AMENDMENT NO. 1 TO THE PRE-REMEDIAL DESIGN INVESTIGATION PROJECT PLANS

Central Waterfront Cleanup Site
Bellingham, Washington

September 29, 2023

Prepared for

Port of Bellingham
Bellingham, Washington

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LIST OF ABBREVIATIONS AND ACRONYMS

AMD1	Amendment No. 1
AO	Agreed Order DE 3441
ASB	Aerated Stabilization Basin
ASTM	ASTM International
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene, and total xylenes
C Street subarea	C Street Properties subarea
CAP	Cleanup Action Plan
City	City of Bellingham, Washington
CUL	cleanup level
Ecology	Washington State Department of Ecology
EDR	Engineering Design Report
EISB	enhanced *in situ* bioremediation
EPA	US Environmental Protection Agency
ERT	electrical resistivity tomography
ft	foot/feet
GMS	Groundwater Modeling System
Hilton Avenue subarea	Hilton Avenue Properties subarea
IDW	investigation-derived waste
Landau	Landau Associates, Inc.
LandGEM	Landfill Gas Emissions Model
LFG	landfill gas
LNAPL	light non-aqueous phase liquid
MSW	municipal solid waste
MTCA	Model Toxics Control Act
NAD83	North American Datum of 1983
NAVD88	North American Vertical Datum of 1988
NWTPH-Dx	Northwest TPH extended-range diesel analytical method
NWTPH-Gx	Northwest TPH extended-range gasoline analytical method
PAH	polycyclic aromatic hydrocarbon
PID	photoionization detector
Port	Port of Bellingham
PRDI	Pre-Remedial Design Investigation
PSE	Puget Sound Energy
PVC	polyvinyl chloride
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
RCW	Revised Code of Washington
SAP	Sampling and Analysis Plan
SIM	selected ion monitoring
Site	Central Waterfront Cleanup Site

LIST OF ABBREVIATIONS AND ACRONYMS (CONTINUED)

TGP .... temporary gas probe
TPH .... total petroleum hydrocarbons
TPH-D .... diesel-range total petroleum hydrocarbons
TPH-G .... gasoline-range total petroleum hydrocarbons
TPH-O .... motor oil-range total petroleum hydrocarbons
VOC .... volatile organic compound
WAC .... Washington Administrative Code

1.0 INTRODUCTION AND BACKGROUND

This Amendment No. 1 to the Pre-Remedial Design Investigation (PRDI) Project Plans (PRDI AMD1) outlines additional investigative requirements for the Central Waterfront Cleanup Site (Site), located in Bellingham, Washington (Figure 1). PRDI AMD1 has been prepared by Landau Associates, Inc. (Landau) on behalf of the Port of Bellingham (Port) in accordance with Agreed Order DE 3441 (AO), Amendment No. 4, and the final Cleanup Action Plan (CAP; Ecology 2020) issued by the Washington State Department of Ecology (Ecology).

The Site is being cleaned up under the authority of the Model Toxics Control Act (MTCA), Chapter 70.105D of the Revised Code of Washington (RCW), and the MTCA Cleanup Regulation, Chapter 173-340 of the Washington Administrative Code (WAC).

1.1 Site Background

The Site comprises approximately 51 acres of upland waterfront property in Bellingham, Washington. The Site is bordered to the north by I&J Waterway, to the east by Roeder Avenue, to the south by Whatcom Waterway, and to the west by the Aerated Stabilization Basin (ASB) and Bellingham Bay. Three distinct subareas (Hilton Avenue Properties, C Street Properties, and Landfill Footprint and Perimeter) define the Site, and each subarea has a unique set of cleanup action elements that were presented in the CAP.

Landau conducted a Site-wide PRDI on behalf of the Port in 2020 and 2021, and subsequently prepared a draft Engineering Design Report (EDR). The draft EDR was submitted to Ecology in July 2022 and Ecology provided comments on September 12, 2022. Given the size and complexity of the Site, Ecology recommended that the Port continue to conduct design investigation activities to inform development of a final EDR. The recent AO amendment included a minor modification to the schedule of deliverables to complete two separate PRDI events referenced as PRDI Amendment 1 and Amendment 2. Following completion of PRDI Amendment 2, the EDR will be updated in order to transition to development of the cleanup action plans and specifications. This PRDI AMD1 outlines the plan to collect these data in the Site's subareas (Figure 2).

1.1.1 Site Features and Use

As described in the CAP, the Site is situated between two ongoing sediment cleanup projects: the Whatcom Waterway and I&J Waterway sites. The Site's remedial design is being developed to be compatible with the cleanup of these adjacent sediment sites and to prevent migration of upland contaminants into adjacent sediments following cleanup activities. In addition, the remedial design is being developed in parallel with ongoing land-use planning activities by the Port and the City of Bellingham (City). A community vision of the future of the Bellingham waterfront (referred to as the Waterfront District) is being implemented, and the Site plays a vital role in revitalizing a working waterfront.

The Site extends across several properties, which are owned by the Port, Sanitary Services Company, and Puget Sound Energy (PSE). The State owns adjacent aquatic land in the Whatcom and I&J Waterways that is managed by the Washington Department of Natural Resources. The City also has rights-of-way within the Site. The adjacent intertidal and sediment areas are not included within the Site boundary, with the exception of sediment impacts in the nearshore area of Whatcom Waterway, which were addressed as part of the Whatcom Waterway Phase 1 cleanup.

