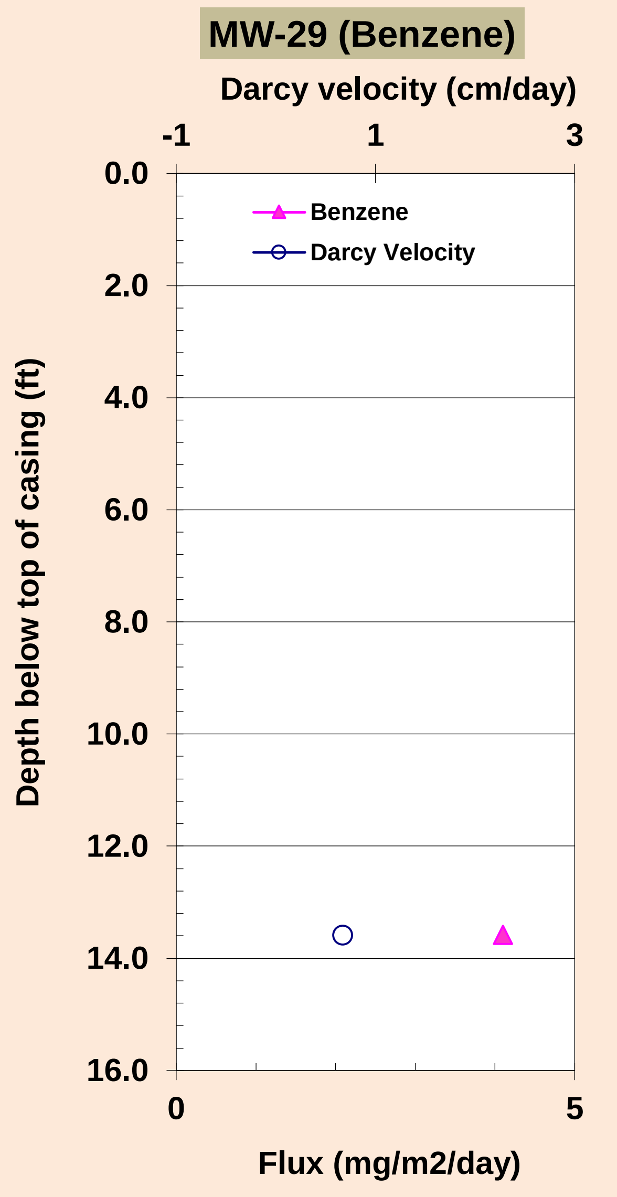
Table 1. Summary of flux values for each well

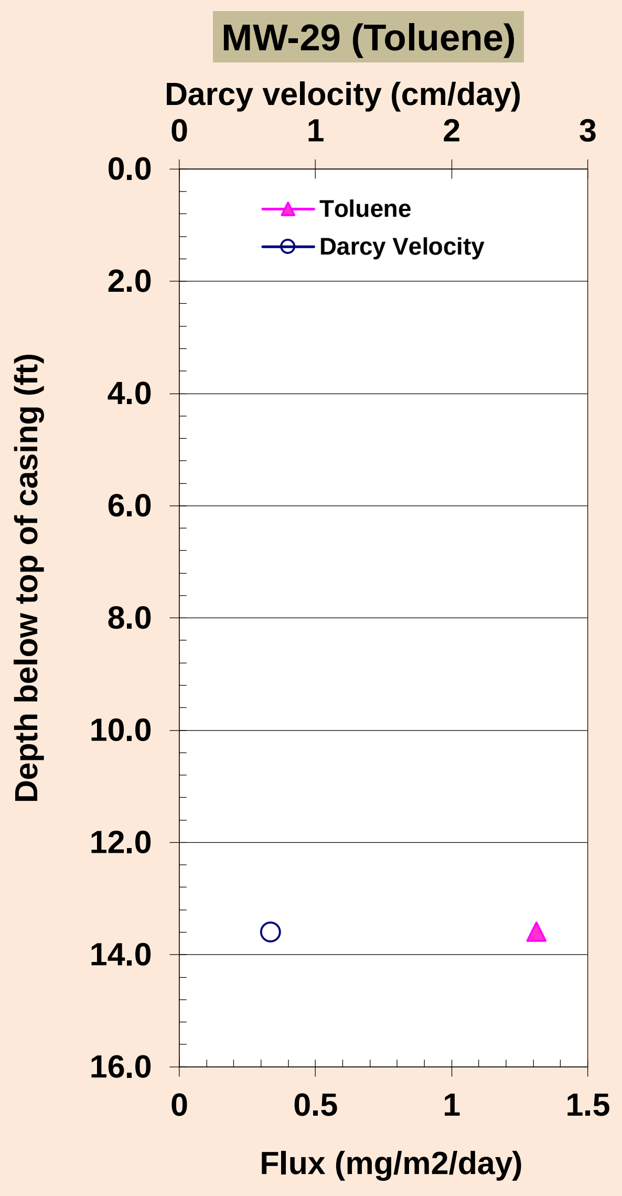
Well_ID	Sample_ID	Depth below top of well casing (ft)	Darcy Velocity (cm/day)	Benzene flux (mg/m^2/day)	Toluene flux (mg/m^2/day)	Ethylbenzene flux (mg/m^2/day)	M,P-xylene flux (mg/m^2/day)	O-xylene flux (mg/m^2/day)	TPH-g flux (mg/m^2/day)	TPH-d flux (mg/m^2/day)	Cyanide flux (mg/m^2/day)
MW-29	**PFM-1-1-1-092823**	10.4	-	-	-	-	-	-	Dry	Dry	-
	PFM-1-2-1-092823	11.3	Dry	Dry	Dry	Dry	Dry	Dry	-	-	-
	PFM-1-3-1-092823	12.1	-	-	-	-	-	-	-	-	Dry
	PFM-1-1-2-092823	12.8	-	-	-	-	-	-	ND (<0.07)	7.31	-
	PFM-1-2-2-092823	13.6	0.7	4.10	1.31	6.24	ND (<0.16)	0.55	-	-	-
	PFM-1-3-2-092823	14.4	-	-	-	-	-	-	-	-	13.4
MW-28	**PFM-2-1-1-092823**	10.4	-	-	-	-	-	-	Dry	Dry	-
	PFM-2-2-2-092823	11.3	Dry	Dry	Dry	Dry	Dry	Dry	-	-	-
	PFM-2-1-2-092823	12.1	-	-	-	-	-	-	-	-	Dry
	PFM-2-1-2-092823	12.6	-	-	-	-	-	-	0.19	36.6	-
	PFM-2-2-1-092823	13.4	2.0	114.13	4.04	6.62	ND (<0.16)	1.87	-	-	-
	PFM-2-3-2-092823	14.3	-	-	-	-	-	-	-	-	ND (<2.9)

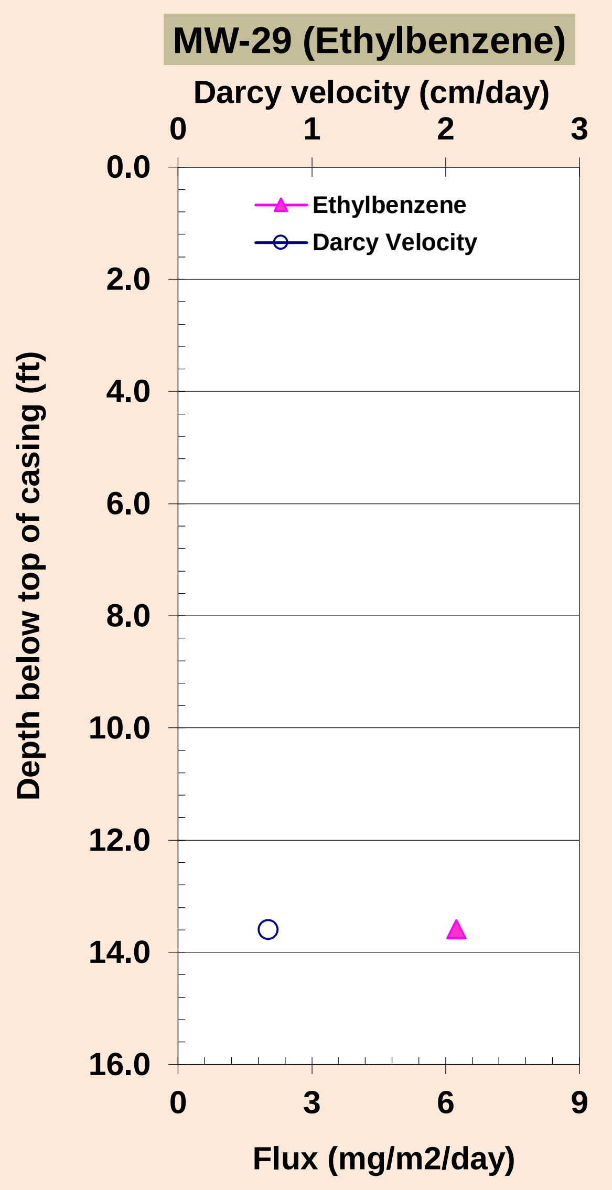
Table 2. Summary of flux average contaminant concentration

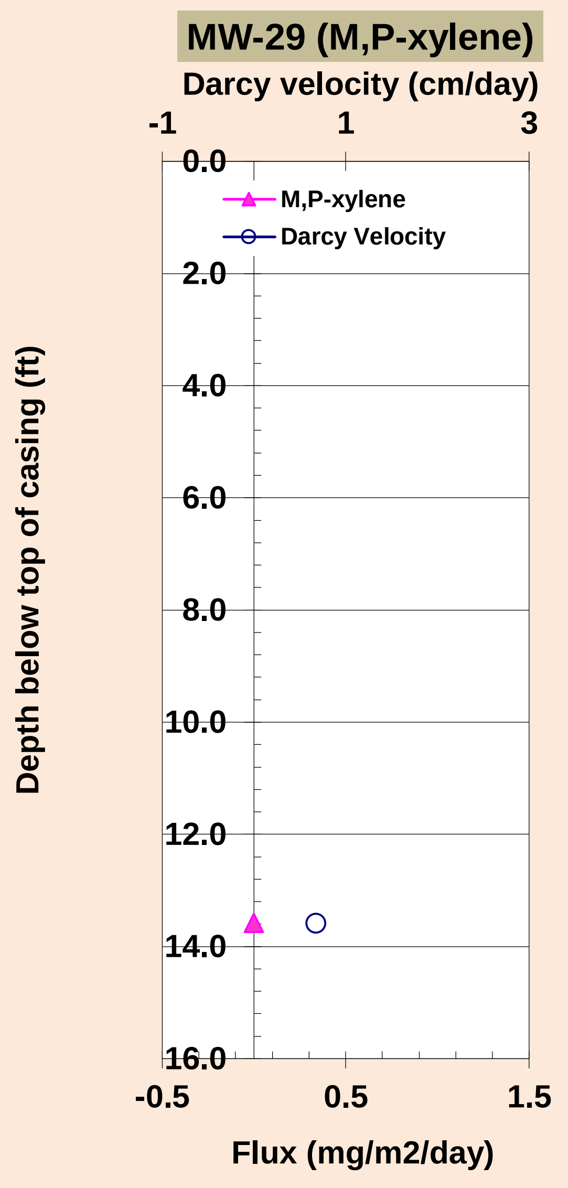
Well_ID	Sample_ID	Depth below top of well casing (ft)	Darcy Velocity (cm/day)	Benzene (ug/L)	Toluene (ug/L)	Ethylbenzene (ug/L)	M,P-xylene (ug/L)	O-xylene (ug/L)	TPH-g (mg/L)	TPH-d (mg/L)	Total Cyanide (mg/L)
MW-29	**PFM-1-1-1-092823**	10.4	-	-	-	-	-	-	Dry	Dry	-
	PFM-1-2-1-092823	11.3	Dry	Dry	Dry	Dry	Dry	Dry	-	-	-
	PFM-1-3-1-092823	12.1	-	-	-	-	-	-	-	-	Dry
	PFM-1-1-2-092823	12.8	-	-	-	-	-	-	ND	1.1	-
	PFM-1-2-2-092823	13.6	0.7	612	196	930	ND	83	-	-	-
	PFM-1-3-2-092823	14.4	-	-	-	-	-	-	-	-	2.0
MW-28	**PFM-2-1-1-092823**	10.4	-	-	-	-	-	-	Dry	Dry	-
	PFM-2-2-2-092823	11.3	Dry	Dry	Dry	Dry	Dry	Dry	-	-	-
	PFM-2-1-2-092823	12.1	-	-	-	-	-	-	-	-	Dry
	PFM-2-1-2-092823	12.6	-	-	-	-	-	-	0.01	1.8	-
	PFM-2-2-1-092823	13.4	2.0	5586	198	324	ND	92	-	-	-
	PFM-2-3-2-092823	14.3	-	-	-	-	-	-	-	-	ND

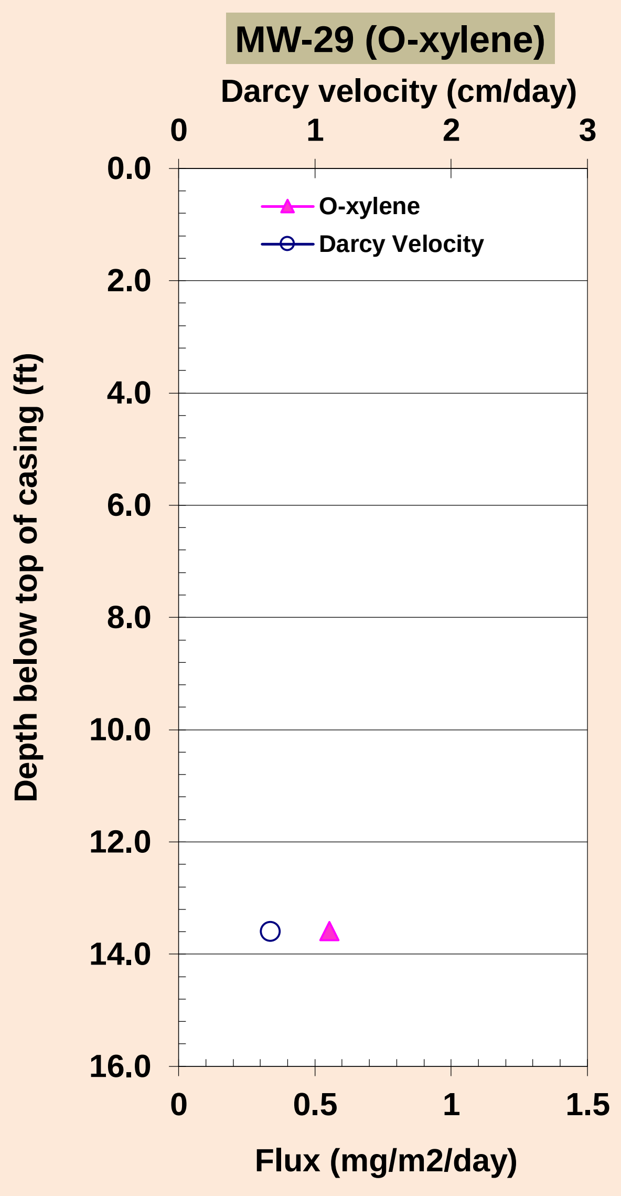
Landau	
Project name:	Former SSSMGP
Project Manager	Clint Jacob
Installation Date	9/7/2023
Sampling Date	9/28/2023
Reporting Date	10/27/2023

