FINAL
ENGINEERING DESIGN REPORT
R.G. HALEY INTERNATIONAL CORPORATION SITE
BELLINGHAM, WASHINGTON

Prepared by

City of Bellingham

210 Lottie Street

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May 13, 2022

Engineering Design Report

R.G. Haley International Corporation Site
Bellingham, Washington

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May 13, 2022

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LIST OF ACRONYMS

°C	degrees Celsius
°F	degrees Fahrenheit
AASHTO	American Association of State Highway and Transportation Officials
AC	activated carbon
AO	Agreed Order
AOC	Area of Contamination
ARARs	Applicable or Relevant and Appropriate Requirements
ASCE	American Society of Civil Engineers
ASTM	ASTM International
BAZ	biologically active zone
bgs	below the ground surface
BMC	Bellingham Municipal Code
BMPs	best management practices
BNSF	BNSF Railway Company
CAP	Cleanup Action Plan
cfm	cubic feet per minute
cfs	cubic feet per second
CFR	Code of Federal Regulations
CHE	Coast & Harbor Engineering
City	City of Bellingham
CLARC	cleanup levels and risk calculations
cm	centimeters
cm/s	centimeters per second
COC	contaminants of concern
Cornwall site	Cornwall Landfill cleanup site
cPAHs	carcinogenic PAHs
CQA	Construction Quality Assurance
CQAP	Construction Quality Assurance Plan
CQC	Construction Quality Control
CSBC	crushed surfacing base course
CSL	Cleanup Screening Level

CSWGP	Construction Stormwater General Permit
CSZ	Cascadia Subduction Zone
CWA	Clean Water Act
CY	cubic yards
D/F	dioxins/furans
DNR	Washington State Department of Natural Resources
Ecology	Washington State Department of Ecology
EDR	Engineering Design Report
ENR	enhanced natural recovery
EPA	Environmental Protection Agency
EPP	Environmental Protection Plan
ESA	Endangered Species Act
GAC	granulated activated carbon
GeoEngineers	GeoEngineers, Inc.
GGBFS	ground granulated blast furnace slag
GHG	greenhouse gas
GIS	geographic information system
GPR	ground penetrating radar
H:V	horizontal to vertical
HASP	Health and Safety Plan
HAZWOPER	hazardous waste operations and emergency response
HDPE	high-density polyethylene
HELP	Hydrologic Evaluation of Landfill Performance
IDP	Inadvertent Discovery Plan
IHSs	Indicator Hazardous Substances
ISS	in-situ soil solidification
ITRC	Interstate Technology Regulatory Council
JARPA	Joint Aquatic Resource Permit Application
kg	kilogram
lbs	pounds
lb/in-width	pounds per inch-width
LDRs	Land Disposal Restrictions

LEAF	Leaching Environmental Assessment Framework
LFG	landfill gas
LGP	low ground pressure
LLDPE	low-permeability, linear low-density polyethylene
LNAPL	light non-aqueous phase liquid
m^2	square meter
MDD	maximum dry density
mg/kg	milligrams per kilogram
µg/L	micrograms per liter
MHHW	mean higher high water
MHW	mean high water
MLLW	mean lower low water
MNR	monitored natural recovery
MSW	municipal solid waste
MTCA	Model Toxics Control Act
NAPL	non-aqueous phase liquid
NAVD88	North American Vertical Datum of 1988
NEPA	National Environmental Policy Act
NESHAP	National Emission Standards for Hazardous Air Pollutants
ng/kg	nanograms per kilogram
NOC	Notice of Construction
NPDES	National Pollution Discharge Elimination System
NSPS	New Source Performance Standards
NWCAA	Northwest Clean Air Agency
O&M	operation and maintenance
OC	organoclay
OHW	ordinary high water
OHWM	ordinary high water mark
OMMP	Operations, Maintenance, and Monitoring Plan
PAHs	polycyclic aromatic hydrocarbons
PCP	pentachlorophenol
PMA	Port Management Agreement

Port	Port of Bellingham
POTW	Publicly Owned Treatment Works
ppm	parts per million
PRDI	Pre-Remedial Design Investigation
psi	pounds per square inch
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project Plan
RCRA	Resource Conservation and Recovery Act
RCW	Revised Code of Washington
RI/FS	Remedial Investigation/Feasibility Study
SAP	Sampling and Analysis Plan
SCO	Sediment Cleanup Objective
SDR	Standard Dimension Ratio
SEPA	Washington State Environmental Policy Act
sf	square foot
Site or Haley Site	R.G. Haley International Corp Site
SLR	sea level rise
SM	black silty sands
SMMWW	Stormwater Management Manual for Western Washington
SMS	Sediment Management Standards
SO_4	sulfate
SOAL	State-Owned Aquatic Lands
SQERs	small quantity emission rates
SSI	Supplemental Sediment Investigation
SWAC	surface weighted average concentration
SWPPP	stormwater pollution prevention plan
TDZ	Tsunami Design Zone
TESC	temporary erosion and sedimentation control
TEQ	Toxic Equivalent Concentration
TLC	thin-layer cap
TOC	total organic carbon
TPH	total petroleum hydrocarbons

UCS	unconfined compressive strength
Upland Work Plan	August 22, 2018 *Pre-Remedial Design Investigation Project Plans – Upland*
USACE	United States Army Corps of Engineers
UV	ultraviolet
VOCs	volatile organic compounds
WAC	Washington Administrative Code
WGS	Washington Geological Survey
WQC	Water Quality Certification
WQMP	Water Quality Monitoring Plan
WSDOT	Washington State Department of Transportation
WWHM	2012 Western Washington Hydrology Model

1.0 INTRODUCTION

This Engineering Design Report (EDR) describes the preliminary engineering design for the final cleanup action at the R.G. Haley International Corp Site (Site or Haley Site). The general location of the Site south of the downtown business district in Bellingham, Washington is shown on Figure 1-1, Vicinity Map. Wood products for commercial use were treated with pentachlorophenol (PCP) at the Site between approximately 1948 and 1985, resulting in contamination of soil, groundwater and sediment. Cleanup actions are planned for the Site Upland Unit and Marine Unit that are separated by the ordinary high water mark (OHWM) as shown on Figure 1-2, Haley Site Units, and discussed in Section 1.2. The Haley Site overlaps with the adjacent Cornwall Landfill cleanup site (Cornwall Site). The relationship between these two sites is described in Section 1.2.2.

Cleanup actions will be completed pursuant to requirements of the Model Toxics Control Act (MTCA), Chapter 70.105D 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 15776 (Ecology 2018a) between the Washington State Department of Ecology (Ecology) and the City of Bellingham (City).

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

Site Name	R.G. Haley International Corp
Property Address	Cornwall Avenue N, Bellingham, Washington, 98227-1075
Cleanup Site ID	3928
Facility Site ID	2870
Remedial Design Agreed Order No.	DE 15776
Remedial Design Agreed Order Date	June 1, 2018
Parties to the Orders	Ecology, City of Bellingham
Current Property Owners	City of Bellingham, Washington State (managed by the Department of Natural Resources and the Port of Bellingham), Port of Bellingham

The final cleanup action at the Haley Site is designed to be protective of human health and the environment. The City plans to develop the Site and adjoining Cornwall Landfill site to the south (Figure 1-3) as a public waterfront park either concurrent with or after cleanup. Design elements may be further developed or modified if needed for compatibility with habitat and future land-use objectives to be more fully defined in the future.

1.1. Cleanup Action Objectives

The cleanup action for the Site is based on the Cleanup Action Plan (CAP; Ecology 2018b). 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 impacted media. The remedial design also incorporates habitat components that will continue to be refined, as needed, based on input from Ecology and other agencies during the permitting phase of the project.

1.1.1. Upland Unit

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

- People and ecological receptors being exposed to hazardous substances in soil and groundwater by direct contact;
- People being exposed to hazardous substances by inhalation of soil vapors;
- Transport of upland contaminated soil to marine sediment as a result of erosion; and
- Leaching of contaminants from soil to groundwater and subsequent transport in groundwater to sediment or surface water.

Cleanup actions for the Upland Unit include installing a low-permeability cap to mitigate the potential exposure pathways described above. The cap will reduce stormwater infiltration and include a landfill gas (LFG) collection system. In addition to reducing the risk of direct contact exposures, the cap will reduce contaminant leaching in vadose zone soil and contaminated groundwater flow through the Upland Unit. In-situ soil solidification (ISS) will be conducted to treat the most heavily impacted area of potentially mobile light non-aqueous phase liquid (LNAPL) near the Haley Site shoreline. The ISS component will substantially reduce LNAPL mobility and contaminant leaching to groundwater. The treated soil mass also will significantly reduce hydraulic conductivity, thereby diverting groundwater flow into relatively cleaner soil beneath and around the ISS mass.

1.1.2. Marine Unit

Potential exposure routes and receptors associated with hazardous substances in the Marine Unit include:

- Aquatic organisms being exposed to hazardous substances in sediment within the biologically active zone (the upper 12 centimeters [cm] of sediment);
- People being exposed to hazardous substances in sediment by direct contact;
- People being exposed to Site-related bioaccumulative compounds by seafood ingestion; and
- Higher trophic level receptors (fish, aquatic-dependent birds and mammals) being exposed to contaminated benthic invertebrate prey via ingestion.

Sediment removal, capping and natural recovery are the planned cleanup actions to address contaminants in the Marine Unit. Sediment in a portion of the intertidal zone will be excavated to reduce the contaminant mass and facilitate placement of a sediment cap. The excavated sediment will be conditioned using cementitious amendments to enhance its structural properties and then consolidated in the Upland Unit beneath the low-permeability cap.

Sediment exceeding cleanup levels in the intertidal and portions of the subtidal zone will be capped with sand amended with organoclay and activated carbon to contain underlying sediment contamination. Capping will include the area of excavated sediment to contain deeper remaining contamination. The capped surfaces will be protected with suitable materials to reduce the risk of erosion and direct contact by humans, and to minimize potential for contact from benthic organisms.

Sediment beyond the amended capping areas has generally lower concentrations of bioaccumulative contaminants. A thin-layer cap (TLC) of gravelly sand will be placed in a portion of this area where episodic erosion may occur until anticipated naturally-deposited sediment accumulates. Deeper water areas beyond the TLC are less susceptible to episodic erosion, and dioxin/furan (D/F) concentrations trend downward toward regional background concentrations. Monitored natural recovery (MNR) will be utilized in these areas, anticipating that continued (net) sediment deposition that is naturally occurring in this part of Bellingham Bay will complete the natural recovery process within a 10-year time frame.

1.2. Site Background

The following sections describe the Haley Site setting and summarize the Site history, environmental investigation findings, geology and hydrogeology, and environmental conditions. The Remedial Investigation/Feasibility Study (RI/FS; GeoEngineers 2016), and Supplemental Sediment Investigation Report (SSI; GeoEngineers 2018) provide additional detail.

1.2.1. Site Description

The Haley Site cleanup area boundary is shown on Figure 1-1 and encompasses the Upland Unit and Marine Unit shown on Figures 1-2 and 1-3. Site property ownership includes parcels owned by the City, Port of Bellingham (Port), and State-Owned Aquatic Lands (SOAL) as shown on Figure 1-4, Haley Site and Property Ownership. A portion of the SOAL is a Port Management Agreement (PMA) area managed by the Port under an agreement with the Washington State Department of Natural Resources (DNR). Properties adjoining the Haley property include the Nielson Brothers parcel to the north[1], City- and State-owned portions of the Cornwall upland property to the south, and an active BNSF Railway Company (BNSF) rail line to the east (BNSF right-of-way).

The Haley Upland Unit shown on Figure 1-2 is relatively flat with ground surface elevations varying from about 12 feet on the north to 16 feet on the south (North American Vertical Datum of 1988 [NAVD88]). A more-detailed layout of the upland Site features and surface topography is presented on Figure 1-5, Current Conditions. Fill mounds along the southern shoreline extend to about elevation 20 feet. Sediment and soil stockpiles are present on the northern portion of the Cornwall site that overlaps the Haley Site, as described below. These stockpiles extend to elevations of 30 feet. The Site is currently fenced and vacant and much of the upland area is asphalt- or concrete-paved. A vertical sheet pile barrier was installed along part of the Haley shoreline during an interim cleanup action in 2002 to control LNAPL entry to Bellingham Bay. Remnant timber pilings and former building foundations and treatment pads remain in various locations.

The Haley Marine Unit includes shoreline, intertidal and deeper subtidal waters of Bellingham Bay. The boundary with the Upland Unit consists of a steep shoreline bank that has been eroded by wave action. The intertidal zone extends roughly 80 to 100 feet seaward between the OHWM and elevation of about -4 feet. The shoreline bank is covered with rock armoring, sparse vegetation, gravel and debris. Below the shoreline bank, the intertidal zone slopes between about 10 feet horizontal to 1 foot vertical (10H:1V) on the north, to 5H:1V on the south. The subtidal zone of the Marine Unit extends from about elevation -4 feet into deeper water below about -25 feet. The subtidal zone becomes less steep in deeper water offshore.

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[1] Directions presented in the EDR text refer to project north, as shown on the figures.

1.2.2. Adjacent MTCA Sites

The Haley Site overlaps the Cornwall site to the south as shown on Figure 1-3. The Haley Upland Unit overlaps Cornwall site Unit MU1 and the Haley Marine Unit overlaps Cornwall site Units MU2 and MU3. The Cornwall MU1 cleanup will include a cap over a former municipal landfill and tideland fill materials east of the landfill. Cornwall cleanup efforts will also stabilize the seaward edge of the landfill in the near-shore area and address contaminated sediment farther offshore in conjunction with Haley. Additional description of the cap in the overlap area is provided in Section 3.1. Details of the Cornwall Site cleanup are described in the MU1 and MU2 Engineering Design Report, Cornwall Avenue Landfill Site prepared by Landau Associates for the Port of Bellingham (Landau 2018). The Cornwall Site cleanup design is undergoing modification as the design progresses, including incorporation of updated sea level rise prediction.

The Haley Marine Unit also overlaps Whatcom Waterway cleanup areas including a portion of Whatcom Waterway Units 6A and 9, and all of Whatcom Waterway Units 6B, and 6C, as shown on Figure 1-3. Monitored Natural Recovery is the required cleanup in these areas, except for capping beneath the Port of Bellingham Barge Dock to prevent potential erosion from vessel propeller scour. The Port is leading cleanup efforts for the Cornwall and Whatcom Waterway sites under agreements with Ecology. The City and the Port are coordinating design planning and construction efforts for the Haley, Cornwall, and Whatcom Waterway sites to ensure that the cleanup action objectives for each site are successfully achieved.

1.2.3. Site History Summary

Prior to development, the Haley Site vicinity consisted of tidelands and open water to the west of the prominent bluff currently located east of the Site. Historically three Native American groups used the area in and around Bellingham Bay: the Lummi, Nooksack and Samish, but historical literature place the project area within Lummi territory. There were numerous Lummi settlements throughout the inland water ways of the Salish Sea including from Cherry Point north of Bellingham Bay to Chuckanut Bay south of Bellingham Bay. Industrialization of the Bellingham shoreline began in the mid-1800s and various kinds of fill material were placed at the Haley and Cornwall sites that progressively shifted the shoreline farther out into the bay to create new land for industrial activities. Historical land uses at or near the Site included railroad activities, lumber mill operations, wood treatment and storage, pulp and paper mill activities, and disposal of municipal waste at the Cornwall Landfill.

Mill operations began at the current location of the Haley and Cornwall sites in the late 1880s and the BNSF railroad was constructed in about 1890. Several over-water wharves and piers were built within and adjacent to the Site to support mill operations and marine shipping. Wood-treating operations were conducted at the Site after the mill was removed and fill was placed near the shoreline to produce the present-day upland. From 1948 to 1985, the R.G. Haley International Corp (and others) operated a wood treatment facility on the parcel currently owned by the City (i.e. the ‘Former Haley Property’) and on the adjacent State-owned land located west of the Inner Harbor Line (Figure 1-4). During the 1950s and 1960s the Cornwall site was used for disposal of municipal refuse, pulp waste, and medical waste. No buildings associated with historical activities remain on the Haley or Cornwall properties, although remnant foundations, and subsurface piping and tanks from the former wood treatment operations remain on the Haley Site (Figure 1-5).

The former wood-treating operations at the Haley Site released contaminants to soil, groundwater and sediment, as described below in Section 1.2.5.

1.2.4. Site Investigation Background and Cleanup Activities

The City and other parties have completed several environmental investigations and cleanup actions at the Haley Site since 1985. Information presented in this EDR builds on findings and data from this previous work, as summarized most recently in the RI/FS, SSI and CAP. Site cleanup activities included the removal of seepage pit sludge in 1985, installation of the shoreline sheet pile wall in 2002 as an independent action to control migration of LNAPL to Bellingham Bay, and placement of an oil absorbent cap over intertidal sediment in 2013 as an interim action to eliminate a petroleum sheen. Periodic removal of LNAPL from selected Site recovery wells began in 2000 and is continuing on a quarterly basis. The RI/FS provides a complete listing and discussion of previous Site studies and cleanup actions prior to 2016. An additional Pre-Remedial Design Investigation (PRDI) was completed by GeoEngineers, Inc. (GeoEngineers) in 2018 to support the development of this EDR. The results of the pre-design upland investigation and habitat surveys are summarized in Section 4.0 and Appendix A.

1.2.5. Geology and Hydrogeology

Haley Site geology and hydrogeology are summarized below, with additional description and detail provided in the RI/FS. Conceptual geologic cross sections from the RI/FS are presented on Figure 1-6, Cross-Section X-X', Figure 1-7, Cross-Section Y-Y' and Figure 1-8, Cross-Section Z-Z' (section lines shown on Figure 1-5).

1.2.5.1. Geology

- Upland fill is the uppermost material encountered in the Haley Upland Unit. Upland fill consists primarily of sand with varying amounts of silt, and lesser amounts of silt and gravel. Coal and brick fragments, wood debris, construction debris and sawdust are also present in this unit. Large rocks and concrete chunks are prevalent in the fill toward the shoreline. The upland fill unit ranges in thickness from approximately 8 to 15 feet.
- Landfill debris consisting of municipal solid waste associated with Cornwall Landfill operations is present beneath the upland fill unit in the southwestern corner of the Haley Upland Unit. Landfill debris consists of typical solid waste materials such as plastic, wood, wire, glass, paper and other refuse mixed with soil. Landfill debris is up to about 20 feet thick on the Haley Site.
- At many locations, wood fill containing sawdust, wood chips, dimensional lumber and log ends is present beneath the upland fill unit and extends into the adjacent nearshore portion of the Marine Unit. The wood fill originated from past lumber mill and overwater activities, and also contains soil, sediment and other debris. The wood fill is present beneath much of the Upland Unit, particularly in the south central and southwest parts of the upland. Offshore, the wood fill overlies the marine fill and native marine geologic units described below. Wood fill thickness is highly variable but exceeds 10 feet in places.
- Marine fill of variable composition underlies the wood fill, upland fill and landfill debris, depending on the location. The marine fill unit consists of silt and silty sand with shells and minor wood fragments and is difficult to distinguish from native marine sediment in places. Marine fill contains debris such as glass, brick and plastic, along with wood waste layers with some zones composed entirely of sawdust. These anthropogenic materials likely originate from historical sawmill and landfill operations. Portions of the marine fill were likely placed by historical dredging operations in Bellingham Bay. Marine fill also includes shoreline materials eroded and reworked from tidal action.
- Native marine sediment consisting of silt, silty sand, and sand with minor gravel, shells and wood fragments are present beneath the wood fill. Offshore, the marine fill unit described above grades

seaward into this native marine sediment. Native marine sediment deposits generally thicken from east to west and are 20 feet thick or more in the Haley Marine Unit.

- Glacial marine drift composed dominantly of silt and clay with minor gravel and shells is locally present beneath native marine sediment at the Haley Site. Glacial marine drift appears to be limited to the south-central area of the Haley Upland Unit and is reported in the Cornwall EDR to reach a thickness of more than 20 feet near the shoreline.
- The Chuckanut Formation consisting dominantly of sandstone and conglomerate bedrock with interlayered mudstone and some coal underlies other units at the Haley Site, although depth to bedrock farther offshore is not known. The upper surface of the bedrock varies from less than 10 feet below ground surface (bgs) at locations toward the eastern boundary of the Site to more than 30 feet bgs near the shoreline.

1.2.5.2. 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 about 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.

1.2.5.3. Offshore Sediment Accumulation

Fine-grained sediment deposited from the Nooksack River make up a significant component of the offshore portion of the Haley native marine geologic unit. Previous studies by Hart Crowser (2009) for Ecology and by RETEC (2006) for the Whatcom Waterway project indicated that significant sediment accumulation has occurred in the vicinity of the Haley Site. The Hart Crowser study identified estimated deposition rates from 0.35 to 1.35 cm/year with an average deposition rate of 1.1 cm/year. The RETEC study identified sediment deposition rates of 1.52 to 1.77 cm/year for inner Bellingham Bay.

In 2019 Coast & Harbor Engineering (CHE), a division of Mott MacDonald, evaluated changes in sea floor bathymetry in the Cornwall and Haley Site vicinities between 2007 and 2015 to support design of the Cornwall cleanup (CHE 2019). Figure 1-9, Sediment Accretion 2007 to 2015 depicts this bathymetric comparison showing sediment accumulation of 1 foot or more in many offshore areas during this time period. Associated deposition rates of 3.7 cm/year or more exceed the estimates listed above, noting that the previous estimates represent longer-term net deposition. The bathymetric patterns also show sediment accumulating in elongate wave-like forms at many locations, suggesting the presence of sediment mudwaves resulting from current action.

1.2.5.4. Hydrogeology

Three hydrostratigraphic units have been defined for the Haley Site that are composed of the geologic units described above. Geologic units that are in direct contact with each other and have similar characteristics were grouped together to define specific hydrostratigraphic units. The hydrostratigraphic units and their corresponding geologic units are as follows:

Hydrostratigraphic Unit	Corresponding Geologic Units
Fill Unit	Upland Fill
	Landfill Debris
	Wood Fill
	Marine Fill
Native Marine Unit	Native Marine Sediment
	Glacial Marine Drift
Chuckanut Formation	Chuckanut Formation

The Fill Unit and Native Marine Hydrostratigraphic Unit are the most significant groundwater-bearing units beneath the Site. The bedrock (Chuckanut Formation) is not expected to store or transmit significant quantities of groundwater. The inland extent of the geologic units that constitute the Fill and Native Marine Hydrostratigraphic Units approximately coincides with the eastern boundary of the Haley property. The thickness of these hydrostratigraphic units increases toward Bellingham Bay.

Site groundwater and product elevations and product thicknesses are monitored quarterly. The depth to groundwater generally ranges from approximately 3 to 11 feet bgs. Groundwater elevations vary by up to several feet seasonally and from tidal influence. Elevations are highest during the wet season and are closest to ground surface toward the eastern boundary of the Site. The highest groundwater elevations have typically been observed in the monitoring wells at the southeast corner of the Haley property and northeast corner of the Cornwall property. Groundwater elevations during the December 2019 high-tide monitoring event are shown on Figure 1-10 and the groundwater elevation contours during the June 2020 low tide monitoring event are shown on Figure 1-11. The general easterly gradient and contour pattern is typical, with some locally higher and lower elevations upgradient of the sheet pile wall.

The estimated horizontal groundwater gradient immediately east (upgradient) of the sheet pile barrier is approximately 0.02 feet/foot at low tide and 0.014 feet/foot at high tide. Farther upgradient (east) of the sheet pile barrier where tidal influence is less, horizontal gradient varies less between low and high tide (0.014 versus 0.018 feet/foot, respectively). Steeper gradients occurred in the southeastern portion of the Haley upland, where gradients of 0.027 feet/foot and 0.021 feet/foot were measured at low and high tide, respectively. The average horizontal gradient calculated by the groundwater flow model developed for the Haley Site is 0.016 feet/foot.

1.2.6. Environmental Conditions

The nature and extent of contamination at the Haley Site are described in the CAP and RI/FS. Haley-related contamination originated from the use and release of wood treatment chemicals consisting of a diesel-like carrier oil with PCP as the active ingredient. The primary contaminants associated with this source include

LNAPL and associated diesel-range petroleum hydrocarbons, polycyclic aromatic hydrocarbons (PAHs), PCP, and D/F. Additional contaminants include volatile organic compounds (VOCs) such as benzene and xylenes.

Site contaminants were released over time into surface soils at the Haley Upland Unit. Oily fractions migrated down to the water table, where they collected and periodically discharged to Bellingham Bay, or were retained in a “smear zone” at the water table. The estimated smear zone thickness is shown on Figure 1-12, Upland Smear Zone Thickness based on sheen and product observations in RI/FS and 2018 PRDI explorations for the Haley Site. Additionally, Figure 1-12 includes the extent of the potential smear zone based on information on sheen present in borings performed as part of the Cornwall Site investigation.

Infiltrating stormwater also carried dissolved contaminants down to the water table, where they entered groundwater. Dissolved-phase contaminants migrated in groundwater toward Bellingham Bay. Sediment along the Haley shoreline also was contaminated by upland stormwater and groundwater discharges, as well as soil erosion along the shoreline bank. Wave activity and tidal currents reworked the contaminated sediment, transporting it within the Marine Unit.

In the Haley Marine Unit, the greatest number and concentration of Haley-related contaminants occur in the nearshore area closest to the former wood treatment operations. Beyond the nearshore area, D/F are present at concentrations above the Bellingham Bay regional background concentrations. These D/F concentrations decline to the regional background concentration at the outer boundary of the Haley Marine Unit. Other Haley bioaccumulative compounds (carcinogenic PAHs [cPAHs] and PCP) have a much smaller footprint, and therefore did not play a role in establishing the boundary of the Haley Marine Unit.

1.2.6.1. Product Thicknesses in Site Wells

Product thicknesses are monitored quarterly in Site wells and recoverable product is removed. Figure 1-13 and 1-14 show product thickness measurements for quarterly monitoring events in December 2019 (high tide) and June 2020 (low tide), respectively. During the December 2019 event, product was most prevalent in wells closer to the shoreline including locations upgradient of the sheet pile wall. Product thicknesses varied between 0.02 and 2.37 feet in these wells (TL-MW-2, TL-MW-3, TL-MW-4, TL-MW-5A and TL-MW6), with the thickest product observed in well TL-MW-2. Well MW-12 to the south had a product thickness of 0.14 feet. In general, product thicknesses in these wells increased slightly from September 2019 (low tide monitoring event), noting that the thickness in well MW-2 increased from 0 to 2.37 feet between September and December. The product thickness increase in MW-2 is within the range of historical thicknesses and seasonal variation.

Product occurrence was limited to five wells during the June 2020 event. Product thicknesses up to 1.81 feet were noted in wells TL-MW-2, TL-MW-3, TL-MW-4, and TL-MW-5A located near the shoreline just upgradient of the sheet pile wall. North Cornwall well CL-MW-103 had a product thicknesses of 0.02 feet. The measured product thicknesses during the December 2019 and June 2020 monitoring events are within the range of previous results.

Product thickness has varied seasonally and over time in wells where present. Since 2010, product thicknesses of 0.5 feet or more have been present most consistently in wells TL-MW-2, TL-MW-4, TL-MW-5A, TL-MW-6 and TL-MW-12. These wells are all located near the shoreline and upgradient of the sheet pile wall, except for TL-MW-6 which is located outside of the wall on its seaward side. A total of 83 gallons of product has been recovered from Site wells since 2010.

Quarterly monitoring conducted during the August 2018 PRDI upland investigation noted substantial product thicknesses in north Cornwall wells CL-MW-103 and CL-MW-6 in the north part of Cornwall property that overlaps with the Haley Site. Measured product thicknesses in these wells were 1.51 and 2.43 feet, respectively. In contrast, product thicknesses measured quarterly since that time have consistently remained between 0 to 0.02 feet in these wells. Monitoring before August 2018 did not encounter product thicknesses comparable to thicknesses noted at that time. The representativeness of the August 2018 thickness measurements is uncertain and the product observed in CL-MW-103 is thicker and dissimilar to LNAPL related to past Haley wood-treatment operations.

2.0 MEDIA TO BE ADDRESSED AND CLEANUP STANDARDS

Cleanup standards for the Haley Site include (1) chemical concentrations in environmental 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:

- Dioxin evaluated as Toxic Equivalent Concentration (TEQ);
- Individual PAHs including 1- and 2-methylnaphthalene, acenaphthene, fluoranthene, naphthalene, phenanthrene and benzo(a)anthracene;
- Carcinogenic PAHs (cPAHs) evaluated as TEQ;
- PCP;
- Benzene and xylenes; and
- Summed total petroleum hydrocarbons (TPH), and TPH fractions relevant to inhalation.

Cleanup levels for Haley Site IHSs are presented in the CAP along with the basis for each value. This information is presented in EDR Table 2-1, Summary of Cleanup Levels without modification, including cleanup levels for air that address soil vapor to be vented from beneath the planned upland cap. The selected cleanup action also addresses other Site contaminants described in the RI/FS in addition to the IHSs.

2.1. Soil Cleanup Standards

Haley Site soil cleanup levels listed in Table 2-1 are based on the following exposure pathways and receptors for the IHSs indicated:

- Direct contact by people (dioxin TEQ and TPH);
- Protection of groundwater and associated protection of sediment based on risks to benthic organisms (1- and 2-methylnaphthalene);
- Protection of groundwater and associated protection of surface water based on bioaccumulative risks to people (PCP and cPAH TEQ); and
- For the protection of human health and terrestrial ecological receptors via direct contact, the standard point of compliance for soil is from ground surface to 15 feet bgs. The standard point of compliance for soil based on the protection of groundwater is throughout the Site.

The selected cleanup action addresses contaminated soil through upland containment capping, in-situ physical solidification and institutional controls. MTCA recognizes that soil cleanup levels typically are not met at the standard point of compliance for cleanups involving containment, and that these cleanups still comply with cleanup standards under certain conditions, as described in WAC 173-340-740(6)(f). The cleanup action selected for the Haley Site meets these conditions. The point of compliance for soil will be considered to have been met once the Site cleanup actions stated in this EDR have been implemented.

2.2. Groundwater Cleanup Standards

Groundwater cleanup levels listed in Table 2-1 are based on the following exposure pathways and receptors for the IHSs indicated:

- Protection of sediment based on benthic organism toxicity (1- and 2-methylnaphthalene and acenaphthene); and
- Protection of surface water based on bioaccumulative risks to people (dioxin TEQ, benzo(a)anthracene, cPAHs and PCP).

The risk-based cleanup levels for dioxin TEQ, benzo(a)anthracene and cPAHs are typically far less than can be quantified by laboratory analytical testing. Therefore, the cleanup levels for these constituents are set at the analytical practical quantitation limits, as specified in MTCA.

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)(c)). Ecology has determined that the cleanup action selected for the Haley 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 that 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 previously determined that groundwater beneath the Haley Site and other waterfront cleanup sites in Bellingham Bay is non-potable; therefore, use of groundwater as drinking water was not considered in the development of cleanup levels.

2.3. Sediment Cleanup Standards

Sediment cleanup levels listed in Table 2-1 for IHSs are based on the following exposure pathways and receptors:

- Benthic organism toxicity (non-carcinogenic PAHs, benzo(a)anthracene and TPH); and
- Bioaccumulation risks to people and ecological receptors (dioxin TEQ, cPAH TEQ, and PCP).

Sediment cleanup levels are determined from a range of numerical criteria described in the SMS (Chapter 173-204 WAC). The Sediment Cleanup Objective (SCO) is the low end of the range, below which no adverse effects or unacceptable risks are anticipated to human health or the environment. The Cleanup Screening Level (CSL) is the higher end of the range, above which adverse effects or unacceptable risks would be expected to human health and the environment. Sediment cleanup levels are initially established at the SCO and may be adjusted up to, but not higher than, the CSL.

Sediment cleanup levels for the Haley Marine Unit that are based on the protection of benthic organisms are set at the SCO for non-carcinogenic PAHs, benzo(a)anthracene and TPH. The sediment cleanup levels for the remaining three sediment IHSs (dioxin TEQ, cPAH TEQ and PCP), which are bioaccumulative compounds, are based on the following:

- Dioxin TEQ – The sediment cleanup level for dioxins and furans has changed since completion of the RG Haley CAP and is now set at 13 ng/kg TEQ based on a recontamination evaluation. The CAP set the cleanup level at the regional background-based CSL of 15 ng/kg without a recontamination evaluation to provide the rationale for adjusting the cleanup level up from the PQL-based SCO of 5 ng/kg TEQ. As part of Ecology's review of the EDR they requested a recontamination evaluation (Appendix I) to achieve consistency with the SMS. Based on the results of the recontamination evaluation, the SCO cannot be maintained following construction and the cleanup level is adjusted up to 13 ng/kg TEQ.
- cPAH TEQ – The sediment cleanup level for cPAHs has changed since completion of the RG Haley CAP and is now set at the risk-based SCO of 229 µg/kg TEQ. The CAP set the cleanup level at the regional background–based CSL of 86 µg/kg TEQ. As part of Ecology's review of the EDR, Ecology determined that the seafood ingestion risk-based SCO of 229 µg/kg TEQ for the I & J Waterway Site (Ecology 2019) was appropriate to use in establishing the sediment cleanup level for the RG Haley Marine Unit.

  For bioaccumulatives under the SMS, the lowest risk-based concentration is carried forward for consideration in establishing the SCO, then the highest of natural background, applicable risk-based concentrations, or PQL becomes the SCO. Since 229 µg/kg TEQ is less than the direct contact risk-based concentrations in Table 9-3 of the Sediment Cleanup User's Manual (SCUM) (Ecology 2019) (900, 320, and 680 µg/kg TEQ) and greater than natural background (21 µg/kg TEQ) or PQL (9 µg/kg), it is the SCO. The sediment cleanup level for cPAHs is therefore set at the risk-based SCO of 229 µg/kg TEQ.
- PCP – The sediment cleanup level for PCP is set at the SCO. Both the SCO and CSL values for PCP are set at the laboratory PQL.

The sediment cleanup levels based on protection of benthic organisms and bioaccumulative exposures are also protective of direct exposure to contaminated sediment during beach play, clamming, and net fishing activities as described below.

- Dioxin TEQ: The sediment cleanup level of 13 ng/kg TEQ is less than the beach play, clamming, and net fishing direct contact risk-based sediment concentrations of 89 ng/kg TEQ, 15 ng/kg TEQ, and 55 ng/kg TEQ, respectively, provided in Table 9-3 of SCUM (Ecology 2019).
- 2-methylnaphthalene, acenaphthene, fluoranthene, and naphthalene: Benthic sediment cleanup levels for these IHSs are 480 to 9,600 times lower than their respective MTCA Method B unrestricted land use direct contact soil cleanup levels. Direct contact sediment cleanup levels for beach play, clamming, or net fishing would not be lower than unrestricted land use soil cleanup levels.
- Phenanthrene: Toxicity criteria are not available to calculate a direct contact sediment cleanup level for phenanthrene. However, the benthic sediment cleanup level for phenanthrene is 1,600 times lower than the MTCA Method B direct contact soil cleanup level for pyrene, a common surrogate for phenanthrene.
- Benzo(a)anthracene: This IHS is evaluated as part of cPAH TEQ.

- cPAH TEQ. The sediment cleanup level of 229 µg/kg TEQ is less than the beach play, clamming, and net fishing direct contact risk-based sediment concentrations of 900 µg/kg TEQ, 320 µg/kg TEQ, and 680 µg/kg TEQ, respectively, provided in Table 9-3 of SCUM (Ecology 2019).
- PCP: Sediment cleanup level is based on the PQL. A direct contact sediment cleanup level would not be lower than the PQL.
- TPH Sum: The site-specific benthic sediment cleanup level is less than site-specific Method B direct contact soil cleanup level. A direct contact sediment cleanup level for beach play, clamming, or net fishing would not be lower than the Method B unrestricted land use soil cleanup level.

For marine sediment, the point of compliance for the protection of benthic organisms is the biologically active zone (BAZ), which is considered to be the upper 12 cm of sediment in Bellingham Bay. This same point of compliance addresses protection of humans and higher trophic level ecological receptors with respect to consumption of seafood gathered from subtidal areas (i.e., where digging below near-surface is not likely to occur). The point of compliance for the protection of human health from consumption of shellfish collected from the intertidal zone is the upper 45 cm (1.5 feet). This point of compliance is based on the most likely digging depth if clam harvesting was allowable and if armoring was not present as a barrier for clam habitation and digging.

For protection of benthic organisms, compliance monitoring data will be evaluated on a point-by-point basis. For protection of human health and higher trophic level ecological receptors with regard to bioaccumulatives, compliance monitoring data will be averaged on an area-weighted basis. This is because bioaccumulative exposures largely occur though ingestion of fish and shellfish and these receptors average their exposures over an area. Surface-weighted average concentrations (SWACs) will be calculated to determine compliance with cleanup levels for bioaccumulative compounds.

2.4. Air Cleanup Standards

Air cleanup levels listed in Table 2-1 are based on the protection of human health (inhalation) for the Site IHSs naphthalene, benzene, xylenes, and the petroleum hydrocarbon fractions indicated. These constituents were detected in soil vapor samples obtained at the Site at concentrations greater than MTCA Method B sub-slab soil vapor screening levels. Ecology's sub-slab soil vapor screening levels are applicable to soil vapor samples obtained at depths between 0- to 15-feet bgs. The soil vapor samples at the Site were obtained at depths of 5 feet bgs. The standard point of compliance is ambient air throughout the Site.

3.0 PLANNED CLEANUP ACTION

The final cleanup action for the Haley Upland Unit involves using ISS methods to treat soil near the Haley shoreline bank with potentially mobile LNAPL and constructing a low-permeability containment cap over the upland area. The final cleanup action for the Haley Marine Unit involves moving a portion of the LNAPL-impacted nearshore sediment to the upland, placing sediment caps to contain contamination, and monitoring the progress of natural recovery in more seaward areas.

The design and construction of the Haley upland and marine cleanup elements will be closely coordinated with the Cornwall and Whatcom Waterway Sites to ensure that the cleanup action objectives for each Site are successfully achieved. Cleanup actions for the Haley Site will also include habitat improvement elements to be developed following this EDR in coordination with Ecology and other permitting agencies.

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

3.1. Haley Upland Unit Final Cleanup Action Overview

1. Soil near the shoreline will be treated using ISS methods to reduce LNAPL mobility and contaminant leaching to groundwater. The treated soil mass will also have a significantly reduced hydraulic conductivity, thereby causing groundwater to preferentially flow around and under the mass through cleaner soil. This will enhance natural attenuation processes, resulting in reduced contaminant discharge from the upland to the bay.

   - Soil will be mixed in place with an ISS slurry between depths of about 4 to 17 feet bgs over an area of approximately 0.76 acres. ISS will be applied over a target soil thickness of 11 feet within this depth range.
   - An ISS mix with Portland cement and ground granulated blast furnace slag (GGBFS) will be used, following bench-scale treatability testing that determined such mixes achieve the required strength, hydraulic conductivity, and contaminant leachability.
   - The adjacent shoreline will be isolated in the dry with a cofferdam to protect surface water from ISS residuals and contaminated media disturbed during ISS application.

2. A low-permeability cap will be constructed throughout the main portion of the Upland Unit to contain soil with contaminants exceeding cleanup levels for direct contact and protection of groundwater. The upland cap will cover approximately 9.4 acres including the Haley-Cornwall overlap area. The upland cap will be suitable for constructing a future City park on the cap surface without disturbing the cap below the vegetated surface of the cover layer, and without adversely affecting the function and performance of the cap.

   - The upland will be graded at a minimum 2 percent slope to the west and north to accommodate the cap, which will include venting and drainage features.
   - Haley cap components from bottom to top will consist of:
     - A geocomposite soil gas collection layer with connections to vents with passive carbon treatment. Soil gas includes soil vapor containing TPH and related Haley contaminants, and subsurface gas from the Cornwall landfill. Collectively these sources are referred to as ‘landfill gas’ for the purposes of the EDR. Carbon treatment is a precautionary measure pending post-construction sampling results to verify emission concentrations.

- A low-permeability, linear low-density polyethylene (LLDPE) liner;
- A geocomposite drainage collection layer with underdrains to discharge locations along the bank;
- Minimum 18-inch thick layer of clean, imported sandy soil cover suitable for retaining sufficient moisture for vegetation rooting; and
- Minimum 6-inch topsoil layer with grass.

- The upland cap will transition into the shoreline bank to the west.
- The Haley cap will also transition into the Cornwall upland cap over the portion of Cornwall Upland Unit MU1 where the sites overlap (Figure 3-1). The Cornwall cap will be comprised of the same upland cap components including LFG collection and venting, an LLDPE liner, a drainage collection layer, and soil cover and top soil layer with grass that will be the functional equivalent of the Haley cap. The Cornwall cap components are described in the Cornwall EDR and fulfill Haley design and performance requirements including containment of Haley contaminants.

3. Asphalt will be placed over an approximate 0.13 upland area near the Pine Street beach to isolate existing soils from direct contact. The subgrade will be, graded, compacted and then a geotextile designed for separation will be installed over the subgrade. A 6-inch thick layer of crushed surfacing base course (CSBC) will be installed over the geotextile and the geotextile will serve to keep the CSBC from subsiding into the compacted subgrade and provide a barrier from potential contaminants below. A 4-inch thick layer of asphalt will be installed over the CSBC as the finished surface.

3.2. Haley Marine Unit Final Cleanup Action Overview

1. A portion of the LNAPL-impacted sediment volume with elevated concentrations of PCP, cPAHs, and other contaminants will be excavated within an approximate 0.56-acre area of the intertidal zone adjacent to the shoreline bank.
   - Contaminated sediment will be excavated up to approximately 7 feet below the mudline to reduce contaminant mass and facilitate placement of a sediment cap to contain underlying residual contaminants. The containment layer will be protected with armor rock transitioning landward to the shoreline bank slope and upland cap.
   - Sediment excavation includes areas with TPH concentrations indicative of potentially mobile non-aqueous phase liquid (NAPL) and locations where product sheen and seepage were previously observed. These areas also include locations with elevated concentrations of other associated IHS constituents including PCP, 1- and 2-methylnaphthalene, cPAH TEQ, and dioxin TEQ.
   - A cofferdam will be used to excavate sediment in the dry and contain the work.
   - The excavated sediment will be temporarily stockpiled in a location immediately upland of the excavation. The stockpiled sediment will be mixed with 3-percent Portland cement to condition the material to be suitable for use as fill for placement under the upland cap.
   - A 2-foot-thick sand cap with organoclay (OC) amendment will be placed inside the cofferdam in the dry to contain potential LNAPL and other residual contaminants below the excavation.
2. Outside the excavation area, engineered caps will be placed over an approximate 9.3-acre area of the seafloor to contain contaminants in sediment. Most of the capping area outside the excavation addresses elevated concentrations of bioaccumulative IHSs (dioxin TEQ, cPAH TEQ, and PCP). A small portion of this capping area also addresses SMS contaminants based on benthic toxicity.

- A 2-foot thick sand cap with OC and activated carbon (AC) amendments will be placed in nearshore areas to contain PCP and 1- and 2-methylnaphthalenes where groundwater discharge from the upland is prevalent. The cap is also protective for contaminants less mobile in the aqueous phase.

  A 1-foot thick sand cap with AC amendment will be placed in areas farther offshore where upward groundwater flow is controlled more by diffusion than advection.

  A geotextile fabric will be placed at the base of the amended sand caps to promote uniform settlement to maintain cap thickness and integrity. Another geotextile fabric layer will be placed to separate the top of the caps from overlying cap erosion protection material.

- In areas beyond the amended sand caps that are generally less contaminated, a 1-foot-thick gravelly sand TLC will be placed for containment of contaminants and protection of the seafloor from erosion. TLC areas are expected to be covered by natural deposition of clean sediment that is expected to accumulate over the TLC surface over time. The TLC surface provides seafloor erosion protection from potential episodic scour events as sediment accumulates on the TLC surface.

3. MNR is planned beyond the engineered capping areas over an area of approximately 50 acres. Concentrations of D/F in surface sediment in MNR areas exceed cleanup levels but are expected to achieve cleanup levels within 10 years as a result of ongoing natural deposition of clean sediment.
4. Engineered cap areas will be protected with armor rock, gravel/cobble and gravel/sand material to withstand erosive wave and current forces. The gravelly sand for the TLC serves as protection from erosion in deeper water.
   - The type, sizing, thickness, and lateral extent of cap and seafloor erosion protection was determined from coastal engineering analysis. This analysis used a 100-year design event, considering sea level rise (SLR) and related effects of storm surge, wave runup, and potential overtopping of the bank (see Section 5.5).
   - The Haley shoreline bank will be regraded based on coastal engineering considerations to protect the upland and marine cleanup elements, optimize resiliency, and reduce the size and thickness of armor needed.

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:

- 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 Cleanup Action Components

- ISS
    - Treat soil using ISS at nearshore locations to bind and encapsulate contaminants, reducing the potential for mobile LNAPL migration to the marine unit;
    - Identify an ISS reagent mixture that achieves a target hydraulic conductivity of $1x10^{-5}$ centimeters per second (cm/s) or less and a 28-day unconfined compressive strength between 30 and 200 pounds per square inch (psi);
    - Reduce the leachability and discharge of contaminants in the nearshore LNAPL area, and alter the flow path of upland groundwater through deeper, less contaminated soil;
    - Contain and recover fluids generated during ISS application;
    - Protect surface water from ISS residuals and contaminated media disturbed during implementation using a cofferdam.
    - Manage piling and debris; and
    - Construct a structurally stable ISS mass.
- Low-Permeability Cap
    - Cap contaminated upland areas to contain and isolate soil from direct contact, prevent surface water infiltration, and reduce groundwater discharge to Bellingham Bay;
    - Collect and vent landfill gas and address applicable air quality emissions requirements;
    - Achieve post-construction grading and drainage incorporating excavated conditioned sediment beneath the cap, managing post-construction runoff, and transitioning smoothly to the Cornwall cap;
    - Estimate anticipated settlement and stability under static and seismic loading, including excavated sediment consolidated with ISS mixture and placed beneath cap;
    - Manage piling and debris including existing foundations and subsurface structures;
    - Create a suitable surface for future park construction and preserve cap integrity and performance;
    - Transition smoothly to the Cornwall Site cleanup action; and
    - Provide for cap integrity and functionality as sea level rises.

3.3.3. Marine Cleanup Action Components

- Sediment Excavation
    - Excavate a portion of the sediment within the LNAPL-affected area to reduce the volume of LNAPL and related contaminants;
    - Excavate sediments to up to approximately 7 feet below the seafloor to facilitate placement of a containment cap for underlying residual contaminants;
    - Isolate the excavation area to work in the dry using a cofferdam;

- Maintain a safe and stable work area and dewater as needed to facilitate excavation and control contamination; and
- Condition the excavated sediment and incorporate into the Upland Unit prior to placement of the low-permeability cap.

- Sediment Caps
  - Cap contaminated marine areas to protect the benthic community (point by point basis) and protect human and ecological health from bioaccumulative chemicals (area-weighted average) within a 10-year time frame;
  - Determine cap thicknesses and suitable materials including OC and AC amendment based on cap performance modeling;
  - Estimate anticipated settlement and stability under static and seismic loading including weight of overlying armor;
  - Establish stable final grades; and
  - Transition smoothly to the Cornwall Site cleanup action.
- Sediment Cap Armoring
  - Design storm criteria considering current and tidal effects, SLR, storm surge, and wave runup and bank overtopping;
  - Identify appropriate armor types/sizes, placement areas, and layer thicknesses;
  - Consider changes to seafloor and habitat; and
  - Transition smoothly to the Cornwall Site cleanup action.
- MNR
  - Apply to uncapped areas of the Marine Unit assuming a typical natural sediment deposition rate of approximately 1.5 cm/year, and noting that comparison of bathymetric data between 2007 and 2015 indicates higher rates as described in Section 1.2.5.2;
  - Evaluate coastal engineering considerations for long-term stability of the sea floor bed; and
  - Consider current and future use.

The design of shoreline and bottom slope erosion protection for the Haley Site includes climate change effects from projected SLR. A potential SLR of up to 50 inches over the next 100 years (Year 2120) was used for the Haley design based on substantive requirements of the Bellingham Municipal Code (BMC). The City applies a SLR criterion of 50 inches for municipal planning and review of shoreline and building permits for development projects.

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 provided that it is 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 temporary cofferdams during ISS shoreline work and sediment excavation;
- Collecting and containing water and LNAPL as needed;
- Handling contaminated materials to prevent cross contamination with clean materials;
- Installing and maintaining temporary erosion and sedimentation control (TESC) structures and implementation of best management practices (BMPs) during construction of cleanup action;
- Covering and securing loads during off-site hauling of impacted materials, if needed;
- Decontaminating all construction equipment and haul trucks prior to exiting the Site;
- Installing floating oil and debris containment 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 cofferdam overtopping during storm events or other emergency release events, and maintaining emergency response materials on site.

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

3.3.6. Protection of Worker and Public Safety

It is expected that standard environmental remediation construction methods and safety practices will mitigate potential risks to site workers and the public. A Site 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 design features associated with the cleanup action are expected to be protective of the long-term safety of workers and the public, as determined through post-construction confirmational monitoring described in Section 8.0.

3.3.7. Hazardous Materials Management

Remediation-derived soil, sediment, and debris containing wood treatment-related chemicals from historical operations at the R.G. Haley facility will be classified as F032-listed dangerous waste based on designation criteria described in Chapter 173-303 WAC. Ecology previously identified an Area of Contamination (AOC) at the Haley Site for the purpose of on-site excavation, movement, stabilization and consolidation of contaminated soil and sediment. Per Ecology's 1991 AOC Policy, moving dangerous waste within an AOC is not considered waste "generation" as defined in Chapter 173-303 WAC. Ecology's AOC Policy further states that "containment, treatment and disposal of consolidated wastes within an AOC does not automatically trigger the dangerous waste regulations." Also, Land Disposal Restrictions (LDRs) do not automatically apply at sites where dangerous wastes are being excavated, consolidated or moved within the defined AOC.

The cleanup action will result in the consolidation of remediation-derived waste within the boundaries of the designated AOC. Site cleanup activities are based on the expectation that LDRs or other aspects of dangerous waste or Resource Conservation and Recovery Act (RCRA) regulations are not triggered by these actions, except those determined to be relevant and appropriate to the Site and action.

Remediation-derived materials that cannot be consolidated in the upland portion of the AOC will be transported and disposed of off-site as dangerous waste subject to LDRs, or may be suitable for disposal under an Ecology contained-in policy determination. Fluids separate from other remediation-derived materials will be evaluated for potential National Pollution Discharge Elimination System (NPDES) discharge suitability with treatment as needed, or for off-site disposal based on appropriate waste designation.

3.4. Permitting and Regulatory Requirements

Applicable or Relevant and Appropriate Requirements (ARARs), permitting and other regulatory requirements for the Haley Site cleanup action are described below.

3.4.1. ARARs

Cleanup actions at the Haley 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 ARARs. ARARs regulate specific components of the cleanup, including standards for cleanup of sediment, disposal of hazardous waste, and management of stormwater during construction.

Federal statutes and implementing regulations for the Haley Site 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 dredging or sediment capping.
- 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 armoring.
- 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 the potential listing of Coastal/Puget Sound bull trout.
- National Historic Preservation Act (16 USC 470 et seq. Section 106).

State statutes and implementing regulations for the Haley Site 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 Washington State Water Quality Standards for Surface Waters (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.
- Washington State Clean Air Act implemented by and air quality regulations (Chapters 173-400 WAC and 173-460) for point source emissions.
- Washington State Hydraulic Code Rules under 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 ARAR for the Haley Site Cleanup. In 2018 Ecology completed SEPA review of the cleanup action and made a Determination of Non-Significance as the SEPA lead agency. The NEPA review will be completed by the U.S. 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 Clean Air Act, Solid and Hazardous Waste Management Act, Hydraulic Code Rules, Water Pollution Control Act, SEPA and local regulations. Regardless of the permit exemptions, all cleanup actions must meet the substantive requirements of the subject regulations/permits. Ecology will consult with responsible agencies for the exempted permits and identify the substantive requirements following completion of 60% 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 as well as a DNR Use Authorizations for State-Owned Aquatic Lands.

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.

BMC requirements and Whatcom County building and construction permits, including demolition, grading, and drainage approvals, are not required because of the MTCA permit exemption. 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.

As part of the cleanup action, stormwater that infiltrates through the soil cap and meets the low permeability LLDPE liner will be conveyed to Bellingham Bay by a geocomposite drainage layer and perforated piping. Stormwater runoff from the vegetated surface of the cap will also be directed to the bay. The City of Bellingham maintains a Municipal Separate Storm Sewer System (MS4) Phase II Stormwater permit for stormwater discharges to surface waters and groundwaters of the state. The MS4 permit regulates stormwater discharges from parks and open spaces, and the stormwater discharge from the Haley Site after the cleanup action is constructed will be managed under this permit. The stormwater discharge will meet the requirements of the municipal operation and maintenance (O&M) Plan required in S5.C.7.d.xi of the MS4 general permit.

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-DESIGN INVESTIGATION RESULTS

This section summarizes activities and results for PRDI upland work tasks and habitat surveys at the Haley Site. PRDI activities were completed by GeoEngineers to provide additional information for the remedial design.

4.1. PRDI Upland Investigation

PRDI upland investigation activities were completed during the late summer and fall of 2018. The work was completed in accordance with the August 22, 2018 Pre-Remedial Design Investigation Project Plans – Upland (Upland Work Plan) and the October 17, 2018 Addendum to the Upland Work Plan prepared by GeoEngineers, Inc. and approved by Ecology. PRDI activities included:

- Evaluating the extent of LNAPL to refine the footprint of ISS;
- Evaluating the extent of petroleum product in the north Cornwall area (Haley-Cornwall overlap area);
- Delineating the northern extent of upland soil and groundwater contamination;
- Completing a Site-wide groundwater sampling event; and
- Completing a subsurface ground penetrating radar (GPR) survey to explore for debris, utilities and other buried features of interest.

Results and findings of the PRDI activities are summarized below. Figure 4-1 identifies explorations completed for the PRDI including direct-push borings, near-surface soil samples, and new groundwater monitoring well HS-MW-20. Appendix A-1 presents additional PRDI details, tabulated analytical data for soil and groundwater samples, supporting figures, exploration logs, laboratory analytical documentation, and data validation/review reports.

4.1.1. LNAPL Extent and ISS Footprint Refinement

Upland field work included advancing direct-push borings ISS1 through ISS35 at the locations shown on Figure 4-1 to help select the area and depth of ISS. Borings were advanced to a maximum depth of 20 feet bgs to observe subsurface conditions and collect a total of 63 samples for TPH laboratory analysis and 9 samples for analysis of total organic carbon (TOC), PAHs, and PCP. Testing results are provided in Appendix A Table A-1-1.

TPH data from the ISS borings were reviewed in conjunction with previous data to refine the estimated footprint of potentially mobile LNAPL for ISS application near the Haley shoreline. TPH data are presented for different depth intervals on Appendix A Figures A-1-2 through A-1-5. NAPL was inferred to be potentially mobile based on the results of free product mobility testing conducted during the RI. Those data suggest the residual saturation concentration for LNAPL in soil may be greater than 17,770 milligrams per kilogram (mg/kg) TPH. The refined ISS application area is based on a more conservative threshold of 15,000 mg/kg and is depicted on Figure 3-1. The refined ISS footprint extends slightly farther south and southeast relative to the area previously estimated in the Haley RI/FS. The ISS basis of design is described further in Section 6.0 and associated figures.

The ISS soil borings also provided information to update the interpreted extent of the upland "smear zone." The term "smear zone" refers to the upper portion of the saturated soil zone, where LNAPL has been "smeared" during seasonal and tidal fluctuations of the groundwater table. Visual indicators of LNAPL in the direct-push borings were used to further evaluate the smear zone conditions in conjunction with previous site data. The updated smear zone is shown on Figure 1-12. The ISS soil boring observations suggest the southwest margin of the smear zone from Haley extends slightly beyond the limit previously identified. Core observations also provided better definition of the northern and southern limits, as wells as more-detailed smear zone thickness data at many locations. Soil without a sheen and containing measured TPH concentrations up to 1,500 mg/kg extend beyond the boundary of the smear zone. Figures A-1-2 through A-1-5 in Appendix A present the results from the PRDI for TPH concentrations in soil beyond the boundary of the smear zone. Additional information concerning TPH concentrations in soil are presented in the RI/FS (GeoEngineers 2016).

Selected samples from the ISS borings were submitted for additional analyses unrelated to defining the footprint of ISS, and also to further assess the suitability of the ISS mix design. Laboratory testing included PAHs, PCP, and TOC. Testing results for these constituents are presented for different depth intervals on Appendix A Figures A-1-8 through A-1-23. As expected, many of the samples with elevated TPH concentrations also contained elevated PAH concentrations. ISS in these areas will reduce leaching and groundwater flow through nearshore soils containing these constituents. The testing results also indicated that soils outside the ISS footprint contain PAH concentrations that are suitable for containment beneath the planned low-permeability cap and do not need to be incorporated into the ISS footprint. No PCP was detected in any of the samples. Elevated TOC concentrations (up to 45 percent) indicated the presence of substantial wood waste in several samples, as expected, and are not anticipated to present a problem for ISS.

4.1.2. Haley-Cornwall Overlap Area Petroleum Product Evaluation

Substantial product thicknesses were encountered in monitoring wells CL-MW-103 and CL-MW-6 in the north part of the Cornwall site (Haley-Cornwall Overlap Area) during PRDI groundwater/product monitoring conducted on August 30, 2018 (see Appendix A Figure A-1-25). The measured product thicknesses in these wells were 1.51 and 2.43 feet, respectively. Relatively insignificant product thicknesses were observed in this area during the Haley RI. Since August 30, 2018, product thicknesses in these wells have consistently remained between 0 to 0.02 feet during additional quarterly monitoring events including December 2019 and June 2020 (Figure 1-13 and Figure 1-14, respectively). The representativeness of the August 2018 thickness measurements is uncertain and the product observed in CL-MW-103 is thicker and visually dissimilar to LNAPL related to past Haley wood-treatment operations.

Several direct-push borings were advanced in November 2018 to further investigate the extent of elevated TPH concentrations and petroleum product occurrence in the north Cornwall area and the downgradient area to the northwest (see Appendix A Figures A-1-3 and A-1-4). TPH concentrations in soil samples from ISS32 and previous borings CL-SB-102, CL-SB-103, and CL-MW-103 exceeded 15,000 mg/kg, the conservative estimated residual saturation concentration, as shown on Figure A-1-3 (5 to 10 feet bgs) and Figure A-1-4 (10 to 15 feet bgs). The elevated TPH concentrations (>15,000 mg/kg) and product occurrence in the north Cornwall area appear to be isolated from the estimated areas of potentially mobile LNAPL (>15,000 mg/kg) near the downgradient Haley shoreline. The north Cornwall area will continue to be monitored for LNAPL until the remedial action for the Haley-Cornwall overlap area has been implemented. Figure 4-2 presents the results for TPH concentrations in soil (5 to 10 feet bgs) in the Haley-Cornwall overlap area.

4.1.3. Northern Extent of Upland Contamination Delineation

Direct-push soil borings NER01 through NER06 were completed to depths up to 12.5 feet bgs at the locations shown on Figure 4-1 to further delineate the northern extent of PAH and PCP contamination in upland soil. Eight near-surface samples (SS1 through SS8) also were collected for D/F testing. Testing results are presented on Appendix A Figures A-1-8 through A-1-24 and in Table A-1-1.

Concentrations of PCP and some PAH constituents from borings NER01 through NER03 (southern transect of NER borings) exceeded applicable cleanup levels. Concentrations of D/F in six of the eight surficial soil samples also exceeded the D/F TEQ cleanup level as presented on Figure 4-3. These results indicated the need to extend the low-permeability upland cap to the northern boundary of the Haley property. Additional testing of samples from borings NER04 through NER06 (northern transect of NER borings) was not completed based on these findings.

4.1.4. Site-Wide Groundwater Sampling Event

The last Site-wide groundwater sampling event prior to the PRDI occurred in 2012, with results reported in the RI/FS. The PRDI groundwater sampling event was completed in late August and early September 2018 to obtain updated TPH, PAH and PCP data from 22 monitoring wells identified on Figure A-1-26. Samples from selected wells were also analyzed for D/F.

As expected, TPH concentrations were highest in groundwater samples from monitoring wells near the western (shoreward) edge of the Upland Unit, particularly upgradient of the sheet pile wall (Figure A-1-27). The highest TPH groundwater concentrations occurred within the planned ISS application footprint and were generally higher than in 2012 at several locations near the shoreline. TPH concentrations decreased compared to 2012 levels in monitoring wells HS-MW-4 and HS-MW-5 near the upgradient boundary of the Site.