The Site is largely paved, with some portions covered with gravel and others with asphalt or concrete. The grade varies across the Site, with some steep transitions between areas. Several buildings are located on the Site some of which are owned by the Port and operated by Port tenants, and some are privately owned and operated.

1.1.2 Site History and Operations

The Site's shoreline was initially created during early development of the Whatcom and I&J Waterways. Early dredging activities in the Whatcom and I&J Waterway areas in the early 1900s included shallow channels, with side-casting of the dredged materials behind bulkheads for creation of shoreline fill areas. Additional localized dredging events were conducted between 1961 and 1979 (Ecology 2020).

The ASB, located to the west of the Site, was constructed in 1978 and 1979, along with installation of wastewater pipelines beneath Whatcom Waterway, and installation of an offshore outfall from the ASB (Ecology 2020).

The Site has been used for industrial activities by multiple parties since the 1880s. Industrial structures and operations conducted within the area include, but are not limited to: lumber mill, truck dispatching, shallow-water marine area used for log rafting, boat maintenance and storage, bulk fuel terminals, foundry operations, coal storage and shipping, cement warehouse, electrical equipment operations, seafood distribution, fueling operations with underground storage tank use, municipal landfill, olivine rock processing plant, US Naval Reserve, gravel hauling, PSE substation, disposal company, and warehousing. Between 1965 and 1974, the Roeder Avenue Landfill was operated as a disposal site for wood waste and other material from the Georgia-Pacific Corporation mill and as the main disposal site for municipal solid waste (MSW) by the City (Ecology 2020).

1.1.3 Summary of Current Environmental Conditions

Several environmental investigations were conducted within the Site prior to developing the CAP. The Remedial Investigation/Feasibility Study Report, finalized in 2018, presents the Site conceptual site model including the nature and extent of contamination. The summary of Site environmental conditions is based on those prior studies, as presented in the CAP (Ecology 2020). Contaminants of concern within the Landfill Footprint and Perimeter subarea were identified as metals, petroleum hydrocarbons and associated constituents (i.e., gasoline-, diesel-, and motor oil-range total petroleum hydrocarbons [TPH-G, TPH-D, and TPH-O, respectively], which are collectively referred to as total petroleum hydrocarbons [TPH]), volatile organic compounds (VOCs), benzene, and semivolatile organic compounds (SVOCs). Contaminants of concern within the C Street Properties subarea (C Street subarea) were identified as TPH, benzene, polycyclic aromatic hydrocarbons (PAHs), metals, and VOCs in soil, groundwater, soil gas, porewater, and sediments (Ecology 2020). Contaminants of concern within the Hilton Avenue Properties subarea (Hilton Avenue subarea) were identified as TPH-G, metals (arsenic and lead), and PAHs in soil. Additional metals (such as nickel, mercury, and silver) did not exceed soil direct contact cleanup levels but did exceed sediment criteria and were identified as a potential soil erosion pathway to the I&J Waterway. Soil impacts in this subarea are not a source of groundwater contamination (Ecology 2020).

Two interim cleanup actions have been conducted at the C Street subarea, including underground storage tank decommissioning and petroleum-related contamination cleanup, which removed impacted soils and improved stormwater and utility infrastructure.

1.2 Agreed Order Amendment

AO DE 3441, entered into by Ecology, the Port, and the City in 2006, required completion of a Remedial Investigation/Feasibility Study. The first amendment (August 2012) required an interim action to excavate and remove non-aqueous phase liquid petroleum and petroleum-contaminated soils and sediment from the former Chevron area. The second amendment (November 2018) required a public review of the draft CAP. The third amendment (February 2020) required the preparation and submittal (for Ecology's review and approval) of the documents necessary to complete the design and permitting phase of the cleanup action described in the final CAP.

The recent fourth amendment (May 2023) updated the deliverables schedule, which included a revised series of PRDI Project Plans. This PRDI AMD1 (and associated future addenda) has been prepared to address the requirement of the fourth amendment to the AO.

The Scope of Work defined in the AO and its amendments is divided into three major tasks:

- **Task 1: PRDI Project Plans, Addenda, and Implementation**. Describes the work necessary to further investigate the Site to inform effective design of the prescribed remedy. Planned activities discussed in this PRDI AMD1 include an existing surface conditions assessment, enhanced *in situ* bioremediation (EISB) field pilot study design and implementation, additional groundwater sampling to further inform required remedial design, and supplemental landfill gas (LFG) evaluation. The fourth amendment to the AO also describes an Amendment No. 2 to PRDI Project Plans that will provide additional investigation effort to inform and refine design elements for the prescribed remedy. Specific activities chosen for Amendment No. 2 to the PRDI Project Plans will be informed by the results of the investigation elements described below, and may include additional soil and groundwater sampling, geotechnical evaluation, and an expansion of the EISB pilot study.
- **Task 2: Engineering Design Report (EDR)**. Preparation of revised Ecology review draft and final EDRs that provide sufficient information to develop 30 percent design level details and specifications.
- **Task 3: Construction Plans and Specifications**. Preparation of Ecology review and final construction plans and specifications based on the final EDR.

2.0 ELEMENTS OF THE PRE-REMEDIAL DESIGN INVESTIGATION, AMENDMENT 1

A general summary of the investigation elements to be included as part of PRDI AMD1 activities includes the following:

- **C Street Subarea – Field Pilot Study (Groundwater Treatment)**. During the initial PRDI investigation of the status of hotspot contaminant concentrations in the C Street subarea soil, groundwater sampling results indicated the presence of TPH concentrations above Site cleanup levels (CULs) and, therefore, further consideration of the need for groundwater treatment is warranted. A field pilot study assessing the efficacy of EISB as a viable approach to groundwater treatment in the area will be conducted.