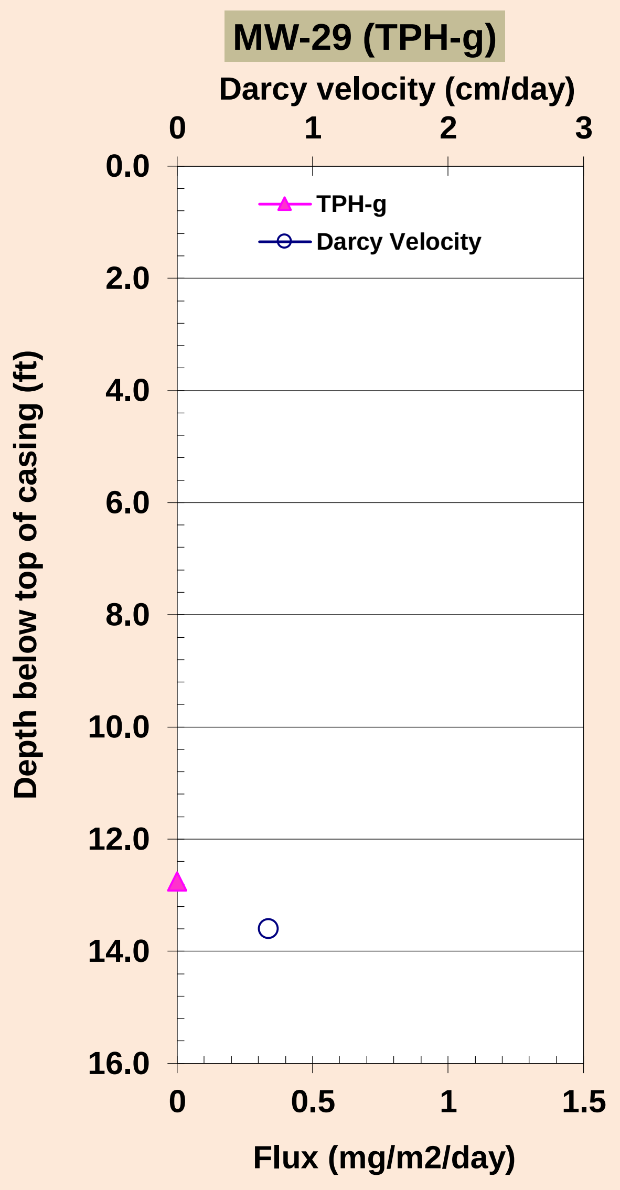


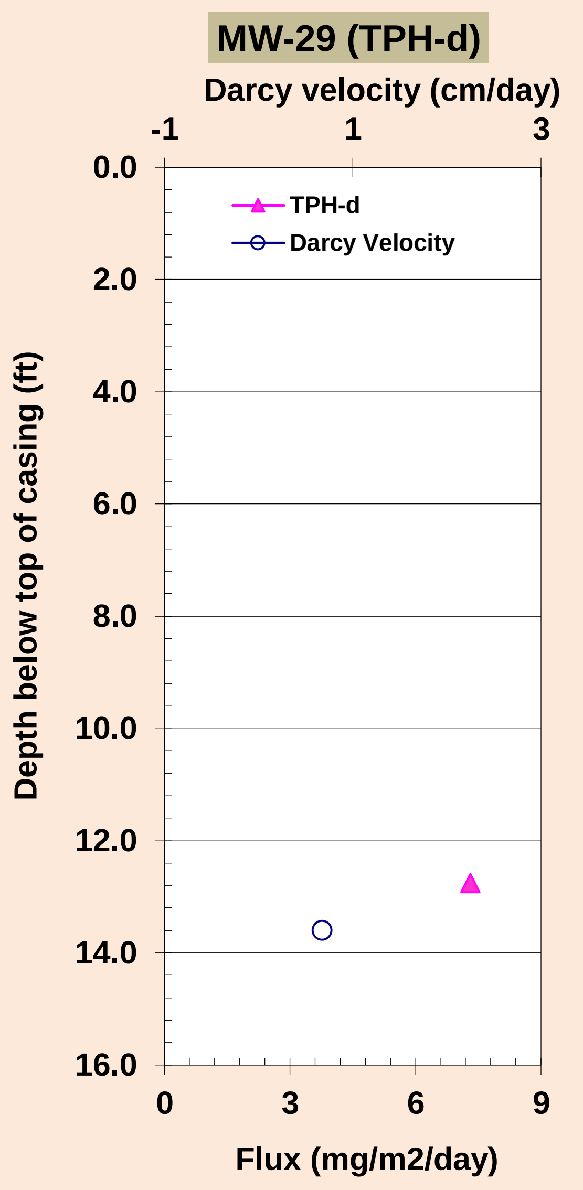


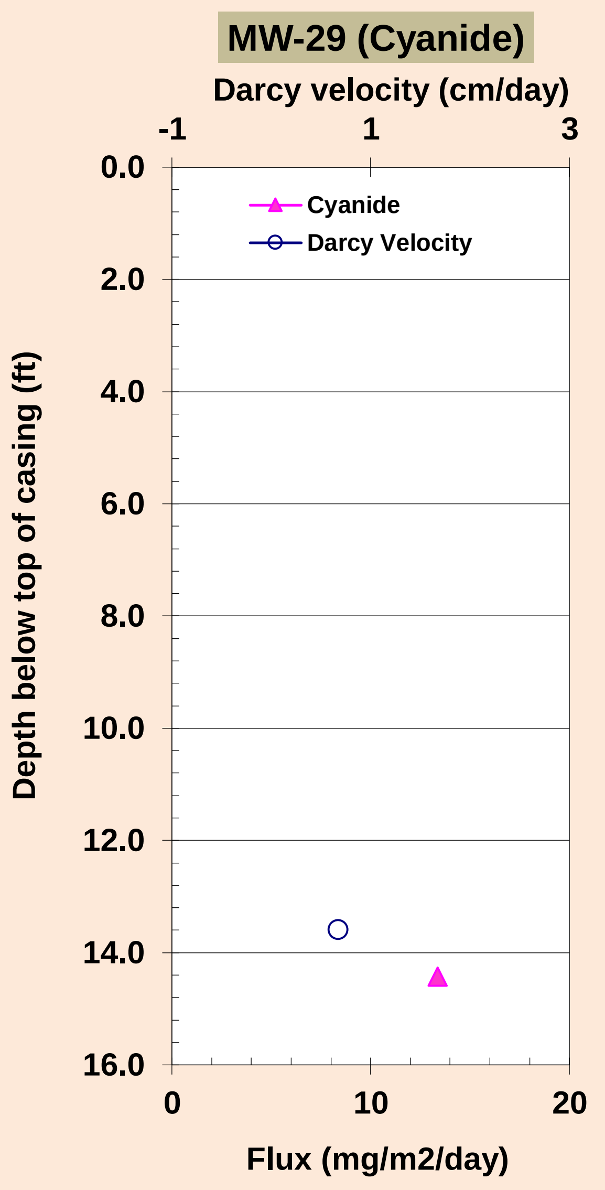


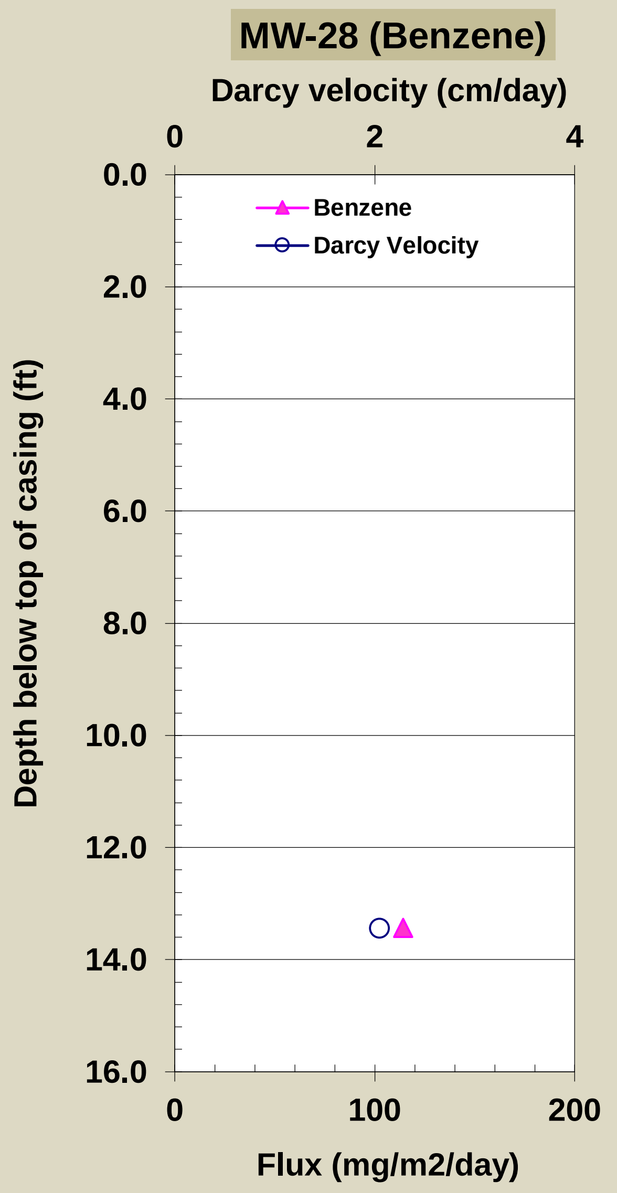


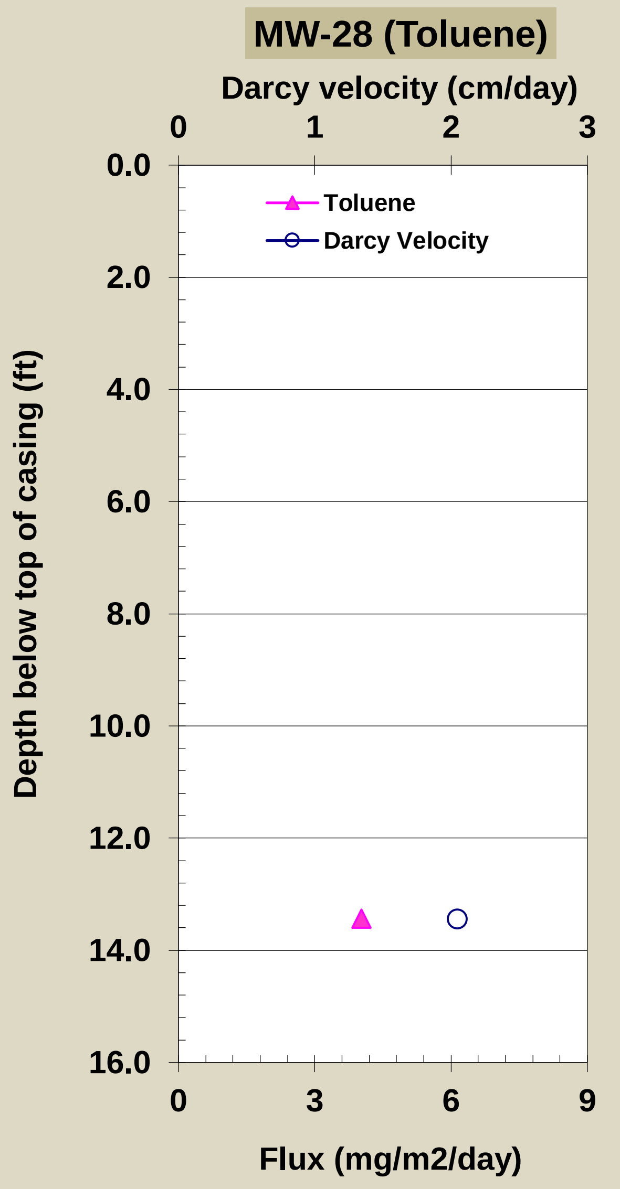


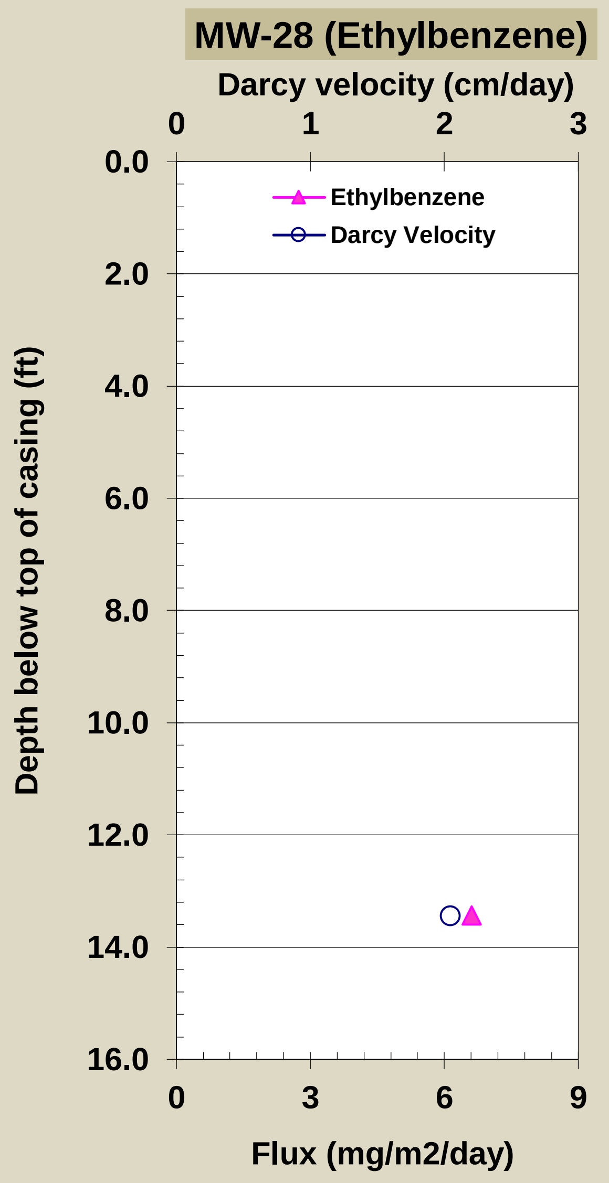


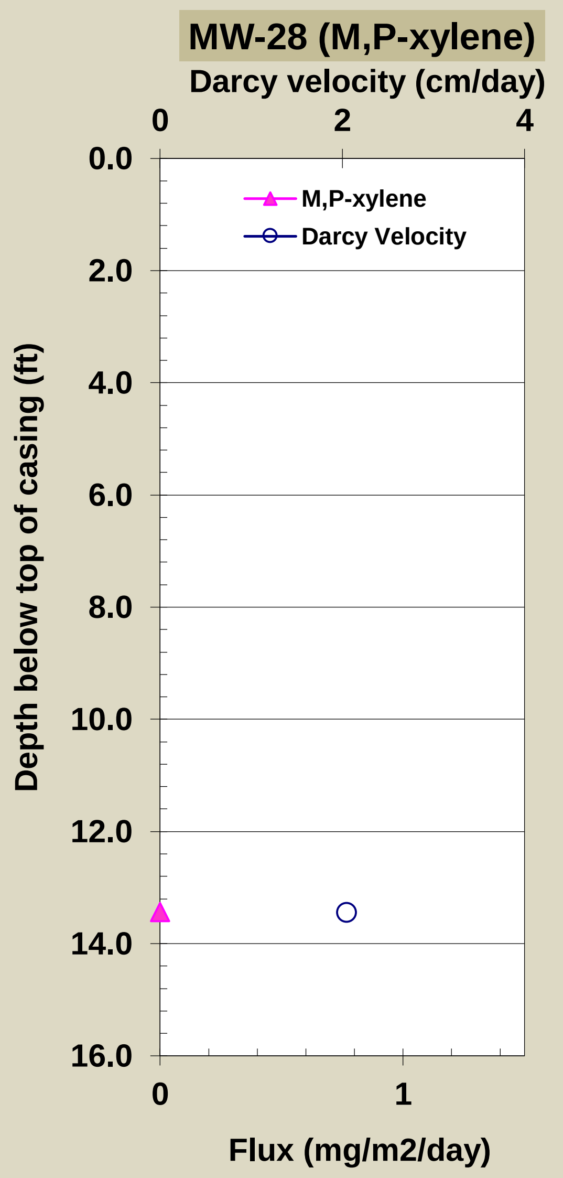


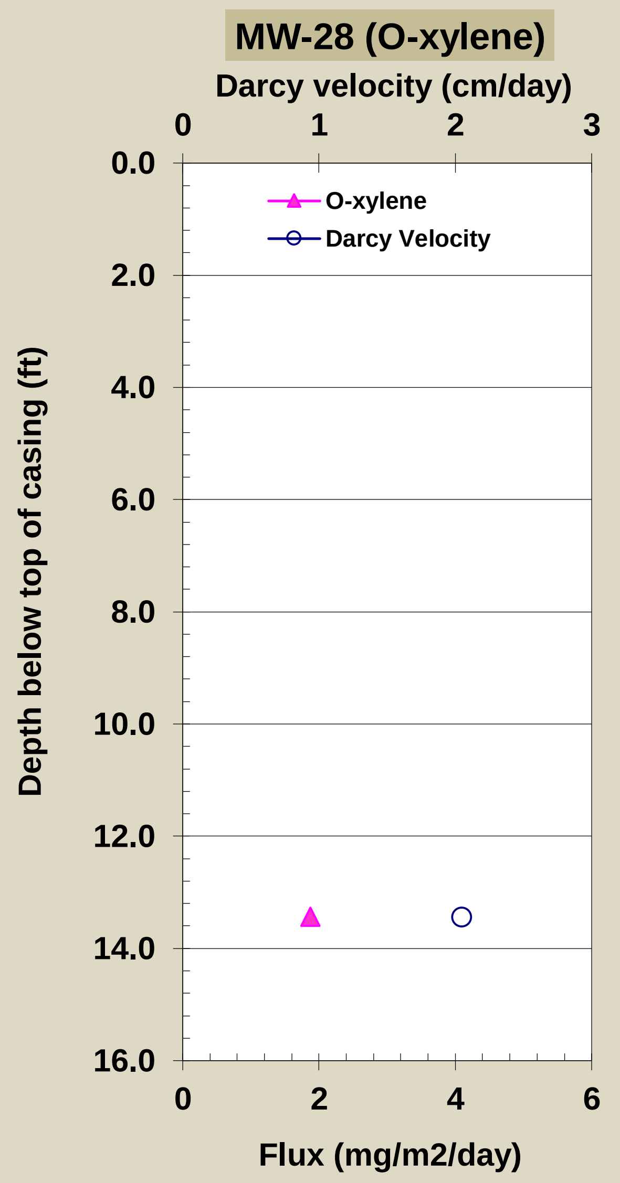


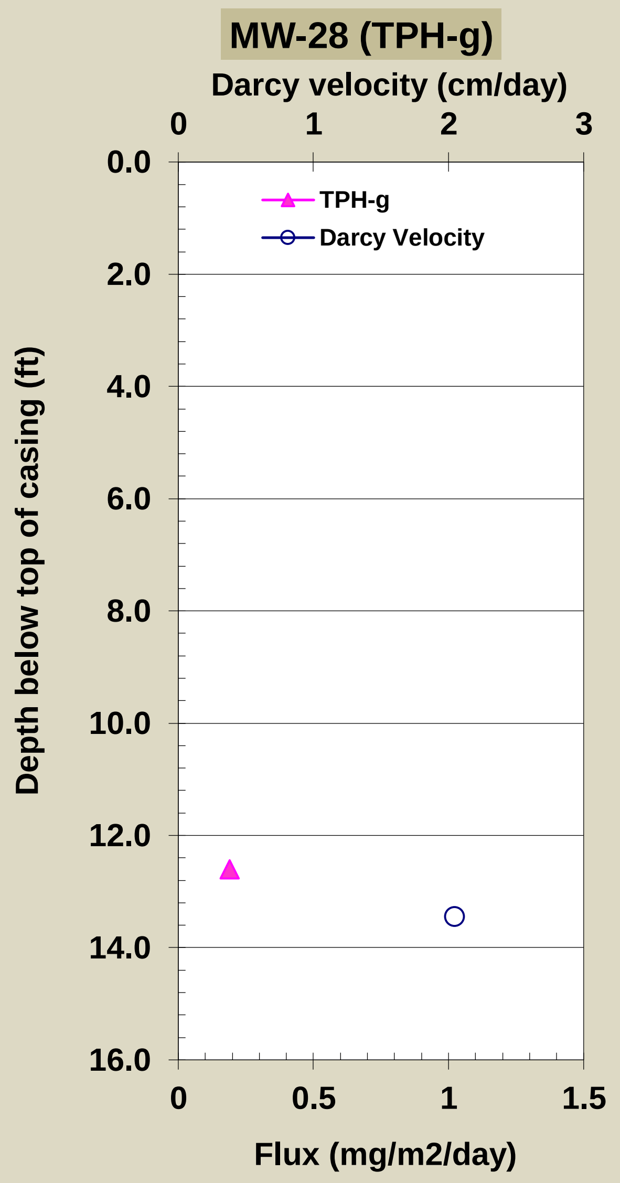


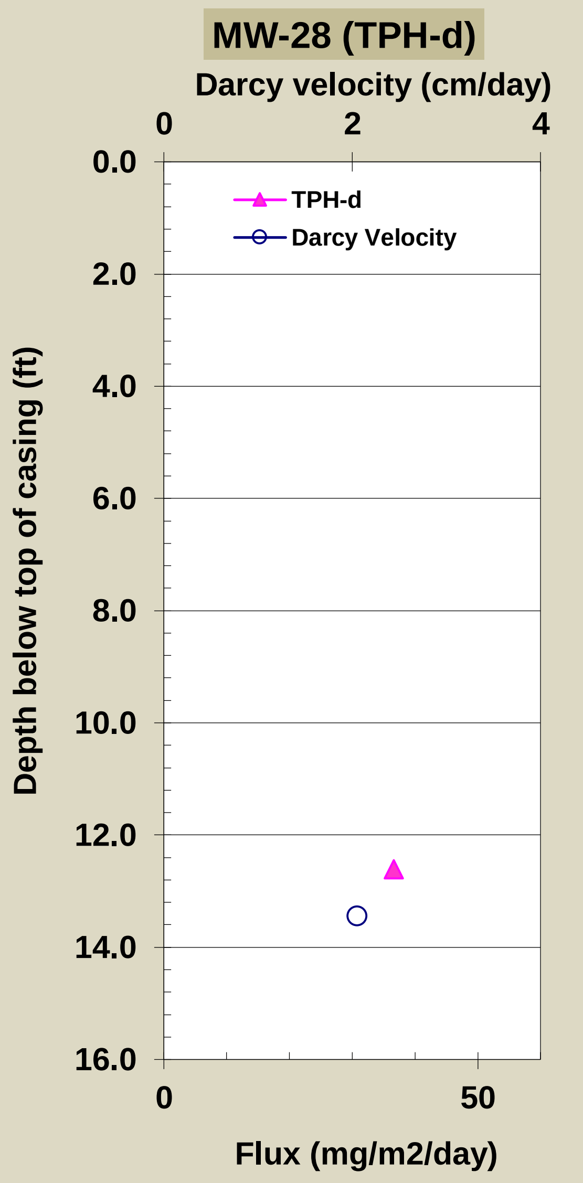


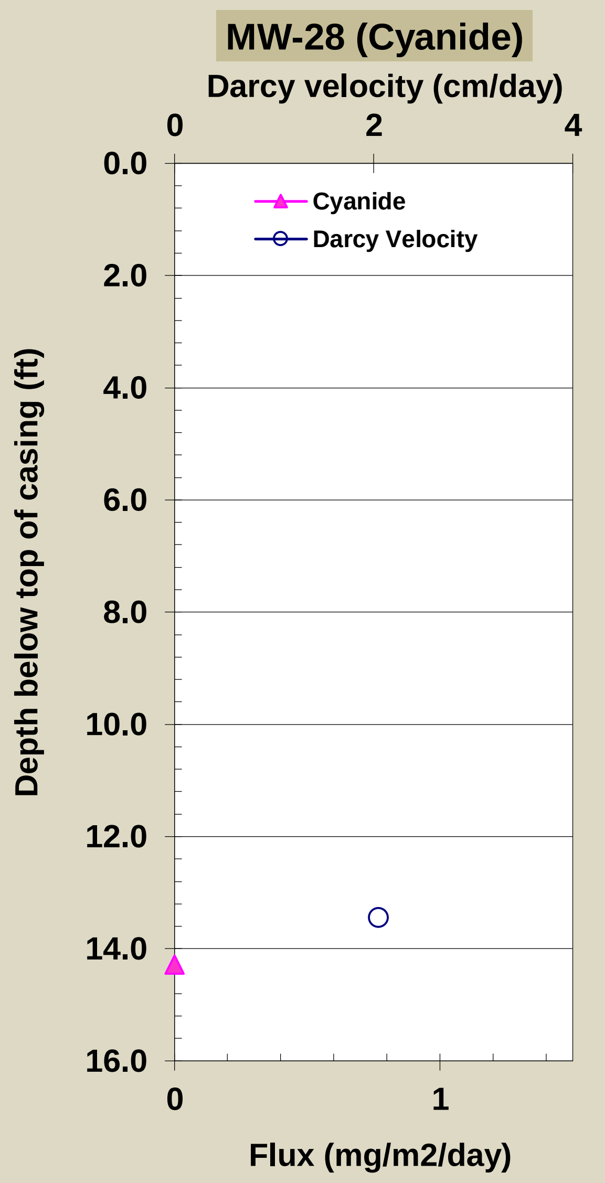












Landau	
Project name:	Former SSSMGP
Project Manager	Clint Jacob
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Table 3. Mass discharge per unit width for aquifer of each well

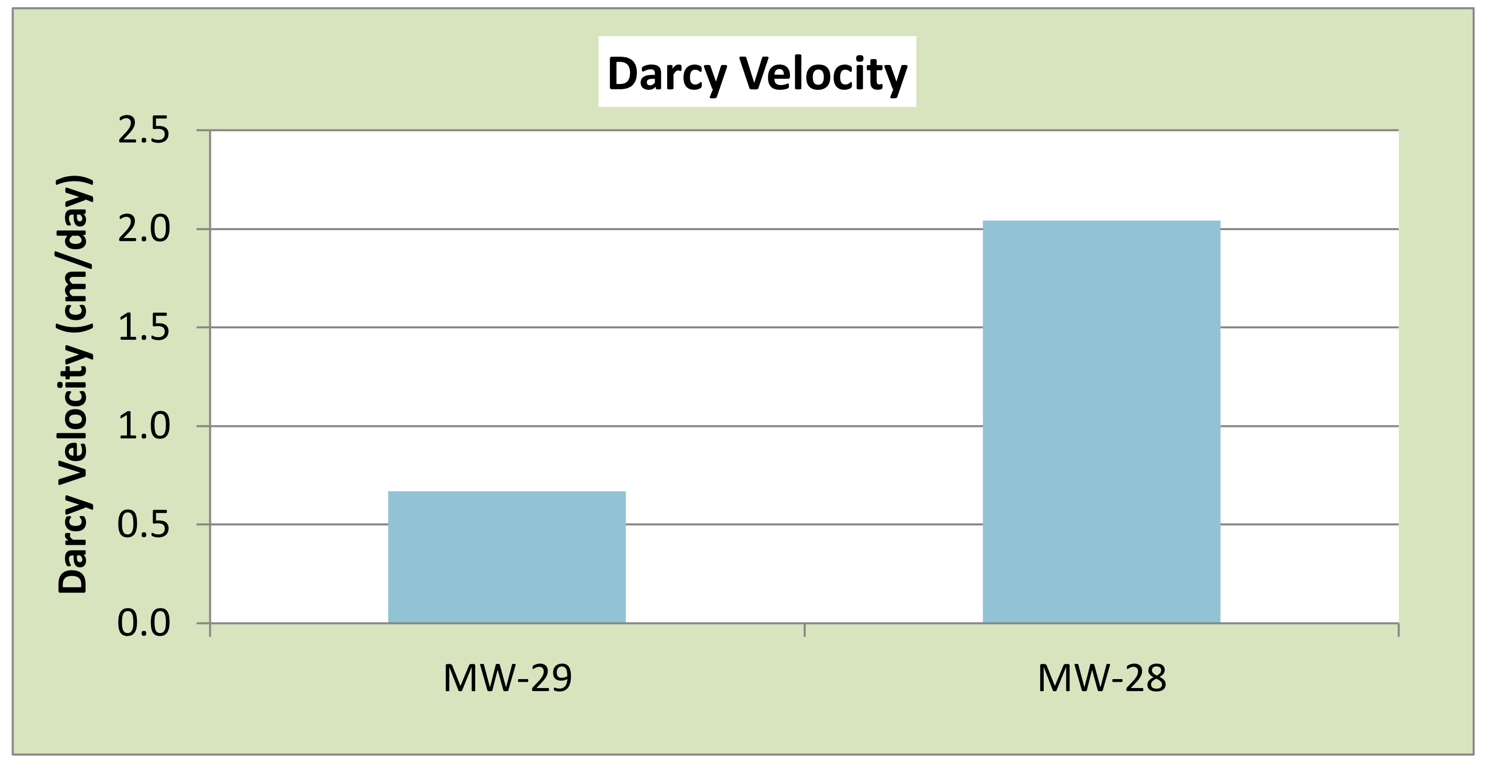
Well	Darcy Velocity (cm/day)	Benzene discharge (mg/m/day)	Toluene discharge (mg/m/day)	Ethylbenzene discharge (mg/m/day)	M,P-xylene discharge (mg/m/day)	O-xylene discharge (mg/m/day)	TPH-g discharge (mg/m/day)	TPH-d discharge (mg/m/day)	Cyanide discharge (mg/m/day)
MW-29	0.7	3.13	1.00	4.75	ND	0.42	0.06	5.57	10.2
MW-28	2.0	87.0	3.1	5.04	ND	1.43	0.14	27.9	ND

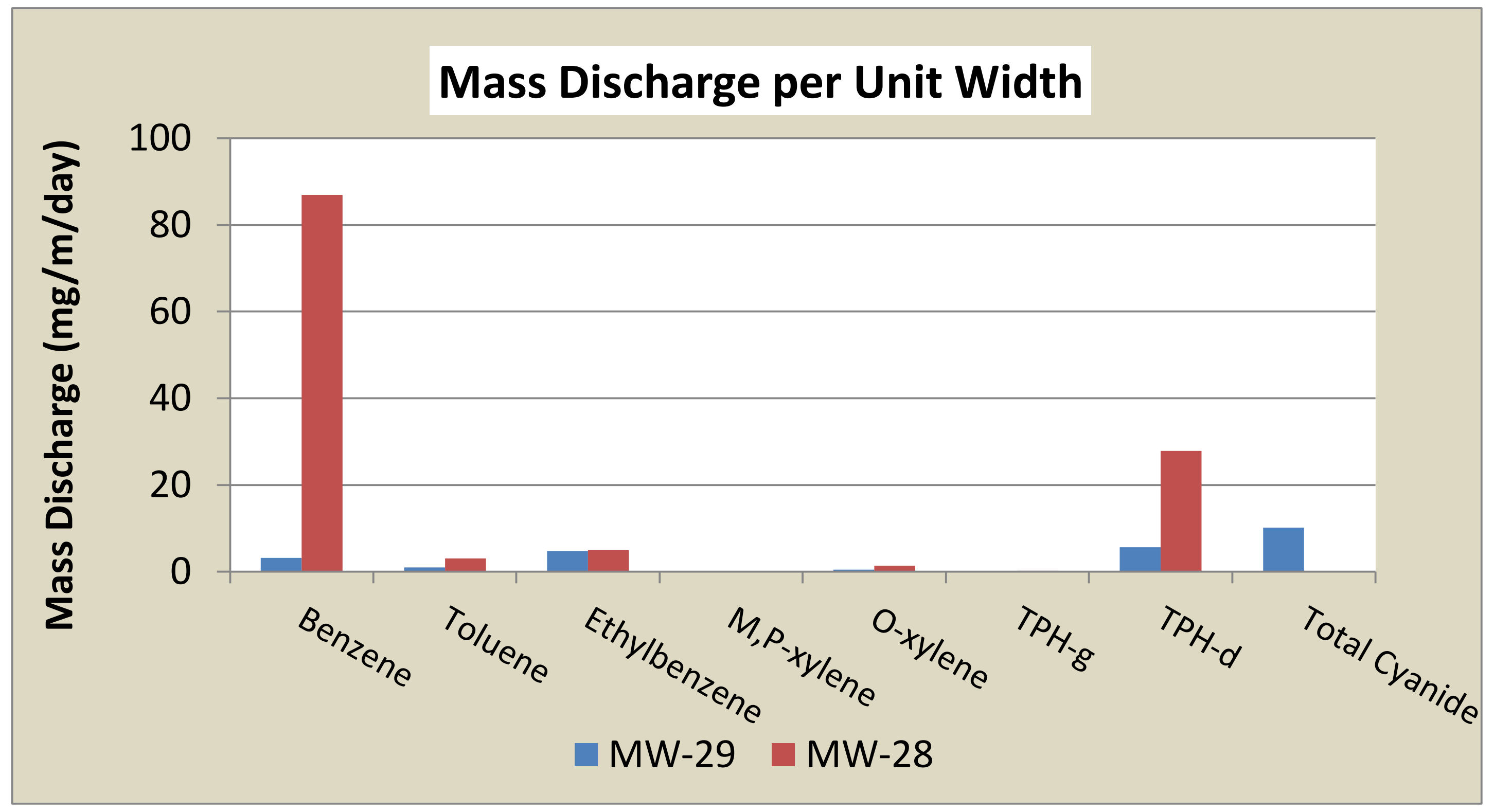
Table 4. Well average values of mass flux based on PFMs

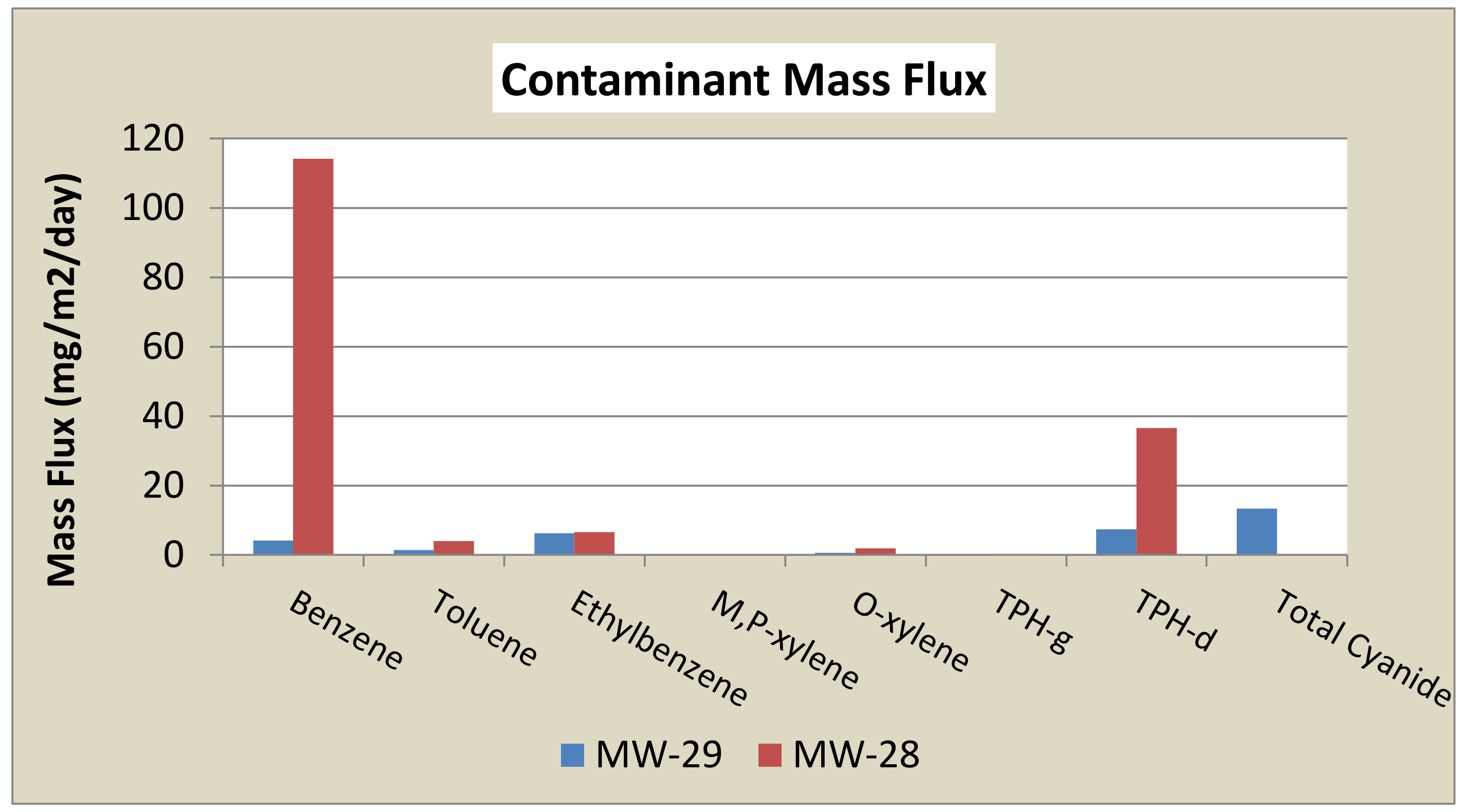
Well	Darcy Velocity (cm/day)	Benzene flux (mg/m^2/day)	Toluene flux (mg/m^2/day)	Ethylbenzene flux (mg/m^2/day)	M,P-xylene flux (mg/m^2/day)	O-xylene flux (mg/m^2/day)	TPH-g flux (mg/m^2/day)	TPH-d flux (mg/m^2/day)	Cyanide flux (mg/m^2/day)
MW-29	0.7	4.10	1.31	6.24	ND (<0.16)	0.55	0.07	7.31	13.4
MW-28	2.0	114.13	4.04	6.62	ND (<0.16)	1.87	0.19	36.6	ND (<2.9)

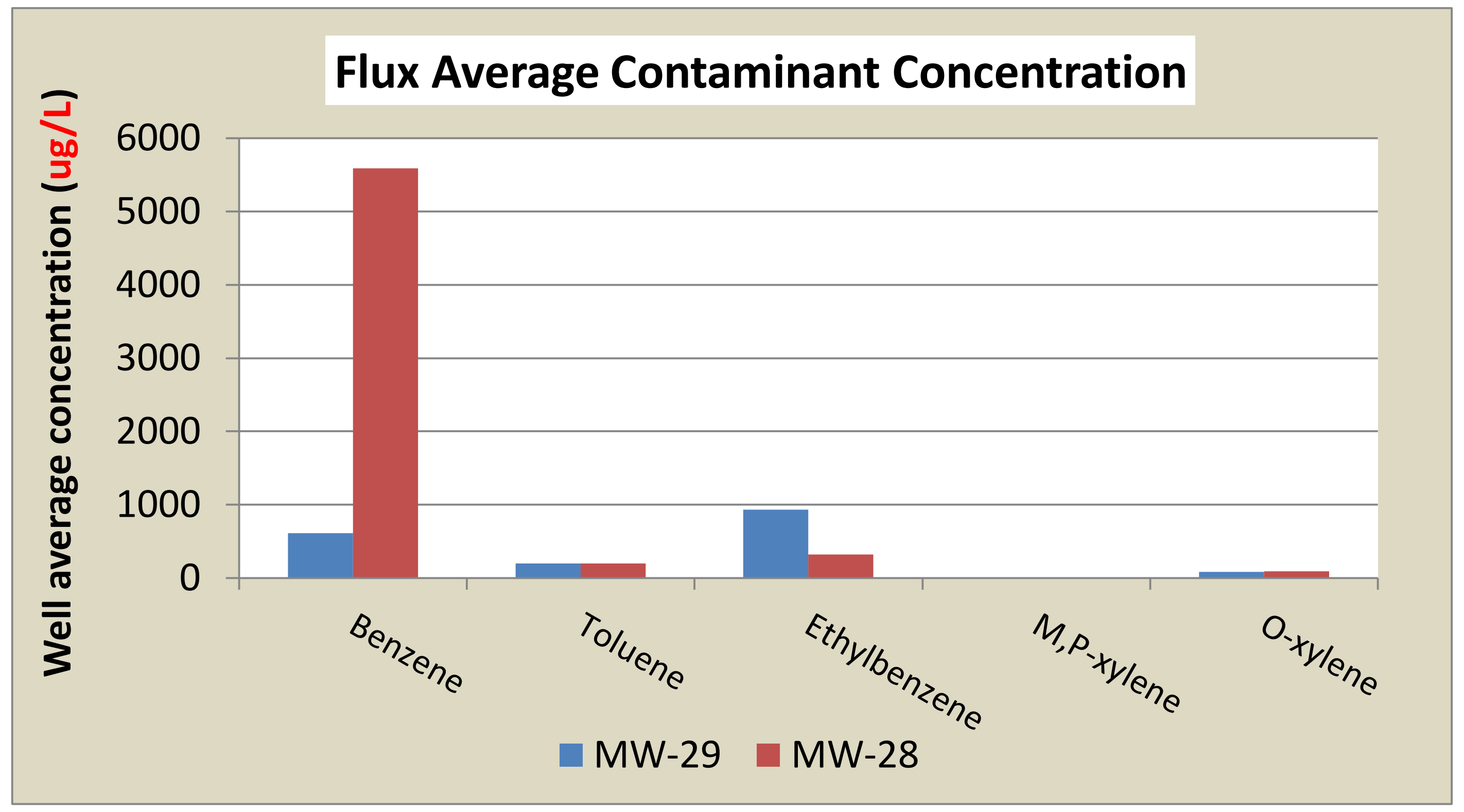
Table 5. Flux average contaminant concentration on PFMs

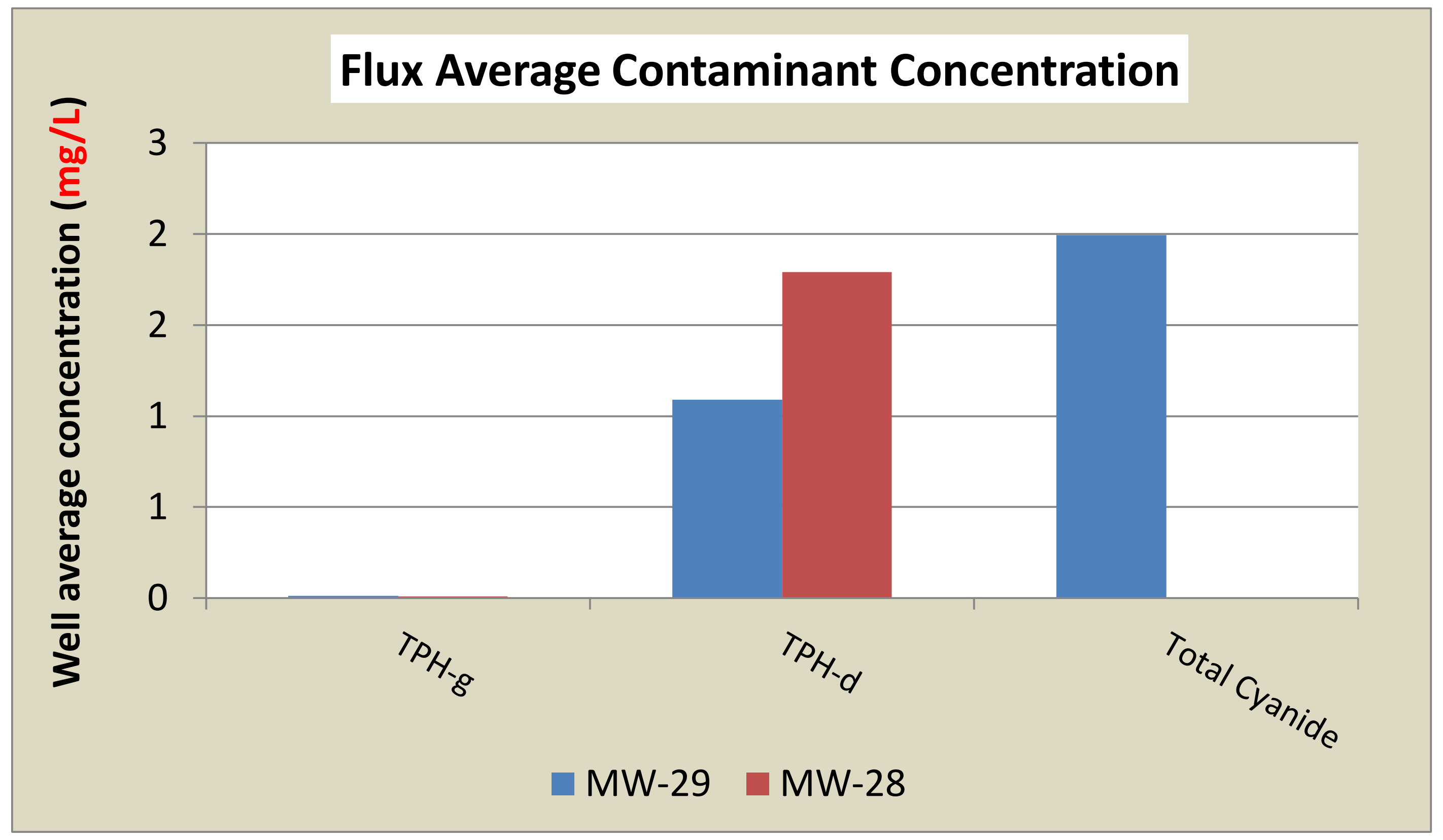
Well	Darcy Velocity (cm/day)	Benzene (ug/L)	Toluene (ug/L)	Ethylbenzene (ug/L)	M,P-xylene (ug/L)	O-xylene (ug/L)	TPH-g (mg/L)	TPH-d (mg/L)	Total Cyanide (mg/L)
MW-29	0.7	612	196	930	ND	83	0.01	1.1	2.0
MW-28	2.0	5586	198	324	ND	92	0.009	1.8	ND











Appendix D

Sediment Cap Performance Modeling

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List of Acronyms and Abbreviations

AC	activated carbon
CAP	Cleanup Action Plan
cPAH	Carcinogenic polyaromatic hydrocarbons
cm/yr	centimeters per year
EDR	Engineering Design Report
ENR	Enhanced Natural Recovery
EPA	United States Environmental Protection Agency
foc	fraction organic carbon
IHS	indicator hazardous substances
µg/L	micrograms per liter
Site	South State Street Site
TLC	thin-layer containment
USACE	United States Army Corps of Engineers

1.0 Introduction

This appendix summarizes sediment cap performance modeling completed to evaluate chemical isolation and containment as part of the sediment cap design for the marine unit of the South State Street Site (Site). The sediment cap model CapSim (Version 4.2) was used to evaluate the functionality of sediment cap amendment technologies for treatment of sediment contaminants that may migrate through a conventional sand cap over the lifespan of the cleanup action. As shown on Figure D-1, planned sediment cleanup actions for the marine unit include:

- Placing an amended sand cap in areas of mobile contaminants to enhance chemical containment;
- Placing a conventional sand cap in low-mobility areas of sediment contamination requiring capping;
- Placing erosion control and habitat substrate layers on the cap chemical containment layers, as needed to protect the cap and mitigate habitat impacts; and
- Enhanced Natural Recovery (ENR) in the northern end of the marine unit.

The sediment cap modeling described in this appendix was completed to support design of areas of amended sand capping. The Feasibility Study (FS) identified sediment cap alternatives meeting the cleanup action objectives for the marine unit that were further described in the FS (Landau and GeoEngineers, 2019), the Cleanup Action Plan (CAP; Washington State Department of Ecology 2020) and in Section 1.1 of the Engineering Design Report (EDR).

2.0 Cap Performance modeling Objectives

The objective of cap performance modeling is to identify sediment cap design parameters that remediate contaminants present in underlying sediment and associated porewater to the degree necessary to meet cleanup levels at the applicable points of compliance. During the FS, indicator hazardous substances (IHS) were evaluated to identify those contaminants in the porewater and sediment requiring the most robust cap design to achieve cleanup standards. Based on this analysis, benzene, cyanide, and naphthalene were identified as the key IHSs for cap modeling. Carcinogenic polyaromatic hydrocarbons (cPAHs) were identified as an IHS in the FS, as well. However, the cPAHs were not modeled for cap design as they are generally much less mobile than the modeled contaminants and are effectively addressed by the isolation function of the proposed caps.

Cap modeling was completed to verify that the key IHSs driving cap design, benzene, cyanide, and naphthalene, are physically and chemically isolated, thereby achieving sediment and porewater cleanup levels during a 100-year design life for the remedy. The ability of the cap profiles to meet cleanup levels over this time period was the guiding performance criterion for cap modeling. The sediment point of compliance for the cleanup action is discussed in Section 2.3 of the EDR text.

3.0 Modeling Approach

A one-dimensional transient model was used to evaluate contaminant transport within cap material under selected cap design scenarios. Analyses were performed using the transient numerical modeling program CapSim© (Version 4.2) developed by Dr. Danny Reible and associates (Texas Tech University, 2023). The

CapSim program is a well-accepted model that is commonly used to evaluate the contaminant isolation capability of sediment caps. Application of the CapSim model also addresses cap design considerations for chemical containment described in the U.S. Environmental Protection Agency (EPA) and U.S. Army Corps of Engineers (USACE) guidance for contaminated sediment capping (Palermo et al. 1998).

The modeling was completed to support design of the cap over a portion of the intertidal area of the South State Street marine unit, where contaminant concentrations and predicted groundwater discharge rates are expected to result in cleanup level exceedances under a conventional cap design using clean sand. Benzene and cyanide were considered to require the most robust cap design because of their prevalence, relative mobility, and low cleanup levels in the aqueous phase. The approach for modeling included completing iterative modeling runs to support development of a single cap design (thickness and amendment application) that achieves cleanup goals for the modeled contaminants. The modeled cap amendment in the chemical isolation layer included activated carbon (AC). The modeling results indicated that using AC as a cap amendment provides adequate treatment of all modeled contaminants so modeling additional cap amendments was determined to be unnecessary.

The modeling approach considered the conservative scenario that cleanup levels must be met within the chemical isolation layer using the attenuation provided solely by the amendment included in the cap material. In the modeled capping zone additional erosion protection material will be placed above the chemical isolation layer. This results in the top of the chemical isolation layer being a significant distance below the point of compliance based on the biologically active zone. The model was set up to include this erosion protection layer, but because this additional material is typically clean sand or rock, with little capacity for chemical attenuation, this modeling exercise used the top of the chemical containment layer as a surrogate point of compliance when evaluating cap performance.

4.0 Model Inputs

4.1 POREWATER CONCENTRATIONS

The CapSim cap model relies on user-input values for dissolved-phase contaminant concentrations in porewater entering the cap. Chemical analytical data from the Pre-Remedial Design Investigation (PRDI) (GeoEngineers, 2023) was the source of the porewater concentrations used in the CapSim model. Conservative concentrations of benzene, cyanide, and naphthalene were selected from the data set and were used as input values in CapSim. These modeled concentrations as well as other model inputs are included in Table D-1. The following porewater concentrations were used for modeling:

- Benzene: 6.07 µg/L (PRDI porewater sample location PRDI-2C)
- Cyanide: 15.0 µg/L (PRDI porewater sample location PRDI-4)
- Naphthalene: 3.87 µg/L (PRDI porewater sample location PRDI-2C)

The primary drivers of cap design are benzene and cyanide because of their low cleanup levels (1.6 µg/L and 5 µg/L, respectively). The naphthalene porewater concentration above is less than the naphthalene groundwater cleanup level of 83 µg/L. For modeling purposes, concentrations of constituents in porewater entering the cap from below were conservatively assumed to remain fixed over the 100-year design life that was modeled. This assumption simulates an infinite source of contamination to the overlying sediment cap.

4.2 BOUNDARY AND INITIAL CONDITIONS

Boundary conditions represent conditions above and below the sediment cap that affect the model calculations. The primary boundary condition above the cap surface is the ambient concentrations of the IHSs in surface water above the cap. The surface water concentrations are assumed to be zero for the IHSs immediately above the cap as a result of the cap itself isolating contaminants from direct contact with surface water, the inclusion of an armor layer above the chemical isolation layer of the cap, and the mixing occurring in the tidally influenced environment of the amended cap zones.

The boundary conditions below the cap are the primary conditions affecting cap performance and consist of the following:

- Groundwater (Darcy) velocity discharging across the existing mudline that would be entering the bottom of the cap following placement of cap materials; and
- Contaminant concentration in porewater in existing sediments below the cap representing the contaminant concentrations in water passing through the cap material.

The Darcy velocity, the rate of groundwater entering the pores in the cap, was determined using the groundwater flow measurements performed by Landau using passive flux meters (PFMs) at MW-28 and MW-29. The PFMs were installed during the PRDI, and details of which are summarized in Appendix C of the EDR.

Porewater concentrations of modeled contaminants were based upon porewater samples obtained during the PRDI. Porewater concentrations below the cap were conservatively assumed to remain constant throughout the duration of the cap model simulation. While contaminant transport by advection is considered the driver for cap design, the CapSim model allows for consideration of contaminant diffusion. Contaminant diffusion was calculated from the sediment porewater concentration, the contaminant-specific molecular diffusivity in water and the hydrodynamic dispersivity of the cap material (parameter values are noted in Table D-1).

4.3 CAP MATERIAL PROPERTIES

Cap materials proposed for marine capping at the South State Street Site consist primarily of clean sand from local upland sources for the chemical isolation layer, overlain by larger materials ranging from gravel to rock to provide erosion protection for the chemical isolation layer. The modeled cap design included both the chemical isolation layer and the erosion protection layer. These materials are typically free of organics and provide low capacity for attenuation of mobile contaminants. The use of amendments in the chemical isolation layer was added for the necessary adsorption and consequent treatment of the IHSs in the chemical isolation layer. Activated carbon was evaluated as the cap amendment in the cap modeling for all three IHSs: benzene, cyanide, and naphthalene.