PAH constituents were detected in 13 of the wells, with 1- and 2-methylnaphthalene concentrations exceeding cleanup levels in several wells in the central shoreline area and in wells HS-MW-7 and HS-MW-8 farther inland (Figure A-1-28 and Figure A-1-29). Concentrations of these constituents were consistent with 2012 concentrations in well HS-MW-7, increased in well TL-MW-7, and decreased in several other wells near the shoreline and in HS-MW-4 and HS-MW-5 near the eastern (upgradient) boundary of the Site. PAH concentrations were highest in wells RW-5, RW-6 and TL-MW-7. Concentrations of at least one of the constituents acenaphthene, benzo(a)anthracene, and total cPAH TEQ exceeded their respective cleanup levels in samples from several wells within the planned ISS application footprint (HS-MW-6, TL-MW-7, RW-5, RW-6, and TL-MW-11), and upgradient (HS-MW-4, HS-MW-7, and HS-MW-8). These results were not unexpected and were comparable to the 2012 results. Notably, no PCP was detected in any of the wells. Testing results for D/F in groundwater samples from wells TL-MW-11, TL-MW-14 and TL-MW-16 exceeded the total D/F TEQ cleanup level (Figure A-1-31).

The analytical results from the PRDI Site-wide monitoring event were generally consistent with the anticipated conditions and provided key information for technical analyses supporting ISS, upland capping, and sediment capping components of the remedial action.

4.1.5. GPR Survey

A GPR survey was completed on September 17, 2018 in portions of the ISS footprint and other locations in the central portion of the Site. The objective of the GPR survey was to evaluate the extent and type of subsurface debris, underground utilities and shallow subsurface foundation remnants and other structures. The GPR technique was not successful in identifying subsurface features of interest.

4.2. PRDI Habitat Surveys

Habitat surveys were completed to assess existing conditions and included evaluation of eelgrass/macroalgae, shoreline/intertidal, and riparian/terrestrial habitats. Figure 4-4 shows the surveyed extent of eelgrass and intertidal habitats at the Site. These surveys update information collected in 2012 that was previously summarized in the RI/FS. Additional discussion of the 2019 habitat surveys, including methods and detailed results, is provided separately in EDR Appendix A-2. Mitigation options for habitats affected by Haley remedial actions will be evaluated during project permitting.

4.2.1. Eelgrass/Macroalgae Survey

The eelgrass/macroalgae habitat survey was completed using a combination of georeferenced underwater video, divers, and a shore-based survey during low tide. Eelgrass bed boundary locations, eelgrass shoot densities, and species determinations were made by divers and from shore during low tide. Transect orientations and spacings varied by eelgrass bed location as described in Appendix A-2. Drone-generated orthoimagery was collected during the eelgrass survey to provide additional verification of the location of the eelgrass beds within the site. The complied orthoimage photographs are presented on Figure A-2. Results from the survey found the eelgrass beds ranged in elevation between about -1 and -10 feet NAVD88. Mean shoot densities ranged from 72.2 to 99 shoots per square meter (m^2) across the Site.

A total of 101,770 square feet (sf; 2.34 acres) of eelgrass bed area was documented within the habitat survey limits shown on Figure 4-4. The survey excluded additional eelgrass beds to the west along the northern shoreline, as these areas are not affected by Haley remedial actions. The total area of eelgrass in Areas 1, 2, and 3A that will be affected by the planned Haley sediment capping is 78,010 sf (1.79 acres).

4.2.2. Shoreline and Intertidal Survey

The shoreline and intertidal habitat survey included 19 transects extending from elevations of approximately 10 to -2 feet NAVD88 to characterize the condition of nearshore resources. Along each transect, data were collected regarding the presence/absence and cover of substrate, macroalgae, invertebrates and other habitat features in order to make a qualitative assessment on habitat function. The habitat survey in the nearshore environment primarily identified riprap, other large sandstone boulders, and other debris in the upper shoreline bank elevations. These substrates transition seaward to cobble material, then to large gravels and sand, with finer material observed across the Pine Street beach area.

Zones of two types of macroalgae were documented within the intertidal survey, *Fucus* sp. and *Ulva* sp., with eelgrass extending seaward from approximately 0 feet to -2 feet (NAVD88). Remnant piles were observed throughout the shoreline with additional large rocks and wood debris such as old planks within the upper shoreline area. Generally, the habitat condition of the intertidal area is disturbed, with extensive armoring and scattered debris consisting of rebar, scrap metal, refuse, bricks, and angular rock from off-site. Landfill waste is exposed along the beach bluff in the southern end of the Site.

4.2.3. Marine Riparian/Terrestrial Survey

The terrestrial and marine riparian habitat survey involved visually evaluating upland areas and areas adjacent to the upper shoreline bank for soil types or impervious groundcover, vegetation, wildlife, and signs of wildlife use. Findings indicate that there is no well-developed native terrestrial and marine riparian vegetation at the Site. The fenced containment area is dominated by tansy, Himalayan blackberry, and scattered red alder and cottonwood saplings growing in areas of gravel or between concrete paved areas. The red alder and cottonwood trees are intermixed with non-native herbs and shrubs. Marine riparian habitat immediately adjacent to the upper shoreline is dominated by Scotch broom, Himalayan blackberry, tansy, and invasive clematis, with limited patches of native trees (e.g., red alder, cottonwood and Douglas fir).

5.0 MODELING AND TESTING RESULTS SUPPORTING REMEDIAL DESIGN

Several design elements for the Haley cleanup action required testing or modeling to determine design parameters that will ensure that these 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. ISS Treatability Testing Summary

ISS treatability testing was performed in accordance with the Treatability Study Work Plan (CRETE 2015). Multiple reagents were used to formulate amendment mixtures that were then tested to evaluate ISS properties relative to performance criteria. The purpose of the treatability work was to develop general design parameters and a baseline for construction bidding purposes.

Results from the ISS treatability testing were evaluated against the following performance criteria:

- ISS Hydraulic Conductivity: preliminary hydraulic conductivity target of less than $1x10^{-5}$ cm/s.
- ISS Strength: preliminary target range for 28-day unconfined compressive strength (UCS) between 30 and 200 psi. The lower limit was derived to match existing site soil strength.

ISS ductility was also a consideration but was not set as a performance criterion. The diffusion-controlled release of chemicals from an ISS mass is a function of surface area and that surface area could be increased if significant cracks form in the ISS mass. Strength, permeability, and ductility can be competing properties, so the approach taken was to evaluate the mix designs that achieved the strength/hydraulic conductivity performance requirements and also showed higher axial strain values at failure.

One of the primary goals of ISS is to reduce the potential for soluble contaminants to partition to the dissolved phase (leach) by binding and encapsulating contaminants within the soil matrix. Leach testing was performed during treatability testing using methods consistent with the Leaching Environmental Assessment Framework (LEAF). Environmental Protection Agency (EPA) Method 1315 was designed specifically to estimate the mass transfer rates (release rates) of analytes contained in a bench-scale test monolith, under diffusion-controlled release conditions, as a function of leaching time. Some of the leachate data was used as a conservative estimate of sediment porewater concentrations for sediment cap modeling purposes (Section 5.3).

Treatability soil samples were collected from five upland test pit locations as described in the draft Treatability Study Results report (Appendix B). Based on the observed test pit conditions, separate ISS South and ISS North treatability samples were created. The ISS South sample includes landfill debris and sawdust and was expected to have lower chemical constituent concentrations. The ISS North sample includes wood debris and wood fill and was expected to have higher chemical constituent concentrations.

The results of the baseline analysis of the untreated material indicated that the ISS South and ISS North composite materials are classified as black silty sands (SM) with a slightly acidic pH of 6. The ISS South material has a significantly higher organic content (9.18 percent) and soluble sulfate concentration (35.43 grams sulfate per kilogram [SO_4/kg] soil) than the ISS North material (3.61 percent and 15.65 grams SO_4/kg soil).

The soluble sulfate concentration results indicated that the soil at the site represents severe to very severe sulfate exposure (Hayes 2007). Publications are available describing mitigation measures to prevent sulfate attack on Portland Cement (Bhatty and Taylor 2006; Lafarge 2016). One of the mitigation measures is to use an amendment mix that includes GGBFS such that the maximum ratio of Type I Portland Cement to GGBFS is 2:1.

In addition to physical properties testing, untreated composite materials were subjected to analytical testing. In general, the results of analytical testing indicate that the untreated ISS North was slightly more TPH/LNAPL-impacted than the untreated ISS South. The ISS North sample was spiked with additional LNAPL obtained from the Site to more closely approximate product conditions representative of the ISS area. Concentrations of PAHs and PCP were relatively low in both untreated composite samples.

ISS treatability testing demonstrated that numerous combinations of Type I Portland Cement, GGBFS, and bentonite were capable of achieving the preliminary performance criteria for compressive strength and hydraulic conductivity. The most cost-effective amendment mix meeting performance criteria included 4 percent Richmond Type I Portland Cement and 8 percent GGBFS (ISS Mix). These amendments are both locally available with the Portland Cement manufactured in Richmond, British Columbia and the GGBFS, a recycled industrial byproduct, available in Seattle, Washington.

This ISS Mix achieved 28-day compressive strengths of 61 psi for ISS South and 52 psi for ISS North Spiked samples, and a hydraulic conductivity of 2.4×10^{-7} cm/s for ISS South and 1.4×10^{-7} cm/s for ISS North Spiked samples. The ISS Mix satisfies the performance criteria by achieving the minimum compressive strength of 30 psi and hydraulic conductivities less than 1×10^{-5} cm/s. Sulfate compatibility of the amendment mix was achieved using a Portland Cement to GGBFS ratio of 1:2, well below the maximum recommended ratio of 2:1 (Appendix B).

Axial strain was also considered during ISS amendment mix development to reduce the potential for fracture of the solidified matrix. Axial strain for the above-described mix was measured during UCS testing at 1.32 percent for ISS South and 1.53 percent for ISS North Spiked. The strain value was the highest reported for the ISS North Spiked sample and was 93 percent of the maximum strain value reported for the ISS South samples.

5.2. Sediment Conditioning Treatability Testing Summary

As a component of ISS treatability testing, intertidal sediment was sampled and tested to determine the physical conditioning required to place the excavated sediment as fill in the Haley Upland Unit. The objective of the intertidal sediment conditioning was to evaluate the geotechnical conditions of the sediment and demonstrate that the sediment can be conditioned using a cementitious material to be geotechnically suitable for placement and compaction beneath the low-permeability upland cap with other contaminated soil. Additional details on the sediment conditioning testing are presented in Appendix B.

The overall goal for intertidal sediment conditioning is to remove free water and create a material that is workable and compactable using standard construction equipment, as indicated by evaluating moisture content, Atterberg Limits, and moisture-density relationships (Proctor compaction testing) during treatability testing.

Samples collected and used for the conditioning testing included intertidal sediment samples collected from outside the known footprint of LNAPL-impacted sediment. This was done to prevent disturbing subsurface sediment that would be expected to have LNAPL impacts and could potentially be disturbed during sampling activities. As a surrogate for sediment within the zone of expected LNAPL impacts, LNAPL-impacted soil was collected from upland test pits at approximately the same elevation and lithologic horizon as the intertidal sediment to be excavated.

Initial observations indicated that the sediment collected from the southern portion of the planned nearshore excavation area was relatively coarse grained and drained freely, so was not further evaluated for conditioning needs. Proctor tests and paint filter tests performed on untreated sediment from the sediment samples from the northern portion of the excavation area indicated a higher moisture content than desired and the moisture did not drain during paint filter tests, indicating the likely need for conditioning prior to use as fill. This sediment, as amended with 3 percent Portland Cement, was cured for 28 days and tested for:

- Standard Proctor – ASTM International (ASTM) D698;
- Atterberg Limits – ASTM D4318;
- Particle Size w/Hydrometer – ASTM D422;
- Hydraulic Conductivity – ASTM D5084; and
- Consolidated, Undrained Triaxial Shear Test – ASTM D4767 (Three point).

The testing indicated that the conditioned sediment is expected to compact to at least 95 percent of the ASTM D698 maximum dry density (MDD) after 28 days of curing, thereby providing a workable and compactable material. The test results suggest that the amended material should exhibit relatively little consolidation upon placement and its behavior should be similar to a well-drained granular soil. These conclusions indicated that conditioning excavated sediment with 3 percent Type I Portland Cement will produce a suitable material for use under the upland low-permeability cap.

5.3. 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 C.

A one-dimensional transient model, CAPSIM© (Version 3.6), developed by Dr. Danny Reible at Texas Tech University and associates (Reible 2018) was used to evaluate contaminant fate and transport within cap material under selected cap design scenarios. The CAPSIM program 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 EPA and USACE guidance for contaminated sediment capping (Palermo et al. 1998).

The most sensitive parameter affecting contaminant transport and model results is the rate at which groundwater and porewater travels through sediment and discharges across the plane of the sediment surface and either into surface water under current conditions or into the cap material following placement of a sediment cap. The term groundwater flux is used in this document to describe the quantification of the rate of discharge, applied per unit area of the sediment surface. To account for varying groundwater flux values across the cap area, the general modeling approach considered three main zones; Zone 1 between the OHWM and mean lower low water (MLLW) (-0.48 feet NAVD88) where the majority of groundwater discharge occurs, Zone 2 between the MLLW and the offshore limit of significant groundwater flux based on groundwater flow modeling, and Zone 3 where groundwater flux, and advective contaminant transport, are minimal. The modeling zones are identified on Appendix C Figure C-1.

Cap modeling focused on containment of PCP and 2-methylnaphthalene as representative target constituents because of their prevalence and relative mobility in the aqueous phase. TPH also was modeled as a key constituent of interest and because of its association with PCP and 2-methylnaphthalene. The CAPSIM cap model relies on user-input values for dissolved phase contaminant concentrations entering the cap. Input concentrations for PCP in all zones were based on calculated equilibrium values using sediment data, as these calculated porewater concentrations were consistently more conservative (higher) than potential PCP contributions from upland groundwater and leachate from the ISS mass. Zone 1 conditions for 2-methylnaphthalene were modeled using leachate concentrations observed during ISS treatability testing, as this data represented most conservative conditions. Further offshore, 2-methylnaphthalene dissolved concentrations were calculated from sediment concentrations, similar to PCP. For modeling purposes, porewater concentrations were assumed to be constant over the modeling period (100 years), conservatively simulating an infinite source of contamination to the overlying sediment cap.

The following ranges of porewater concentrations were used for modeling:

- PCP: 136 micrograms per liter (µg/L) (Zone 1) to 7.1 µg/L (Zone 3)
- 2-methylnaphthalene: 72 µg/L (Zone 1) to 0.98 µg/L (Zone 3)
- TPH: 370.3 µg/L (Zone 1) to 17.9 µg/L (Zone 3)

Results of the cap modeling informed and optimized configuration of chemical isolation layers consisting of sand with OC and/or AC amendments determined to be necessary to contain contaminants in sediment and porewater. Based on this approach, the amended sand cap designs needed to contain 2-methylnaphthalene and PCP also provide containment for other IHSs that are less mobile. The results for the various cap zones and selected cap configurations are as follows:

- Zone 1 within excavation limits: The selected chemical containment layer consists of 2 feet of sand amended with 10 percent (by weight) OC to address IHSs as well as residual, potentially mobile LNAPL that may be present in underlying sediment. The cap model indicated that using this cap configuration under the selected high-groundwater flux condition and the Zone 1 contaminant concentrations, contaminants attenuate within the chemical containment layer to the degree necessary to meet cleanup levels at respective points of compliance over the assumed 100-year operational lifespan. It should also be noted that the excess cap amendment capacity is projected after the 100 years.
- Zone 1 outside excavation limits: The selected chemical containment layer consists of a 1-foot-thick layer of sand amended with 1 percent (by weight) OC overlain by a 1-foot-thick layer of sand amended with 1 percent activated carbon. The model results indicated that this cap configuration is capable of

containing contaminants within the chemical containment layer, preventing migration of contaminants to respective points of compliance at concentrations above cleanup levels.

- Zone 2: The lower groundwater flux of Zone 2, seaward of Zone 1 and located approximately between elevations 0 MLLW and -5 MLLW, places less demand on cap amendments. Based on model results, the optimized cap profile in this area consists of a 2-foot-thick mixture of sand with 1 percent OC.
- Zone 3: The offshore conditions of Zone 3 are expected to include minimal groundwater flux. Cap modeling indicated that the planned 2-foot sand cap in this zone could potentially result in eventual breakthrough of PCP by diffusive transport through the sand cap material due to the low organic fraction in the cap material. The cap model indicated that a small fraction of organic material (0.1 percent by weight) added to the clean sand is adequate to attenuate PCP. The cap model results indicate that this small fraction of activated carbon provides the necessary attenuation of PCP to meet cleanup levels at points of compliance.

Additional sediment and porewater quality data will be collected in the future as part of a PRDI Addendum, and incorporated into the design, to further inform and confirm expected cap performance based on the modeling scenarios summarized above. In particular, additional sediment and porewater data will be collected in Zone 1 to supplement existing data. Using this information, additional cap modeling will be performed to confirm whether the existing cap configurations are protective or if they require potential modifications.

5.4. Landfill Gas and Soil Vapor Evaluation

Portions of the Haley Site are underlain by wood waste. In addition, municipal solid waste (MSW) associated with the adjacent Cornwall Avenue Landfill is present at locations where the Haley and Cornwall sites overlap (Figure 1-5). Both the wood waste and MSW are expected to continue generating LFG as organic components in these wastes decompose through natural processes. LFG also includes soil vapors containing vinyl chloride, benzene, naphthalene and other VOCs associated with former wood treatment chemicals and LNAPL present at Haley Site.

Appendix D presents an evaluation of soil vapor conditions to determine requirements for collecting and venting LFG as a component of low-permeability upland capping. The evaluation includes consideration of LFG sources and regulatory requirements to develop engineering design recommendations. LFG modeling and system design are similar to and consistent with work completed for the Cornwall EDR (Landau 2018).

To complete the LFG and soil vapor evaluation, a model of the gas generation rate using field investigation data including contributions from both MSW and wood waste buried at both the Haley and Cornwall Sites was developed. This modeled flow rate in cubic feet per minute (cfm) was then combined with laboratory analytical results for soil vapor samples collected at both sites to develop mass discharge rates. These rates were then used to evaluate compliance with air quality regulations and as inputs for the air dispersion model. The air dispersion model results are used to predict the breathing-zone ambient air impacts to inform system design. Predicted gas generation rates are provided on Figure 5-1.

The LFG and soil vapor evaluations also considered planned future Site usage as a public park. The evaluation results confirmed the need for proper sub-liner ventilation to prevent accumulation of gases, provided the data necessary to evaluate regulatory considerations for venting the LFG, and provided an assessment of the expected ambient air quality conditions for future park visitors and workers. The detailed modeling evaluation provided in Appendix D is summarized in the following sections.

5.4.1. Soil Vapor and Landfill Gas Monitoring

During separate RI activities, a total of 21 soil vapor/LFG monitoring probes were installed at the Cornwall and Haley Sites (Figure 5-2). Monitoring locations were selected to characterize both the typical LFG components (i.e., methane, carbon dioxide, oxygen, carbon monoxide, hydrogen sulfide, balance gas), and also the VOCs. The results of soil vapor and typical LFG monitoring are provided in Appendix D. VOCs are a component of LFG and were detected at the anticipated (low) concentrations at the Cornwall site. At the Haley Site, the VOCs in soil vapor are lower molecular weight Site contaminants associated with wood treating, volatilized from soil, groundwater, and residual LNAPL.

Laboratory analytical results for samples collected in the field for both sites were presented in the respective RI/FS reports and tabulated in Appendix D with additional discussion. For the purposes of this evaluation, it is conservatively assumed that the highest detected concentrations of VOCs in soil vapor are representative of the VOC concentrations in the gases released from LFG system vents. The soil vapor and LFG monitoring data are compared to applicable MTCA air cleanup levels developed for the protection of ambient air and to Washington State air quality standards.

5.4.2. Landfill Gas Generation Modeling

The industry-standard approach—the EPA's LandGEM spreadsheet model—was used to estimate gas production rates, which for the Haley Site, primarily result from anaerobic decomposition of buried MSW and wood waste. The model is used to estimate gas generation for assessing regulatory compliance and for LFG control system design. The estimate is based on the quantity of buried waste, waste age, type, and physical factors related to the subsurface environment that affect kinetics. Haley Site VOC and LNAPL sources do not significantly contribute to LFG production rates. However, for the purposes of this report, LFG at the Haley site collectively includes subsurface gas derived from the decomposition of wood waste at the Site, subsurface gas derived from landfill waste on the southern portion of the Site and soil vapor from the volatile components of Haley Site contaminants,

Modeling input details, including the approach for modeling combined LFG sources, is presented in Appendix D. The modeling estimates indicate a total LFG generation rate of 3.6 cfm for year 2020, which includes the combined contributions of LFG generated from the degradation of wastes at both sites as shown on Figure 5-1. To provide a factor of safety in design considerations, the LFG generation rate was rounded up to 10 cfm.

5.4.3. Air Dispersion Modeling

Using the modeled generation rate of LFG, and the concentrations of VOCs determined from field investigations, air dispersion modeling was used to estimate ambient air impacts in the breathing zone from proposed LFG system vents. The dispersion model determines the reduction in contaminant concentration between the point of release (LFG system vent) to the potential point of exposure, where in the future, park visitors or park workers could potentially be exposed to vent emissions. An EPA-recommended air screening model, AERSCREEN (version 16216), was used to estimate maximum exposure concentrations using worst-case emissions conditions. Additional modeling details are provided in Appendix D.

5.4.4. Federal Standards

The cleanup activities and proposed LFG system equipment (vents) were found not to be subject to federal standards, including New Source Performance Standards (NSPS) or National Emission Standards for Hazardous Air Pollutants (NESHAP). NSPS and NESHAP dictate reporting requirements and additional emission standards for sources found to be subject to its rulings.

5.4.5. Northwest Clean Air Agency Standards

The site is subject to New Source Review pursuant to Northwest Clean Air Agency (NWCAA) Regulation 300. Emissions from the Site were calculated and compared to *de minimis* values and small quantity emission rates (SQERs; WAC 173-460) in consideration of a NWCAA permit in Appendix D. The evaluation showed that a NWCAA Notice of Construction (NOC) permit application should be submitted prior to construction of the LFG collection and venting system.

The estimated emissions of VOCs are presented in Appendix D and were compared to the SQERs and *de minimis* emission values (WAC Chapter 173-460). The comparison determined that further permitting or consideration of potential treatment may be necessary. Carbon adsorption was selected as the treatment technology and it was estimated that this treatment technology could achieve a 90 percent reduction for VOCs.

5.4.6. MTCA Method B Cleanup Standards

MTCA Method B criteria for air emissions must be met from remediation systems with atmospheric emissions. The expected ambient air impacts from the LFG vents were compared to MTCA Method B air cleanup criteria (both cancer and non-cancer risks) for VOCs with toxicology data available on the Ecology's cleanup levels and risk calculations (CLARC) database from Ecology's website that was updated in May 2019. Cleanup levels were met in the ambient air, except for naphthalene, using an LFG system vent height of 12 feet above ground surface, and without active treatment. Modeled naphthalene concentrations are slightly greater than the MTCA Method B Cleanup Standards and installation of a carbon adsorption system is therefore planned to reduce vent emissions to less than the MTCA standards.

5.4.7. LFG System Design Considerations

Results of the LFG evaluation included the following considerations for the LFG control system design:

- The LFG production rate was estimated to be relatively low. The design will be based on a flow of 10 cfm and it is assumed, for the purposes of design, that LFG is being produced throughout the Site. As a result, an LFG collection layer will be included throughout the Site, beneath the low-permeability layer of the landfill cover system.
- The highest production of LFG is likely to be in areas with the thickest buried wood waste. Passive extraction wells will be used in these areas to capture LFG where it is expected to be present at the highest concentrations, and to prevent the buildup of pressure that could promote lateral migration.
- In order to meet air quality criteria the LFG system vents will be installed to a height of 12 feet above ground surface, and each of the vents will initially be outfitted with a subsurface activated carbon filter system.
- It should be noted that, although treatment was determined to be required, it is anticipated that the worst-case scenarios used in this evaluation will result in an over-estimation of the actual emissions.

The actual emissions may meet ambient air quality and MTCA air cleanup standards without treatment. Future compliance monitoring will be conducted prior to public access that could confirm that filtration or other treatment of the LFG emissions is not required and air permitting considerations are no longer warranted. These evaluations and determinations will be undertaken in coordination with Ecology and the local air quality agency.

5.5. Coastal Dynamics Evaluation

The nearshore area of the Haley 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 Haley cleanup action. As a result, coastal processes were modeled and a design developed to protect seafloor and shoreline bank areas that are susceptible to wave erosion. The Basis of Design report for coastal process modeling is provided in Appendix E of this EDR and presents coastal process modeling input data, assumptions, and design criteria.

Modeling evaluated storm surge, wave runup, and potential overtopping of the bank by waves, in addition to the vertical component of SLR. The coastal modeling basis of design is also consistent with recommendations described in Ecology's Adaptation Strategies for Resilient Cleanup Remedies guidance document (Ecology 2017) for increasing the resilience of sediment remedies to climate change impacts. Key assumptions for the design storm and wave erosion modeling are summarized below.

5.5.1. Wave Conditions for Modeling

Wave conditions at the Haley Site were the major controlling factor for the design of coastal engineering element, and the effect of tidal currents and other factors on design were found to be negligible. Therefore, detailed wave analysis and numerical modeling was performed to establish the wave conditions for existing conditions prior to the project and for post-project conditions after construction of the proposed coastal protection elements. Descriptions of the wave modeling as well as the basis of design for each coastal element are presented in the Basis of Design Report provided in Appendix E.

A 100-year return period storm event was selected for analysis and numerical modeling to determine the stable materials for shoreline and bottom slope protection design. Wave conditions at the project site were developed based on numerical modeling of wind-wave generation for the 100-year wind speeds from the south to west directions corresponding to the limiting wave fetches for the Haley Site location in Bellingham Bay. The 100-year storm event was selected as the design wave storm criteria considering major storm events over this time period. Use of the 100-year event for design purposes is consistent with design criteria for the Whatcom Waterway and Cornwall cleanup projects. The 100-year design storm is more conservative than many other shoreline protection projects that are typically designed to withstand 25- or 50-year return period events. The wave modeling outputs were used to analyze and optimize of the various components of the shoreline and bottom slope erosion protection described in Section 6.2.4.

5.5.2. Sea Level Rise (SLR)

The design of shoreline and bottom slope erosion protection for the Haley Site considered climate change effects including projected SLR. A potential SLR of up to 50 inches over the next 100 years (Year 2120) was used for the Haley design based on substantive requirements of BMC Chapter 16.30 Planned Actions. Exhibit A to Chapter 16.30 requires that:

"As part of construction of on-site infrastructure, site grades shall be raised to accommodate potential long-term sea level rise and tsunami conditions, appropriate to the design lifetime of the project, as determined using the higher end of the range predicted using best available science."

Accordingly, the City applies a SLR criterion of 50 inches for municipal planning and review of shoreline and building permits for commercial development projects. The City determined that applying the 50-inch SLR criteria for Haley Site remediation is appropriate for meeting the substantive requirements of the BMC.

The 50-inch SLR criterion represents a likelihood of occurrence of less than about 5 percent in 2120, as presented on the Washington Coastal Hazards Resilience Network Website (https://wacoastalnetwork.com/chrn/research/sea-level-rise/). Future SLR projections presented on this website are probabilistic predictions developed as part of a SLR assessment for Washington state based on low and high greenhouse gas (GHG) scenarios (Miller et al. 2018, updated July 2019). This study describes the likelihood of future SLR changes and accounts for relative SLR given the geographic variability in the vertical movement of the land surface across Washington state. The probabilistic SLR projections from the study are intended for consideration during risk management assessment and planning.

5.5.3. Modeling Cases for Design

SLR in conjunction with high and low tide elevations were considered to develop modeling cases for wind/wave effects and engineering design of shoreline and bottom erosion protection. Design of the upper portion of the shoreline bank protection used a SLR of 50 inches and corresponding storm wave height, assuming a design storm occurred at the mean higher high water (MHHW) tidal stage (currently 9.73 feet NAVD88). The upper elevation of armor rock was determined to be 15.5 feet (see Section 6.2.4).

A SLR of 2.4 feet was used to analyze potential erosion impacts in the lower intertidal and subtidal zones, assuming that a design storm occurred at the MLLW tidal stage (currently -0.48 feet). SLR of 2.4 feet was used to account for erosion impacts at these elevations that are anticipated to be more intense than for 50 inches of SLR. This is because the predicted water column depth during MLLW is less for SLR of 2.4 feet than for 50 inches, increasing the potential for erosion. The likelihood of exceedance for SLR of 2.4 feet is between 17 and 83 percent based on the 2018 Miller et al. study, noting that this SLR scenario would precede any higher rise in sea level. Based on this scenario the lower elevation limit of armor rock is near 0 feet, with finer grained erosion protection material needed at lower elevations (see Section 6.2.4).

5.5.4. Tsunami Considerations

In addition to coastal modeling potential tsunami impacts were evaluated at the Haley Site based on tsunami hazard modeling results published by the Washington Geological Survey (WGS) and DNR (Tsunami Hazard Maps of the Anacortes–Bellingham Area, Washington—Model Results From a ~2,500-year Cascadia Subduction Zone [CSZ] Earthquake Scenario, [Eungard et al. 2018]). The model calculates wave elevations and velocities at specified time intervals to simulate the generation, propagation, and inundation of a tsunami following a L1-style earthquake approximating a 2,500-year event from the CSZ. As reported in the modeling study, the L1 earthquake scenario closely approximates design requirements for critical facilities in the Washington State building code for seismic hazards and is more conservative (greater inundation) than previous tsunami modeling. This scenario represents the maximum considered tsunami event that a facility may be subjected to during its operational lifetime. The model was developed as a tool to guide evacuation planning and is calculated for a tsunami event occurring at mean high water (MHW, elevation

7.31 feet NAVD88). The model was developed independently of other tidal effects and does not take those effects into account.

Tsunami hazard modeling results for the Haley Site vicinity indicate that the first indication of an incoming tsunami wave following strong shaking from a CSZ earthquake would be a gradual drop in water level immediately prior to arrival of the first rapidly rising wave. The model predicts that the first wave would arrive near the Site in about 2 hours and 15 minutes and have water depths ranging from 2.5 to greater than 6 feet over the Haley Site area if the tsunami occurred during MHW tidal conditions (Figure 5-3). Areas in the central and northern parts of the Site are predicted to experience the most inundation. For comparison, the highest wave predicted at the Port of Bellingham area from the model is 13.1 feet during MHW conditions. Modeled current velocities of the tsunami waves are in the range of 0 to 3 knots in the upland areas. Tsunami waves are projected to potentially continue to reach the Haley Site vicinity for at least 8 hours.

A comparable tsunami inundation area is also predicted in the Haley Site vicinity from the Tsunami Design Zone (TDZ) map for Bellingham Bay published by the American Society of Civil Engineers (ASCE) (ASCE 7-16 TDZ Maps for Selected Locations 2017). The inundation area is based on the 2,500-year probabilistic tsunami hazard analysis (2,500-year offshore maximum wave amplitude), adapted from methodology consistent with probabilistic seismic hazard assessment.

5.5.5. Haley Site Resiliency

The ability of the Haley Site remediation components including shoreline and bottom protection to withstand tsunami impacts would depend on the magnitude of the earthquake/tsunami events, the energy and destructive forces associated with those events, wave frequency, entrained debris, and other factors. The constructed cleanup remedy would also raise the existing land surface elevations by up to about 5 feet, thus increasing resiliency. Construction of a future park may raise site grades to higher elevations at some locations (to be determined), providing additional resiliency.

Site areas with raised elevations would experience less inundation than predicted for the current land surface. The predicted tsunami current velocities of 0 to 3 knots are relatively low, and for comparison, would not be expected to cause damage to ships and docking facilities at ports based on the 2018 WGS and DNR tsunami hazard modeling study. Events of lesser magnitude than modeled for the 2,500-year earthquake would result in correspondingly less impact and potential damage requiring repair. Repair of relatively minor damage would be similar to periodic maintenance. More extensive repair would potentially be needed after higher magnitude events causing more damage, similar to infrastructure damaged in other coastal areas during the event.

6.0 ENGINEERING DESIGN CONSIDERATIONS AND CONSTRUCTION APPROACH

The Haley Site cleanup action consists of ISS and low-permeability containment capping in the Upland Unit and excavating a portion of the LNAPL-impacted nearshore sediment, sediment capping, and monitored natural recovery in the Marine Unit. Site-specific design and construction considerations, design details, and the general approaches for construction are presented in this section. Supporting figures with additional design details for specific cleanup action elements are presented on Figures 6-1 to 6-26.

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 below.

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:

- Relatively flat upland land surface for establishing suitable cap grading and drainage toward Bellingham Bay.
- Stormwater ponding along the east edge of the Site and run-on from the adjacent railroad tracks requiring appropriate cap grading and drainage to avoid comingling with Haley stormwater.
- Presence of wood waste, landfill waste and compressible soils promoting settling during loading from capping and future park development.
- Presence of Cornwall Landfill stockpiles that are adjacent and overlap the Haley site.
- Presence of sheet pile wall adjacent to a portion of the shoreline.
- Wave/current dynamics including shoreline erosion and sea level rise (see Section 5.5) requiring bank and sediment cap protection measures.
- Assumption that all Site media is contaminated and should be permanently managed on-site to the extent practicable.
- Subsurface upland LNAPL distribution and residual NAPL in the aquatic environment.
- Integration of City of Bellingham storm drains with the remedy.

Site setting considerations during construction, operations, and monitoring include:

- Upland access restricted to the north end of the Site from City rights-of way, or from the water side.
- Access at the north end of the Site restricted by office building located adjacent to north end of Site.
- Upland work restrictions and authorization required to work adjacent to BNSF railroad property and/or right-of-way.
- Tidal conditions constraining aquatic access and vessel size and type.
- Tidal conditions affecting ISS, bank, and sediment remediation methods.

- LNAPL, bank/sediment seepage water, and ISS mixture requiring containment and management during ISS and nearshore sediment excavation.
- Presence of wood and other debris, pilings, and subsurface structures affecting ISS, upland capping and grading, and sediment excavation.
- Vegetation requiring removal and placement beneath the upland cap.
- Utilities and other subsurface structures associated with the former R.G. Haley facility requiring removal or abandoning in-place, as appropriate.
- Protection and uninterrupted operation of City of Bellingham storm drains.
- Existing pavement and foundations requiring break-up for placement under the upland cap (pavement may be temporarily left in place if useful during staging).
- Future access to Haley and Cornwall Sites for monitoring and maintenance.

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 these 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 excavation, upland capping and fill placement, and ISS operations. Subsurface drainage structures and other utilities should also be installed below the 12-inch frost depth typically used for construction projects in Bellingham. For the Marine Unit, high winds and rough seas can hinder sediment capping and also affect cofferdam design and use during ISS and sediment excavation activities. 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 (SLR), and Tsunami

The upland cap must prevent precipitation and runoff from infiltrating into the underlying contaminated soils. The cap drainage system will also be designed to manage a 100-year design storm event and convey the clean runoff from the cap cover to Bellingham Bay.

Section 5.5 summarizes coastal engineering analysis results for the projected SLR of up to 50 inches over the 100-year project design life. Remedial design considerations for SLR include protecting sediment caps and bank areas from anticipated increases in wave and current energy. The seaward edge of the upland cap must also be protected from potential wave run-up during storm surge conditions. The upland cap liner must effectively shed wave-driven water overtopping the cover.

Section 5.5 also summarizes tsunami considerations based on current WGS/DNR and ASCE hazard modeling and inundation maps for Bellingham Bay. The Haley and Cornwall upland areas are projected to experience inundation depths of more than 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 events, the energy and destructive forces associated with those events, wave frequency, entrained debris, and other factors.

6.1.5. Geotechnical Stability

Geotechnical analyses were completed to assess settlement and stability of the upland cap, ISS-treated soil, sediment caps (including armor sections), and existing underlying soil and sediment under static and seismic (pseudo-static) conditions. These analyses addressed potential concerns about localized differential settling throughout the upland cap because of discontinuity of material below the cap. Furthermore, seismic conditions were analyzed to determine conditions to reduce the risk of ISS or cap failure during a seismic event. Technical details of the geotechnical analysis including material properties, seismic parameters, and other assumptions are described in detail in Appendix F-1. Material properties used in the geotechnical analyses were derived from field observations and laboratory testing of samples collected during previous Haley Site investigations. The geotechnical analysis informs design, constructability, construction sequencing, and potential future maintenance and repair including the following:

- Compressible wood debris, sawdust and fine grain soils in the subsurface are present in varying amounts in portions of the Upland Unit and Marine Unit. The additional load from upland and sediment capping materials and future park development in the upland will likely cause settlement of the caps. Potential settlements of up to about 2 feet over the cap design life are estimated from the geotechnical analysis, requiring preloading as one means to reduce potential for differential settlement.
    - Upland and sediment cap design and construction must achieve relatively even settlement across the capping areas.
    - Upland capping must account for loading from the future planned park, and sediment capping must account for loading from protective armor.
    - Preloading upland areas using temporary stockpiles of clean import fill (to be used later for capping) is a prudent approach to address potential settlement and allows for a less steep finished grade for cap liner and cover drainage.
- After accounting for settlement effects, the upland and sediment caps and ISS mass should remain statically stable over the long term without other special measures.
- The seaward edge of the ISS mass requires a cutback to establish a slope with an angle of 0.5H:1V or less to maintain a suitable safety factor during sediment excavation (Appendix F-2).
- Seismic analysis considered a high Richter magnitude event associated with a 2,475-year return period, consistent with typical building code practice for comparative purposes. Analysis results indicate that the sediment caps are expected to move in this scenario. The ability of the upland and sediment caps and ISS mass to withstand potential damage from seismic events depends on 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 will likely be most prevalent during the upland cap preloading phase and dissipate markedly with distance from the train track. It is unlikely that rail traffic vibrations will promote post-construction settlement concerns.

6.1.7. Existing and Future Site Use

The Site is currently vacant and is fenced on the north, south, and west sides. Following construction of the Haley and Cornwall cleanup actions, the City plans to develop these sites as a public park with landscaping, paved parking and small buildings for bathrooms and concessions. Additional park planning and design are in-progress including placement of additional soil fill on top of the upland cap. The Haley cleanup design will provide a suitable surface on which the park can be constructed and operated for public use, considering the following:

- Prevention of potential damage to upland and sediment caps including a prohibition on near-shore digging.
- Protection of the upland cap including the LFG collection system and stormwater drainage system.
- Protection of the upland cap from loading from park fill placement including a planned observation hill in the upland overlap area of the Haley and Cornwall Sites, paved parking, and other structures.
- Potable water, sanitary, and electrical utilities to serve the future park.
- Maintaining acceptable indoor air quality inside park buildings.
- Access for long-term monitoring and maintenance for monitoring wells, landfill gas control equipment, and other cleanup action components after park construction.

The upland cap system must be designed to protect the public and other potential receptors from direct contact by establishing a physical barrier between contaminated materials beneath the liner and the vegetated top-of-cover surface. The LFG collection, emission, and vent system must be constructed such that people will be protected from unacceptable LFG exposures. LFG vents and LFG/monitoring well access vaults must be suitably located and secured to avoid disturbance from future park activities.

6.1.8. Coordination with Cornwall and Whatcom Waterway Site Cleanups

Remedial design and construction at the Haley, Cornwall, and Whatcom Waterway Sites must be closely coordinated and sequenced to ensure that cleanup action objectives for each site are met. The Haley Upland Unit overlaps with upland portions of the Cornwall site and the Haley Marine Unit overlaps with the Cornwall and Whatcom Waterway aquatic areas. Cleanup components for each site must transition smoothly in these upland and aquatic areas.

6.1.8.1. Cornwall Site

Cleanup in the Haley-Cornwall upland overlap area affects capping, LFG collection, and stormwater drainage for each site. The Haley upland cap will transition into the Cornwall low-permeability upland cap in the overlap area, with the Cornwall cap fulfilling design and performance requirements for both sites. The Haley Marine Unit capping and erosion protection system will extend across the overlap area and transition into the shoreline bank. The Cornwall 60 percent design will include details for transitions in the upland and offshore overlap areas consistent with Haley EDR design concepts.

Cleanup actions for Haley and Cornwall sites are expected to be implemented as a single construction project with additional planning details, contracting requirements, and sequencing to be developed during later phases of design for each site, or in combination. A number of cleanup components may be constructible as common efforts between the sites, whereas construction of certain elements such as ISS are specific to the Haley Site.

6.1.8.2. Whatcom Waterway Site

The Haley cleanup action will be coordinated with cleanup of Phase 2 Areas of the Whatcom Waterway site. Haley sediment capping and MNR concepts are compatible with Whatcom Waterway cleanup actions. Areas planned for Haley sediment capping overlap with Whatcom Waterway MNR areas, and areas planned for Haley MNR overlap with Whatcom Waterway MNR and capping areas. The cleanup actions for both sites are complementary.

6.1.9. Cornwall Avenue and Cedar Street Outfalls

The City operates and maintains the Cornwall Avenue and Cedar Street outfalls discharging to Bellingham Bay along the Haley Site shoreline (Figure 1-5). These outfalls drain public rights-of-way and adjacent drainage basins north and east of the Haley Site. The City relocated the Cornwall Avenue outfall to the present location shown on Figure 1-5 in the fall of 2019. Historical outfalls that have been abandoned are noted on Figure 1-5. Sediment capping/armoring and other elements of the Haley design must preserve the discharge function of the Cornwall Avenue and Cedar Street outfalls storm drains and allow for continued maintenance access. The Haley design must also consider long-term protection of the Cedar Street storm drain from potential soil, tidal or groundwater entry beneath the Haley uplands. Re-lining the pipe is planned as the most direct and least impactive approach.

6.2. Design Details

6.2.1. ISS Design Basis

Various ISS mixtures were compared to performance criteria during treatability testing. The quantitative criteria included hydraulic conductivity and UCS. The primary performance criteria are presented below in Section 6.2.1.3. Other criteria included the maximization of axial strain to minimize potential cracking of the ISS mass during a seismic event and the selection of mix proportions that provide sulfate resistance. Other considerations for ISS design include:

- The sheet pile wall will remain in place and will help contain contaminants during ISS placement and curing.
- Where the sheet pile is not present along the shoreline (south and north of the existing sheet pile wall), ISS will be designed with structural properties that will allow the cured ISS mass to act as shoring to facilitate nearshore sediment removal up to the ISS mass.
- To maintain an appropriate safety factor for structural stability, the seaward edge of the ISS will be sloped at an angle 0.5H:1V. This sloping criterion applies to the ISS mass beyond the sheet pile wall, and also to ISS behind the sheet pile wall because the design assumes no structural reliance on the wall.
- The temporary cofferdam and associated water collection systems (discussed in Section 6.3.3) will be in place west of the ISS area during ISS and curing to prevent discharges to surface water.
- Cured ISS material must have a low enough strength that it can be excavated during post-ISS grading.

6.2.1.1. ISS Footprint and Estimated Quantities

The areal and vertical extent of the ISS treatment area was developed to treat potentially mobile LNAPL and associated contaminated soil near the shoreline. The ISS footprint was determined based on several considerations regarding the nature and extent of site contamination:

- Presence of current or historical measurable LNAPL (as free product) in monitoring wells.
- Presence of petroleum product or sheens in soil and groundwater during upland investigations.
- Soil TPH data, especially petroleum hydrocarbon concentrations exceeding 15,000 mg/kg as a more conservative threshold for the estimated residual LNAPL saturation concentration of about 18,000 mg/kg.
- Concentrations of TPH, PCP, and methylnaphthalenes in groundwater.

The lateral extent of ISS is presented on Figure 6-1. Cross-sectional views of the lateral and vertical extent of ISS are presented on Figures 6-2, 6-3, and 6-4. Tables and figures presenting TPH data used to interpret the extent of potentially mobile LNAPL are presented in Appendix A-1.

Overburden soil that is not expected to have potentially mobile LNAPL will be removed prior to initiating ISS. ISS treatment will occur over target elevation ranges of -1 feet to 9 feet NAVD88.

The estimated volume of soil that will be treated by ISS is 13,400 CY. Expansion (swell) of the treated soil volume is expected as a result of the addition of ISS materials to the soil being treated. A degree of expansion of 30 percent of the in-place volume of soil to be treated was assumed, resulting in a final volume of ISS-treated soil of about 17,000 cubic yards (CY). This expansion of the soil volume will be managed during construction as part of the overall ISS mass for upland grading.

6.2.1.2. Debris

Explorations completed to collect the ISS treatability samples confirmed the presence of significant subsurface debris. Pieces of dimensional lumber are present in most locations while bricks, concrete, pipes, and larger wood piles and structures are present less consistently. Other wood debris including scraps and sawdust are also present. Relatively small- and medium-sized debris (dimensions to be confirmed) should be suitable for incorporation in the ISS body. The larger debris, wood piling, and large pieces of dimensional lumber and concrete will need to either be reduced in size for ISS incorporation or removed to facilitate the ISS mixing process. Larger debris may be removed either in a separate pass before ISS mixing, or during the ISS mixing process. The selected cleanup contractor will be responsible for developing and implementing their preferred approach for ISS debris management.

During PRDI activities, a GPR survey was completed including the ISS area to determine if this geophysical technique could successfully identify debris. GPR was not successful at identifying this subsurface debris and no further surveying was completed.

6.2.1.3. Performance Criteria

Treatability testing provided useful design information regarding the ISS design mix that will best satisfy performance criteria (Appendix B). It was determined that an ISS mix of 4 percent by weight Richmond Type I Portland Cement and 8 percent by weight GGBFS is a suitable mix meeting performance criteria. As part of the construction process, the selected contractor will have the opportunity to excavate test pits and collect soil samples and perform additional treatability testing to verify the performance criteria will be achieved. Based on the results of the treatability testing, the criteria selected for ISS are:

- An axial strain similar to that achieved during design treatability testing (1.2 percent to 1.6 percent).
- An amendment mix that shall include GGBFS such that the maximum ratio of Type I Portland Cement to GGBFS is 1:2.
- Hydraulic conductivity less than $1x10^{-5}$ cm/s.
- UCS of 30 to 50 psi at 28 days, with a 50 psi target along the waterward edge where the ISS mass will be exposed during sediment excavation.

An additional goal of ISS is to reduce the potential for soluble contaminants to partition to the dissolved phase (leach) by binding and encapsulating contaminants within the soil matrix. Leach testing of ISS test materials was conducted to assess potential post-ISS conditions, noting that testing results do not represent equilibrium conditions for constituents in groundwater immediately outside the ISS mass. Leach testing is summarized in Section 5.1 with methods and results further described in Appendix B. These results were considered during sediment capping design.

6.2.1.4. Implementation Criteria

In addition to the performance criteria, there are sequencing and timing elements that will impact ISS implementation:

- The temporary cofferdam and associated water collection systems (Section 6.2.3) will be in place during ISS placement and curing to prevent discharges to surface water. The contractor will be required to operate and maintain these systems to meet pollution prevention objectives during the time period that the systems are in place.
- The sheet pile wall immediately adjacent to the shoreline will remain in place to help contain contaminants during ISS placement and curing.
- Excavations adjacent to the ISS mass where the sheet pile wall is not present should not be completed until the 28-day curing process has occurred for the ISS mixture.

6.2.2. Upland Capping

A low-permeability cap will be constructed in the Haley Upland Unit to contain soil with contaminants exceeding cleanup levels (Figure 6-5). The upland cap will be designed to reduce stormwater infiltration in contaminated soil, thereby reducing contaminated groundwater flux to the Marine Unit. It will also include components to collect underlying soil vapors and treat them prior to venting. The cap will direct stormwater drainage towards Bellingham Bay. The Haley upland cap will transition into the Cornwall low-permeability upland cap in the overlap area, with the Cornwall cap fulfilling design and performance requirements for both sites including containment of Haley contaminants.

The upland cap will be suitable for constructing a future City park without adversely affecting the cap's function and performance. As part of the MTCA remedy, a soil and pavement cap will also be placed upland of the Pine Street beach for physical separation from the underlying soil.

6.2.2.1. Grading

The Haley Site north of the overlap area is relatively flat from east to west and increases in elevation by about 3 feet from north to south, which produces a northerly sloping grade of about 0.3 percent. The finished cap surface will have a minimum 2 percent grade to promote runoff toward the bay and reduce infiltration through the soil and towards the lining system. The grading plan for the Haley Upland Unit is presented on Figure 6-5 with associated cross sections provided on Figures 6-6, 6-7, 6-8 and 6-9. The Site will be sloped to the east along the eastern boundary an approximate angle of 4H:1V (25 percent). Finished upland grades will have a total elevation change of about 6 feet.

On-site material sources will be used in conjunction with clean imported fill to establish upland grading. All on-site fill material sources are considered to be contaminated and will be placed beneath the low-permeability cap liner and above the water table[2]. Fill comprised of material from the Site will be managed using appropriate handling techniques to prevent off-site contaminant migration or exposure to workers and the environment.

Site materials to be excavated or removed for placement beneath the upland cap liner include soil, sediment, concrete/asphalt pavement, and rock and wood debris including wooden piles removed or cut to facilitate sediment excavation, ISS and grading. Excavated sediment will be conditioned by mixing with a cementitious mixture to improve physical and handling properties prior to placement, as described below. Soil, rock, wood, and other debris will be excavated along the shoreline to create a smooth bank slope for sediment cap and armor protection placement. Overburden soil will be excavated from the ISS footprint, and other areas in the south-central portion of the Upland Unit where existing grades need to be lowered to accommodate upland capping and final sloping. Vegetation will be cleared and incorporated into the grading fill. Existing concrete and asphalt surfaces will be broken in-place before additional overlying fill is placed, and subsurface concrete and metal structures will be removed and broken or cut for incorporation beneath the cap liner.

Rough grading below the cap will be finished approximately 2 feet below finished grade to accommodate the cap and cover components. The fill materials below the liner will be placed in controlled lifts and evenly distributed to prevent accumulation of pockets of rock, wood, concrete and asphalt. Fill placement will also be carefully coordinated with installation of the LFG collection system.

Along the southern part of the shoreline, the finished grade of the upland cap will transition seaward at elevation 15.5 feet into the armored shoreline bank and sediment capping occurring as part of cleanup actions in the Marine Unit. The final surface of the upland cap will be vegetated as grass turf with a crushed rock in the shoreline transition and buffer zone. The vegetated surface and slope grading are designed to accommodate stormwater infiltration into the top of the cap, with drainage toward the bay on top of the underlying low-permeability liner. The vegetated surface will reduce the risk of soil erosion at the cap surface. The cap design also accounts for planned future park construction and public use.

6.2.2.2. Estimated Cut and Fill Quantities

Estimated cut and fill quantities associated with the Haley cleanup are summarized in Table 6-1. The estimated in-place excavation volume of materials to achieve the required grading including sediment excavation and the embankment/nearshore portions of the Haley-Cornwall overlap area is 15,900 CY. In addition to the in-place excavation volume, an additional 3,600 CY of material resulting from swell generated by ISS will require regrading. An estimated 15,400 CY of ISS swell material and excavated soil, rock, wood debris, asphalt and concrete will be used for grading beneath the liner within the Haley property boundary. It is anticipated that the remaining approximate 4,100 CY of excavated soil, rock and wood

[2] For the purposes of this EDR and subsequent design and construction documents, management of materials excavated or removed from other locations of the Haley Site (remediation-derived wastes) and relocated and consolidated beneath the low-permeability liner is termed as ‘placement’ or ‘filling’ for general reference purposes only. Use of these terms does not imply generation of Dangerous Waste (DW) under Washington State DW regulations, RCRA ‘placement,’ or triggering of Landfill Disposal Restrictions under State DW Regulations or RCRA within Ecology’s designated Area of Contamination (AOC) for the Haley Site.

debris, consolidated sediment, asphalt and concrete will be used beneath the liner to construct the design grades in the Haley-Cornwall overlap area. An additional estimated 14,700 CY of clean import fill for the cap cover will be placed within the Haley property. The Pine Street Beach area will require approximately 400 CY of import fill to construct the soil and pavement cap as a physical isolation barrier for underlying soils.

TABLE 6-1: SUMMARY OF EARTHWORK VOLUMES (CY)

Haley Cleanup Excavation Volumes[1]		Disposition of Excavated Material		
Construction Element	**In-Place Volume**	**Construction Element**	**Place on Haley Property**	**Place in Haley/Cornwall Overlap Area**
Pre-ISS overburden excavation	7,200	Place under the upland cap	7,200	--
ISS Swell[1]	–	Increased volume following ISS	3,600	--
Sediment excavation	2,300[2]	Place under the upland cap		2,300
Upland and shoreline bank excavation/grading for cap placement	6,400[3]	Place under the upland cap	4,600	1,800
Clean import	–	2-foot-thick cap cover above liner	14,700	--
	–	Pine Street Beach upland soil and pavement cap	400[4]	--
Totals	**15,900**		**30,600**	**4,100**

1- Estimated swell/expansion of 30-percent is expected to occur as a result of the ISS treatment, as shown on Figures 6-2 through 6-4. Based on a treatment thickness of 10 feet, approximately 3 feet of swell is expected. This swell is generated in-situ but is counted in the table as volume "placed" on the Haley property.

2- Includes only excavation for contaminant mass removal within the "Extent of Sediment Removal" presented on Figure 6-16 and does not include sediment excavated to accommodate cap placement to achieve design grades (See Note 3).

3- Includes marine sediment and upland soil removal to accommodate cap placement to achieve design grades. For estimating purposes, sediment excavation volumes were identified as excavations occurring below the OHWM (9.73 feet, NAVD88). Excavation occurring above Elevation 9.73 was considered as upland excavation.

4- Pine Street beach is located on Port property.

Soil, rock, and wood debris excavated during cleanup activities at the Cornwall site will also be placed as fill in the upland overlap area to achieve final grades needed for both sites. The placement of the fill in the overlap area will be consistent between the two sites. Fill material below the liner in the overlap area will be placed in controlled lifts and evenly distributed to prevent accumulation of pockets of rock, wood, concrete and asphalt. Fill placement will also be carefully coordinated with installation of the LFG collection system.

6.2.2.3. Sediment Conditioning

Marine sediment excavated from nearshore portions of the Haley Marine Unit will be utilized as fill to be placed under the Haley upland cap liner. Due to the wet and highly organic conditions anticipated with excavated intertidal sediment, physical conditioning of the excavated material is expected to be necessary to achieve suitable consolidation properties to meet handling and structural requirements. Treatability testing was conducted as described in Section 5.2 to evaluate the need for, and applicable methods of, conditioning to allow use of the excavated sediment for upland fill.

The treatability testing indicated that some sediment contains enough granular material that it may readily drain and will be suitable for fill without conditioning. However, finer-grained sediment to be excavated will require conditioning for suitability, which was determined to be achieved by amending the excavated sediment with a 3 percent (by weight) mixture of Type 1 Portland cement. Following conditioning, the sediment is expected to compact to at least 95 percent of the ASTM D698 MDD after 28 days of curing, thereby providing a workable and compactable material. All sediment excavated from the Haley Marine Unit is planned to be conditioned with the cement amendment regardless of granularity.

6.2.2.4. Upland Cap and ISS Stability

Upland capping design included geotechnical analysis to evaluate potential settlement and slope stability under loading during grading/capping and future fill placement for planned park construction (Appendix F-1). Geotechnical analysis included cases for long-term static and seismic (pseudo-static) conditions for upland capping areas and the ISS mass. Analysis results determined that the upland capping areas and ISS mass should remain statically and seismically stable over the long term.

Analysis results also indicated that potential differential settlements of up to about 2 feet could occur because of the presence of relatively compressible soils and the high content of saw dust and other wood debris in many upland locations. Preloading is planned to manage potential settlement. Preloading involves placing a fill load (surcharge) to allow ground settling and soil consolidation prior to cap placement to minimize potential for additional post-construction settlement. Preloading also helps to preserve the long-term stability of final 2 percent grade.

The Haley Upland Unit including the overlap area will be preloaded with surcharge fill soil sourced from the Site and clean imported soil (will not be mixed). Preload fill is planned to be placed around the existing stockpiles in the overlap area. The existing stockpiles are currently acting to preload a portion of the overlap area and minimal settlement has been observed. The piles are constructed to an elevation of approximately 30 ft NAVD88 which is near the currently anticipated final elevation after the cleanup action. The final elevations in the overlap area are being designed under the Cornwall site plans and the fill volumes and grading plans will be coordinated between the Cornwall and Haley sites as design work at both sites moves forward. Soil used for preloading is planned to have a minimum unit weight of 110 pounds per cubic foot and will be placed to a height approximately 50 percent thicker than the proposed fill thickness. Areas will be preloaded for 6 months or more before cap construction (to be determined during preload monitoring). Preloading will exclude the area for ISS as a precaution against disturbing soils with potentially mobile LNAPL. The ISS soil-cement mass and overburden removal are expected to adequately address potential settlement issues in this area.

Following preloading, surcharge soils derived from contaminated Site soils will be retained for placement beneath the upland cap liner. Clean import soils will be retained for upland cap cover or sediment capping.

Geotechnical analysis also evaluated the static stability of the ISS mass during sediment excavation (Appendix F-2). Results indicated that the seaward edge of the ISS should be sloped at an angle no steeper than 0.5H:1V during sediment excavation based on the planned excavation cut depths.

6.2.2.5. Upland Cap Profile

The upland cap north of the overlap area will consist of five distinct layers to prevent exposures to underlying contaminated soil and other Site fill materials. A detail of the cap profile and other details are provided on Figure 6-10. Starting from the upper, finished surface, the profile of the cap will include the following:

- 6-inch-thick topsoil and turf layer;
- 18-inch-thick soil protection layer;
- Geocomposite drainage layer;
- LLDPE geomembrane; and
- Geocomposite LFG collection layer.

The Cornwall cap will be constructed in the overlap area and include a low-permeability soil layer beneath a geomembrane liner, LFG collection, and drainage control as the functional equivalent of the Haley cap as described in Section 6.2.2.12.

6.2.2.6. Topsoil and Turf Layer

The 6-inch clean topsoil layer will be imported from an off-site source and meet the requirements of the City's Design Standards for Park and Trail Development, landscaping specification, Section 02900, 2.02 Planting Soil for Turf. The turf surface will meet the requirements of Section 02900, 2.10 Seed Lawn. Straw, mulch and/or tackifiers will be used to stabilize the topsoil surface and reduce erosion following placement.

6.2.2.7. Soil Protection Layer

The 18-inch-thick soil protection cover layer under the topsoil will protect the underlying geosynthetic materials, include sufficient fines to retain moisture for surface vegetation to establish a strong root system and allow excess water to infiltrate downward to the drainage layer. The protection layer will consist of a well-graded silty sand with a hydraulic conductivity equal to or greater than $1x10^{-3}$ cm/s.

6.2.2.8. Geocomposite Drainage Layer

The geocomposite drainage layer will consist of three separate materials bonded together including a bi-planar polyethylene geogrid, sandwiched between two nonwoven polypropylene needle-punched geotextiles. The polyethylene geogrid is expected to have a similar lifespan to the LLDPE geomembrane liner. Polypropylene geotextiles have expected lifespans of about 200 years and they generally are not susceptible to biological or physical degradation under normal conditions. This includes direct soil burial and contact with landfill leachates (SI Geosolutions, 1997).

The top geotextile separates the overlying soil from the geogrid yet allows water to pass through and into the geogrid. The geogrid provides a flow path for infiltrating stormwater. By providing this flow path, potential for water to build up or "head" on the underlying LLDPE geomembrane liner is minimized. Minimizing the head on the geomembrane liner is important to maintain cap stability and reduce the potential for leakage through the geomembrane. The bottom geotextile protects the underlying LLDPE by providing a cushion between the LLDPE and the geogrid. The geocomposite will have a hydraulic conductivity of at least 4.7 cm/s to minimize head over the geomembrane and allow drainage along the 2 percent slope of the geomembrane.

6.2.2.9. LLDPE Geomembrane Liner

The LLDPE is a low permeability geosynthetic that will minimize potential for water infiltration and, in conjunction with overlying components of the cap, provides a barrier between human and ecological receptors and underlying contaminated materials. The LLDPE geomembrane will have a 2 percent slope that mirrors the finished grade of the cap cover. The LLDPE will be 30-mils thick and field-welded using thermal bonding techniques including hot wedge welding and extrusion welding. Quality Assurance/Quality Control (QA/QC) procedures will be implemented to verify seam integrity and strength. QA/QC procedures will include testing seam strength before production welding, collecting destructive seam samples to verify seam strength of production welds and non-destructive tests of seams. Non-destructive testing will include air channel, vacuum box, and potentially spark testing as a contingency, if determined to be needed (e.g. following regulatory review) for specific applications. Spark testing would likely be reserved for welds if such locations can't be effectively tested by air channel or vacuum box testing. This includes irregular penetrations through the liner such as LFG vent piping, stormwater culverts and site utilities for future park land use. Design considerations will include minimizing the number of penetrations through the liner and allowing correct tolerances to accommodate welding equipment during installation.