  Additional soil and groundwater quality data for the C Street subarea will be collected to evaluate performance of the field pilot study EISB system and continue to inform final remedial design requirements. Performance monitoring of the EISB system will include evaluation of optimal system design, including slug testing and tidal studies.

- **Hilton Avenue Subarea – Groundwater Quality Evaluation**. Initial PRDI activities included an evaluation of groundwater conditions in the vicinity of the shoreline at the end of Hilton Avenue and adjacent to the ASB. Results indicated that contaminant concentrations exceeding Site CULs were detected in groundwater samples collected from two initial PRDI wells (i.e., HH-MW-1 and ASB-MW-1); further investigation is warranted to assess area groundwater quality and potential cleanup requirements.

  Existing and newly installed groundwater wells will be used to evaluate hydraulic conditions near the shoreline, and at the interface between the Landfill Footprint and Perimeter subarea and the ASB, including a tidal study. Porewater and surface water sampling will also be conducted immediately offshore of the subarea to assess if detected contaminants in the local groundwater aquifer are affecting Bellingham Bay.

- **ASB – Hydraulic Dynamics and Potential Groundwater Controls**. The final CAP identified that the clay berm located between the ASB and the Landfill Footprint and Perimeter subarea was acting as a physical diversion for groundwater. As changes to the Whatcom Waterway Phase 2 cleanup action related to the ASB configuration have been finalized, additional evaluation of groundwater hydraulics along the clay berm is warranted to inform future groundwater management strategies within the Landfill Footprint and Perimeter subarea and potential discharge points around the berm. Groundwater data (e.g., water elevations at various tide cycles, etc.) will be used to support the hydraulic studies conducted in neighboring investigation areas (e.g., Hilton Avenue and C Street subareas).

- **Site-Wide – Surface Conditions Assessment**. The final CAP identified the installation of new and/or maintenance of existing physical barrier and reduced-permeability caps at various locations at the Site to address the soil pathway for direct contact and erosion of soils. Additional evaluation of the condition and composition of the existing Site surface, including mapping and further geotechnical exploration (if warranted), will be completed to continue to develop an appropriate final engineering design strategy.

- **Landfill Gas Quality and Indoor Air Assessment**. Some of the LFG probe locations installed and sampled during the initial PRDI will be resampled to collect additional data on LFG quality that will be used to inform the design of final LFG controls (two sampling rounds are anticipated).

Several buildings that were not accessible during the initial round of indoor air sampling will be accessed during PRDI AMD1 activities to address indoor air quality data gaps.

3.0 PRE-REMEDIAL DESIGN INVESTIGATION AMENDMENT 1 ACTIVITIES

This section summarizes the data gaps to be addressed and investigation activities planned to support further development of the Site's remedial design. Section 4 includes additional details on the means, methods, and procedures to be used to implement the PRDI activities discussed in this section.

Landau anticipates that Site PRDI AMD1 activities will be implemented across multiple mobilizations as new Site data are evaluated and additional focused activities are planned and undertaken. Future Site investigation activities, as required, are anticipated to be detailed in Amendment No. 2 to the PRDI Project Plans for review and approval by Ecology in advance of further Site work.

The initial PRDI Project Plans included several guidance documents that were prepared to support execution of the planned investigation activities, management of the resulting data, and support remedy design. These documents, which consisted of the Sampling and Analysis Plan (SAP), Quality Assurance Project Plan (QAPP), Site Health and Safety Plan, and Inadvertent Discovery Plan, will continue to support the investigation activities discussed herein, with updates via addenda included as appendices to this documentation, as appropriate (Landau 2020).

3.1 Site Reconnaissance and Utility Locate

A Site reconnaissance will be completed prior to conducting additional investigation activities. Multiple Site visits are anticipated to plan and implement the various elements described in this PRDI AMD1. These Site visits will involve inspecting existing PRDI monitoring wells for evidence of damage and evaluating potential access issues by noting Site features and/or tenant materials that overlie or impede drilling access to proposed and existing investigation locations.

As appropriate, proposed investigation locations will be marked in white paint per RCW 19.122.030 and a public utility locate request will be submitted through the Washington Utility Notification Center. A private underground utility locate will also be conducted following the Site reconnaissance visit. Investigation locations described elsewhere in this PRDI AMD1 may be moved based on the results of the Site reconnaissance to avoid subsurface utilities or other infrastructure.

3.2 Site Survey

The top-of-casing and ground surface elevations for existing PRDI monitoring wells and pre-PRDI monitoring wells have not been professionally surveyed, which prevents development of representative elevation contour maps and precludes a clear understanding of flow directions and gradients at the Site. An accurate understanding of seasonal flow directions will be necessary to inform potential groundwater treatment and control strategies that may be necessary for final remedial strategy at the Site.

The location, top-of-casing, and ground surface elevation of existing Site monitoring wells, as well as the wells installed as part of the proposed PRDI AMD1 activities (Table 2) will be surveyed by a Land

Surveyor licensed in the State of Washington. Additional features necessary to support ongoing PRDI evaluation include nearby dock or surface elevations, surface water tidal gauges, etc., will also be surveyed.

The survey will reference the NAD83[1] horizontal datum and the NAVD88[2] vertical datum. After the installation of the proposed new monitoring wells in the C Street subarea (Section 3.3.3) and the End of Hilton Avenue area (Section 3.4.2), additional professional surveying activities will be completed to collect survey data to inform a greater understanding of the Site. Surveyed top-of-casing elevations will be used to calculate groundwater elevations at each monitoring well to evaluate groundwater flow dynamics (Section 4.2).