Material properties for the cap materials were selected based on general properties that are default in the CapSim model, as shown in Table D-1. The amended cap material properties were calculated to be a combination of the material and the amount of these materials present in the amended cap. The key input parameters for cap material properties are those affecting contaminant sorption, such as fraction of organic carbon, bulk density, and porosity. Where available, partitioning coefficients based on empirical contaminant-material equilibrium behavior (i.e., cyanide/organic carbon partitioning) were used in lieu of the standard K_{oc}*f_{oc} method to calculate equilibrium solid-water concentrations. The cap model accounts for incremental adsorption capacity needed in locations where contaminants are comingled. The fraction of organic carbon (f_{oc}) used in the model is the standard value for each cap material.

4.4 CHEMICAL PROPERTIES

The key chemical input parameters are soil-water equilibrium adsorption coefficients (K_d, K_{oc} and K_f), which are generally dependent on the amount of organic carbon found in the sediment. The equilibrium parameters characterize the degree to which the contaminants adsorb to respective cap materials, and thus the rate at which they move through the cap material.

Cyanide adsorption onto clean sand is characterized by the sorption coefficient K_d, which is specific for this contaminant-adsorbant combination. The K_d value used for the cyanide-sand combination was provided in the Texas Commission on Environmental Quality (TCEQ) chemical database, which is a primary source of reviewed and validated data utilized by the CapSim model. The cyanide-AC adsorption is the dominant attenuation process despite the small fraction of AC in the cap relative to sand. The cyanide sorption onto AC is modeled using the Freundlich isotherm and the Freundlich sorption parameter, K_f. The empirical parameter used for this behavior of cyanide sorbing onto activated carbon is sourced from an academic research journal (Behnamfard and Salarirad, 2009). The sorption parameters (K_f and K_{oc}) for benzene and naphthalene onto sand and activated carbon are also sourced from the TCEQ database of chemical information. All contaminant-specific input parameters used in the model are listed in Table D-1.

4.5 INPUT PARAMETER SUMMARY

Table D-1 summarizes the input parameters used for the CapSim model and the basis for the input values. Input parameters are presented including chemical inputs and capping materials with amendments and other properties for containing contaminants over the 100-year design life. Input parameters were derived from previous site sampling and testing data, literature review, and communication with subject-matter experts, including Dr. Danny Reible, the CapSim model developer.

5.0 Model Results

Sediment cap modeling using CapSim was completed for the marine unit using the input values described above. CapSim model output values include porewater and solid concentration data along a one-dimensional (vertical) profile through the sediment cap for the selected design period. Selected cap profiles and model results are explained below and presented in Tables D-2 and D-3.

Figures D-2 through D-6 present CapSim model output graphs of benzene, cyanide, and naphthalene porewater versus depth within the cap profile. Concentrations in solids (sediment cap material) are shown in Figure D-5 through D-7 for benzene, cyanide, and naphthalene. The output graphs illustrate the respective contaminant concentrations within the different cap profiles at 20-year increments over the modeled 100-year design lifespan. The modeling results indicate that cleanup levels for benzene, cyanide, and naphthalene are expected to be achieved over a 100-year period at depths within the caps below their respective points of compliance.

The key input parameters and modeling-derived cap profiles that were determined by the cap modeling to achieve cleanup levels within the chemical isolation layer are summarized below:

- Groundwater flux was estimated to be approximately 750 centimeters per year (cm/yr). This flux was calculated as an average of the entry and exit groundwater flux rates measured in Benchtop study (Landau, 2023).
- The input porewater concentrations for benzene, cyanide, and naphthalene were 6.07 µg/L, 5 µg/L, and 3.87 µg/L, respectively. These values were selected as conservative porewater concentrations from the PRDI data set.
- Cap modeling results indicated that amendments would be needed to meet cleanup levels in intertidal areas of the marine unit where porewater concentrations exceed cleanup levels. Modeling showed that AC effectively attenuates all three IHSs, benzene, cyanide, and naphthalene, within the chemical isolation layer over a 100-year design life modeled.
- Contaminant containment can be achieved by capping the areas using a 1-foot amended sand chemical containment horizon. The amended cap would utilize 1 percent (by weight) AC mixed into the clean sand cap material.

6.0 Sensitivity Analysis for cPAHs

As previously described, the key contaminants used to evaluate cap performance were benzene, cyanide, and naphthalene because of their prevalence, low cleanup levels, and mobility. However, a sensitivity analysis was performed to confirm that the proposed cap profiles will also contain cPAHs present in sediment and porewater.

The CapSim model was run using a conservative input benzo(a)pyrene porewater concentration, the highest groundwater flux conditions, and the cap amendment condition (1-foot of AC-amended sand, 1 foot of clean sand, and 2 feet of erosion protection material). Benzo(a)pyrene was used as a surrogate for cPAH TEQ because benzo(a)pyrene is the most toxic cPAH and is the basis for the cPAH TEQ calculation. Input parameters used for sediment and porewater conditions are as described in Table D-1 and cap materials are as presented in Table D-2. The model input parameters and results specific to benzo(a)pyrene are presented in Table D-3.

The model run used the highest cPAH TEQ concentration observed in upland groundwater as a worst-case scenario to confirm the cap performance for cPAHs. As presented in Table D-3, the results of the conservative model run for benzo(a)pyrene indicates that benzo(a)pyrene attenuates very quickly within the 1-percent AC amended sand cap and after 100 years, the concentrations of benzo(a)pyrene in sediment exceeding cleanup levels would migrate only 7 cm into the cap material. Based on this result for the most conservative scenario, further cap modeling for cPAHs was not conducted.

7.0 Sediment Cap Design

The sediment cap for the marine unit of the Site will consist of three layers (listed from bottom to top): 1 foot of AC-amended sand, 1 foot of clean sand, and approximately 2 feet of erosion protection material (erosion protection material is variable based on coastal engineering described in Appendix E of the EDR). The amended sand portion of the cap consists of clean sand mixed with 1% activated carbon by weight.

The AC-amended sand portion of the cap will be placed on the existing sediment surface to contain dissolved benzene, cyanide, and naphthalene within the chemical isolation layer and prevent porewater at the biologically active zone of the cap from exceeding the Site's cleanup levels.

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Appendix D Tables

TABLE D-1. INPUT PARAMETER SUMMARY FOR CAP MODELING

MODEL INPUT PARAMETERS		UNIT	INTERTIDAL ZONE	DATA SOURCE/RATIONALE
			VALUE	
Mass Transport Properties				
Groundwater Darcy velocity		cm/yr	750	Approximate average value of LAIs darcy velocity data from EnviroFlux PFM study (MW-29 and MW-28 top and bottom intervals each)[1]
Depositional velocity		cm/yr	0	Assumed no net sedimentation in intertidal zone.
Boundary layer mass transfer coefficient		cm/hr	2.37	Conservative assumption consistent with CapSim Manual guidance.
Chemical Properties				
Diffusivity in water	Cyanide	cm^2/s	2.28e-5	LookChem/TCEQ/F300 from CapSim standard database (benzene, naphthalene, and benzo(a)pyrene).[2] TCEQ (cyanide).[3]
	Benzene	cm^2/s	8e-6	
	Naphthalene	cm^2/s	7.5e-6	
	Benzo(a)pyrene	cm^2/s	9e-6	
Organic Carbon Sorption Isotherm	Cyanide (K_d)	L/kg	39.8	
	Benzene (K_{oc})	Log(L/kg)	1.15	
	Naphthalene (K_{oc})	Log(L/kg)	3.19	
	Benzo(a)pyrene (K_{oc})	Log(L/kg)	5.98	
Sediment Screening Level (cap material)	Cyanide	µg/kg (dw)	420,000	Direct contact (cyanide and benzene) and benthic (naphthalene) screening levels for sediment at the Site. The benzo(a)pyrene sediment screening level is the bioaccumulation sediment cleanup level for cPAH TEQ. In the area of the amended capping, the point of compliance for cyanide, benzene, and benzo(a)pyrene is 45 cm below the top of the final cap surface
	Benzene	µg/kg (dw)	41,000	
	Naphthalene	µg/kg (dw)	2,100	

MODEL INPUT PARAMETERS		UNIT	INTERTIDAL ZONE	DATA SOURCE/RATIONALE
			VALUE	
	Benzo(a)pyrene	µg/kg (dw)	229	and the point of compliance for naphthalene is 12 cm below the top of the final cap surface.
Surface Water Cleanup Level	Cyanide	µg/L	5	Cleanup levels for porewater at the Site. The conditional point of compliance is 12 cm below the top of the final cap surface in the zone of the amended capping.
	Benzene	µg/L	1.6	
	Naphthalene	µg/L	83	
	Benzo(a)pyrene	µg/L	0.1	
Source Properties				
Sediment fraction organic carbon (f_{oc})		--	0.001	Conservative assumption based on material properties.
Underlying porewater concentration	Cyanide	µg/L	15	Based on site porewater data from PRDI-2C for benzene and naphthalene and PRDI-4 for WAD cyanide.
	Benzene	µg/L	6.07	
	Naphthalene	µg/L	3.87	
	Benzo(a)pyrene	µg/L	0.48	Based on the highest cPAH TEQ concentration in upland groundwater.
Cap Material/Placement Properties				
Maximum consolidation depth		cm	NA	Not modeling consolidation.
Time to 90% consolidation		Yr	NA	
Cap thickness excluding erosion protection layer		ft	2	Cap thickness based on physical/chemical containment properties, constructability, and bathymetry considerations.
Bioturbation zone thickness		cm	NA	Not modeling bioturbation.
Depositional velocity		cm/yr	0	Conservative assumption of no net sedimentation.
Porosity		--	0.4 (sand), 0.6 (AC)	CapSim standard values. [2]
f_{oc} of sand before amending		--	0.001	
Bulk density		g/cm^3	1.25 (sand), 0.4 (AC)	
Chemical Isolation Sorption Isotherm		--	Linear KocFoc (sand), Freundlich (AC)	Standard practice.

MODEL INPUT PARAMETERS		UNIT	INTERTIDAL ZONE	DATA SOURCE/RATIONALE
			VALUE	
Activated Carbon Isotherm	K_F (Freundlich)	μg/kg/ (μg/L)^N	7.25 x 10^6 (Naphthalene) 1.26 x 10^6 (Benzene) 3.14 x 10^6 (Cyanide) 1.61 x 10^6 (Benzo(a)pyrene)	CapSim standard values for benzene naphthalene, and benzo(a)pyrene. [2] Behnamfard and Salarirad, 2009 for cyanide.[4]
	N (Freundlich)	--	0.42 (Naphthalene) 0.533 (Benzene) 0.401 (Cyanide) 0.44 (Benzo(a)pyrene)	CapSim standard values for benzene naphthalene, and benzo(a)pyrene.[2] Behnamfard and Salarirad, 2009 for cyanide. [4]

Notes:

[1] Additional information regarding the EnviroFlux Passive Flux Meters (PFM) study is available in the Landau Associates, Inc. report found in Appendix C of the South State Street Engineering Design Report.

[2] Citation: Texas Tech University – Reible Research Group, 2023. CapSim v. 4.2. Accessed online at: https://www.depts.ttu.edu/ceweb/research/reiblesgroup/capsim.php.

[3] Citation: Texas Commission on Environmental Quality, 2023. May 2023 Tier 1 Soil and Groundwater PCL Tables. https://www.tceq.texas.gov/remediation/trrp/trrppcls.html

[4] Citation: Behnamfard and Salarirad, 2009. Equilibrium and kinetic studies on free cyanide adsorption from aqueous solution by activated carbon. Journal of Hazardous Materials Vol 170 (2009) p. 127-133.

μg/L = micrograms per liter
μg/kg = micrograms per kilogram
mg/kg = milligrams per kilogram
AC = activated carbon
cm = centimeters
CAP = cleanup action plan
CUL = cleanup level
ft= feet
f_{oc} = fraction organic carbon
FS = feasibility study
g/cm^3 = grams per cubic centimeter
L/kg = liters per kilogram
LAI = Landau Associates, Inc.
Kf = Freundlich equation constant
K_d = solid-water distribution coefficient
K_{oc} = dissolved organic carbon partitioning coefficient
K_{ow} = octanol-water partitioning coefficient
N=1/n= Freundlich equation constant
NA = not applicable
OC = organic carbon
PRDI = pre-remedial design investigation
RI = remedial investigation
SSI = supplemental sediment investigation
TCEQ = Texas Commission on Environmental Quality
yr = year

TABLE D-2. MODELED CAP PROFILE

AREA	MODELED CAP PROFILE[1]	
	CHEMICAL CONTAINMENT LAYER(S)	EROSION PROTECTION LAYER(S)
Intertidal Zone	1 foot (30.48 cm) Sand (above amendment) 1 foot (30.48 cm) Sand Amended with 1% AC	2 foot (60.96 cm) Armor Rock

Notes:

[1] Amendment percentages by weight.

AC = activated carbon

TABLE D-3. CAPSIM MODEL RESULTS

MODELED COC	CLEANUP LEVEL AND POINT OF COMPLIANCE			DEPTH TO WHICH IHS CONCENTRATIONS ARE LESS THAN CLEANUP LEVELS AFTER 100 YEARS[1]
	CONCENTRATION	MEDIUM	POC	INTERTIDAL ZONE
Benzene	1.6 µg/L	Porewater	12 cm	103 cm
	30 µg/kg	Sediment	45 cm	94 cm
Cyanide	5 µg/L	Porewater	12 cm	106 cm
	-	Sediment	-	-
Naphthalene	83 µg/L	Porewater	12 cm	120 cm
	5,000 µg/kg	Sediment	45 cm	112 cm
cPAH TEQ[2]	0.02 µg/L	Porewater	12 cm	113 cm
	229 µg/kg	Sediment	45 cm	111 cm

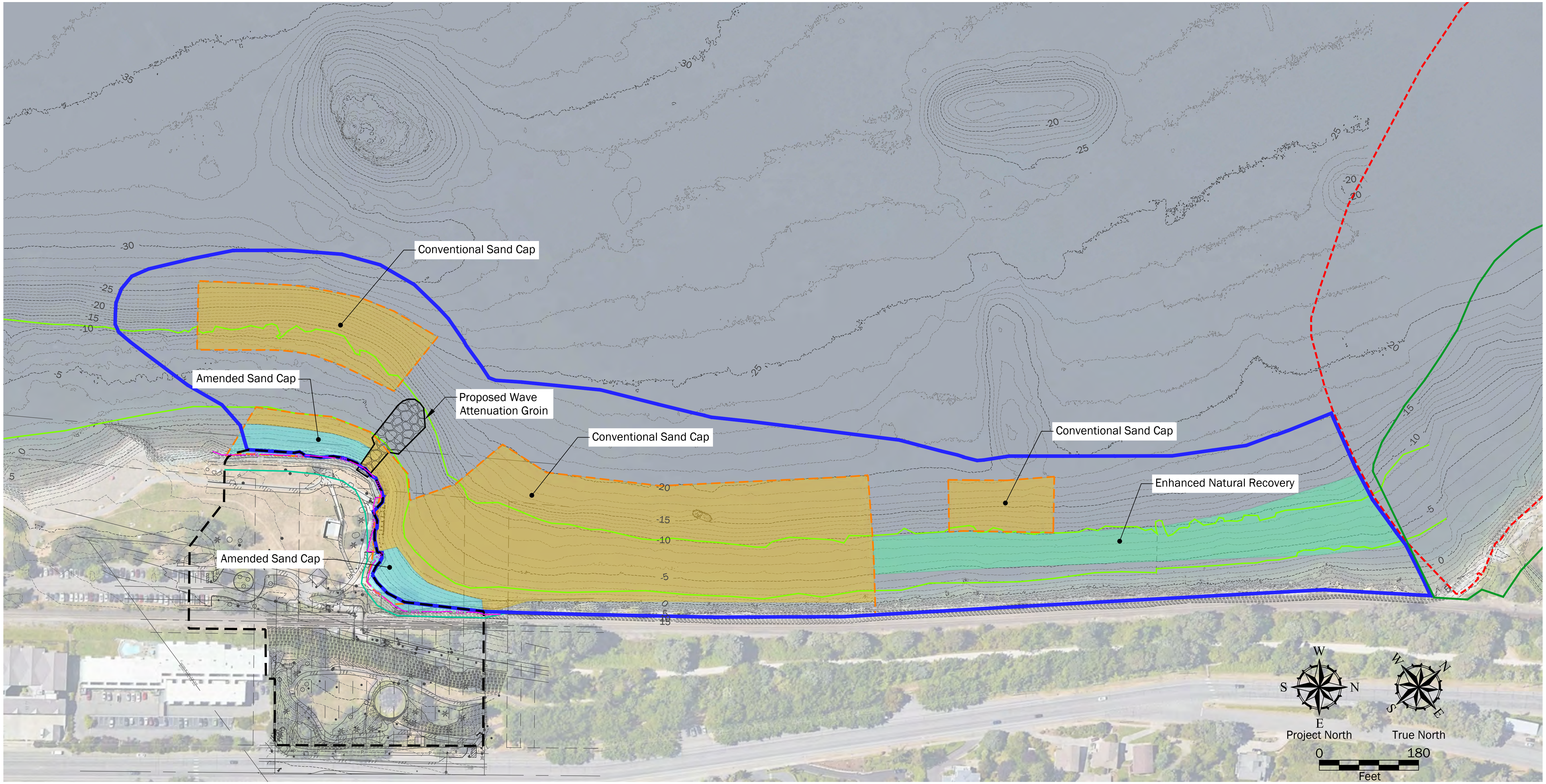
Notes:

[1] The sediment and porewater within the cap will be less than the cleanup levels to the depth identified in the table after 100 years based on the results of cap modeling.

[2] cPAH TEQ was modeled using input parameters for benzo(a)pyrene as a surrogate for the mixture of cPAHs.

µg/L = micrograms per liter
µg/kg = micrograms per kilogram
mg/kg = milligrams per kilogram
dw = dry weight
COC = contaminant of concern
cPAH = carcinogenic polycyclic aromatic hydrocarbon
POC = Point of compliance below final cap surface, including erosion protection layer
TEQ = toxic equivalent concentration
NA = not applicable

Appendix D Figures



Note(s):

1. Elevations on this plan reference the North American Vertical Datum of 1988 (NAVD88).
2. Sample location data was collected during sediment sampling with GPS mounted on research vessel.

Source(s):

- Survey data from David Evans and Associates, 2021
- Aerial from Google Earth Pro, dated 7/31/22
- Cornwall 60% Design from Landau Associates, 2021

Projection: Washington State Plane, North Zone, NAD83, US Foot

Disclaimer: This figure was created for a specific purpose and project. Any use of this figure for any other project or purpose shall be at the user's sole risk and without liability to GeoEngineers. The locations of features shown may be approximate. GeoEngineers makes no warranty or representation as to the accuracy, completeness, or suitability of the figure, or data contained therein. The file containing this figure is a copy of a master document, the original of which is retained by GeoEngineers and is the official document of record.

Legend

Upland Unit Boundary
Marine Unit Boundary
Haley Marine Unit Boundary
Cornwall Sediment Cap and Shoreline Stabilization Boundary (60% Design)
Approximate Limits of Aquatic Vegetation
HTL Existing High Tide Level

Conventional Sand Cap (2-foot sand layer, erosion protection layer, and habitat substrate)
Amended Sand Cap (2-foot activated carbon amended sand layer, erosion protection layer, and habitat substrate)
ENR (4-in sand layer placed in 2 lifts to preserve eelgrass)
Armor Stone Groin Structure (armor stone on 1-foot quarry spalls bedding layer)

Sediment Capping Plan

South State Street MGP Site
Bellingham, Washington

GeoEngineers

Figure D-1

Figures D-2 through D-9: CapSim Model Outputs

Notes:
AC = activated carbon
dw = dry weight

Figure D-2 *CapSim Model Output: Benzene Porewater Concentrations*

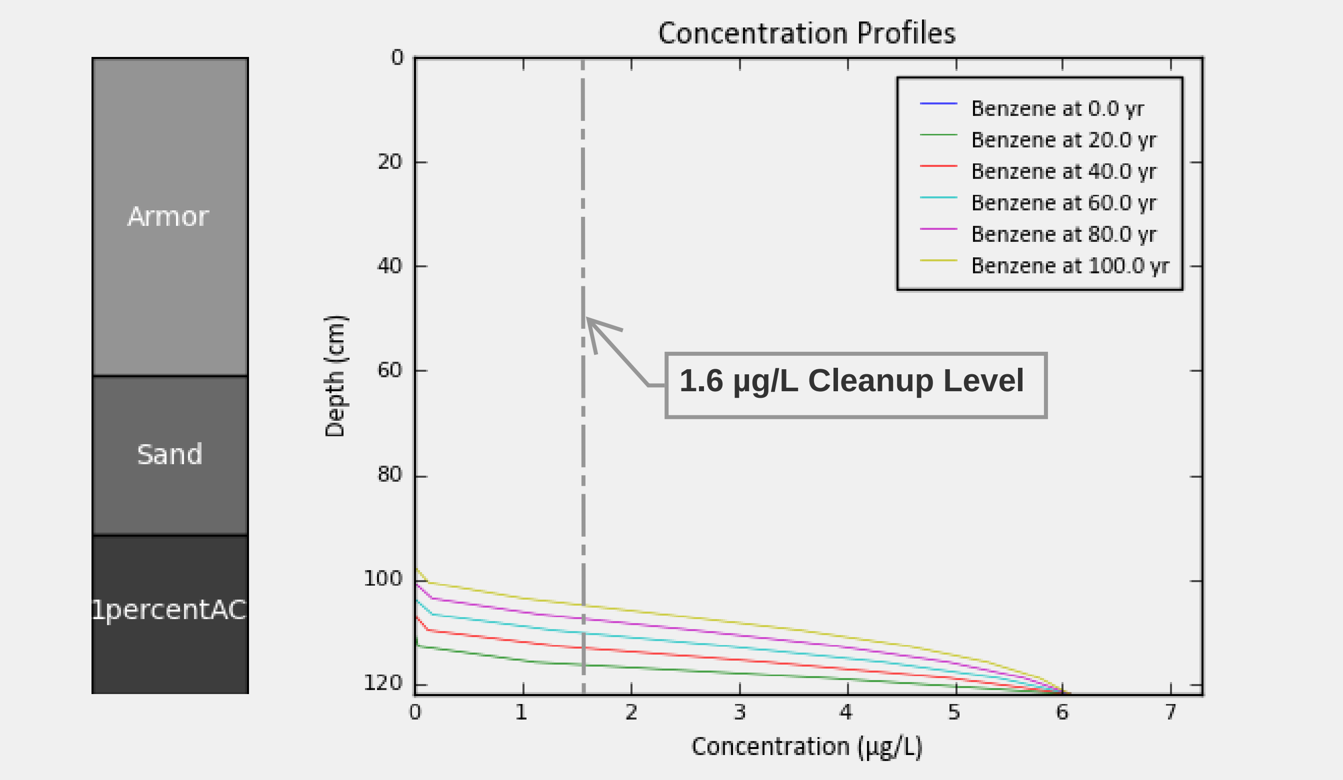


Figure D-3 *CapSim Model Output: Cyanide Porewater Concentrations*

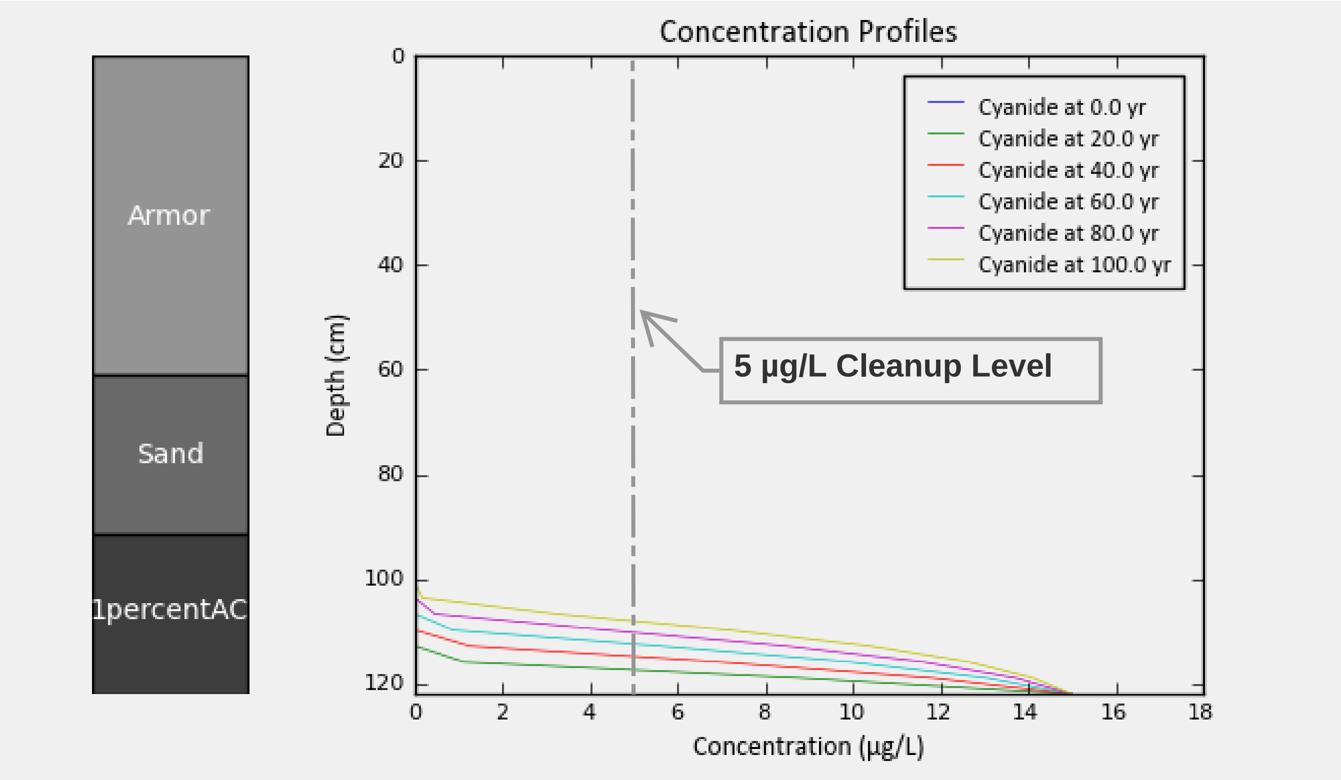


Figure D-4 *CapSim Model Output: Naphthalene Porewater Concentrations*

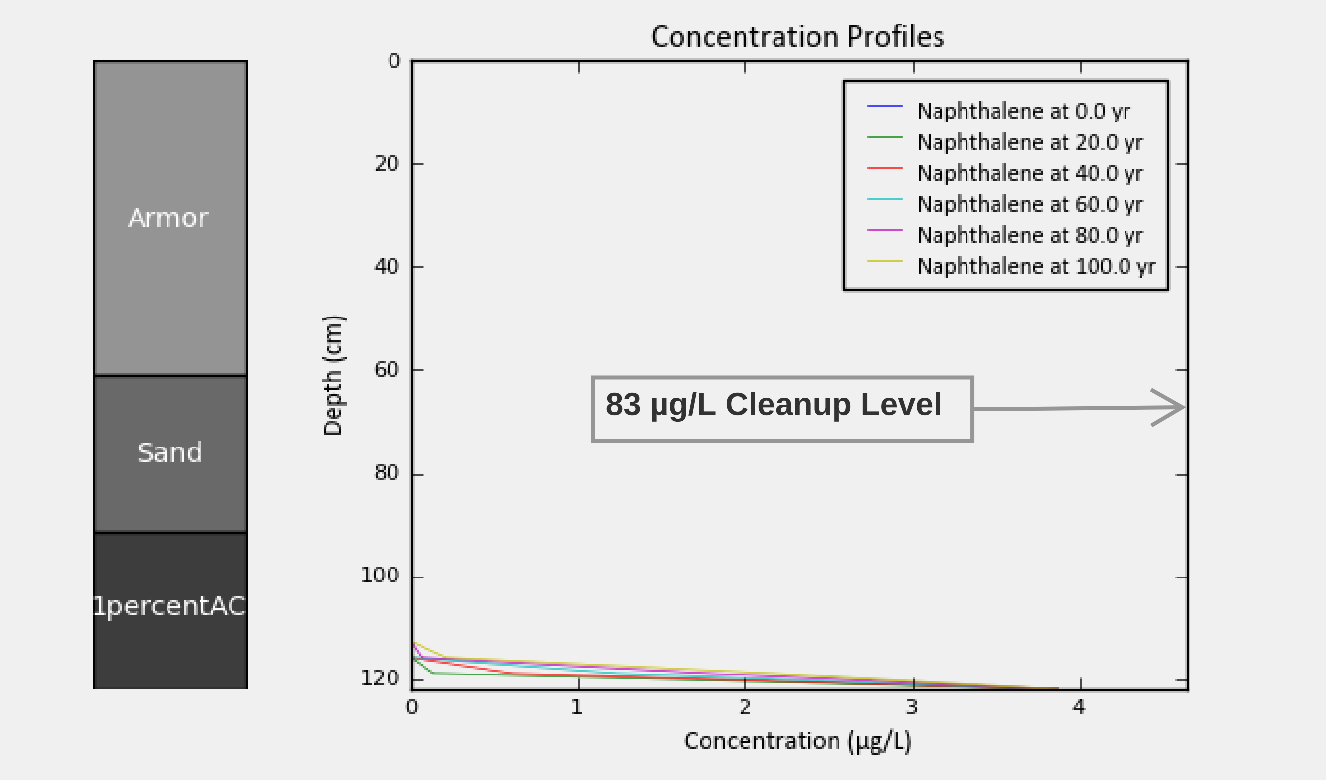
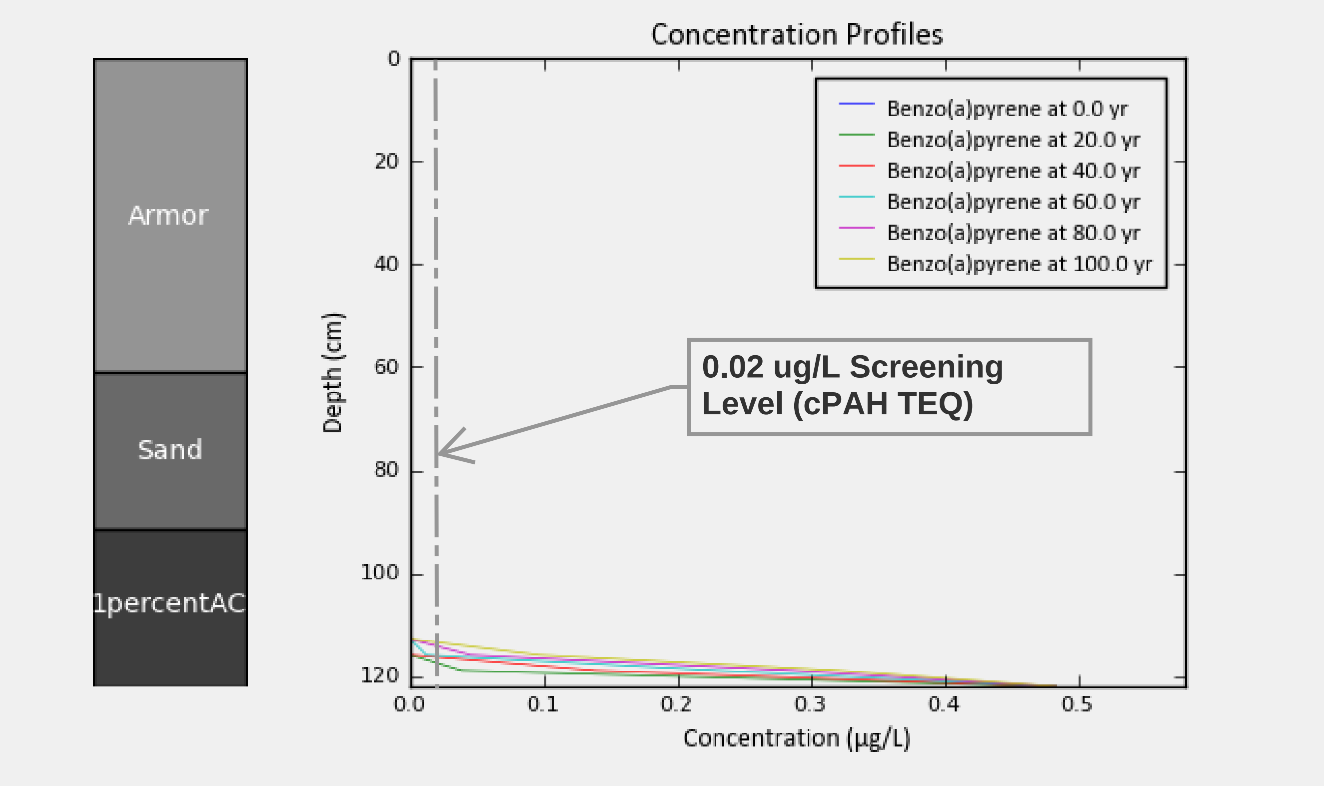


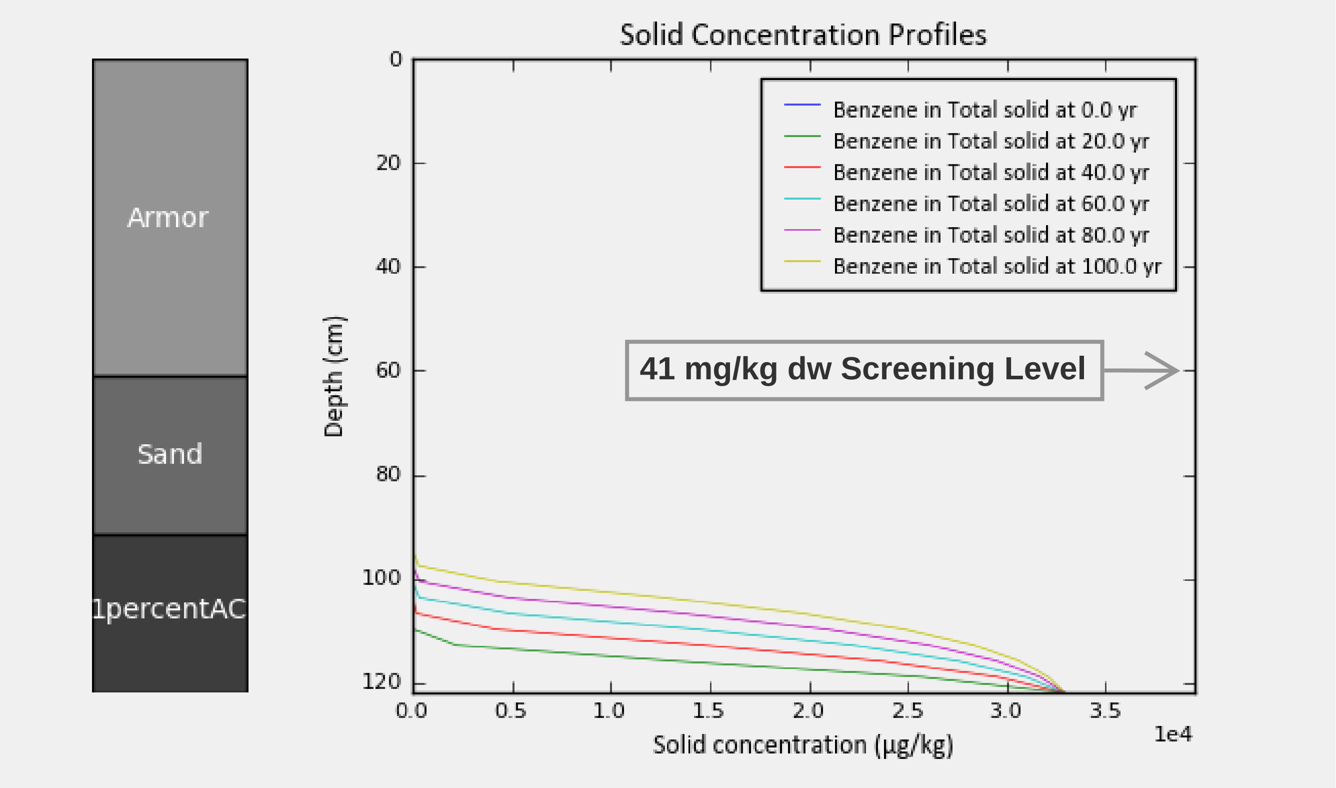
***Figure D-5** CapSim Model Output: Benzo(a)pyrene Porewater Concentrations*



0.02 ug/L Screening Level (cPAH TEQ)

Benzo(a)pyrene is a surrogate for cPAH TEQ, which is a groundwater indicator hazardous substance.