LLDPE was selected as the most-suitable geomembrane material to provide a low-permeability barrier for the upland cap. LLDPE has exceptional ultraviolet (UV) radiation protection and has appropriate elongation properties to accommodate settlement of the subsurface without tearing the geomembrane. Although the liner will not be exposed to direct sunlight, the UV rating demonstrates the durability of the material. LLDPE is considered more flexible than high-density polyethylene (HDPE). The LLDPE specified for the design will have a tensile break strength of at least 200 pounds per inch-width (lb/in-width) and an elongation of 800 percent at breakage to meet the design intent. LLDPE is generally considered resistant to diesel-range hydrocarbons (a known contaminant at the Site) at exposure temperatures of 73°Fahrenheit (°F; 23°Celsius [°C]). Because the LLDPE will be buried and out of direct sunlight, geomembrane temperatures in excess of 73°F/23°C are expected to be minimal and the LLDPE is expected to maintain chemical resistance during its lifespan. Substantial exposure of the LLDPE liner to free product diesel is not expected.

Under conditions with no direct exposure to UV comparable to the Haley application, HDPE has a predicted half-life of approximately 446 years at 20°C and 265 years at 25°C (Koerner et al. 2011). LLDPE has a formulation similar to HDPE, but the lower crystallinity of LLDPE allows oxygen to diffuse into the polymer structure quicker, which results in a shorter lifespan of the LLDPE geomembrane in comparison to HDPE (Koerner et al. 2011). Although the lifespan of LLDPE is shorter than HDPE, the LLDPE geomembrane is expected to have a service life of more than 100 years.

6.2.2.10. LFG Collection Layer and Control System

The LFG collection layer is designed to collect vapors emitted from the underlying sources and safely vent them to the atmosphere in a controlled manner. Potential sources of the vapors include decaying organic matter and volatilization of contaminants. The conceptual configuration of the LFG system and details are provided on Figures 6-11 through 6-13. Additional details for the landfill gas control system design are presented in Appendix D.

The LFG collection system is composed of a geocomposite immediately below the LLDPE liner that allows vapors emitted from the subsurface to permeate through the geotextile and enter the geogrid transmissivity layer and connecting header pipe system (Figure 6-11 and Figure 6-12). The geocomposite grid is the same LFG collection material planned for installation at the neighboring Cornwall site. Use of this geocomposite is expected to provide a cost savings compared to installation of a permeable gravel layer and associated trenching and piping. The edges of the geocomposite will be embedded into the subsurface soil near the lateral edges of the cap to reduce the chance of LFG short circuiting to the atmosphere. Bedding sand will be used as needed to create a smooth surface between the LFG geocomposite and subgrade. The bedding sand and LFG geocomposite also provide further physical separation of the LLDPE and underlying contaminants including free product, where present.

The LFG collection layer will be placed under the LLDPE and directly over contaminated in-place soil and fill materials excavated from other Site locations. Bedding sand will be utilized as needed to seat the LFG collection piping and to create a surface with minimal irregularities under the LFG geocomposite. Draintube™ geocomposite by AFITEX-Texel will be used for LFG collection. Draintube is a geocomposite that includes an HDPE drainage net between two layers of a non-woven needle punched polypropylene geotextile. The geotextile layers of the geocomposite protect the LLDPE from punctures or irregularities from the underlying soils, fill, and/or bedding material. The Draintube™ geocomposite incorporates 0.5 to 1 inch diameter flexible perforated piping spaced from 10 to 80 inches apart into the geotextile layer which can be easily connected to the LFG ventilation headers and ventilation system. This layer is expected to have a similar life span as the geocomposite drainage layer, because it is constructed of similar materials.

The geogrid component of the LFG collection system will allow for horizontal migration of collected vapors into solid 2-inch diameter Standard Dimension Ratio (SDR)-11 HDPE header pipes installed near the perimeter of the cap, as shown on Figure 6-11. Header pipes will be sloped to reduce condensate accumulation in the piping and allow it to drain back into the subsurface or vent to the atmosphere. The LFG collection and control system will merge with a similar control system to be established for the Cornwall cap in the overlap area. The LFG collection system in the overlap area will be installed below the low-permeability soil layer of the Cornwall cap.

Vapors from the header pipes will be exhausted to the atmosphere through one of two vertical exhaust vents with passive wind powered turbines mounted to the top. The turbines will create a slight pressure gradient to promote LFG to migrate from the subsurface and into the atmosphere. The vents will be constructed of vertical stainless steel pipe and rise approximately 12 feet above the finished grade at the locations shown on Figure 6-12. Two subsurface LFG vertical extraction wells will be installed and connected to the header system to passively remove vapors in areas with substantial wood waste where generation of LFG could potentially be greater as a result of decaying organic matter. The LFG vertical extraction wells will be screened from just above the projected seasonal high water table to about 3 feet beneath the LFG geocomposite layer. LFG vent/well details are shown on Figure 6-13.

Using subsurface vapor analytical testing results obtained during the RI (GeoEngineers 2016) and soil contaminant concentrations, the EPA's LandGEM spreadsheet model was used to predict LFG emissions from the Haley Site. LandGEM modeling indicated that an LFG flow rate of 10 cfm is appropriate to design the LFG capture and control system. The capture and control system was also designed with a factor of safety greater than 2 relative to the LFG production rate. Model results predicted that naphthalene concentrations emitted by the LFG system could exceed the MTCA Method B cleanup level within the breathing zone at the Site. However, based on the conservative nature of the modeling, it is considered likely that the actual emissions measured after construction will not pose an unacceptable risk to human health. Regardless, LFG will be treated before discharge to the atmosphere pending compliance monitoring results to verify whether emissions meet the cleanup levels. LFG modeling results and further discussion are provided in Section 5.4 and in Appendix D.

Before LFG is emitted to the atmosphere, it will be routed through granulated activated carbon (GAC) to remove contaminants and control odors. GAC canisters will be installed within subsurface vaults located near the two exhaust vents (Figure 6-11 and Figure 6-13). Contaminants will be adsorbed by the GAC particles. LFG vapors will be monitored on the influent and effluent sides of the GAC canisters to evaluate contaminant removal, estimate GAC exhaustion rates and compliance with air standards. GAC canisters will be changed out as needed before contaminant breakthrough occurs.

6.2.2.11. Stormwater Drainage

The final grade of most of the upland cap will slope in a westerly direction to promote drainage toward Bellingham Bay as sheet flow (Figure 6-5). The stormwater design was developed to reduce the stormwater discharge volume into the bay and reduce infiltration through Site soils during storm events. Much of the site currently exists as an impervious or low-permeability surface, and the proposed vegetated surface is expected to reduce runoff volumes through evapotranspiration and moisture storage in the clean cover material comprising the upper 2 feet of the upland cap.

The vegetated cap will be maintained in accordance with the project operation and maintenance (O&M) plan, including substantive requirements of the City's Phase II Municipal Stormwater Permit. This includes following application requirements for fertilizers, pesticides and herbicides and BMPs for landscape maintenance, vegetation disposal, and management of trash and pet waste.

The 2012 Western Washington Hydrology Model (WWHM) was used to evaluate runoff conditions for the Haley Site north of the overlap area for pre- and post-construction (development) conditions. For pre-development conditions, it was estimated that 4.64 acres of the Site were impervious, and 0.83 acres were vegetated, for a total drainage area of 5.47 acres. For the pre-development conditions the WWHM estimated a stormwater runoff of about 2 cubic feet per second (cfs) from the Site for a 2-year, 24-hour design storm. Post-development, the WWHM model estimated stormwater runoff of 0.04 cfs for the 2-year, 24-hour design storm, showing a substantial decrease in runoff volume compared to pre-development conditions. Detailed hydrologic calculations and stormwater model inputs are provided in Appendix G.

An underdrain system will be installed to collect water that infiltrates though the topsoil and protective layer and minimize head buildup over the geomembrane (Figure 6-14). The underdrain and surface drainage systems will merge with similar systems established for the Cornwall cap in the overlap area. Head minimization above the geomembrane is key to increase the stability of the overlying soil and reduce the chance of sloughing. The underdrain system will utilize HDPE perforated pipes sleeved with separation fabric to intercept water flowing through the geocomposite drainage layer and route the intercepted water through a piping system. The separation fabric will reduce the chance of soil from the upland cap entering into the stormwater piping. Water collected by the underdrain system will be discharged to the stabilized shoreline above the OHWM. Perforated underdrain piping will be surrounded with drain rock and wrapped in geotextile. Solid piping will be installed directly into the soil protection layer.

The EPA's Hydrologic Evaluation of Landfill Performance (HELP) model was used to estimate head buildup in the subsurface and determine the spacing interval for the underdrain intercept piping. The soil cover layer of the cap is designed to be 24-inches thick and the design frost depth for Bellingham is 12 inches. To reduce the chance of water in the underdrain system freezing, the underdrain spacing was varied using the HELP model until the head (water depth) on top of the geomembrane liner was less than 6 inches, well below the 12-inch frost depth. HELP modeling indicated an underdrain spacing of 100 feet will result in maximum head of about 4.6 inches over the geomembrane liner. HELP model calculations and a summary of model inputs and outputs are provided in Appendix G.

The Cornwall EDR completed similar stormwater and underdrain modeling for the Cornwall cap including the area where the sites overlap. The Haley and Cornwall cap drainage designs can be readily merged based on the combined modeling results for both sites.

6.2.2.12. Haley-Cornwall Overlap Area

As described in Section 6.2.2.2, soil, rock, wood debris, consolidated sediment, asphalt and concrete excavated as part of the Haley Site remedial action will be placed in the Haley-Cornwall overlap area. Soil, debris and waste excavated as part of grading for Cornwall Landfill remedial action will also be placed in the Haley-Cornwall overlap area. The excavated material will be placed in the overlap area beneath the upland cap as shown in Section A-A' on Figure 6-6.

It is estimated that 4,100 CY of material excavated as part of the Haley Site remedial action will be placed in the Haley-Cornwall overlap area as shown in Table 6-1. The material placed in the overlap area will be incorporated into the final grading plan for the Cornwall Site. Stockpiles of soil that are currently within the overlap area and being used for preloading will be relocated prior to placement of excavated material from the Haley Site remedial action.

The upland cap in the Haley-Cornwall overlap area will be constructed in a similar configuration and with similar materials as the cap to be constructed at the Haley Site. However, the cap in the overlap area will include a 2-foot layer of low permeability soil as part of the Cornwall site upland cap as shown in the detail on Figure 6-10. Starting from the upper, finished surface, the profile of the cap in the overlap area will include the following:

- 6-inch-thick topsoil and turf layer;
- 18-inch-thick soil protection layer;
- LLDPE and geocomposite drainage layer;
- 24-inch low-permeability soil layer; and
- Geocomposite LFG collection layer.

The low permeability soil layer will be constructed using the existing soil stockpiles that are being used for preloading of the Cornwall Site. The stockpiled soil will be set aside until it can be installed as part of the low-permeability soil layer within the upland cap.

The similar capping configuration and materials for the two sites allows the upland caps to be contiguous between the sites. The geocomposite LFG collection layer, LLDPE liner and geocomposite drainage layers (Draintube™ geocomposite by AFITEX-Texel) will be connected together (seamed) and therefore, will be continuous in the Haley-Cornwall overlap area.

Fill placement and upland cap construction sequencing will be coordinated between the Haley and Cornwall sites. It is anticipated that construction of the remedial actions for the Haley and Cornwall site will be performed by the same contractor under a single contract. The Haley and Cornwall design will continue to be coordinated as they each move forward through design to align the design and construction requirements and sequencing in the overlap area.

6.2.2.13. Pine Street Beach Upland Soil and Pavement Cap

A soil and pavement cap will be placed over the area designated as Pine Street beach shown on Figure 6-5 and Figure 6-9. The purpose of the cap is to provide a physical isolation barrier to direct contact with underlying soil that is assumed to be contaminated. After the existing soil surface is graded and prepared for capping, a geotextile will be placed over the area to separate the clean imported soil cap from the underlaying soil. The geotextile will function as a physical barrier and keep the imported fill and underlying existing soil from mixing. The geotextile should 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 import sandy fill and/or crushed surfacing base course will be placed over the area and graded to the design grade surface elevation shown on cross-section E-E' on Figure 6-9. Asphalt pavement will be placed over the soil cap to prevent potential erosion from surface runoff and wave action. Figure 6-15 provides a detail of the cap section.

6.2.2.14. Site Access Road

An access road is incorporated into the upland cap design to accommodate maintenance access including the LFG vent assemblies carbon filters and entry to the neighboring Cornwall site as shown on Figure 6-5. A typical road section is provided in Figure 6-15. Access to the vent pipes is needed to service the GAC canisters installed in subsurface vaults near the vent pipes. As a basis of design, a design load of 56,000 lbs (legal maximum highway loading in most states) and design criteria general in accordance with the American Association of State Highway and Transportation Officials (AASHTO) Guide for Design of Pavement Structures (AASHTO 1993) were used to establish material thickness and structural properties. If access for equipment/loads weighing more than 56,000 lbs becomes necessary, operations and maintenance planning will include provisions for additional reinforcement and/or pad construction as needed to accommodate the activities.

The road section will consist of the following starting with the upper road surface:

- Minimum 10-inch-thick crushed surfacing base course (CSBC) layer in accordance with Washington State Department of Transportation (WSDOT) specification 9.03.9(3);
- Biaxial geogrid;
- Minimum 8-inch-thick CSBC layer; and
- Minimum 6-inch-thick bedding sand layer in accordance with WSDOT specification 9.03.13.

The 6-inches of bedding sand will be placed directly on top of the geocomposite drainage layer described in section 6.2.2.7. The road section will not interfere with the performance and function of the upland cap including the liner and drainage layer.

6.2.2.15. Cedar Street Stormwater Pipe

The Cedar Street drainage pipe requires long-term protection and preservation from potential soil or tidal or groundwater entry beneath the Haley uplands. Re-lining the pipe is expected to be the most direct approach and create the least disturbance. Pipe re-lining will consist of either fold and form or cured in place pipe.

Stormwater / surface water drainage from the east slope of the upland cap and stormwater runon from the BNSF property toward the Haley Site will be treated and discharged into the Cedar Street stormwater pipe. Stormwater management improvements along the eastern boundary of the Haley Site will be incorporated into the 60 percent design for the remedial action. The potential need for additional stormwater management actions on the BNSF property to reduce infiltration may be considered in the future as a contingency action.

6.2.2.16. Future Park Utilities

Water, sanitary sewer, and electrical utilities are anticipated for the future park. These utilities are expected to be routed in fill placed above the current upland cap cover system, and as such are not expected to interfere with the cap performance. However, connection of the park utilities to utilities in the adjacent right-of-way north of the Haley property may require routing through the upland cap liner near the entrance to the property. Details of such penetrations will be determined but will include robust sealing through the penetration point(s). Alternatively, future design for Haley remediation could also consider a utility corridor adjacent to the road (or other location) within the upland cap cover system. A separate surface runoff, drainage, and discharge system will be established for the future park.

6.2.3. Intertidal Sediment Excavation

The area of upper intertidal sediment excavation is presented on Figure 6-16 in relation to other Haley sediment capping and ISS areas. Intertidal sediment will be excavated to reduce the volume of highly contaminated sediment present offshore of upland soils with potentially mobile LNAPL where ISS is planned. Groundwater discharge (flux) from the upland is also relatively high in the sediment excavation area near the shoreline. Reducing the volume of highly contaminated sediment in this area enhances the performance and lifespan of the overlying sediment cfap and increases the overall protectiveness of the Haley cleanup action. As an additional benefit, nearshore excavation reduces the seaward shift of the OHWM and MHHW associated with cap construction.

6.2.3.1. Contaminated Sediment Excavation Limits

Within the footprint of contaminated sediment removal presented on Figure 6-16, up to approximately 7 feet of sediment and overlying debris/rock is to be excavated. The depth of sediment excavation and associated elevations vary based on existing bathymetry and distance from the shoreline, as shown on cross sections B-B' and C-C' presented on Figures 6-17 and 6-18, respectively. The vertical excavation limits depicted on Figures 6-17 and 6-18 represent minimum excavation depths that will remove much of the sediment with elevated concentrations of Site IHSs including locations where potentially-mobile LNAPL, if present, is most likely to occur. The minimum excavation depths shown were used to design the overlying capping layers, including the amended sand cap layer to contain underlying residual contamination.

The depth of excavation may be increased based on conditions observed in the field. If localized product or heavy sheens indicative of potentially mobile LNAPL are observed at the base of the excavation, the excavation depth may be increased to 'chase' contamination as practicable at such locations, depending on geotechnical and safety limitations. To aid design and construction planning, additional investigation is proposed in the sediment excavation area to evaluate the depth of excavation. Alternatively, pre-excavation 'pothole' characterization of the sediment surface within the excavation footprint may be performed to identify and assess the feasibility of potential deeper localized excavation. Overexcavation is not planned to extend deeper than an elevation of approximately 1-foot NAVD88 based on the expected footing elevation of the cofferdam and constructability considerations.

6.2.3.2. Nearshore Excavation Behind Cofferdam

A temporary cofferdam is planned to isolate the sediment excavation area from tidal waters for the duration of excavation and capping. Completing sediment excavation in dry conditions provides a high degree of excavation control after seawater is pumped from the enclosure. Working in the dry also reduces potential impacts to adjacent surface water and sediment compared to wet dredging through the water column. Several cofferdam methods are available and the specific method will be selected by the contractor. For design purposes, the Portadam® cofferdam method is considered viable based on successful use at a similar Irondale sediment cleanup site near Port Hadlock, Washington. The Portadam® is expected to be positioned at approximately elevation 1-foot NAVD88 as shown on Figures 6-17 and 6-18. Further discussion of cofferdam methods is presented in Section 6.3.5.

6.2.4. Sediment Capping

Design analyses for Haley 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.

6.2.4.1. Cap Performance Modeling

Containment of contaminants in sediment was a primary consideration in cap design. The sediment cap was designed to achieve cleanup standards (Table 2-1) based on the protection of humans, benthic organisms and other higher trophic level species, as described in Section 2.3.

Simplified fate and transport modeling was conducted to evaluate performance of selected sediment cap designs for achieving sediment and surface water cleanup standards for PCP, 2-methylnaphthalene, TPH, and D/F. A one-dimensional transient numerical modeling program, CAPSIM© (Version 3.6) developed by Dr. Danny Reible and associates (Shen et al. 2018), was used to evaluate the fate of contaminants entering the cap and the resulting chemical concentrations dissolved in porewater and adsorbed to solids at respective depths within the cap. In all cases the caps were effective in containing and attenuating contamination well below the top of cap interface with surface water and the sediment point of compliance within biologically active zone in the upper 12 cm of the cap over the 100-year design-life. A summary of the cap modeling results is presented in Section 5.3 and a more detailed discussion of cap modeling is presented in Appendix C.

As described in Section 5.3, the rate of upwelling at the sediment mudline was found to be the most sensitive parameter affecting chemical containment. Therefore, three main zones of the estimated groundwater flux in the marine unit were considered during cap modeling as shown on Figure 6-16. These zones include:

1. A nearshore high flux zone that includes the nearshore sediment excavation area where the highest concentration of contaminants is expected in sediment adjacent to the upland ISS body (Zone 1a) and nearshore areas north and south of the sediment excavation area (Zone 1b).
2. A shallow subtidal moderate flux zone (Zone 2).
3. A deeper subtidal minimal flux (diffusion-dominant) zone (Zone 3) and seaward areas.

Estimates of groundwater flux in the Marine Unit are based on output from a groundwater flow model (MODFLOW) developed for the Site.

6.2.4.2. Amended Caps

Modeling results indicated that amended caps are required for chemical containment in each zone, as summarized in Table 6-2. Figure 6-16 depicts the areas for each cap type and locations of representative cross-sections. Cross section profiles of the sediment caps are presented on Figures 6-19 through 6-25. OC was selected as an amendment in Zones 1a, 1b and 2 where higher groundwater flux is expected. This amendment will sequester PCP in all three of these zones as well as residual LNAPL that may remain beneath the excavation in Zone 1a. Activated carbon was also selected as an amendment in Zone 1b because it can sequester 2-methylnaphthalene more effectively than organoclay. In this zone, the activated carbon will be used as an amendment in a separate horizon above an organoclay-amended sand cap layer. The lower organoclay-amended horizon is intended to sequester petroleum hydrocarbons and heavier PAHs while the overlying activated carbon amendment sequesters lighter compounds such as 2-methylnaphthalene. Farther offshore where minimal flux is expected (Zone 3), a sand cap with minimal total organic carbon is suitable for containing contaminants in sediment under diffusion-dominant transport conditions. For Zone 3, a material with a moderate level of organic carbon, such as dredged material available for beneficial reuse, may provide adequate sequestration of contaminants; however, for design purposes amendment with activated carbon was assumed.

As noted in Table 6-2, cap modeling for Zone 1 indicated that a 1-foot-thick layer of sand amended with 1 percent (by weight) OC overlain by a 1-foot-thick layer of sand amended with 1 percent AC will contain contaminants and prevent further upward migration. However, a 10 percent OC-amended layer is planned as a more protective design for containment of potential residual LNAPL and associated sheens remaining below the capped surface, if present. This design will be verified and finalized based on the results of additional nearshore porewater sampling and sampling of the interim organoclay cap material. The additional porewater and interim action organoclay sampling will be completed as an addendum to the PRDI.

TABLE 6-2 SEDIMENT CAP DESIGN DETAILS

Groundwater Flux Zone	Cap Design Based on Modeling Results
1a (nearshore area with potential residual LNAPL, high groundwater flux)	1 foot of OC-amended sand (1% OC by weight) overlain by 1 foot of AC-amended sand (1% AC by weight)*

Groundwater Flux Zone	Cap Design Based on Modeling Results
1b (nearshore area unlikely to have residual LNAPL, high groundwater flux)	1 foot of OC-amended sand (1% OC by weight) overlain by 1 foot of AC-amended sand (1% AC by weight)
2 (shallow subtidal, moderate groundwater flux)	2 feet of OC-amended sand (1% OC by weight)
3 (deeper subtidal, minimal groundwater flux)	1 foot of AC-amended sand (0.1% AC by weight)

*Capping with 2 feet of OC-amended sand (10% OC by weight) is planned as an alternative based on additional consideration for containment of potential residual LNAPL below the sediment excavation area.

6.2.4.3. Thin-Layer Capping

Based on evaluations completed during the Haley RI/FS (GeoEngineers 2016), MNR and enhanced natural recovery (ENR) were identified for areas farther offshore where contaminant concentrations are relatively low. These areas were not included in cap performance modeling because of the low contaminant concentrations and expected insignificant groundwater upwelling. Coastal modeling completed to support remedial design indicated that the existing seafloor in the formerly-proposed ENR area might be subject to infrequent scour until sufficient net sedimentation occurs. As a result, a 1-foot thick TLC of gravelly sand is proposed for the area previously identified for ENR. The TLC will isolate underlying contaminated sediment and achieve cleanup standards at the time of construction. The TLC will also protect the sea floor from potential infrequent erosion as discussed below. Additional sediment accumulation is expected in this area but is not required for additional natural recovery of sediment quality to achieve compliance. MNR planned for the outermost areas of the Haley Marine Unit is discussed in Section 6.2.5.

6.2.4.4. Cap Erosion Protection

Sediment caps constructed in the Haley Marine Unit must be designed to withstand the erosive forces of wave action and current energy. Coastal modeling and engineering was performed to support the design of cap materials that will remain stable and protect the chemical containment horizon over a 100-year design life. EDR Section 5.5 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.

Based on the coastal engineering analysis, erosion protection materials were designed using two methods that account for wave hydrodynamics. The first method considers the stability of erosion protection material under the impact of breaking waves. This method was applied to capping and bank areas above elevation 0 feet corresponding to the approximate wave break elevation of the design storm. The second method of evaluation considers the stability of material subject to impacts from the wave orbital motion and associated velocities. This method was applied to capping areas below elevation 0 feet.

The stability analysis yields 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, i.e. 50 percent of the material (by weight) will be larger and 50 percent will be smaller. Each type of material, its extent and function is described below. The distribution of the different erosion protection materials for the Haley Marine Unit is shown on Figure 6-26, with erosion protection layer thicknesses shown on the sediment cap cross sections presented on Figures 6-19 through 6-25.

TABLE 6-3 STABLE MATERIAL SIZE RESULTS

Range of Surface Elevation (NAVD88)	Approximate Average Bottom Slope Angle	Stable D50 Material Size
Max = bank crest up to 15.5 feet Min = 0 feet	7H:1V to 20H:1V	0.8 feet
Max = 0 feet Min (range) = -2 feet to -9 feet	7H:1V to 13H:1V	1.5 in
Max (range) = -2 feet to -9 feet Min = Seaward limit of Site	3H:1V to 15H:1V	0.4 in

Armor Rock – Armor rock used in the upper intertidal zone will be a graded mixture of angular rock with a D50 particle size of 0.8 feet. The armor rock will protect intertidal capped surfaces above elevation 0 feet and the shoreline bank from wave runup. The armor rock layer will have a minimum thickness of 2.0 feet between elevation 0 and 3.5 feet and will have a minimum thickness of 2.5 feet between elevation 3.5 feet and up to 15.5 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.

Gravel/Cobble Mix – The gravel/cobble mix will be a graded mixture of round rock with a D50 particle size of 1.5 inches. The gravel/cobble mix will be used to protect capped surfaces transitioning between lower intertidal and subtidal conditions to minimum elevations of -2.0 and -9.0 feet. The gravel/cobble mix will be 1.5-feet thick and will be placed directly on top of the chemical containment horizon. The gravel/cobble mix will be underlain by a geotextile fabric to prevent piping of materials and further protect the underlying chemical containment horizon.

Gravel/Sand Mix – The gravel/sand mix will be a graded mixture with a D50 of 0.4 inches to protect amended cap surfaces. The gravel/sand is also suitable as the entire profile of the TLC for both contaminant containment and erosion protection. The gravel/sand mix will be 1-foot-thick and will be placed directly on the seafloor in subtidal areas below elevation -2 to the outer boundary of the TLC.

6.2.4.5. Marine Cap Stability

Geotechnical analyses were completed to evaluate the slope stability and potential settlement of the sediment capping areas under loading from cap materials including erosion protection (EDR Appendix F). Material properties used in the geotechnical analyses were derived from field observations and laboratory testing of samples collected during previous Haley Site investigations. Geotechnical analyses included cases for long-term cap stability under static and seismic (pseudo-static) conditions in nearshore areas and steeper offshore areas.

Geotechnical analysis results indicate that sediment caps should remain statically stable but are expected to move during the 2,475-year return event considered for the seismic case. The ability of the sediment caps to withstand potential damage from seismic events; however, depends with magnitude and duration of such events, associated energy and destructive forces, and other factors. Analysis results also indicate that potential differential settlements of up to about 2 feet could occur based on the presence of soft sediments. To resist cap thinning or shearing via differential settlement, a permeable geotextile fabric will be placed at the base of the amended sediment caps to promote uniform settlement to maintain cap thickness and integrity.

6.2.4.6. Upper Intertidal Debris and Sediment Removal

Removal of shoreline debris and limited surface sediment is required for grading purposes in the upper intertidal sediment capping areas. Typical debris and sediment grading are presented on the sediment cap cross sections on Figures 6-19 through 6-25. The thickest accumulation of debris and large riprap boulders is present at the south end of the Site in the Haley-Cornwall overlap area (Cross Section A-A', Figure 6-19). Debris and surface sediment removal are planned to be completed during low-tide intervals to allow access for land-based excavation equipment, negating the need for a cofferdam. Typical BMPs will be implemented for water quality protection during the work.

6.2.5. Monitored Natural Recovery

MNR is planned for deeper subtidal areas where Site-related bioaccumulative compounds exceed cleanup levels to a lesser degree and net sediment deposition is naturally occurring (Figure 3-1). A sediment recovery model was used to evaluate the effectiveness of MNR and incorporated several factors such as contaminant concentration, depositional rate, depth of the biologically active zone and restoration time frame. The following sections describe the natural recovery estimate and how compliance with the cleanup levels for bioaccumulative compounds will be achieved on an area-weighted average basis for the Haley Marine Unit.

6.2.5.1. Natural Recovery Estimate

Estimates of natural recovery were developed based on guidance from the Interstate Technology Regulatory Council (ITRC) for remediation of contaminated sediments (ITRC 2014), described below. The primary mechanism for natural recovery in the vicinity of the Haley Marine Unit is burial by and mixing with naturally-deposited sediments including contributions from the Nooksack River. The ITRC provides guidance for calculating contaminant concentration reduction as a result of burial in the presence of bioturbation within the biologically active zone. The calculation used to determine contaminant concentrations suitable for natural recovery simulates a mixed reactor (representing constant bioturbation within the biologically active zone) with the consistent addition of clean material (deposition of clean sediment), as follows:

$$Co/C = 1 / e\text{-}Qt/T$$

Where:

Q = net deposition rate, 1.5 cm/year based on deposition rates observed at nearby Whatcom Waterway station (RETEC 2006)

T = bioturbation depth, 12 cm based on the bioactive zone in Bellingham Bay

t = reasonable maximum restoration timeframe, 10 years based on SMS requirement

C = contaminant cleanup level within the biologically active zone

Co = sediment concentration expected to naturally recover within the restoration timeframe

Co/C = non-chemical specific exceedance factor expected to naturally recover within the restoration timeframe

The deposition rate of 1.5 cm/year is considered to be a conservative estimate of recent sediment accumulation conditions based on comparison of seafloor bathymetry between 2007 and 2015, as described in Section 1.2.5.3 and depicted on Figure 1-9. Results of that bathymetric comparison indicated deposition rates of 3.7 cm/year or greater in portions of the Haley Marine Unit.

The ITRC calculation described above results in an exceedance factor of 3.5, meaning that natural recovery will be expected to achieve cleanup levels where the contaminant concentrations are up to 3.5 times higher than the cleanup level. The natural recovery concentration resulting from the ITRC calculation is applicable on a location-specific basis. Compliance with the cleanup levels for bioaccumulative compounds is based on a surface weighted average concentration (SWAC) basis as described in the following section.

Based on the natural recovery estimate, the planned MNR area is shown on Figure 3-1. The primary driver for the inner limit of the MNR area is D/F concentrations in surface sediment. Based on the calculated exceedance factor of 3.5, the approximate dry weight concentration of D/F amendable to natural recovery is 45.5 ng/kg TEQ, which is 3.5 times the D/F cleanup level of 13 ng/kg TEQ. The other bioaccumulative compounds that exceed cleanup levels, PCP and cPAHs, are not dependent on natural recovery to meet cleanup levels in the MNR area. PCP and cPAHs currently meet the cleanup levels in the MNR area on a SWAC basis and will meet the cleanup levels throughout Marine Unit upon completion of remedial action capping as described in the following section.

6.2.5.2. Surface Weighted Averaging

Compliance with the cleanup levels for bioaccumulative compounds including D/F, PCP and cPAHs is on a surface weighted average concentration (SWAC) basis across the entire Marine Unit. As discussed in Section 2.3, this is because bioaccumulative exposures largely occur though ingestion of fish and shellfish and these receptors average their exposures over an area. Based on the ITRC natural recovery calculation described above and SWACs for D/F, PCP and cPAHs, the MNR area is anticipated to meet D/F cleanup levels within 10 years and currently meets cleanup levels for PCP and cPAHs.

A Marine Unit-wide SWAC for D/F was calculated for expected conditions immediately following construction. Using existing surface D/F concentration data in the planned MNR area and assuming a surface sediment replacement concentration of 5 ng/kg (representing the programmatic dioxin and furan TEQ PQL [Ecology 2019]) across the footprint of newly-capped areas, a SWAC was calculated using geographic information system (GIS) spatial interpolation as the standard approach accepted by Ecology. The calculated post-construction SWAC for D/F was 18 ng/kg. This Marine Unit-wide SWAC for D/F will decrease overtime as concentrations in the MNR area naturally recover, and is anticipated to meet the cleanup level of 13 ng/kg TEQ within 10 years following construction.

A Marine Unit-wide SWAC was also calculated for PCP for expected conditions immediately following construction. The post-construction SWAC for PCP was calculated using existing surface concentration data in the planned MNR area and assuming a surface sediment replacement concentration of 100 µg/kg (PCP PQL) across the footprint of the newly capped areas. The calculated post-construction SWAC for PCP was 65.8 µg/kg. Therefore, the Haley Marine Unit will meet the PCP cleanup level (100 µg/kg) upon completion of remedial action construction. A SWAC was also calculated for PCP in the MNR area using existing data. The SWAC for the MNR area was 50.7 µg/kg and therefore, PCP in the MNR area is currently less than the cleanup level on a SWAC basis.

Similarly, a Marine Unit-wide SWAC was also calculated for cPAHs for expected conditions immediately following construction. The post-construction SWAC for cPAHs was also calculated using existing surface concentration data in the planned MNR area and assuming surface sediment replacement concentrations of 9 µg/kg (representing the programmatic cPAH TEQ PQL [Ecology 2019]) across the footprint of the newly capped areas. The calculated post-construction SWAC for cPAHs was 65.8 µg/kg. Therefore, the Haley Marine Unit will meet the cPAH cleanup level (229 µg/kg) upon completion of remedial action construction. A SWAC was also calculated for cPAHs in the MNR area using the existing data. The SWAC for the MNR area was 94.1 µg/kg and therefore, cPAHs in the MNR area are currently less than the cPAH cleanup level on a SWAC basis.

6.3. Construction Approach

This section describes general sequencing and constructability considerations for the cleanup action components in the Haley 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 ISS near the shoreline bank, sediment excavation and capping, and shoreline slope grading. Although a cofferdam will be installed to create dry conditions for these activities, or work will be done during low tide periods, the design assumes that all work below the OHWM must be completed within the in-water work window. ISS near the shoreline bank, sediment excavation, and sediment capping are anticipated to require up to two in-water work window construction periods. 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 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 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 to be determined.

6.3.1.2. General Construction Sequencing

The general sequence of construction is to first complete upland demolition and preloading followed by ISS, and then transition to sediment excavation and capping of the excavated areas. Upland capping is planned to be completed later, followed by capping of the remaining sediment areas as the final activity.

ISS is planned to be completed earlier in the construction sequence to reduce potential for upland LNAPL and associated constituents to migrate toward sediment areas to be remediated. In addition, completing ISS along the shoreline prior to sediment excavation provides a stabilized structure that can support adjacent excavation without use of shoring. Capping of the sediment excavation will be completed in the dry immediately following excavation while the area is dewatered behind the planned cofferdam. The upland cap will be constructed later in the sequence to maintain upland access to the shoreline area and provide staging areas for operations, equipment, and supporting facilities until upland grading and landscaping are complete. The remaining intertidal and subtidal sediment capping will be completed last to minimize potential for recontamination of the cap surface during construction.

Upland Preparation/Demolition and Preloading

- Mobilize and establish secure work and staging areas and install stormwater erosion control and management features/facilities.
- Clear vegetation and demolish and fracture pavement, remove surface and subsurface structures and debris, and decommission or remove abandoned utilities. Note: pavement may be temporarily left in place if useful during construction staging.
- Decommission and abandon existing groundwater monitoring wells that would likely be damaged during construction.
- Re-line the Cedar Street outfall pipe.
- Initiate upland grading and place excavated material and clean import fill to preload upland soils for a period of 6 months or longer to reduce longer-term settlement.

ISS

- Install and dewater a cofferdam to protect surface water from ISS residuals and contaminated media disturbed during implementation.
- Remove overburden soil from the ISS area and use the soil for upland grading.
- Complete ISS and curing.
- Complete shoreline bank grading in ISS area.

Sediment Excavation and Capping

- Install and dewater a cofferdam surrounding the sediment excavation area to facilitate sediment excavation to approximately elevation 1-foot NAVD88. Note: the contractor may elect to install a single cofferdam for both the ISS application and sediment excavation work.
- Excavate sediment and debris to design grades and conduct field screening to evaluate need for additional contingency excavation.
- Place capping material including erosion protection.
- Amend excavated sediment with cementitious mixture to enhance its structural properties, and retain the amended sediment for consolidation under the Haley upland cap.
- Remove cofferdam.

Upland Capping

- Complete upland and shoreline grading for the cap installation.

- Complete upland capping and cover placement including integration with the Cornwall cap in the overlap area and establish final grades and surface drainage.
- Vegetate the cap surface with grass and plant shoreline bank vegetation strip.
- Complete upland capping in Pine Street Beach area.

Remaining Sediment Capping

- Complete intertidal and subtidal sediment capping outside the sediment excavation area.
- Complete erosion protection placement for the shoreline bank slope.
- Demobilize when all construction elements are complete.

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. Stormwater control measures, utility checks, demolition and other preparatory activities will also be completed before transporting equipment and materials to the Site to construct the remedial action components.

6.3.2.1. Construction Access, Haul Routes, and Site Security

Access to the Upland Unit is currently restricted by security fencing except along the shoreline bank. The gated, locked entrance situated at the terminus of Cornwall Avenue at the north end of the Site will be the primary upland access point (Figure 1-5). This access point is the southern extension of Cornwall Avenue and is a City-owned paved access road. The upland entrance and haul roads will be stabilized using quarry spalls or other material as needed to minimize soil tracking. The existing asphalt drive across the Haley property will be preserved and reinforced as needed for equipment, or a new access corridor will be constructed. The contractor will provide traffic control and determine traffic flow patterns within the Site and construct temporary roads, work pads, etc. as needed to support construction activities. The contractor will provide additional fencing and other site security measures as needed.

6.3.2.2. Utilities Checks

Underground public and private utilities will be located and marked with paint prior to construction. Figure 1-5 identifies locations of known utilities at the Site. The contractor will be responsible for field-locating all utilities using appropriate methods. Existing utilities associated with past Site operations will be abandoned, as described below. Utility checks will also be completed for potential offshore utilities including contacting telecommunications companies regarding marine cables. A 16-inch diameter inactive water main, is located along the eastern site boundary. This utility will either be decommissioned and left in place or potentially maintained for post-remediation use for the future park (to be determined).

6.3.2.3. Clearing and Grubbing

Vegetated areas will be cleared and grubbed across the Upland Unit to prepare ground surfaces for equipment staging and construction activities. Trees and vegetation removed during clearing will be temporarily managed on site for placement under the upland cap liner.

6.3.2.4. Stormwater and Dewatering Water 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 of Bellingham's stormwater management regulations (Chapter 15.42) and Ecology's Construction Stormwater General

Permit (CSWGP) or an individual stormwater permit. 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. Additional stormwater management discharge requirements may be established if Ecology determines that an individual permit is necessary. Management of Site stormwater will transition to the City's MS4 program after completion of construction.

Site dewatering water from upland and sediment excavations is not expected to be suitable for discharge to surface water. Instead, dewatering water will be collected for temporary storage in the Upland Unit for management and discharge, either through the City's Publicly Owned Treatment Works (POTW) if feasible, a permitted off-site facility or an on-site treatment system. Specific storage and pretreatment facilities will be determined but are expected to require Baker tanks and potential additional settling and filtration elements. If an on-site treatment system is used, the design and performance monitoring will be reviewed and approved by the City and Ecology.

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 and subsurface structures remaining from previous Site operations will be removed or modified as needed to prepare the upland area for ISS and capping. As shown on Figure 1-5 these structures include asphalt and concrete surface pads, concrete foundations and vaults, steel piping, and underground storage and surge tanks that were previously abandoned in place. A 12-inch square wooden storm drain outfall, 8-inch diameter concrete storm drain outfall, and associated piping will also be removed or backfilled in-place with concrete grout. The existing asphalt and concrete pads will be broken in place. Other removed structures and utilities will be sized in manageable pieces. Wooden piling (most prevalent in the west-central portion of the Site) will be cut off and removed from the ISS footprint and sized in manageable pieces. Pilings at other locations will be cut-off and removed below the ground surface as needed to accommodate upland grading. Demolished pavement, piling, and other debris will be placed beneath the upland cap (pavement may be temporarily left in place if useful during staging).

6.3.2.7. Groundwater Monitoring Wells

Many of the existing groundwater monitoring wells are within the ISS area and/or are located within the area where excavation will be performed to slope the shoreline to support placement of the sediment cap and armor rock. As a result, the existing wells will need to be decommissioned prior to the start of work in these areas. 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 area maybe protected during earthwork, if practical, for use in compliance monitoring after the remedy is constructed. 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).

New wells will need to be installed to support compliance monitoring after the remedy is constructed. New wells for compliance monitoring will be installed after site grading has been completed and prior to installation of the upland cap LLDPE liner. The liner would be installed around the new wells as well as any existing wells that are retained as described in Section 6.3.4.4.

The wells that are to be decommissioned and retained, as well as the new wells to be installed will be identified in the Operation, Maintenance and Monitoring Plan prepared as part of the remedial design.

6.3.2.8. Demobilization

Upon completing the cleanup action, the contractor will clean the work premises and remove associated surplus and discarded materials for off-site disposal. The contractor will dismantle temporary facilities and stormwater controls (after final BMP stabilization is achieved) and remove vehicles and equipment in preparation for post-construction monitoring.

6.3.3. ISS

ISS construction activities will require careful planning and flexibility to optimize the means, methods, and sequencing with other Site cleanup activities. ISS work will be completed based on performance-based specification requirements where the selected contractor will determine the ISS means and methods to achieve these requirements. The contractor will be required to demonstrate that their proposed mix design can achieve the specification requirements and that their mixing means and methods are suitable for site soil and debris conditions. The following sections describe the general approach for implementing ISS over the area shown on Figures 6-1 through 6-4. The ISS contractor will develop construction planning documentation to address:

- Additional bench-scale ISS mix testing and rationale as needed to confirm mix design;
- An ISS test cell(s) to demonstrate the efficacy of ISS means and methods;
- The layout and sequencing of grid cells for ISS application;
- Cofferdam containment of near-shore ISS areas;
- Excavation and handling of overburden soil above the ISS zone;
- Debris removal from the ISS footprint;
- Handling of wastes generated during ISS (grout wastes, NAPL, equipment wash water, etc.); and,
- QA/QC protocols including sampling and performance testing during ISS batching and application.

6.3.3.1. Final ISS Mix Design

Initial treatability testing to determine the feasibility of ISS and to test initial mix design has been completed and is summarized in Appendix B. The ISS contractor will be responsible for determining a final ISS mix design that can be implemented in the field and meets the performance criteria for hydraulic conductivity and UCS. The contractor will review the initial treatability testing results and determine if additional testing for potential changes to the mix are desirable based on implementability considerations. The contractor will present supporting rationale including additional treatability testing results, with testing methods to be determined.

Site access will be provided for the contractor to excavate test pits to further assess the variability of Site conditions and collect soil samples as needed to develop the final mix design. The final mix design is intended to be applied over the range of Site conditions to be encountered.

6.3.3.2. ISS Test Cell(s)

ISS is anticipated to be completed in a systematic manner based on a grid cell system and sequential progression to be developed by the contractor. The contractor will establish a test cell or cells for ISS application prior to full-scale implementation. The test cell(s) will be located within the ISS footprint away from the shoreline and will not require cofferdam containment as planned for full-scale implementation. The contractor will use the test cell information to demonstrate that the selected ISS approach can be effectively implemented to meet performance criteria prior to proceeding with full-scale ISS construction. Key to this demonstration is confirming that the ISS mixing method is expected to be implementable and effective at full scale using excavators or other methods to be determined by the contractor. Debris management is an additional factor affecting the implementability of ISS at full scale. The test cell information will help to determine whether a separate debris removal step is needed before ISS construction, or if debris can be effectively removed simultaneously with ISS construction.

ISS will be observed in the test cell(s) to evaluate the completeness of mixing of the soil containing LNAPL and the extent to which debris is adequately incorporated into the final mixture. Representative samples of the ISS batch mix and ISS-soil mixture will be collected and tested to determine if the mixture meets the required performance criteria using the contractor's selected mix design and construction means and methods. The final test cell objectives and parameters will be detailed in future design phases and contract specifications. Test cell results will be used to confirm that that ISS process is suitable for full-scale implementation over the range of Site conditions to be encountered. Test cell ISS-soil mixtures not meeting performance requirements may require remixing using different methods and/or modified mix design.

6.3.3.3. ISS Grid Cells and Sequencing

The contractor will determine the layout, required overlap, and sequential progression of ISS grid cells across the ISS footprint shown on Figure 6-1. It is anticipated that each grid cell will represent an area suitable for full-depth ISS during a work shift or other time duration to be determined. ISS-soil mixing will continue in a specific cell until the entire soil mass targeted for ISS in that cell is treated. Performing ISS in discrete cells will also help to promote relatively uniform curing.

Overburden soil above the ISS application elevation will require removal to provide an operating surface for ISS equipment. The ISS contractor will coordinate overburden removal within the overall ISS grid cell sequencing plan and transfer the removed soils elsewhere on-site for incorporation into the upland cap below the low-permeability liner.

The grid cell sequence will also consider:

- Appropriate cell overlaps for uniform blending of the ISS-soil mass across the ISS footprint;
- The need for modified mixing approaches closer to the edge of bank, or in locations where soil conditions are different or more variable than expected;
- Management of the expected vertical expansion of the ISS-soil mixture above the application surface;
- Removal, handling, and disposition of debris that cannot be incorporated into the ISS mix because of type or size; and,

- The southern end of the sheet pile wall that curves away from the shoreline and is likely to present challenges for ISS mixing in that area.

6.3.3.4. Temporary Cofferdam

A temporary cofferdam will be established in the intertidal area prior to ISS construction to prevent tidal inundation and contain the ISS mix and potential bank seepage from displaced groundwater. The cofferdam isolates the shoreline bank and protects adjacent marine areas during the ISS process. The cofferdam will be installed before initiating full-scale ISS and will be maintained for the duration of ISS construction and curing. The specific placement location and configuration of the cofferdam will be determined in later stages of design or by the contractor.

For this EDR it is assumed that a cofferdam will be constructed using a Portadam® structure, water- or sand-filled bags, or other methods to be determined by the contractor. The Portadam® structure is installed with footings that would sit directly on the surface of the intertidal zone. To reduce water seepage beneath the bottom of the cofferdam, debris on the sediment surface may require removal. The shoreline edge of the cofferdam must also be seal out seawater and will require similar debris removal. These materials will be moved to the upland for subsequent placement beneath the upland cap.

ISS construction will begin after the cofferdam is placed and a collection system is in place to capture potential bank seepage. The cofferdam will be constructed to an appropriate height to accommodate expected tidal fluctuations during the ISS work.

A temporary cofferdam is also envisioned for use to isolate the intertidal sediment excavation area from surface water during a separate phase of work, as described in Section 6.3.5. A sheet pile cofferdam is likely to be less feasible because of the presence of subsurface debris that could obstruct installation of the sheets and disturb contaminated subsurface sediment. The contractor could elect to use the same cofferdam configuration for ISS and sediment excavation or reset the cofferdam for sediment excavation after ISS is complete.

6.3.3.5. Debris Management

Debris within the ISS footprint will require removal of material greater than about 1 to 2 feet (to be determined) in the largest dimension, or if otherwise incompatible with the ISS method and curing (to be further evaluated during later design phases). Oversized debris will be downsized and incorporated into the ISS mix if feasible or will be removed from the ISS footprint for consolidation under the upland cap beneath the low-permeability liner. The contractor will determine if and how debris can be downsized or otherwise removed from the ISS footprint. A significant amount of debris is present in the ISS footprint. The project specifications will notify contractors regarding the presence of debris as a significant consideration for the contractor's selection of ISS construction means and methods.

6.3.3.6. QA/QC Sampling and Performance Testing

The contractor will document reagent quantities and proportions during ISS batching and mixing. The contractor will collect samples of the freshly mixed ISS-treated soil in test cylinders for QA/QC testing during the ISS test cell(s) and full-scale construction. ISS samples will be submitted for testing for hydraulic conductivity, UCS, and other parameters to demonstrate compliance of the ISS mixed soil with performance requirements described in the specifications.

The type, location/depths, number, and frequency of ISS samples for QA/QC testing will be determined during later design and through the contractor's construction planning documents reviewed by the City and

Ecology. The scope of ISS QA/QC testing will also depend on the ISS construction method(s), grid cell size, ISS batching methods, variability of the batching process, and other factors to be identified. Samples for UCS are typically collected for 7- and 28-day testing. ISS sample test results will be reviewed by the City for conformance with performance criteria.

6.3.4. Upland Cap

This section presents information for construction of the low-permeability upland cap to be constructed north of the Haley-Cornwall overlap area. Surface grading for the completed upland cap is shown on Figure 6-5. For cap construction, typical land-based construction equipment will be suitable for preloading, fill placement, and grading. 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. Careful planning will be needed to maintain equipment access throughout the upland construction area as the cap components are placed and coordinated with cleanup actions on the adjacent Cornwall site.

The Haley cap will transition into the Cornwall low-permeability upland cap in the overlap area, with the Cornwall cap fulfilling design and performance requirements for both sites including containment of Haley contaminants. The Cornwall cap will feature low-permeability soil and geomembrane layers, LFG collection, and drainage control as the functional equivalent of the Haley cap. The Cornwall cap components are described in the Cornwall EDR and will be further refined in later stages of design.

6.3.4.1. Preloading

The southern extent of the upland cap including the Haley-Cornwall overlap area will be preloaded for a minimum of 6 months before the final cap is constructed and will be one of the first construction elements. Geotechnical analysis indicates that preloading will be required in areas where the finished grade will exceed 3 feet above the existing surface; however, this includes the entire upland, considering the future planned land use as a park. The ISS area will not be preloaded. The specific location, height and duration of preload materials will be determined as part of the final design and based on settling during preloading.

Materials used for preload will include fill soil sourced from the Site and/or clean imported soil as needed. The sequence and location of fill placement at the Site for preloading purposes will be determined by the contractor. Contaminated soil used for preloading at the Site will be segregated from clean imported soil. Soil used for preloading will require erosion protection and stormwater runoff from the piles will need to be managed appropriately.

6.3.4.2. Fill Placement and Grading

Multiple materials will be used to construct the design grades for the upland cap. Fill used to achieve upland grades is expected to primarily include on-site material including concrete, asphalt, brick, wood, excavated sediment and soil. The contractor will determine grading and fill sequencing. The wood debris will be distributed throughout the Site within other (non-wood) fill materials to reduce future settlement as the wood degrades over time. Most wood waste will be placed near the bottom of the fill profile within and adjacent to the Haley-Cornwall overlap area. Large wood debris such as piles will be reduced to manageable sizes and placed such that void spaces are not created around the debris.

Similar considerations must be accounted for during placement of concrete, brick, asphalt and cobbles and boulders. Placement of these materials will occur so that they are mixed with smaller particles to avoid large void spaces, thereby reducing the risk and magnitude of future settlement.

Sediment and soil excavated from the shoreline will be conditioned and consolidated for placement in the upland fill area. Heavy equipment will be used to mix the excavated sediment with 3 percent cement (by weight) in order to increase the strength and improve the handling characteristics of this material. It is anticipated that curing will require at least 28 days before use for grading. Additionally, following curing of the ISS treated soil, the seaward edge of the solidified ISS body will be sloped at about 7H:1V in preparation for the shoreline bank grading shown on the Figure 6-5 plan view and Figure 6-20 and 6-21 cross sections. Excavation and grading of the ISS body will be integrated into the sequence of sediment excavation. Conditioned sediment and excavated ISS treated soil will be placed in the Haley-Cornwall overlap area.

Water from the excavated sediment and stormwater that contacts exposed contaminated soil and sediment will be infiltrated into the ground surface and not discharged back into Bellingham Bay. Water that can't be infiltrated will be collected, treated (if needed) and disposed off-site in accordance with agreements with the City of Bellingham POTW or other offsite facilities that can accept the water. Grades for the upland cap will be constructed to within 3 inches of the top of subgrade below the liner and before installation of the LFG collection layer. The final surface of the subgrade before installation of the geosynthetics will be rolled with a smooth drum roller and bedding sand used as needed to provide a smooth surface for installation of the cap geosynthetic layers. If existing monitoring wells within the grading areas will be preserved, the wells will be extended vertically as the fill is placed around the groundwater well.

6.3.4.3. Cap Construction North of Overlap Area

The upland cap layers and other features will be constructed as shown on Figure 6-10 through 6-14. After rough-grading for the subgrade is completed, groundwater monitoring wells and LFG collection system components will be installed. LFG components include the vertical LFG wells and HDPE header pipe. After installation of the LFG components and groundwater monitoring wells, the upland fill area will be final graded, the bedding sand placed, and a smooth drum roller will be used to construct the finished subgrade to 2 feet below the final finished surface. Bedding sand will be placed as needed to maintain a smooth uniform finish and at a minimum thickness necessary to maintain at least 6-inches of cover over irregularities or protrusions in the subgrade.

After the subgrade is prepared, the LFG geocomposite collection layer will be installed and connected to the LFG header pipes. Immediately following placement of the LFG collection layer, the rest of the cap geosynthetics will be placed including the LLDPE geomembrane and the drainage layer geocomposite. During placement of each geosynthetic layer, vertical penetrations through the geomembrane will be marked and constructed as described below. After placement of the drainage layer geocomposite, the HDPE underdrain pipes and utilities for the future park that can accommodate installation depths of less than 2 feet will be installed.

As the LLDPE geomembrane panels are deployed the seams will be fusion welded using a hot wedge welder. At seam intersections and repair locations, patches will be installed using extrusion welding techniques. Strict QA/QC will be adhered to during the geomembrane welding. This includes testing equipment and welded seam strength before welding and collecting destructive seam strength samples for independent analysis in general accordance with ASTM D6392. Each weld will be non-destructively tested for seam integrity. Fusion welds will be tested using the air channel method in general accordance with ASTM D5820 and extrusion welds will be tested using a vacuum box in general accordance with ASTM D5641. Seams that cannot be effectively air channel- or vacuum-tested may be spark tested in general accordance with ASTM D6365, if deemed to be necessary by the owner or following regulatory review.

Underdrain pipes will be placed at the locations shown on Figure 6-14. The underdrain pipes terminate within the shoreline armor rock and construction sequencing will need to accommodate their installation. The soil protection layer and access road will be installed around the underdrain pipes. Wheeled or tracked equipment will not be allowed to travel directly onto the geocomposites.

To install the cover materials over the geosynthetics, a low ground pressure (LGP) dozer will be used to push soil over the geosynthetics. The LGP dozer will not exceed ground pressures of 5 pounds per square inch and at least 12 inches of soil will be maintained between the geosynthetics and dozer tracks. Careful planning and coordination will be needed to place the imported cover soil, underdrain pipe bedding and access road while maintaining at least 12 inches of soil cover over the cap geosynthetic layers. Once the loose 12-inch cover soil lift is placed it will be compacted using a smooth drum roller to 95 percent of the MDD in general accordance with ASTM D1557. Cover soil will be placed in an additional lift until the final 18-inch thick soil protection layer thickness is achieved. The final 6 inches of the cap cover consisting of topsoil and turf or hydroseed mixture will not be compacted. Once the turf is placed, vehicle traffic will not be allowed on the vegetated surface unless protected with mats or other load-distributing measures are used to prevent compaction and rutting. Vehicle traffic will be limited to site access roads.

6.3.4.4. Cap Penetrations

Cap penetrations will include groundwater monitoring wells and the LFG vertical extraction wells. Through the final design process, penetrations through the cap will be identified with intent of minimizing the number of penetrations. Utilities for the future park are planned to be installed in the cover soils and/or additional park fill placed above the vegetated soil cover. If utilities to support the future park will penetrate the liner, details of penetrations will be provided in the final design. Field or shop fabricated boots will be installed around cap penetrations as shown on Figure 6-12. Where vertical penetrations occur through the cap, metal piping will be used and the LLDPE will be secured to the piping using stainless steel banding in general accordance with ASTM D6497. If determined to be necessary, welded seams for pipe penetrations will be spark tested in general accordance with ASTM D6365. The metal piping used for the penetration will serve as the conductive material to accommodate the spark tests.

6.3.5. Sediment Excavation

This section describes planned sediment excavation activities, including methods, construction dewatering, verification sampling, sediment capping, and excavated sediment management. Site work will include excavation of approximately 2,300 in-place CY of contaminated sediment from the upper intertidal area of the Haley Marine Unit (Figure 6-16). The actual quantity of sediment to be excavated may be greater or less than this estimate based on conditions during construction.

6.3.5.1. General Excavation Approach and Methods

Excavation is focused on reducing the volume of highly contaminated sediment in the upper intertidal portion of the Haley Marine Unit located adjacent to upland soils with potentially mobile LNAPL. The general approach for contaminated sediment removal consists of the following elements:

- Isolate the planned excavation footprint inside a dewatered cofferdam. The excavation will be maintained in a dry condition to the extent feasible, with excavation seepage water dewatered as needed to complete the work. Extracted water will be collected and managed as needed for off-site disposal.

- Excavate surface and shallow sediment using land-based equipment from within the excavation footprint or from the upland bank of the excavation. Sediment excavation will extend to the lateral and vertical limits presented in Figures 6-16, 6-17, and 6-18 to remove contaminated sediment.
- Perform field screening such as water sheen screening and visual checks for heavy sheen or product indicative of potentially mobile LNAPL Field screening will include base of excavation areas to evaluate the need for potential additional localized excavation of sediment with potentially mobile LNAPL below the target base elevation, if feasible.
- Perform additional localized excavation below the current target limits to remove potentially mobile LNAPL to an elevation no deeper than 1-foot NAVD88, depending on side slope stability, water seepage, and other conditions at the time of the work.
- Following completion of sediment excavation, collect sediment samples for laboratory analysis from the excavation sidewalls and base for the purpose of characterizing and documenting the condition of sediment left in place under the containment cap to be placed in the excavation.
- Place cap materials in the excavation as described in Section 6.3.6 while maintaining dry conditions behind the cofferdam.
- Following cap placement, remove the cofferdam and allow the excavation area to inundate.

The spatial progression of excavation and capping behind the cofferdam will be determined during later design phases, plan, and specification development, and/or in the contractor's work plans. Excavating and capping in smaller cells within the excavation footprint may help limit water seepage (if present) and minimize dewatering. Similar cell by cell excavation and backfilling approaches have been successfully used on other intertidal sediment cleanup projects completed in the dry in Puget Sound.

6.3.5.2. Temporary Cofferdam

Intertidal sediment is planned to be excavated in the dry by temporarily isolating the excavation work area from surrounding tidal waters. Several methods are proven and available to achieve this goal, including excavating during low tide periods, installing cofferdams using sheet piles or large bags or tubes filled with water or sand. The specific cofferdam method to be used will be determined by the selected contractor.

For design purposes, the commercially available Portadam® cofferdam is considered viable based on successful use in similar intertidal marine conditions at the Irondale sediment cleanup site near Port Hadlock, Washington. The Portadam® system can be safely operated and maintained in tidal conditions with up to about 10 feet of water depth on the seaward side. The Portadam® consists of a synthetic waterproof membrane mounted on the seaward side of a steel support frame supported with footings on the seafloor surface. Hydraulic loading of the membrane against the frame seals and stabilizes the structure. The membrane is extended seaward of the support frame on the seafloor bed to prevent water from piping beneath the support footings. The cofferdam method selected by the contractor will be required to meet or exceed the capabilities of the commercially available Portadam® system.

The cofferdam, or alternative isolation method, will be installed prior to initiating sediment excavation. The cofferdam and other equipment needed inside the cofferdam, will be operated and maintained constantly during the periods in which excavation areas are exposed. Following placement of cap material over the exposed base of excavation, the area behind the cofferdam will be allowed to inundate. Due to the length of shoreline where excavation is proposed cofferdam installation and associated excavation and backfill capping may be completed in phases, to be determined in later design phases or by the contractor.

6.3.5.3. Construction Dewatering and Wastewater Disposal

The extent of dewatering needed behind the cofferdam to maintain dry work areas will depend on several factors:

- Sediment excavation approach and the cofferdam method selected by the contractor;
- The elevation where excavation or capping is occurring;
- Potential seepage of tidal water beneath the cofferdam to the excavation area; and
- Upland groundwater discharging through sediment into to the excavation.

The specific dewatering methods are expected to be integral to the selected excavation, capping, and cofferdam method and will be determined by the contractor.

Excavation dewatering water will be pumped for temporary storage in the Upland Unit for characterization, management and off-site disposal. Sheen removal and control of total suspended solids and other constituents is expected to be required prior to disposal, including settling and possibly other methods such as product skimming, filtration, or chitosan application. Water is planned to be disposed of either through the City's POTW if feasible, or at a permitted off-site commercial facility. The contractor will be responsible for coordinating and compliance with discharge approvals, managing on-site water storage, and tracking discharge events and volumes.

6.3.5.4. Debris Removal and Handling

Rock and concrete riprap, wood, landfill refuse, and other debris are present in the sediment that must be excavated, noting that a substantial amount of riprap may have already been removed along a portion of the shoreline to facilitate ISS cofferdam placement as described in Section 6.3.3. The remaining riprap will be removed prior to beginning excavation and transferred to the Upland Unit for size reduction and consolidation beneath the upland cap liner. Riprap will not be reused for sediment cap armoring.

Significant wood debris is present in the intertidal sediment that will be removed during excavation. It may be possible to segregate the larger wood debris and transfer it to the Upland Unit for size reduction and consolidation with other materials beneath the upland cap. Smaller wood debris including sawdust will be removed with the excavated sediment for consolidation in the Upland Unit.