3.3 C Street Properties Subarea

The selected cleanup action for the C Street subarea included removal of hotspot soils, monitored natural attenuation of groundwater, and installation of a containment system to prevent direct contact with subarea contamination. As mentioned previously, initial PRDI results determined that removal of hotspot soils was no longer warranted; however, elevated levels of groundwater contamination in the C Street subarea identified during initial PRDI activities required further evaluation, including consideration of potential groundwater treatment strategies.

Due to the uncertainties associated with the limited data set available from the C Street subarea, a bioremediation field pilot study will be conducted as part of the PRDI AMD1 activities with the goal of demonstrating that a bioremediation strategy (specifically, EISB) can be used to effectively treat groundwater to achieve Site CULs and may represent an appropriate final cleanup remedial option.

Landau's EISB Bioremediation Field Pilot Study Work Plan (Appendix A) describes in detail how EISB will supplement and enhance natural attenuation of groundwater contamination within the C Street subarea. EISB will be stimulated through injection of electron acceptors to contaminated portions of the shallow aquifer through a series of infiltration trenches. Sulfate, present in seawater from the adjacent Whatcom Waterway, will be the primary source of electron acceptor; nitrate may also be added as additional electron acceptor based on performance results of the installed system. Sulfate and nitrate electron acceptors are used by naturally-occurring bacteria to obtain energy for the destruction of TPH. Appendix A describes the proposed approach to conducting the field pilot study, including information about the proposed installation of trenches, piping, and vaults necessary to conduct the EISB field pilot study, as well as the methodology for the application of selected electron acceptor substrate.

The investigation activities detailed below will be conducted to support and inform the implementation of EISB in the C Street subarea, monitor performance of the field pilot study, and inform eventual remedy selection during development of the EDR.

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[1] North American Datum of 1983

[2] North American Vertical Datum of 1988

3.3.1 Groundwater and Soil Investigations

To inform an understanding of baseline conditions prior to the implementation of the EISB field pilot study and to evaluate Site conditions to refine and finalize the basis for the study's design, additional groundwater and soil investigation activities will be conducted in the C Street subarea.

The investigation will involve direct-push drilling for collection of soil and groundwater grab samples from temporary borings. A total of 15 locations (CS-014 through CS-028) are proposed, as shown on Figure 3. Investigation activities at each boring and analytical methods are summarized below and in Table 1.

Ten of the planned soil borings (CS-015, -016, -018 through -022, -024, -025, and -028) will be located proximate to the proposed infiltration trenches (as discussed in Appendix A and Section 3.3.2). Continuous soil coring to 20 feet (ft) below ground surface (bgs) will be conducted at each boring location and a Landau environmental professional will conduct lithologic logging, screening for TPH contamination, and estimation of the depth to groundwater (Section 4.2.1). If present at the time of drilling, evaluation and relative thickness of the smear zone will inform the final depths of the planned infiltration trenches. A soil sample selected from each boring will be submitted for laboratory analysis, as described in Section 4.1.2 and in Table 1.

Groundwater grab samples will be collected at each of the 15 borings to refine the understanding of the extent of TPH contamination and to increase the density of data from within the known contaminated area.

Results of this investigation will be used to determine:

- The lateral extent and vertical interval requiring EISB treatment. Results may be used to refine additional future trench locations, lengths, and depths, etc.
- The appropriate mixture of electron acceptor substrate material.

3.3.2 Bioremediation Field Pilot Study

As described in significantly more detail in Appendix A, a bioremediation field pilot study will be conducted in the C Street subarea to evaluate the potential to remediate groundwater contaminants to achieve CULs using EISB treatment. The study will use filtered seawater containing electron acceptors that will be added to the aquifer through injections into infiltration trenches. The field pilot study design includes construction of six infiltration trenches across the proposed treatment zone at the approximate locations shown on Figure 3 and as depicted in Appendix A. The precise location of trenches will be modified based on existing infrastructure and other conditions observed in the field, but will be generally installed upgradient of, and within, the areas of maximum TPH concentrations and in locations specifically targeted to intercept contaminated groundwater flow.

After the installation of the trenches, multiple injections of sulfate are anticipated to occur over the course of the initial field pilot study period (expected to last approximately 12 months). Details regarding the EISB Pilot Study are presented in the Bioremediation Field Pilot Study Work Plan (Appendix A).

3.3.3 Monitoring Well Installation and Baseline/Performance Monitoring

To evaluate the effectiveness of the bioremediation field pilot study, additional groundwater well installation and monitoring will be required to inform potential future EISB system adaptation/ expansion and final remedial strategies. Up to six new groundwater monitoring wells will be installed during the PRDI AMD1 activities, including three new monitoring wells (i.e., CS-MW-7 through CS-MW-9) to be installed for EISB performance groundwater monitoring (as described in Appendix A). Up to an additional three new monitoring wells (i.e., CS-MW-10 through CS-MW-12) will be installed to evaluate area groundwater flow and contaminant levels to support evaluation of EISB treatment efficacy, to understand current Site conditions, and to inform local hydraulic evaluation and groundwater elevation contouring. New monitoring well CS-MW-12 will be installed only if historical well RWM-7 cannot be located or is unusable. Planned locations for the new groundwater wells are shown on Figure 4. Field screening and grab sampling will be conducted during boring activities as detailed in Sections 4.1.1 and 4.1.2. It is anticipated that these wells will be installed after the infiltration trenches discussed in Section 3.3.2 and Appendix A to avoid damage to new wells during trench construction.