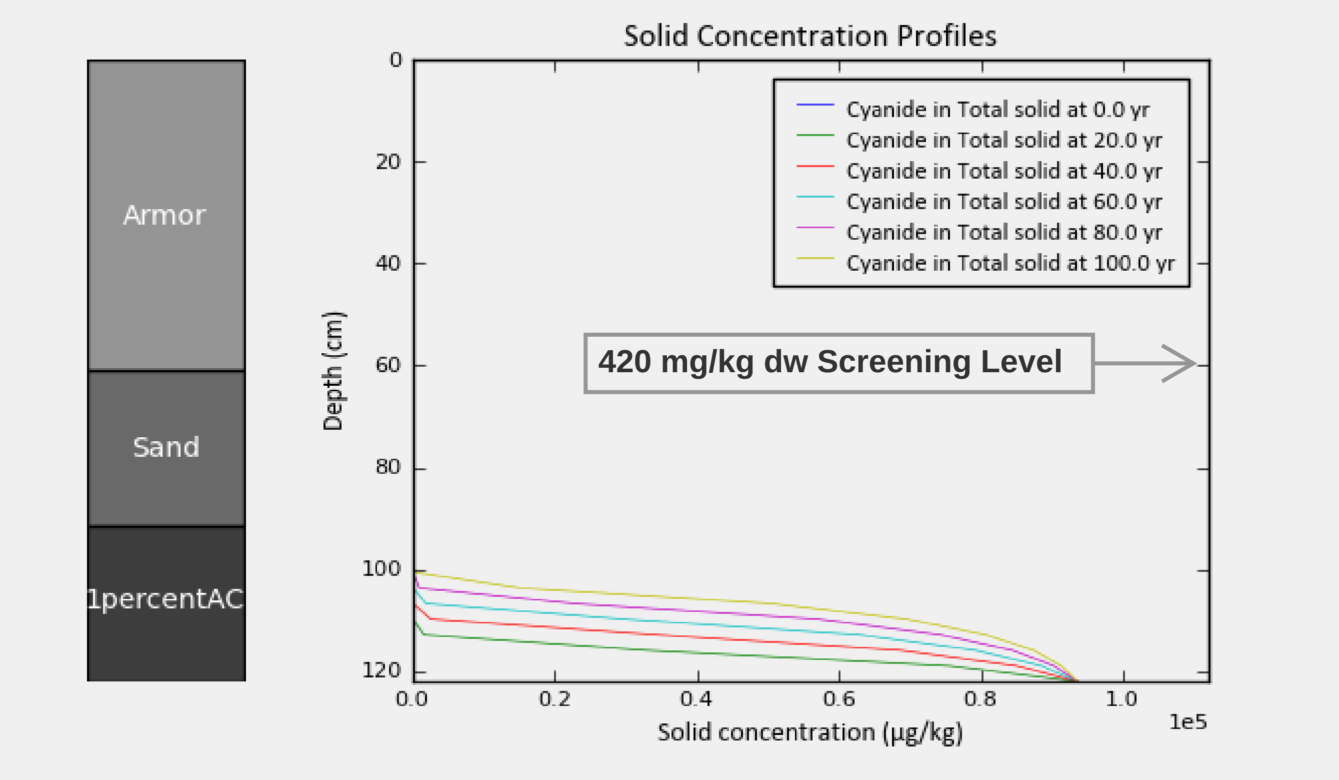
***Figure D-6** CapSim Model Output: Benzene Sediment Concentrations*



41 mg/kg dw Screening Level

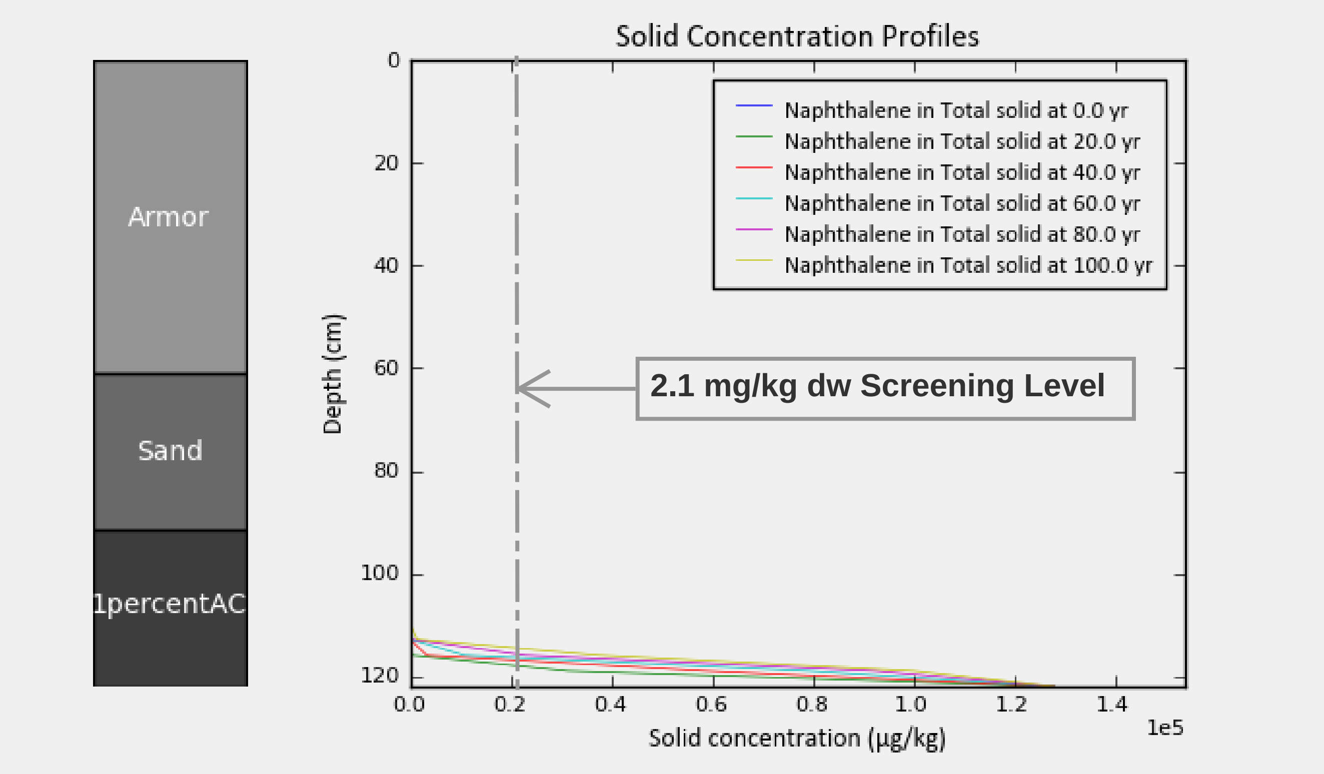
Benzene is not a sediment indicator hazardous substance. The sediment screening level, which is based on direct contact exposure via subsistence clam digging, is presented for informational purposes only.

Figure D-7 *CapSim Model Output: Cyanide Sediment Concentrations*



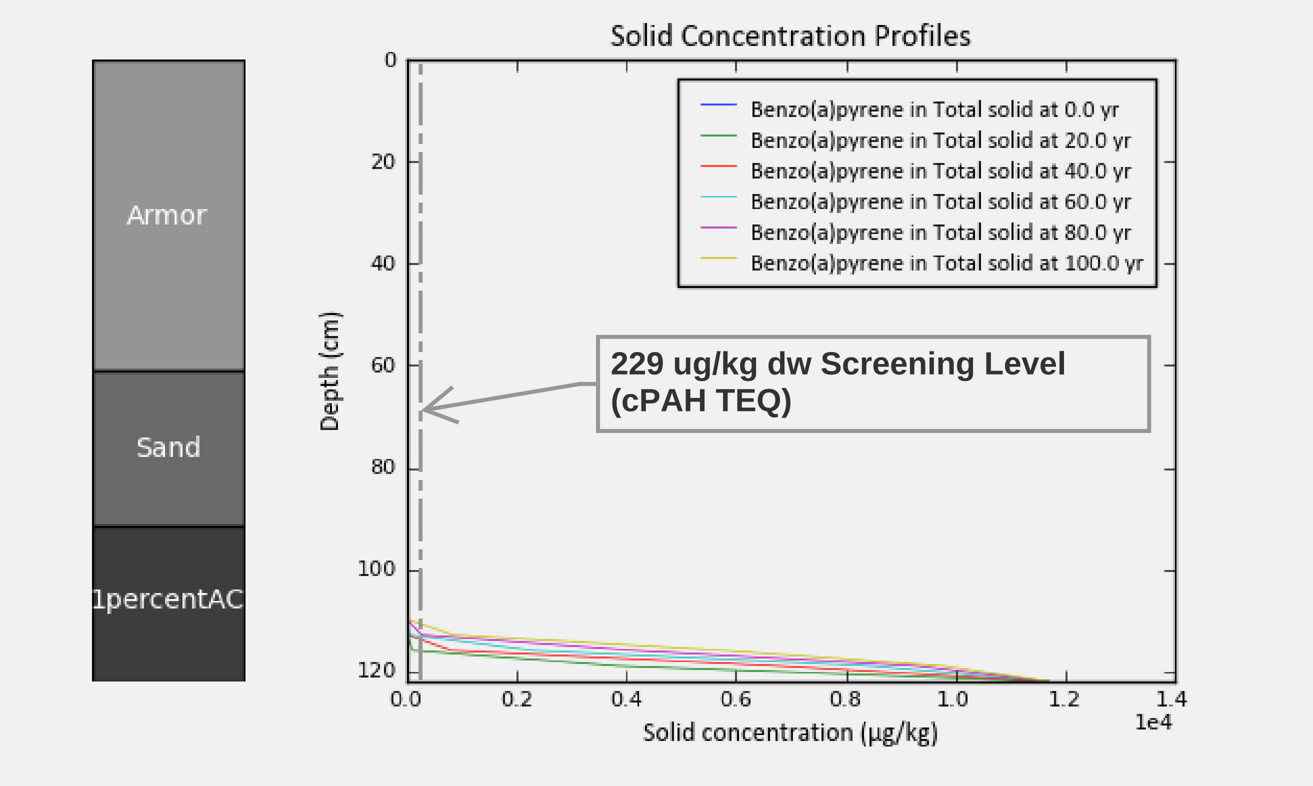
Cyanide is not a sediment indicator hazardous substance. The sediment screening level, which is based on direct contact exposure via beach play, is presented for informational purposes only.

Figure D-8 *CapSim Model Output: Naphthalene Sediment Concentrations*



Naphthalene is not a sediment indicator hazardous substance. The sediment screening level, which is based on the benthic exposure, is presented for informational purposes only.

Figure D-9 *CapSim Model Output: Benzo(a)pyrene Sediment Concentrations*



Benzo(a)pyrene is a surrogate for cPAH TEQ, which is a sediment indicator hazardous substance.

Appendix E

Coastal Conditions Assessment and Modeling Report

Coastal Conditions Assessment and Modeling
Engineering Design Report
South State Street Manufactured Gas Plant

Prepared for GeoEngineers Inc.
Prepared by Natural Systems Design + Coastal Geologic Services, Inc.

March 14, 2024

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Introduction

This coastal assessment and modeling report has been prepared to support the Engineering Design Report (EDR) for the South State Street Manufactured Gas Plant (SSSMGP) Cleanup Project. This report summarizes additional analyses of wind data and wave and morphodynamic modeling performed following completion of the previous coastal study during the Pre-Remedial Design Investigation (PRDI). The main objectives are to further establish and confirm the coastal engineering basis of design, and to support engineering design of in-water and shoreline sediment cap erosion protection (remediation) and habitat recovery (mitigation).

This study was designed to support remedial and mitigation design concept development and identify areas that require gravelly sand, gravelly cobble, or armor rock materials for erosion protection or for sustainable habitat recovery, and to confirm material types and grain sizes in different contamination areas or mitigation zones.

Two key design criteria have been adopted for this study:

- A 100-year design life for the design of contamination containment/erosion protection
- A 10-year design life for the design of habitat recovery/mitigation measures

This study also included the City of Bellingham's standard for inclusion of long-term sea level rise (SLR) impact with a projection of 50-inch SLR by year 2020. These criteria are consistent with WDOE's guidelines as described in "Sustainable Remediation: Climate Change Resiliency and Green Remediation guidance" (WDOE 2023).

In the previous PRDI phase, an in-depth coastal study was performed that included an extensive geomorphological review of the site and its environs, and collection and processing of relevant coastal data including wind, bathymetry, and water level data. The current EDR phase of the project aims to supplement the PRDI effort with a more thorough evaluation of design winds in the Bellingham Bay, and to carry out a coastal modeling effort to determine design wave conditions and to predict morphologic changes to inform sediment stability criteria, required armor material sizes, and to determine required shore crest elevation to minimize potential wave overtopping and upland erosion.

The report covers the following:

- PRDI review and previous established design criteria
- Coastal data processing and analysis (wind and bathymetry/topography)
- Wave model setup
- Modeling of design wave conditions
- Modeling of proposed coastal structure (groin) impact
- Modeling of beach morphodynamics with proposed design concept
- Summary of coastal engineering design basis and main conclusions

Site specific design conditions developed during the PRDI were reviewed and any additional relevant data, particularly the new Bellingham Bay wind data, were obtained and analyzed to support wave and morphodynamic modeling.

Additional sediment sample data and newly surveyed bathymetry/topography data covering the expanded project area to the north were reviewed and incorporated into the coastal modeling efforts.

For this Project, the Delft SWAN model was used for modeling wave generation and propagation to determine design wave conditions in the project area and rock sizing for shore protection and armor rock erosion protection design. The Delft XBeach model was used for morphodynamic modeling to evaluate bed sediment responses in both intertidal and subtidal zones in support of sediment cap erosion protection and habitat mitigation design.

Tsunami impact, associated risks, and possible risk mitigation measures were assessed and summarized to meet regulatory requirements. The main findings of the tsunami impact assessment are summarized in a separate project memorandum (Appendix F). Tsunami conditions were not considered as a design condition due to its extremely low probability and high uncertainties.

The main findings from the coastal engineering analysis and wave and morphodynamic modeling, together with the findings from the PRDI coastal study report, are summarized in this report and are used as a basis to establish coastal engineering design criteria for the EDR.

Design Water Levels

This section summarizes the coastal engineering design criteria associated with tides, water levels and SLR that were derived in the PRDI coastal study report (Appendix A). Design winds and waves have been further reviewed and established in this phase of the coastal study.

Tides

Tides for the site are presented in Table 1. Refer to the PRDI report (Appendix A) for more details.

Table 1. Tidal elevation statistics at Bellingham Station (#9449211) in FT NAVD88.

Description	Datum	Bellingham [FT]
High Tide Line	HTL	9.29
Mean Higher-High Water	MHHW	8.03
Mean High Water	MHW	7.31
Mean Tide Level	MTL	4.59
Mean Low Water	MLW	1.87
NAVD88	NAVD88	0.00
Mean Lower-Low Water	MLLW	-0.48

Extreme Water Levels

Extreme water levels for the site were derived in the PRDI in reference to the published extreme water levels at a long-term NOAA tidal station, Friday Harbor, WA (#9449880) with applied adjustments based on tidal and storm surge differences between the Bellingham and Friday Harbor stations. The results are presented in Table 2. Refer to the PRDI report (Appendix A) for more details.

Table 2. Extreme water levels.

Return Period [year]	1	2	5	10	50	100
Water level, Bellingham (FT, NAVD88)	10.0	10.3	10.5	11.0	11.2	11.4

Sea Level Rise

Climate-change induced SLR is projected to increase water elevations because of global warming, melting of glaciers and ice sheets, and land water storage changes, which will generally lead to higher coastal water levels that pose a risk for low-lying coasts and communities (IPCC, 2019).

According to a recent study completed by Miller et al. (2018), the projected SLR by year 2100 for Washington State for the high greenhouse gas emission scenario (RCP 8.5) is presented in Table 3, with two probability levels, the 50% likelihood and 10% likelihood levels.

The City of Bellingham Municipal Code (BMC 16.30 EXHIBIT A – Section B 1-7) has adopted a substantive requirement for SLR impact consideration for critical shoreline infrastructure and development projects which is a 50-inch SLR by 2120 (Table 3). This is in line with Miller et al.'s (2018) high emission scenario at an approximate 5% likelihood projection. The 50-inch SLR projection is required for the cleanup design consideration for this project.

Table 3. SLR projections for the high greenhouse gas scenario (RCP 8.5, Miller et al., 2018, and BMC 16.30)

Year	SLR [FT, 10% likelihood]	SLR [FT, 50% likelihood]
2030	0.3	0.2
2050	0.9	0.6
2070	1.6	1.1
2100	3.0	2.0
2120	4.2 (50" - City of Bellingham BMC)	

Wind Analysis

This section summarizes Project site wind conditions and results of additional wind analyses for Bellingham Bay and at the site.

Data Sources

In Bellingham Bay, regional storm winds are the primary driver of wave generation. The PRDI phase of the Project evaluated wind data from the following sources (Figure 1):

- Bellingham Airport (KBLI)
- Fairhaven Ferry Terminal (FH)

The present EDR phase supplemented the PRDI analyses with additional wind data from the following sources (Figure 1):

- A National Data Buoy Center (NDBC) weather buoy in Bellingham Bay (NDBC Station #46118), owned and maintained by the Northwest Association of Networked Ocean Observing Systems (NANOOS)
- A short-term wind gauge that was deployed by the USGS in 2020 and 2021
- Long-term wind prediction data from Environment and Climate Change Canada, the Regional Deterministic Prediction System (RDPS) and the High-Resolution Deterministic Prediction System (HRDPS)

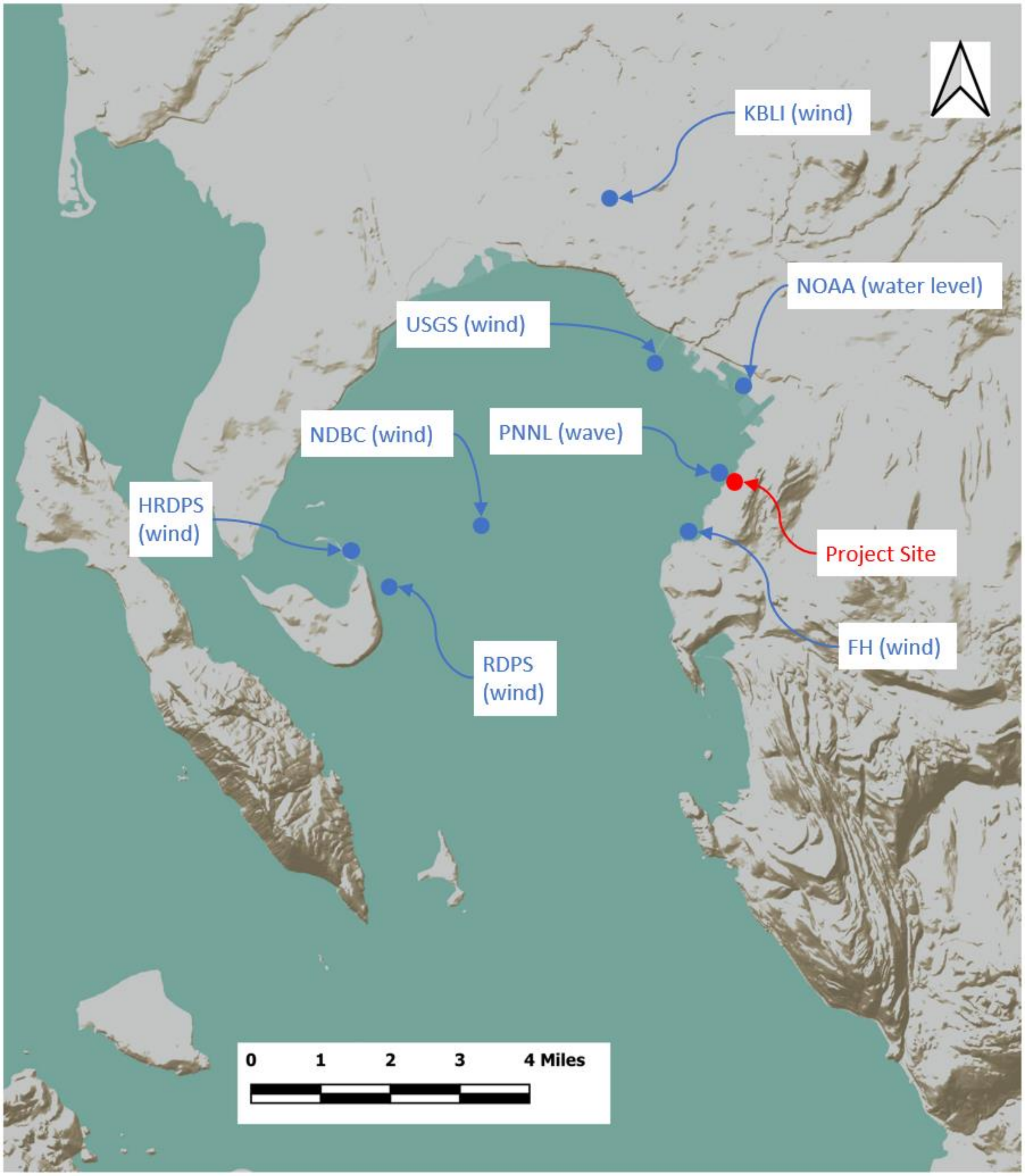

Figure 1. Project location map, and wind, wave, and water level data stations in the vicinity (blue points).

The RDPS and HRDPS modeling frameworks are climate models implemented and managed by the Canadian Meteorological Centre (CMC), Environment and Climate Change Canada, that provide forecast of atmospheric conditions, including wind speed and direction, on modeling grids covering Canada and the USA. RDPS is a coarser resolution model with a spatial resolution of approximately 10 kilometers, or 6 miles, and HRDPS is a newer and finer resolution model with a spatial resolution of approximately 2.5 kilometers, or 1.5 miles, that supersedes the RDPS model. The RDPS model was run by CMC as a hindcast model for the period of 1980 through 2018. The HRDPS model has been run as a forecast model from May 2017 to present. As an alternative to the long-term KBLI wind data, the combined RDPS and HRDPS model data permits a robust analysis of long-term winds for the Project, and especially their effects on wave generation in Bellingham Bay, as they provide in-water model data with few missing records and less impact from land topography. A relatively short, but high quality, record of wind data was collected by the USGS from the abandoned dock 2000 FT off Little Squalicum Beach. The onshore and short-term wind data were collected and analyzed mainly to cross-check the quality of the long-term wind data.

Table 4. Wind data sources and availability.

Station ID	Station Feature	Start Year	End Year	Missing Years	Years in Record
KBLI	Long-term airport data, upland	1948	2023	1965 to 1972	68
NDBC (46118)	Short-term buoy data, over-water (presently offline)	2016	2020	Nov. 2017 to Apr. 2018 Aug. to Sep. 2018 Sep. 2019 to Jul. 2020	5
USGS	Short-term weather station data, onshore (discontinued)	2020	2021	None	1.5
FH (D8969)	Long-term weather station data, onshore	2011	2022	May to July of 2014	12
RDPS	Long-term climate model, over-water	1980	2018	None	39
HRDPS	Long-term climate model, over-water	2017	2023	None	7

Note: All wind records are provided as hourly-interval time series.

Wind Data Quality Check

Wind records for each of the stations shown in Table 4 were compared against each other to determine the most appropriate wind record, or a combination thereof, for wind wave and morphodynamic modeling described below. Different model grid points in the middle of Bellingham Bay from the HRDPS and RDPS model outputs were used for comparisons, showing consistent wind speeds and directions. As such, the HRDPS/RDPS data from the model grid cells closest to the NDBC Bellingham Bay buoy station, near the middle of the bay, were used.

The wind data sets were processed and then plotted with wind roses to describe the predominant wind climate of the area. Figure 2 shows wind roses for the six stations listed in Table 4. All six stations show that wind predominantly comes from the southerly directions, with variation between SW and SE.

The USGS and FH wind data (Figures 2C and 2D, respectively) are from the two onshore stations which better capture storm winds from SSW, SW, and W along Bellingham's shore, but their records may under-represent high winds from S and SE and are too short for long-term analysis. Wind data for the NDBC buoy (Figure 2B) are inconsistent between periods of missing records with direction sharply changing from predominantly SE to S; only the wind data from 2018 to 2019 were considered of high confidence and kept for further use.

The KBLI wind rose, and the corresponding joint occurrence frequency distribution (Table 5), show winds from more concentrated directions, largely from southern directions (S and SSE, 44%) and secondly from northerly directions (NNE and N, 17%), but very low percentage of winds from SW, W, and northwest directions (13%). It is also noted that the KBLI winds have higher occurrence of strong northerly (NNE and N) storm winds due to the proximity to the Nooksack River/Fraser River Valley, even when winds in Bellingham Bay are westerly or southwesterly. This is largely because the KBLI station is a land-based station, where winds are more influenced by topographic features, affecting both wind speed and direction. Data quality and accuracy in recording actual wind directions in earlier time periods could also be a potential cause.

Previous analyses (Appendix A) relied on winds from the KBLI station for extremal analysis and forcing wind-wave models without considering wind directions. The present analysis, however, has collected new model wind data from RDPS and HRDPS winds. Figures 2E and 2F show the wind roses of two data sets, which are fairly similar and consistent, and better match the two onshore stations for winds from SSW to W. The quality of these two data sets was checked through comparison, as presented below.

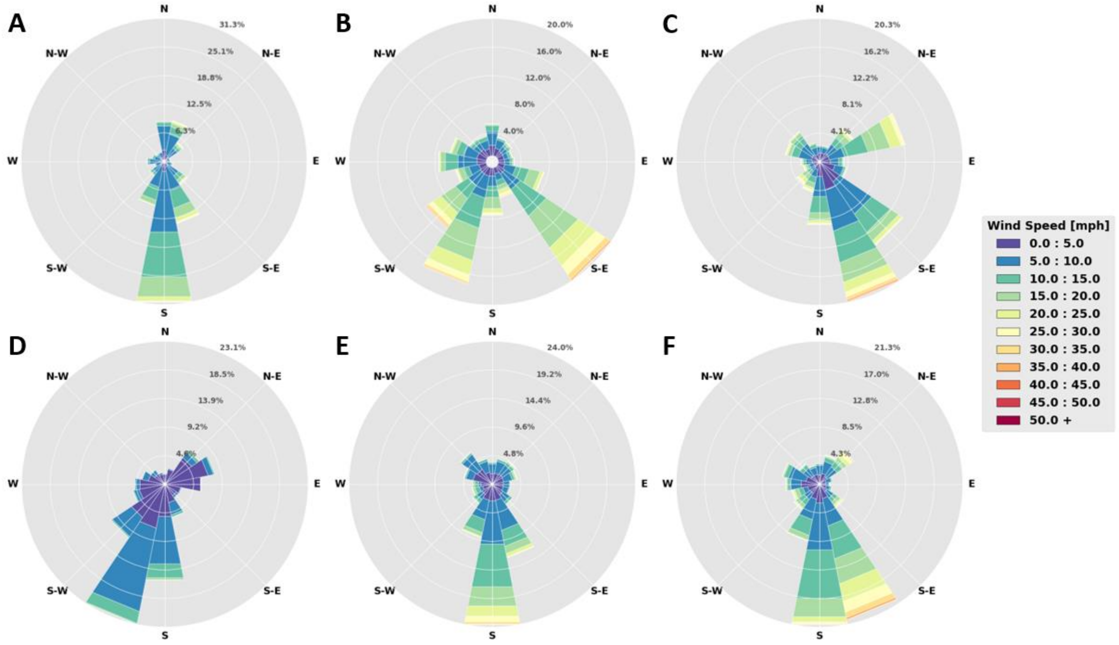

Figure 2. Wind roses for A) KBLI, B) NDBC, C) USGS, D) FH, E) RDPS, and F) HRDPS.

Table 5. Joint frequency distribution of wind speed and direction for the KBLI station

Speed [mph]	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total	Cumul.
0-5	2.10	1.10	0.75	0.26	0.35	0.33	0.78	0.84	1.79	0.73	0.49	0.28	0.50	0.28	0.41	0.50	11.49	100.00
5-10	5.35	4.57	2.36	0.61	0.57	0.91	2.61	5.32	13.45	4.58	2.02	1.14	2.27	1.49	1.06	1.11	49.43	87.85
10-15	0.80	1.61	0.78	0.10	0.08	0.26	1.19	3.91	9.97	2.92	0.65	0.27	0.47	0.48	0.26	0.17	23.91	38.41
15-20	0.18	0.83	0.47	0.05	0.02	0.10	0.73	2.21	4.37	1.04	0.23	0.07	0.08	0.07	0.04	0.02	10.49	14.51
20-25	0.04	0.37	0.22	0.02	*	0.02	0.25	0.79	0.91	0.16	0.04	0.01	*	*	*	*	2.87	4.02
25-30	*	0.15	0.08	*	*	*	0.07	0.24	0.17	0.01	*	*	*	*	*	*	0.76	1.15
30-35	*	0.06	0.04	*	-	*	0.02	0.09	0.05	*	*	*	*	*	-	-	0.27	0.39
35-40	*	0.03	*	*	*	*	*	0.03	*	*	*	-	-	-	-	-	0.09	0.12
40-45	*	0.01	*	*	-	-	*	*	*	*	-	-	-	-	-	-	0.03	0.04
45-50	*	*	*	-	-	-	*	*	*	-	-	*	-	-	-	-	*	0.01
50-55	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	*
55-60	-	*	-	-	-	-	-	*	-	-	-	-	-	-	-	-	*	*
>60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	8.49	8.74	4.70	1.04	1.02	1.63	5.66	13.43	30.72	9.45	3.44	1.78	3.32	2.33	1.77	1.81		
Cumul.	8.49	17.23	21.93	22.98	24.00	25.63	31.29	44.71	75.43	84.89	88.32	90.10	93.42	95.76	97.53	100.00		

Note: Values are in percent (%); * denotes values less than 0.01%; - denotes no record in bin.

The HRDPS wind data were compared to both the USGS and NDBC wind data. The USGS wind data are of high quality and there is substantial overlap between the USGS and HRDPS data sets. The NDBC dataset represents winds in the middle of Bellingham Bay where waves experienced at the site are generated by winds across the Bay. Figure 3 shows plots of HRDPS and USGS wind speeds for an overlapping period in April and May 2021. In general, the USGS peak winds are slightly larger than HRDPS, but the average winds are similar, differing by only 1.4 mph. The higher wind speeds observed at the USGS gauge are largely due to a higher resolution sampling rate for the USGS gauge of 15-minutes, as opposed to the 1-hour resolution of the HRDPS data. The higher resolution USGS data shows more peaks in the wind record, resulting in larger measured wind speeds. Figure 4 shows HRDPS wind speeds plotted against NDBC wind speeds for a period in October and November 2018. The two datasets compare well with each other with NDBC wind speeds, on average, approximately 2.5 mph higher than HRDPS wind speeds. Given favorable comparisons between measured winds in the Bellingham Bay and HRDPS winds, the HRDPS and RDPS winds were used for the extremal analysis of return period winds described in the Extreme Winds section below.

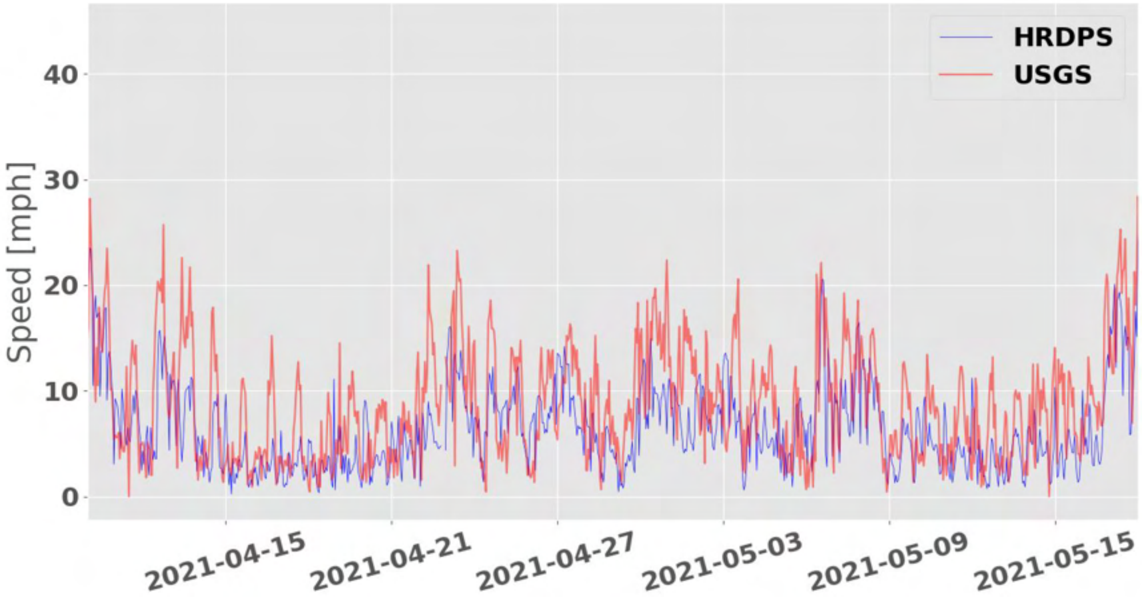

Figure 3. HRDPS and USGS wind speeds for a period in April and May 2021.