Numerous remnant wood piles are anticipated to be present at or near the sediment surface in the excavation area. Broken piles or other large wood pieces exposed on the surface or encountered during excavation will be removed and managed as noted above. Remaining intact piles will be cut at the base of the excavation and the cut pieces will be managed beneath the upland cap as described above. Piling will not be removed from the sediment excavation area as removal of piling may cause a preferential pathway for contaminant transport from deeper sediment and groundwater to the surface. Piling removal would also likely cause differential settlement of sediment on which the sediment cap is placed which could result in discontinuities in the cap material and reduced effectiveness or failure of the cap.

6.3.5.5. Sediment Handling

Excavated sediment and debris will be transferred upland using methods to be determined by the contractor. Transfer methods will most likely use some combination of loaders, haul trucks, and crane equipment. Excavated sediment (and debris) will be placed on the ground in an open area away from the shoreline for mixing with 3 percent (by weight) Portland cement to increase the strength of the material prior to being placed as upland fill. The timing and location of the amendment mixing will be determined by the contractor. The conditioned sediment will be placed and compacted during grading for construction of the Haley upland cap, as described in Section 6.3.4.

6.3.5.6. Verification Sampling

Verification sampling will involve collecting sediment samples from the base and sidewalls of the excavation limits to document concentrations of contaminants remaining in sediment at the Site following completion of the cleanup action. The number, frequency, and location of verification samples and analytes to be tested will be identified in the compliance monitoring plan to be developed with the construction documents.

6.3.6. Sediment Capping

The cleanup action within the Haley Marine Unit includes placement of sediment caps in intertidal and subtidal environments as a key project component. This section summarizes the approach and methods for constructing the selected sediment cap designs in the areas shown on Figure 6-16. Figures 6-19 through 6-25 present the completed capping profiles in relation to existing and post-capping bathymetry. Figure 6-26 presents the post-capping surface including the top of the erosion protection layer.

6.3.6.1. Capping Surface Preparation

Sediment capping within the intertidal sediment excavation footprint will occur in the dry on the smooth graded surface prepared for backfilling following the excavation phase. Debris and piles in the excavation footprint will have already been removed during excavation. Outside the excavation footprint, intertidal and subtidal cap placement will first require removal of loose surface debris and broken wood piles. Numerous remnant in-place piles are also present that will be cut off at the mudline along with debris if embedded in the seafloor. Debris and cut piles will be transferred for placement beneath the upland cap.

Limited removal of near-surface sediment will be required in some areas of the upper intertidal zone to achieve the required base grades for cap placement. Sediment removal and grading outside the excavation area will be conducted during low-tide periods using land-based excavation equipment, negating the need for a cofferdam. Typical BMPs will be implemented for water quality protection during the work. The thickest accumulation of debris requiring removal is present in the Haley-Cornwall overlap area, as shown on Figure 6-19a for the nearshore part of cross-section A-A’. A lesser amount of debris removal and grading is needed prior to cap placement in the intertidal zone farther north, as shown on Figure 6-22a for the nearshore part of cross-section D-D’.

6.3.6.2. Capping Types and Areas

Engineered caps of various designs will be placed over specific intertidal and subtidal areas of the Haley Marine Unit shown on Figure 6-16. As described in Section 6.2.4, the caps consist of a chemical containment layer to isolate contaminants in underlying sediment and porewater, and an erosion protection layer to provide long-term protection from wave action and other disturbance. In addition to these primary cap materials, the cap construction will utilize geotextile fabrics to resist differential settling of the cap containment layer and prevent the overlying erosion protection material from penetrating into the containment layer. Geotextile fabric will be used in areas where armor rock and gravel cobble erosion protection are shown on Figure 6-26.

Farther seaward, engineered capping will consist of a gravelly sand TLC to provide both contaminant containment and erosion protection. No geotextile fabric is needed for the TLC that will be placed directly on the seafloor.

6.3.6.3. 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. OC and AC 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.

6.3.6.4. Cap Placement Methods

Placement methods for capping materials will depend on the location and bathymetry of each capping zone shown on Figure 6-16 and described below.

- Zone 1a – The area within sediment excavation footprint will be capped using land-based equipment following completion of excavation but prior to removing the cofferdam. The base of the excavation will be covered with geotextile fabric before placing the overlying amended sand containment layer. A second geotextile layer will be placed to separate the top of the containment layer and armor rock gravel bedding.

  Capping materials will likely be placed in spatially sequenced cell areas in the excavation capping footprint, with equipment progressively retreating from completed cells to avoid traversing over newly capped surfaces. Geotextile sections will be connected between grids using field stitching or other mechanical method.

- Zone 1b – The intertidal cap area outside the footprint of the sediment excavation area is expected to be capped during low tide periods using land-based equipment staged on the beach or on top of the bank. The general concept for cell by cell cap placement in Zone 1b is expected to be the same as described for Zone 1a. Placement of armor rock over the containment layer during each work shift will be essential to protect completed cap segments from the incoming tide.

  Alternatively, the contractor could place intertidal caps through the water column during periods of tidal inundation using barge-based or long-reach shore-based equipment. Armor rock would be placed over each capping area to protect the containment layer from tidal action. Geotextile layers would still be most easily placed in the dry during low tide periods to avoid underwater placement as described below for Zone 2 and Zone 3.

- Zone 2 and Zone 3 – These zones include the deeper intertidal and subtidal zones with water depths of up to about 25 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 carefully place the amended sand layers in a controlled fashion to achieve proper distribution on the seafloor. Armor rock and gravel cobble erosion protection will be placed in Zone 2 and Zone 3 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.

  In Zones 1 through 3, geotextile fabric will be placed at the base and top of the containment layers where armor rock and cobble/gravel erosion protection material are placed for structural purposes and to prevent penetration of overlying erosion protection materials. Installing geotextile fabric through the water column will likely require sinkable material such as polyester or a polyester/polypropylene blend, specialized placement methods and potential diver-assistance to spread and secure the geotextile evenly.

- Zone 4 – Placement of the subtidal gravelly sand TLC in water depths of up to about 30 feet will require barge-based equipment and placement methods as described for Zone 2 and 3. No additional erosion protection or geofabric are needed.

The containment and erosion protection layers in each zone will be placed in lifts no greater than 1-foot thick to promote even coverage and reduce the tendency for differential settlement. 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 QA 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 layers will be surveyed to confirm that the top-of-cap surface elevations and design thicknesses are achieved in the field. The post-placement bathymetry will also provide a baseline for future comparison.

7.0 CONSTRUCTION REQUIREMENTS

This section summarizes general contracting considerations, construction quality control (CQC) and construction quality assurance (CQA) requirements, and construction documentation for the Haley cleanup. 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.

7.1. Pre-Construction Requirements

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

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

7.1.1. Contracting and Construction Planning

Construction contracting for the Haley and Cornwall cleanups are planned to be integrated with the intent of streamlining the contracting process and establishing consistent performance requirements to ensure that the cleanup action objectives for each site are successfully achieved. Contracting elements common to each project will be identified along with components that are unique to each site or require specialized experience, such as ISS and sediment capping at the Haley Site. These unique construction elements will be contracted and constructed accordingly. In accordance with WAC 173 340 400(7)(b), 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 project engineer.

7.1.2. Plans and Specifications

The plans and specifications will be submitted to Ecology for review and comment during the 60 percent, 90 percent and 100 percent (final) design phases in accordance with the Amended AO. Construction plans and specifications (Contract Documents) will be prepared based on the final design for remediation including supporting figures and related information needed for contracting. The Contract Documents will describe the scope of work to be completed and related details of the cleanup action. These documents will be supported by a summary of existing and environmental conditions including survey data or survey update requirements. Contract Documents will also include pertinent permits and approvals and associated conditions, including substantive requirements of exempted permits.

The draft Contract Documents are anticipated to be developed during and/or following 60 percent design, and when permitting has progressed sufficiently so that major design modifications are not anticipated. It is expected that design of the Haley and Cornwall Cleanup sites will be integrated during completion of the 90 percent design. The Contract Documents will be finalized following 100 percent (final) design.

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 quality control (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, construction quality control and quality assurance 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.
- 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 Construction Quality Assurance (CQA) activities needed to demonstrate the adequacy of the work completed will be prepared in conjunction with the contract documents following 60 Percent Design and when permitting has progressed sufficiently so that major design modifications are not anticipated. The CQAP will include 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.

The CQA Plan will be submitted to Ecology for review and will be included in the final Contract Documents.

7.1.4. Water Quality Monitoring Plan

A Water Quality Monitoring Plan (WQMP) will be developed by the City to describe the frequency, scope and documentation requirements for monitoring surface water quality during in-water construction activities. The water quality monitoring requirements will be determined and included as a provision of the U.S. Army Corps of Engineers permit required for marine construction work. The 401 Water Quality Certification (WQC) 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 Inadvertent Discovery Plan (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 Safety and Health.

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. Further 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 information, change documentation, 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 contain, manage and prevent releases of contaminated media in accordance with requirements of the Contract Documents. The EPP will identify management planning steps 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 of interest that may potentially be affected.

Excess soil, sediment, ISS solids, and debris that are temporarily stockpiled for upland grading and consolidation in the upland cap will be protected from contact with stormwater, particularly runoff that has potential for entering surface water. Shoreline and in-water BMPs may include silt curtains and debris/petroleum containment booms, as needed.

Stormwater, surface water, and air quality source control, BMPs, and monitoring plans 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 Construction Stormwater General Permit (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 required stormwater monitoring to be conducted by the Contractor. Stormwater and dewatering water management must also consider the designation of construction water as a Dangerous Waste per Chapter 173-303 WAC, where such water contacts Site wastes from wood preserving.

The EPP will also describe temporary storage, pretreatment, and off-site POTW or other permitted disposal of dewatering water and (as needed) collected 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 import of materials to the Site, the contractor will submit all documentation verifying that the material meets the requirements of the Contract Documents. The submittals will include documentation that the material conforms with specified materials types, gradations and meets 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 Health and Safety Plan (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 site 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. The City engineer or 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, 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 City engineer or 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:

- Survey verification of the preloading settlement and post-preloading ground surface elevations.
- Land surveys (record surveys) of the pre-construction ground surface and constructed features will be conducted under the supervision of a licensed professional land surveyor in the State of Washington and include:
    - ISS footprint and application locations/area;
    - Top of subgrade fill surface underlying the containment cap and shoreline bank transition cap to the OHWM;
    - Location and grades for landfill gas and water drainage components of the upland cap;
    - Top of cap cover and access road;
    - Existing shoreline bank, regraded bank surface, and top of armor rock surface above ordinary high water (OHW);
    - Location and elevation for groundwater monitoring well and landfill gas vent monuments and casings; and
    - Utilities.
- ISS mix proportions, strength and hydraulic conductivity performance testing results, application and swell quantities.
- LLDPE geomembrane line leak and seam testing.
- Observation of seam overlap for geocomposites.
- Import fill and other cap construction material characteristics and quality.

Planned CQA monitoring activities for the Marine Unit include:

- Bathymetric surveys and topographic survey (record surveys) in the intertidal zone:

    - Pre-construction sediment surface and visible piling and debris locations;
    - Sediment excavation/dredged surface;
    - Pre-capping sediment surface outside the excavation area;
    - Top of sediment cap containment horizon(s) and thicknesses; and
    - Top of armor rock erosion protection and thicknesses.
- Bathymetric surveys in the subtidal zone:
    - Pre-capping sediment surface and visible debris locations;
    - Top of sediment cap containment horizon(s) and thicknesses;
    - Top of gravel-cobble erosion protection and thickness; and
    - Top of gravelly-sand erosion protection and thickness.
- 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 problems and corrective actions. Contractor documentation will also include meeting minutes, requests for information as needed, and requests for payment.

7.2.3.2. Construction Meetings

Weekly construction meetings including owner and CQA representative(s) are anticipated to discuss progress, planning, quality and environmental issues, and upcoming scheduled work along with problems and solutions. Contractor meetings also include daily safety and work planning meetings prior to 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 and other BMPs. Monitoring, documentation and reporting for stormwater and surface water will be in accordance with the permit requirements, SWPPP and WQMP.

In-water construction activities will utilize water quality protection measures including:

- ISS placement, sediment excavation, and sediment capping within the excavation footprint are planned to be conducted within cofferdam enclosures to separate the work areas from the adjacent marine environment.
- Upland groundwater that may be displaced seaward through the shoreline bank during ISS is planned to be intercepted and collected within the cofferdam containment and will not be discharged to marine waters.
- Intertidal sediment grading and bed leveling and capping outside of the cofferdam enclosure are planned to be conducted in the dry during low tide periods, as practical.

Other water quality BMPs will be implemented such as silt fencing for upland stormwater control, and floating booms to contain debris and oil, if present. A silt curtain will be deployed during sediment capping and other in-water work, if expected to be effective. Additional BMPs will be used during debris and piling removal to minimize potential for debris and petroleum product to be released to surface water.

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 ISS application or if petroleum materials encountered during the work create odors or fumes adversely affecting air quality.

Monitoring of the BMPs will be using regular inspections and documentation will be 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, commercial, municipal, and Port 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). The construction completion report will include:

- 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 CQC/CQA 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.
- Documentation of where excavated sediment, ISS fluff, and other deleterious materials (e.g., LNAPL-soaked soil or sediment, large wood debris, etc.) have been placed beneath the upland cap.
- Monitoring well decommissioning or 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.

7.3.1. 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 capping, ISS, and sediment excavation and capping are designed to meet the cleanup levels at the points of compliance immediately following completion of cleanup action construction. Groundwater and sediment porewater will also be monitored to establish post-construction baseline conditions for comparison to the results of future confirmational monitoring.

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. Areas of the Marine Unit where MNR is used is expected to achieve cleanup levels within 10 years following construction, and potentially much sooner. Post-construction confirmational monitoring described below will be completed to determine if MNR meets cleanup objectives within the restoration timeframe.

8.0 OPERATIONS, MAINTENANCE AND MONITORING

This section presents a general description of operations, maintenance, and monitoring following construction for the Haley Site cleanup action. A draft Operations, Maintenance, and Monitoring Plan (OMMP) fulfilling requirements of WAC 173-340-400-(4)(c) will be developed concurrent with completion of 90% design and submitted to Ecology for review. The final OMMP will be prepared after construction is completed. The OMMP will describe inspection and maintenance activities for effective operations and performance of the remedial action. The OMMP will also 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. Site operations, maintenance, and monitoring activities are assumed to continue after construction through Year 30. Ecology, City and Port will determine if a combined OMMP for the Haley and Cornwall Landfill sites would be more efficient.

8.1. Operations, Maintenance, and Monitoring Plan

A draft OMMP will be prepared concurrently with development of 90% 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 the OMMP will include:

- Contact information for responsible individuals.
- Roles and responsibilities.
- Process description and operating principles.
- Design criteria and operating parameters.
- As-built drawings.
- Startup, operating, and emergency/contingency procedures including detailed procedures discussion, controls, parameters, safety features, and other relevant information.
- Procedures and sample forms for operation and maintenance records.
- Equipment specifications, as-builts, parts inventory, warranties and operation/maintenance schedules.
- Materials sources/suppliers.
- Maintenance schedules incorporating manufacturers' recommendations.
- Contingency procedures for spills, releases, and accidents.
- Confirmational monitoring details and schedule, and associated plans (e.g. SAP and QAPP).
- Health and safety provisions, contaminant action levels and contingency plans.
- Facility inspection and maintenance procedures including removal of unneeded equipment and maintenance of caps/cover materials and monitoring devices.
- Institutional controls.
- 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 Site operations, maintenance, and monitoring.

8.1.1. Inspections

The scope and timing of the inspection program and other aspects of long-term operations and maintenance monitoring will be specified in the OMMP. Inspections will commence when construction of each remedial element is substantially complete and will include visual assessment and other appropriate evaluation of the conditions and integrity of the upland and intertidal caps, ISS area, shoreline armor, and drainage control features. Inspections will also include the existing municipal stormwater outfalls discharging to the Haley Marine Unit. Site inspections will document physical conditions, 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

As previously discussed in Section 6.3.2.7, many of the existing groundwater monitoring wells are within the ISS area and/or are located within the area where excavation will be performed to slope the shoreline to support placement of the sediment cap and armor rock. As a result, the existing wells will need to be decommissioned prior to the start of work in these areas. Selected wells in the upland capping area maybe protected during earthwork, if practical, for use in compliance monitoring after the remedy is constructed. 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. Additionally, new wells will need to be installed to support compliance monitoring after the remedy is constructed. New wells for compliance monitoring will be installed after site grading has been completed and prior to installation of the upland cap LLDPE liner. The wells that are to be decommissioned and retained, as well as the new wells to be installed will be identified in the OMM Plan.

Confirmational monitoring will be performed following completion of performance monitoring (baseline groundwater monitoring at Year 0) after construction. The scope of and schedule for confirmational groundwater monitoring will be proposed in the draft OMMP and confirmed in the final OMMP to be completed after construction.

Ecology has determined that the Haley 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 and therefore, the conditional point of compliance for groundwater will be 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.

Results of the groundwater monitoring will be reviewed to assess changes in groundwater quality and evaluate the extent of contaminant degradation over time. Constituent concentrations in groundwater will also be compared to monitoring results for porewater and sediment to assess potential trends and interrelationships.

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. Bathymetric 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 including the MNR area.

Chemical quality monitoring of the bulk 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 with respect to consumption of seafood gathered from subtidal areas and higher trophic-level ecological receptors.

The point of compliance in the intertidal zone for protection of human health from consumption of shellfish is the upper 45 cm (1.5 feet) if clam harvesting was allowable. However, digging will not be allowed in these areas and armor rock and gravel/cobble erosion protection present a barrier for clam habitation and digging. Monitoring will focus on sampling bulk sediment overlying the erosion protection materials or accumulating in the interstices of erosion protection materials, as feasible. Sampling will extend to a maximum depth of up to 45 cm, although the typical depth of accumulated sediment within the erosion protection materials is expected to be shallower or limited by rock cover.

As feasible, porewater within the amended sand cap containment layer will be sampled using passive samplers to assess the changes in constituent concentrations at selected depths within the containment layer resulting from upward transport of constituents in groundwater. In subtidal areas the porewater sampling locations will target the combined gravelly-sand TLC and erosion protection layer overlying the seafloor. Sediment porewater monitoring criteria will also include concentration and depth-based early warning levels for chemical testing results.

Sediment and porewater sample testing results will be compared to the numerical cleanup standards established for the Haley Site. Sediment quality and capping effectiveness near the Cedar Street and Cornwall Avenue municipal outfalls will also be evaluated to assess potential for recontamination of the Marine Unit.

8.1.4. LFG and Air Monitoring

The LFG vents will be sampled at an interval identified in the OMMP. Similar to LFG monitoring to be completed for the Cornwall site, it is expected that the monitoring will confirm that the collection and venting systems effectively mitigate LFG to prevent unacceptable LFG build-up below the liner and in ambient air. Ambient air sampling locations and parameters will be identified in the OMMP.

8.1.5. 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 Corps of Engineers permit and will be based on review by various natural resource agencies.

8.1.6. OMMP Revisions

The OMMP will be revised as needed based on Site conditions including future public park land use. The OMMP may be further updated during periodic reviews by 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

Haley Site institutional controls will be developed 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 state-owned and Port-owned land 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, the small area of Port-owned property, and state-owned property including Port Management Agreement (PMA) areas (see Figure 1-3 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, establish easements for these activities, 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 will place restrictions on activities that could result in releases of hazardous substances or exposure to maintenance workers and 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 and the associated LFG collection/venting and water drainage systems. Institutional controls will also protect the ISS 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 breach or otherwise damage the sediment cap and shoreline bank armor transitioning to the Upland Unit. Prohibited activities will include digging and shellfish collection in the engineered cap areas. Vessel anchoring will also be prohibited throughout the Marine Unit, except as determined to be acceptable for Port activities associated with the Barge Dock and Bellingham Shipping Terminal Pier. 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 with as-built information, surveys, other record drawings, and 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, landfill gas control, stormwater control, sediment cap monitoring, landfill 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 AND PERMITTING

A planning schedule for design and permitting 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 and permitting schedule is provided in Appendix H. This schedule lists the remaining remedial design and permitting, activities that are planned to be implemented for the Haley cleanup action.

This schedule represents the current plan for design and permitting of the Haley cleanup action; however, the timing may be impacted by coordination needs with the Cornwall Site cleanup, permitting agency review schedule, and/or other factors. As a result, the schedule provided in Appendix H should be considered preliminary. Scheduling for construction of the Haley 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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Table 2-1

Summary of Cleanup Levels

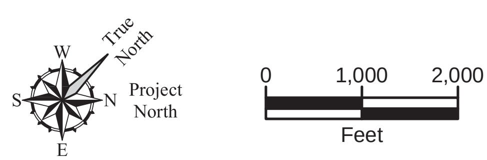
R.G. Haley Site

Bellingham, Washington

Indicator Hazardous Substance	Soil	Groundwater	Sediment Organic Carbon (0.5% to 3.5%)	Sediment Organic Carbon (<0.5% or >3.5%)	Air	Basis for Cleanup Level
Dioxins/Furans						
Dioxin TEQ	13 ng/kg	32 pg/L	13 ng/kg dw	13 ng/kg dw	na	**Soil:** Human health - based on direct contact **GW:** Protection of surface water (bioaccumulative risks to people), adjusted up to the derived PQL **Sed:** Human and ecological health - bioaccumulative risks to people and ecological receptors, adjusted up from the PQL-based SCO based on recontamination evaluation (see Appendix I)
PAHs						
1-Methylnaphthalene	42 µg/kg	15 µg/L	na	na	na	**Soil:** Protection of groundwater - based on protection of sediment (benthic organism toxicity) **GW:** Protection of sediment based on benthic organism toxicity (using 2-methylnaphthalene as a surrogate).
2-Methylnaphthalene	41 µg/kg	15 µg/L	38 mg/kg oc	670 µg/kg dw	na	**Soil:** Protection of groundwater - based on protection of sediment (benthic organism toxicity) **GW:** Protection of sediment based on benthic organism toxicity **Sed:** Benthic organism toxicity (SMS SCO)
Acenaphthene	na	5.3 µg/L	16 mg/kg oc	500 µg/kg dw	na	**GW:** Protection of sediment based on benthic organism toxicity **Sed:** Benthic organism toxicity (SMS SCO)
Fluoranthene	na	na	160 mg/kg oc	1,700 µg/kg dw	na	**Sed:** Benthic organism toxicity (SMS SCO)
Naphthalene	na	na	99 mg/kg oc	2,100 µg/kg dw	0.074 µg/m^3	**Sed:** Benthic organism toxicity (SMS SCO) **Air:** Human health - inhalation
Phenanthrene	na	na	100 mg/kg oc	1,500 µg/kg dw	na	**Sed:** Benthic organism toxicity (SMS SCO)
Benzo(a)anthracene	na	0.01 µg/L	110 mg/kg oc	1,300 µg/kg dw	na	**GW:** Protection of surface water (bioaccumulative risks to people), adjusted up to the PQL **Sed:** Benthic organism toxicity (SMS SCO). Potential bioaccumulative risks addressed by the cPAH TEQ sediment cleanup level.
cPAH TEQ	7.6 µg/kg	0.02 µg/L	229 µg/kg dw	229 µg/kg dw	na	**Soil:** Protection of groundwater - based on protection of surface water (bioaccumulative risks to people), adjusted up to the derived PQL **GW:** Protection of surface water (bioaccumulative risks to people); adjusted up to the derived PQL **Sed:** Human and ecological health - bioaccumulative risks to people and ecological receptors (risk-based SCO)
SVOCs						
Pentachlorophenol	6.3 µg/kg	0.04 µg/L	100 µg/kg dw	100 µg/kg dw	na	**Soil:** Protection of groundwater - based on protection of surface water (bioaccumulative risks to people), adjusted up to the PQL **GW:** Protection of surface water (bioaccumulative risks to people). **Sed:** Human and ecological health - bioaccumulative risks to people and ecological receptors (PQL-based SCO)
VOCs						
Benzene	na	na	na	na	0.32 µg/m^3	**Air:** Human health - inhalation
m- and p-Xylenes	na	na	na	na	46 µg/m^3	**Air:** Human health - inhalation
o-Xylene	na	na	na	na	46 µg/m^3	**Air:** Human health - inhalation
Petroleum Hydrocarbons						
TPH Sum	1,534 mg/kg	na	260 mg/kg dw	260 mg/kg dw	na	**Soil:** Human health - based on direct contact **Sed:** Benthic organism toxicity (site-specific SCO)
Total TPH	na	na	na	na	140 µg/m^3	**Air:** Human health - inhalation

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.
ng/kg = nanogram per kilogram
oc = organic carbon
PAH = polycyclic aromatic hydrocarbons
PQL = practical quantitation limit
SCO = sediment cleanup objective
SVOC = semivolatile organic compound
Sed = sediment
SMS = Sediment Management Standards
TEQ = toxic equivalent concentration
TPH SUM = total petroleum hydrocarbons; sum of diesel- and lube oil-range
Total TPH = total petroleum hydrocarbons; sum of c5 to c8 aliphatics, c9 to c12 aliphatics, c9 to c10 aromatics, benzene, toluene, ethylbenzene, xylenes and naphthalene
µg/kg = microgram per kilogram
µg/L = microgram per liter
µg/m^3 = microgram per cubic meter
VOC = volatile organic compound



Reference: Whatcom County GIS, City of Bellingham GIS, Aerial from Esri, 2017.

Notes:
1. The locations of all features shown are approximate.
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Projection: NAD 1983 UTM Zone 10N

Vicinity Map

R.G. Haley Site
Bellingham, Washington

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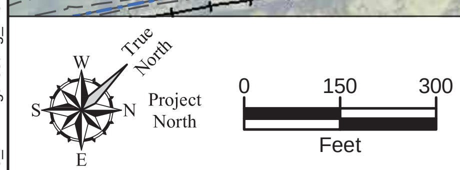
Figure 1-1

Path: P:\0\0356114\GIS\MXDs\2018_EDRFigures\Fig_1-01_VicinityMap.mxd Map Revised: 11 July 2019 glohrmeyer



Data Source: Aerial from City of Bellingham, 2016.
NAVD88 vertical datum.
Projection: NAD 1983 StatePlane Washington North FIPS 4601 Feet

Notes:

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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.
3. Base survey by Wilson Engineering & Surveying 10/28/15, updated along north shoreline 5/8/2019
4. 2016 Hilton Avenue Stockpile topography provided from April 30, 2018 Cornwall Site EDR

- Haley Cleanup Area Boundary
- OHWM
- BNSF Railroad
- Elevation Contour (5ft-Interval)
- Haley Marine Unit
- Haley Upland Unit

Haley Site Units

R.G. Haley Site
Bellingham, Washington

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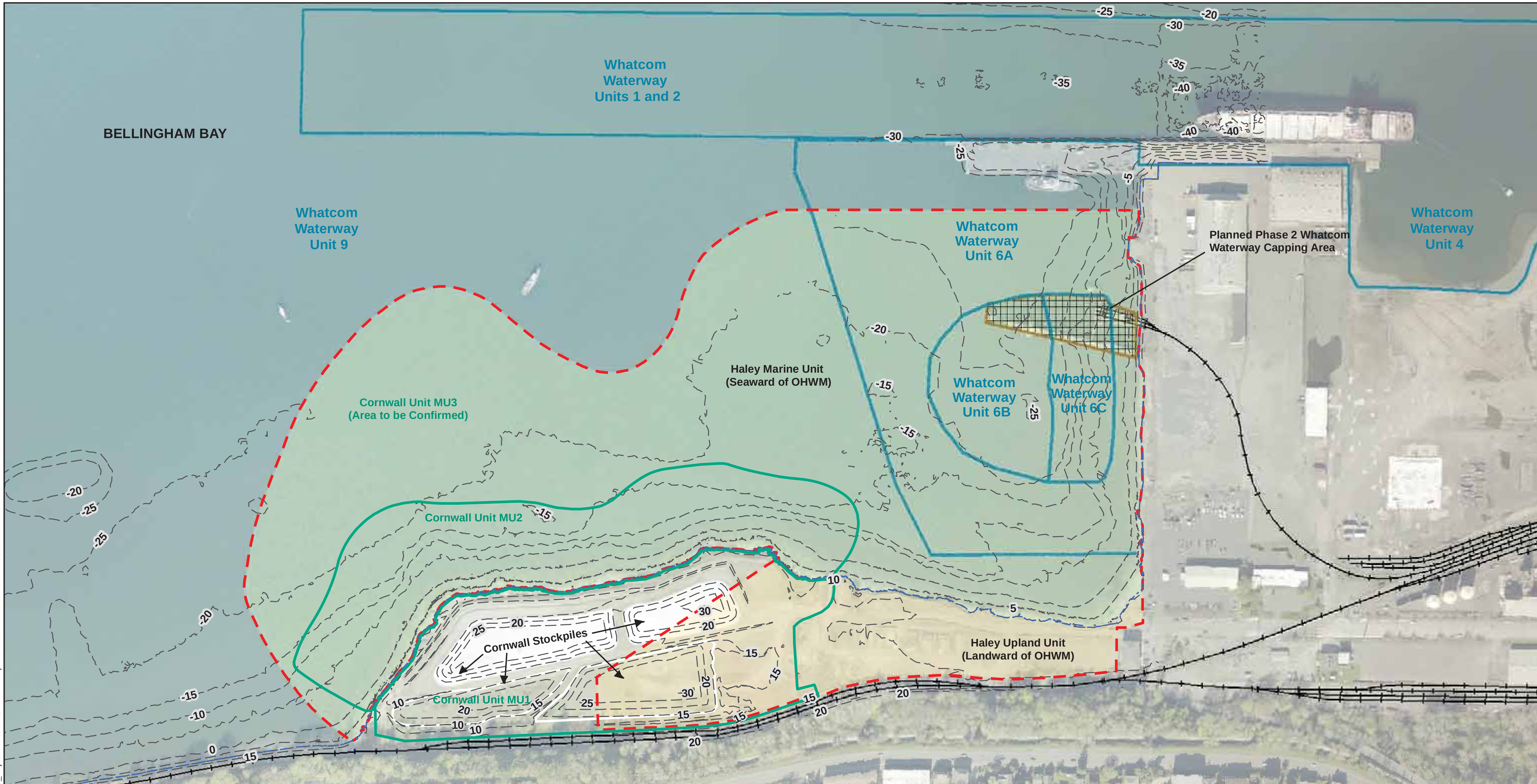
Figure 1-2

Path: P:\0\0356114\GIS\MXDs\2018_EDRFigures\Fig_1-02_HaleySiteUnits.mxd Map Revised: 18 March 2021 ccabrera



True North
Project North

0 150 300
Feet

Data Source: Aerial from City of Bellingham, 2016.
NAVD88 vertical datum.
Projection: NAD 1983 StatePlane Washington North FIPS 4601 Feet

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.
3. Base survey by Wilson Engineering & Surveying 10/28/15, updated along north shoreline 5/8/2019
4. 2016 Hilton Avenue Stockpile topography provided from April 30, 2018 Cornwall Site EDR

Legend:
- Haley Cleanup Area Boundary
- OHWM
- BNSF Railroad
- Elevation Contour (5ft-Interval)
- Haley Marine Unit
- Haley Upland Unit

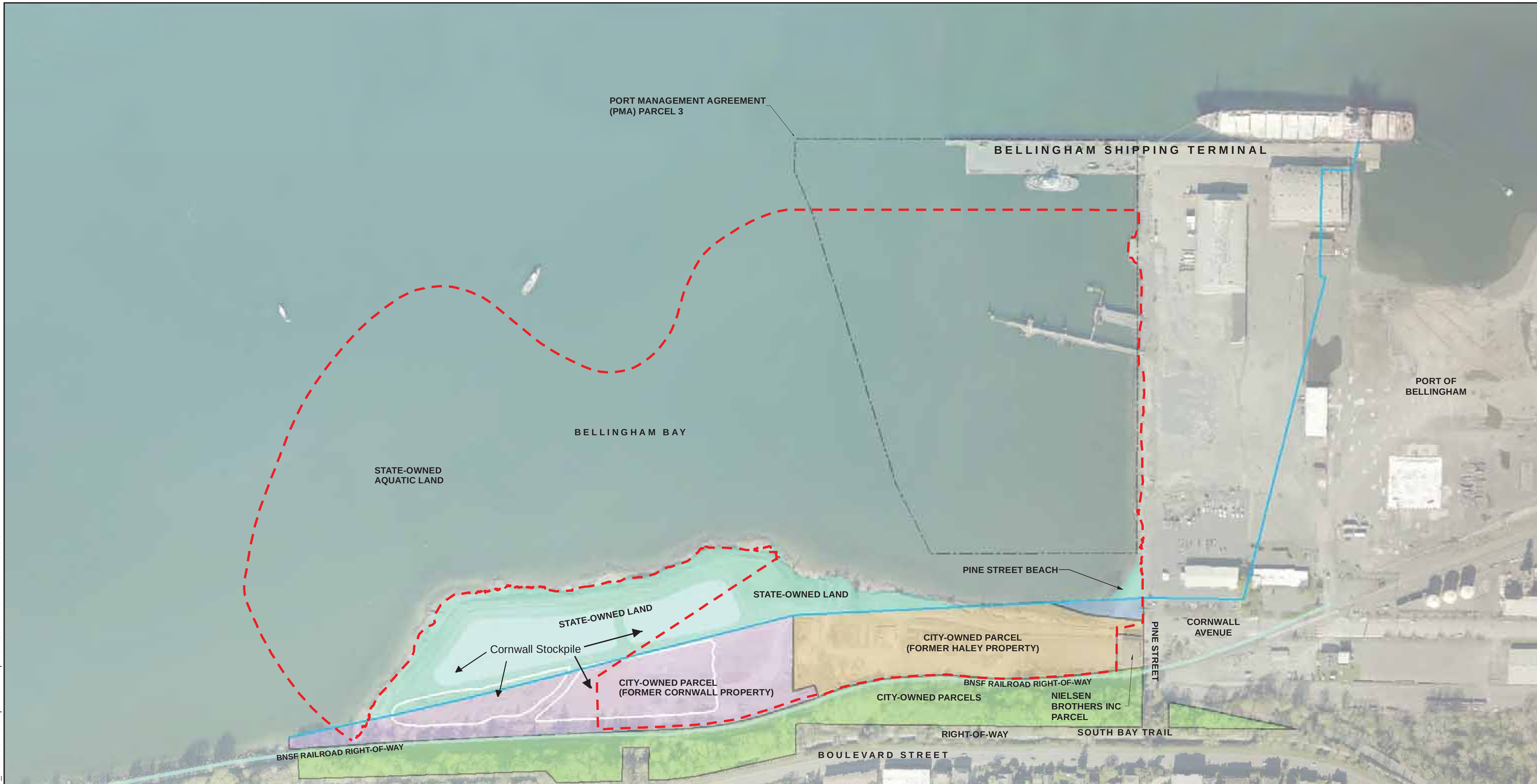
Haley, Cornwall and Whatcom Waterway Site Units

R.G. Haley Site
Bellingham, Washington

GeoEngineers

Figure 1-3

Path: P:\0\0356114\GIS\MXDs\2018_EDRFigures\Fig_1-03_AdjacentSiteUnits.mxd Map Revised: 18 March 2021 ccabrera



True North
Project North

0 150 300
Feet

Haley Cleanup Area Boundary
Inner Harbor Line (State-Owned Land Waterward of Line)
Port Management Agreement Parcel 3

Data Source: Aerial from City of Bellingham, 2016.

Projection: NAD 1983 StatePlane Washington North FIPS 4601 Feet

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.

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Haley Site and Property Ownership

R.G. Haley Site
Bellingham, Washington

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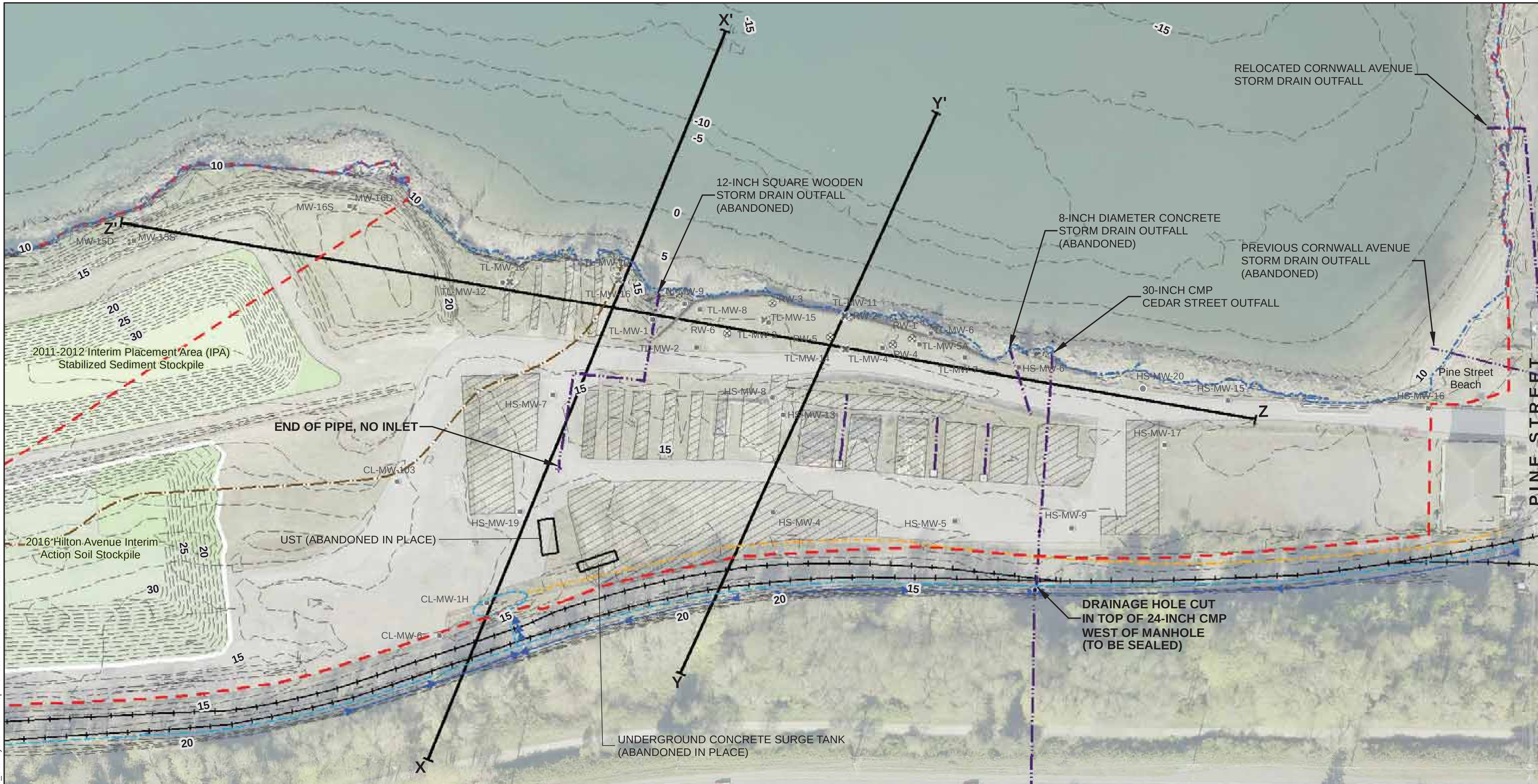
Figure 1-4



True North
Project North

0 50 100
Feet

Data Source: Aerial from City of Bellingham GIS, 2016.
NAVD88 vertical datum.
Projection: NAD 1983 StatePlane Washington North FIPS 4601 Feet
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.
3. Base survey by Wilson Engineering & Surveying 10/28/15, updated along north shoreline 5/8/2019.
4. 2016 Hilton Avenue Stockpile topography provided from April 30, 2018 Cornwall Site EDR

- Existing Deep Monitoring Well
- Existing Shallow Monitoring Well
- Existing Recovery Well
- Stormwater Inlet Grate
- Manhole
- Asphalt
- Concrete
- Cornwall Temporary Stockpiles
- Haley Cleanup Area Boundary
- OHWM
- Cornwall Approximate Landward Boundary of Landfill Refuse
- Ground Surface and Bathymetric Contour (5ft interval, NAVD88 Datum)
- Geologic Cross Sections (Information as presented from Haley RI)
- Storm Drain Pipe
- Drainage Ditch or Depression
- 16" Water Main (inactive)
- Sheet Pile Wall
- Apparent Stormwater Flow Direction

Site Features

R.G. Haley Site
Bellingham, Washington

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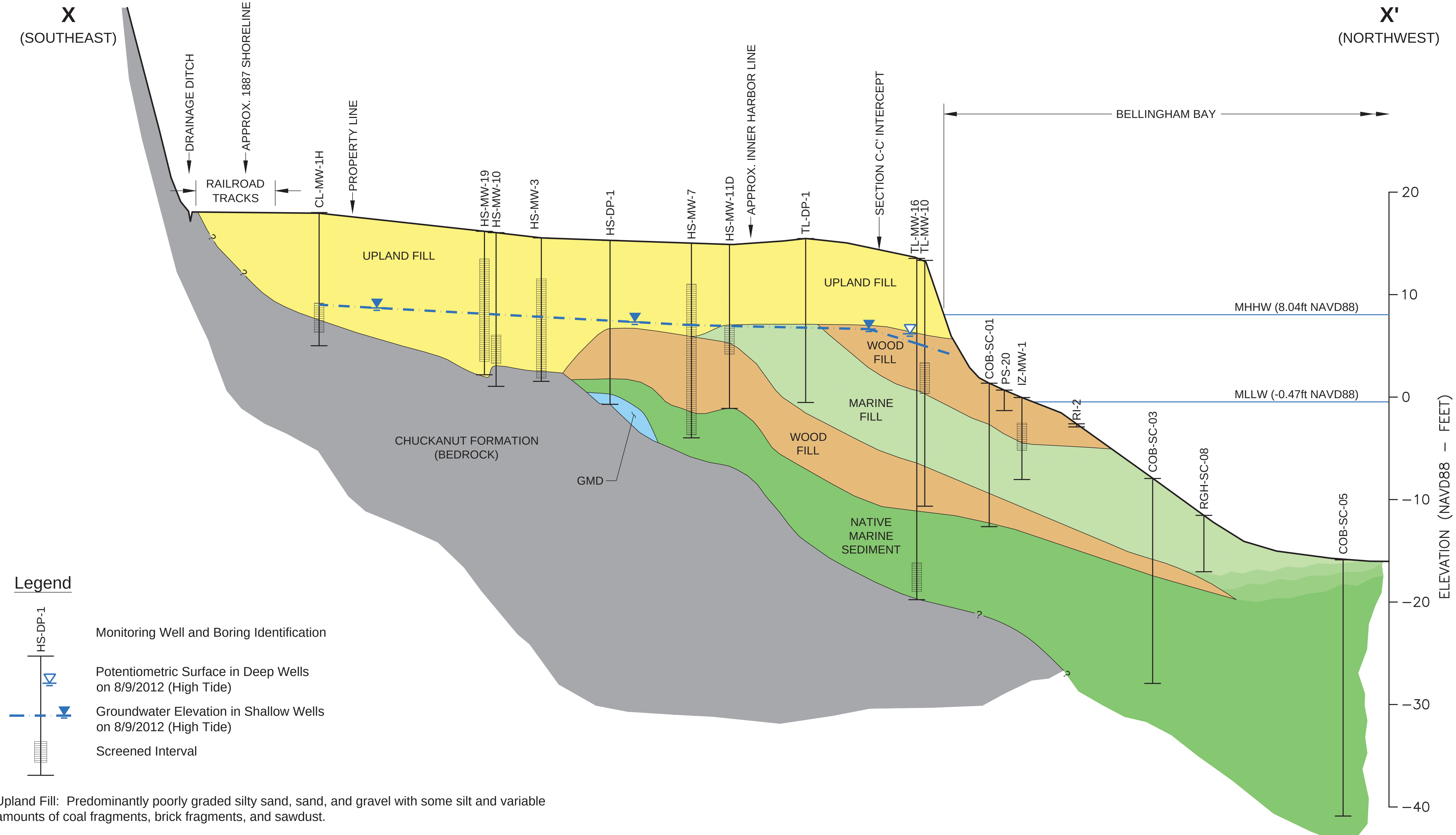
Figure 1-5

Path: P:\0\0356114\GIS\MXDs\2018_EDRFigures\Fig_1-05_SiteLayout.mxd Map Revised: 18 March 2021 ccabrera



Upland Fill: Predominantly poorly graded silty sand, sand, and gravel with some silt and variable amounts of coal fragments, brick fragments, and sawdust.

Marine Fill: Predominantly silt, silty sand, and poorly graded fine to medium grained sand with shell fragments and occasional wood fragments.

Wood Fill: At least 50 percent wood based on visual estimate with some silt and occasional sand. Wood present as sawdust, chips, or fragments.

Native Marine Sediment: Predominantly silt, silty sand, and poorly graded fine to coarse grained sand with occasional gravel, shell fragments, and wood fragments.

GMD (Glacial Marine Drift): Stiff silt and clay with occasional gravel and shells.

Chuckanut Formation: The Eocene-age Padden Member of the Chuckanut Formation is predominantly siltstone where encountered in borings.

HORIZONTAL SCALE: 1"= 60'
VERTICAL SCALE: 1"= 10'
VERTICAL EXAGGERATION: 6X

60 0 60
FEET

Notes

1. Information shown as presented in RI/FS.
2. Directions given on cross section line refer to Project North.
3. 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.
4. Please refer to Figure 1-5 for cross section location.
5. This figure is for informational purposes only. It is intended to assist in the identification of features discussed in a related document.

Cross-Section X-X'

R.G. Haley Site
Bellingham, Washington

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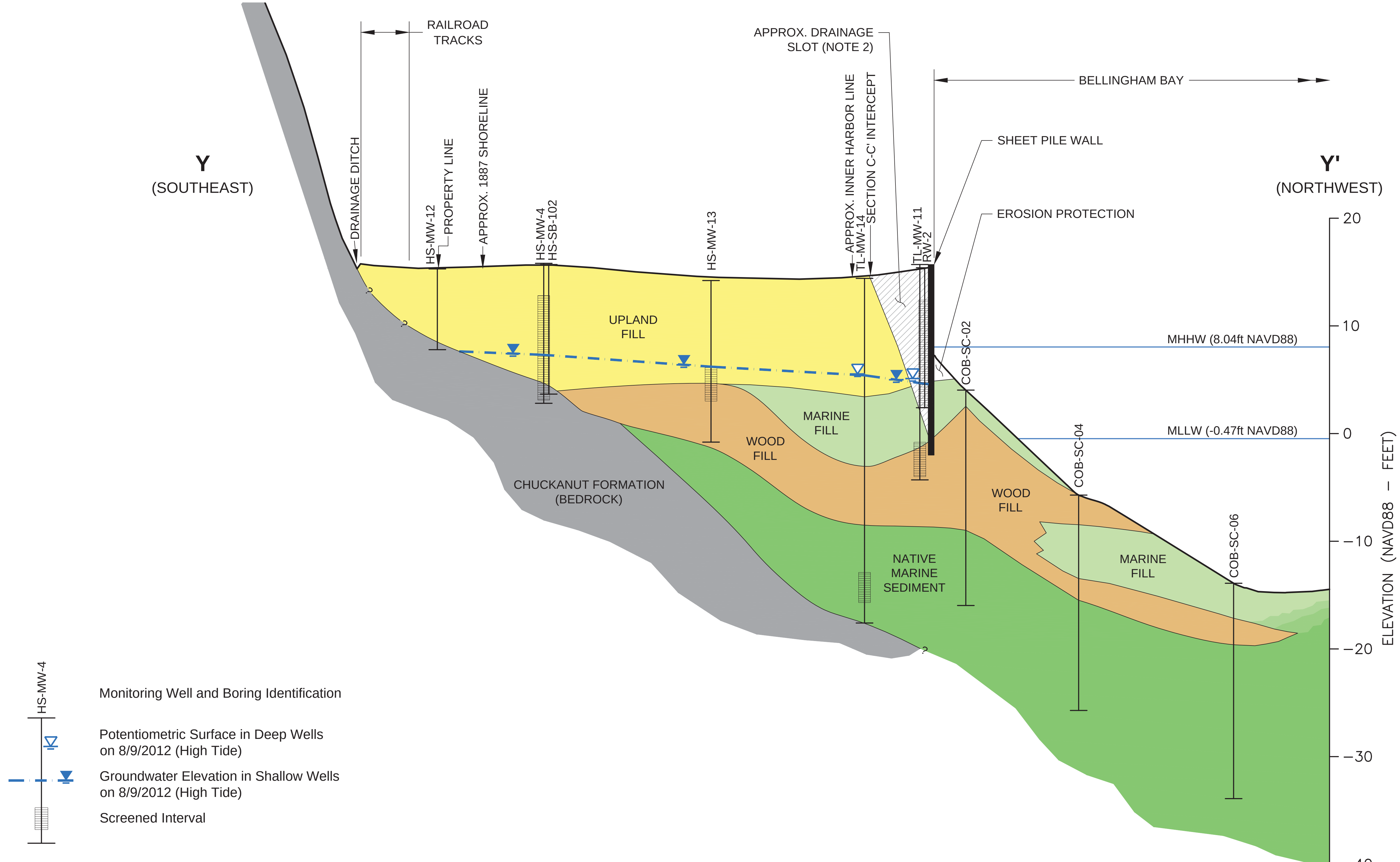
Figure 1-6

P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures\0356114\08_EDR_F01-6_Geologic Cross-Section XX.dwg TAB:XX Date Exported: 07/02/19 - 13:51 by tmichaud



Upland Fill: Predominantly poorly graded silty sand, sand, and gravel with some silt and variable amounts of coal fragments, brick fragments, and sawdust.

Marine Fill: Predominantly silt, silty sand, and poorly graded fine to medium grained sand with shell fragments and occasional wood fragments.

Wood Fill: At least 50 percent wood based on visual estimate with some silt and occasional sand. Wood present as sawdust, chips, or fragments.

Native Marine Sediment: Predominantly silt, silty sand, and poorly graded fine to coarse grained sand with occasional gravel, shell fragments, and wood fragments.

Chuckanut Formation: The Eocene-age Padden Member of the Chuckanut Formation is predominantly siltstone where encountered in borings.

HORIZONTAL SCALE: 1"= 60'
VERTICAL SCALE: 1"= 10'
VERTICAL EXAGGERATION: 6X

60 0 60
FEET

Notes

1. Information shown as presented in RI/FS.
2. Directions given on cross section line refer to Project North.
3. Drainage slot consists of coarse sand gravel backfill.
4. 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.
5. Please refer to Figure 1-5 for cross section location.
6. This figure is for informational purposes only. It is intended to assist in the identification of features discussed in a related document.

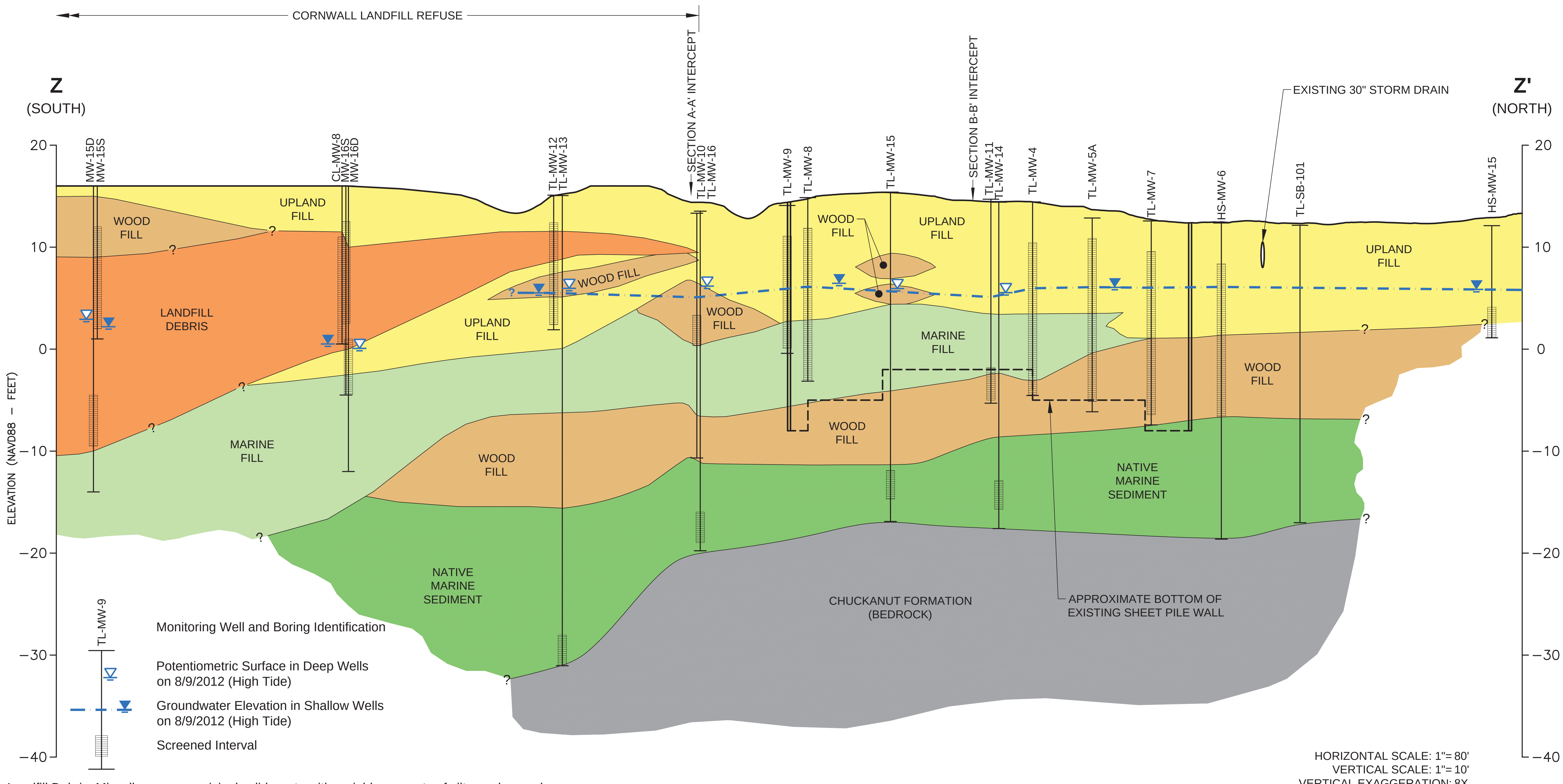
Cross-Section Y-Y'

R.G. Haley Site
Bellingham, Washington

GeoEngineers

Figure 1-7

P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures\0356114_08_EDR_F01-7_Geologic Cross-Section YY.dwg TAB:YY Date Exported: 07/02/19 - 13:55 by tmichaud



Landfill Debris: Miscellaneous municipal solid waste with variable amounts of silt, sand, gravel and wood debris.

Upland Fill: Predominantly poorly graded silty sand, sand, and gravel with some silt and variable amounts of coal fragments, brick fragments, and sawdust.

Marine Fill: Predominantly silt, silty sand, and poorly graded fine to medium grained sand with shell fragments and occasional wood fragments.

Wood Fill: At least 50 percent wood based on visual estimate with some silt and occasional sand. Wood present as sawdust, chips, or fragments.

Native Marine Sediment: Predominantly silt, silty sand, and poorly graded fine to coarse grained sand with occasional gravel, shell fragments, and wood fragments.

Chuckanut Formation: The Eocene-age Padden Member of the Chuckanut Formation is predominantly siltstone where encountered in borings.

Notes

1. Information shown as presented in RI/FS.
2. Directions given on cross section line refer to Project North.
3. 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.
4. Please refer to Figure 1-5 for cross section location.
5. Depth to groundwater in Cornwall wells MW-15D/15S and MW-16D/16S based on Cornwall RI (Landau 2013a) for September 2012 (high tide).
6. This figure is for informational purposes only. It is intended to assist in the identification of features discussed in a related document.

Cross-Section Z-Z'

R.G. Haley Site
Bellingham, Washington

GEOENGINEERS

Figure 1-8

P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures\0356114\08_EDR_F01-8_Geologic Cross-Section ZZ.dwg TAB:ZZ Date Exported: 07/02/19 - 13:57 by tmichaud

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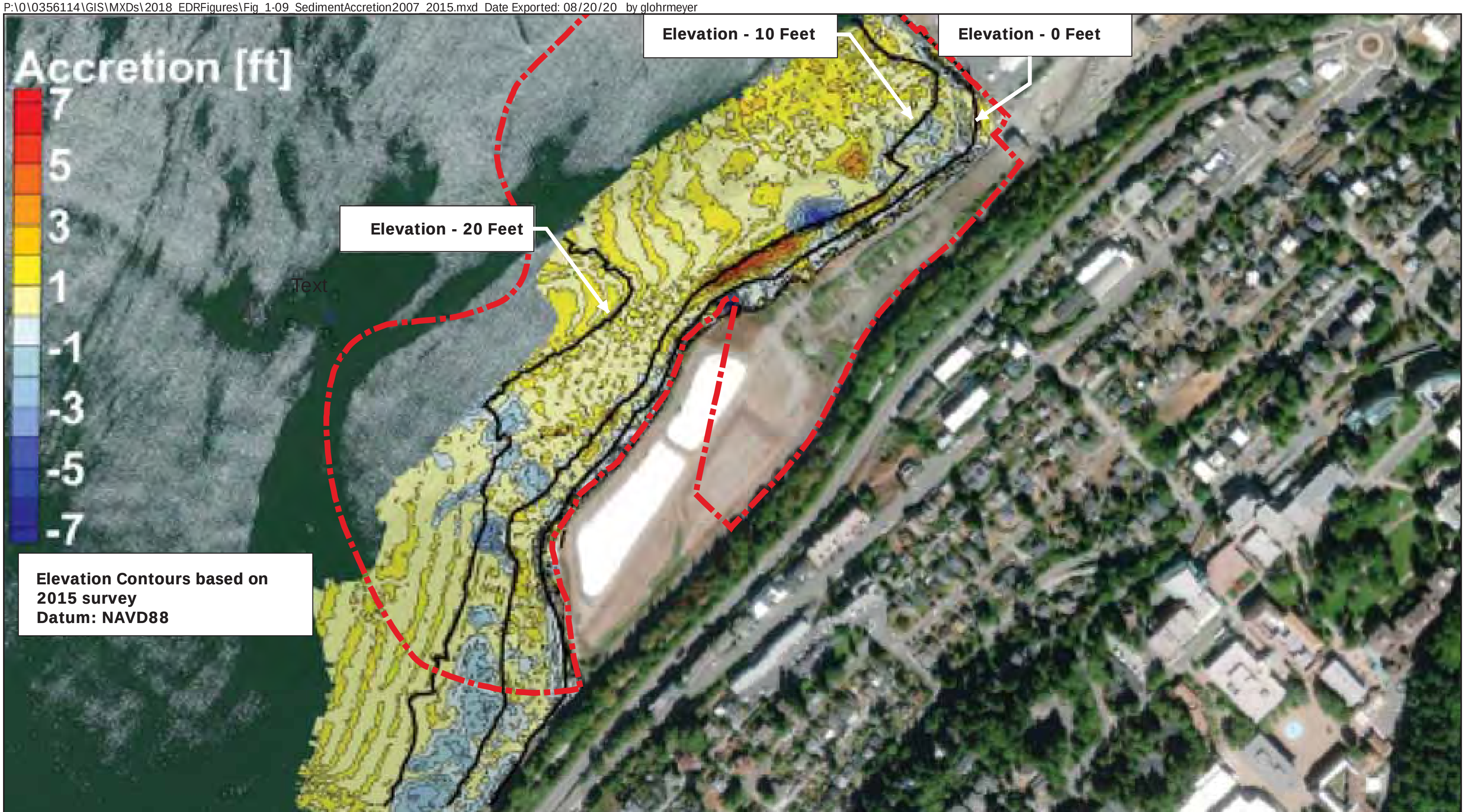

Notes:
1. The locations of all features shown are approximate.
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3. Modified from Mott MacDonald figure presented during April 10, 2019 coordination meeting with the City and the Port.
Accretion determined by Mott MacDonald by subtracting 2007 depths to seafloor from 2015 depths.
Haley Cleanup Area Boundary added for reference.