To support EISB field pilot study performance evaluation, up to 11 existing and 6 new monitoring wells in the C Street subarea will be sampled using peristaltic pumps [upgradient well MW-7(B) previously sampled as part of PRDI evaluation will not be included]. Wells will initially be sampled prior to field pilot study implementation to establish a baseline set of data in advance of injections, and then quarterly thereafter. Wells will be sampled with dedicated tubing for each well to prevent cross-contamination between wells. Low-flow sampling techniques will be used for purging and sample collection. Additional information on the methods and techniques to be used for groundwater sampling is provided in the SAP and QAPP documents included in the initial PRDI Project Plan (Landau 2020), and in the SAP/QAPP Amendment 1 (SAP/QAPP AMD 1; Appendix B).

3.3.4 Groundwater Flow Dynamics Evaluation and Tidal Study

Due to uncertainties associated with the limited amount of data available from the C Street subarea, additional groundwater hydraulic evaluation, including flow direction, tidal influence, and seepage velocities, is necessary to inform ongoing final remedy evaluation. Hydraulic conductivity will be estimated through falling and/or rising head slug tests, as appropriate, based on subsurface material and well screen construction relative to the groundwater table. Data will be collected using automated dataloggers installed in selected monitoring wells. Groundwater elevations and gradients, which likely vary with the seasons and tides, will be measured under a range of conditions (e.g., dry-season and wet-season high- and low-tide conditions).

The following activities will be used collectively to evaluate local groundwater hydraulic dynamics in the C Street subarea (Figure 3):

- Depth-to-groundwater measurements at existing PRDI monitoring wells (Table 2) will be collected using the procedures and methods detailed in Section 4.2.1. on the days that dataloggers are initially set, repeated during regular groundwater monitoring events, and when the dataloggers are removed to evaluate seasonal groundwater elevation changes. Results and their evaluation will include:

  - Synoptic groundwater elevation data (converted from depth-to-water measurements referenced to surveyed measuring point elevation data) at PRDI wells
  - Estimated hydraulic gradients throughout the C Street subarea, as documented in representative groundwater elevation contour maps showing interpolated groundwater elevations during dry- and wet-season low- and high-tide conditions
  - Local flow directions at different tidal stages.

- To evaluate tidal influences in the area, a period of semi-continuous (e.g., hourly) water level monitoring at eight existing monitoring wells [i.e., CS-MW-3, CS-MW-5, CS-MW-6, CWF-CW-1, CWF-CW-2, MW-10(B), MW-13(B), and MW-50(C), see Figure 3] using datalogging submersible hydrostatic pressure sensors using the procedures and methods detailed in Section 4.2.2. Semi-continuous water-level measurements will be collected over a period of approximately 1 week and will be benchmarked to manual groundwater-level measurements. Results will include:
  - Semi-continuous groundwater elevation data during daily tidal cycles
  - Variations in hydraulic gradients at different tidal stages.
- Semi-continuous water level monitoring at one surveyed surface water monitoring location (i.e., CS-TD-1) using a datalogging submersible hydrostatic pressure sensor. Results will consist of real-time tidal data for the Site for correlation to groundwater data (e.g., for tidal efficiency evaluations at the semi-continuous monitored groundwater locations).
- Falling- and/or rising-head slug tests at four existing monitoring wells [i.e., CS-MW-3, CS-MW-6, CWF-CW-2, and MW-50(C)]. These tests will be attempted at the end of the approximately 1 week of semi-continuous water-level logging, before removing dataloggers from the Site. For the purposes of the slug testing, the dataloggers will be reprogrammed to collect data on a higher frequency (e.g., 1 second or less) that is suitable for measuring the relatively small water-level perturbations of slug tests. Results will include:
  - Local hydraulic conductivity estimates
  - Local Darcy velocity estimates, based on hydraulic conductivity and hydraulic gradient estimates and reasonable assumptions for soil porosity.

It should be noted that slug testing is most effective in fine-grained materials with lower permeability than the sand pack used during well installation. The heterogeneous nature of the lithology in the C Street subarea may impact data collection. If inadequate information is collected during the PRDI AMD1 activities, a pumping test in specifically installed wells may be required and proposed for future rounds of investigation.

3.4 End of Hilton Avenue Properties Subarea

The cleanup action for the Hilton Avenue subarea includes maintenance of existing and/or placement of new physical barrier elements (e.g., soil/gravel with underlying layer and/or hard surface) to address protection against direct contact and erosion of potentially contaminated soils. The initial PRDI activities included additional groundwater sampling within and adjacent to this subarea, with results from two wells (i.e., HH-MW-1 and ASB-MW-1) indicating contaminant concentrations exceeding Site CULs, which merits further evaluation.

The final remedy in this subarea will include, at a minimum, repair and/or replacement of the existing gravel surfacing to meet the direct contact barrier requirement within the overlapping Landfill Footprint and Perimeter Subarea. The existing gravel surfacing may be replaced or overlaid with asphalt or concrete paving in some areas. Placement of paving or gravel may extend beyond areas requiring remedy to promote smooth transitions between different surfacing types and tenant use of operational areas.

3.4.1 Soil Investigation

To inform an understanding of the groundwater-to-surface water interface at the Hilton Avenue subarea and to evaluate Site soil conditions in the uplands area adjacent to the shoreline to inform potential requirements for groundwater treatment design, additional soil investigation activities will be conducted in the Hilton Avenue subarea.