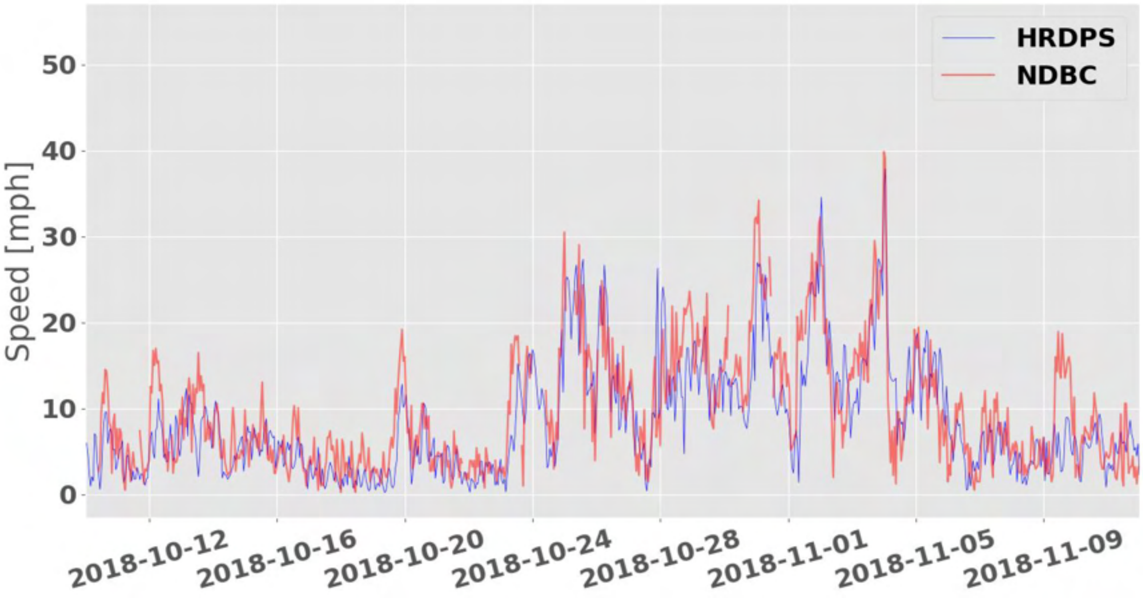

Figure 4. HRDPS and NDBC wind speeds for a period in October and November 2018.

Combined RDPS and HRDPS wind speeds provide a long and continuously updated source of wind data for the Project site. RDPS and HRDPS wind data were compared to each other for an overlapping period from May 2017 through December 2018 to determine the relationship between the two in order to combine them into a continuous dataset. Due to spatial and temporal differences between the two models, we found that multiplying the RPDS wind speeds by 1.3 resulted in the best alignment between RDPS and HRDPS wind speeds. The factor was based on the average difference between the two datasets for the period of overlap. Figure 5 shows a comparison of time series wind speeds for HRDPS and RDPS adjusted winds. The adjusted RDPS winds compare well with HRDPS winds, particularly at peak wind conditions, lending the combined dataset well to extremal analyses.

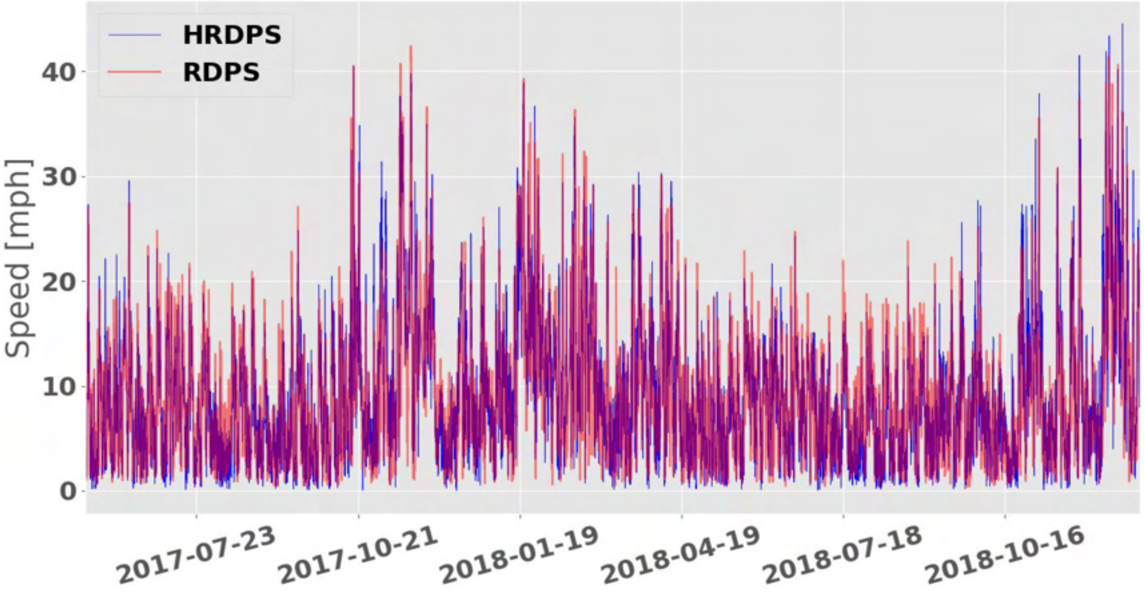

Figure 5. RDPS and HRDPS winds speeds for overlapping period with RDPS adjustment factor of 1.3.

Wind Climate

Figure 6 and Table 6 show the wind rose and joint frequency distribution table, respectively, for combined RDPS and HRDPS winds. The combined winds show strong southerly winds, with the largest contributions from S, SSE, and SSW.

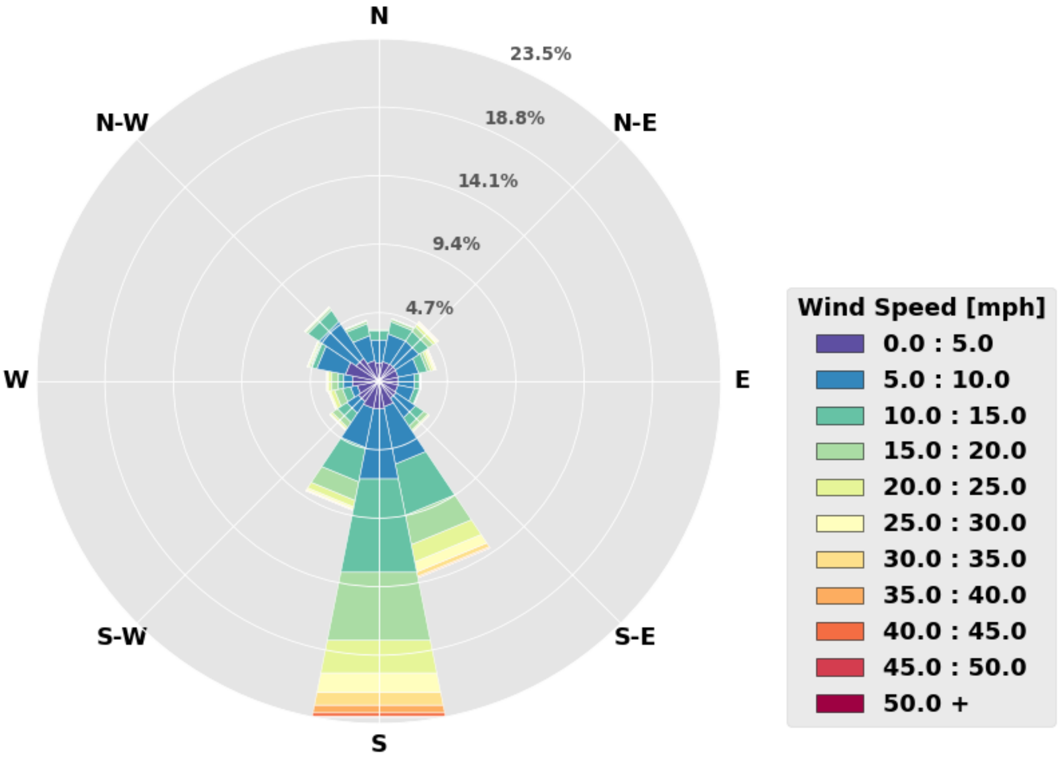

Figure 6. Wind rose for combined RDPS and HRDPS winds.

Table 6. Joint frequency distribution table of wind speed and direction for combined RDPS and HRDPS winds.

Speed [mph]	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total	Cumul.
0-5	1.28	1.36	1.40	1.36	1.32	1.35	1.42	1.79	1.93	1.90	1.69	1.51	1.85	2.33	1.88	1.45	25.82	100.00
5-10	1.59	1.94	1.92	1.44	1.16	1.14	1.62	4.02	4.90	2.75	0.95	0.48	0.61	2.02	3.05	1.74	31.32	74.18
10-15	0.66	0.86	0.81	0.61	0.35	0.35	0.69	3.59	6.55	2.40	0.77	0.57	0.37	0.34	0.93	0.84	20.68	42.86
15-20	0.08	0.18	0.37	0.22	0.05	0.05	0.33	2.06	4.77	1.30	0.43	0.55	0.47	0.18	0.16	0.17	11.37	22.18
20-25	*	0.03	0.22	0.17	*	*	0.10	1.21	2.28	0.45	0.15	0.29	0.24	0.11	0.08	0.05	5.40	10.81
25-30	*	*	0.15	0.14	*	-	0.02	0.70	1.36	0.15	0.05	0.11	0.09	0.04	0.04	*	2.86	5.41
30-35	-	*	0.06	0.06	*	-	*	0.31	0.89	0.06	0.01	0.03	0.02	*	0.01	*	1.47	2.54
35-40	-	-	0.03	0.03	-	-	*	0.09	0.54	0.02	*	*	*	*	*	*	0.72	1.07
40-45	-	-	*	*	-	-	-	0.01	0.24	*	*	*	*	-	*	-	0.27	0.35
45-50	-	-	*	*	-	-	-	*	0.05	*	*	*	*	-	-	-	0.06	0.08
50-55	-	-	*	*	-	-	-	-	0.01	-	-	-	-	-	-	-	0.01	0.01
55-60	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-	*	*
>60	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-	*	*
Total	3.62	4.39	4.95	4.03	2.88	2.90	4.18	13.77	23.54	9.05	4.07	3.55	3.64	5.02	6.15	4.26		
Cumul.	3.62	8.01	12.97	17.00	19.88	22.78	26.96	40.73	64.27	73.32	77.39	80.93	84.57	89.59	95.74	100.00		

Note: Values are in percent (%); * denotes values less than 0.01%; - denotes no record in bin.

Extreme Winds

The extreme wind speeds were derived utilizing the 44-year hourly wind speed data from the combined RDPS and HRDPS model wind data records. A peaks-over-threshold method was utilized to extract the extreme events from the wind record, and the peaks were fit to a Generalized Pareto Distribution. The resulting return-period hourly wind speeds are presented in Table 7.

Table 7. Extreme winds.

Return Period [year]	2	5	10	30	50	100
Design Wind Speed [mph] – S	49	52	54	57	59	61
Design Wind Speed [mph] – SSW	49	52	54	57	59	61
Design Wind Speed [mph] – SW	36	39	42	46	48	51
Design Wind Speed [mph] – W	35	38	39	43	45	47
Design Wind Speed [mph] – N	32	36	39	43	46	49

The extreme wind speeds given in Table 7 can be considered as the design wind speeds for southerly to south-southwesterly winds, and for northwesterly winds, as storm winds from these directions are the strongest and most frequent in the region. Given the inherent uncertainty in the extremal analysis due to lower samples of representative storm events for the southwesterly and westerly directions, a 10% increase of wind speed has been applied to the design winds for these directions. The resulting design winds for the Project are presented in Table 8. Wind generated waves were not evaluated in the present study for winds from the northwest considering the preponderance of observed incident waves from the SW.

Table 8. Design winds.

Return Period [year]	10	30	100
Design Wind Speed [mph], SSW winds	54	57	61
Design Wind Speed [mph], SW winds	46	51	56
Design Wind Speed [mph], W winds	43	47	52

Representative Storm Event

Understanding how the shore and beach respond to episodic storm events is important in order to evaluate the effectiveness of beach design configurations, layouts, and sediment characteristics in storm events. For the Project site, SW and W storms tend to have more significant impact. Several known storms have caused significant shore erosion, flooding, and coastal infrastructure damage, including storms in March 2008, November 2015, and December 2018. Not all of these storm events were recorded by available wind stations. Also, some land-based or onshore station data were not representative of wind conditions in Bellingham Bay due to local topographic effect and other potential reasons. A review and comparison of the wind records from the KBLI, FH, and NDBC stations for these storms revealed that the wind data from the NDBC buoy station best captured the December 2018 storm event in Bellingham Bay. As a result, this storm was selected as the representative storm event.

Figure 7A shows wind speeds and directions for 5 days from December 18, 2018 to December 23, 2018. The primary portion of the storm occurred over a 36-hour period from December 20, 2018 to midday December 21, 2028. This long-lasting storm has a peak wind speed of 44 mph with wind direction fluctuating between SW and NW during the peak wind period. The storm is considered the worst storm of Bellingham Bay in recent history, with a return-period estimated to be over 30 years.

Observed and predicted water levels for the NOAA Friday Harbor tidal station (Station 9449880) during the December 2018 storm are presented in Figure 7B. The difference between the observed and predicted water levels represents the effect of atmospheric conditions on the water levels, or the storm-induced surge. The water levels show the maximum storm-induced surge was 2.4 FT occurring on December 20, 2018, at 12:00 PM (8:00 PM GMT). This storm event was used to model morphodynamic design beach response to storm conditions using XBeach (see the Morphodynamic Modeling section below).

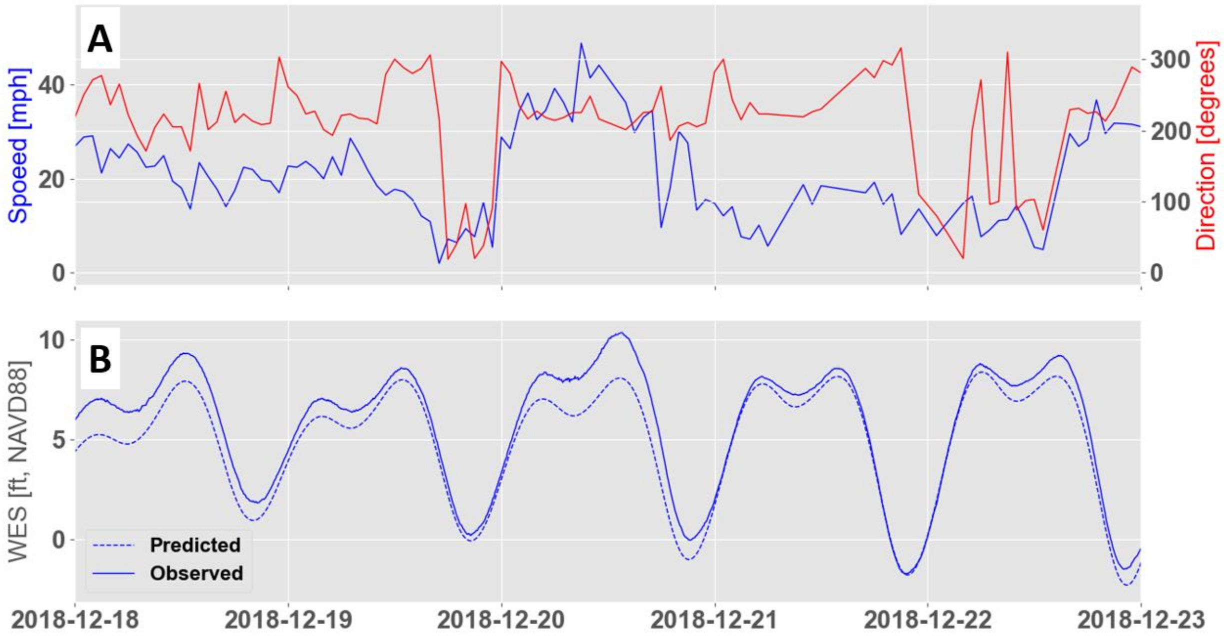

Figure 7. December 2018 storm A) wind speed and direction at Bellingham Bay Buoy Station 46118; B) observed water levels and predicted tides at Friday Harbor, WA (NOAA Station 9449880).

Coastal Wave Modeling

Coastal wave modeling was conducted using SWAN, a third-generation wave model, to determine design waves at the site for storms under different conditions.

This section presents SWAN model setup, modeling scenarios, and main results of design waves associated with these design conditions.

SWAN Model

SWAN is a two-dimensional spectral wave coastal wave model developed at the Delft University of Technology which solves the energy balance equation in the whole computational domain (Booij et al., 1999). The model computes random, short-crested wind-generated waves in coastal regions and inland waters due, in part, to windstorm events. The wave energy is discretized in a frequency and directional domain at each node of the spatial computational grid and allowed to propagate in space.

For the Project, the following wave processes are represented in the model:

- Wave generation by wind
- Wave propagation, shoaling, and refraction
- wave-wave interactions
- White-capping, bottom friction, and depth-induced wave breaking as sources of energy dissipation

The model uses a Cartesian grid and can nest multiple subdomain grids (child grids) in parent grids to effectively resolve complex coastal structures and bathymetry near the shore while minimizing computational overhead.

Model Setup

SWAN models are set up and run under the metric unit system with water depth referenced to NAVD88. To accurately simulate wind-generated waves, the model domain must cover a sufficient portion of the fetch area. Three nested model domains were set up for modeling wave generation and transformation from the bay into the Project site. Figure 8 shows the medium size model domain (left) nesting inside the large size model domain (right). Figure 9 shows the small size model domain (left) nested inside the medium size model domain (right).

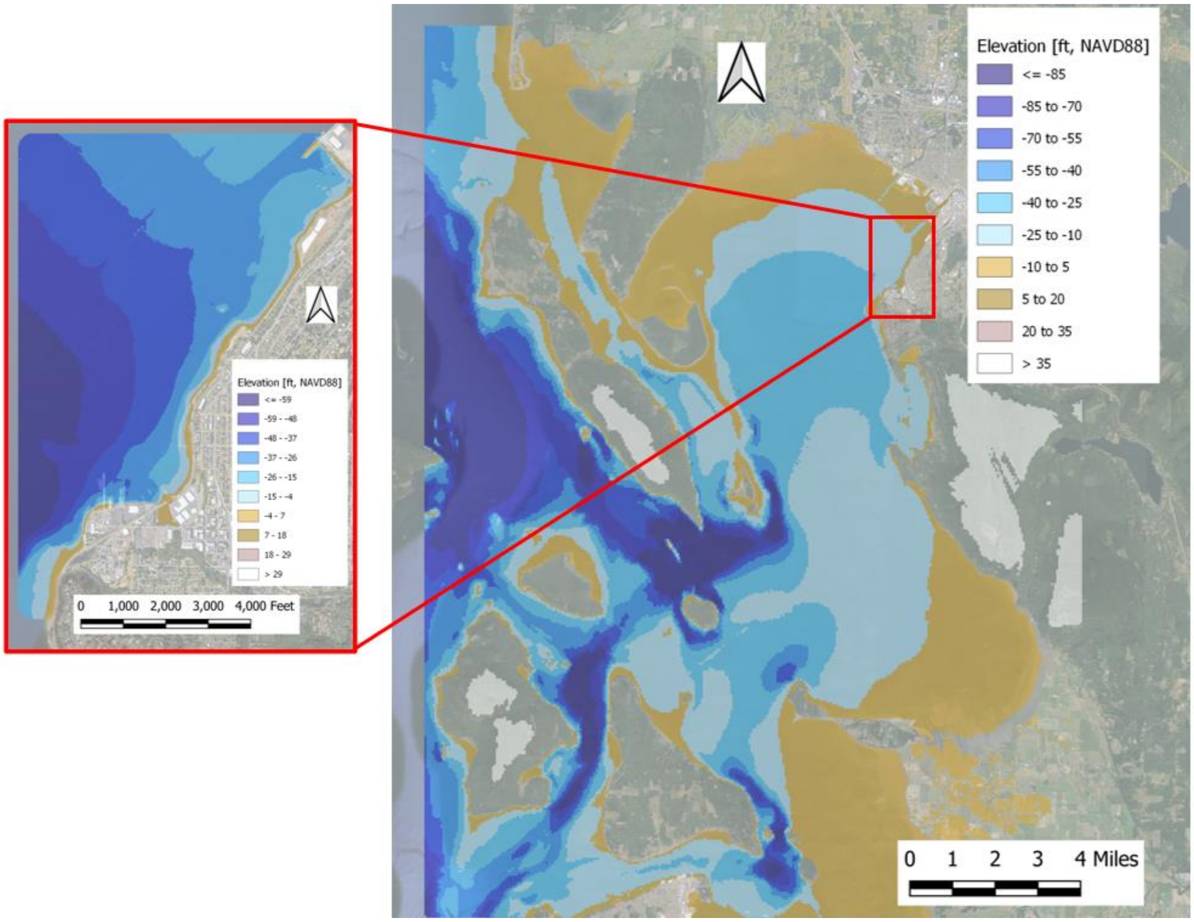

Figure 8. Medium size model domain (left) nested inside large size model domain (right) (elevation in FT, NAVD88).

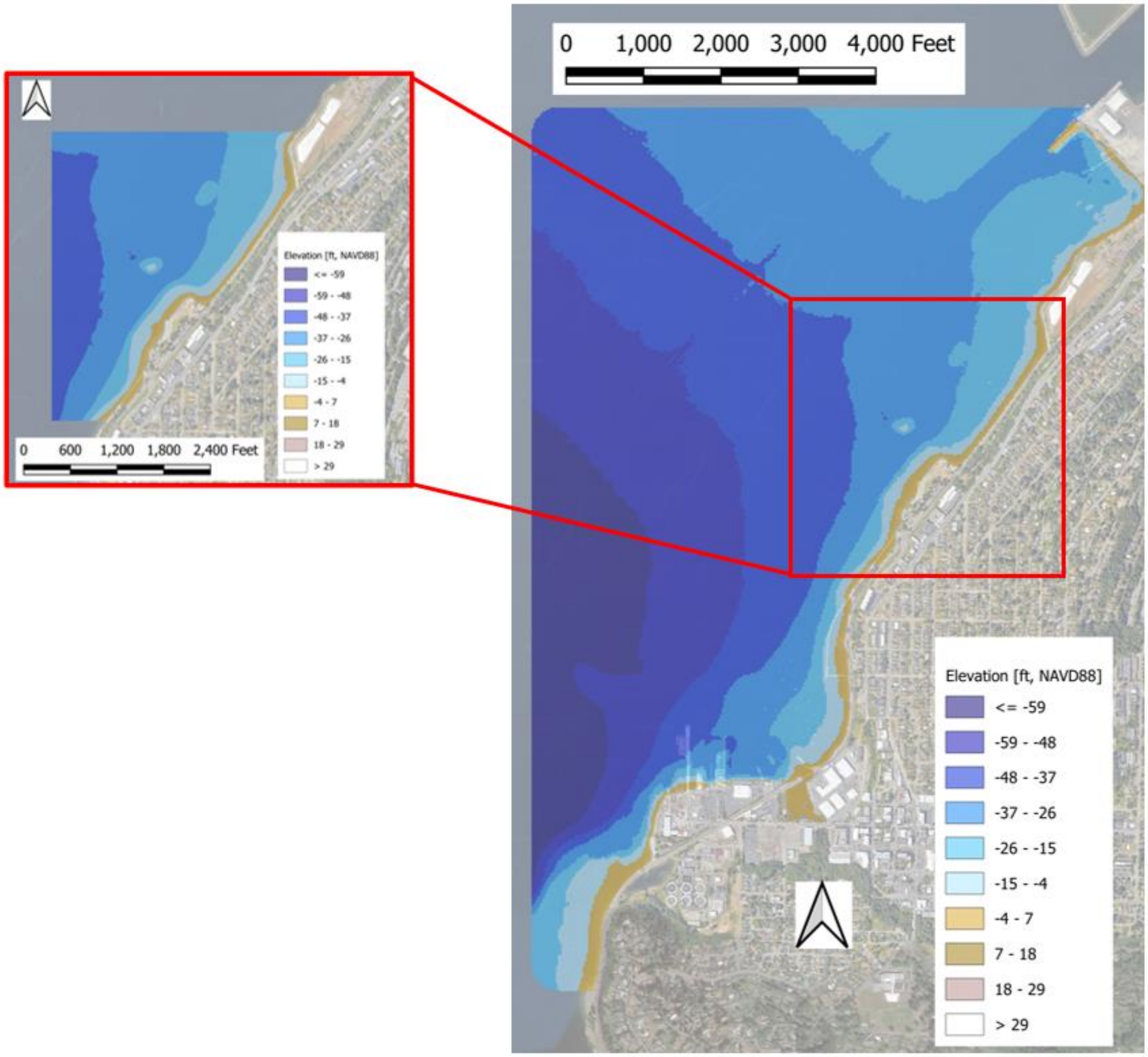

Figure 9. Small size model domain (left) nested inside medium size model domain (right) (elevation in FT, NAVD88).

The largest size model domain covers all of Bellingham Bay, the medium size model domain covers an area approximately 2-miles north to south and 1.5-miles east to west over the Project area, and smallest size model domain covers an area approximately 3,200 FT north to south and 2,200 FT east to west over the Project area using the compiled latest bathymetric survey data as described in the Site Conditions section. The large size model domain has a grid resolution of approximately 100-m by 100-m, consisting of 83,328 grid points; the medium size model domain has a grid size of approximately 10-m by 10-m consisting of 83,820 grid points; and the small size model domain has a grid size of approximately 2-m by 2-m consisting of 250,000 grid points.

Modeling Scenarios

Design Return Periods

Wave modeling with SWAN was performed to determine two return-period design storm conditions:

- 100-year design storm conditions were modeled for the design of contamination containment/erosion protection based on the 100-year design life criterion
- 30-year design storm conditions were modeled for the design of intertidal habitat recovery/mitigation measures based on the 10-year design life criterion

30-year storm conditions were selected for the scenario of the 10-year design life criterion because there is 29% likelihood for a 30-year storm to occur in the next 10 years. Consideration of the use of a 30-year return period storm provides a more conservative assessment for the 10-year design life mitigation design.

Storm Directions

SWAN models were initially run in 5-degree increments from 180 degrees (due south) to 355 degrees (5 degrees W of due north) to determine the worst wind directions (corresponding to the highest waves) in different directional wind bins. Thereafter, three directions representing three governing wind direction bins (SSW, SW, and W) were modeled for the design wind speeds. The east side of the wind compass was not run since the wind would blow offshore given the orientation of the site toward the W.

Water Level Scenarios

Both high and low water levels are considered as potential governing conditions for erosion protection and mitigation designs as a higher water level corresponds to higher wave energy on the higher shoreline and a lower tide leaves the subtidal seabed (which is associated with eelgrass mitigation zone) more susceptible to wave erosion.

Five representative design water levels were selected for both low tide and high tide conditions corresponding to both 100-year and 30-year return period design conditions:

- Two low water scenarios: MLLW – 2 FT (extreme low water) and MLLW
- Two High water scenarios: MHHW and MHHW + 2 FT (with storm surge)
- One SLR scenario: MHHW + 2 FT + SLR

Joint Design Storm Cases

The selection of joint design storm cases for wave modeling takes into account the joint probability of a particular storm event at particular water levels. Two joint design storm cases were used that include an extreme storm event during a range of high water level, and a less extreme storm event with a more extreme low water level, for the two design return period conditions. These include the following.

- 100-year design storm conditions (for the 100-year design life remediation design):
    - 100-year design wind coupled with 4 tidal scenarios, MLLW, MHHW, MHHW + 2FT, and MHHW + 2FT + 4.2FT SLR (SLR from Table 3, with 2120 projection)
    - 30-year design wind coupled with an extreme low water, MLLW – 2FT (also considered as a 100-year joint storm scenario due to the low probability during the 100-year design life)
    - Three wind directions: SSW, SW, and W
- 30-year design storm conditions (for the 10-year design life mitigation design):

- 30-year design wind coupled with 4 tidal scenarios, MLLW, MHHW, MHHW + 2FT, and MHHW + 2FT + 0.9FT SLR (SLR from Table 3, with 2050 projection and 10% likelihood)
- 10-year design wind coupled with an extreme low water, MLLW – 2FT (also considered as a 30-year joint storm scenario due to the low probability during the 10-year design life)
- Three wind directions: SSW, SW, and W

Model Simulations

The SWAN model was first set to run a total of 15 selected 100-year return period design cases (as listed in the previous page) to determine the governing 100-year design wave conditions for the design of contamination cap erosion protection and stability of shore protection/erosion control structures. Table 9 summarizes model input parameters for each of the run cases.

For mitigation design, similar model run cases can be defined for the 30-year return period design storm conditions as listed in the previous page using relevant design wind speeds from Table 7.

Table 9. Model run cases for 100-year design storm conditions.

Water Level Scenario	Run ID	Wind Return Period [year]	Wind Speed		Wind Direction
			[mph]	[m/s]	
MLLW-2FT	Case 1	30	57	25.5	SSW
	Case 2	30	49	21.9	SW
	Case 3	30	47	21.0	W
MLLW	Case 4	100	62	27.7	SSW
	Case 5	100	56	25.0	SW
	Case 6	100	52	23.2	W
MHHW	Case 7	100	62	27.7	SSW
	Case 8	100	56	25.0	SW
	Case 9	100	52	23.2	W
MHHW+2FT	Case 10	100	62	27.7	SSW
	Case 11	100	56	25.0	SW
	Case 12	100	52	23.2	W
MHHW+2FT+4.2FT	Case 13	100	62	27.7	SSW
	Case 14	100	56	25.0	SW
	Case 15	100	52	23.2	W

Figure 10 shows the locations of six cross-shore profiles initially set up to cover the marine areas of the cleanup project with each presenting a zone of different marine contamination level and coverage. Two wave extraction points were selected at each profile for extraction of wave conditions, one in the deep water (as waves approach to shore) and the other nearshore before the wave breaks. As shown in Figure 10, the deepwater extraction point is at the seaward termini (blue dots) of the profile and the other is in the midsection where the bed elevation is at approximately -5 FT (red dots). The depths (below NAVD88) for the extraction points are presented in Table 10.

Table 10. Water depth at extraction points.

Profile	Deep-Water Extraction Point	Depth below NAVD88 [FT]	Nearshore Extraction Point	Depth below NAVD88 [FT]
A	A	42.7	A1	5
B	B	38.5	B1	5
C	C	33.4	C1	5
D	D	35.1	D1	5
E	E	26.2	E1	5
F	F	28.7	F1	5

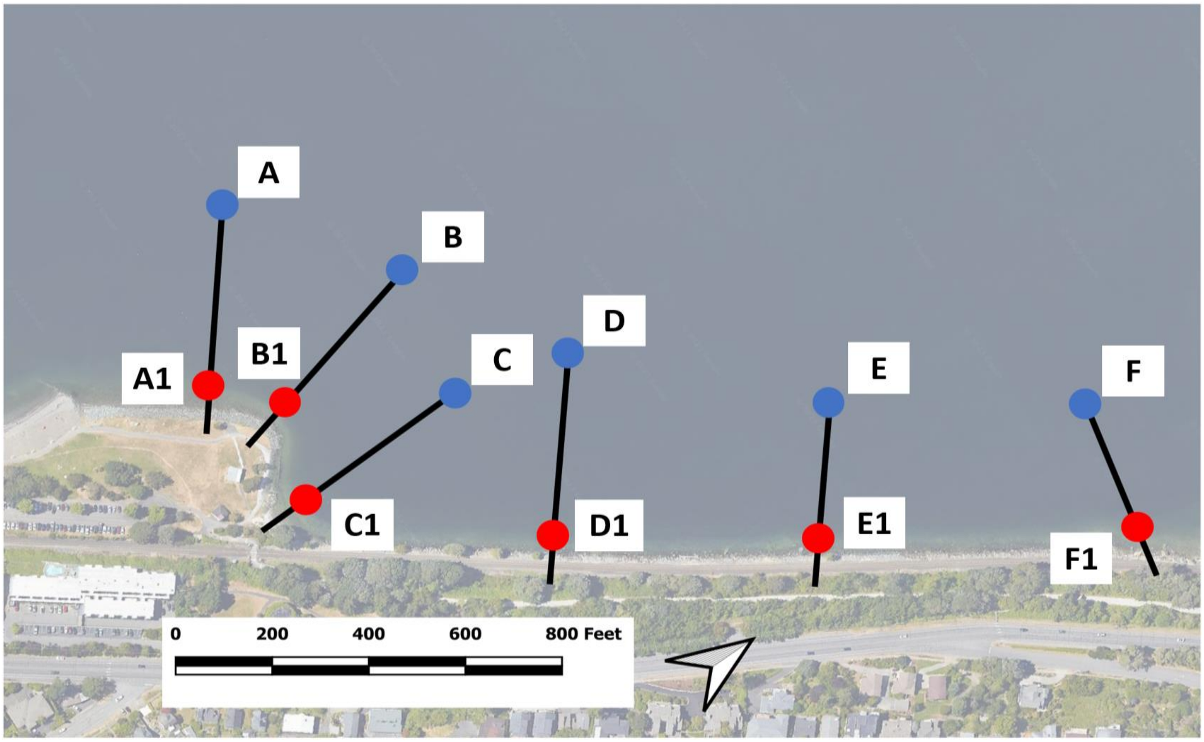

Figure 10. Shore-perpendicular profiles for six design cross-shore profiles. A-F are wave extraction points representing offshore conditions, while A1-F1 are wave extraction points representing nearshore conditions.

Model Results

100-year Design Storm Conditions

Figure 11 depicts significant wave height profiles for the extreme high-tide plus SLR scenario at the six profile locations shown in Figure 10. Wave height varies across the shore, decreasing as the wave transforms from the bay going onto the intertidal beach at the project site. Offshore of the site, winds from the SW produce the largest waves due to both higher wind speeds and longer fetch than winds from the W. In the nearshore however, winds from the W produce larger waves due to wave diffraction. In contrast, waves coming from the SW and SSW decrease in height as the waves bend around the west facing shore and some of their energy spreads out across a wider section of shore. The intertidal beach along all six profiles shows similar wave conditions for winds from the SW and W, while winds from the SSW produce noticeably smaller waves in the middle shore for northern profiles. Westerly winds, for the purposes of this study, therefore, are the governing winds and produce the largest waves for the nearshore for all profiles.