Projection: NAD 1983 StatePlane Oregon North FIPS 3601 Feet

Legend
Haley Cleanup Area Boundary

500 0 500
Feet

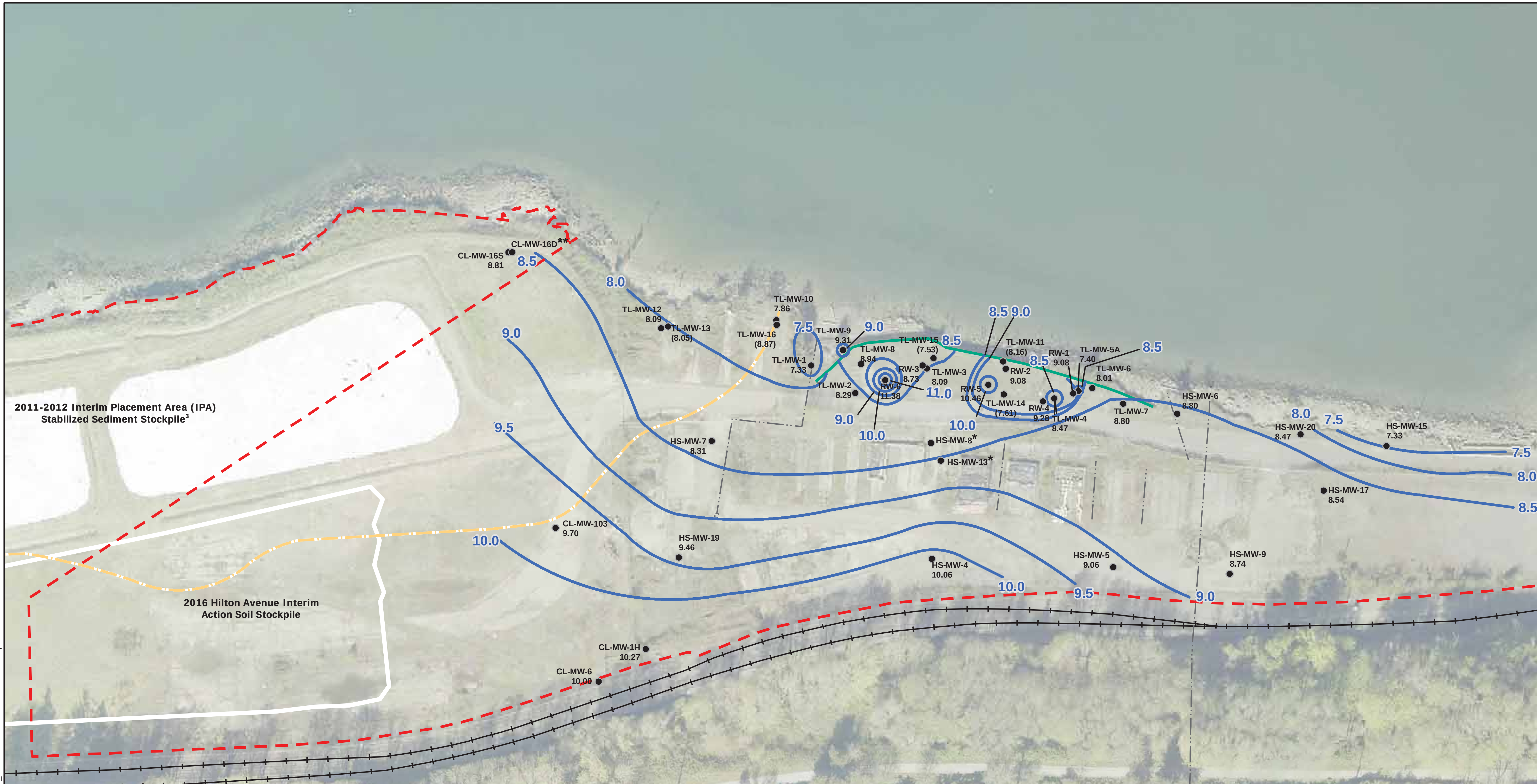
N W E S

Sediment Accretion 2007 to 2015

R.G. Haley Site
Bellingham, Washington

GeoEngineers

Figure 1-9



●	Monitoring Well
9	Groundwater Contour
6.07	Groundwater Elevation in Feet (NAVD88)
(6.02)	Deep Well Groundwater Elevation in Parentheses (Not Used for Contouring)
RW-X	Recovery Well Installed in Sheet Pile Wall Backfill
	Haley Cleanup Area Boundary
	Sheet Pile Wall
	Storm Drain
	Cornwall Approximate Landward Boundary of Landfill Refuse

High tide at elevation 8.80 feet at 1153 hours,
low tide at 1.61 feet at 1913 hours (NAVD88).

Estimated tide height between 7.0 and 8.8 feet (NAVD88)
during monitoring 1000 to 1430 hours.

* Well monuments underwater, no measurement obtained
** Well damaged, no measurements obtained

Data Source: Aerial from City of Bellingham GIS, 2016.

Projection: NAD 1983 StatePlane Washington North FIPS 4601 Feet

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.
3. Stockpiles are covered with white plastic protective sheeting.

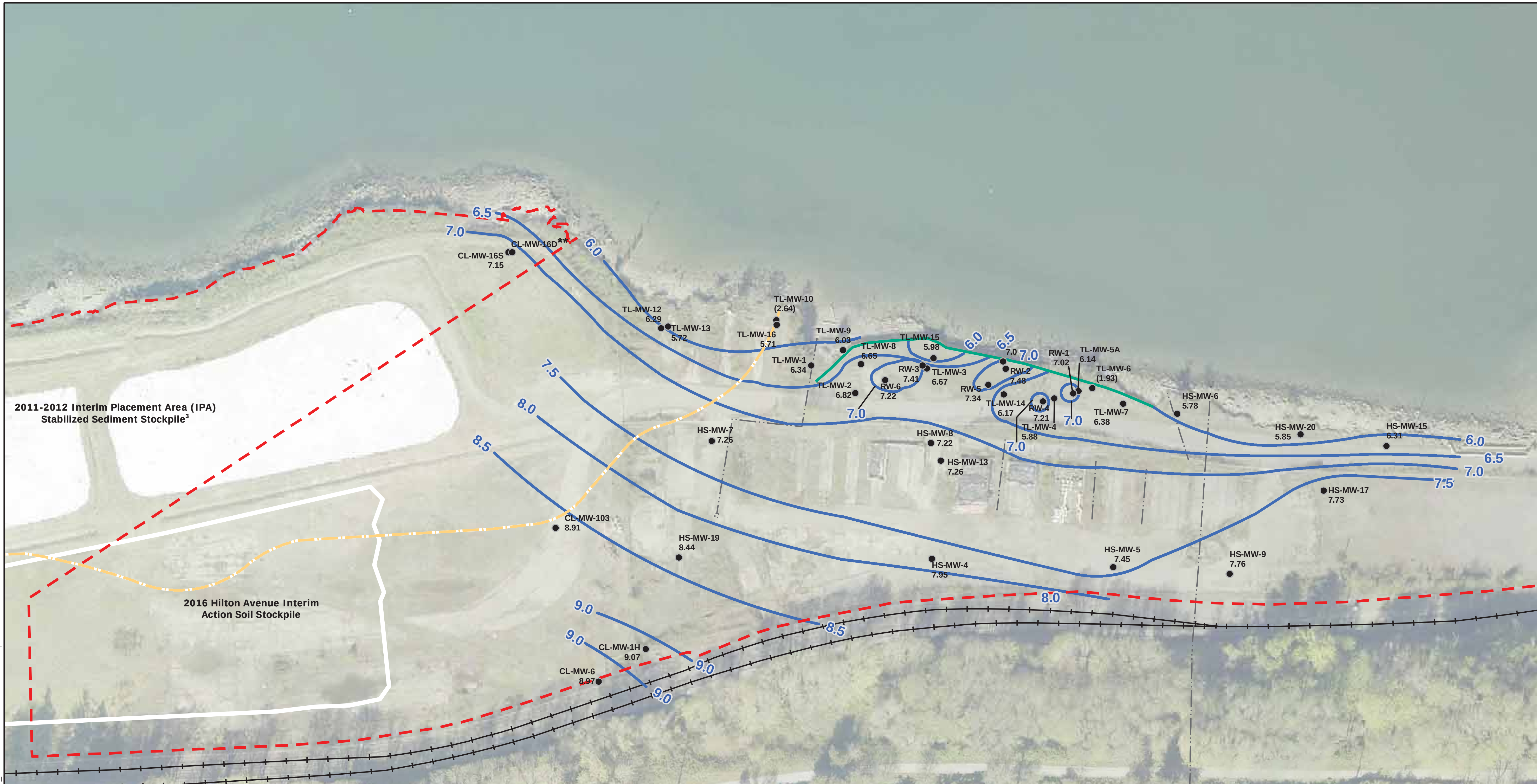
Groundwater Elevation Contours
December 20, 2019

R.G. Haley Site
Bellingham, Washington

GEOENGINEERS

Figure 1-10

Path: P:\0\0356114\GIS\MXDs\2018_EDRFigures\Fig_1-10_Dec2019GWElevations.mxd Map Revised: 18 March 2021 ccabrera



0 50 100
Feet

True North
Project North

Data Source: Aerial from City of Bellingham GIS, 2016.

Projection: NAD 1983 StatePlane Washington North FIPS 4601 Feet

Notes:
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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.
3. Stockpiles are covered with white plastic protective sheeting.

●	Monitoring Well
9	Groundwater Contour
6.07	Groundwater Elevation in Feet (NAVD88)
(6.02)	Deep Well Groundwater Elevation in Parentheses (Not Used for Contouring)
RW-X	Recovery Well Installed in Sheet Pile Wall Backfill
	Haley Cleanup Area Boundary
	Sheet Pile Wall
	Storm Drain
	Cornwall Approximate Landward Boundary of Landfill Refuse

High tide at elevation 8.41 feet at 2154 hours,
Low tide at -2.66 feet at 1402 hours (NAVD88).

Estimated tide height between -2.0 and -0.5 feet (NAVD88) during monitoring 1230 to 1613 hours.

** Well damaged, no measurements obtained

Groundwater Elevation Contours
June 24, 2020

R.G. Haley Site
Bellingham, Washington

GEOENGINEERS

Figure 1-11

Path: P:\0\0356114\GIS\MXDs\2018_EDRFigures\Fig_1-11_June2020GWElevations.mxd Map Revised: 18 March 2021 ccabrera

PRDI (2018) Direct Push Exploration
Previous Exploration

R.G. Haley Property, City-Owned
Cornwall Property, City-Owned
Port of Bellingham Property
Sheet Pile Wall
Storm Drain
Cornwall Approximate Landward Boundary of Landfill Refuse

Estimated Petroleum Smear Zone Footprint
2 Smear Zone Thickness (feet) Based on Moderate or Heavy Sheen in Soil
2 Approximate Smear Zone Thickness in Feet (Thickness in Previous Explorations From Haley RI Figure 6-4)
NS = No Sheen

W True North, Project North, S, N, E

0 50 100
Feet

Data Source: Aerial from City of Bellingham GIS, 2016.

Projection: NAD 1983 StatePlane Washington North FIPS 4601 Feet

Notes:
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3. Stockpiles are covered with white plastic protective sheeting.

Upland Smear Zone Thickness

R.G. Haley Site
Bellingham, Washington

GeoEngineers

Figure 1-12

Path: P:\0\0356114\GIS\MXDs\2018_EDRFigures\Fig_1-12_UplandSmearZoneThickness.mxd Map Revised: 18 March 2021 ccabrera

W S E N True North Project North

0 50 100 Feet

- Measurable LNAPL in Well (December 2019) (0.51 ft) Measured Product Thickness
- Historical LNAPL in Well
- Historical Trace LNAPL in Well
- LNAPL Never Observed
- Abandoned or Not Located

- R.G. Haley Property, City-Owned
- Cornwall Property, City-Owned
- Port of Bellingham Property
- Sheet Pile Wall
- Storm Drain
- Cornwall Approximate Landward Boundary of Landfill Refuse

Data Source: Aerial from City of Bellingham GIS, 2016.
Projection: NAD 1983 StatePlane Washington North FIPS 4601 Feet

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.
3. Stockpiles are covered with white plastic protective sheeting.
4. Not measured during this monitoring event due to well being submerged.

LNAPL Occurrence In Wells - Decemeber 2019

R.G. Haley Site
Bellingham, Washington

GEOENGINEERS

Figure 1-13

Path: P:\0\0356114\GIS\MXDs\2018_EDR\Figures\Fig_1-13_LNAPLDec2019.mxd Map Revised: 18 March 2021 ccabrera

True North
Project North

0 50 100
Feet

Data Source: Aerial from City of Bellingham GIS, 2016.

Projection: NAD 1983 StatePlane Washington North FIPS 4601 Feet

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.
3. Stockpiles are covered with white plastic protective sheeting.

- Measurable LNAPL in Well (June 2020) (0.51 ft) Measured Product Thickness
- Historical LNAPL in Well
- Historical Trace LNAPL in Well
- LNAPL Never Observed
- Abandoned or Not Located

- R.G. Haley Property, City-Owned
- Cornwall Property, City-Owned
- Port of Bellingham Property
- Sheet Pile Wall
- Storm Drain
- Cornwall Approximate Landward Boundary of Landfill Refuse

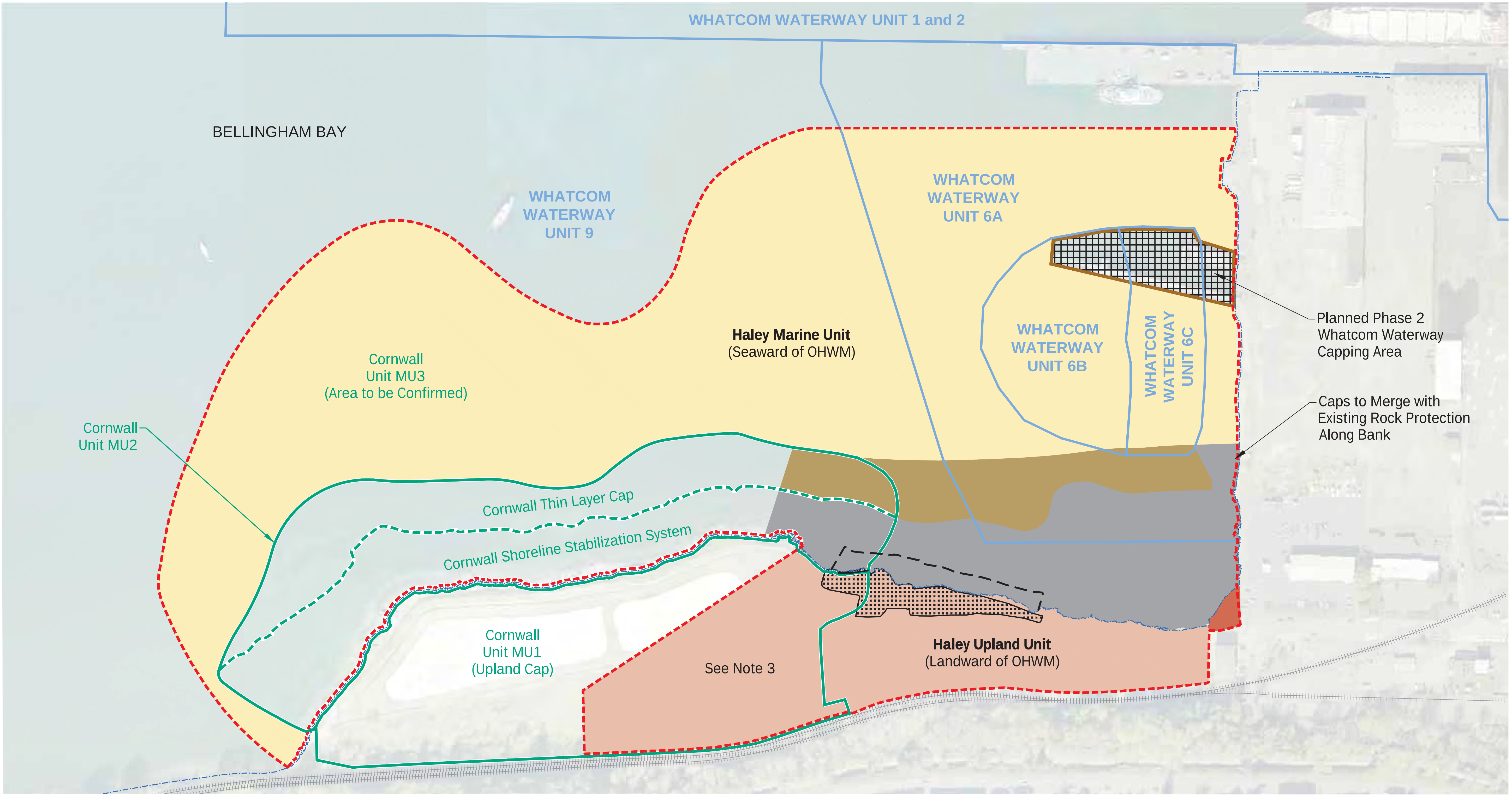
LNAPL Occurrence In Wells - June 2020

R.G. Haley Site
Bellingham, Washington

GeoEngineers

Figure 1-14

Path: P:\0\0356114\GIS\MXDs\2018_EDRFigures\Fig_1-14_LNAPLJune2020.mxd Map Revised: 18 March 2021 ccabrera



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.
3. Haley cap will transition into the Cornwall cap where the site areas overlap.

Data Source: Aerial Photo from City of Bellingham, 2016.

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

Legend

- Haley Cleanup Area Boundary
- OHWM
- Low-Permeability Upland Cap
- Upland Soil Cap
- Organoclay and Activated Carbon Amended Sand Caps (See Section 6.0 for Additional Capping Details)
- Gravelly Sand Thin Layer Sediment Cap
- Monitored Natural Recovery
- Approximate ISS Area
- Extent of Sediment Removal

*See Section 6.0 for Additional Capping Details

True North / Project North

250 0 250
Feet

Cleanup Action Components

R.G. Haley Site
Bellingham, Washington

GEOENGINEERS

Figure 3-1

P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures [R02 - Ecology Comments]\0356114-08_EDR_F03-1_Cleanup Action Components.dwg TAB:11x17 Landscape Date Exported: 06/09/21 - 15:29 by tmichaud

W True North
S N Project North
E

0 50 100
Feet

■ PRDI (2018) Direct Push Exploration
◆ Surface Sample
◎ HS-MW-20 Well

R.G. Haley Property, City-Owned
Cornwall Property, City-Owned
Port of Bellingham Property
Sheet Pile Wall

Storm Drain
Cornwall Approximate Landward Boundary of Landfill Refuse

Data Source: Aerial from City of Bellingham GIS, 2016.

Projection: NAD 1983 StatePlane Washington North FIPS 4601 Feet

Notes:
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2018 PRDI Explorations

R.G. Haley Site
Bellingham, Washington

GeoEngineers

Figure 4-1

Path: P:\0\0356114\GIS\MXDs\2018_EDRFigures\Fig_4-1_2018Explorations.mxd Map Revised: 18 March 2021 ccabrera

True North
Project North

0 50 100
Feet

Data Source: Aerial from City of Bellingham GIS, 2016.

Projection: NAD 1983 StatePlane Washington North FIPS 4601 Feet

Notes:
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3. Note: If multiple samples were analyzed within 5 foot depth zone, sample with highest concentration only is shown.
4. Stockpiles are covered with white plastic protective sheeting.

- PRDI (2018) Direct Push Soil Exploration
- Previous Soil Exploration

TPH (Sum Diesel Plus Lube Oil)
Total TPH Concentrations in mg/kg as shown

- No Soil Samples Collected
- Result > 15,000 mg/kg
- Result > 10,000 and ≤ 15,000 mg/kg
- Result > 1,534 and ≤ 10,000 mg/kg
- Result ≤ 1,534 mg/kg
- TPH Concentration Contour
- Unknown Extent Based on Available Data

Cleanup Level for TPH is 1,534 mg/kg

- R.G. Haley Property, City-Owned
- Cornwall Property, City-Owned
- Port of Bellingham Property
- Sheet Pile Wall
- Storm Drain
- Cornwall Approximate Landward Boundary of Landfill Refuse
- Projected ISS Footprint
- Estimated Petroleum Smear Zone Footprint
- U Not Detected Above Analytical Reporting Limit
- ND Not Detected (reporting limit not available)

TPH in Soil (5-10 Feet Below Ground Surface)

R.G. Haley Site
Bellingham, Washington

GeoEngineers

Figure 4-2

Path: P:\0\0356114\GIS\MXDs\2018_EDRFigures\Fig_4-02_Soil_TPH_5-10.mxd Map Revised: 18 March 2021 ccabrera

True North / Project North (W, S, N, E)

0 50 100 Feet

- ■ PRDI (2018) Direct Push Exploration
- ◆ Near Surface Sample
- ● Previous Soil Exploration

Total Dioxin/Furan TEQ
Total Dioxin/Furan TEQ Concentrations in ng/kg as shown

- No Soil Samples Collected
- Result ≥10x Cleanup Level
- Result >1x and < 10x Cleanup Level
- Result ≤ 13 ng/kg Cleanup Level

Cleanup Level for Total Dioxin/Furan TEQ is 13 ng/kg

All PRDI samples collected within 0.75 feet of ground surface

- R.G. Haley Property, City-Owned
- Cornwall Property, City-Owned
- Port of Bellingham Property
- Sheet Pile Wall
- Storm Drain
- Cornwall Approximate Landward Boundary of Landfill Refuse
- Estimated Petroleum Smear Zone Footprint

Data Source: Aerial from City of Bellingham GIS, 2016.

Projection: NAD 1983 StatePlane Washington North FIPS 4601 Feet

Notes:
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3. Note: If multiple samples were analyzed within 5 foot depth zone, sample with highest concentration only is shown.
4. Stockpiles are covered with white plastic protective sheeting.

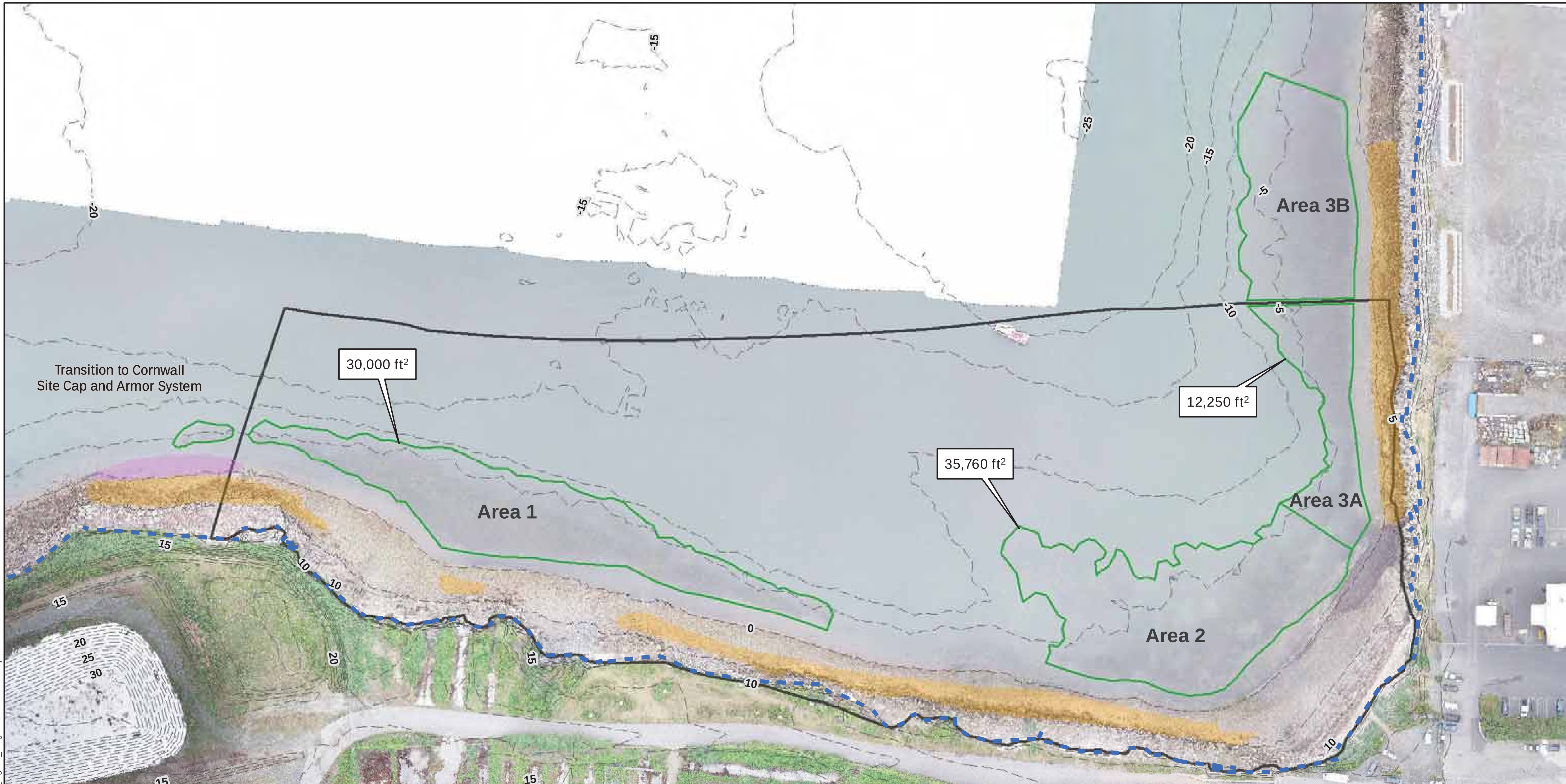
Total Dioxin/Furan in Near Surface Soil

R.G. Haley Site
Bellingham, Washington

GeoEngineers

Figure 4-3

Path: P:\0\0356114\GIS\MXDs\2018_EDR\Figures\Fig_4-3_Soil_Dioxins_Nearsurface.mxd Map Revised: 08 June 2021 ccabrera



True North
Project North
0 50 100
Feet

- OHWM
- Eelgrass Bed (Surveyed by GeoEngineers July, 2019)
- Fucus Zone
- Ulva Zone
- Haley Cap Extent
- Ground Surface and Bathymetric Contour (5ft interval, NAVD88 Datum)

Reference: Drone photography performed by Research Support Services (July 12th, 2019);
Orthomosaic imagery processed by GeoEngineers, 2019.
Contour elevation displayed is referenced to NAVD88 vertical datum.

Notes:
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3. If eelgrass beds are identified outside of the anticipated areas of eelgrass, transects will be extended or more transects will be added to conduct density and species assessments within those beds.
4. Eelgrass bed square footages exclude areas beyond Haley cap extent, i.e. areas unaffected by Haley remedial actions.
5. The survey excluded additional Site eelgrass beds located to the west near the northern shoreline, as these areas are not affected by Haley remedial actions.

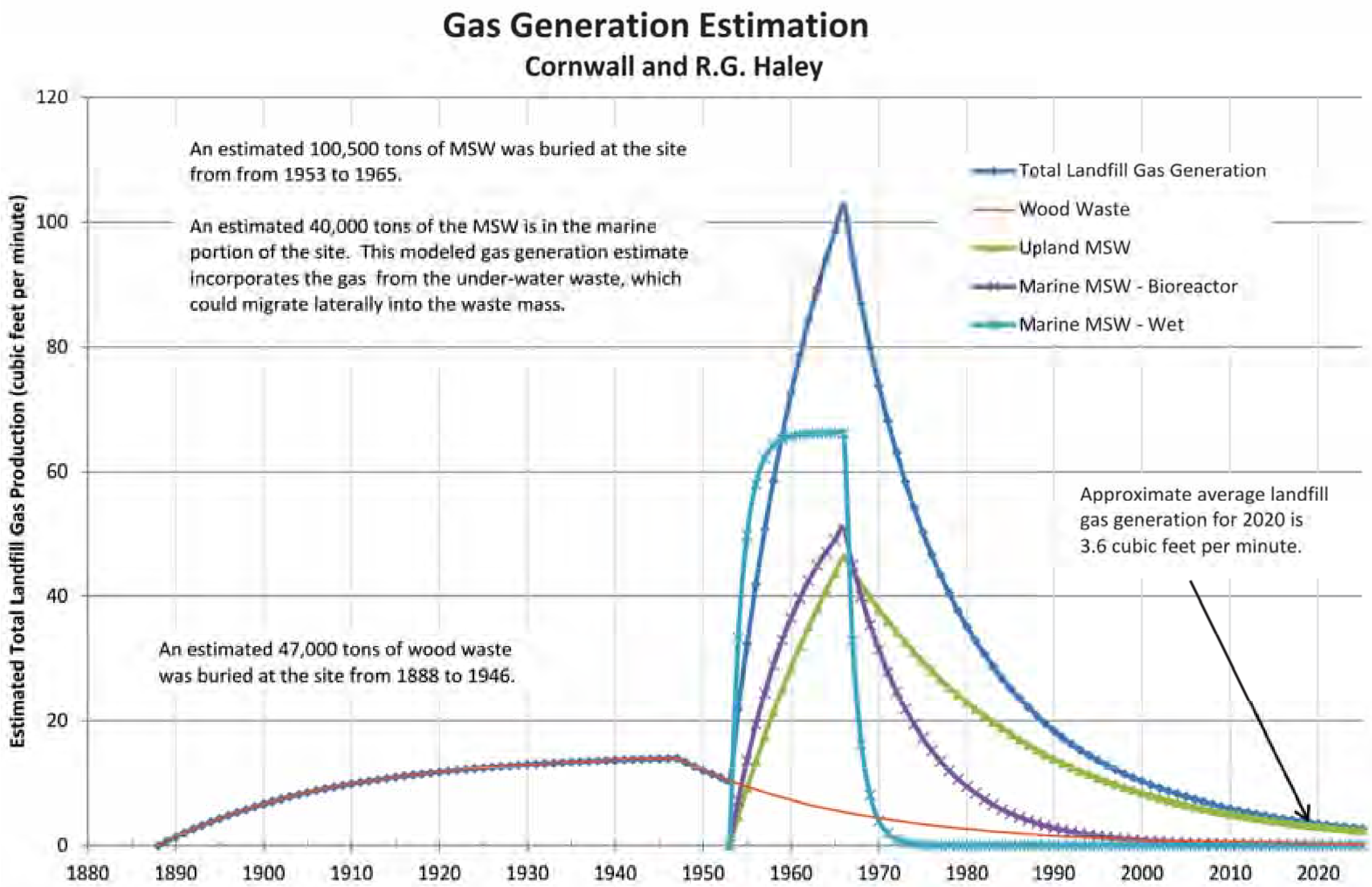
Extent of Eelgrass Beds and Intertidal Habitats at Site

R.G. Haley Site
Bellingham, Washington

GeoEngineers

Figure 4-4

Path: P:\0\0356114\GIS\MXDs\2018_EDRFigures\035611406_Fig044_EelgrassBed.mxd Map Revised: 18 March 2021 ccabrera



LFG Generation Estimate

R.G. Haley Site
Bellingham, Washington

GeoEngineers

Figure 5-1

Notes:

1. 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: Landau Associates, Figure 2 of Engineering Design Report "Gas Generation Estimate" dated 5-23-19.

Notes:
1. Gas probes were completed on the ground surface shown here, prior to the placement of fill on the eastern portion of the site in June 2016. Gas probes under the additional fill were decommissioned by a professional engineer prior to placement of the fill.
2. The locations of all features shown are approximate.
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: Landau Associates, Figure 3 of Engineering Design Report "Gas Monitoring Locations" dated 5-22-19.

Projection: WA State Plane, N Zone, NAD83, US Foot

Legend

- HS-SV-1 — Soil Vapor Monitoring Points
- Approximate Haley Upland Unit
- Approximate Extent of Refuse & Wood Debris
- Approximate Landward Boundary of Landfill Refuse
- Property Line
- Fence

True North / Project North (W, S, N, E)

120 0 120
Feet

LFG Monitoring Locations

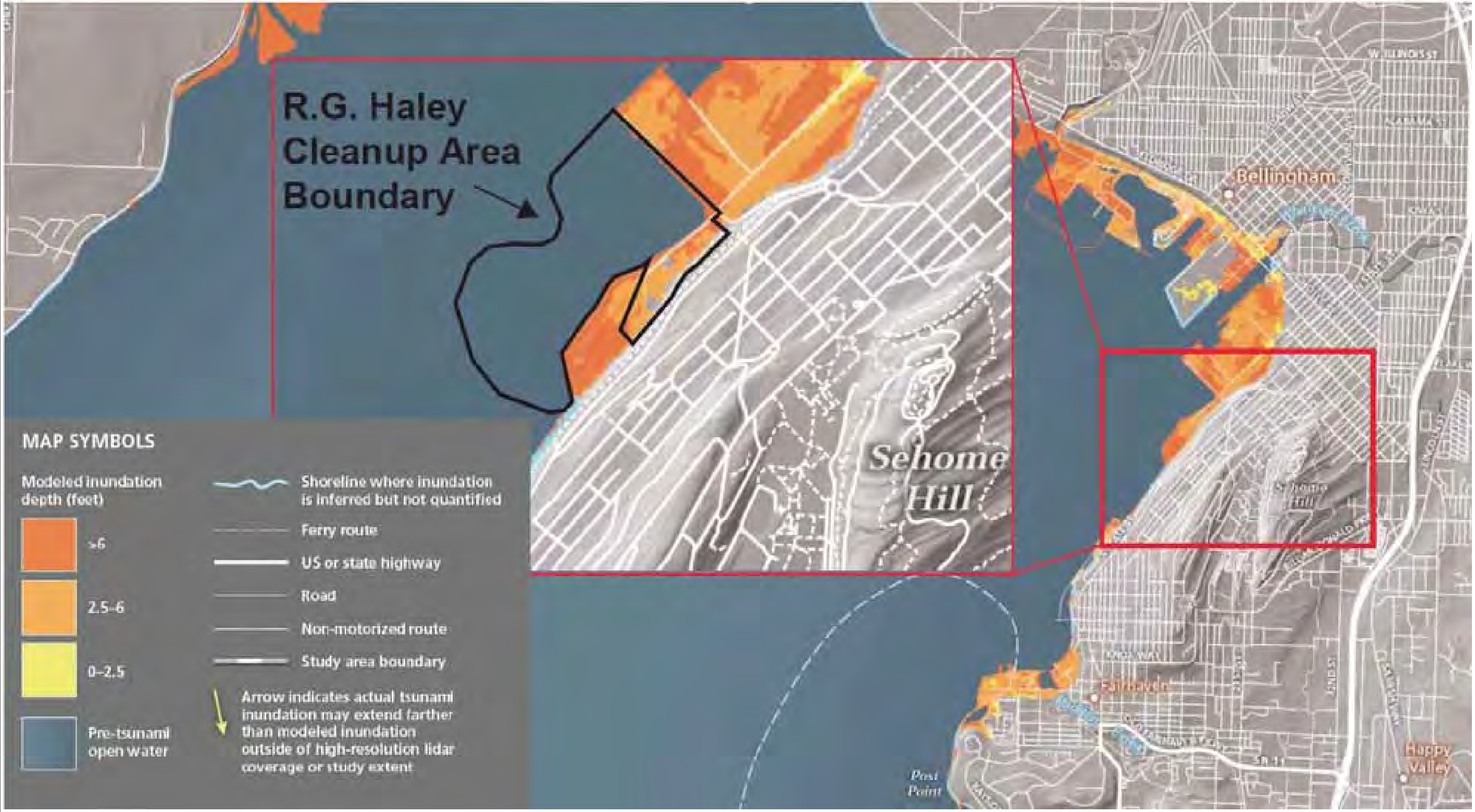
R.G. Haley Site
Bellingham, Washington

GeoEngineers

Figure 5-2

P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures\035611408_EDR_F05-2_LFG Monitoring Locations.dwg TAB:11x17 Landscape Date Exported: 08/12/19 - 8:52 by syi

P:\0\0356114\GIS\MXDs\Fig_5-3_PredictedTsunamiInundation.mxd Date Exported: 08/27/19 by ccabrera



Notes:

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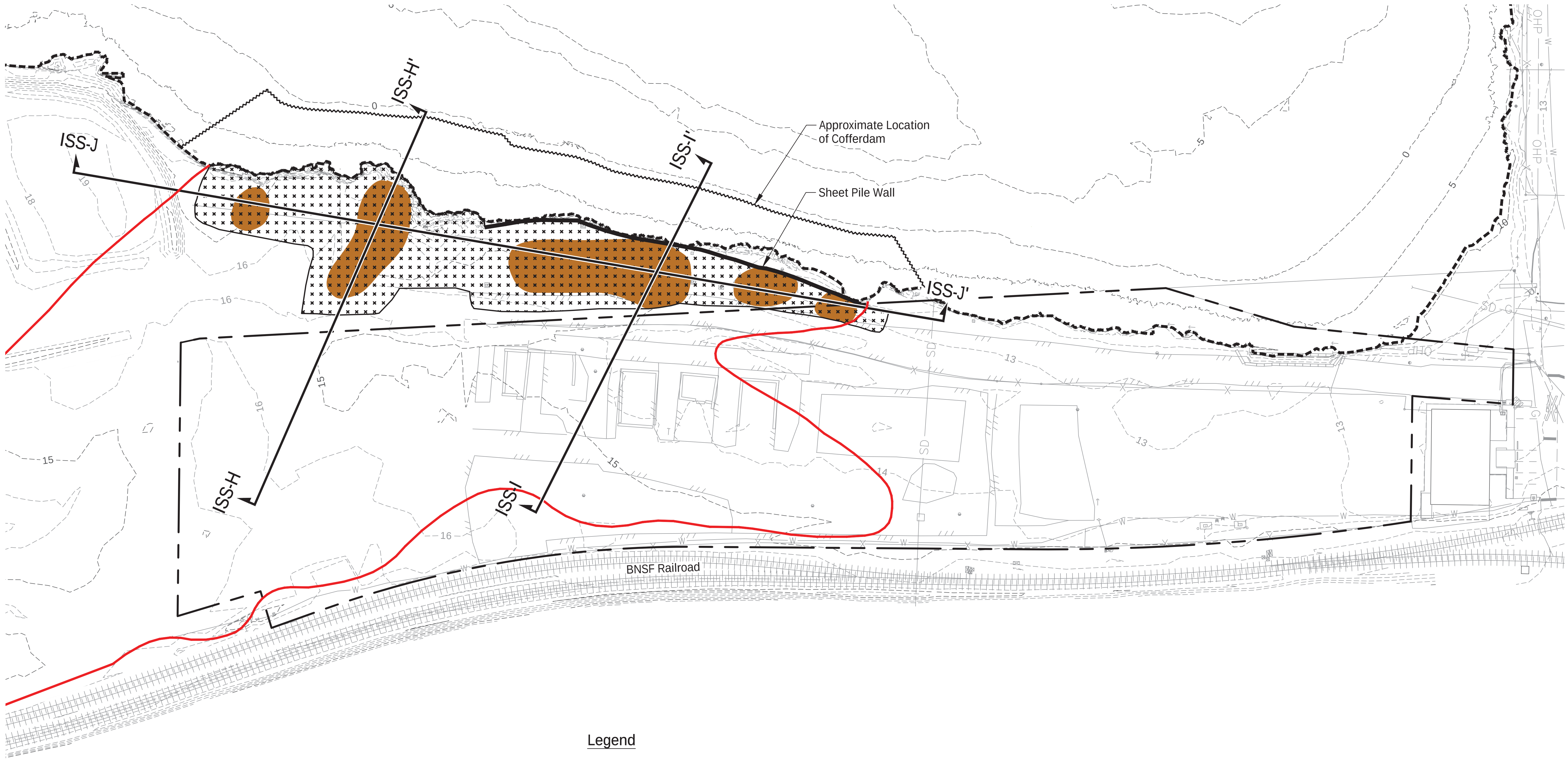
3. Modified from Map Sheet 1 'Tsunami Inundation of the Bellingham Area' from 'Tsunami Hazard Maps of the Anacortes- Bellingham Area, Washington – Model Results from a ~ 2,500-year Cascadia Zone Subduction. Eungard et al. (2018).
4. See Eungard et al. Map Sheet 1 for additional notes.
5. Elevations represent water depths over land surface for tsunami occurring during MHW (Elevation 7.31 feet NAVD88) tidal conditions.

Predicted Tsunami Inundation in the R.G. Haley Site Vicinity

R.G. Haley Site
Bellingham, Washington

GeoEngineers

Figure 5-3



Legend

- Estimated Extent of Petroleum Smear Zone Footprint
- Estimated Extent of Potentially Mobile LNAPL
- ISS-H ISS-H' Cross Section Location
- Haley Marine Unit Boundary (OHWM - Elevation 9.73 Feet NAVD88)
- 20 Existing Elevation Contour in Feet (NAVD88)
- City-Owned Parcel (Former Haley Property)
- Approximate Extent of ISS
- Approximate Location of Temporary Cofferdam during ISS

Notes:
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3. Smear zone includes soil sheen observations from 2018 PRDI and older explorations.

Data Source: Base survey by Wilson Engineering & Surveying 10/28/15.

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

True North / Project North

80 0 80 Feet

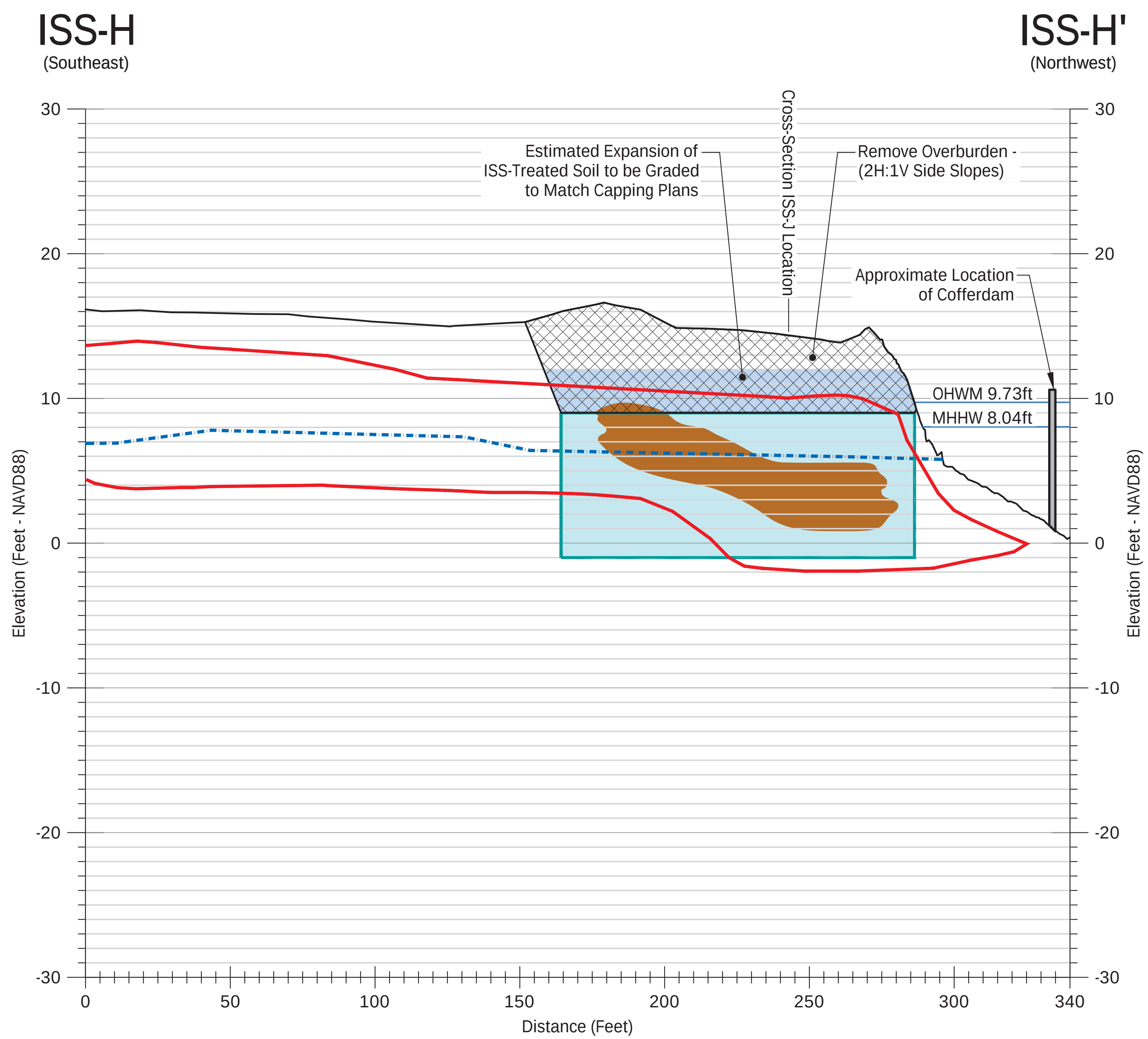
ISS Site Plan

R.G. Haley Site
Bellingham, Washington

GeoEngineers

Figure 6-1

P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures [R02 - Ecology Comments]\035611408_EDR_F06-1_ISS Site Plan.dwg TAB:11x17 Landscape Date Exported: 03/30/21 - 8:39 by tmichaud



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. 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.
3. Surface topography and bathymetry based on October 28, 2015 Wilson Engineering survey drawings (Project No. 2015-088) prepared for the City of Bellingham (R.G. Haley Site Cleanup Project Topo - EC-0018).
4. Estimated extent of petroleum smear zone and potentially mobile NAPL are based on the TPH concentrations and visual observation from the 2018 PRDI (EDR Appendix A) and previous and explorations discussed in the Haley RI/FS (GeoEngineers 2016).

Vertical Datum: NAVD 88.

Legend

- Approximate Groundwater Table
- Estimated Extent of Petroleum Smear Zone
- Estimated Extent of Potentially Mobile LNAPL
- Approximate Extent of ISS
- Overburden Soil to be Excavated prior to ISS

50 0 50
Horizontal Scale in Feet
10 0 10
Vertical Scale in Feet
Vertical Exaggeration: 5X

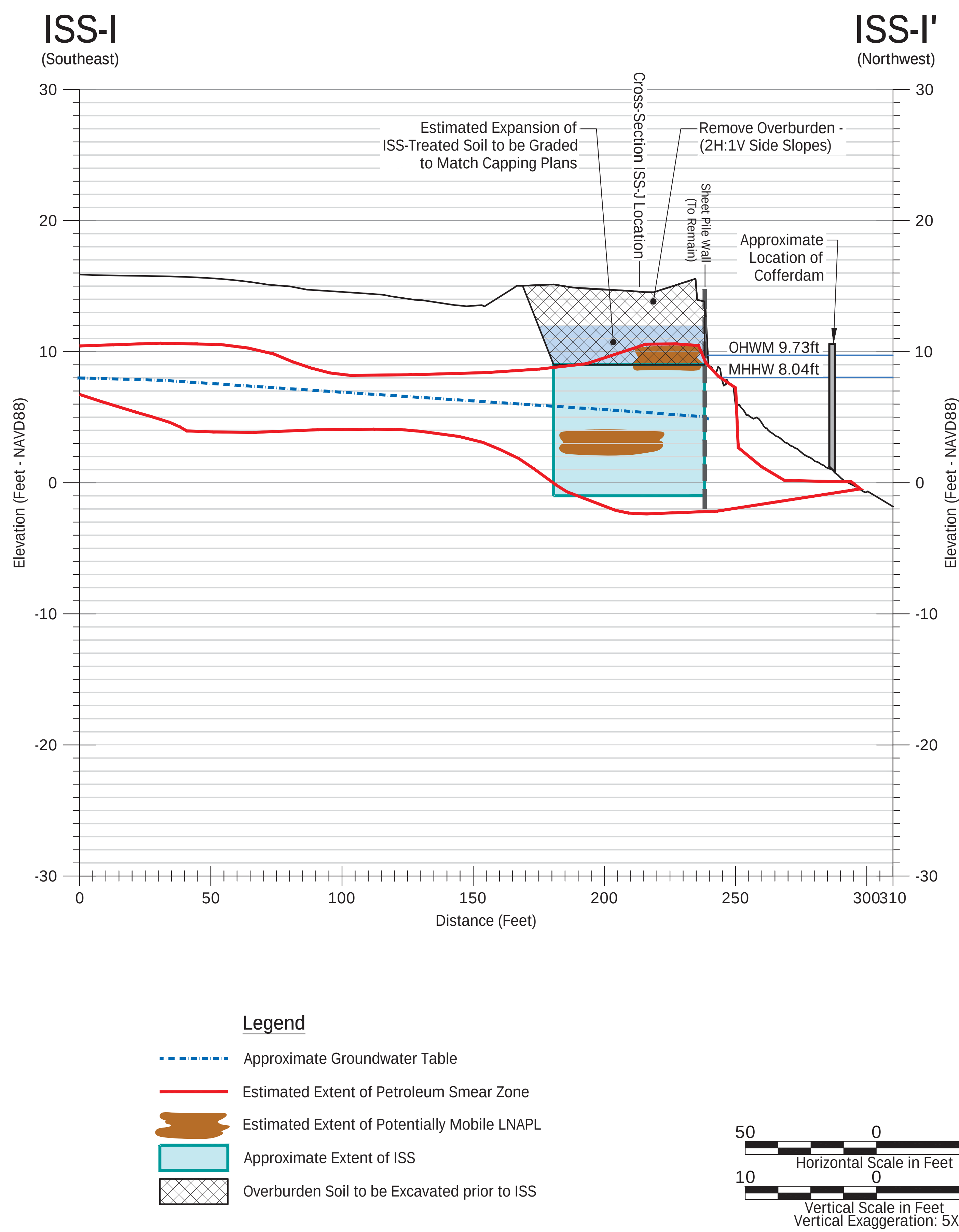
ISS Cross-Section H-H'

R.G. Haley Site
Bellingham, Washington

GeoEngineers

Figure 6-2

P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures [R02 - Ecology Comments]\035611408_EDR_F06-2-06-4_ISS Cross-Sections.dwg TAB:Cross-Section HH Date Exported: 03/22/21 - 16:36 by tmichaud



Notes:

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4. Estimated extent of petroleum smear zone and potentially mobile NAPL are based on the TPH concentrations and visual observation from the 2018 PRDI (EDR Appendix A) and previous and explorations discussed in the Haley RI/FS (GeoEngineers 2016).

Vertical Datum: NAVD 88.

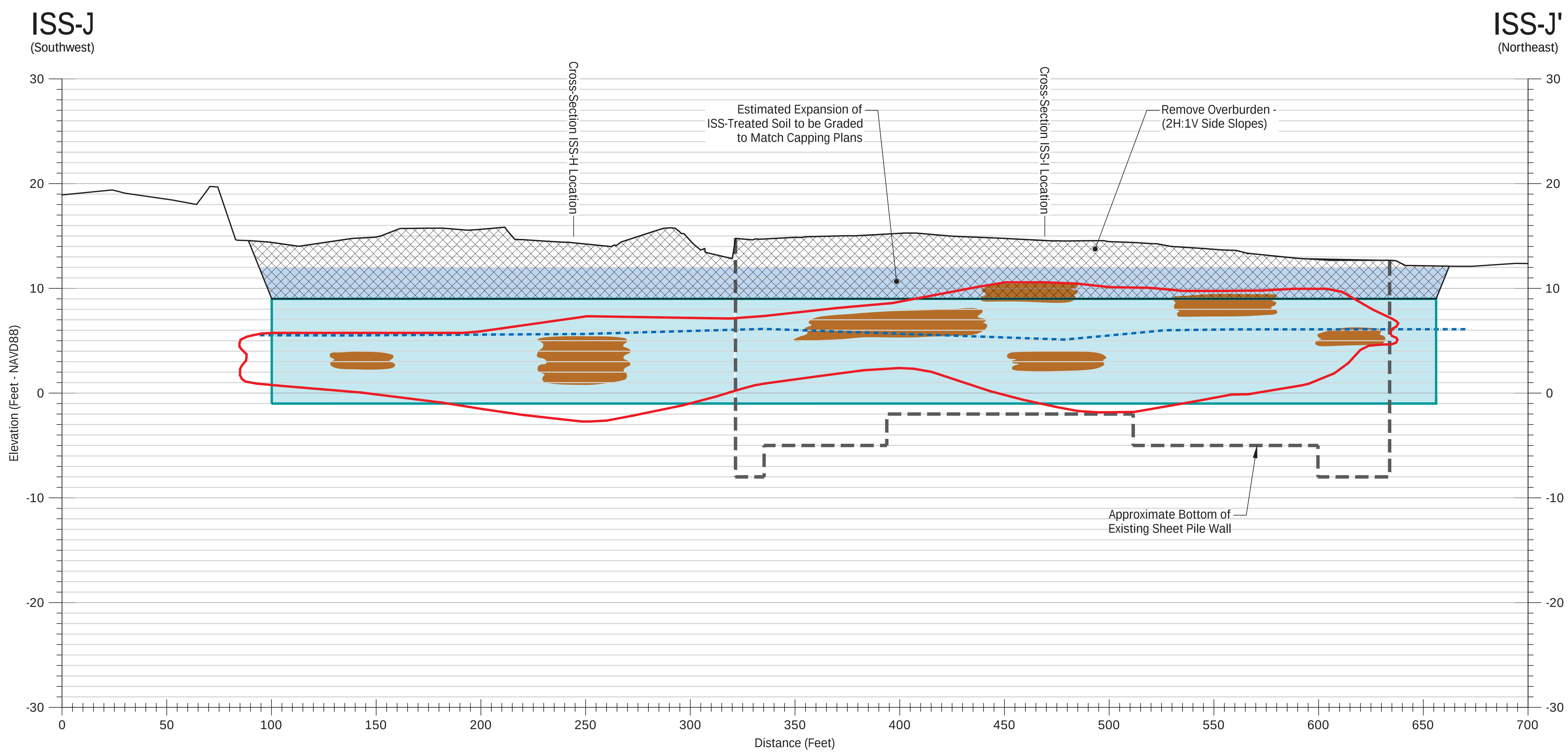
ISS Cross-Section I-I'

R.G. Haley Site
Bellingham, Washington

GeoEngineers

Figure 6-3

P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures [R02 - Ecology Comments]\035611408_EDR_F06-2-06-4_ISS Cross-Sections.dwg TAB:Cross-Section II Date Exported: 03/22/21 - 18:01 by tmichaud



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. 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.
3. Surface topography and bathymetry based on October 28, 2015 Wilson Engineering survey drawings (Project No. 2015-088) prepared for the City of Bellingham (R.G. Haley Site Cleanup Project Topo - EC-0018).
4. Estimated extent of petroleum smear zone and potentially mobile NAPL are based on the TPH concentrations and visual observation from the 2018 PRDI (EDR Appendix A) and previous and explorations discussed in the Haley RI/FS (GeoEngineers 2016).

Vertical Datum: NAVD 88.

Legend

- Approximate Groundwater Table
- Estimated Extent of Petroleum Smear Zone
- Estimated Extent of Potentially Mobile LNAPL
- Approximate Extent of ISS
- Overburden Soil to be Excavated prior to ISS

50 0 50
Horizontal Scale in Feet

10 0 10
Vertical Scale in Feet
Vertical Exaggeration: 5X

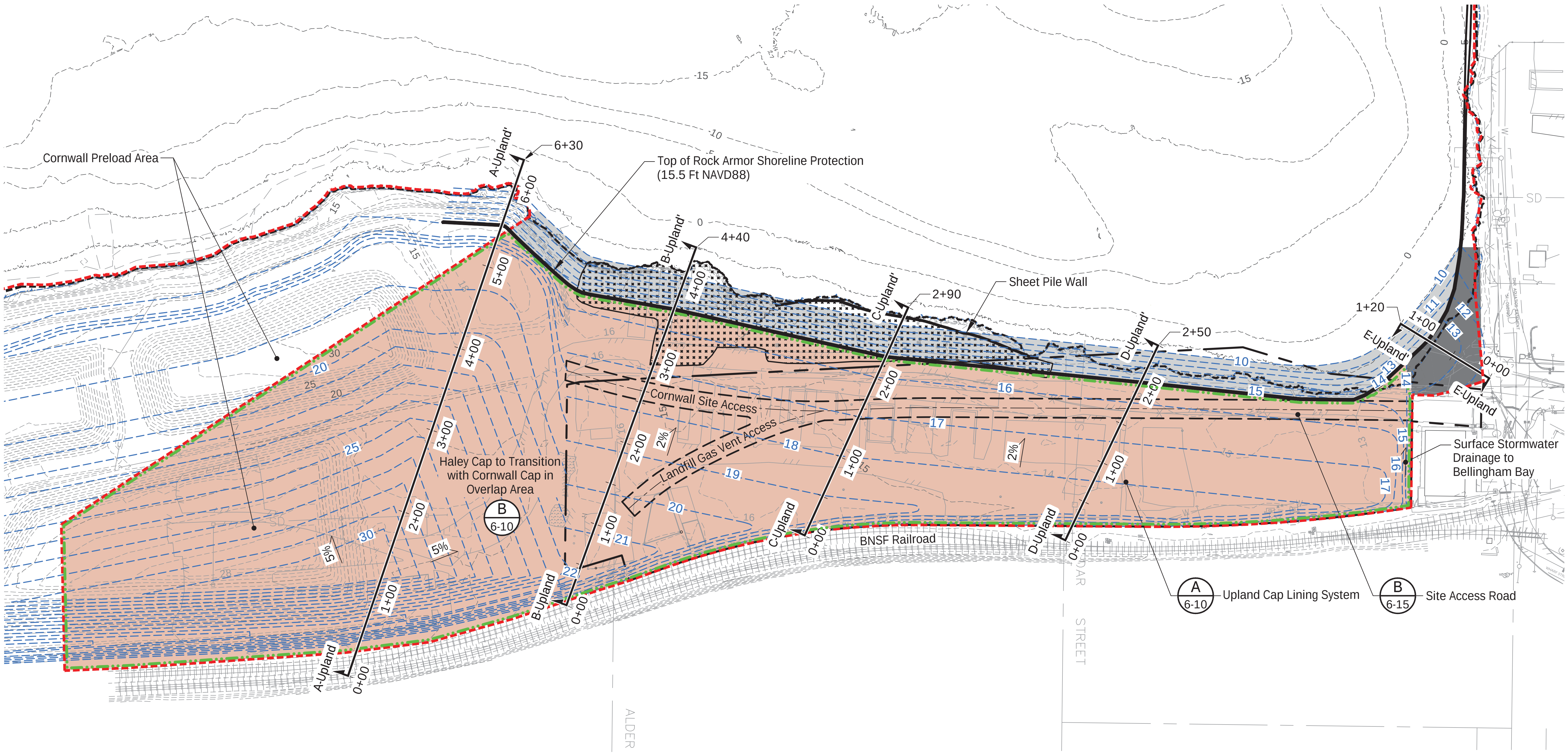
ISS Cross-Section J-J'

R.G. Haley Site
Bellingham, Washington

GeoEngineers

Figure 6-4

P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures [R01]\035611408_EDR_F06-2-06-4_ISS Cross-Sections.dwg TAB:Cross-Section JJ Date Exported: 07/06/20 - 12:12 by tmichaud



B-Upland B-Upland'

Notes:

1. Generalized contours shown for discussion purposes; they will be refined including in transition to bank and railroad areas.
2. The locations of all features shown are approximate.
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. 2016 Hilton Avenue Stockpile topography provided from April 30, 2018 Cornwall Site EDR.

Data Source: Base survey by Wilson Engineering & Surveying 10/28/15.