The investigation will involve direct-push drilling for collection of soil grab samples from temporary borings. Four locations (HH-001 through HH-004) are proposed, as shown on Figure 5. Investigation activities at each boring and analytical methods are summarized below and in Table 1.

The planned soil borings will be located along the fence line adjacent to the shoreline. Continuous soil coring to 20 ft bgs will be conducted at each boring location and a Landau environmental professional will conduct lithologic logging, screen for TPH contamination, and estimate the depth to groundwater (Section 4.2.1). A soil sample selected from each boring will be submitted for laboratory analysis, as described in Section 4.1.2 and in Table 1.

3.4.2 Monitoring Well Installation and Groundwater Evaluation – Hilton Avenue Properties Subarea

As described above, initial PRDI results indicated that groundwater in the Hilton Avenue subarea contained contaminant concentrations exceeding Site CULs. As part of the PRDI AMD1 activities, four new monitoring wells (i.e., HH-MW-2 through HH-MW-5) will be installed in the subarea to evaluate groundwater hydraulic dynamics and contaminant concentrations to evaluate potential needs and strategies for groundwater treatment design. Planned monitoring well locations are shown on Figure 5. Well installation and sampling procedures are detailed in Section 4.1.4.

To support an assessment of potential design requirements for a groundwater treatment system or associated control measures within the subarea, the two existing groundwater wells (i.e., HH-MW-1 and ASB-MW-1) and the four new monitoring wells in the Hilton Avenue subarea will be sampled for chemical analysis using the procedures and methods detailed in Section 4.1.3. Additional information on the methods and techniques to be used for groundwater sampling is provided in the SAP and QAPP documents provided in the initial PRDI Project Plan (Landau 2020), and in the SAP/QAPP AMD1 (Appendix B).

3.4.3 Porewater and Surface Water Sampling

Groundwater contaminants exceeding Site CULs were detected during initial PRDI activities in the Hilton Avenue subarea and adjacent ASB well. To assess the potential for migration of contaminated groundwater to the adjacent marine surface water, surface water and porewater samples will be collected. Porewater samples will be collected in the intertidal zone along the Site's northwestern shoreline at three locations and will be co-located with surface water samples at three locations.

The three approximate porewater and surface water sampling locations are shown on Figure 5, labeled HH-PW-1 through HH-PW-3, and HH-SW-1 through HH-SW-3, respectively. The porewater samples will be collected from approximately 1 ft below the sandy surface during falling tide, and the locations may vary slightly from what is proposed on the figure, based on the presence of large rock or other impediments along the shoreline. The three surface water sampling locations are intended to be as close to the three porewater sampling locations as possible, with one sample collected from each location at both low and high tides (total of six surface water samples).

3.4.4 Geophysical Evaluation

Because the portion of the Hilton Avenue subarea that overlies the Landfill Footprint and Perimeter subarea has a history of differential settlement, which has resulted in impacts to the tenant's operations, limited geophysical assessment of area conditions is included as part of the PRDI AMD1 activities. To further define the lateral and vertical extent of the landfill refuse within the Hilton Avenue subarea, a geophysical survey technique (such as electrical resistivity tomography [ERT]) will be used. The geophysical survey will include up to five transects (designated as HH-ERT-1 through HH-ERT-5). The methodology for this evaluation is presented in further detail in Section 4.3; anticipated transect locations are shown on Figure 5. It is anticipated that additional testing and analysis will be required to evaluate geophysical conditions regarding the compressibility characteristics of the refuse and surrounding and underlying soils to inform design of the planned containment remedy. This additional testing and analysis may be required and proposed in related PRDI Amendment No. 2 documentation.

3.4.5 Groundwater Dynamics Evaluation (Hilton Avenue Subarea and ASB)

Groundwater wells were installed within the Hilton Avenue subarea and adjacent to the ASB during the initial PRDI to further evaluate the potential influence of surface water elevations in the ASB on local groundwater elevations within the adjacent Landfill Footprint and Perimeter subarea. Seven wells were installed to assess water quality and seasonal groundwater-level fluctuations: HH-MW-1 and ASB-MW-1 (along the northern edge of the ASB), ASB-MW-2 through ASB-MW-5 (directly adjacent to the ASB), and ASB-MW-6 (along the southern edge of the ASB). All seven wells were installed within the footprint of the former landfill (see Figure 5).

Groundwater-level elevation measurements were collected from these seven wells during the February, May, and September 2021 monitoring events. Previous water-level measurements, in conjunction with current measurements to be collected from the initial PRDI wells and the four new monitoring wells to be installed within the Hilton Avenue subarea, will be used to evaluate current groundwater flow dynamics. This evaluation will include flow directions and gradients, an evaluation of hydraulic conductivity using falling and/or rising head slug tests, as appropriate, and a tidal study within the Hilton Avenue subarea and areas adjacent to the ASB to further assess influence on groundwater dynamics from tides and from the presence of the constructed clay berm between the ASB and the landfill.