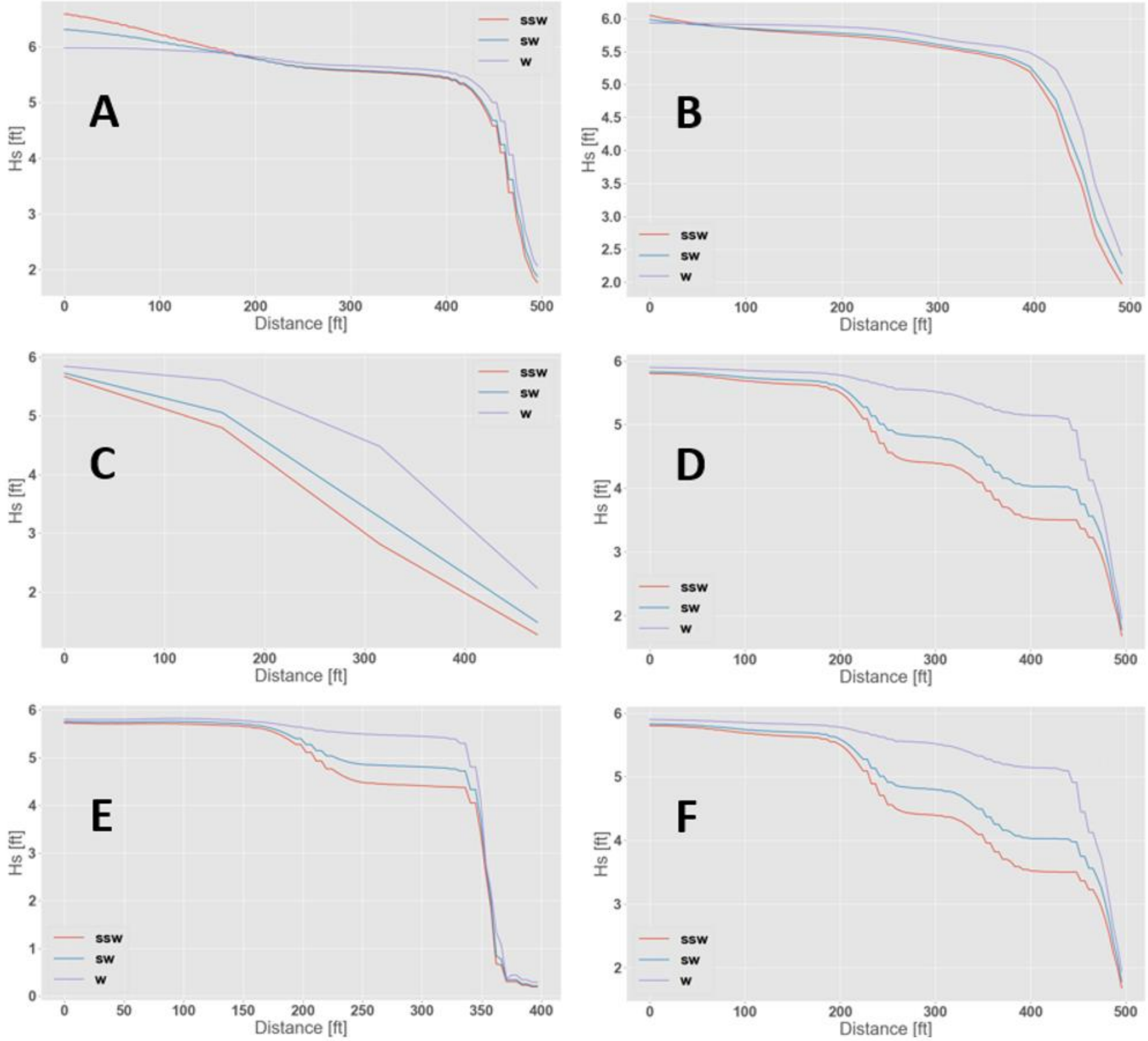

Figure 11. H_s along profiles A, B, C, D, E, and F for 100-year design winds from three directions at MHHW+2FT+SLR.

Figure 12 shows significant wave height diagrams for all run cases associated with westerly winds. Higher water levels produce more inundation and, for a given wind speed and direction, result in more landward intrusion of wave energy. Also, the site is more exposed to wave energy in the south and north areas (Profiles A, B and E, F) but the mid-section (Profiles C and D) is more sheltered with lower wave energy, particularly within the pocket beach in Profile C.

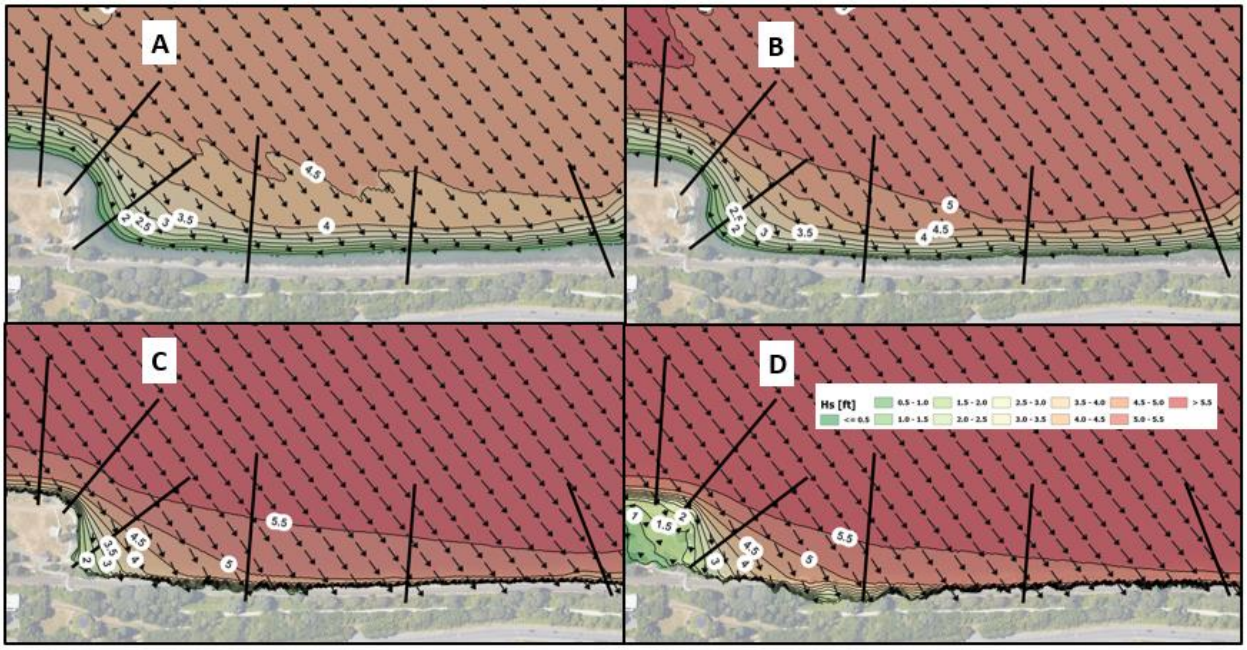

Figure 12. Significant wave height and direction for westerly wind, existing conditions. A) 30 YR winds at MLLW–2FT; B) 100 YR winds at MLLW; C) 100 YR winds at MHHW+2FT, and D) 100 YR winds at MHHW+2FT+SLR.

Compiled model results for existing conditions are shown in Table 11 for the six offshore extraction points and Table 12 for the nearshore extraction points where H_s is significant wave height and T_p is peak wave period. Red coloring in the significant wave height column indicates relatively larger waves (relative to all the wave heights in the table), and green indicates smaller waves. Wave energy propagates further inland under higher water level conditions, expressed in larger wave heights for higher water levels. Waves generated by westerly winds are slightly higher in the nearshore than waves generated by SSW and SW winds due to shore orientation and less wave refraction and diffraction despite lower wind speeds and shorter fetch. Profile C sees a reduction in wave heights further inland compared to the other profiles due to sheltering and wave diffraction.

Table 11. 100-year design waves at offshore extraction points

				Profile A			**Profile B**		
Water Level	**Return Period Wind**	**Direction**	**Speed [mph]**	Hs [ft]	Tp [s]	Direction [degrees]	Hs [ft]	Tp [s]	Direction [degrees]
MLLW - 2'	30 YR	SSW	57	5.08	5.07	237	4.99	5.07	238
		SW	49	4.72	4.47	243	4.64	4.47	244
		W	47	4.87	3.95	264	4.75	3.95	265
MLLW	100 YR	SSW	62	5.68	5.07	237	5.57	5.07	238
		SW	56	5.60	5.07	243	5.50	5.07	244
		W	52	5.53	4.47	264	5.42	4.47	265
MHHW	100 YR	SSW	62	6.28	5.07	234	5.84	5.07	237
		SW	56	6.10	5.07	240	5.78	5.07	244
		W	52	5.83	4.47	265	5.77	4.47	265
MHHW + 2'	100 YR	SSW	62	6.40	5.07	233	5.92	5.07	237
		SW	56	6.18	5.07	240	5.86	5.07	244
		W	52	5.88	4.47	265	5.82	4.47	265
MHHW + 2' + SLR	100 YR	SSW	62	6.58	5.07	232	6.05	5.07	236
		SW	56	6.31	5.07	240	5.99	5.07	243
		W	52	5.98	4.47	265	5.94	4.47	266
				Profile C			**Profile D**		
Water Level	**Return Period Wind**	**Direction**	**Speed [mph]**	Hs [ft]	Tp [s]	Direction [degrees]	Hs [ft]	Tp [s]	Direction [degrees]
MLLW - 2'	30 YR	SSW	57	3.54	4.47	252	4.81	5.07	240
		SW	49	3.63	4.47	258	4.52	4.47	246
		W	47	4.36	3.95	272	4.66	3.95	266
MLLW	100 YR	SSW	62	4.07	4.47	251	5.42	5.07	239
		SW	56	4.36	4.47	257	5.38	5.07	246
		W	52	5.02	4.47	272	5.33	4.47	266
MHHW	100 YR	SSW	62	5.37	5.07	241	5.70	5.07	239
		SW	56	5.43	5.07	248	5.68	5.07	245
		W	52	5.62	4.47	268	5.72	4.47	266
MHHW + 2'	100 YR	SSW	62	5.54	5.07	241	5.74	5.07	239
		SW	56	5.57	5.07	247	5.73	5.07	245
		W	52	5.70	4.47	267	5.77	4.47	266
MHHW + 2' + SLR	100 YR	SSW	62	5.67	5.07	240	5.80	5.07	239
		SW	56	5.73	5.07	247	5.83	5.07	246
		W	52	5.84	4.47	267	5.90	4.47	266
				Profile E			**Profile F**		
Water Level	**Return Period Wind**	**Direction**	**Speed [mph]**	Hs [ft]	Tp [s]	Direction [degrees]	Hs [ft]	Tp [s]	Direction [degrees]
MLLW - 2'	30 YR	SSW	57	4.57	5.07	241	4.81	5.07	239
		SW	49	4.35	4.47	247	4.49	4.47	245
		W	47	4.57	3.95	266	4.61	3.95	265
MLLW	100 YR	SSW	62	5.21	5.07	240	5.42	5.07	239
		SW	56	5.21	5.07	246	5.38	5.07	245
		W	52	5.23	4.47	266	5.28	4.47	264
MHHW	100 YR	SSW	62	5.62	5.07	239	5.73	5.07	239
		SW	56	5.60	5.07	246	5.70	5.07	245
		W	52	5.60	4.47	266	5.65	4.47	265
MHHW + 2'	100 YR	SSW	62	5.66	5.07	239	5.76	5.07	239
		SW	56	5.65	5.07	246	5.75	5.07	245
		W	52	5.66	4.47	266	5.72	4.47	265
MHHW + 2' + SLR	100 YR	SSW	62	5.73	5.07	240	5.83	5.07	239
		SW	56	5.75	5.07	246	5.85	5.07	245
		W	52	5.80	4.47	267	5.85	4.47	266

Table 12. 100-year design waves at nearshore extraction points.

				Profile A			**Profile B**		
Water Level	**Return Period Wind**	**Direction**	**Speed [mph]**	Hs [ft]	Tp [s]	Direction [degrees]	Hs [ft]	Tp [s]	Direction [degrees]
MLLW - 2'	30 YR	SSW	57	0.08	1.00	292	0.06	1.00	286
		SW	49	0.09	2.71	296	0.07	1.00	307
		W	47	0.13	5.07	309	0.06	1.13	324
MLLW	100 YR	SSW	62	0.16	4.47	298	0.16	1.45	314
		SW	56	0.19	4.47	301	0.17	1.45	322
		W	52	0.23	5.74	309	0.20	5.74	337
MHHW	100 YR	SSW	62	4.16	5.07	246	3.13	4.47	261
		SW	56	4.25	5.07	253	3.42	4.47	268
		W	52	4.59	4.47	273	4.14	4.47	281
MHHW + 2'	100 YR	SSW	62	4.80	5.07	243	3.67	4.47	255
		SW	56	4.84	5.07	250	3.95	4.47	262
		W	52	5.07	4.47	270	4.65	4.47	278
MHHW + 2' + SLR	100 YR	SSW	62	5.39	5.07	241	4.77	5.07	246
		SW	56	5.41	5.07	247	4.90	5.07	253
		W	52	5.52	4.47	268	5.31	4.47	272
				Profile C			**Profile D**		
Water Level	**Return Period Wind**	**Direction**	**Speed [mph]**	Hs [ft]	Tp [s]	Direction [degrees]	Hs [ft]	Tp [s]	Direction [degrees]
MLLW - 2'	30 YR	SSW	57	0.03	1.00	234	0.06	1.13	288
		SW	49	0.03	1.00	242	0.06	5.07	299
		W	47	0.06	1.00	297	0.13	5.74	306
MLLW	100 YR	SSW	62	0.05	1.00	267	0.28	5.07	286
		SW	56	0.07	1.00	283	0.31	5.07	286
		W	52	0.09	3.48	338	0.34	5.74	294
MHHW	100 YR	SSW	62	1.08	3.08	308	3.31	4.47	262
		SW	56	1.42	3.48	309	3.75	4.47	267
		W	52	2.33	3.95	314	4.61	4.47	277
MHHW + 2'	100 YR	SSW	62	1.19	3.08	305	3.42	4.47	262
		SW	56	1.55	3.48	307	3.91	4.47	266
		W	52	2.52	3.95	312	4.90	4.47	276
MHHW + 2' + SLR	100 YR	SSW	62	1.84	3.95	284	3.51	4.47	262
		SW	56	2.21	3.95	291	4.03	4.47	265
		W	52	3.07	4.47	304	5.13	4.47	276
				Profile E			**Profile F**		
Water Level	**Return Period Wind**	**Direction**	**Speed [mph]**	Hs [ft]	Tp [s]	Direction [degrees]	Hs [ft]	Tp [s]	Direction [degrees]
MLLW - 2'	30 YR	SSW	57	0.08	1.00	282	0.10	4.47	282
		SW	49	0.06	1.65	291	0.12	2.71	289
		W	47	0.12	3.08	309	0.17	5.07	298
MLLW	100 YR	SSW	62	0.26	5.07	283	0.19	3.95	291
		SW	56	0.28	4.47	287	0.20	4.47	296
		W	52	0.34	5.74	294	0.27	5.74	301
MHHW	100 YR	SSW	62	4.12	5.07	252	4.15	5.07	249
		SW	56	4.35	4.47	256	4.30	5.07	254
		W	52	4.78	4.47	271	4.65	4.47	269
MHHW + 2'	100 YR	SSW	62	4.30	5.07	251	4.61	5.07	246
		SW	56	4.62	4.47	256	4.75	5.07	252
		W	52	5.14	4.47	270	5.09	4.47	269
MHHW + 2' + SLR	100 YR	SSW	62	4.39	5.07	251	5.31	5.07	242
		SW	56	4.79	5.07	255	5.38	5.07	248
		W	52	5.42	4.47	270	5.53	4.47	267

30-year Design Storm Conditions

Two additional model cases were set up and run for the 30-year design storm conditions in support of habitat material assessment.

The 30-year design storm condition model run results revealed that the westerly wind combined with the highest water level (with SLR) resulted in highest waves in the entire project area which is likely to cause the greatest impact to the intertidal area and shoreline. The lowest water level scenario is also expected to have the greatest impact on subtidal seabed where eelgrass mitigation is located. Therefore, only the W wind direction and two extreme water level scenarios (MLLW-2FT and MHHW+2FT+ 0.9 FT SLR) were modeled. Table 13 summarizes model input parameters for each of the run cases, representing the worst-case-scenario 30-year return period design conditions.

Table 13. Model run cases for habitat material assessment design conditions.

Water Level Scenario	Run ID	Wind Return Period [year]	Wind Speed		Wind Direction
			[mph]	[m/s]	
MLLW-2FT	Case 16	10	43	19.2	W
MHHW+2FT+0.9FT SLR	Case 17	30	47	21.0	W

Wave conditions from SWAN runs for these two cases are shown in Table 14 and Table 15 for offshore and nearshore extraction points, respectively. These are considered the 30-year return period worst-case storm scenarios specifically for evaluating the stability of eelgrass habitat material in the proposed eelgrass mitigation areas and nearshore intertidal habitat material. While sediment cap erosion protection must be stable under 100-year return period storm conditions, the 30-year return period design conditions were adopted for the design of habitat restoration (corresponding to 10-year winds for eelgrass habitat restoration and 30-year winds for intertidal habitat restoration). As shown above, winds from the W govern nearshore design wave conditions and the lowest water level is expected to cause the most disturbance of bed sediment in the subtidal zone (between elevations -3 FT to -13 FT [NAVD88]) where eelgrass is present, and the highest water level is expected to cause the most disturbance in the intertidal zone.

Table 14. 30-year design waves at offshore extraction points.

				Profile A			Profile B		
Water Level	**Return Period Wind**	**Direction**	**Speed [mph]**	Hs [ft]	Tp [s]	Direction [degrees]	Hs [ft]	Tp [s]	Direction [degrees]
MLLW - 2'	10 YR	W	43	4.35	3.95	264	4.27	3.95	265
MHHW + 2' + SLR	30 YR	W	47	5.22	4.47	265	5.18	4.47	266
				Profile C			**Profile D**		
Water Level	**Return Period Wind**	**Direction**	**Speed [mph]**	Hs [ft]	Tp [s]	Direction [degrees]	Hs [ft]	Tp [s]	Direction [degrees]
MLLW - 2'	10 YR	W	43	3.95	3.95	272	4.20	3.95	266
MHHW + 2' + SLR	30 YR	W	47	5.08	4.47	267	5.14	4.47	266
				Profile E			**Profile F**		
Water Level	**Return Period Wind**	**Direction**	**Speed [mph]**	Hs [ft]	Tp [s]	Direction [degrees]	Hs [ft]	Tp [s]	Direction [degrees]
MLLW - 2'	10 YR	W	43	4.10	3.95	266	4.14	3.95	265
MHHW + 2' + SLR	30 YR	W	47	5.04	4.47	266	5.09	4.47	265

Table 15. 30-year design waves at nearshore extraction points.

				Profile A			Profile B		
Water Level	**Return Period Wind**	**Direction**	**Speed [mph]**	Hs [ft]	Tp [s]	Direction [degrees]	Hs [ft]	Tp [s]	Direction [degrees]
MLLW - 2'	10 YR	W	43	0.11	5.07	309	0.07	1.13	323
MHHW + 2' + SLR	30 YR	W	47	4.73	4.47	269	4.42	4.47	275
				Profile C			**Profile D**		
Water Level	**Return Period Wind**	**Direction**	**Speed [mph]**	Hs [ft]	Tp [s]	Direction [degrees]	Hs [ft]	Tp [s]	Direction [degrees]
MLLW - 2'	10 YR	W	43	0.03	1.00	314	0.10	5.07	310
MHHW + 2' + SLR	30 YR	W	47	2.38	3.95	311	4.44	4.47	276
				Profile E			**Profile F**		
Water Level	**Return Period Wind**	**Direction**	**Speed [mph]**	Hs [ft]	Tp [s]	Direction [degrees]	Hs [ft]	Tp [s]	Direction [degrees]
MLLW - 2'	10 YR	W	43	0.08	2.40	311	0.14	5.07	300
MHHW + 2' + SLR	30 YR	W	47	4.68	4.47	270	4.72	4.47	268

Design Waves

The maximum wave heights obtained from the above model runs, for both the 100-year and 30-year design storm conditions, are considered as the design waves for rock structure, erosion protection, and habitat designs, and for morphodynamic modeling as offshore incident wave conditions. These design wave conditions at extraction points as shown in Figure 10 are presented in Table 16.

Table 16. Design waves offshore and nearshore.

Profile	Sig. Wave Height offshore [FT]		Sig. Wave Height Nearshore [FT]	
	30-year RP	100-year RP	30-year RP	100-year RP
A	4.35	6.58	4.73	5.52
B	4.27	6.05	4.42	5.31
C	3.95	5.84	2.38	3.07
D	4.20	5.90	4.44	5.13
E	4.10	5.80	4.68	5.42
F	4.14	5.85	4.72	5.53

Design Concept Development

The overall goal of this coastal study, including coastal and geomorphic analyses and modeling, is to support the development of erosion protection design that provides bed stabilization for different in-water portions of the Site and different levels of contamination, and to addresses the need for placement of habitat substrate materials. Based on wave conditions this coastal study delineates the areas that require different erosion protection materials including gravelly sand, gravelly cobble, or armor rock and identifies what appropriate habitat substrate materials should be placed on the planned erosion protection areas to provide more habitat-friendly surfaces or to meet mitigation requirements resulting from capping. The study also evaluates the need for a rock groin structure proposed for wave attenuation and shore protection to benefit erosion protection and habitat mitigation goals.

Figure 13 shows a plan view of the proposed remedial action and mitigation design concept. Six cross sections are shown in the plan, going from Profile A to Profile F and from south to north. Additional details for the erosion protection and habitat recovery mitigation designs, including cross section profile details discussed in this section, are presented in the EDR report.

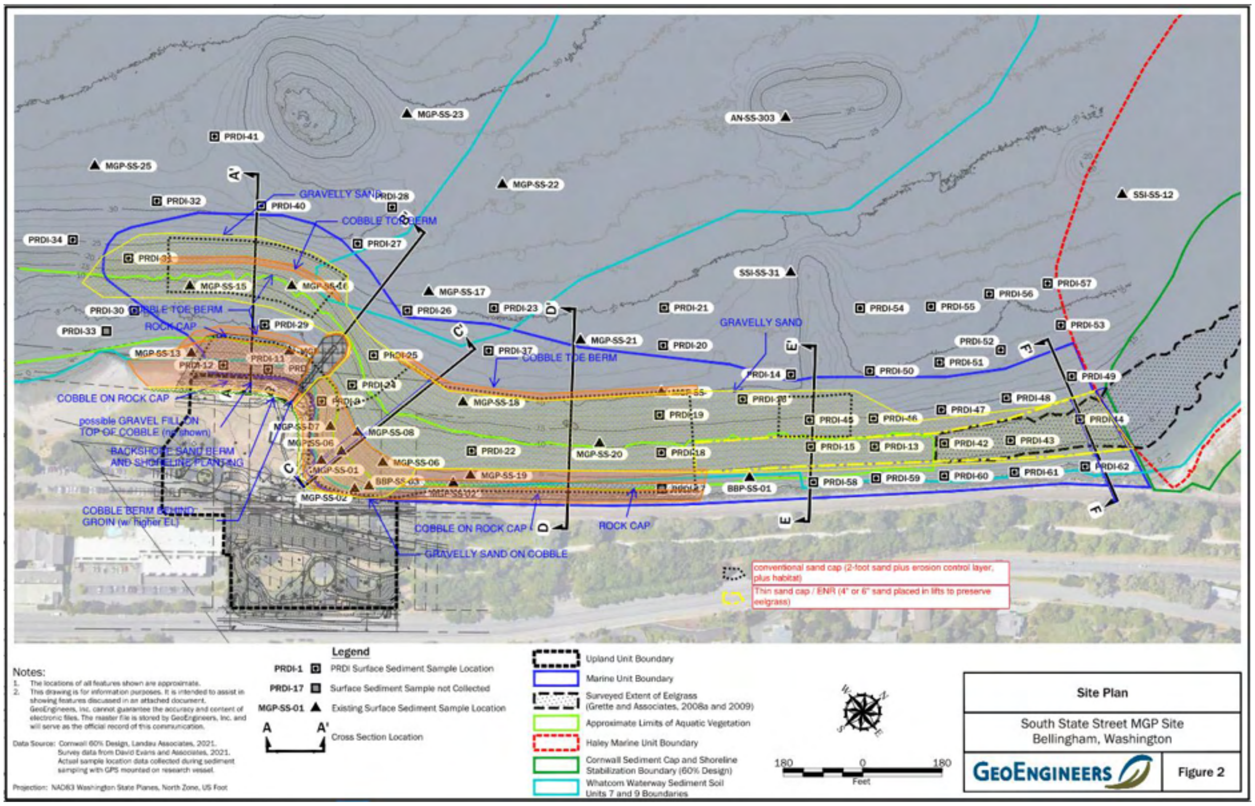

Figure 13. Plan view of conceptual design for SSSMPG.

Proposed Sediment Cap Erosion Protection

The erosion protection materials and coverage were initially derived based on contamination area coverage, the modeled wave conditions nearshore (as shown in Figure 12 – existing condition, and Figure 14 below – proposed conceptual design condition, including the rock groin structure), and the expected wave impact to the shoreline.

In general, wave impact on the seabed or shoreline is greater in the shallow intertidal area and decreases as water depth increases offshore. Also, wave impact is expected to be more significant in the high wave energy zones in the south and north areas (Profiles A, B and E, F) and the weakest in the inner pocket beach in Profile C due to local shoreline sheltering and wave diffraction (Figure 12).

Sediment in Profiles A through D, and a small portion of E, contain higher contamination levels and require sediment capping. The sediment capping in the intertidal area will require erosion protection, either by armor rock or by smaller gravelly cobble in the pocket beach depending on wave conditions in different zones. Profiles A through E also have subtidal capping areas requiring erosion protection. In the deeper, lower impact zones, gravelly sand is proposed to provide erosion protection for the underlying containment layer.

Proposed Mitigation Concept

Mitigation efforts proposed for the Site consist of several elements including placement of habitat substrate materials at the final surface in intertidal areas where larger erosion protection materials are used and placement of eelgrass substrate material at elevations suitable for eelgrass growth to mitigate for loss of eelgrass areas as a result of cap placement.

In the intertidal areas, gravelly cobble is proposed to be placed on armor rock south of the groin around profile A and north of the pocket beach around Profile D; gravelly sand is proposed on top of the gravelly cobble north of the groin and in the pocket beach.

At the locations represented by Profiles A through D, and a portion of Profile E, existing eelgrass beds in the subtidal zone will be covered in contaminated areas by sediment capping and erosion protection material placement. Gravelly sand material is proposed to be placed at elevations suitable for eelgrass habitat as part of mitigation for impacts resulting from capping and erosion protection material placement. In these subtidal areas, gravelly sand can be placed on top of the erosion protection for eelgrass restoration. Profiles E and F in the northern zone are similar and have areas of lower levels of contamination where placement of a thin layer of gravelly sand by small lifts (i.e., 2-inches thick each time) is proposed to enhance the natural recovery of sediment in the eelgrass area while preserving the existing eelgrass habitat.

Proposed Groin Structure

Profile C is in the pocket beach area where the nearshore 100-year design wave height is 44% less than the nearshore design wave height at Profile A for existing conditions. However, the nearshore highest design wave height in the pocket beach area is still 3.07 FT (Table 12) without any wave energy reduction measures south of the pocket beach. With sand capping that is required for the pocket beach area, the water depth over the entire area will be less, which increases the wave erosion potential for the lower intertidal area offshore of the pocket beach area and toward north in Profile D. This would likely result in requirement of armor rock for erosion protection in the waterward portion of the pocket beach.

To further reduce the wave energy in the pocket beach area, a groin structure is proposed along Profile B (Figure 13). The proposed groin design has a uniform minimum crest elevation of 12 FT from offshore to where the existing ground is approximately -1 FT elevation. The crest elevation then goes up to 14 FT elevation to meet the upper beach profile.

The primary function of the groin is to block or minimize wave transmission (through overtopping) into the pocket beach area around Profile C, with the objective of achieving the following:

- To extend the wave sheltering area of the pocket beach toward the subtidal zone and further north allowing for the use of gravelly cobble or gravelly sand material for erosion protection in the pocket beach area relative to the baseline assumption of a 2-foot layer of armor rock, particularly under SLR conditions
- To allow for the use of a smaller grain size gravelly sand over the erosion protection layer in the pocket beach area

The groin at this location will also serve another important function, which is:

- To adequately contain and stabilize placed habitat material (gravelly cobble) over the armor rock cap on this high energy intertidal beach south of the proposed groin

As the predominate wind and wave direction is from S to SW, certain longshore transportation of the habitat material toward the north by storm events is expected on the south beach depending on the placed material grain size. As the groin contains and blocks gravelly cobble habitat material over time, a sloped beach may be built up by the net longshore transport southward, and may reach an equilibrium whereby no further movement of gravelly cobble material will take place. This would also allow placement of larger size cobble material in the more erosive southern beach area while keeping smaller size gravelly cobble substrates in areas closer to the groin to enhance the habitat benefit.

In the absence of the groin, the habitat material could eventually migrate away from the area around Profile A, leaving armor rock more exposed and providing no further habitat benefits.

Modeling of Proposed Concept Conditions – Groin Effect

Figure 14 shows significant wave height diagrams for four wave model run cases associated with westerly storms and the proposed design concept including the groin structure. Model results show apparent attenuation of wave heights for all water level scenarios, and a much larger low wave energy zone in the pocket beach area (Profile C) as compared to Figure 12.

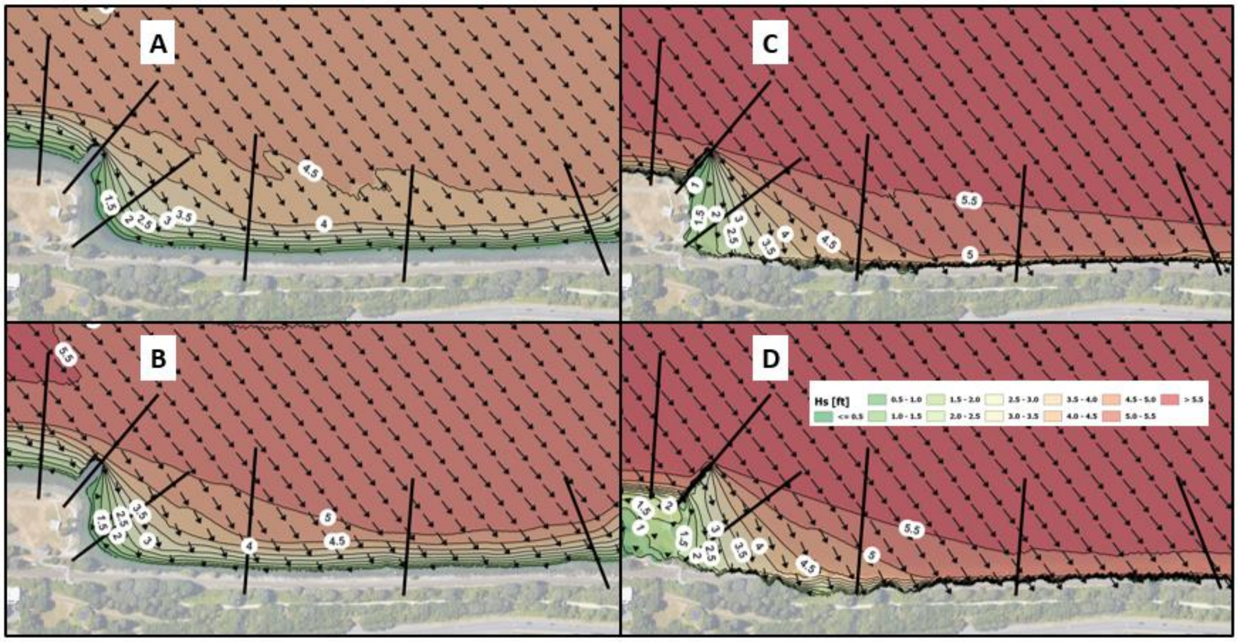

Figure 14. Significant wave height and direction for westerly wind, proposed conditions. A) 30 YR winds at MLLW–2FT; B) 100 YR winds at MLLW; C) 100 YR winds at MHHW+2FT, and D) 100 YR winds at MHHW+2FT+SLR.

Figure 15 compares the wave conditions with and without a groin in in the pocket beach area behind the groin. The areas of low wave energy in the intertidal zone (elevation greater than -5 FT, NAVD88), where wave heights are less than 3.5 FT, are delineated and are depicted in blue in Figure 15. Without the groin, the outskirts of the pocket beach in the intertidal area still experience higher waves, which will require armor rock for erosion protection. With the rock groin the entire pock beach area in the intertidal area falls in the low wave zone. The low wave energy area in the intertidal area has expanded waterward by a total of 22,800 SF, and the maximum wave height in the intertidal zone has reduced from 5.5 FT to less than 3.5 FT. This has allowed elimination of armor rock protection for erosion control in the intertidal zone.