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

Legend

- Cross Section Location (See Figures 6-6 through 6-9)
- Existing Marine Unit Boundary (OHWM - Elevation 9.73 Feet NAVD88)
- 20 Existing Elevation Contour in Feet (NAVD88)
- 20 Post-Construction Surface Elevation Contours
- Haley Cleanup Area Boundary
- City-Owned Parcel (Former Haley Property)
- Low-Permeability Upland Cap
- Area of Preload
- Pavement Cap
- Approximate Extent of ISS
- Shoreline Bank Transition between Upland and Marine Units
- Access Road
- Surface Slope

W True North S N Project North E

120 0 120
Feet

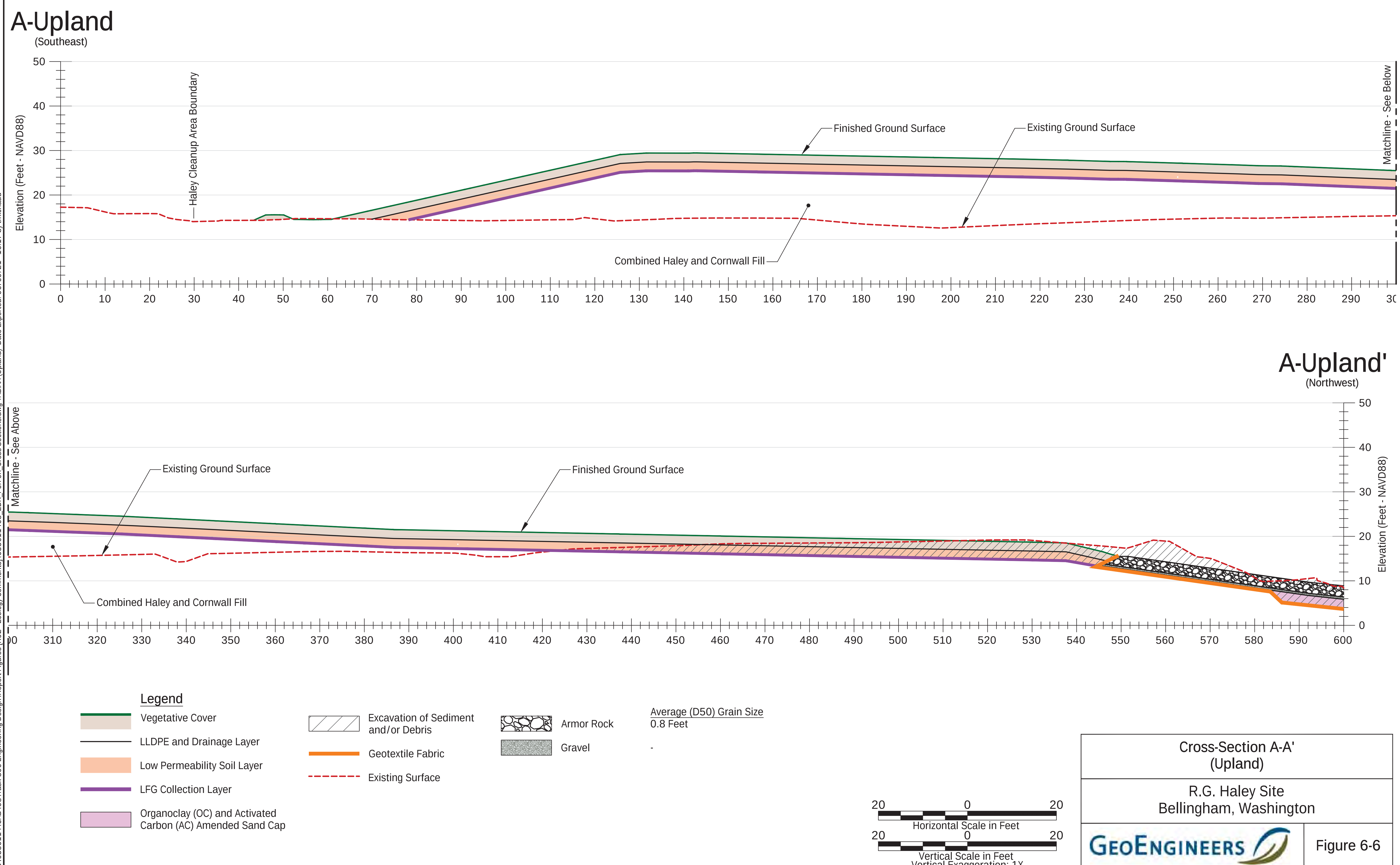
Upland Grading Plan

R.G. Haley Site
Bellingham, Washington

GeoEngineers

Figure 6-5

P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures [R02 - Ecology Comments]\035611408_EDR_F06-05_Upland Grading Plan.dwg TAB:11x17 Landscape Date Exported: 06/16/21 - 11:52 by tmichaud



Cross-Section A-A'
(Upland)

R.G. Haley Site
Bellingham, Washington

GeoEngineers

Figure 6-6

P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures [R02 - Ecology Comments]\035611408_EDR_F0X-0X_Cross-Sections.dwg TAB:AA (Upland) Date Exported: 06/09/21 - 16:17 by tmichaud

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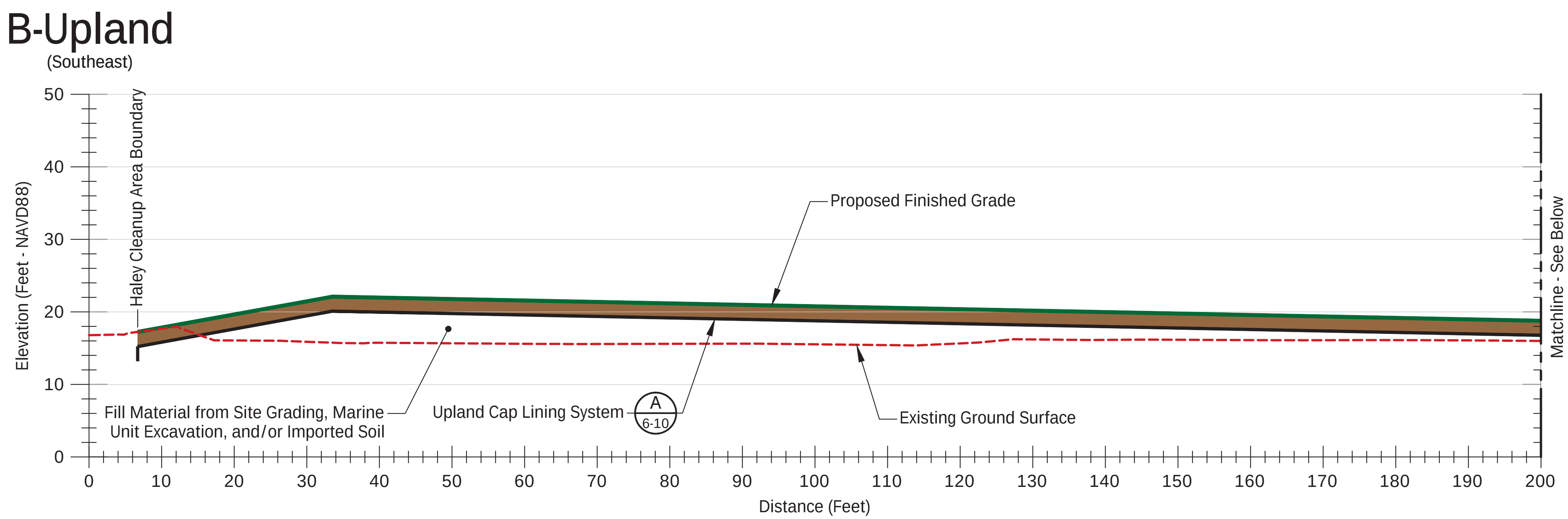
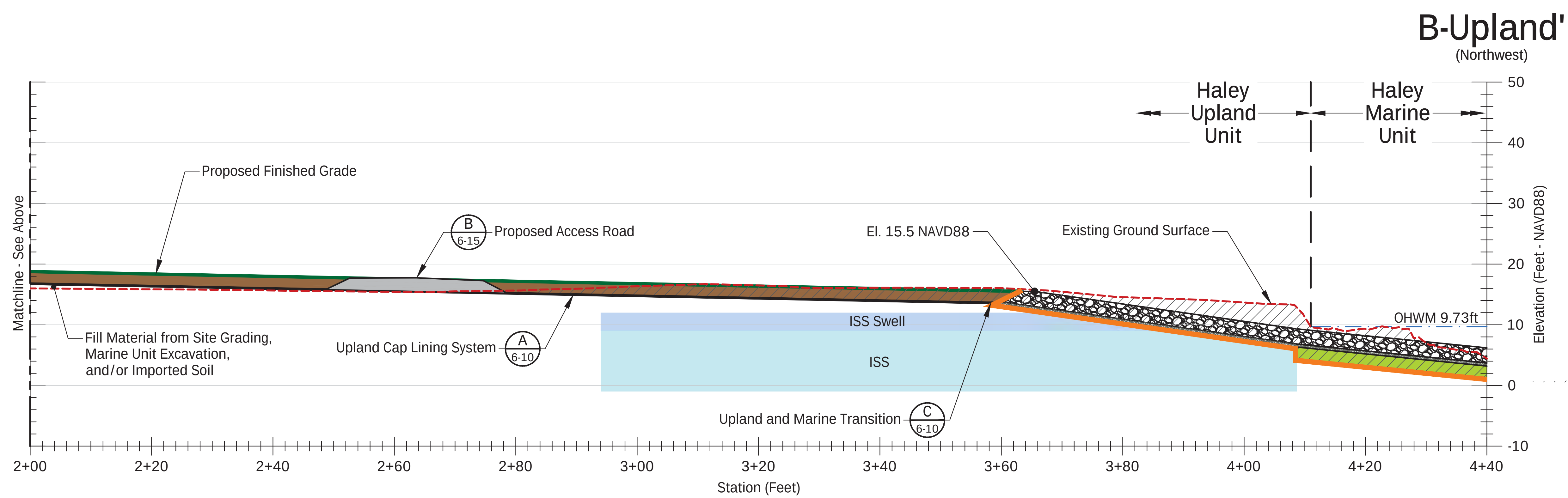




Legend

- Approximate Extent of ISS
- Estimated ISS Swell
- Upland Low-Permeability Vegetated Capping System
- High-Content Organoclay (OC) Amended Sand Cap
- Excavation of Sediment and/or Debris
- Geotextile Fabric
- Existing Surface
- Upland Cap Lining System
- Armor Rock
- Gravel

Average (D50) Grain Size
0.8 Feet
-

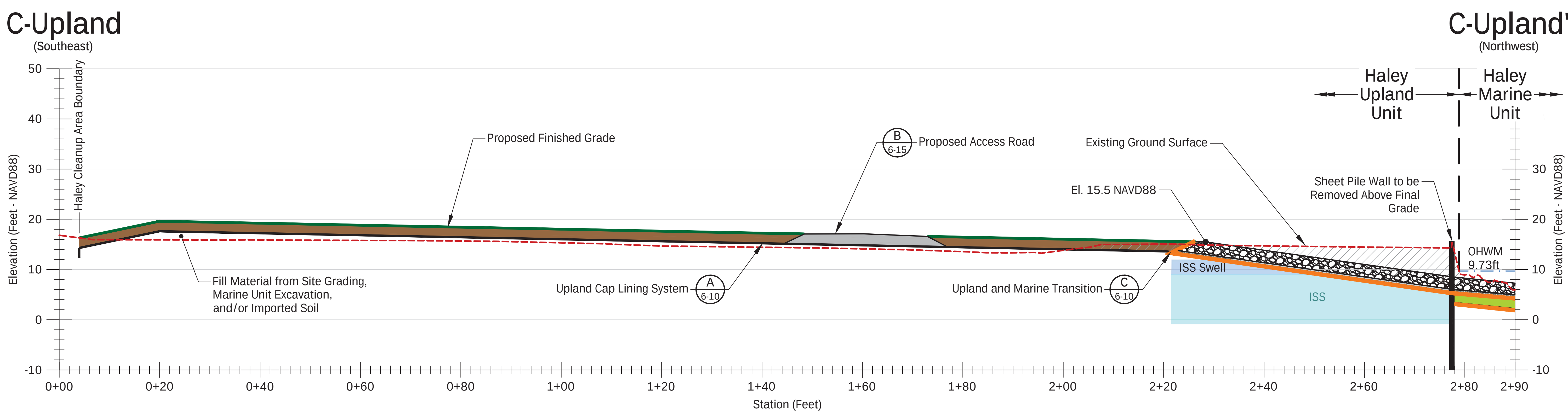
20 0 20
Horizontal Scale in Feet
20 0 20
Vertical Scale in Feet
Vertical Exaggeration: 1X

Cross-Section B-B' (Upland)

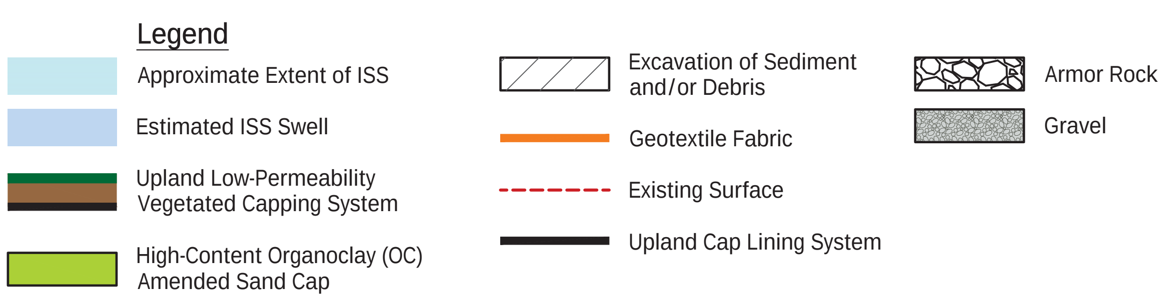
R.G. Haley Site
Bellingham, Washington

GeoEngineers

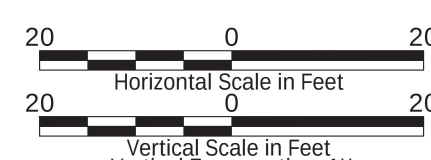
Figure 6-7



Legend



Average (D50) Grain Size
0.8 Feet
-



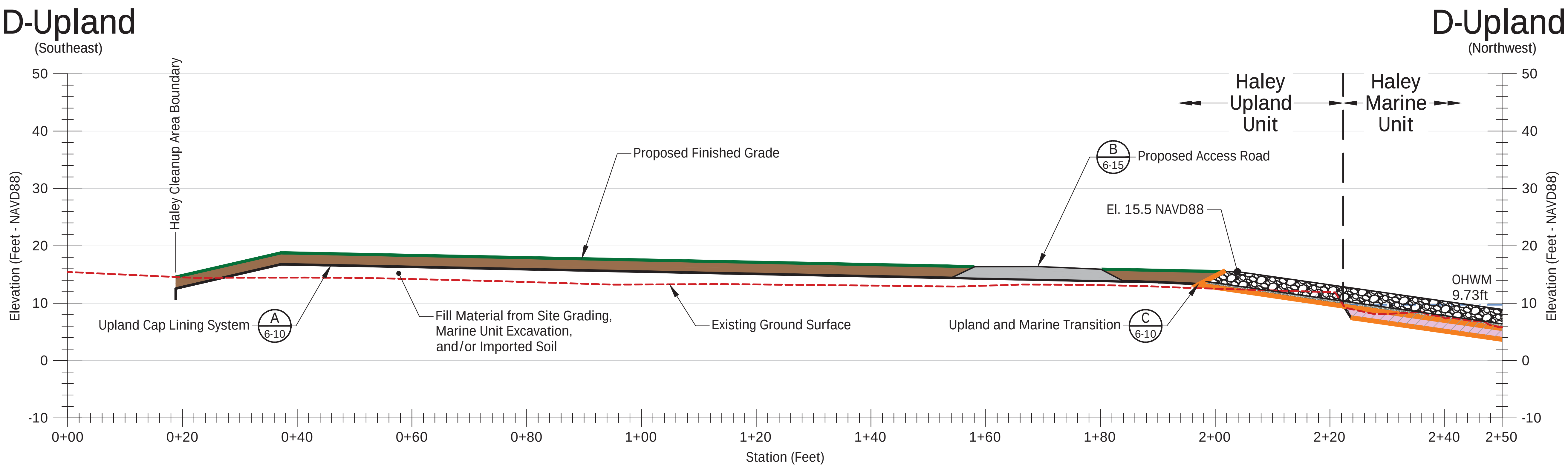
Cross-Section C-C' (Upland)

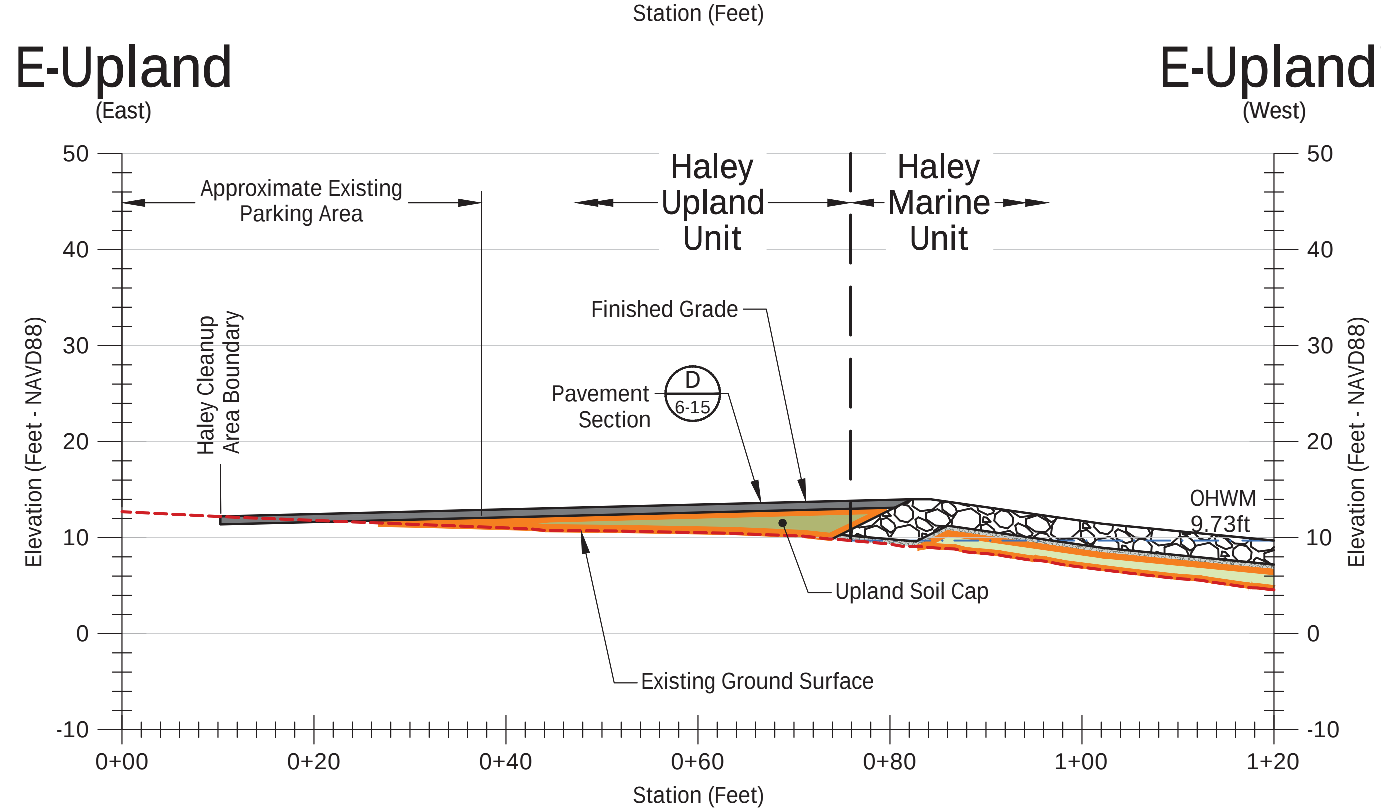
R.G. Haley Site
Bellingham, Washington

GeoEngineers

Figure 6-8

P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures [R02 - Ecology Comments]\035611408_EDR_F0X-0X_Cross-Sections.dwg TAB:CC (Upland) Date Exported: 06/09/21 - 16:21 by tmichaud





Legend

- Asphalt Pavement over CSBC
- Upland Low-Permeability Vegetated Capping System
- Organoclay (OC) and Activated Carbon (AC) Amended Sand Cap
- Organoclay (OC) Amended Sand Cap
- Sandy Fill and/or Crushed Surfacing Base Course
- Excavation of Sediment and/or Debris
- Geotextile Fabric
- Existing Surface
- Upland Cap Lining System
- Armor Rock
- Gravel

	Average (D50) Grain Size
Armor Rock	0.8 Feet
Gravel	-

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

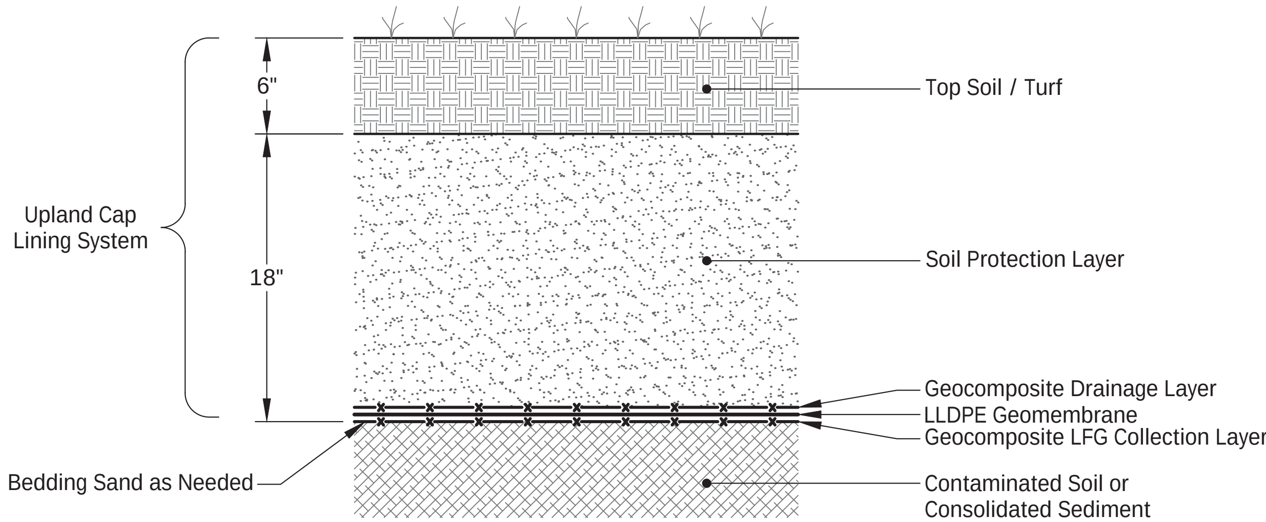
Cross-Section D-D' and E-E'
(Upland)

R.G. Haley Site
Bellingham, Washington

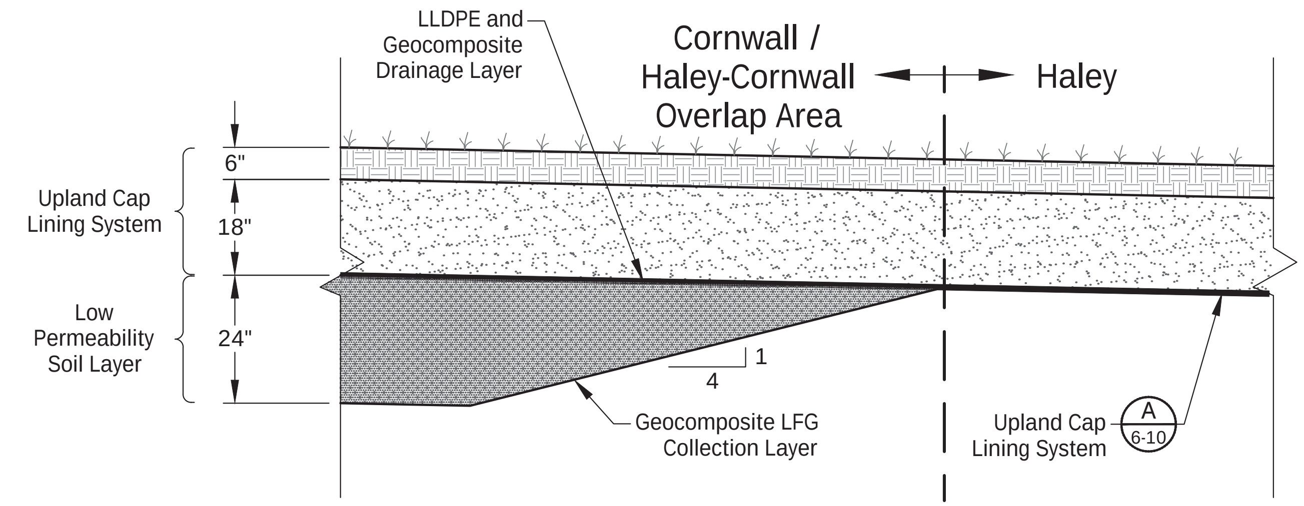
GeoEngineers

Figure 6-9

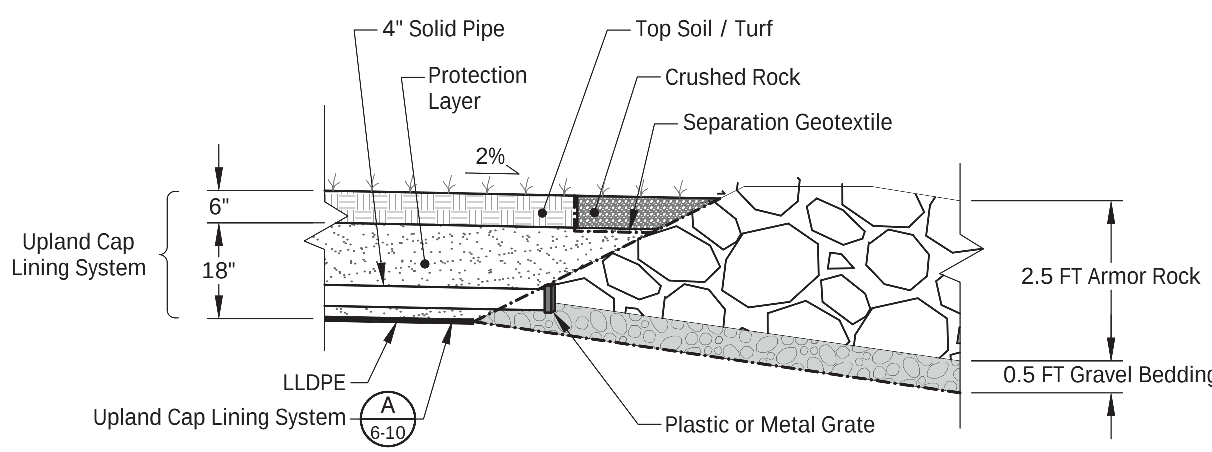
P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures [R02 - Ecology Comments]\035611408_EDR_F0X-0X_Cross-Sections.dwg TAB:DD EE (Upland) Date Exported: 06/09/21 - 16:23 by tmichaud



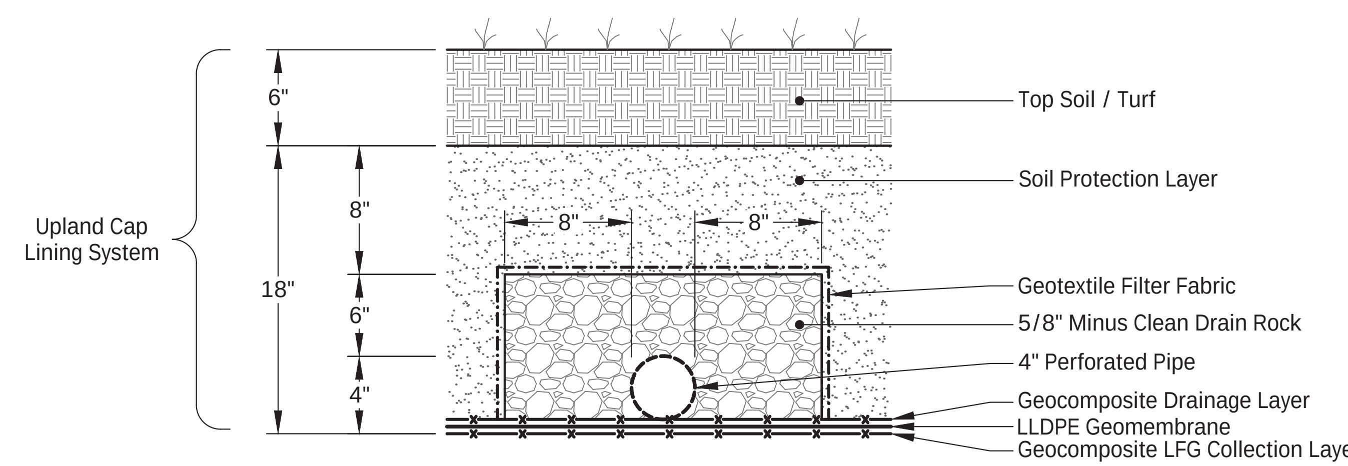
A
--
Upland Cap Lining System
Not to Scale



B
6-5
Transtion from Haley Cap to Cornwall Cap
Not to Scale



C
--
Upland and Marine Transition
Not to Scale



D
6-14
Underdrain Detail
Not to Scale

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.

Typical Upland Cap Details

R.G. Haley Site
Bellingham, Washington

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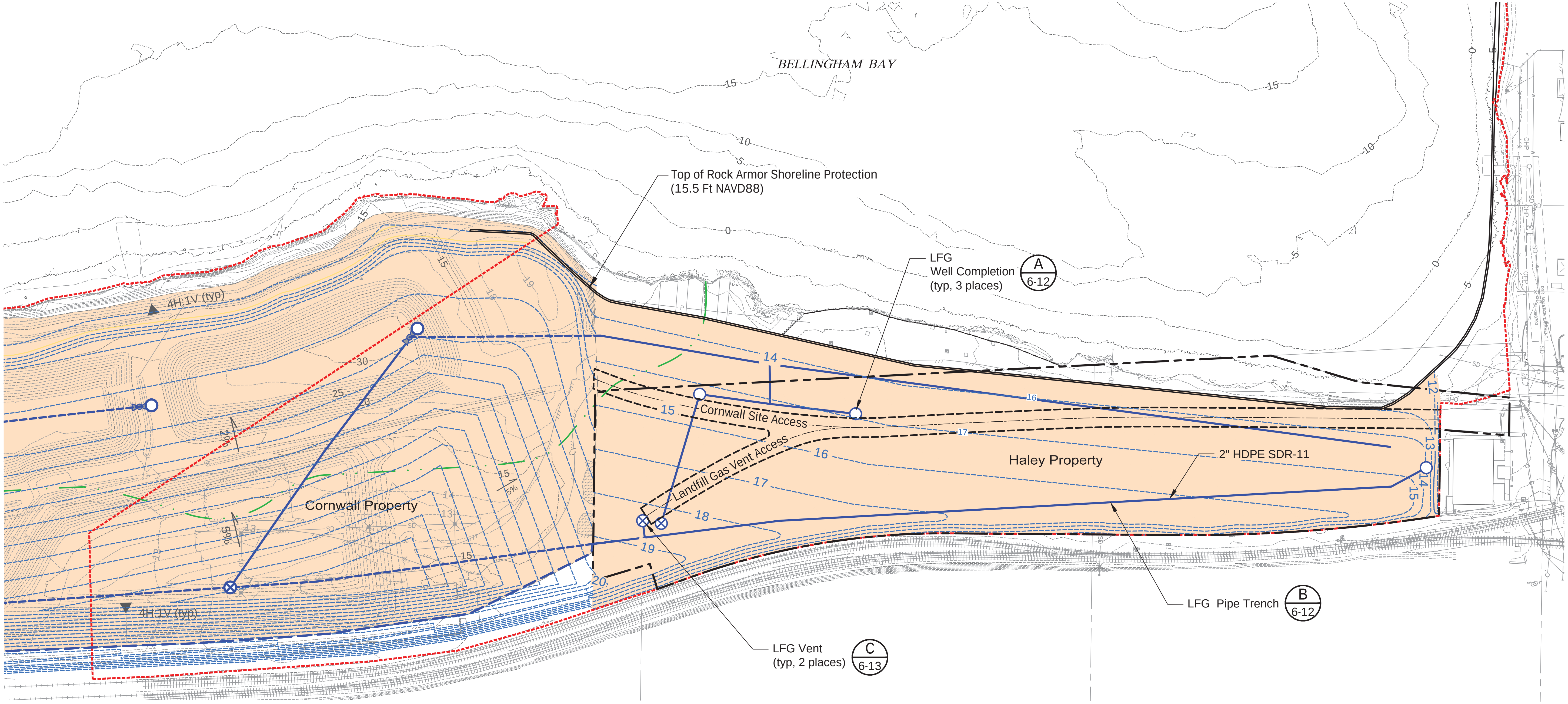
Figure 6-10

P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures [R02 - Ecology Comments]\035611408_EDR_F06-10 and 06-15_Details.dwg TAB:6-10 Date Exported: 06/16/21 - 10:15 by tmichaud



P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures [R02 - Ecology Comments]\035611408_EDR_F06-11_LFG Control Plan.dwg TAB:11x17 Landscape Date Exported: 10/18/21 - 12:59 by tmichaud

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.
3. Cornwall LFG features from Landau Associates, "MU1 and MU2 Engineering Design Report, Cornwall Avenue Landfill Site", Landau Associates, Figure 8 April 30, 2018.

Data Source: Landau Associates, Figure 4 of Engineering Design Report "Gas Control Plan Below Cover" dated 5-23-19. Grading contours on Cornwall provided by Landau & Associates on 11/6/19.

Projection: WA State Plane, N Zone, NAD83, US Foot

Legend

- City-Owned Parcel (Former Haley Property)
- Approximate Landward Boundary of Landfill Refuse
- LFG Vent Location
- LFG Well Completion
- Haley Cleanup Area Boundary
- 18 — Geocomposite LFG Collection Layer Elevation Contour
- LFG Collection Layer Geocomposite
- LFG Header Pipe
- 2" Diameter Perforated Pipe
- Access Road

True North / Project North

120 0 120
Feet

LFG Control Plan
Below Cover

R.G. Haley Site
Bellingham, Washington

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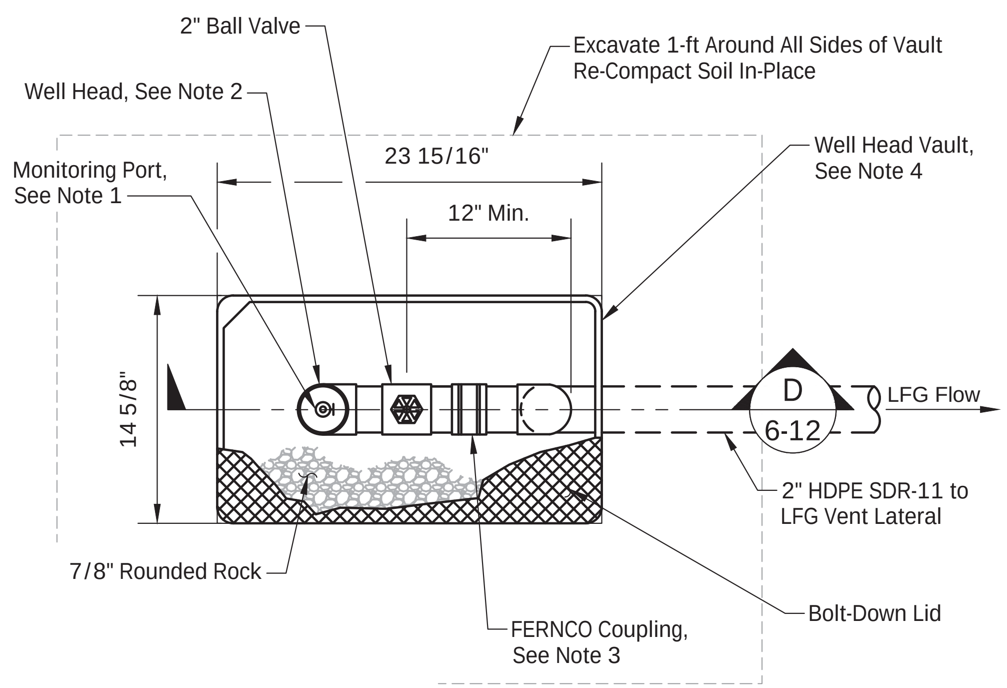
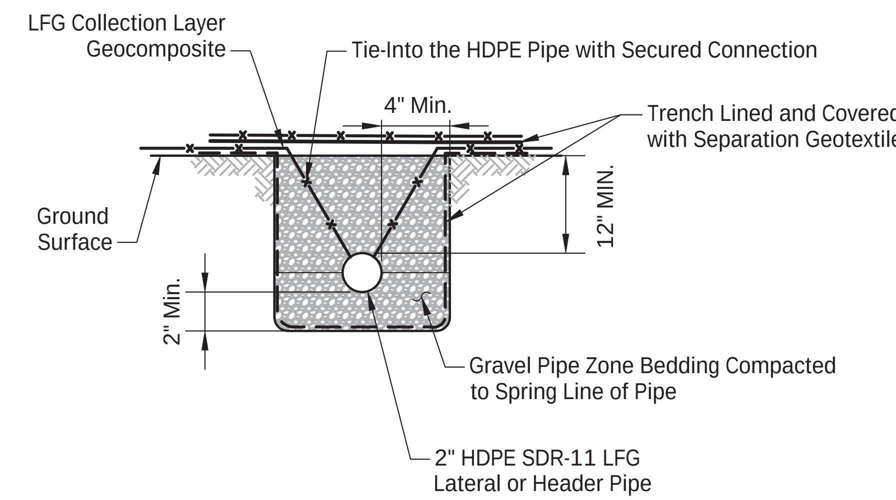
Figure 6-11



Notes

1. 1/4" threaded CPVC ball valve with hose barb for air sampling spears part no. 1529-002CA or approved equivalent minimum clearance between hose barb and vault lid is 6 inches.
2. LFG extraction well head minimum clearance to vault inner wall is 3 inches. Top is threaded PVC cap drilled and tapped to accept monitoring port, see note 1.
3. FERNCO 1059 series stock coupling part no. 1059-150 or approved equivalent.
4. Well head vault fibrelyte utility box with 6" extension and locking bolt-down lid by old castle precast inc. par nos: FL30T box 24, FL30X6, FL30T. Lid to be etched by old castle precast with the well name. Contractor to confirm locking mechanism is provided.

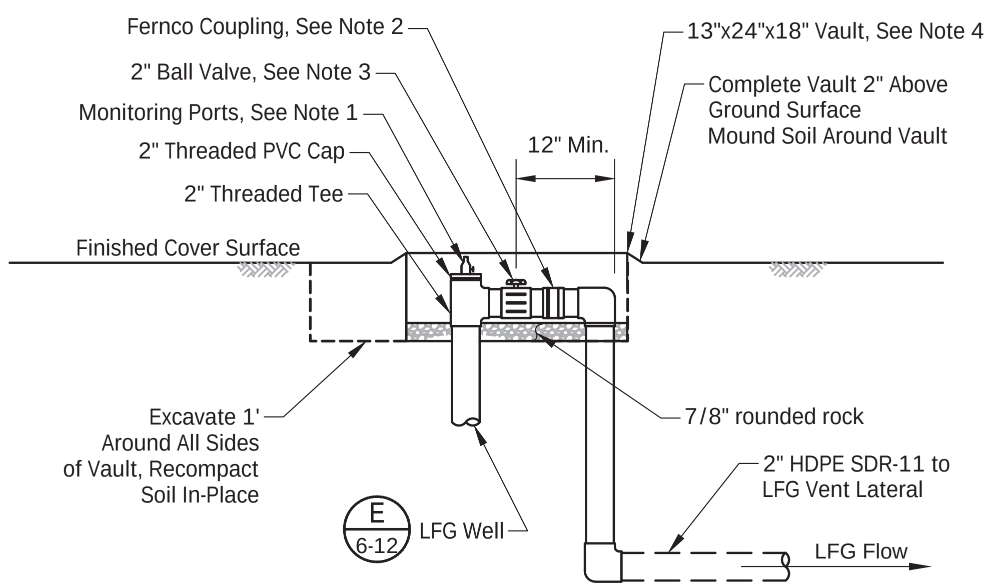


A (6-11) LFG Collection Well Completion Plan

1 0 1
Feet

B (6-11) LFG Pipe Trench Section

2 0 2
Feet

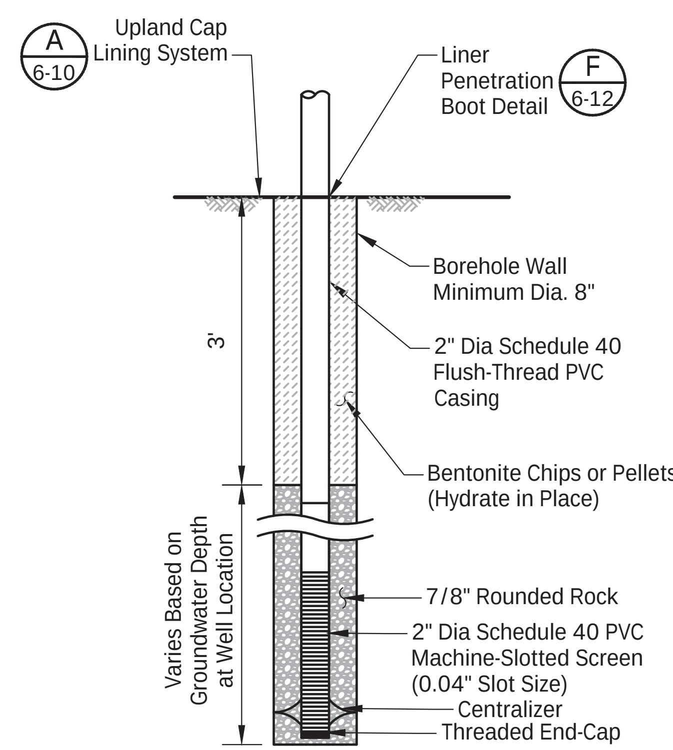


Notes

1. 1/4" threaded CPVC valve with barb for gas sampling. SPEA's part no 1529-002CA or approved equivalent.
2. FERNCO 1059 series stock coupling part no. 1059-150.
3. 2" threaded true-union PVC ball valve ASAHI type 21/21A or approved equivalent.
4. Well head vault fibrelyte utility box with 6" extension and locking bolt-down lid by old castle precast inc. par nos: FL30T box 24, FL30X6, FL30T. Lid to be etched by old castle precast with the well name. Contractor to confirm locking mechanism is provided.

D (6-11) LFG Collection Well Completion Section

2 0 2
Feet

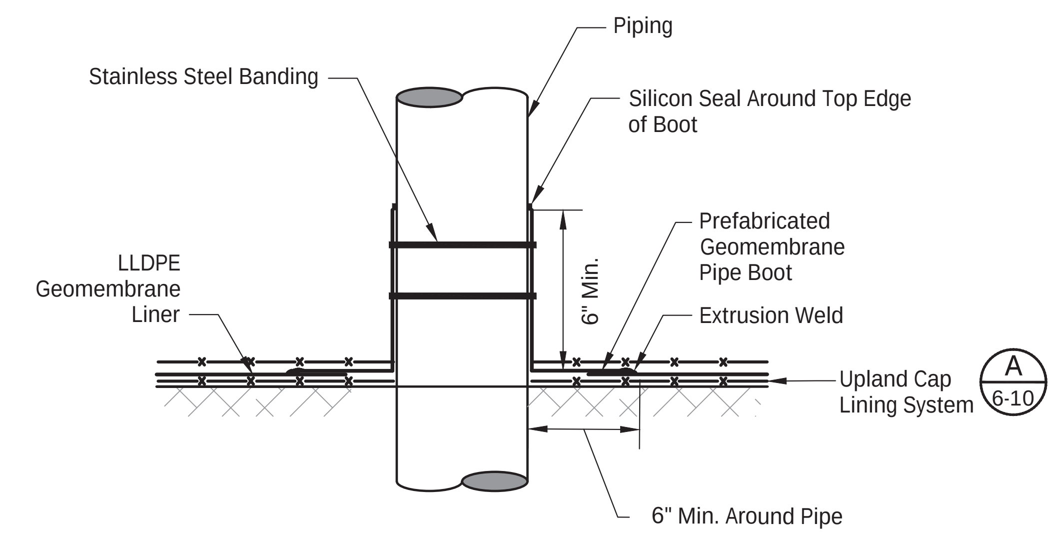


Note

1. Install extraction wells when earthwork reaches the final grading elevation and prior to LFG geotextile placement.

E (6-11) LFG Well

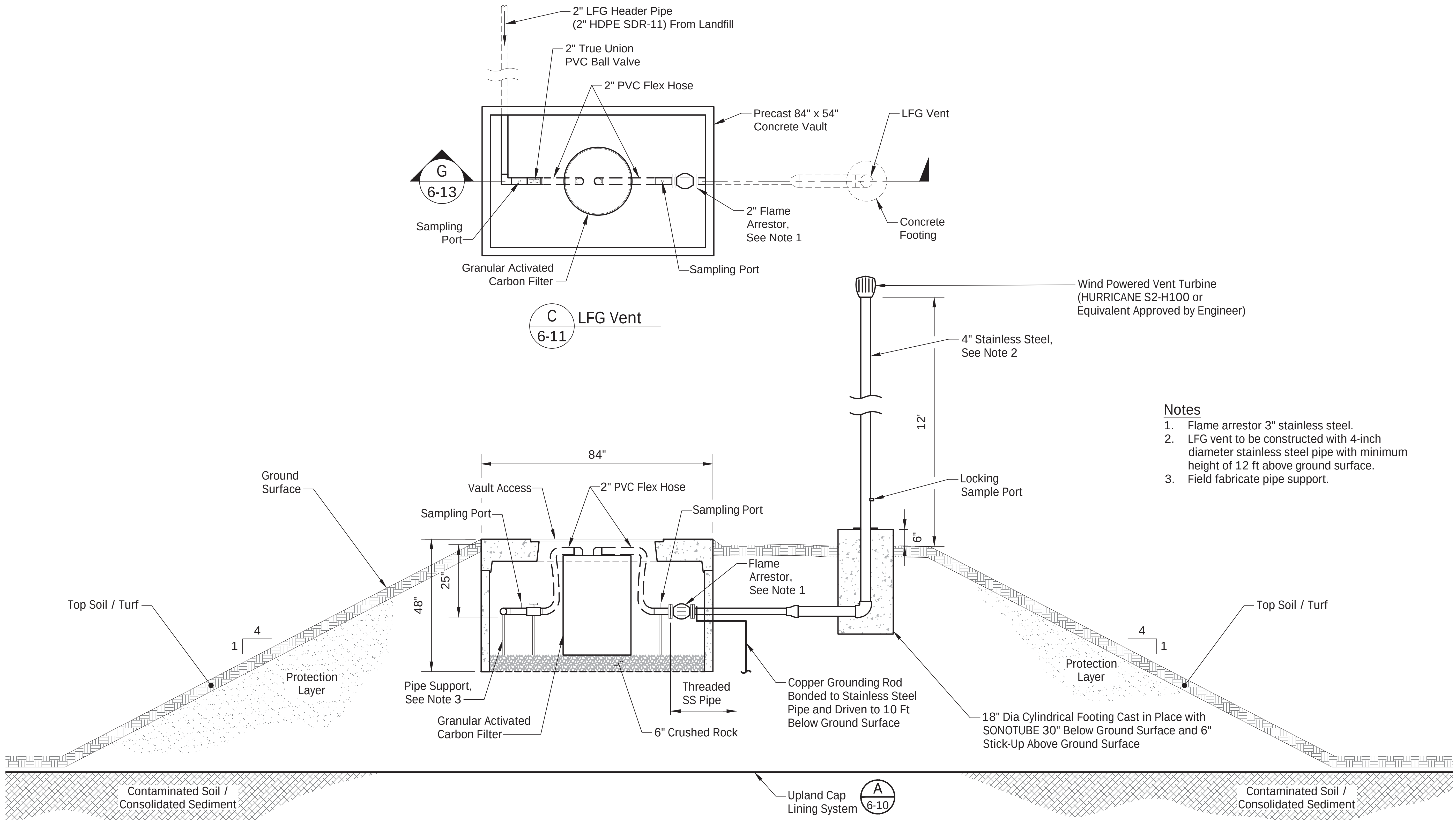
2 0 2
Feet



F (6-12) Liner Penetration Boot Detail
(TYP.FOR GAS WELLS, MONITORING WELLS AND OTHER LINER PENETRATIONS)

LFG Well and Header Pipe Details
R.G. Haley Site Bellingham, Washington
GeoEngineers — Figure 6-12

P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures [R02 - Ecology Comments]\0356114-08_EDR_F06-12-13_LFG Details.dwg TAB:F0X-0X LFG Well and Header Pipe Date Exported: 06/16/21 - 10:39 by tmichaud



G 6-13 LFG Vent Section

3 0 3
Feet

Notes

1. Flame arrestor 3" stainless steel.
2. LFG vent to be constructed with 4-inch diameter stainless steel pipe with minimum height of 12 ft above ground surface.
3. Field fabricate pipe support.

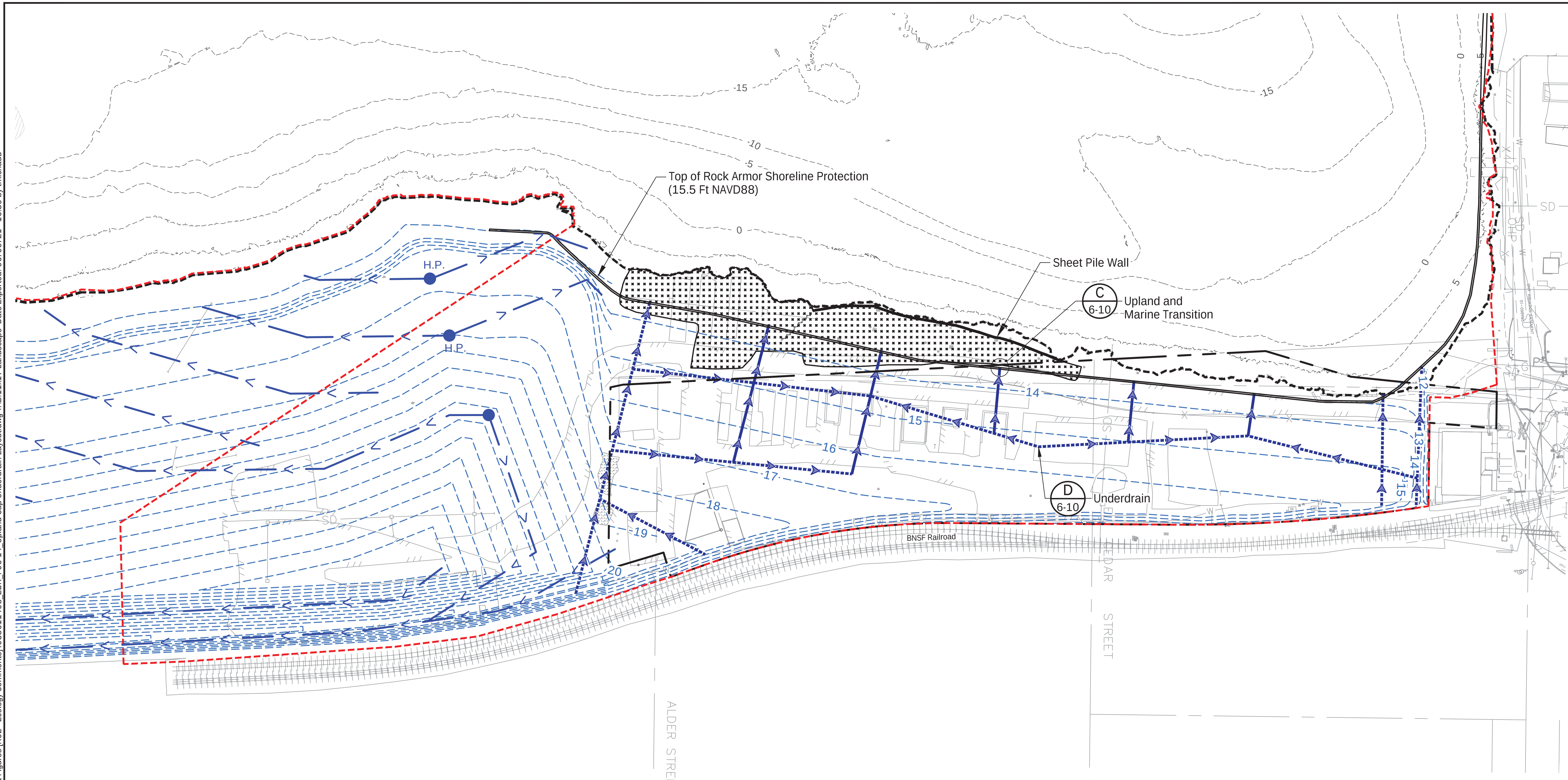
LFG Vent Details

R.G. Haley Site
Bellingham, Washington

GeoEngineers

Figure 6-13

P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures [R02 - Ecology Comments]\0356114 08_EDR_F06-12-13_LFG Details.dwg TAB:F0X-0X LFG Vent Details Date Exported: 06/16/21 - 10:34 by tmichaud



Notes:

1. Generalized contours shown for discussion purposes; they will be refined including in transition to bank and railroad areas.
2. The locations of all features shown are approximate.
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. Cornwall Underdrain features from Landau Associates, "MU1 and MU2 Engineering Design Report, Cornwall Avenue Landfill Site", Landau Associates, Figure 10 April 30, 2018.

Data Source: Base survey by Wilson Engineering & Surveying 10/28/15. Grading contours on Cornwall provided by Landau & Associates on 11/6/19.

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

Legend

- Haley Marine Unit Boundary (OHWM - Elevation 9.73 Feet NAVD88)
- Geocomposite Drainage Layer Elevation Contours (18)
- City-Owned Parcel (Former Haley Property)
- Haley Cleanup Area Boundary
- Approximate Extent of ISS
- 4" Diameter Perforated Pipe
- 4" Diameter Solid Pipe
- Flow Direction
- Cornwall Underdrain Piping

W, S, N, E — True North — Project North

80 0 80
Feet

Upland Cap Underdrain Layout

R.G. Haley Site
Bellingham, Washington

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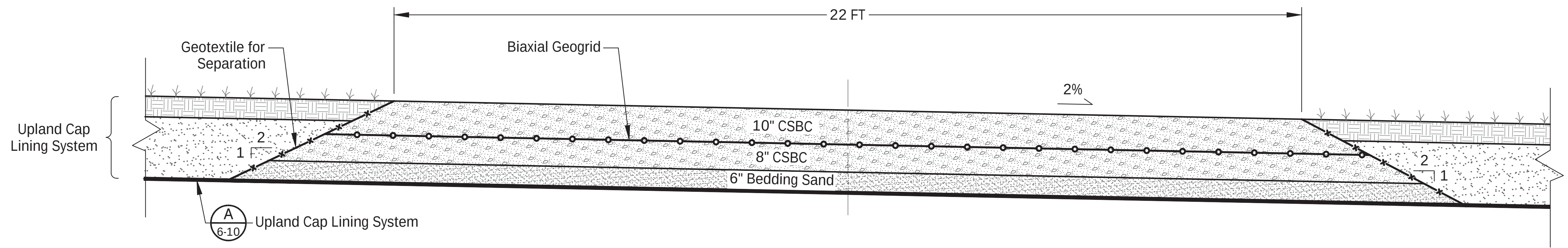
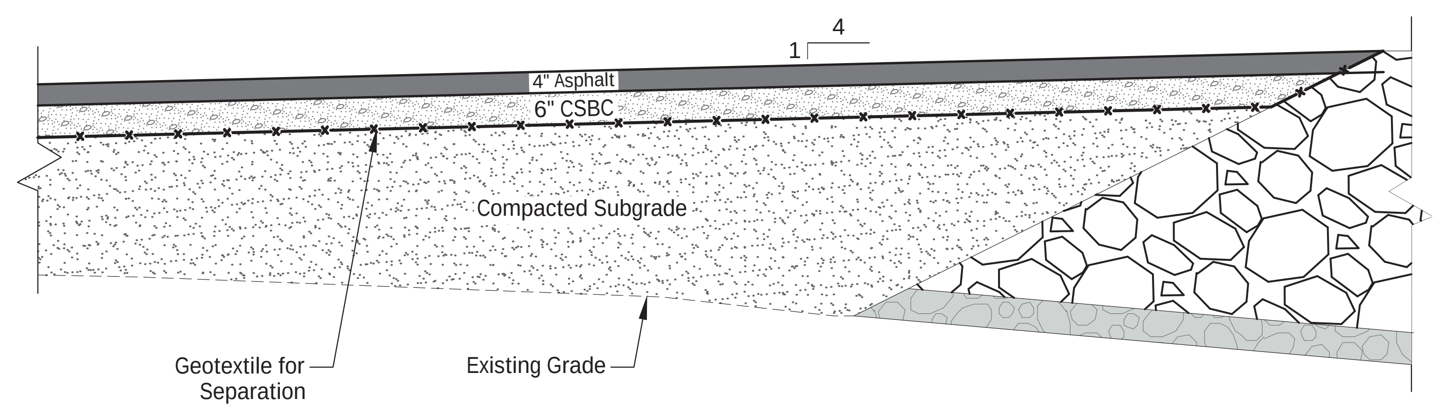
Figure 6-14

P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures [R02 - Ecology Comments]\035611408_EDR_F06-14_Upland Cap Underdrain Layout.dwg TAB:11x17 Landscape Date Exported: 06/09/21 - 16:39 by tmichaud



B
--
Typical Access Road Section
Not to Scale



D
6-9
Typical Pavement Section
Not to Scale

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.

Access Road Section Typical Detail

R.G. Haley Site
Bellingham, Washington

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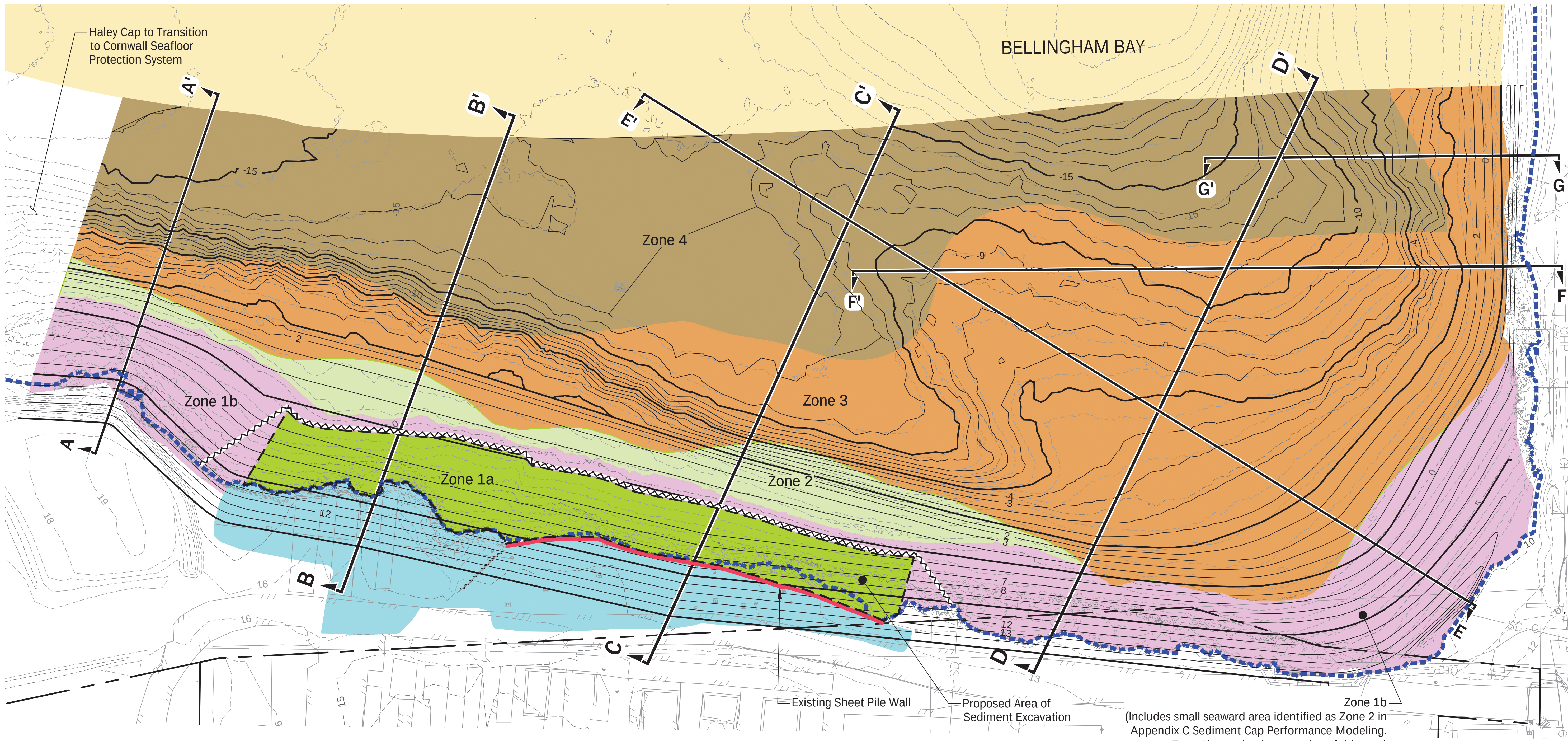
Figure 6-15

P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures [R02 - Ecology Comments]\035611408_EDR_F06-10 and 06-15_Details.dwg TAB:6-15 Date Exported: 06/16/21 - 10:16 by tmichaud



Legend

A — A'	Cross Section Location
Blue dashed line	Haley Marine Unit Boundary (OHWM)
Dashed line	Extent of Sediment Removal
—10—	Proposed Top of Cap Chemical Containment Layer Elevation Contour in Feet (NAVD88)
Zigzag line	Approximate Location of Temporary Cofferdam during Sediment Excavation
Red line	Existing Sheet Pile Wall

Sediment Cap Zones

- Zone 1a - High-Content Organoclay Amended Sand Cap
- Zone 1b - Organoclay and Activated Carbon Amended Sand Cap
- Zone 2 - Organoclay Amended Sand Cap
- Zone 3 - Activated Carbon Amended Sand Cap
- Zone 4 - Combined Gravelly Sand Thin-Layer Containment Cap and Seafloor Erosion Protection
- Monitored Natural Recovery
- Approximate Maximum Potential Extent of Upland ISS

W S N E — True North — Project North

80 0 80
Feet

Notes:

1. Generalized contours shown for discussion purposes; they will be refined including in transition to bank and railroad areas.
2. The locations of all features shown are approximate.
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 survey by Wilson Engineering & Surveying 10/28/15.