The following activities will be used collectively to evaluate local groundwater flow dynamics in the Hilton Avenue subarea and the areas adjacent to the ASB:

- Depth-to-groundwater measurements at the existing PRDI monitoring wells (i.e., HH-MW-1 and ASB-MW-1 through ASB-MW-6) and the four additional wells (i.e., HH-MW-2 through HH-MW-5) will be collected using the procedures and methods detailed in Section 4.2.1 on the days that dataloggers are set, repeated during regular groundwater monitoring events, and when the dataloggers are removed to evaluate seasonal changes. Results and their evaluation will include:
  - Synoptic groundwater elevation data (converted from depth-to-water measurements referenced to surveyed measuring point elevation data) at all wells
  - Estimated hydraulic gradients throughout the Hilton Avenue subarea and the area adjacent to the ASB, as documented in representative groundwater elevation contour maps showing interpolated groundwater elevations during dry- and wet-season low- and high-tide conditions
  - Local flow directions at different tidal stages.
- To evaluate tidal influences in the area, a period of semi-continuous (e.g., hourly) water-level monitoring at existing monitoring wells (HH-MW-1 and ASB-MW-1 through ASB-MW-6) and the four new PRDI wells (HH-MW-2 through HH-MW-5) using datalogging submersible hydrostatic pressure sensors using the procedures and methods detailed in Section 4.2.2. Semi-continuous water-level measurements will be collected over a period of approximately 1 week and will be benchmarked to manual water-level measurements. Results will include:
  - Semi-continuous groundwater elevation data during daily tidal cycles
  - Variations in hydraulic gradients at different tidal stages.
- Semi-continuous water level monitoring at one surveyed surface water monitoring location (HH-TD-1) using a datalogging submersible hydrostatic pressure sensor. Results will consist of real-time tidal data for the Site for correlation to groundwater data (i.e., for tidal efficiency evaluations at the semi-continuous monitored groundwater locations).
- Falling- and/or rising-head slug tests at two existing monitoring wells (ASB-MW-1 and HH-MW-1) and one new PRDI well (HH-MW-2). These tests will be conducted at the end of the approximately 1 week of semi-continuous water-level logging, before removing dataloggers from the Site. For the purposes of the slug testing, the dataloggers will be reprogrammed to collect data on a higher frequency (e.g., 1 second or less) that is suitable for measuring the relatively small water-level perturbations of slug tests. Results will include:
  - Local hydraulic conductivity estimates

- Local Darcy velocity estimates, based on hydraulic conductivity and hydraulic gradient estimates and reasonable assumptions for soil porosity.

It should be noted that slug testing is most effective in fine-grained materials with lower permeability than the sand pack used during well installation. The heterogeneous nature of the lithology in the Hilton Avenue subarea may impact data collection. If inadequate data is collected during the PRDI AMD1 activities, a drawdown/pumping test in specifically installed wells may be required and proposed for PRDI AMD2.

3.5 Surface Condition Assessment

Many of the elements of the final CAP's selected remedy consist of physical separation (i.e., containment or reduced permeability) of subsurface contamination to remain-in-place via maintenance or installation of physical barriers (e.g., caps) and other associated institutional controls. Evaluation of the current status and condition of existing surfaces at the Site is warranted to inform final design considerations and potential options for physical barrier placement.

An assessment will be conducted of the existing surface conditions, quality, and make-up throughout the Site. The evaluation will include review of available reference documents and pertinent reports and a site reconnaissance to observe and assess current conditions. The status of surface conditions will be used to inform further investigation requirements and remedial design strategies, including the need for geotechnical assessments, stormwater infrastructure evaluation, survey data collection, etc.

Further details on the elements of the surface condition assessment are as follows:

- Available reference documents will be reviewed prior to conducting a site reconnaissance, as appropriate. Reference documents may include record drawings, photographs, sketches, previous inspection reports, environmental reports, and other information available, as applicable to the scope of the surface condition assessment.
- Visual evaluations will be conducted by walking the Site to assess the condition and composition of existing surfaces, including visual inspection and documentation of existing impermeable or low-permeability areas (e.g., asphalt, concrete, buildings, and other visible surface features). Inspectors will note general conditions, damage or deterioration, and compare layouts and dimensions to those in reference documents (if available). Photographs will be taken to document the observations. The locations and approximate extent of surface feature types and the relative transition between composition and grades will be documented during the Site reconnaissance, including collection of GPS information.
- The information will be summarized in tabular and graphic form to support further data needs evaluation and inform remedial design strategies. The collected photographs of typical conditions and damage or deterioration will be cataloged to support design considerations. Where possible, mechanisms producing the damage or deterioration will be discussed, and recommended methods for additional evaluation will be provided for further consideration. The findings of the surface condition assessment will be used to inform related elements of the remedial design program for the Site, as appropriate, and will aid in focusing additional survey needs.

3.6 Landfill Gas Evaluation

As part of the final cleanup action for the Site, LFG must be mitigated to protect Site workers and visitors from potential exposure, prevent offsite migration of LFG, protect indoor air quality, and prevent the accumulation of LFG to unsafe or unhealthy levels beneath impermeable surfaces. Initial PRDI activities included field investigation and computer modeling to evaluate the quantity and quality of the LFG currently being generated at the Site, which included several rounds of soil vapor quality measurements and indoor air sampling. The results of these activities indicated that methane concentrations remained high in most soil vapor locations sampled; however, an evaluation of indoor air quality at the Site did not indicate a current threat to worker health and safety from LFG (and in particular, methane) emissions at the Site (Landau 2022). During initial PRDI activities, three buildings (C St-20, C St-22, and Roeder-11) were inaccessible for inspection and indoor air evaluation is still warranted.