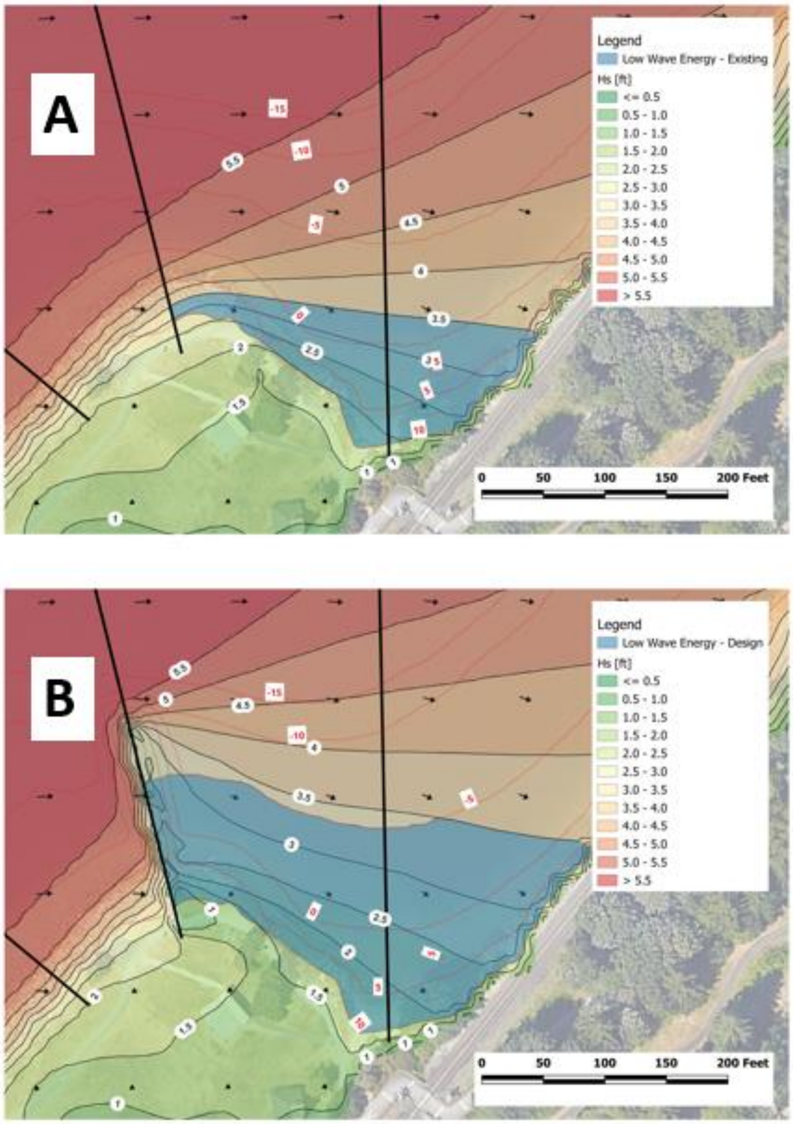

Figure 15: Significant wave height and direction for westerly wind and 100 YR winds at MHHW+2FT+SLR. A) without groin; B) with groin. Blue polygon indicates area of low wave energy in the intertidal (Hs < 3.5 FT).

The effect of the groin along Profile B for varying wind and water levels scenarios is shown in Figure 14 and Figure 16. The groin substantially reduces wave heights in the pocket beach area along Profile C. Wave height reduction immediately northeast of the groin is greater than 4 FT for the highwater conditions (Figure 16C and Figure 16D) and by over 40% at about 130 FT offshore for 100-year westerly winds at MHHW+2’ as shown in Figure 17.

Table 17 compares nearshore wave heights for existing conditions and with the groin. The 30-year design condition does produce inundation or wave action on top of the groin, so there is no value for Profile B for the 30-year design storm. The 30-year design condition sees approximately a 30% reduction in nearshore wave height for Profile C and a 20% reduction for the 100-year design condition.

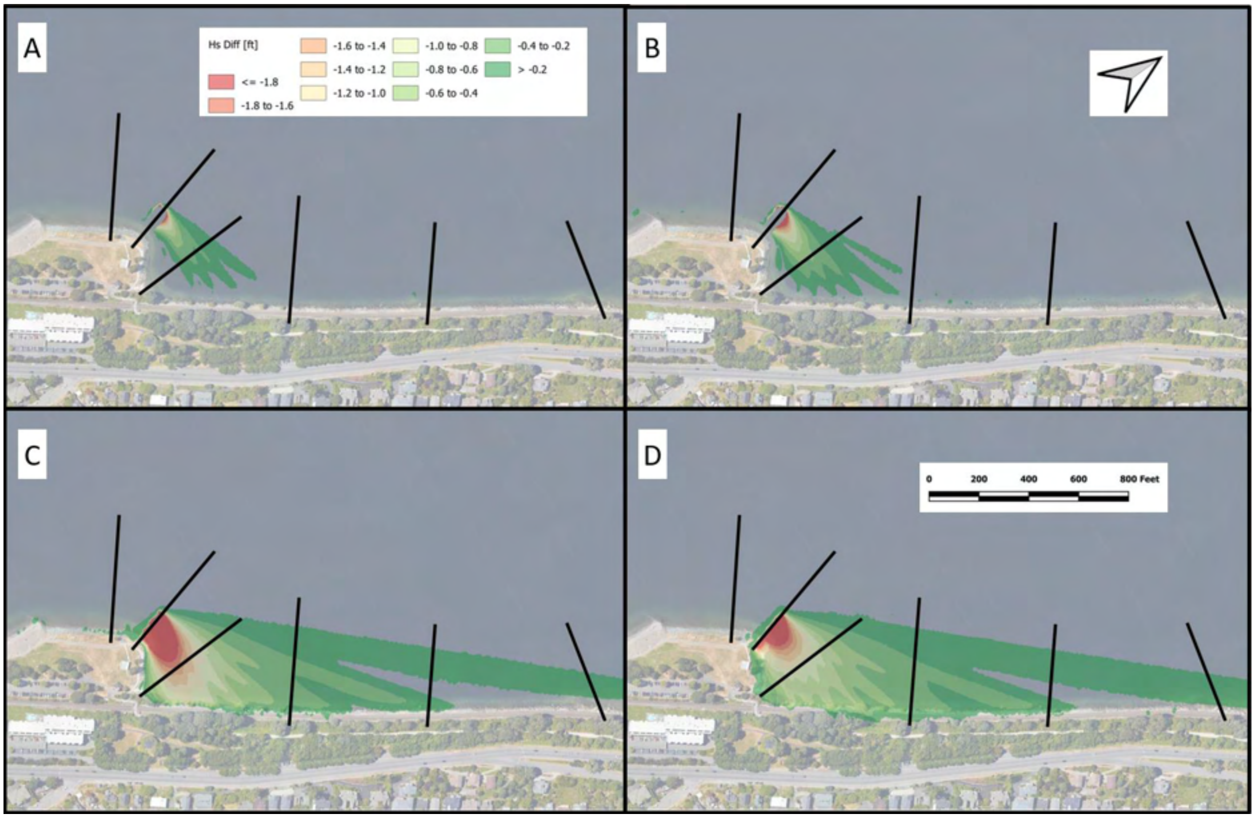

Figure 16. Difference of significant wave height (Hs) resulting from westerly wind with groin. A) 30 YR winds at MLLW-2FT, B) 100 YR winds and MLLW, C) 100 YR winds and MHHW+2FT, and D) 100 YR winds at MHHW+2FT+SLR

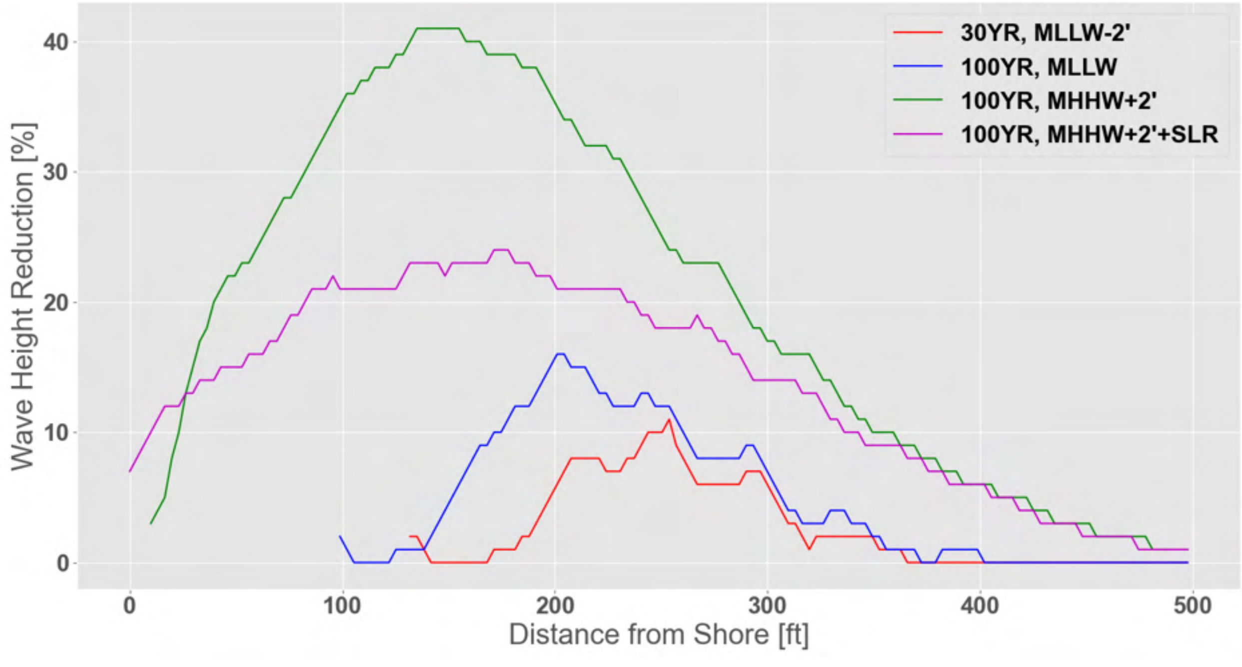

Figure 17. Wave Height reduction along Profile C for extreme water levels and wind conditions.

Table 17. Comparison of nearshore design wave heights between existing conditions and proposed design conditions (with groin). Wave extraction locations are shown in Figure 10.

Location	Sig. Wave Height - Existing Condition [FT]		Sig. Wave Height - Proposed Condition [FT]	
	30-year	100-year	30-year	100-year
A1	4.73	5.52	4.72	5.52
B1	4.42	5.31	N/A	2.24
C1	2.38	3.07	1.56	2.42
D1	4.44	5.13	4.18	4.91
E1	4.68	5.42	4.55	5.29
F1	4.72	5.53	4.68	5.44

Morphodynamic Modeling

Morphodynamic modeling was conducted with the XBeach 1D model, described below, to assess proposed gravelly cobble or gravelly sand beach responses and sustainability to a set of design storm scenarios and a representative individual storm. The 100-year design storm conditions were applied for proposed erosion protection layer material and the 30-year design storm conditions were applied for proposed habitat substrate material. The armor rock layer where it is proposed as erosion protection is assumed as non-erodible in the model. The armor rock and rock for shore protection structures were sized to be stable based on empirical formulations which is presented in the next section.

XBeach Model

XBeach is a process-based numerical model for simulating nearshore wave transformation and morphological processes and impacts on both sandy and gravelly coasts. The model was originally developed with sandy beaches in mind but has since been expanded to include new gravelly beach formulations, with increasing applications to the Puget Sound region.

The model includes the hydrodynamic processes of short-wave and long-wave transformation, wave-induced setup, as well as overwash and inundation. The morphodynamic processes include bed load and suspended sediment transport, dune face avalanching, bed update, and breaching. Extensive sensitivity tests were conducted in the initial model calibration stage to properly set up model parameters for modeling both sandy beaches and gravel beaches, including non-hydrostatic effect, water infiltration and exfiltration through sandy and gravel beds, and the effect of eelgrass.

For the Project, the 1-D XBeach model was adopted to model selected representative design beach profiles covering both intertidal and subtidal zones. The 1-D model was run in a non-hydrostatic mode for all model cases to more accurately resolve short wave hydrodynamics and wave interaction with the seabed in shallow waters.

The following wave processes are represented in the XBeach model:

- Wave propagation and shoaling from offshore to shore
- Shortwaves and shortwave runup
- Non-linear wave-wave interaction
- Wave breaking and bottom friction
- Eelgrass effect
- Infiltration and exfiltration (through sandy or gravelly beaches)
- Sediment transport and morphodynamic processes

XBeach Model Setup

Subtidal Gravelly Sand Bed

The proposed design for the subtidal area includes habitat material for eelgrass mitigation and restoration overlaying gravelly sand or gravelly cobble cap erosion protection material in contaminated areas. One purpose of the morphodynamic modeling was to assess the response of the eelgrass habitat material under 30-year design storm conditions. For subtidal areas with high contamination, a thicker layer of gravelly sand cover is proposed to ensure a sufficient layer of gravelly sand will remain stable and serve as the erosion protection even under the 100-year design storm conditions. These 100-year design conditions were also modeled.

The stability of gravelly sand placed in the subtidal area was modeled as sand-type beach using XBeach sand formulation. The grain size set up in the model for simulating gravelly sand consists of a 50% sand fraction with D_{50} of 0.5-mm (0.018-inches), and a 50% gravel fraction with D_{50} of 12-mm (0.47-inches), where D_{50} refers to the median grain size.

Intertidal Gravelly Cobble Bed

The intertidal mitigation and beach restoration in higher energy areas typically consists of gravelly cobble overlaying rock armor. Armor rock as erosion protection is typically required for high contamination areas in the intertidal zone where energetic waves break on the beach and at the shoreline, except for Profile C where waves are greatly attenuated due to local shore geometry and the proposed new groin. North of the proposed groin, in the area of Profile D, armor rock as erosion protection will also be required for containment of contaminated sediments.

Morphodynamic modeling for the intertidal beach was performed to assess the stability of the gravelly cobble beach in response to the 30-year design storm conditions. As such, the intertidal beaches were modeled as gravel-type beaches using XBeach gravel formulation. The grain size set up in the model for modeling gravelly cobble beach consists of a single fraction cobble material with D_{50} of 1.75-inches. The armor rock below the gravelly cobble layer is set as non-movable bed in the model.

The proposed design for the pocket beach Profile C in the intertidal consists of gravelly cobble as the erosion protection layer and overlayed by gravelly sand for the entire beach area (including subtidal) as part of proposed habitat mitigation and restoration.

Model Simulations

The 1D XBeach model was set up for two cross-shore profiles, Profile A and Profile D, representing different cleanup designs. The model was initially run for the existing conditions for Profile A for the purpose of model calibration and verification, and then run for the proposed design profiles A and D including sand cap, erosion protection and habitat design.

For the existing condition case for Profile A, the beach below elevation -3 FT NAVD88 is assumed as sandy beach with grain size D_{50} of 0.31-mm (0.012-inches) based on sediment sampling conducted during the PRDI for the subtidal portion of the beach (see Appendix H of EDR Appendix A). Based on observed armoring coverage (large rocks and bricks) of the portion of Profile A from the eelgrass bed to the existing revetment, it was assumed that the bed material from the eelgrass to the revetment was non-movable in the model. Therefore, this calibration/verification model only tests the morphodynamical subtidal sandy beach.

The selected governing design storm conditions include both 30-year habitat design storm conditions and 100-year erosion protection design storm conditions, with two governing water level scenarios representing the lowest and the highest water level conditions for the habitat and cap erosion protection designs. The low-water scenario is specifically for assessing the gravelly sand erosion protection and eelgrass bed stability in the subtidal zone, while the high-water scenario is for assessing the intertidal gravelly cobble beaches. The four model cases are summarized below.

30-year design storm conditions:

- 10-year design wave at MLLW-2FT: subtidal gravelly sand model
- 30-year design wave at MHHW+2FT+SLR: intertidal gravelly cobble model

100-year design storm condition :

- 30-year design wave at MLLW-2FT: subtidal gravelly sand model
- 100-year design wave at MHHW+2FT+SLR: intertidal gravelly cobble model

In addition, the model case for the representative 2018 storm event (Figure 7) was also modeled for a total of 33 hours with varying wave conditions and water levels. All incoming wave conditions for the XBeach model were derived from SWAN model outputs extracted at offshore locations shown in Figure 10.

Profiles E and F were not modeled as these areas have similar design offshore wave conditions and similar habitat restoration design as Profile D for the subtidal eelgrass zone. Model results from the Profile D simulation for the subtidal area can be correlated to Profiles E and F.

Profile C is located in the pocket beach area behind the proposed groin structure, where waves approach the shore through a strong diffraction zone. Therefore, wave transformation along Profile C cannot be correctly modeled by any 1-D wave model due to strong diffraction. It is believed, based on known nearshore design wave conditions and the proposed beach slope, that a dynamically stable nearshore sandy beach can be established in the pocket beach area through natural processes and will not need other engineered features to contain habitat material. The underlying gravelly cobble is also very stable and a conservative approach for contamination containment. 2-D morphodynamic modeling may be performed in the next design phase to further evaluate the need for the gravelly cobble protection layer in the proposed design.

Model Results

Figure 18 shows the existing beach response for Profile A for the four design conditions identified above, using sand and gravel models for the low- and high-water scenarios, respectively. The upper sub-panels show time varying cumulative erosion (red line) and accretion (blue line) at their maximum values over the profile in inches. The black line in the bottom sub-panels depicts the change in bed elevation in feet over the profile. The blue line in the bottom sub-panels represents the maximum water level over the course of the storms, and the green line represents the significant wave height from the SWAN model for a given storm. The storm condition model runs were executed for 2 hours each, representing enough time for a given storm condition to transition from extreme to non-extreme conditions. The red and blue dots in the bottom panels represent the locations of maximum erosion and accretion along the profile, shown as the corresponding lines in the upper panels.

For all storm conditions, net cumulative erosion and accretion are similar at approximately 2-5 inches over two hours of time. The small amount of erosion can be attributed to the eelgrass canopy and infiltration and exfiltration dissipating incoming wave energy. It should be noted that eelgrass in the model does not include the effects of the root systems securing the bed; it only accommodates wave dissipation in the canopy. This is why there is some small amount of erosion seen in the models; one would expect no erosion with the eelgrass root systems in place.

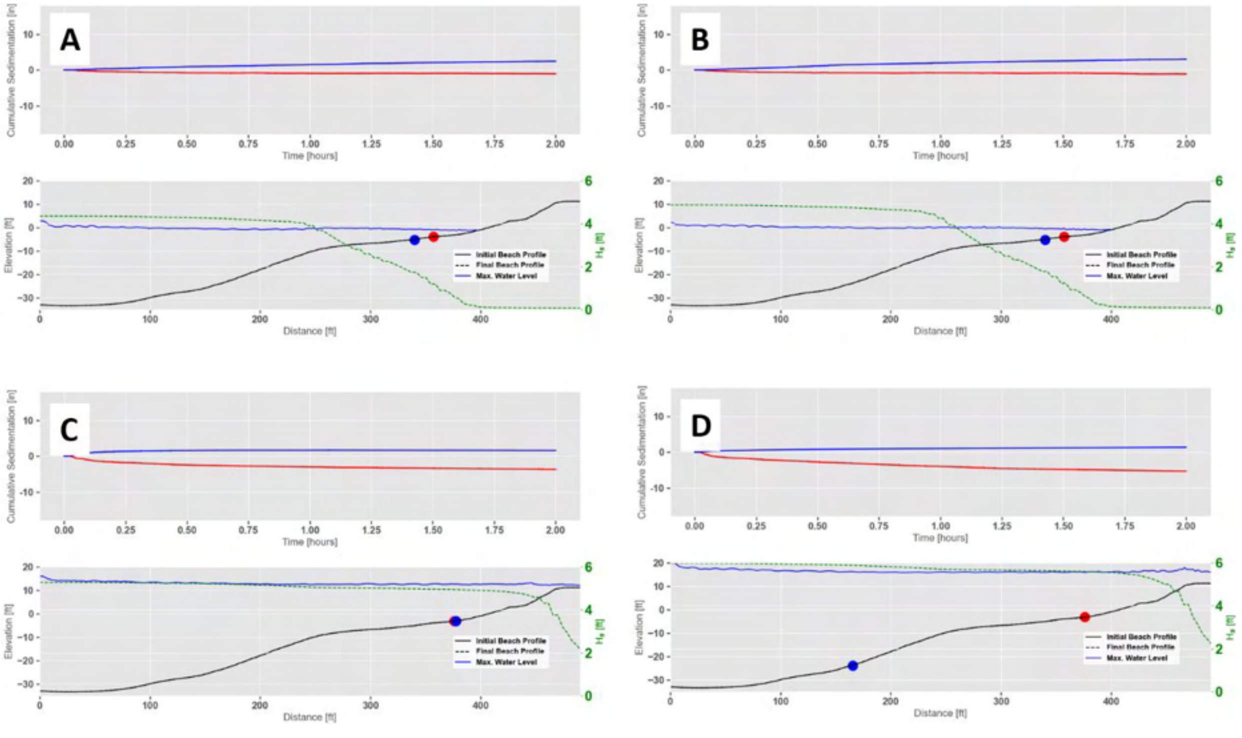

Figure 18. Beach response to design storm conditions for Profile A, existing beach condition, for A) 30 YR Low Water, B) 100 YR Low Water, C) 30 YR High Water, and D) 100 YR High Water.

Beach response to extreme storm conditions for the proposed design beach profile A is shown in Figure 19. The subtidal gravelly sand beach of Profile A shows a small amount of erosion locally over a two-hour storm duration (Figure 19A and 18B, low-tide cases). The modeled erosion is about 2 inches at the base of the cobble toe above the eelgrass bed. Such localized erosion is likely due to wave induced scour at the interface between two grain size sediments. As the tide rises the gravelly cobble may be moved by waves to fill the scoured spaces, creating more smooth transitioning and a more stable beach profile after such adjustment.

The intertidal cobble beach shows a greater response to design storms, with a maximum erosion of about 10-inches for both 30-year and 100-year storms (Figure 19C and Figure 19D, high-water cases). The intertidal beach, consisting of a larger gravelly cobble mix, is designed to dynamically adjust during large storm events. Large waves tend to push cobble up slope creating a steeper berm to stop beach material from moving further up. However, such levels of cobble material movement may result in exposure of armor rock layer in certain elevations and places over the course of storm events, which may not be fully recoverable. Besides, the 1D model did not take into account longshore transport of the habitat recovery material. This impact should be further evaluated in the detailed design phase using more advanced 2D morphodynamic modeling tools. For this EDR report, a larger grain size than what has been modeled is recommended for the southern cobble beach recovery/restoration over the armor rock cap where the beach is more open to large waves from both SW and W storms.

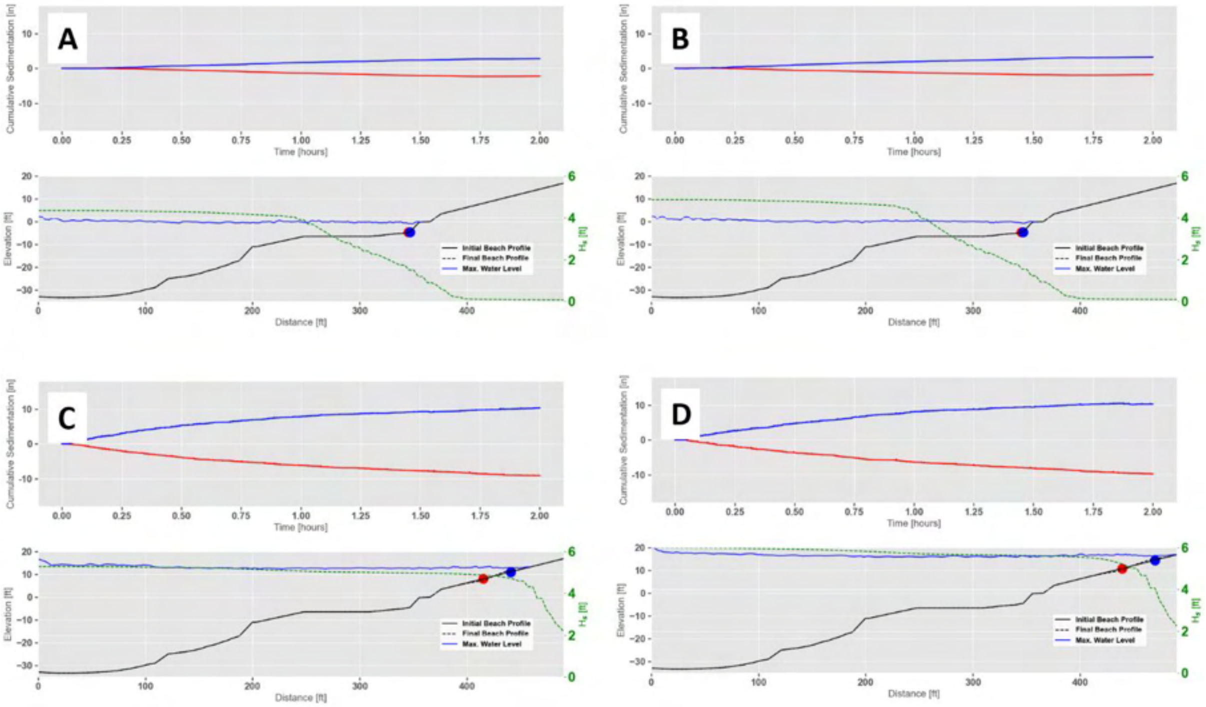

Figure 19. Beach response to design storm conditions for Profile A, proposed beach condition. A) 30 YR Low Water, B) 100 YR Low Water, C) 30 YR High Water, and D) 100 YR High Water.

Beach response to extreme storm conditions for the proposed design beach profile D is shown in Figure 20. The subtidal gravelly sand beach shows a similar response to Profile A with erosion of about 2 inches at the slope transition (Figure 20A and Figure 20B). The intertidal gravelly cobble beach shows less erosion than the subtidal beach as at Profile D waves attenuate more compared to Profile A as waves approach the shore. It also shows that the intertidal beach adjacent to the existing revetment is flatter and with subtidal elevation, both of which make the intertidal cobble beach more stable.

Beach response to the 2018 storm is presented in Figure 21. The response for both profiles is very similar to the results for a 100-year design wind event at MHHW+2FT. This result agrees well with co-occurrence of very high winds and high tide during the 2018 storm. The subtidal area sees almost no erosion given relatively low winds when water levels were low during the storm (Figure 7).

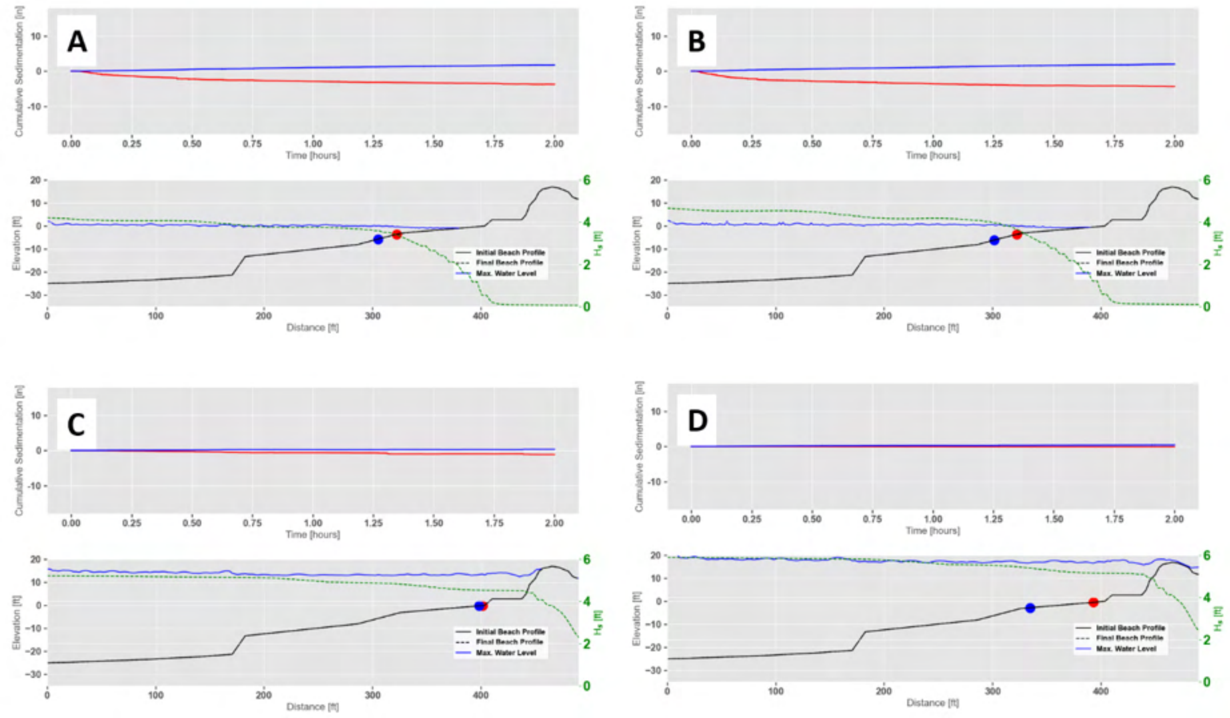

Figure 20. Beach response to design storm conditions for Profile D, proposed beach conditions. A) 30 YR Low Water, B) 100 YR Low Water, C) 30 YR High Water, and D) 100 YR High Water.

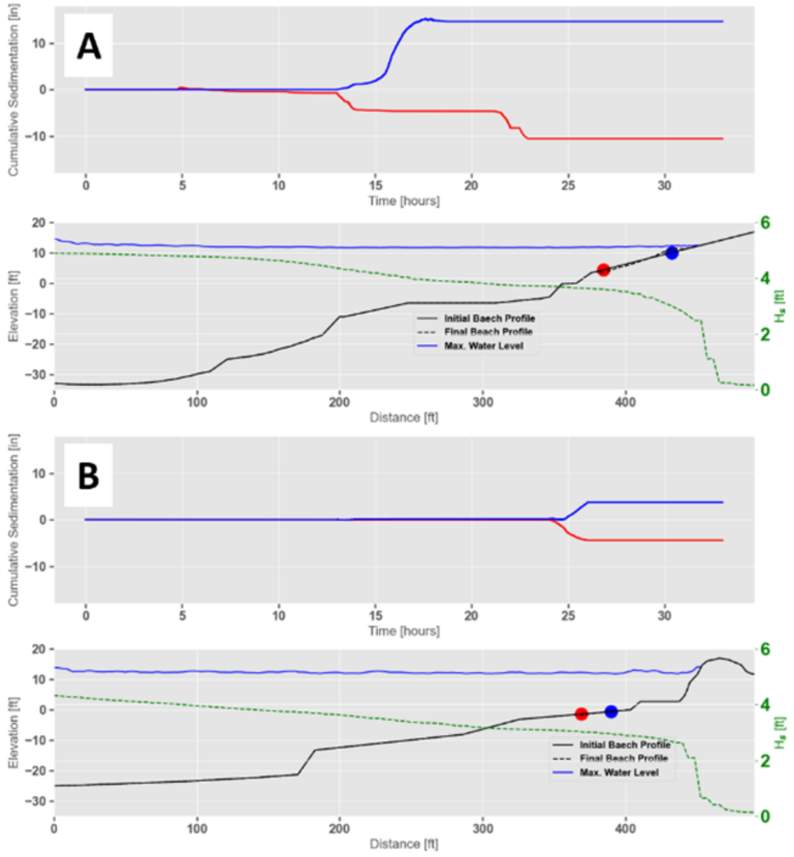

Figure 21. Shoreline response to 2018 storm conditions for A) Profile A and B) Profile D

Erosion Protection and Habitat Material Sizing, and Groin Rock

Nearshore design wave conditions were used to determine armor rock sizing for intertidal armor material, toe rock, and the proposed groin structure (Table 18). Toe rock is a rock structure at the waterward end of the intertidal rock capping for Profiles A and D to stabilize the armor rock toe and to contain intertidal cobble beach material. Rock sizing calculations were carried out using the formulations of Van der Meer (1988) following CEM (2003). The formulations take into account wave height, wave period, wavelength, and structure/beach slope to determine the stability of rock revetments.

Erosion protection and habitat material sizing was determined based on results of XBeach modeling described above. The resulting design rock sizes for cap erosion protection, toe rock, and proposed groin structure and beach aggregate sizes for erosion protection and habitat materials are presented in Table 18 below.

Table 18. Recommended habitat and erosion protection material sizes, and toe rock and groin rock sizes and maximum slopes.

Element	Maximum Slope	Minimum D_{50} [in]/W_{50} [lb]
Subtidal Eelgrass Habitat Gravelly Sand	10:1 ~ 20:1, varies with depth	D_{50} = 0.5”
Subtidal Erosion Protection Gravelly Sand	10:1 ~ 20:1, varies with depth	D_{50} = 0.5”
Low Energy Subtidal Habitat Mitigation Gravelly Sand (for eelgrass bed)	7.5:1	D_{50} = 0.5”
Low Energy Cap Erosion Protection Gravelly Cobble	7.5:1	D_{50} = 2”
High Energy Intertidal Habitat Mitigation Gravelly Cobble Beach	7.5:1	D_{50} = 2”
High Energy Intertidal Cap Erosion Protection Armor Rock	7.5:1	D_{n50} = 12 / W_{50} = 165
Toe Rock	3:1	D_{n50} = 20 / W_{50} = 800
Groin Rock	1.5:1	D_{n50} 28 / W_{50} = 2100

Summary

The data and model results presented in this report provide a comprehensive view of both existing and proposed design shoreline response to an extreme episodic (individual) storm and a range of potential return period storm events. Through an iterative process, the modeling efforts identified appropriate erosion protection and habitat substrate characteristics and shoreline geometry to ensure containment of contaminated sediment and maximize habitat benefits.

Modeling efforts included wind wave and morphodynamic modeling. Wind wave modeling was supported by a comprehensive review of wind data in and around Bellingham Bay, resulting in the production of a 44-year over-water wind record based on a synthesis of two Canadian climate models, RDPS and HRDPS, validated against observed wind records in Bellingham Bay. The wind record was used to develop extreme return period wind events, which were used to force a wave generation-propagation model, SWAN, to develop extreme return period wave conditions both offshore (in deepwater) and nearshore (at Elevation -5 FT NAVD 88, close to waterward limit of intertidal beach) to evaluate the stability of the erosion protection materials and habitat substrates and the effect of a proposed groin structure. Additionally, a representative storm event (the December 2018 storm) was modeled using measured wind records from the NDBC buoy in Bellingham Bay for comparison to the modeled wind conditions.

The resulting nearshore design wave conditions were used for sizing of erosion protection materials, rock toe, and groin material. Offshore wave conditions (approaching waves in deep-water off the site – see Figure 11) were extracted from the wind wave models and used to force morphodynamic models (XBeach) to model subtidal and intertidal morphological responses to extreme and representative storm conditions. The morphological modeling was used to inform/verify design sediment characteristics and beach profiles for both sediment cap erosion protection and habitat mitigation designs in both subtidal and intertidal beach zones under different design criteria.

The suggested cap erosion protection and habitat materials for consideration for subtidal eelgrass bed and intertidal beach restoration, (on top of erosion protection materials), rock cap erosion protection, and the rock material for the groin structure are summarized in Table 18 in the last section.

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Appendix F

Tsunami Impact Assessment Memorandum

Natural Systems Design
COASTAL GEOLOGIC SERVICES

memorandum

Date: February 15, 2024

To: GeoEngineers, Inc

From: Wei Chen, PhD and PE, Avery Maverick, MS and LG, and Ben Johnson, BS and GIT, Natural Systems Design + Coastal Geologic Services, Inc.