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

Sediment Excavation and Capping Areas

R.G. Haley Site
Bellingham, Washington

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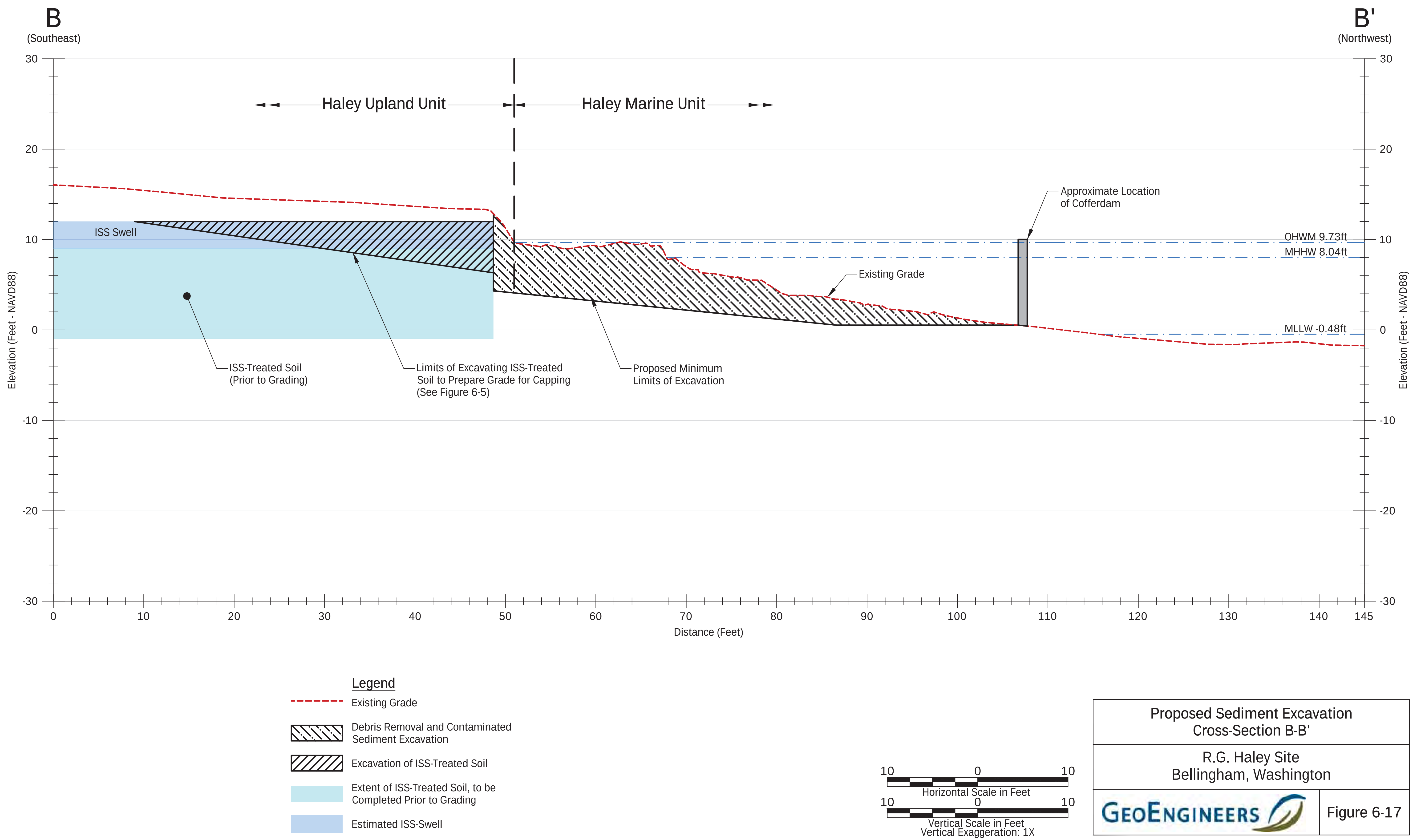
Figure 6-16

P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures [R02 - Ecology Comments]\035611408_EDR_F06-16_Sediment Excavation and Capping Areas.dwg TAB:11x17 Landscape Date Exported: 06/09/21 - 17:10 by tmichaud



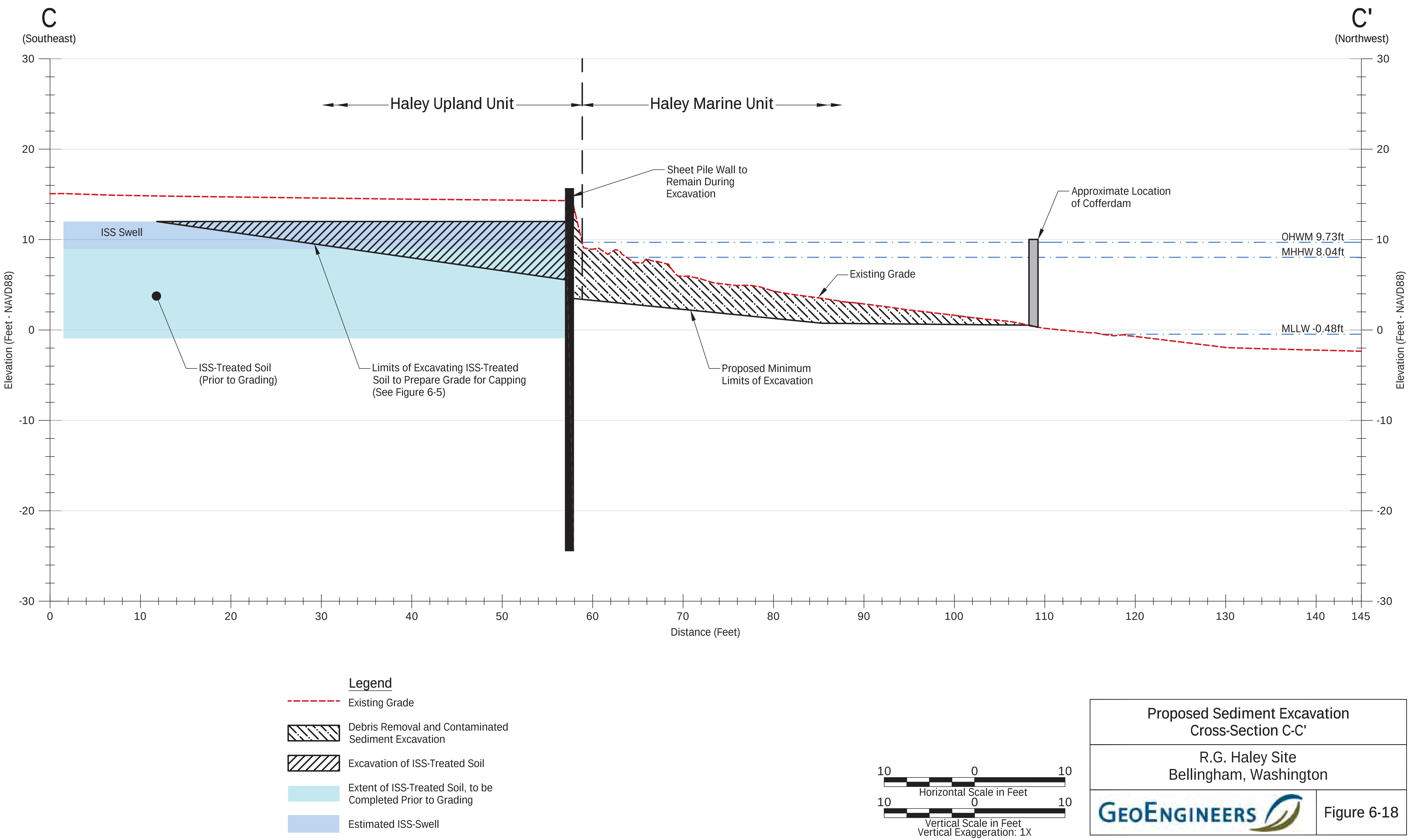
Proposed Sediment Excavation
Cross-Section B-B'

R.G. Haley Site
Bellingham, Washington

GeoEngineers

Figure 6-17

P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures [R02 - Ecology Comments]\035611408_EDR_F06-17-20_Sediment Excavation Cross-Sections.dwg TAB:BB - 1 Date Exported: 06/10/21 - 11:50 by tmichaud



Proposed Sediment Excavation
Cross-Section C-C'

R.G. Haley Site
Bellingham, Washington

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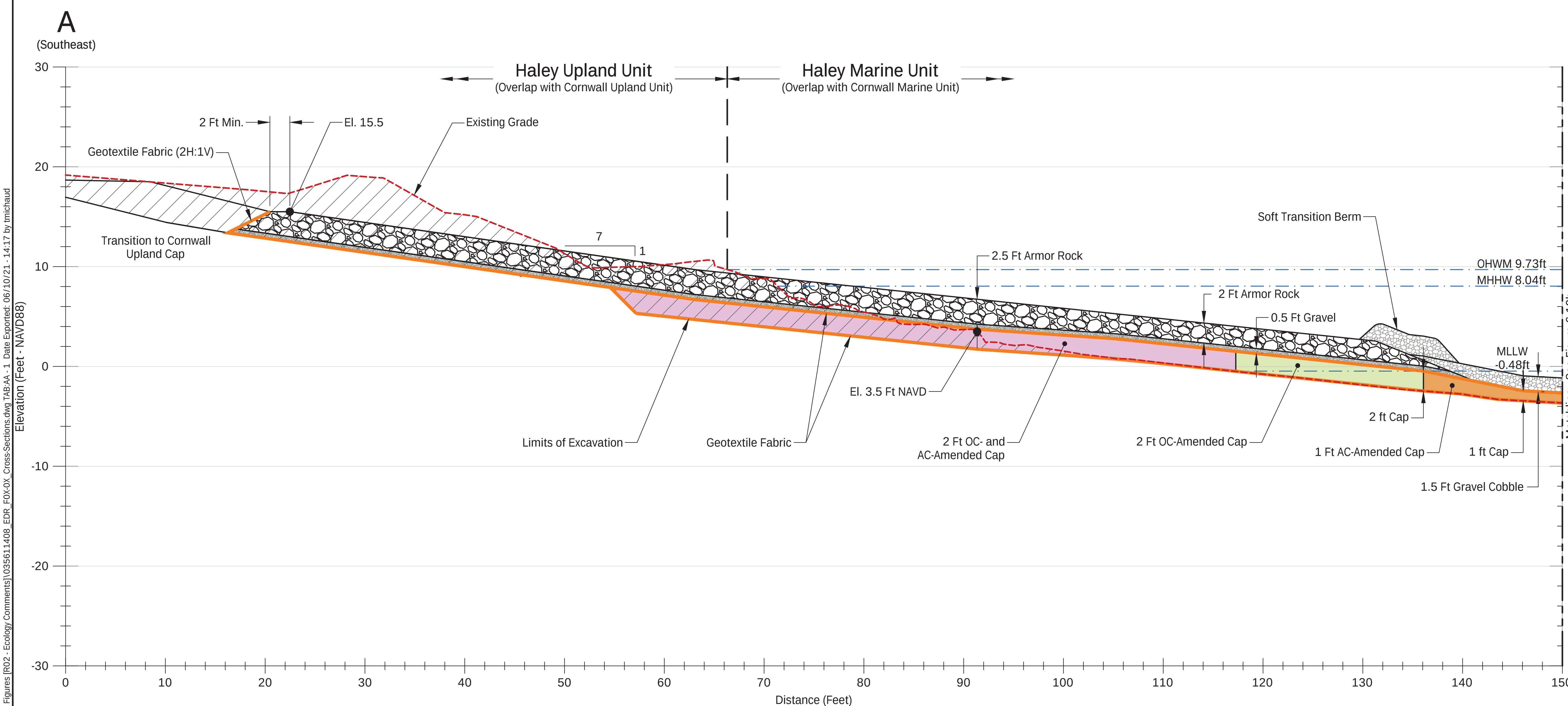
Figure 6-18

P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures [R02 - Ecology Comments]\035611408_EDR_F06-17-20_Sediment Excavation Cross-Sections.dwg TAB:CC - 1 Date Exported: 06/10/21 - 12:04 by tmichaud



Legend

	Organoclay (OC) and Activated Carbon (AC) Amended Sand Cap
	Organoclay (OC) Amended Sand Cap
	Activated Carbon (AC) Amended Sand Cap
	Combined Gravelly Sand Thin Layer Containment Cap and Seafloor Erosion Protection (D50 = 0.4 Inch)
	Excavation of Sediment and/or Debris
	Geotextile Fabric
	Existing Surface

	Average (D50) Grain Size
Armor Rock	0.8 Feet
Gravel	-
Gravel Cobble	1.5 Inch

10 0 10
Horizontal Scale in Feet

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

Cross-Section A-A'
(1 of 2)

R.G. Haley Site
Bellingham, Washington

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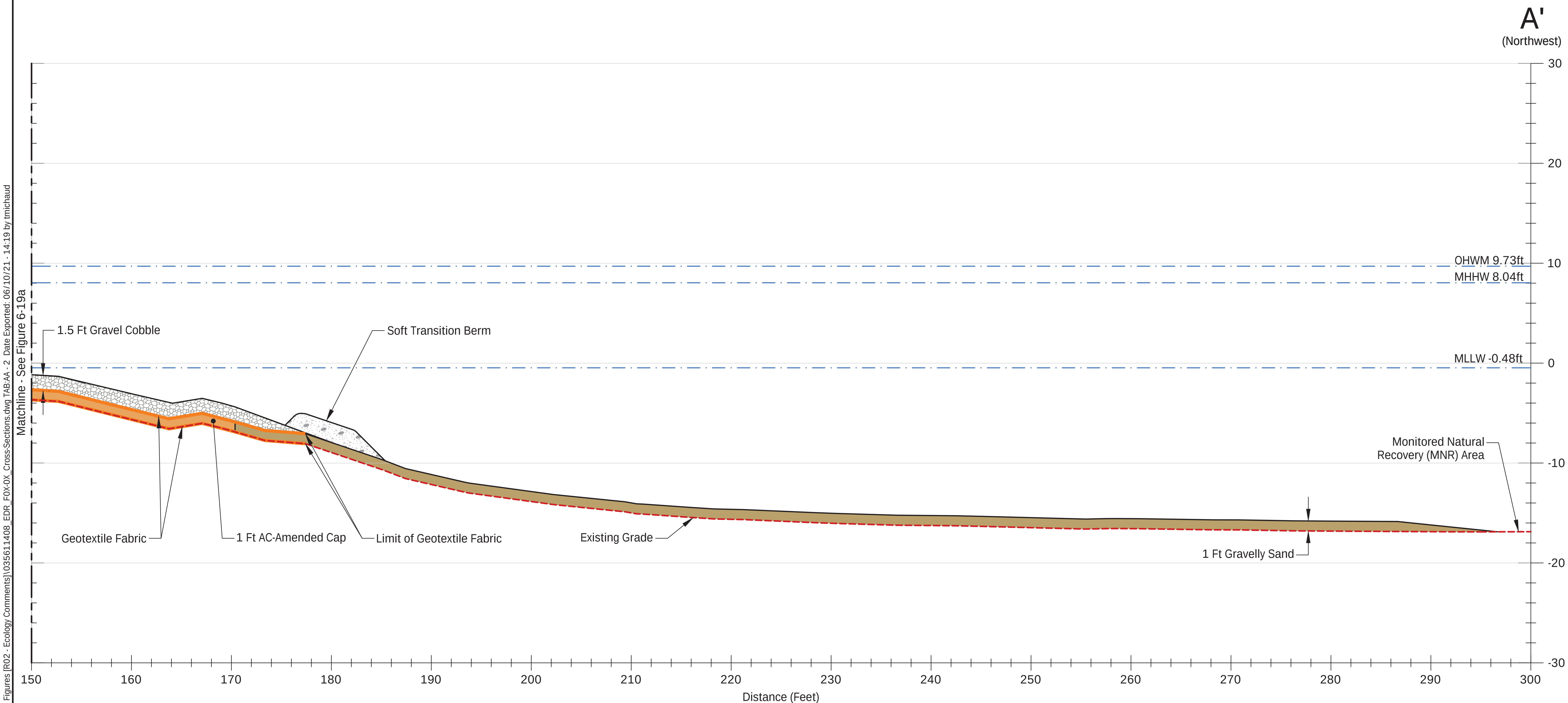
Figure 6-19a

P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures\[R02 - Ecology Comments]\0356114\08_EDR_F0X-0X_Cross-Sections.dwg TAB:AA - 1 Date Exported: 06/10/21 - 14:17 by tmichaud



Legend

Orange fill	Activated Carbon (AC) Amended Sand Cap
Tan fill	Combined Gravelly Sand Thin Layer Containment Cap and Seafloor Erosion Protection (D50 = 0.4 Inch)
Orange line	Geotextile Fabric
Red dashed line	Existing Surface

	Average (D50) Grain Size
Gravel Cobble	1.5 Inch
Gravelly Sand Erosion Protection	0.4 Inch

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

Cross-Section A-A' (2 of 2)

R.G. Haley Site
Bellingham, Washington

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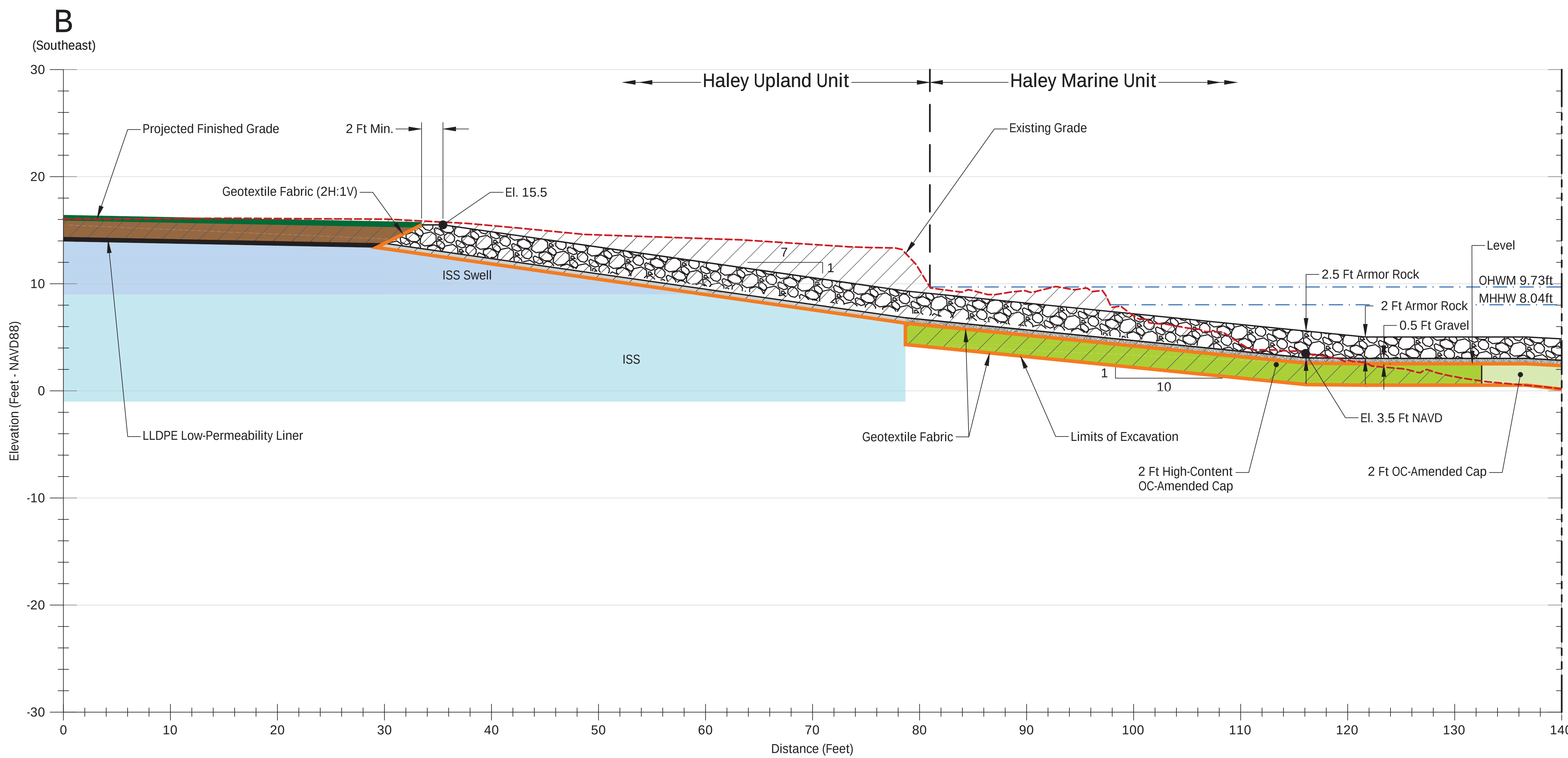
Figure 6-19b

P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures [R02 - Ecology Comments]\035611408_EDR_F0X-0X_Cross-Sections.dwg TAB:AA - 2 Date Exported: 06/10/21 - 14:19 by tmichaud



Legend

Approximate Extent of ISS	Excavation of Sediment and/or Debris	Armor Rock	Average (D50) Grain Size 0.8 Feet
Estimated ISS Swell	Geotextile Fabric	Gravel	-
Upland Low-Permeability Vegetated Capping System	Existing Surface		
High-Content Organoclay (OC) Amended Sand Cap	Upland Cap Lining System		
Organoclay (OC) Amended Sand Cap			

10 0 10
Horizontal Scale in Feet

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

Cross-Section B-B'
(1 of 3)

R.G. Haley Site
Bellingham, Washington

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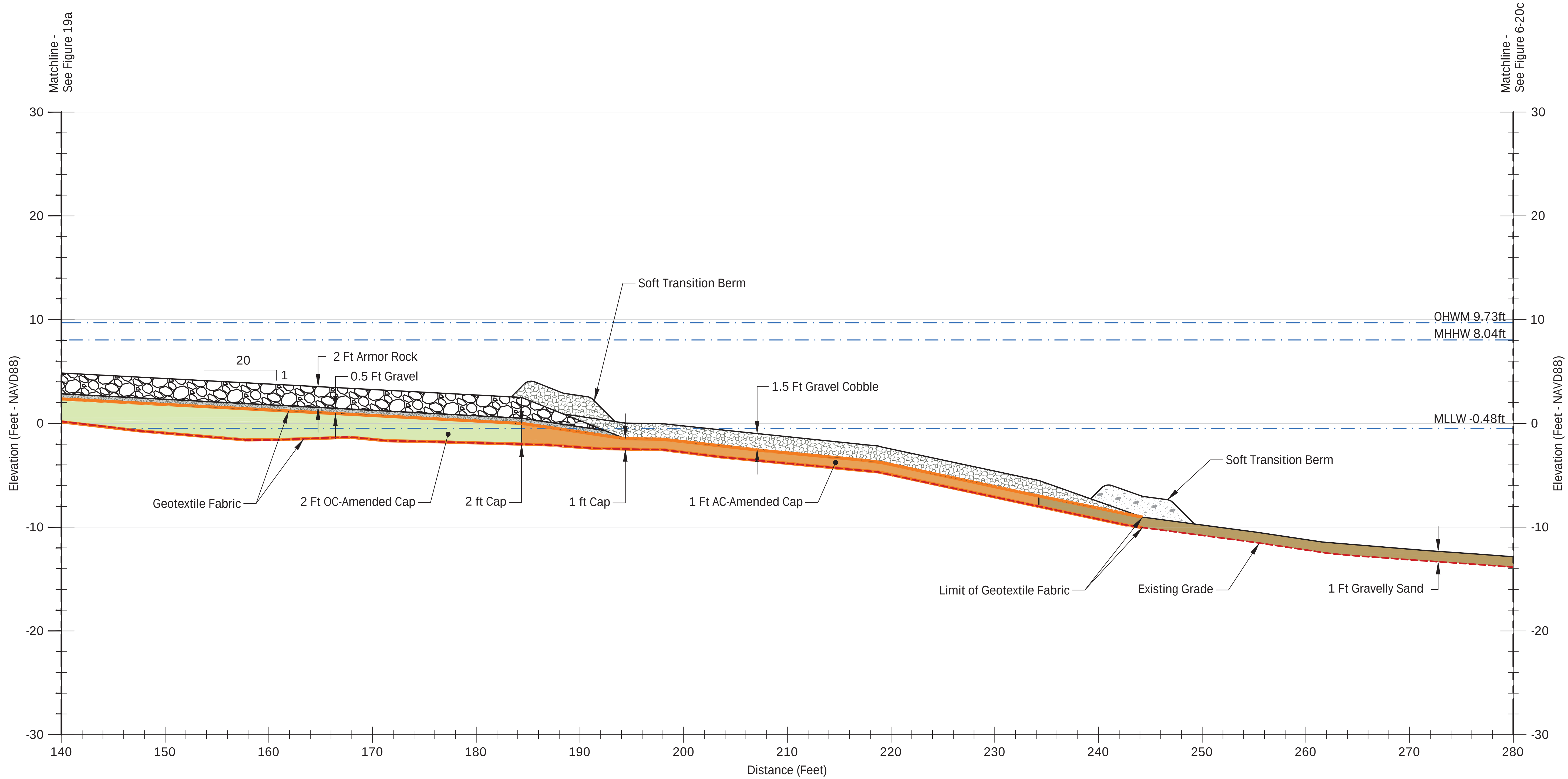
Figure 6-20a

P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures [R02 - Ecology Comments]\035611408_EDR_F0X-0X_Cross-Sections.dwg TAB:BB - 1 Date Exported: 06/10/21 - 14:19 by tmichaud



Legend

Organoclay (OC) Amended Sand Cap	
Activated Carbon (AC) Amended Sand Cap	
Combined Gravelly Sand Thin Layer Containment Cap and Seafloor Erosion Protection (D50 = 0.4 Inch)	
Excavation of Sediment and/or Debris	
Geotextile Fabric	
Existing Surface	

	Average (D50) Grain Size
Armor Rock	0.8 Feet
Gravel	-
Gravel Cobble	1.5 Inch
Gravelly Sand Erosion Protection	0.4 Inch

10 0 10
Horizontal Scale in Feet

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

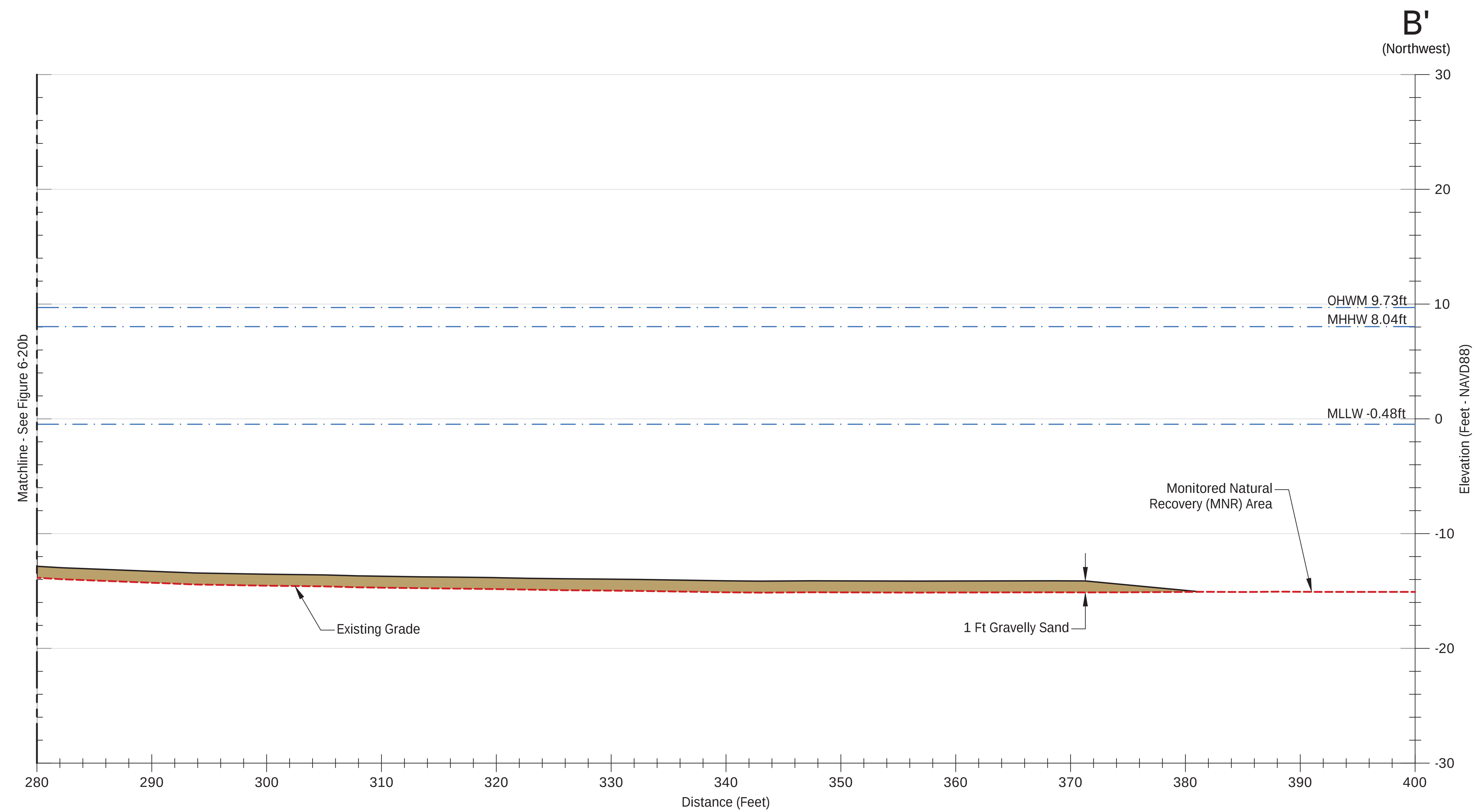
Cross-Section B-B'
(2 of 3)

R.G. Haley Site
Bellingham, Washington

GeoEngineers

Figure 6-20b

P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures [R02 - Ecology Comments]\035611408_EDR_F0X-0X_Cross-Sections.dwg TAB:BB - 2 Date Exported: 06/10/21 - 14:19 by tmichaud



Legend

- Combined Gravelly Sand Thin Layer Containment Cap and Seafloor Erosion Protection (D50 = 0.4 Inch)
- Existing Surface

10 0 10
Horizontal Scale in Feet

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

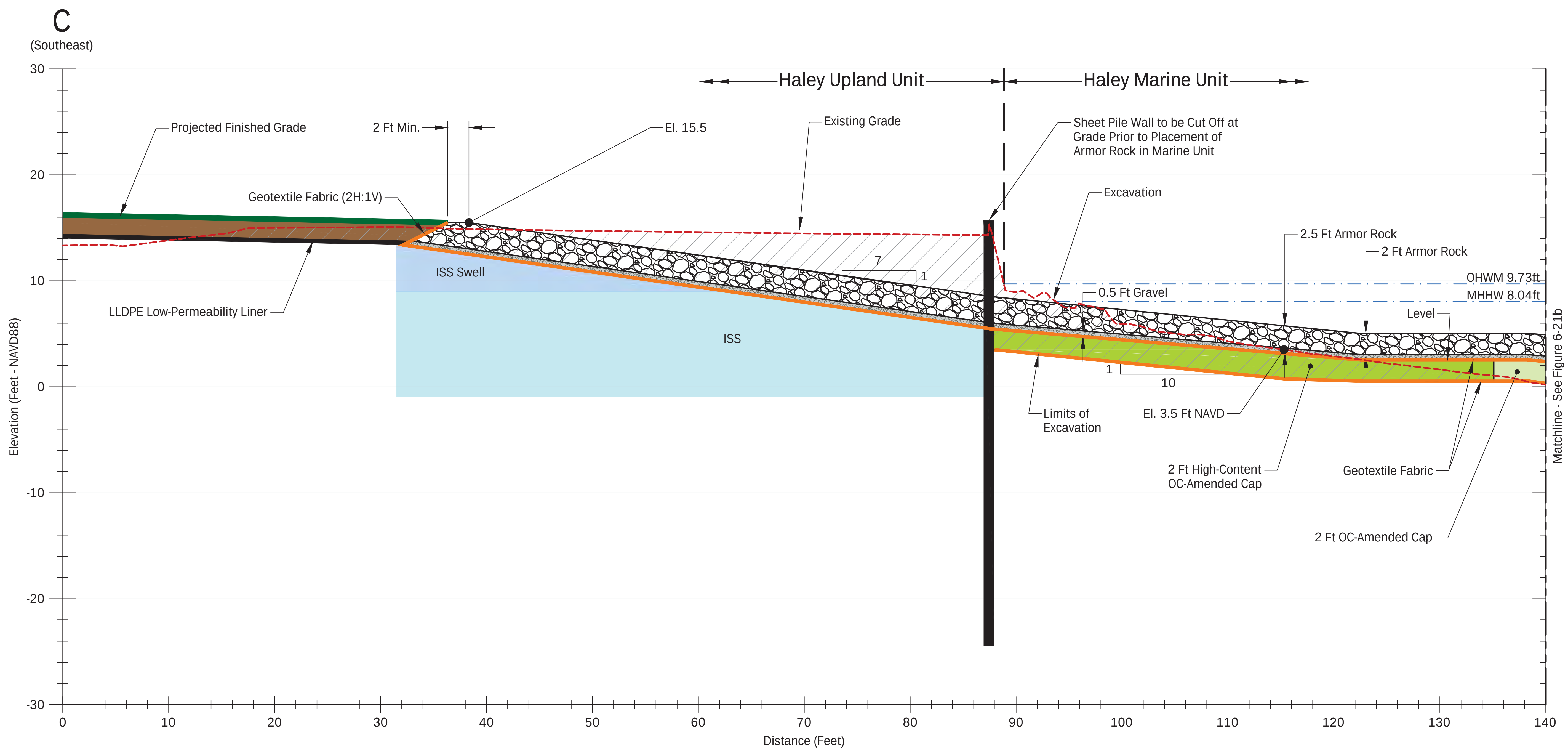
Cross-Section B-B'
(3 of 3)

R.G. Haley Site
Bellingham, Washington

GeoEngineers

Figure 6-20c

P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures [R02 - Ecology Comments]\035611408_EDR_F0X-0X_Cross-Sections.dwg TAB:BB - 3 Date Exported: 06/10/21 - 14:20 by tmichaud



Legend

Approximate Extent of ISS	Excavation of Sediment and/or Debris
Estimated ISS Swell	Geotextile Fabric
Upland Low-Permeability Vegetated Capping System	Existing Surface
High-Content Organoclay (OC) Amended Sand Cap	Upland Cap Lining System
Organoclay (OC) Amended Sand Cap	

	Average (D50) Grain Size
Armor Rock	0.8 Feet
Gravel	-

Horizontal Scale in Feet
Vertical Scale in Feet
Vertical Exaggeration: 1X

Cross-Section C-C'
(1 of 4)

R.G. Haley Site
Bellingham, Washington

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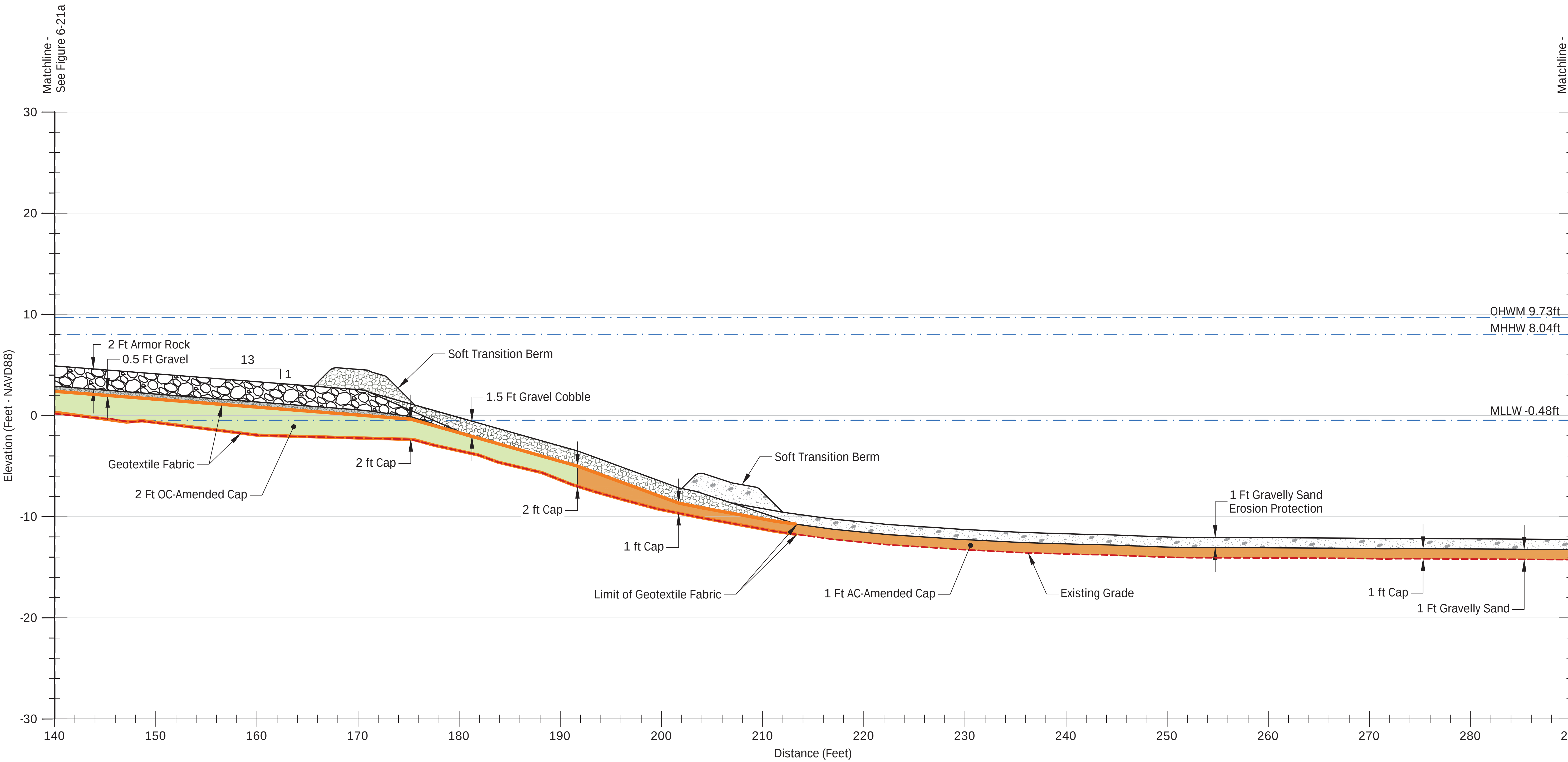
Figure 6-21a

P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures [R02 - Ecology Comments]\035611408_EDR_F0X-0X_Cross-Sections.dwg TAB:CC - 1 Date Exported: 06/10/21 - 14:20 by tmichaud



Legend

Organoclay (OC) Amended Sand Cap		
Activated Carbon (AC) Amended Sand Cap		
Excavation of Sediment and/or Debris		
Geotextile Fabric		
Existing Surface		
Armor Rock	Average (D50) Grain Size	0.8 Feet
Gravel		
Gravel Cobble		1.5 Inch
Gravelly Sand Erosion Protection		0.4 Inch

10 0 10
Horizontal Scale in Feet

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

Cross-Section C-C'
(2 of 4)

R.G. Haley Site
Bellingham, Washington

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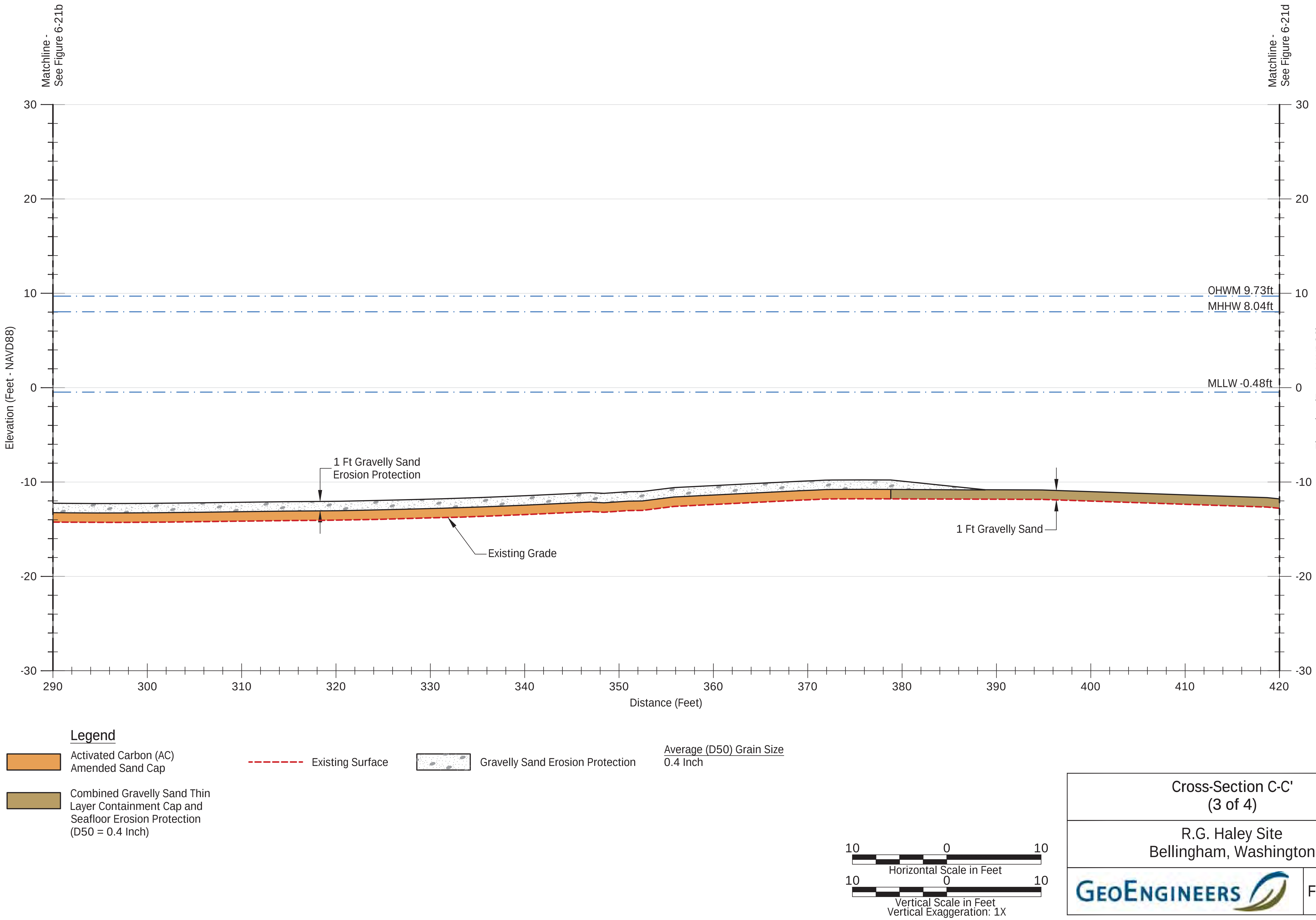
Figure 6-21b

P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures [R02 - Ecology Comments]\035611408_EDR_F0X-0X Cross-Sections.dwg TAB:CC - 2 Date Exported: 06/10/21 - 14:20 by tmichaud



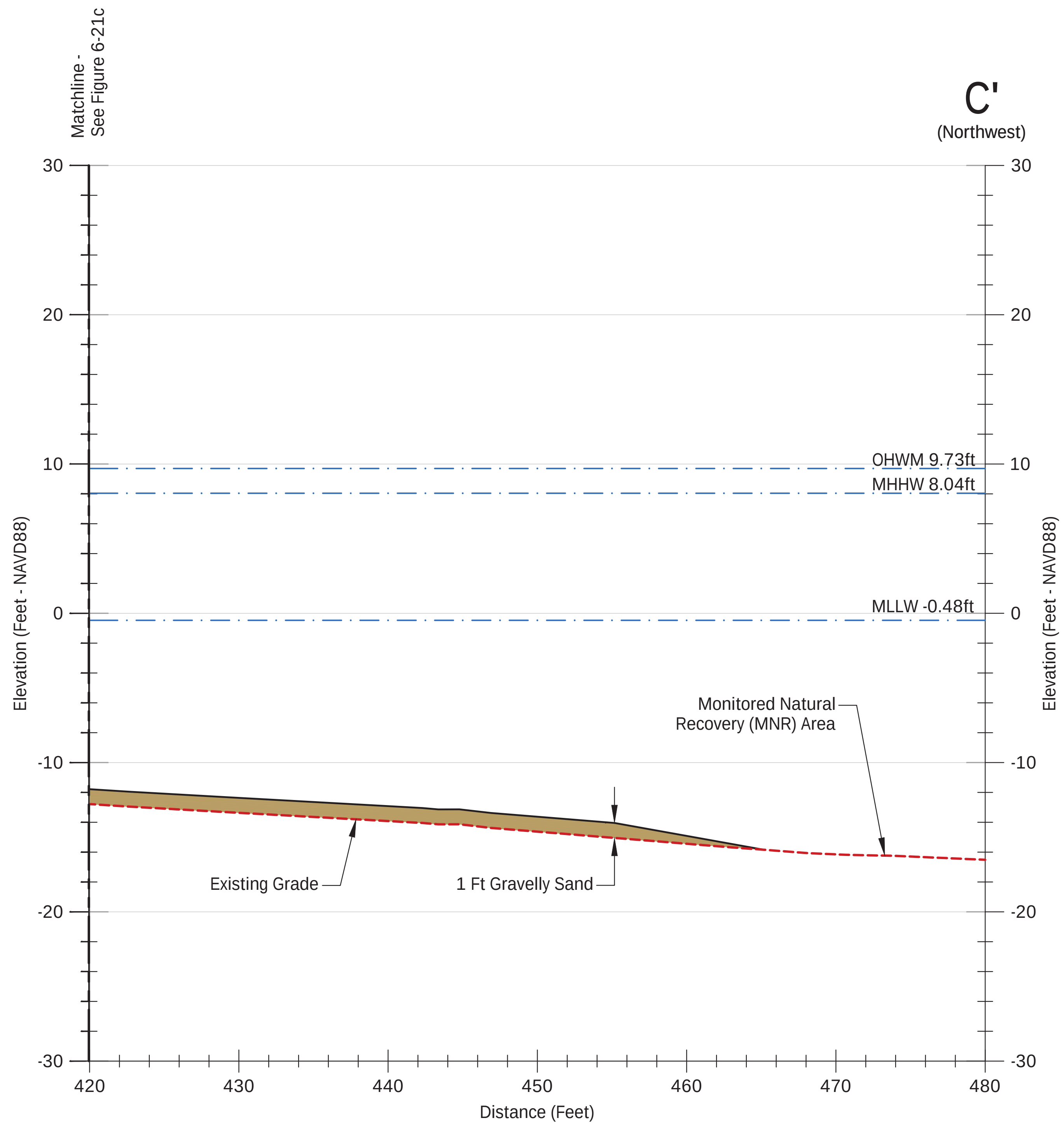
Cross-Section C-C'
(3 of 4)

R.G. Haley Site
Bellingham, Washington

GeoEngineers

Figure 6-21c

P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures [R02 - Ecology Comments]\035611408_EDR_F0X-0X_Cross-Sections.dwg TAB:CC - 3 Date Exported: 06/10/21 - 14:21 by tmichaud



Legend

Combined Gravelly Sand Thin Layer Containment Cap and Seafloor Erosion Protection (D50 = 0.4 Inch)

Existing Surface

10 0 10
Horizontal Scale in Feet

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

Cross-Section C-C'
(4 of 4)

R.G. Haley Site
Bellingham, Washington

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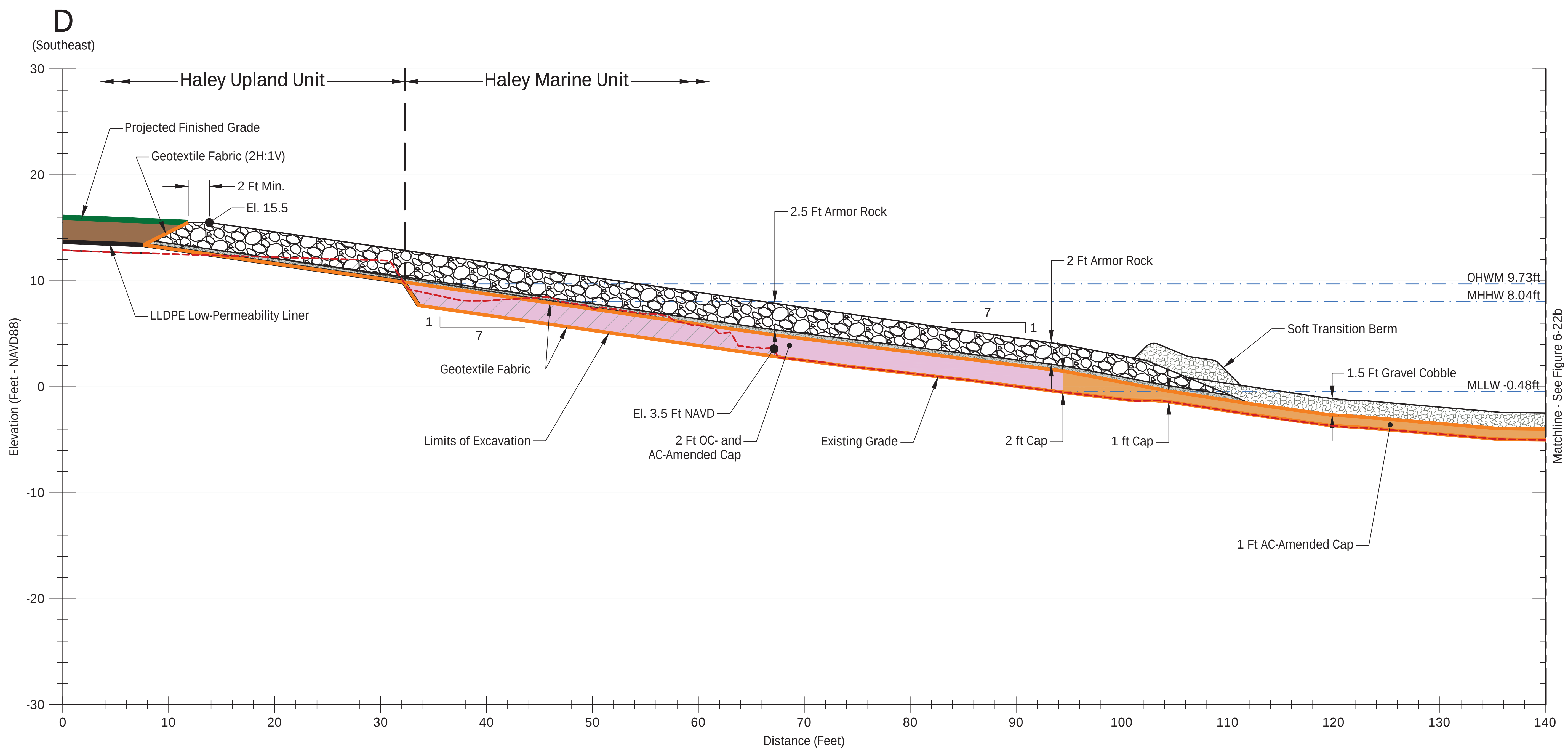
Figure 6-21d

P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures [R02 - Ecology Comments]\035611408_EDR_F0X-0X_Cross-Sections.dwg TAB:CC - 4 Date Exported: 06/10/21 - 14:21 by tmichaud



Legend

Upland Low-Permeability Vegetated Capping System	
Organoclay (OC) and Activated Carbon (AC) Amended Sand Cap	
Activated Carbon (AC) Amended Sand Cap	
Excavation of Sediment and/or Debris	
Geotextile Fabric	
Existing Surface	
Upland Cap Lining System	

	Average (D50) Grain Size
Armor Rock	0.8 Feet
Gravel	
Gravel Cobble	1.5 Inch

10 0 10
Horizontal Scale in Feet

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

Cross-Section D-D'
(1 of 4)

R.G. Haley Site
Bellingham, Washington

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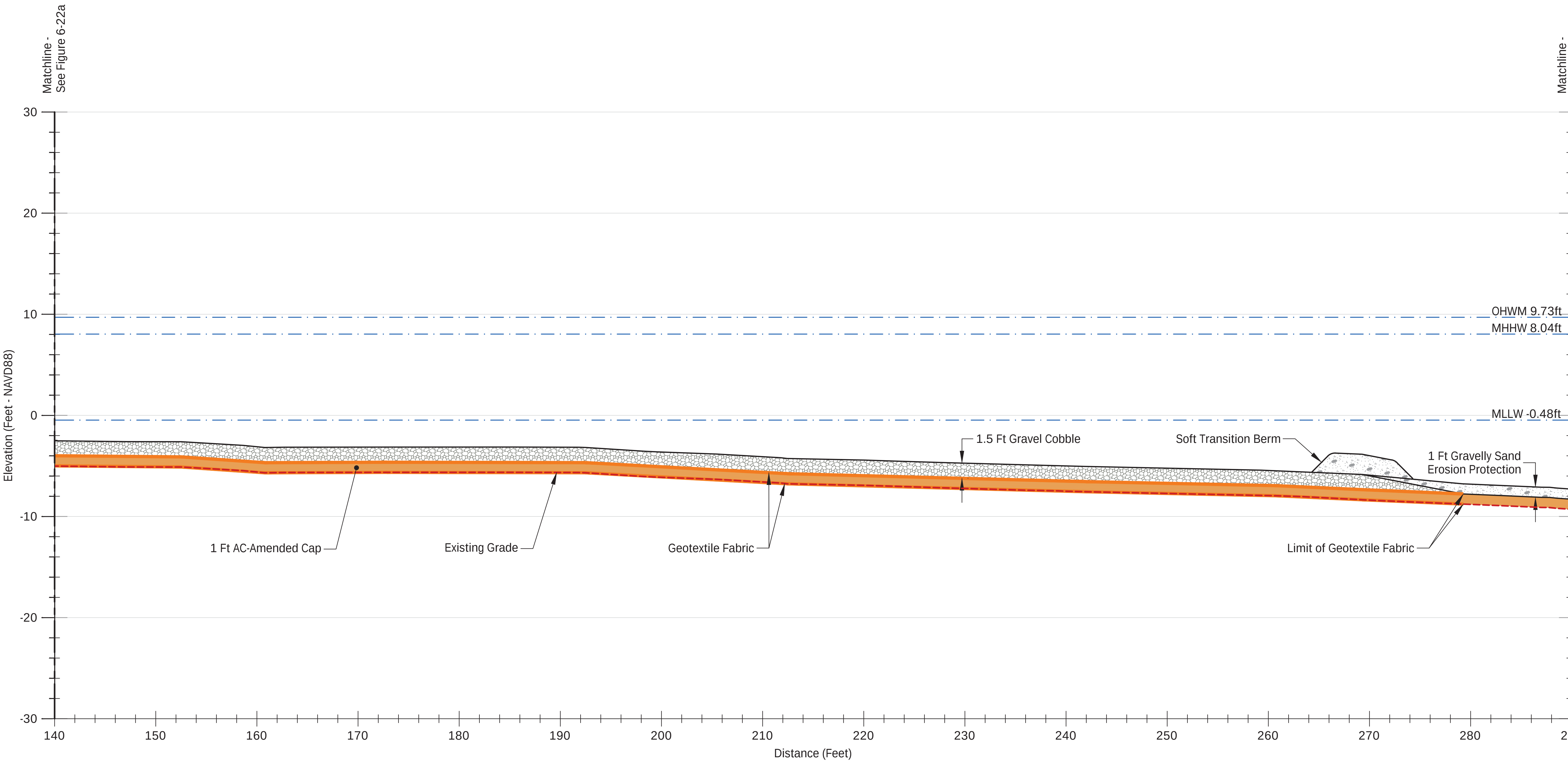
Figure 6-22a

P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures [R02 - Ecology Comments]\035611408_EDR_F0X-0X_Cross-Sections.dwg TAB:DD - 1 Date Exported: 06/10/21 - 14:21 by tmichaud



Legend

		Average (D50) Grain Size
	Activated Carbon (AC) Amended Sand Cap	
	Geotextile Fabric	
	Existing Surface	
	Gravel Cobble	1.5 Inch
	Gravelly Sand Erosion Protection	0.4 Inch

10 0 10
Horizontal Scale in Feet

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

Cross-Section D-D'
(2 of 4)

R.G. Haley Site
Bellingham, Washington

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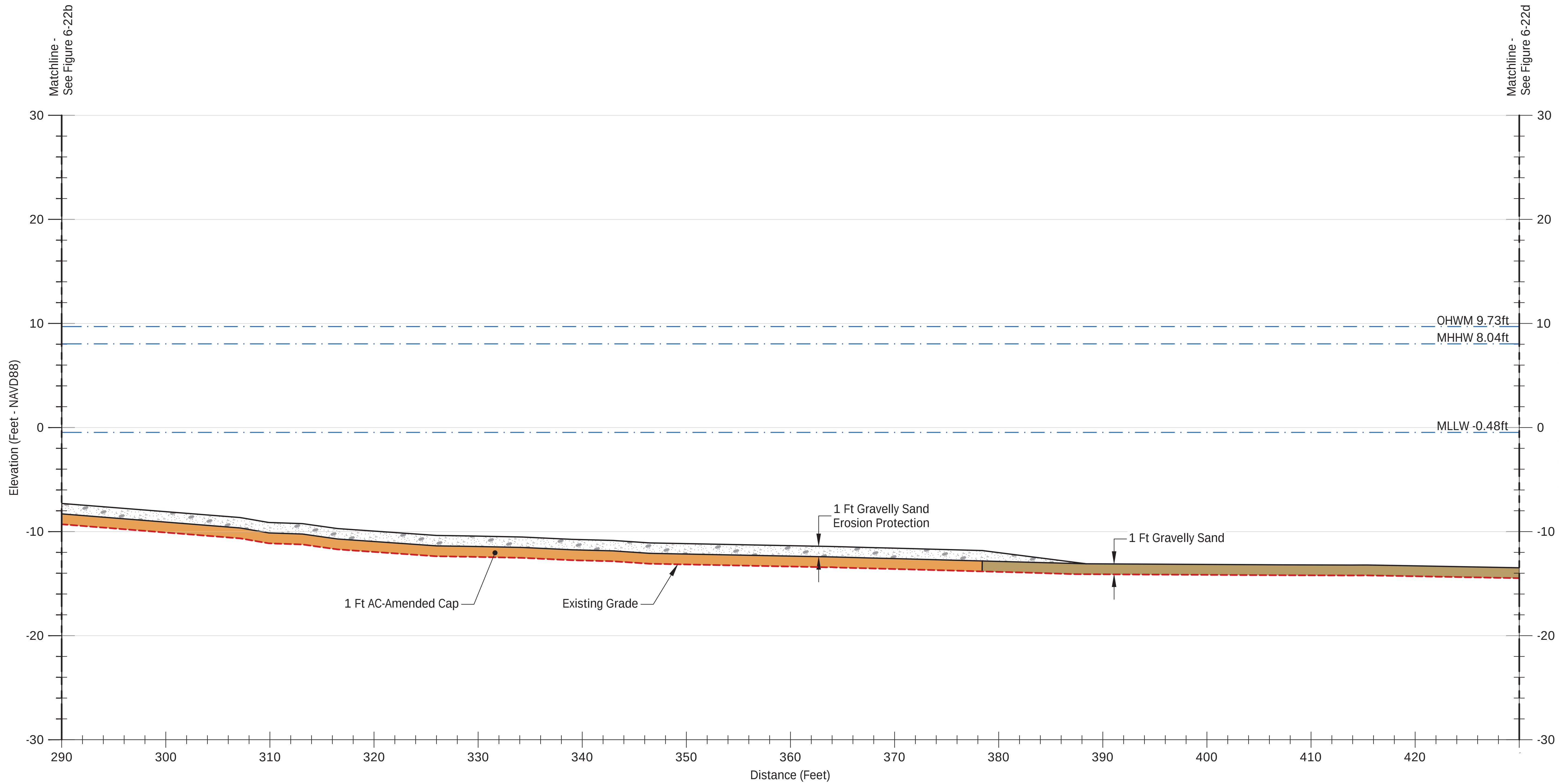
Figure 6-22b

P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures [R02 - Ecology Comments]\035611408_EDR_F0X-0X_Cross-Sections.dwg TAB:DD - 2 Date Exported: 06/10/21 - 14:23 by tmichaud



Legend

- Activated Carbon (AC) Amended Sand Cap
- Existing Surface
- Gravelly Sand Erosion Protection
- Combined Gravelly Sand Thin Layer Containment Cap and Seafloor Erosion Protection (D50 = 0.4 Inch)

Average (D50) Grain Size
0.4 Inch

10 0 10
Horizontal Scale in Feet

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

Cross-Section D-D'
(3 of 4)