Re: Tsunami Impact Assessment – South State Street Manufactured Gas Plant EDR, Bellingham, WA - DRAFT

Introduction and Purpose

The purpose of this memorandum is to outline the potential tsunami hazard at the South State Street Manufactured Gas Plant (SSSMGP) cleanup site, located in Bellingham, Washington and its potential impact to the proposed contamination remediation and habitat mitigation design. The project site is bounded by South State Street to the east and the City of Bellingham's Boulevard Park to the South (Figure 1).

Figure 1. SSSMSG project site and vicinity map.

This assessment is based on the most recent tsunami modeling study for the Bellingham area conducted by the Washington Department of Natural Resources (DNR) (Dolcimascolo et al., 2021). Results of the DNR report include tsunami induced inundation levels and current velocities for the Bellingham area based on tsunami waves generated by a magnitude 9.0 Cascadia Subduction Zone Extended L1 earthquake scenario (a splay fault ground deformation model). Other studies related to local submarine landslides potentially caused by reginal large earthquakes (Shipman, 2001) and quaternary fault movements are also referenced (Atwater, 1992; Williams and Hutchinson, 2000).

Sources of Tsunami Risk

A tsunami is a series of traveling ocean waves generated primarily by earthquakes (crust movement) that occur below or near the ocean floor. Other triggers include underwater landslides and volcanic eruptions. As tsunami waves reach shallow waters near the coast, the waves slow down, and the water can pile up due to shortening of wave length and amplifying wave height. This effect can be magnified by local shoaling effect or where a bay, harbor or lagoon funnels the waves as they travel inland.

The project site is characterized as prone to tsunami hazard by the DNR, and tsunamis associated with the following earthquake scenarios may potentially impact the site.

Cascadia Subduction Zone

In the Pacific Northwest, the major source of tsunamis is the Cascadia Subduction Zone (CSZ, Figure 2) which is an approximately 600-mile-long fault that stretches from north Vancouver Island to Cape Mendocino, California (Roten et al., 2020). The fault zone separates the Juan de Fuca and North American plates, and as the Juan de Fuca plate moves towards the continental plate, it is subducted beneath. Along this plate boundary, the CSZ is locked by friction allowing strain to build up until the frictional strength is exceeded, and the plates slip past each other along the fault in a "megathrust". The displacement and movement of the seafloor generated by an earthquake creates tsunami waves which could reach the Pacific Coast within 15-30 minutes of the earthquake (Clague, 1997).

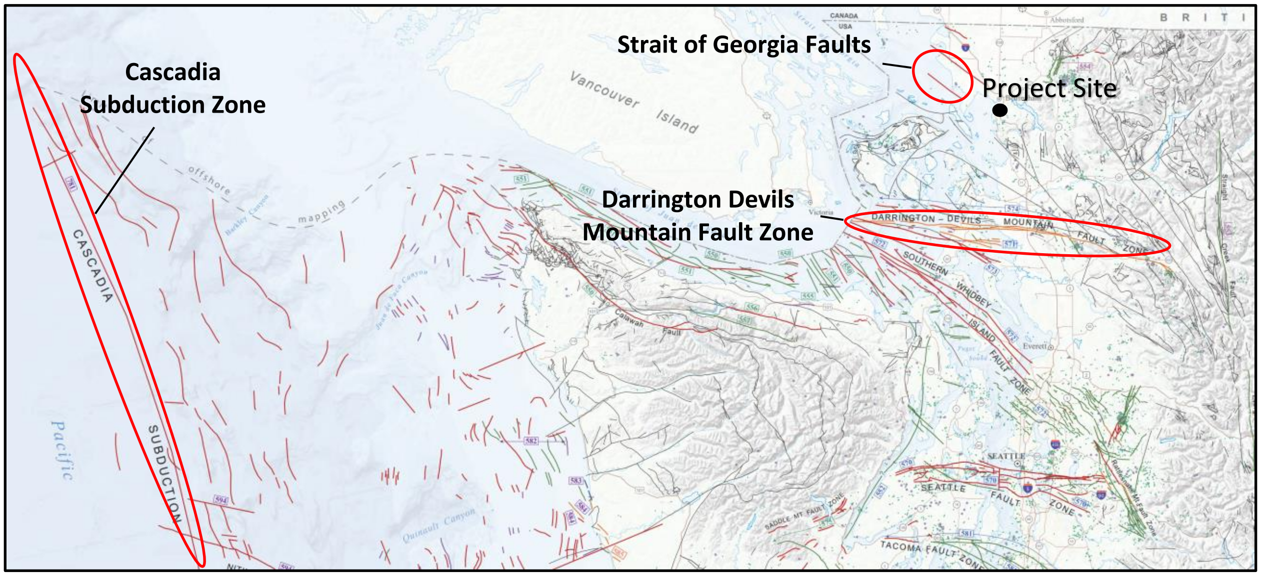

Figure 1. WA Geologic Hazard Maps: 2014 state-wide compilation of active faults (colored lines) (Bowman and Czajkowski, 2019).

The type of earthquakes produced along fault boundaries such as the CSZ are some of the largest in the world. The associated tsunami could impact Whatcom County including the project site at different scales. The CSZ had produced magnitude 9.0 or greater earthquakes in the past and likely will in the future. January 1700 was the last known megathrust earthquake in the Pacific Northwest, and geologic evidence of tsunami deposits indicates that similar earthquake magnitudes have occurred at least six times in the last 3,500 years, with an average recurrence interval (ARI) of about 500 to 540 years (Eungard et al., 2018).

Local Earthquake and Landslides

Other faults in Puget Sound can also move the ocean floor and trigger submarine landslides to cause tsunamis in the region. There is geologic evidence of tsunamis derived from the Seattle Fault that occurred between 500 and 1,700 years ago near Seattle, along Whidbey Island, and in the Strait of Georgia north of Lummi Island (Atwater, 1992). Other local crustal faults such as the Tacoma Fault and Darrington-Devils Mountain Fault Zone could produce tsunamis (Figure 2) (Williams and Hutchinson, 2000). Notably in the 1820s a large landslide at Camano Head triggered a localized tsunami that buried an entire village on Hat Island (Shipman, 2001).

Within the Salish Sea there is other evidence of landslide-generated tsunami deposits that could be attributed to triggering by local earthquakes (Bucknam et al., 1992; Washington Geologic Survey, n.d.). The recurrence intervals of these types of earthquakes are not well known due to the lack of published studies and insufficient records.

The impact of local landslide generated tsunamis would most likely be confined spatially due to the complex geometry in the Puget Sound region. Such tsunami waves would hit only the shorelines with direct exposure to the tsunami source. In the vicinity of the project site, the Darrington–Devils Mountain Fault to the south or other smaller fault zones in the Strait of Georgia (Figure 2) could be potential sources of sea floor landslides. However, tsunami hazards caused by these sources to the project site are likely low as tsunami surge waves would be largely blocked by Whidbey and Lummi Peninsulas and many surrounding islands before they could enter Bellingham Bay. Also the probability of such an earthquake that could trigger a sizeable tsunami at the right location is believed to be low, with an ARI greater than 5,000 years (Johnson et al., 2016). Within Bellingham Bay, the seabed is relatively flat and shallow with no identified active faults. Therefore, the risk of locally generated tsunami impact to the project site is considered extremely low.

Distant Earthquake and Landslides

Subduction zones and faults around the Pacific Ocean can also trigger tsunamis and impact Washington shorelines. However, the areas of impacts are largely communities on the Pacific Coast. Of the many historical events that have occurred, only the 1964 Alaska earthquake generated a tsunami that caused damage on the Washington outer coast. The probability of tsunami impact from these distant events to the project site in Puget Sound is extremely low.

Local Tsunami Impact Modeling

Tsunami generation and propagation and its impact in the Bellingham Bay east shore and the project area were most recently modeled by the NOAA Center for Tsunami Research, the University of Washington’s tsunami modeling group, and the Washington Geological Survey (Dolcimascolo et al., 2021). The study considered an EXTREME tsunami scenario generated by an Extended L1 CSZ earthquake, which was estimated to have occurred in the top three CSZ earthquake events impacting the area in the last approximately 10,000 years, or a recurrence interval between 2,500 and 5,000 years. This is a similar probability of occurrence as the International Building Code seismic standard of 2 percent probability of exceedance in 50 years (Eungard et al., 2018).

Previous studies of the area by the DNR (e.g., Eungard et al., 2018) used the L1 scenario, which depicts the earthquake rupture stopping at approximately the southern end of Vancouver Island and was originally designed for tsunami hazard assessment in Oregon. The Extended L1 scenario continues the rupture to account for the entire length of the subduction zone. When the L1 and Extended L1 earthquake scenarios are compared the truncated L1 scenario noticeably underestimates inundation in Washington's inner waterways, including Bellingham Bay and the Strait of Georgia. The Extended L1 scenario gives a more realistic estimate of tsunami impacts to Washington State from a full CSZ rupture and is therefore the more conservative choice to use when assessing tsunami risk along Washington's inner coastlines (Dolcimascolo et al., 2021).

Inundation

Tsunami induced inundation was modeled with the still water level set at mean high water (MHW). Tidal variations and future sea level rise were not taken into consideration.

The tsunami model results (Figure 3) shows that the entire eastern coast of Bellingham Bay in the vicinity of the SSSMGP site would be impacted by the worst-case scenario tsunami as it is modeled (a return period of over 2500 years). The maximum inundation in downtown Bellingham, located 1.1 miles to the northeast of the SSSMSG site, was modeled and reported at approximately 10.7 FT, and the maximum inundation in Fairhaven (at the ferry terminal), located 1.0 mile southwest of the site, was modeled and reported at approximately 10.3 FT. At the SSSMGP site, the entire marine unit and the western portion of the upland unit was modeled to be inundated (Figure 3). The highest inundation was modeled to be the shore located west of the BNSF railroad, along the central and northern portion of the site. The waterward edge of the site (close to the MHW line) is modeled to experience a maximum inundation likely over 10 FT and approximately the lower half of upland contaminated area, which covers the entire lower park area (mostly west of the railway track) will be under water with inundation ranging from 2 FT to 6 FT. It should be noted that the impacts of a tsunami to this project would not be reflected by coastal inundation but more by tsunami waves and associated currents, which is addressed in the following section. However, it is clear from the below inundation map that the impact of the flooding caused by an extreme tsunami event to the surrounding coastal areas and its associated economic cost would far outweigh its impact to the cleanup project.

Current Speed

The modeled current speed in the DNR mapping is separated into four ranges (Dolcimascolo et al., 2021):

- 0 – 3 knots
- 3 – 6 knots
- 6 – 9 knots
- > 9 knots

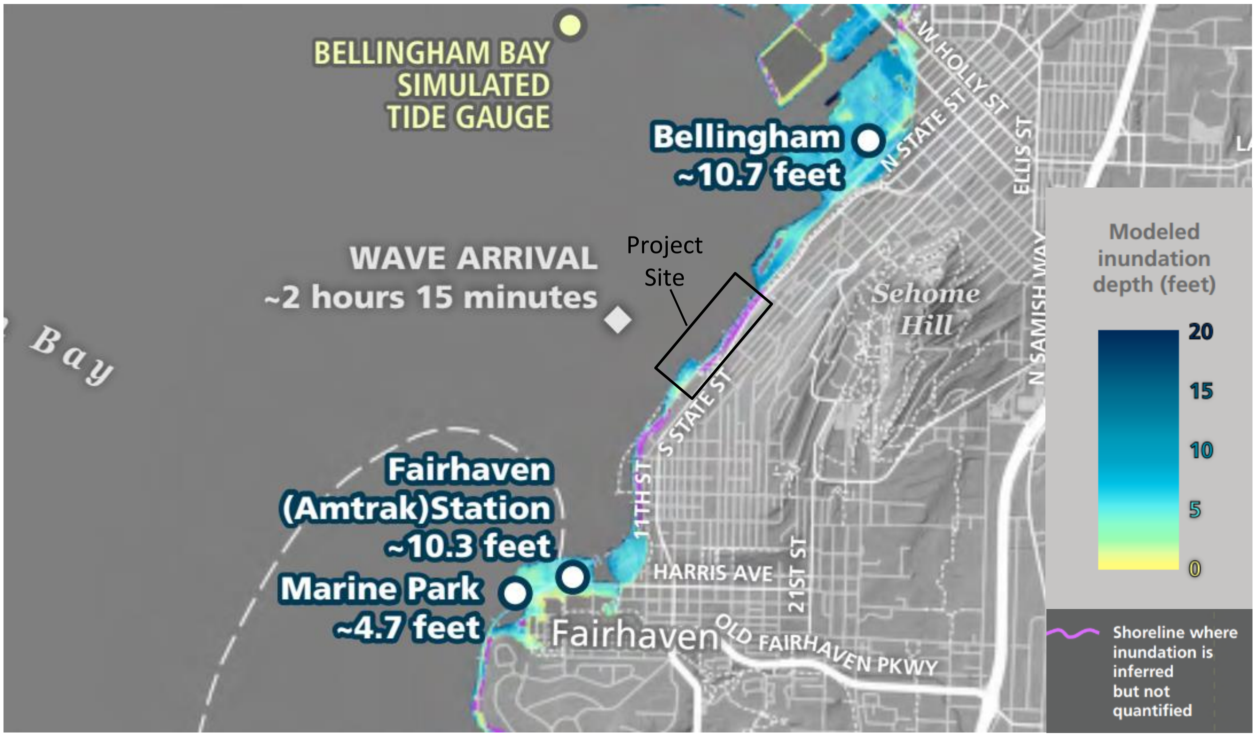

Figure 3. Tsunami inundation map of the project site and vicinity with predicted inundation depth points. Map from WA DNR (Dolcimascolo et al., 2021).

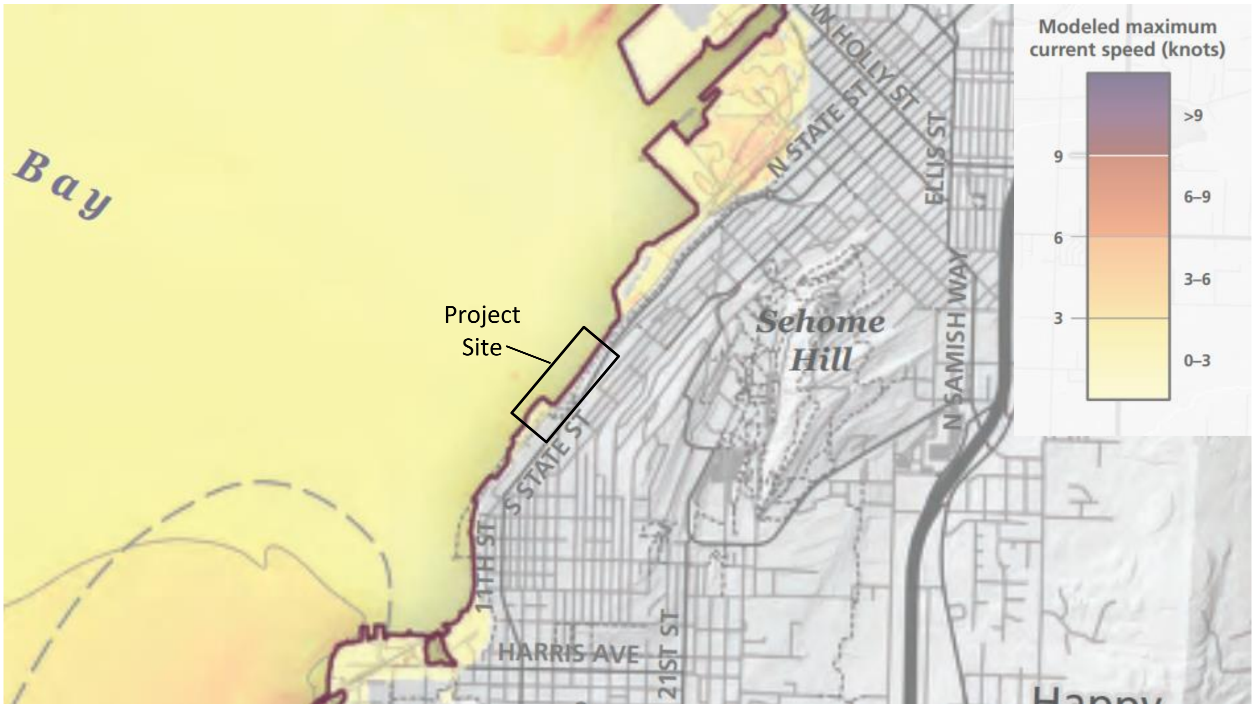

Figure 4. Tsunami current speed map for Bellingham Bay and the SSSMGP site. Data are from Dolcimascolo et al., 2021 for the CSZ extended L1 magnitude 9.0 earthquake scenario.

Modeled current speeds are the strongest in narrower waterway channels and in the nearshore where local bathymetry and geometry can focus currents. Much of Bellingham Bay is broad with few constrictions, and therefore current speeds are lower than in other more constrained areas such as the

San Juan Islands. Along the project site, current speeds are modeled at 0 – 3 knots for the inundated area (Figure 4).

For reference, 3 knots is about the magnitude of large storm wave generated flow velocity in the shallow water or on the beach. In theory, the proposed rock structures and rock capping originally designed for the 100-year storms should withstand such magnitudes of tsunami waves and currents. However, localized damage is possible because of local flow acceleration or debris impact, but such damage level is likely to be limited and can be repaired after the tsunami event.

The resilience of proposed bed sediment cap in the subtidal zone and gravel-cobble or sandy beaches in the intertidal (as part of the mitigation plan) certainly depends on the severity of the tsunami event. The beach may be vulnerable to some level under the extreme tsunami scenario, but it is hard to accurately evaluate the impact level without reviewing more detailed modeling results associated with tsunami flow regimes, processes, and spatial variations. Overall, the impact is believed to be manageable even for the worst-case scenario, and the risk level is considered low due to the following reasons:

- the extremely low occurrence probability
- low short-term environmental impact
- manageable cost for the post-event repair/remediation.

Surge Waves and Timing

Tsunami waves approach the shore in the form of a series of pulsive surge waves. Arrival times were estimated from the time of the earthquake to the first surge water front that rises above high tide. This first surge wave does not necessarily correlate with the maximum inundation. Initial disturbances were modeled at several locations with the closest location being at the Port of Bellingham in Bellingham Bay, approximately 1.4 miles northwest of the site (Figure 5).

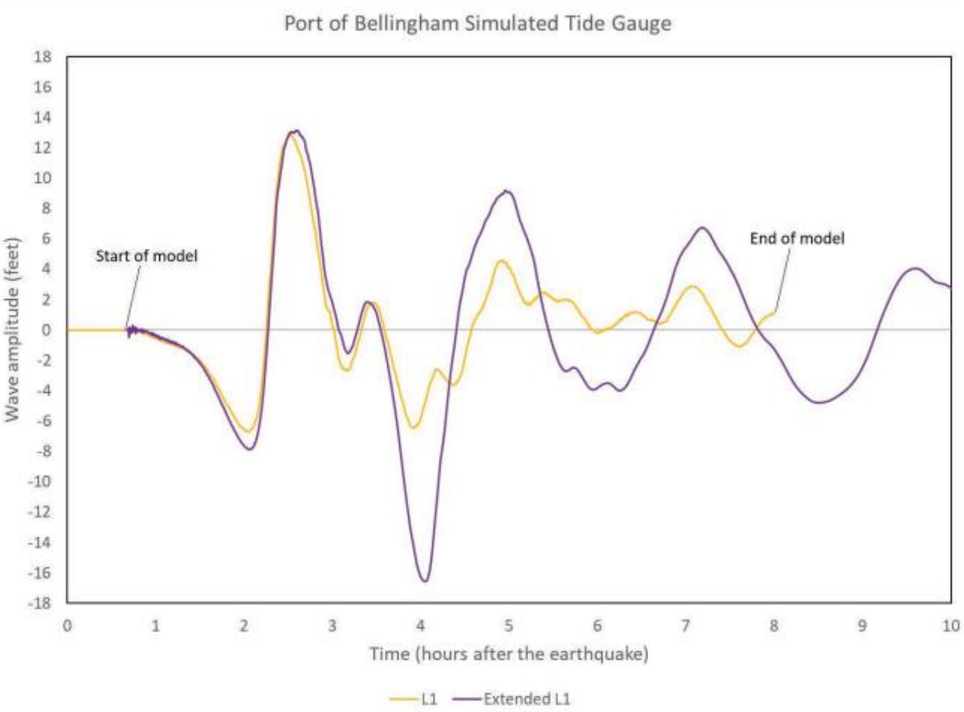

Figure 5. Modeled tsunami wave variations over time for Bellingham Bay. Projections from Dolcimascolo et al., 2021 for the CSZ L1 (yellow) and extended L1 (purple) magnitude 9.0 earthquake scenario.

The initial disturbance in Bellingham Bay was modeled as a gradual 6 to 8 FT fall in water levels occurring between 1 and 2 hours after the earthquake followed by a rapidly rising wave arriving at about 2 hours and 15 minutes (Figure 5). In Bellingham Bay, the first wave is expected to be the largest at about 13 FT (Figure 5), peaking at about 2 hours and 40 minutes after the earthquake. Tsunami waves will likely reach the site at about the same time as the Bellingham Bay simulated tide gauge.

Higher water than normal is expected to last for at least 10 hours and minor inundation and elevated current may continue for 24 hours or longer after the earthquake. To put this into context, the 1964 magnitude 9.2 earthquake in Alaska produced a tsunami on the outer coast of Washington that lasted for about 12 hours (Walsh et al., 2000).

Summary and Conclusions

The SSSMGP cleanup site is potentially exposed to two sources of tsunamis: the Cascadia Subduction Zone (CSZ), and local earthquakes and landslides. Distant earthquakes are not seen as a significant risk as they would be located a significant distance from the site. Local earthquakes causing sea floor landslides inside Bellingham Bay are extremely unlikely as the sea floor in the entire bay is relatively shallow and flat. Local tsunamis generated by sea floor landslides in the vicinity outside the Bay are also rare (over 5000-year recurrence interval) and their impact to the project site is likely limited as tsunami waves would largely be blocked by islands and peninsulas. Of these types, a tsunami produced from the CSZ is seen as the prominent tsunami hazard at this site.

Modeling results outlined in Dolcimascolo et al. (2021) represent an approximately 2,500-year recurrence interval scenario or approximately the 2 percent probability of exceedance in 50 years. Under the extreme circumstances of the model scenario, the low-lying beach and shore bank area above MHW is expected to be inundated by 6-10 FT of water or more, and the entire lower park in the upland contamination unit would be inundated by approximately 2-6 FT of water. The lower peak surging water velocity associated with the tsunami waves as modeled is predicted at 0-3 knots.

The tsunami impact on the proposed project is assessed mainly based on the predicted velocity by the model. At a velocity magnitude of 1-3 knots rockery remediation components including groin structures and rock capping in the intertidal and bank zones are expected to survive the tsunami impact. The impact to sediment capping areas in the subtidal and intertidal areas and the lower upland park is likely to be more significant, but the level of damage will depend on the level and the intensity of the next tsunami event.

The exact earthquake scenario for the next large earthquake will likely differ causing the tsunami to differ as well. Studies have suggested that most likely the next earthquake will be about two-thirds the size of the Extended L1 scenario that is modeled and referenced in this memorandum, creating a smaller tsunami than the reported one (Witter et al., 2011), which could see significantly reduced impact to this project.

Overall, the potential future tsunami impact to this project is believed to be manageable and the risk level is considered low due to its low probability of occurrence. It should be noted that the impact of flooding caused by an extreme tsunami event to the surrounding coastal areas and its associated economic cost would far outweigh its impact to this project.

Limitations of This Report

This memorandum was prepared for the specific conditions present at the subject site. No one other than the project team and their agents should apply this memorandum for any purposes other than that originally contemplated without first conferring with the geologists or engineer that prepared this report. This assessment was mainly based on DNR tsunami modeling work (Dolcimascolo et al., 2021). Even the modeling scenario is considered conservative limitations associated with model assumptions (such as future sea level rise etc.) and the uncertain and complex nature of the tsunami extreme events should be noted.

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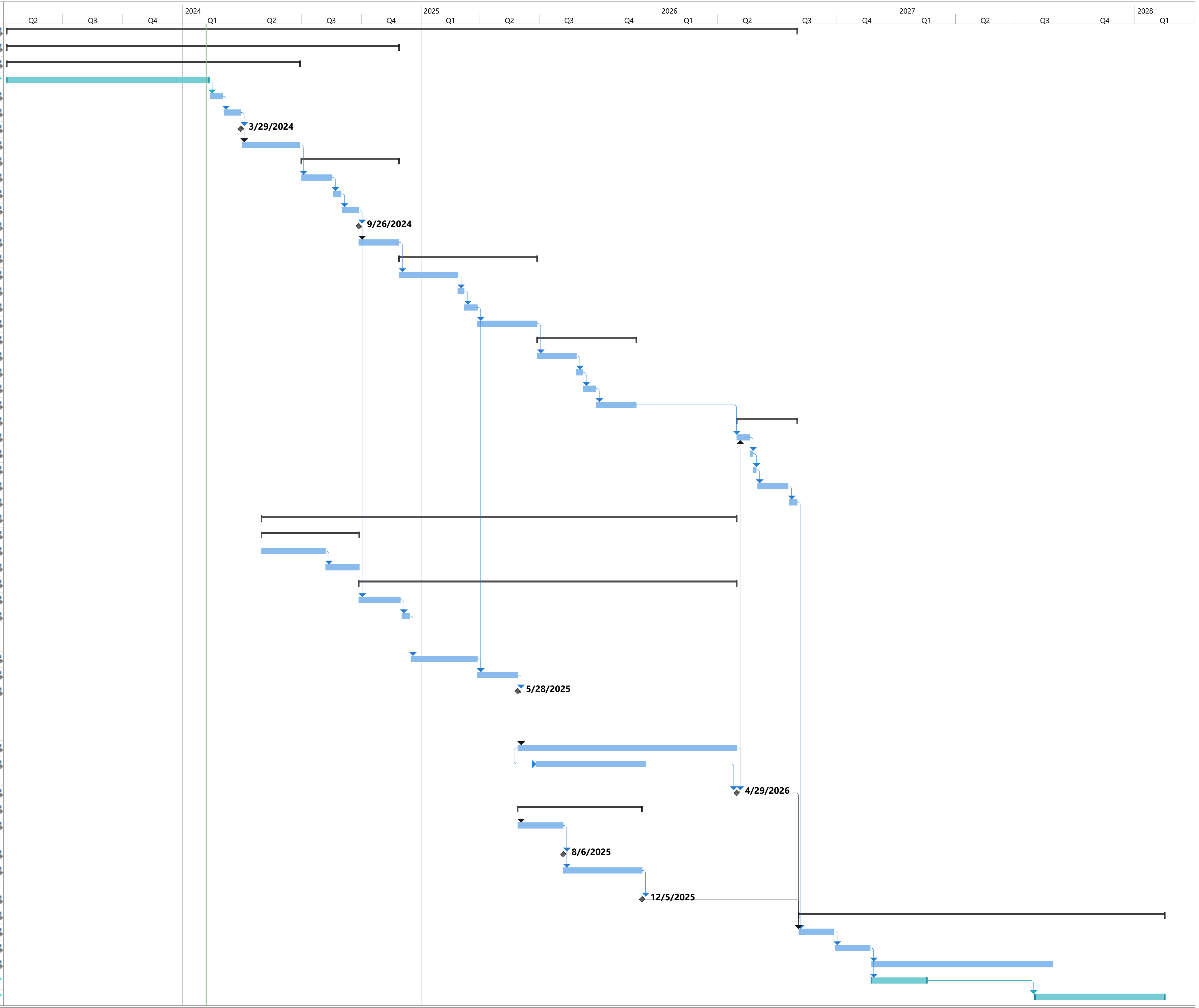
Appendix G

Remedial Design, Permitting and Construction Schedule

Remedial Design, Permitting and Construction Schedule
South State Street Site; Bellingham, Washington

ID	Task Name	Duration	Start	Finish	Predecesso	Task Mode
1	**Design**	**867 days**	**Thu 4/6/23**	**Fri 7/31/26**		➔
2	**30% Design/EDR**	**430 days**	**Thu 4/6/23**	**Wed 11/27/24**		➔
3	**Prepare Draft EDR**	**322 days**	**Thu 4/6/23**	**Fri 6/28/24**		➔
4	Prepare Draft EDR	222 days	Thu 4/6/23	Fri 2/9/24		📌
5	PSE and City Review of Draft EDR	15 days	Mon 2/12/24	Fri 3/1/24	4	➔
6	Prepare Ecology Review Draft EDR	20 days	Mon 3/4/24	Fri 3/29/24	5	➔
7	Submit Draft EDR to Ecology for Review	0 days	Fri 3/29/24	Fri 3/29/24	6	➔
8	Ecology Review of EDR and Issues Comments	65 days	Mon 4/1/24	Fri 6/28/24	7	➔
9	**Final EDR**	**108 days**	**Mon 7/1/24**	**Wed 11/27/24**		➔
10	Prepare Draft Final EDR	35 days	Mon 7/1/24	Fri 8/16/24	8	➔
11	PSE and City Review Draft Final EDR	10 days	Mon 8/19/24	Fri 8/30/24	10	➔
12	Prepare Ecology Review Draft Final EDR	19 days	Mon 9/2/24	Thu 9/26/24	11	➔
13	Submit Final EDR to Ecology for Review	0 days	Thu 9/26/24	Thu 9/26/24	12	➔
14	Ecology Review and Approval of Final EDR	44 days	Fri 9/27/24	Wed 11/27/24	13	➔
15	**60 Percent Design**	**152 days**	**Wed 11/27/24**	**Fri 6/27/25**		➔
16	Prepare Draft 60% Design	90 edays	Wed 11/27/24	Tue 2/25/25	14	➔
17	PSE and City Review of Draft 60% Design	10 edays	Tue 2/25/25	Fri 3/7/25	16	➔
18	Prepare Ecology Review Draft 60% Design	20 edays	Fri 3/7/25	Thu 3/27/25	17	➔
19	Ecology Review of 60% Design and Issues Comments	66 days	Fri 3/28/25	Fri 6/27/25	18	➔
20	**90 Percent Design**	**108 days**	**Fri 6/27/25**	**Wed 11/26/25**		➔
21	Prepare Draft 90% Design	60 edays	Fri 6/27/25	Tue 8/26/25	19	➔
22	PSE and City Review of Draft 90% Design	10 edays	Tue 8/26/25	Fri 9/5/25	21	➔
23	Prepare Ecology Review Draft 90% Design	20 edays	Fri 9/5/25	Thu 9/25/25	22	➔
24	Ecology Review of 90% Design and Issues Comments	44 days	Fri 9/26/25	Wed 11/26/25	23	➔
25	**100 Percent Design**	**67 days**	**Wed 4/29/26**	**Fri 7/31/26**		➔
26	Prepare Draft 100% Design	20 edays	Wed 4/29/26	Tue 5/19/26	24,43	➔
27	PSE and City Review of Draft 100% Design	5 edays	Tue 5/19/26	Sun 5/24/26	26	➔
28	Prepare Ecology Review Draft 100% Design	5 edays	Sun 5/24/26	Fri 5/29/26	27	➔
29	Ecology Review and Approve Draft 100% Design	35 days	Mon 6/1/26	Fri 7/17/26	28	➔
30	Final 100% Design Plans and Specifications	10 days	Mon 7/20/26	Fri 7/31/26	29	➔
31	**Permitting**	**521 days**	**Wed 5/1/24**	**Wed 4/29/26**		➔
32	**Surveys to Support Permitting**	**108 days**	**Wed 5/1/24**	**Fri 9/27/24**		➔
33	Eelgrass and Nearshore Habitat Survey(s) and Reporting	70 days	Wed 5/1/24	Tue 8/6/24		➔
34	Cultural Resources Survey and Reporting	38 days	Wed 8/7/24	Fri 9/27/24	33	➔
35	**Marine Permitting**	**414 days**	**Fri 9/27/24**	**Wed 4/29/26**		➔
36	JARPA Project Description and Mitigation Plan Development	46 days	Fri 9/27/24	Fri 11/29/24	12	➔
37	Pre-Application Meeting (USACE, Tribes, and Resource Agencies) to Discuss Permitting/Mitigation Approach and Application	10 days	Mon 12/2/24	Fri 12/13/24	36	➔
38	Complete Mitigation Plan and Biological Assessment (BA)	74 days	Mon 12/16/24	Thu 3/27/25	37	➔
39	Prepare JARPA and JARPA Drawings and Appendices	44 days	Fri 3/28/25	Wed 5/28/25	18,38	➔
40	Submit JARPA, JARPA Drawings and Appendices including Mitigation Plan, BA, Habitat Survey Report, Cultural Resources Report, Water Quality Monitoring Plan, and SEPA Determination	0 days	Wed 5/28/25	Wed 5/28/25	39	➔
41	Agency Review of JARPA Application	12 mons	Thu 5/29/25	Wed 4/29/26	40	➔
42	NMFS Salish Sea Nearshore Programmatic Submittals and Review	6 mons	Thu 6/26/25	Wed 12/10/25	41SS+20 days	➔
43	Permit Approval	0 days	Wed 4/29/26	Wed 4/29/26	41,42	➔
44	**Substantive Requirements**	**137 days**	**Thu 5/29/25**	**Fri 12/5/25**		➔
45	Prepare Documents to Support Substantive Requirements Review	50 days	Thu 5/29/25	Wed 8/6/25	40	➔
46	Submit to City and Other Agencies	0 days	Wed 8/6/25	Wed 8/6/25	45	➔
47	City and Agency Review of Substantive Requirement Documents	87 days	Thu 8/7/25	Fri 12/5/25	45	➔
48	Responses/Approval from City and Agencies	0 days	Fri 12/5/25	Fri 12/5/25	47	➔
49	**Construction**	**402 days**	**Mon 8/3/26**	**Tue 2/15/28**		➔
50	Contracting	2 mons	Mon 8/3/26	Fri 9/25/26	43,48,30	➔
51	Mobilization	2 mons	Mon 9/28/26	Fri 11/20/26	50	➔
52	Upland Construction	10 mons	Mon 11/23/26	Fri 8/27/27	51	➔
53	Marine Construction In-Water Work Window (2026-2027)	61 days	Mon 11/23/26	Mon 2/15/27	51	📌
54	Marine Construction In-Water Work Window (2027-2028)	143 days	Sun 8/1/27	Tue 2/15/28	53FS+119	📌



Puget Sound Energy
South State Street Schedule
Date: Tue 2/6/24

Task	▬	Milestone	◆	Project Summary	▭	Inactive Milestone	◇	Manual Task	▬	Manual Summary Rollup	▬	Start-only	[	External Tasks	▬	Deadline	⇩	Manual Progress	▬
Split	┈	Summary	▭	Inactive Task	▭	Inactive Summary	▭	Duration-only	▬	Manual Summary	▭	Finish-only	]	External Milestone	◇	Progress	▬		