R.G. Haley Site
Bellingham, Washington

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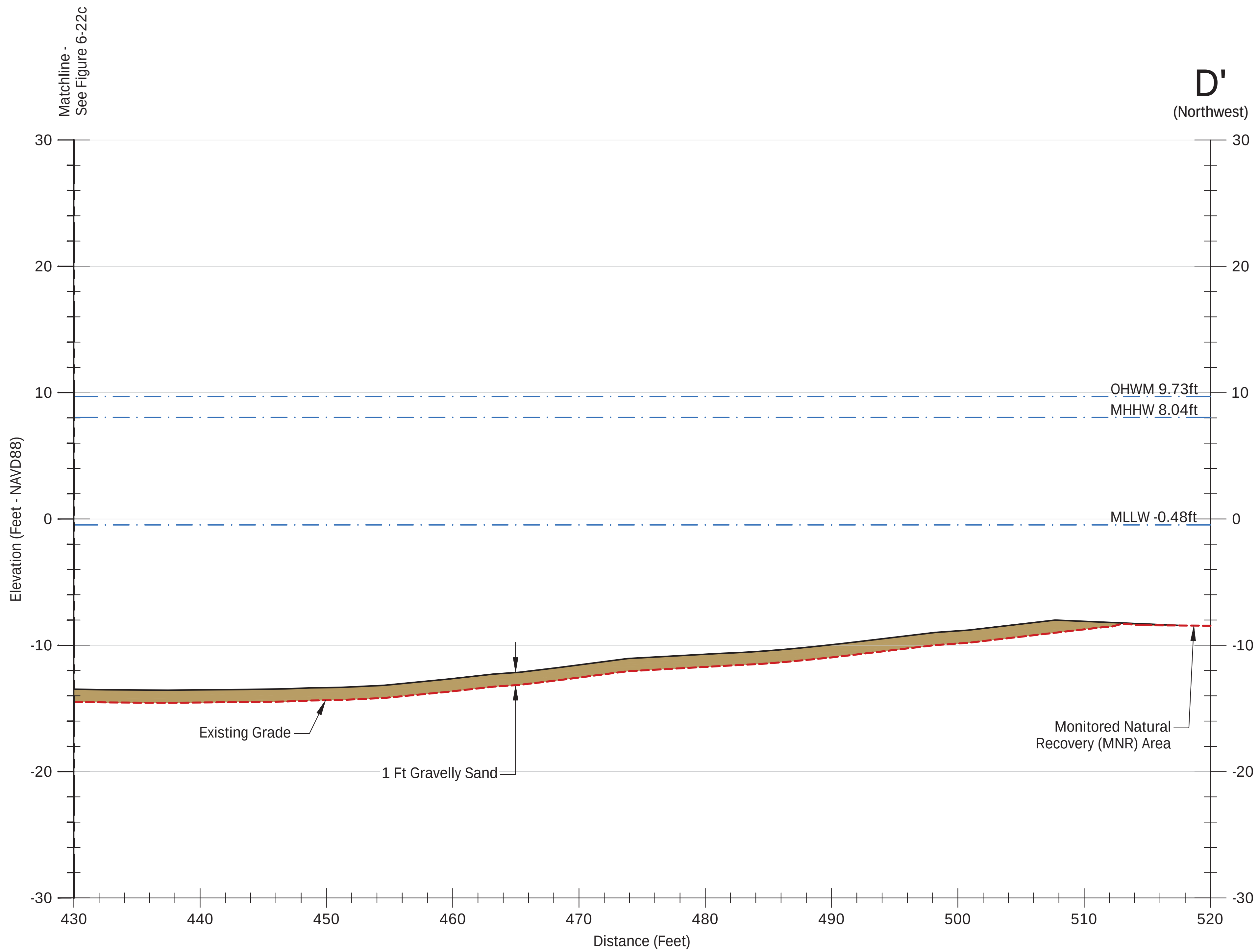
Figure 6-22c

P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures [R02 - Ecology Comments]\035611408_EDR_F0X-0X_Cross-Sections.dwg TAB:DD - 3 Date Exported: 06/10/21 - 14:23 by tmichaud



Legend

Combined Gravelly Sand Thin Layer Containment Cap and Seafloor Erosion Protection (D50 = 0.4 Inch)

Existing Surface

10 0 10
Horizontal Scale in Feet

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

Cross-Section D-D'
(4 of 4)

R.G. Haley Site
Bellingham, Washington

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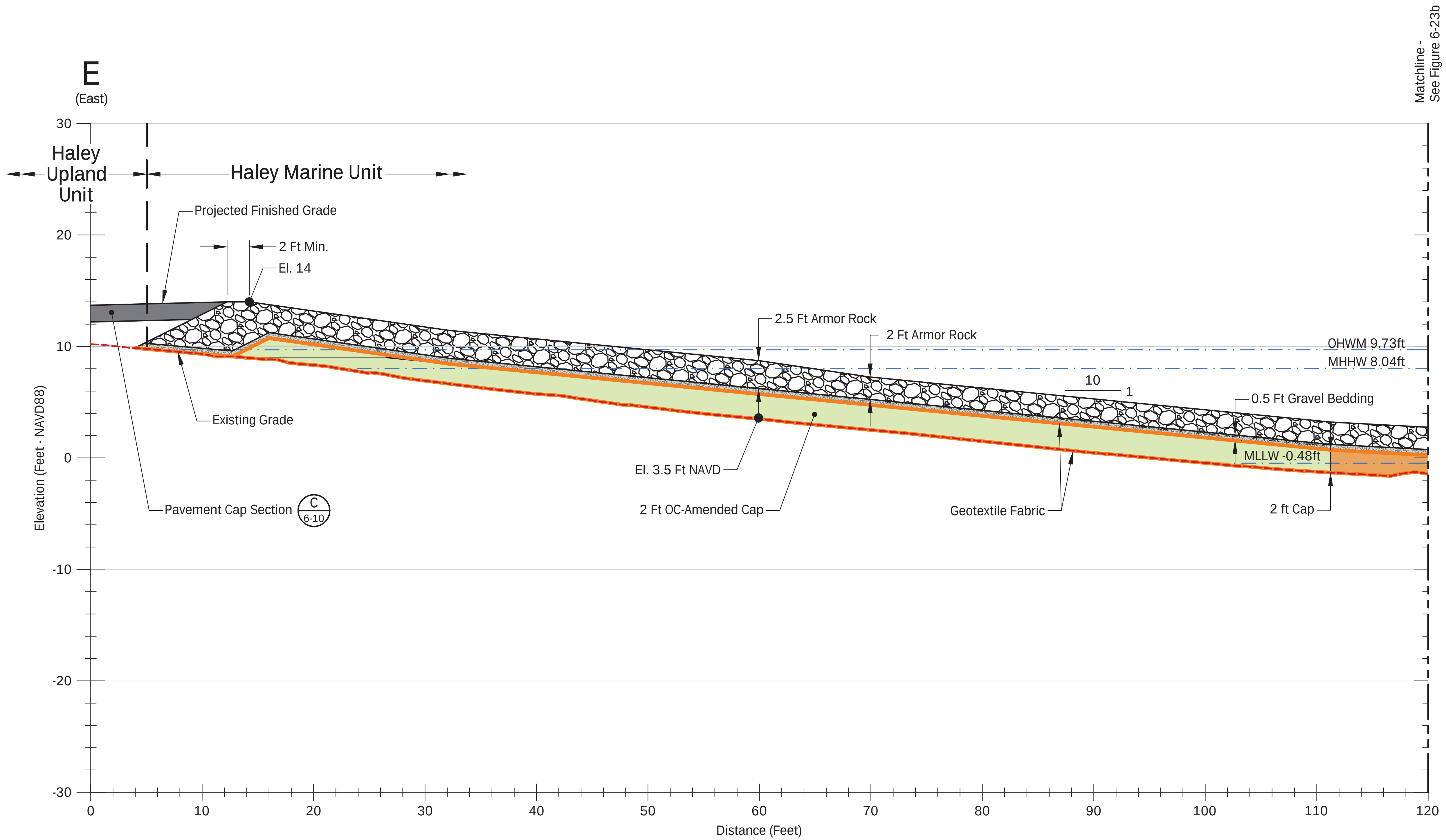
Figure 6-22d

P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures [R02 - Ecology Comments]\035611408_EDR_F0X-0X_Cross-Sections.dwg TAB:DD - 4 Date Exported: 06/10/21 - 14:24 by tmichaud



Legend

- Pavement Cap Section
- Organoclay (OC) Amended Sand Cap
- Activated Carbon (AC) Amended Sand Cap
- Geotextile Fabric
- Existing Surface
- Armor Rock
- Gravel

Average (D50) Grain Size
0.8 Feet

10 0 10
Horizontal Scale in Feet

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

Cross-Section E-E'
(1 of 6)

R.G. Haley Site
Bellingham, Washington

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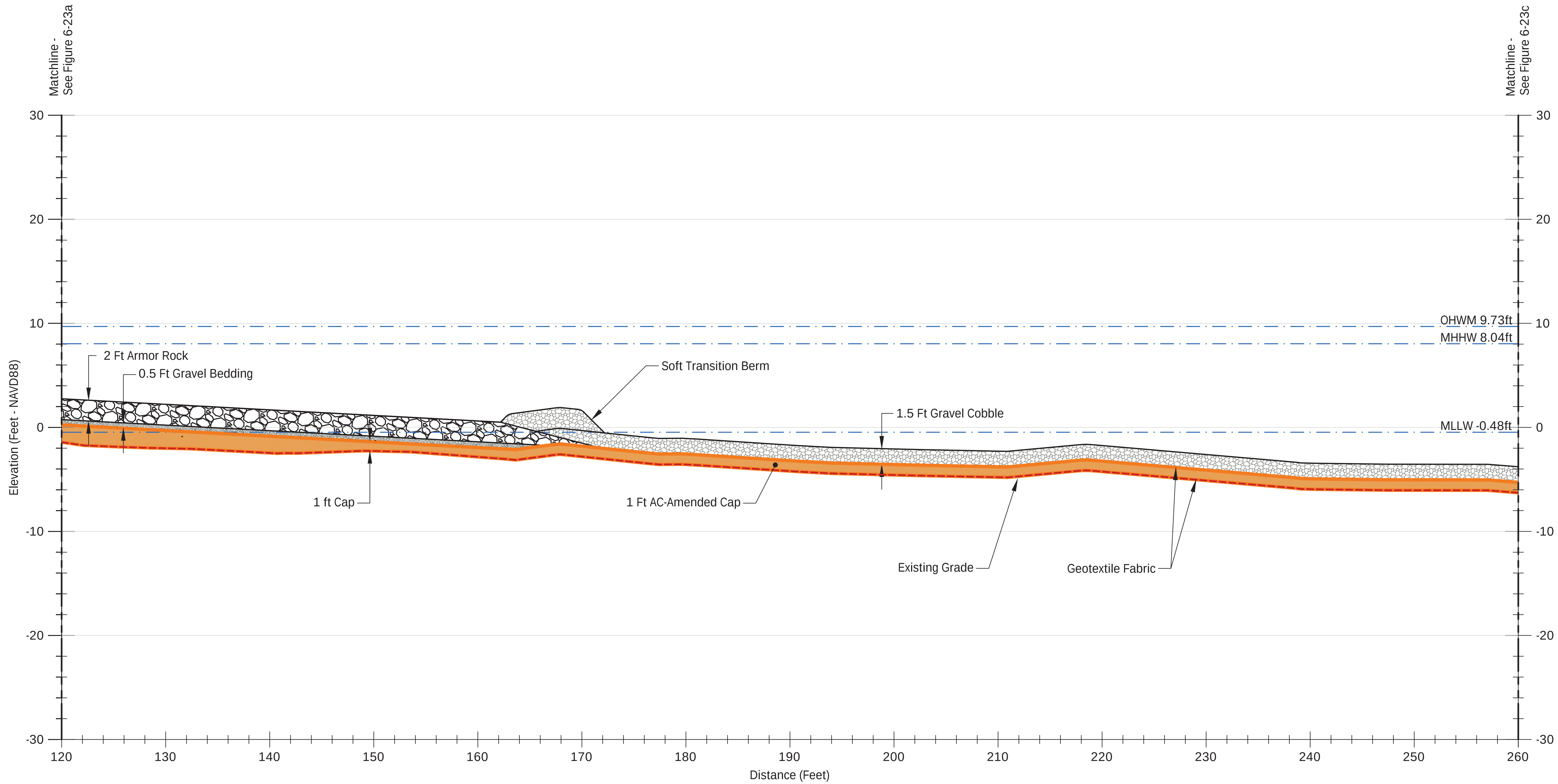
Figure 6-23a

P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures [R02 - Ecology Comments]\035611408_EDR_F0X-0X_Cross-Sections.dwg TAB:EE - 1 Date Exported: 06/10/21 - 14:24 by tmichaud



Legend

Legend			Average (D50) Grain Size
Organoclay (OC) Amended Sand Cap	Geotextile Fabric	Armor Rock	0.8 Feet
Activated Carbon (AC) Amended Sand Cap	Existing Surface	Gravel	-
		Gravel Cobble	1.5 Inch

10 0 10
Horizontal Scale in Feet

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

Cross-Section E-E'
(2 of 6)

R.G. Haley Site
Bellingham, Washington

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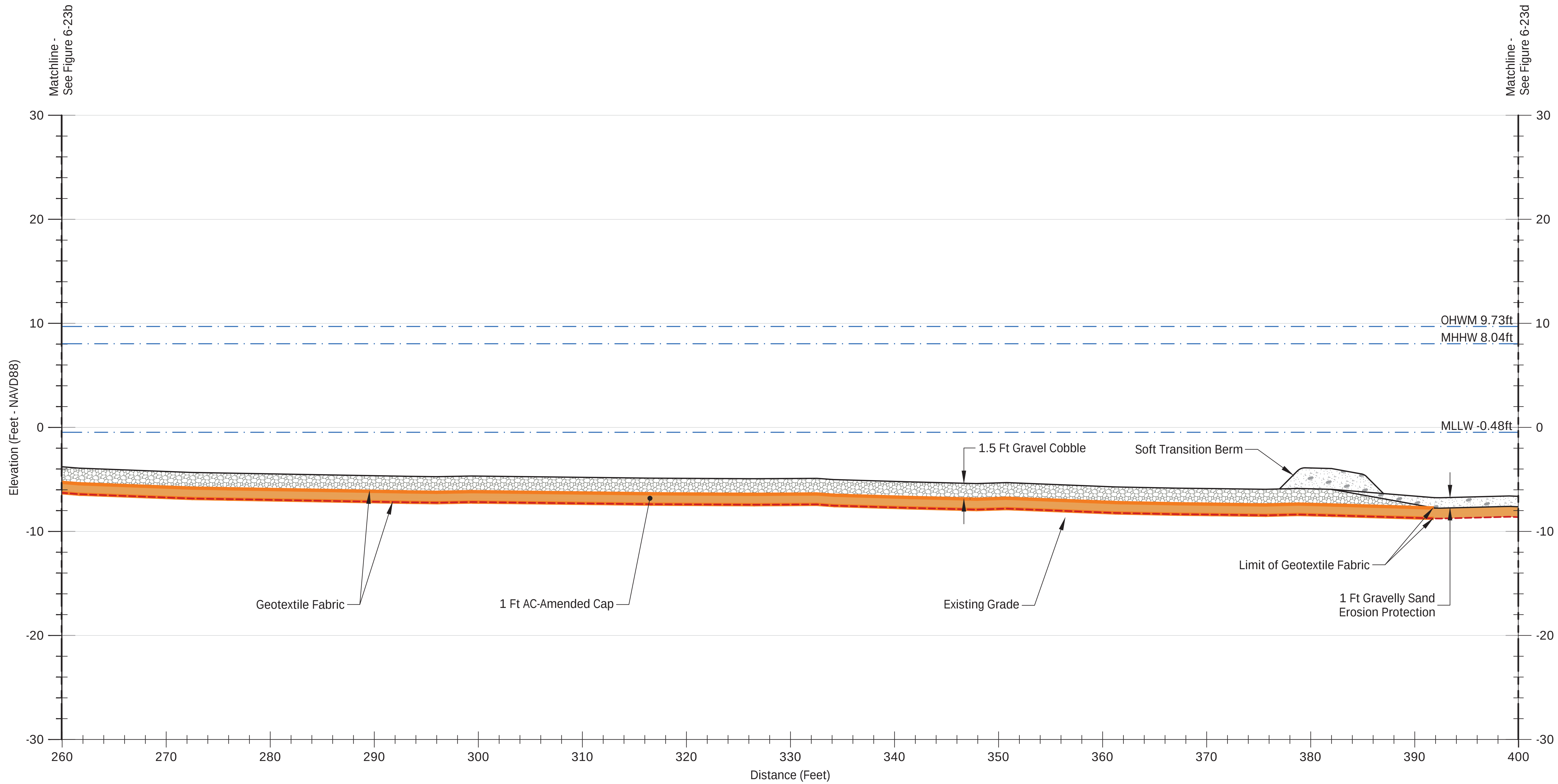
Figure 6-23b

P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures [R02 - Ecology Comments]\035611408_EDR_F0X-0X_Cross-Sections.dwg TAB:EE - 2 Date Exported: 06/10/21 - 14:24 by tmichaud



Legend

Legend		Average (D50) Grain Size
Activated Carbon (AC) Amended Sand Cap		
Geotextile Fabric	Gravel Cobble	1.5 Inch
Existing Surface	Gravelly Sand Erosion Protection	0.4 Inch

10 0 10
Horizontal Scale in Feet

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

Cross-Section E-E'
(3 of 6)

R.G. Haley Site
Bellingham, Washington

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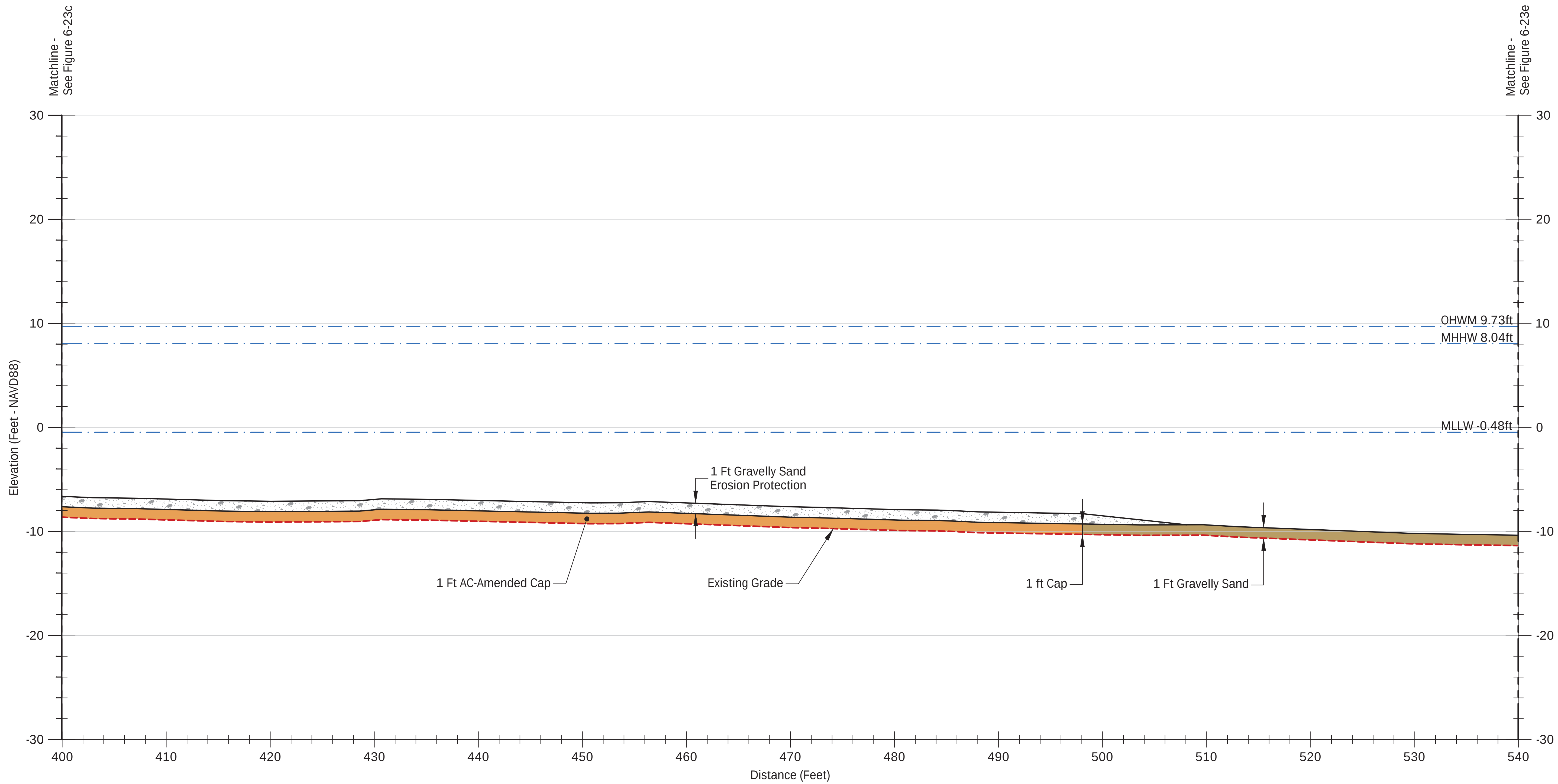
Figure 6-23c

P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures [R02 - Ecology Comments]\035611408_EDR_F0X-0X_Cross-Sections.dwg TAB:EE - 3 Date Exported: 06/10/21 - 14:24 by tmichaud



Legend

- Activated Carbon (AC) Amended Sand Cap
- Existing Surface
- Gravelly Sand Erosion Protection
- Combined Gravelly Sand Thin Layer Containment Cap and Seafloor Erosion Protection (D50 = 0.4 Inch)

Average (D50) Grain Size
0.4 Inch

10 0 10
Horizontal Scale in Feet

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

Cross-Section E-E'
(4 of 6)

R.G. Haley Site
Bellingham, Washington

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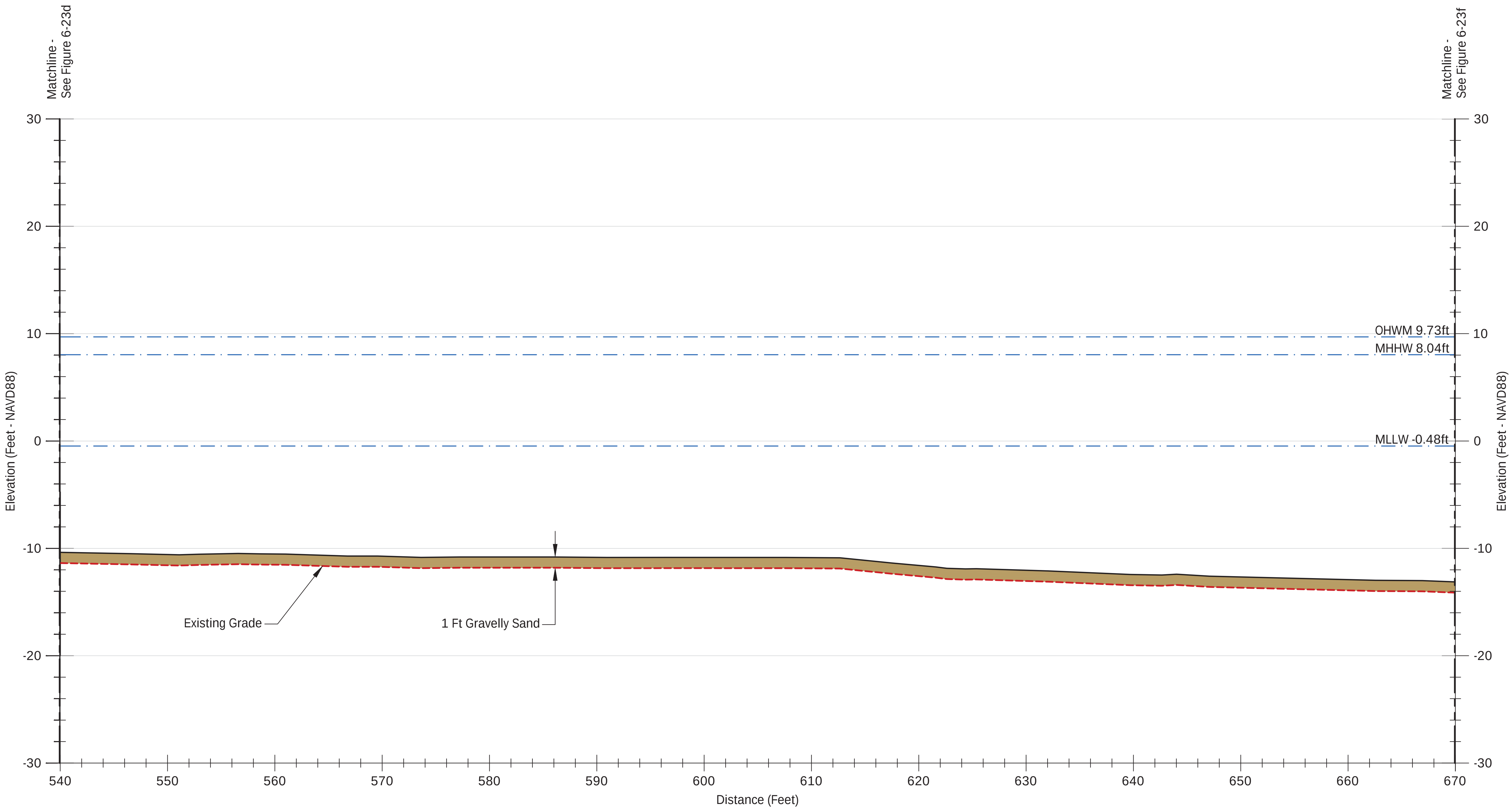
Figure 6-23d

P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures [R02 - Ecology Comments]\035611408_EDR_F0X-0X_Cross-Sections.dwg TAB:EE - 4 Date Exported: 06/10/21 - 14:25 by tmichaud



Legend

Combined Gravelly Sand Thin Layer Containment Cap and Seafloor Erosion Protection (D50 = 0.4 Inch)

Existing Surface

10 0 10
Horizontal Scale in Feet

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

Cross-Section E-E'
(5 of 6)

R.G. Haley Site
Bellingham, Washington

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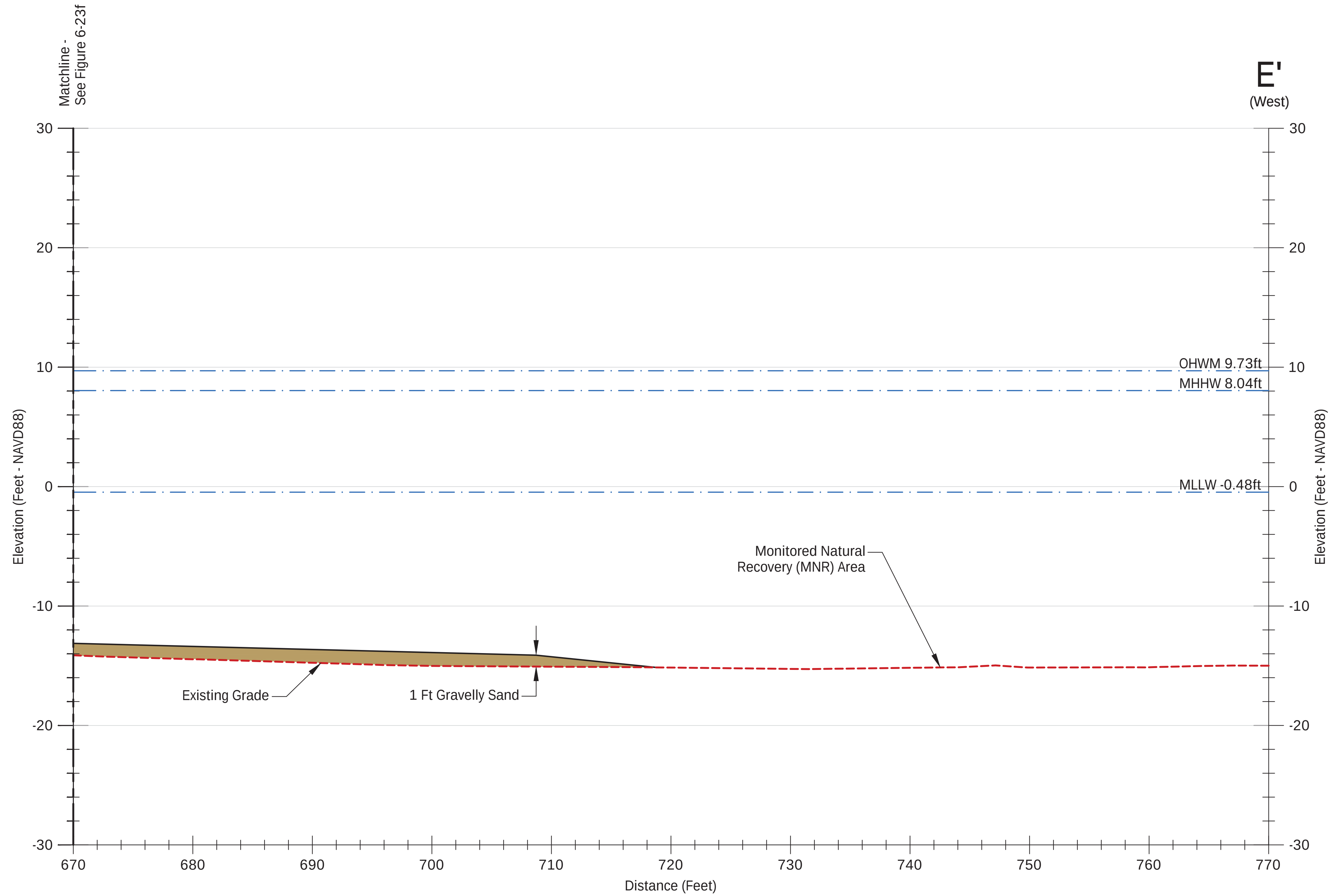
Figure 6-23e

P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures [R02 - Ecology Comments]\035611408_EDR_F0X-0X_Cross-Sections.dwg TAB:EE - 5 Date Exported: 06/10/21 - 14:25 by tmichaud



Legend

Combined Gravelly Sand Thin Layer Containment Cap and Seafloor Erosion Protection (D50 = 0.4 Inch)

Existing Surface

10 0 10
Horizontal Scale in Feet

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

Cross-Section E-E'
(6 of 6)

R.G. Haley Site
Bellingham, Washington

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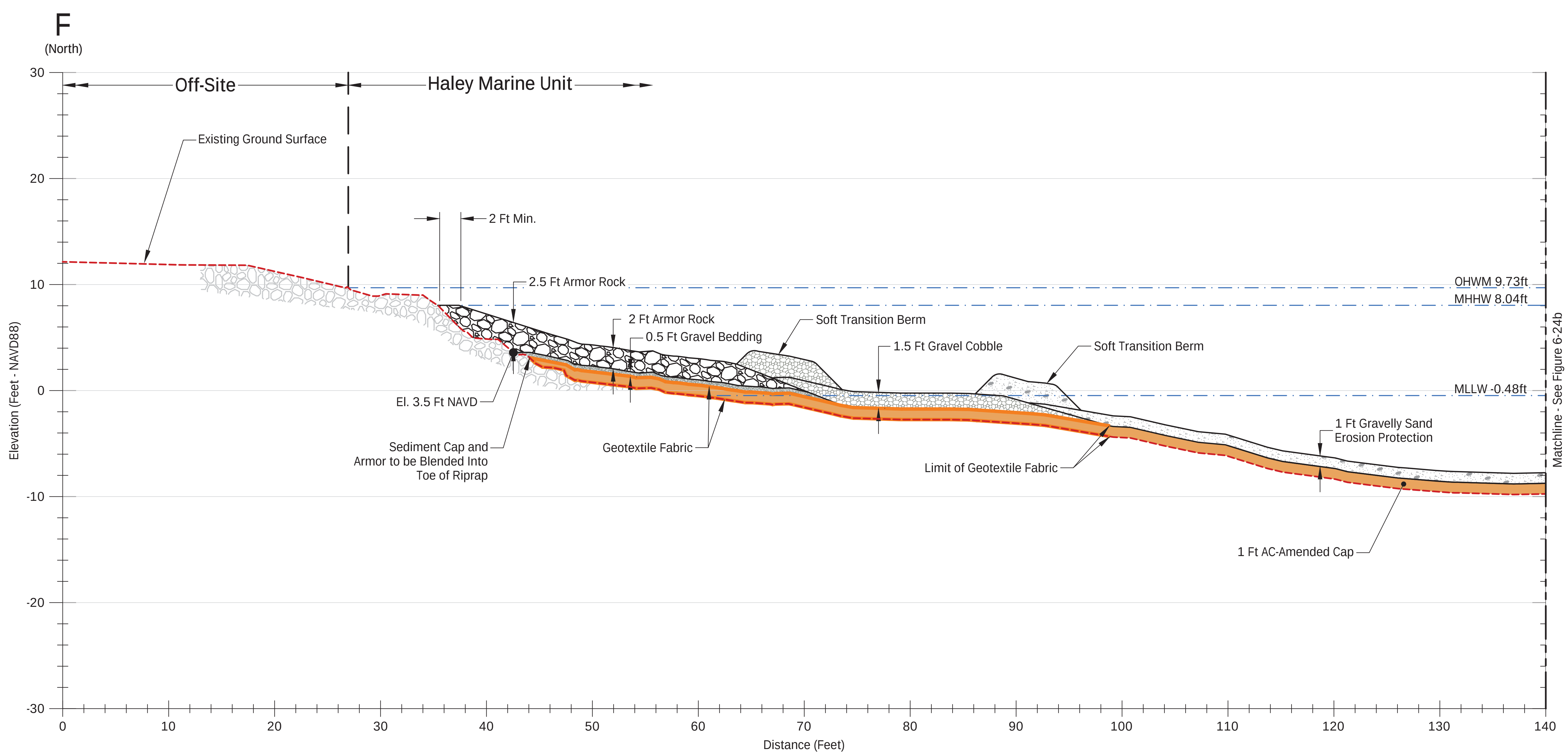
Figure 6-23f

P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures [R02 - Ecology Comments]\035611408_EDR_F0X-0X_Cross-Sections.dwg TAB:EE - 6 Date Exported: 06/10/21 - 14:25 by tmichaud



Legend

Activated Carbon (AC) Amended Sand Cap		
Existing Bank Riprap to Remain		
Geotextile Fabric		
Existing Surface		
		Average (D50) Grain Size
Armor Rock		0.8 Feet
Gravel		-
Gravel Cobble		1.5 Inch
Gravelly Sand Erosion Protection		0.4 Inch

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

Cross-Section F-F'
(1 of 4)

R.G. Haley Site
Bellingham, Washington

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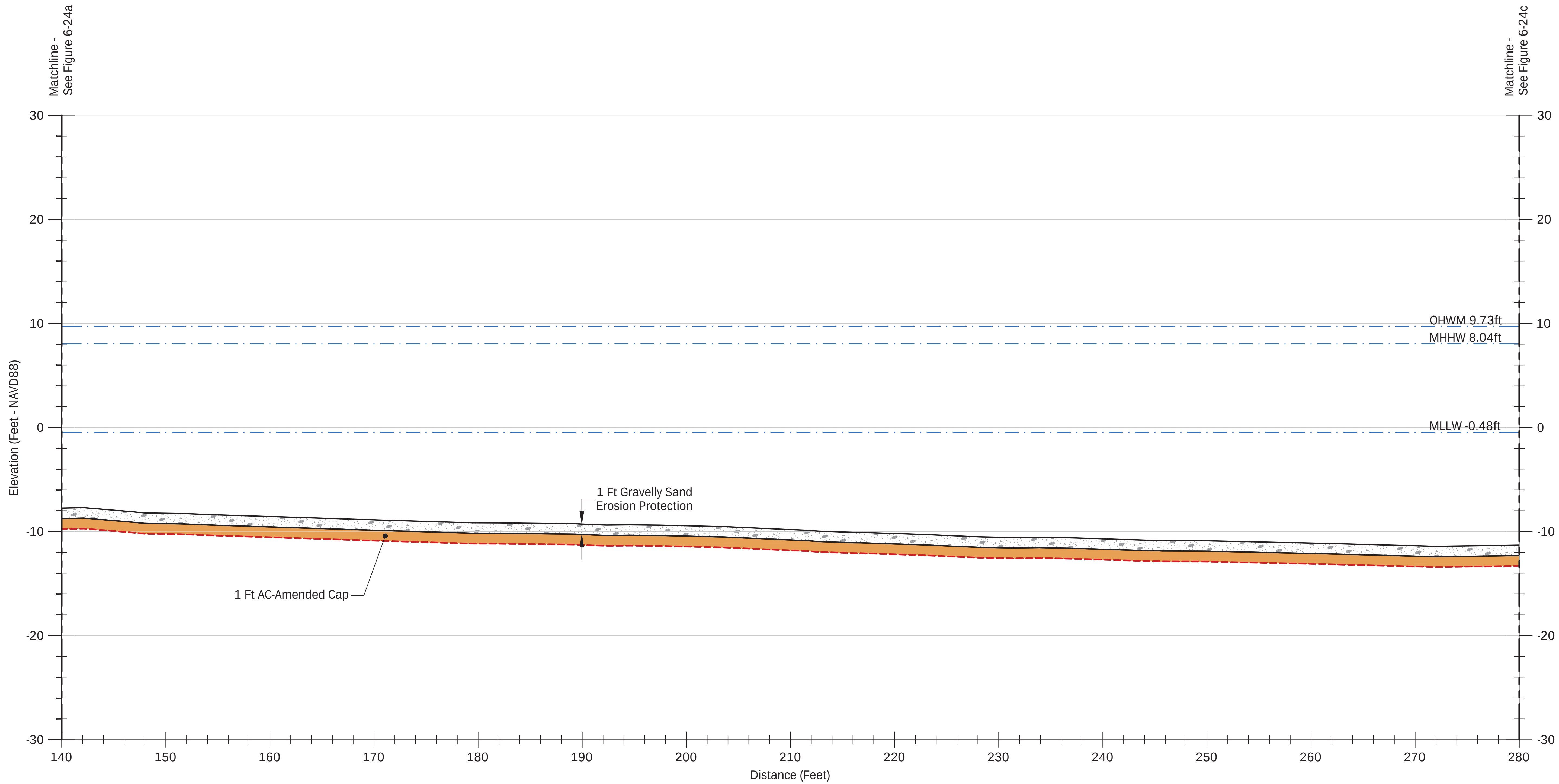
Figure 6-24a

P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures [R02 - Ecology Comments]\035611408_EDR_F0X-0X_Cross-Sections.dwg TAB:FF - 1 Date Exported: 06/10/21 - 14:26 by tmichaud



Legend

Activated Carbon (AC) Amended Sand Cap

Existing Surface

Gravelly Sand Erosion Protection

Average (D50) Grain Size
0.4 Inch

10 0 10
Horizontal Scale in Feet

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

Cross-Section F-F'
(2 of 4)

R.G. Haley Site
Bellingham, Washington

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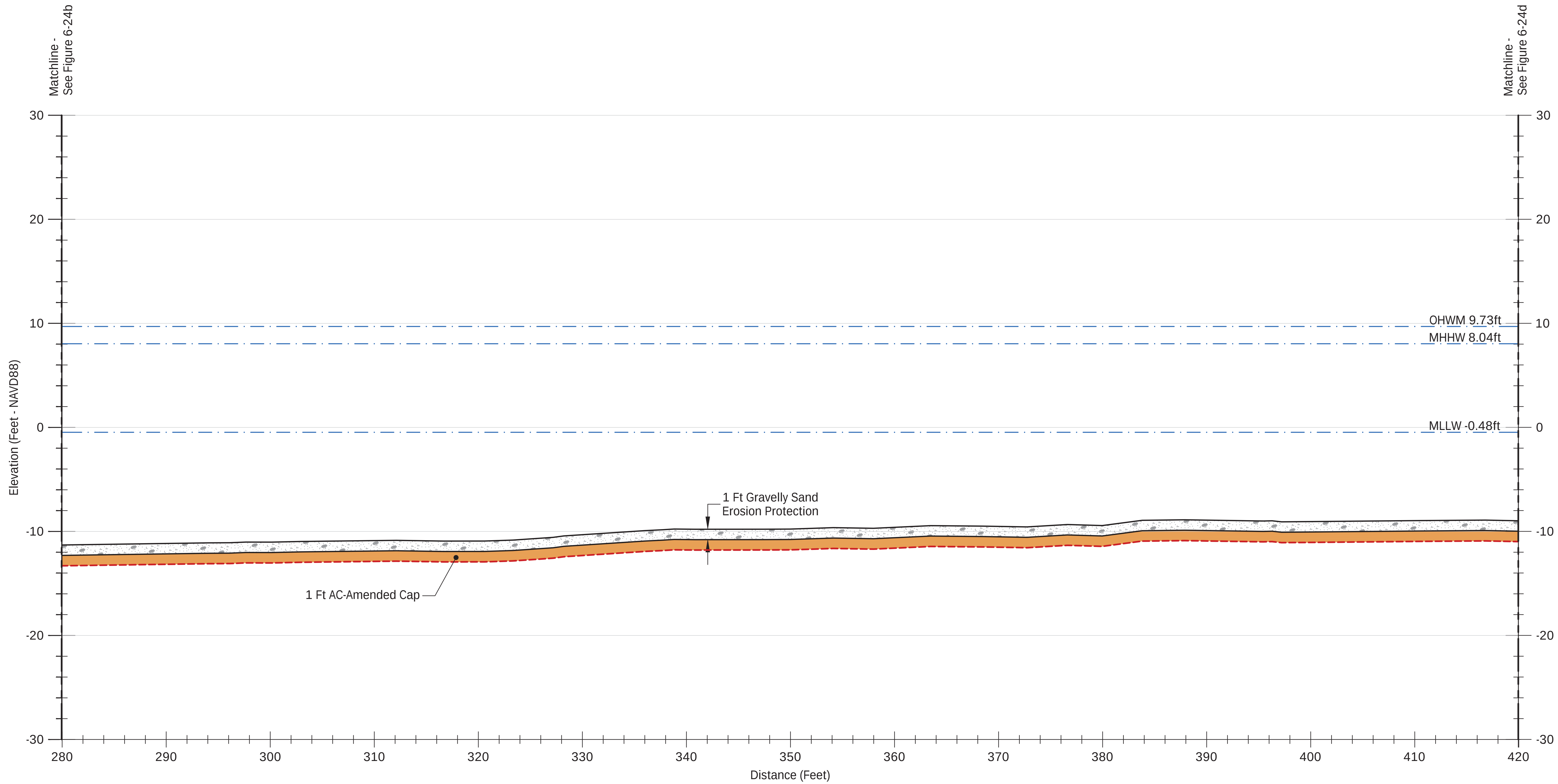
Figure 6-24b

P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures [R02 - Ecology Comments]\035611408_EDR_F0X-0X_Cross-Sections.dwg TAB:FF - 2 Date Exported: 06/10/21 - 14:26 by tmichaud



Legend

Activated Carbon (AC) Amended Sand Cap

Existing Surface

Gravelly Sand Erosion Protection

Average (D50) Grain Size
0.4 Inch

10 0 10
Horizontal Scale in Feet

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

Cross-Section F-F'
(3 of 4)

R.G. Haley Site
Bellingham, Washington

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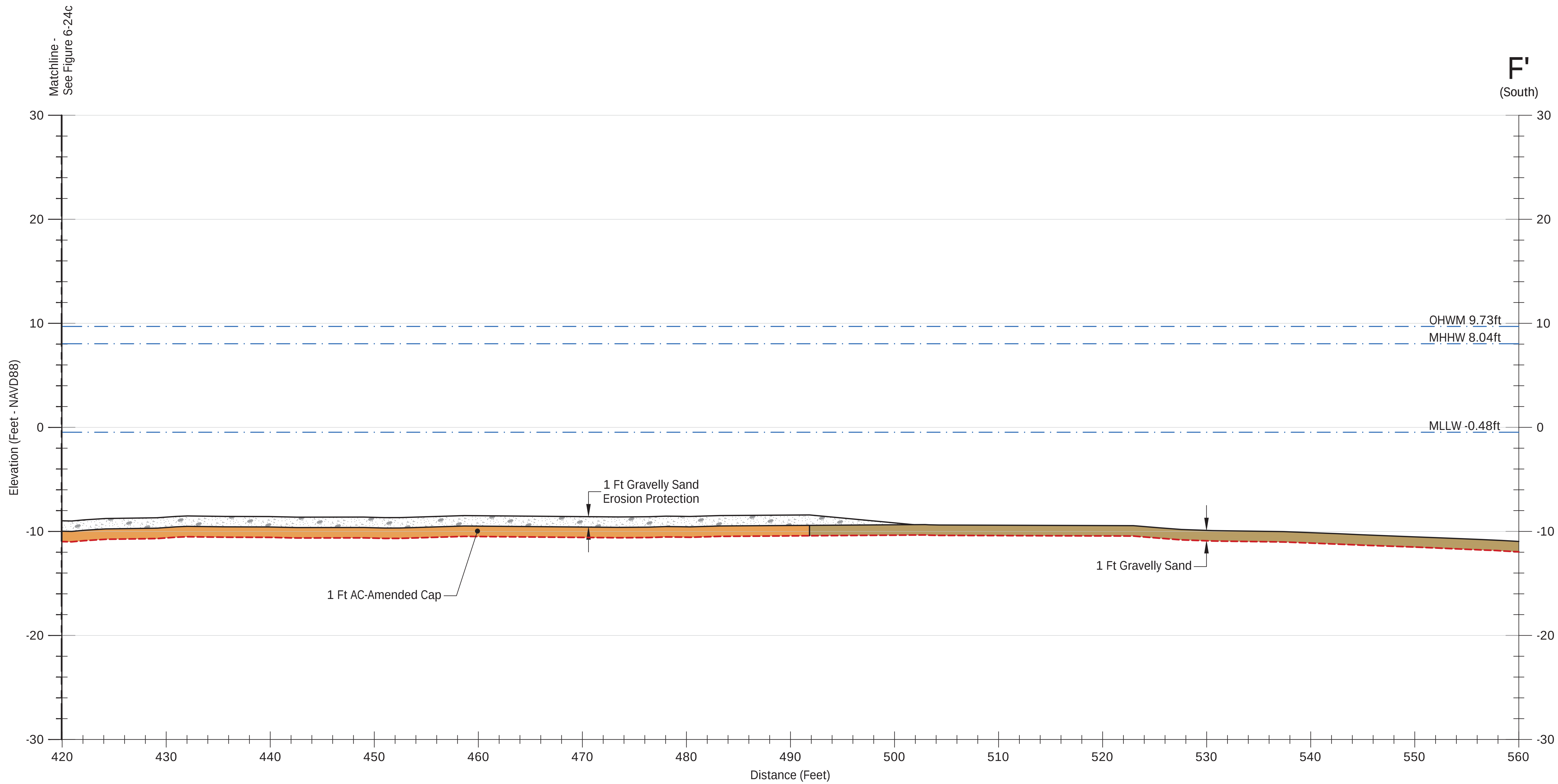
Figure 6-24c

P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures [R02 - Ecology Comments]\035611408_EDR_F0X-0X_Cross-Sections.dwg TAB:FF - 3 Date Exported: 06/10/21 - 14:26 by tmichaud



Legend

- Activated Carbon (AC) Amended Sand Cap
- Existing Surface
- Gravelly Sand Erosion Protection
- Combined Gravelly Sand Thin Layer Containment Cap and Seafloor Erosion Protection (D50 = 0.4 Inch)

Average (D50) Grain Size
0.4 Inch

10 0 10
Horizontal Scale in Feet

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

Cross-Section F-F'
(4 of 4)

R.G. Haley Site
Bellingham, Washington

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Figure 6-24d

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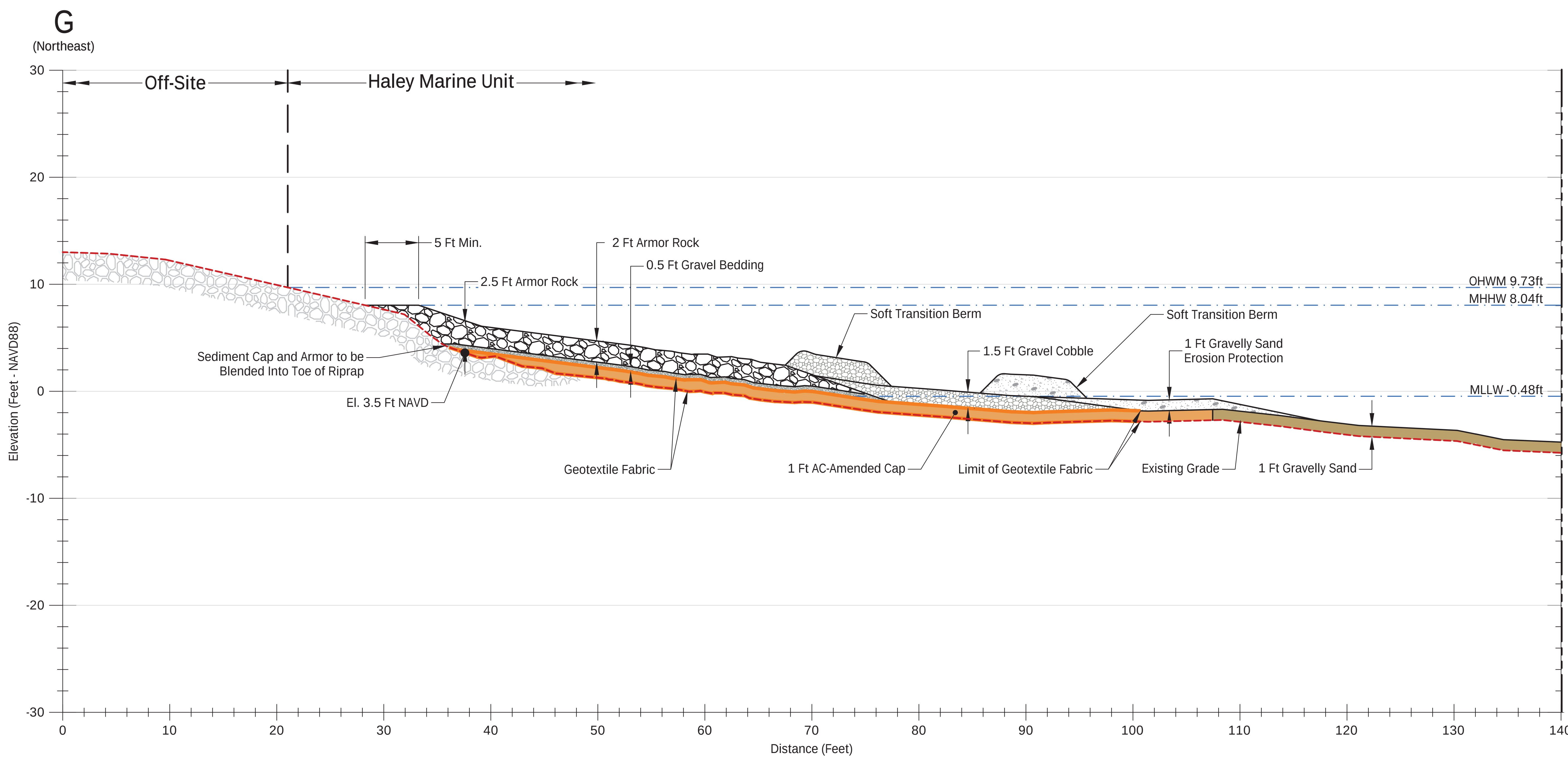

Legend

Legend		Average (D50) Grain Size
Activated Carbon (AC) Amended Sand Cap	Armor Rock	0.8 Feet
Existing Bank Riprap to Remain	Gravel	-
Combined Gravelly Sand Thin Layer Containment Cap and Seafloor Erosion Protection (D50 = 0.4 Inch)	Gravel Cobble	1.5 Inch
Geotextile Fabric	Gravelly Sand Erosion Protection	0.4 Inch
Existing Surface		

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

Cross-Section G-G'
(1 of 2)

R.G. Haley Site
Bellingham, Washington

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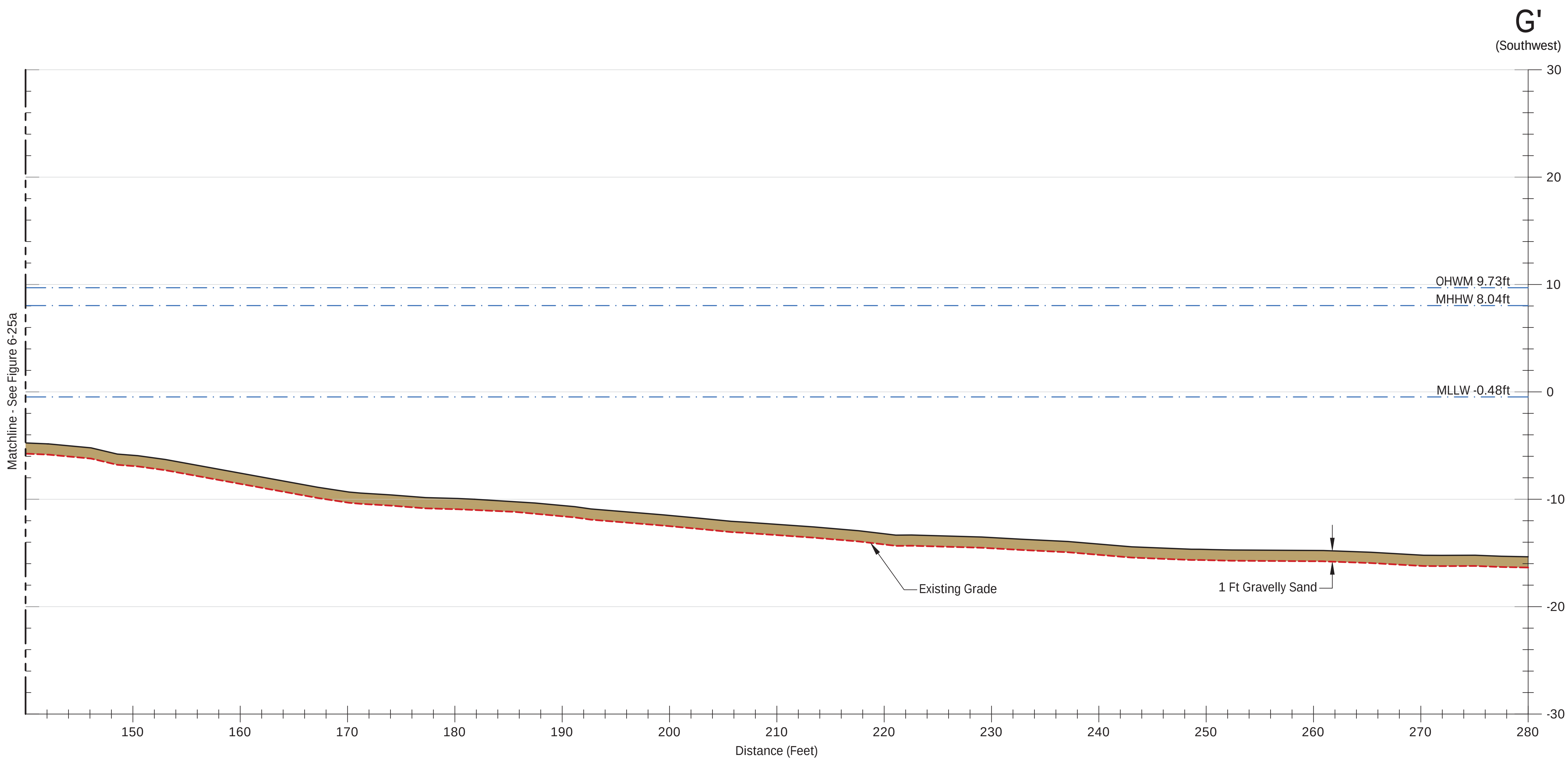
Figure 6-25a

P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures [R02 - Ecology Comments]\035611408_EDR_F0X-0X_Cross-Sections.dwg TAB:GG - 1 Date Exported: 06/10/21 - 14:27 by tmichaud



Legend

Combined Gravelly Sand Thin Layer Containment Cap and Seafloor Erosion Protection (D50 = 0.4 Inch)

Existing Surface

10 0 10
Horizontal Scale in Feet

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

Cross-Section G-G'
(2 of 2)

R.G. Haley Site
Bellingham, Washington

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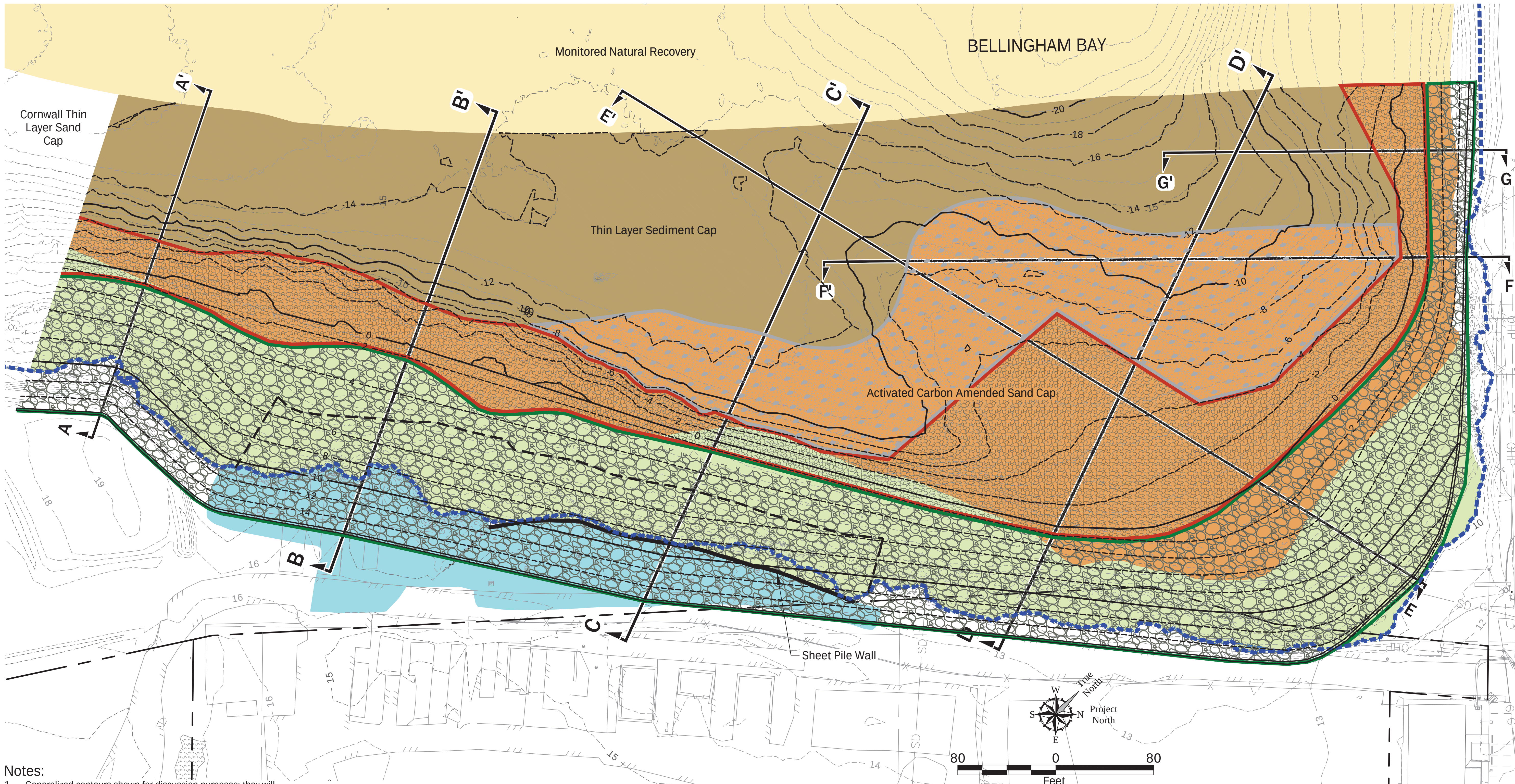
Figure 6-25b

P:\0\0356114\CAD\08\Task 300 Engineering Design\Report Figures [R02 - Ecology Comments]\035611408_EDR_F0X-0X_Cross-Sections.dwg TAB:GG - 2 Date Exported: 06/10/21 - 14:27 by tmichaud



Notes:
1. Generalized contours shown for discussion purposes; they will be refined including in transition to bank and railroad areas.
2. ENR = Enhanced Natural Recovery.
3. MNR = Monitored Natural Recovery.
4. See Figure 6-X for post-capping and armoring elevation contours.
5. The locations of all features shown are approximate.
6. 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 survey by Wilson Engineering & Surveying 10/28/15.

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

Legend

A — A'	Cross Section Location
Blue dashed line	Haley Marine Unit Boundary (OHWM)
Black dashed line	Extent of Sediment Removal
---10---	Existing Elevation Contour in Feet (NAVD88)
—10—	Post-Cap Elevation Contour in Feet (NAVD88)
	Organoclay Amended Sand Cap
	Activated Carbon Amended Sand Cap
	Combined Gravelly Sand Thin Layer Containment Cap and Seafloor Erosion Protection
	Monitored Natural Recovery
	Approximate Maximum Potential Extent of ISS

		Average (D50) Grain Size
	Armor Rock	0.8 Feet
	Gravel Cobble	1.5 Inch
	Gravelly Sand Erosion Protection	0.4 Inch

Sediment Cap and Bank Protection Materials

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Figure 6-26

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