An additional LFG assessment will be conducted as part of the PRDI AMD1 activities to evaluate the current status of the lateral extent of LFG in the subsurface within and adjacent to the Landfill Footprint and Perimeter subarea. These activities will include conducting indoor air monitoring with a flame ionization detector to evaluate for vapor intrusion in those buildings inaccessible during implementation of the initial PRDI. Additional rounds of monitoring will be completed at existing temporary gas probes (TGPs) to assess the status of LFG migration and provide strategies for long-term compliance monitoring. The additional LFG assessment data will be compiled with previous results to update the model that estimates current LFG production and emissions information necessary to continue to inform design strategies, permitting requirements, and construction of the final cleanup remedy.

The following subsections summarize the proposed approach to addressing existing data gaps and providing current LFG data to support evaluation of long-term LFG management requirements; additional details related to conducting the field assessment are provided in Section 4.5 and in the previous (Landau 2020) and amended SAP (Appendix B).

3.6.1 Landfill Gas Production Modeling

As part of previous PRDI activities, levels of LFG production were estimated using modeling software (Landfill Gas Emissions Model [LandGEM]) developed by the US Environmental Protection Agency (EPA), which developed the modeling software to provide a consistent approach for landfill owners to estimate the rate of LFG production and evaluate potential emissions. Existing LFG production models prepared by Landau during earlier phases of the PRDI will be updated for further evaluation in support of final remedy design.

The model is commonly used to estimate LFG production to inform LFG control system design and to support air permitting requirements. LandGEM assumes a first-order decay to model the process of anaerobic decomposition of organic waste, which produces LFG. The model uses emission factors compiled from landfills nationwide (EPA 1995) for some parameters, which can result in overestimates of concentrations and emissions of volatile organic compounds (VOCs) for older landfills, such as the Roeder Avenue Landfill.

As a result, additional field data collection is necessary to supplement the existing modeling information. Updated modeling results will be combined with the existing and newly collected field data and further documented to support the basis and rationale for the design of the LFG control system.

3.6.2 Soil Vapor Evaluation

Soil vapor quality will be evaluated for the presence of LFG at the 14 existing TGPs and three existing monitoring wells [MW-5(B), RMW-12D, and RMW-16] to assess the current status of lateral migration and allow for further assessment of required compliance monitoring strategies. The locations of the TGPs and results from the initial PRDI sampling events are shown on Figure 6.

The primary tool for evaluating soil vapor for the presence of LFG will be a handheld LFG analyzer (Landtec™ GEM 2000 or 5000). The analyzer measures methane, oxygen, carbon dioxide, carbon monoxide, hydrogen sulfide, and static pressure, all of which can be elevated in areas where LFG is produced and not readily ventilated.

In addition to monitoring for the gases noted above using the handheld analyzer, soil vapor samples will be collected from selected locations and submitted to a laboratory for analysis for VOCs by EPA Method TO-15, to determine whether other compounds are present that will require treatment, and to support air permitting considerations. Selected ion monitoring will be conducted for vinyl chloride to achieve the lowest possible reporting limits. Sampling and analysis procedures are described further in Section 4.4 and in the previous SAP (Landau 2020).

3.6.3 Indoor Air Quality

Initial PRDI activities included indoor air monitoring to screen for potential accumulation of LFG in existing structures and to help inform potential mitigation design requirements for future planned buildings/facilities at the Site. Results did not indicate that an unacceptable risk to Site workers from LFG intrusion existed. Three structures (C St-20, C St-22, and Roeder-11) were inaccessible for inspection, and additional rounds of assessment are warranted and to assess indoor air conditions in these structures.

Results of the initial PRDI indoor air assessment and the locations of the buildings to be accessed during this round of sampling are shown on Figure 7. Since methane is the primary component of LFG (present at much higher concentrations than other potentially-present constituents), methane will be used as an indicator substance for monitoring purposes. Indoor air assessment methodology is discussed further in Section 4.5.2.

4.0 FIELD METHODS AND LABORATORY ANALYSES

This section provides further detail on the means, methods, and procedures to be used during the PRDI AMD1 activities discussed in Section 3. Information on specific sampling and analysis procedures, quality assurance/quality control (QA/QC) requirements, and analytical laboratory control information is provided in the SAP and QAPP documents included in the initial PRDI Project Plan (Landau 2020), and as supplemented by the SAP/QAPP AMD1 (Appendix B), when appropriate. In addition to the information included herein, these two documents, along with the Health and Safety Plan and Inadvertent Discovery Plan included with the initial PRDI Project Plan documentation (Landau 2020) will be the guidance documents used to implement the PRDI AMD1 activities.

4.1 Environmental

Methods, procedures, and related laboratory analytical information for the environmental investigations discussed in Section 3 are described in further detail in the following subsections.

4.1.1 Drilling

Borings for collection of soil and/or groundwater grab samples will be completed using direct-push drilling methods; borings for installation of new monitoring wells will be completed using hollow-stem auger drilling methods. Drilling will be conducted by a driller licensed in the State of Washington. Step-down drilling procedures may be required if municipal solid waste (MSW) is encountered during environmental drilling activities. If MSW is encountered during monitoring well installation, the screened interval may need to be adjusted so it does not intersect the vertical transition between the MSW and the soil below. Well screens should be placed either above or below the MSW-soil transition zone.

All drilling locations will be cleared with public and private utility locates prior to mobilization (Section 3.1), but locations will also be hand-cleared (e.g., with a vacuum truck, using hand-augers) down to 5 ft bgs prior to ground penetration with the drill rig.

Regardless of the media being sampled or the final boring completion, lithology in all PRDI borings will be characterized and logged according to the Unified Soil Classification System by a trained Environmental Professional. In direct-push borings, continuous cores will be used for lithologic logging. In hollow-stem auger borings, soil samples will be collected every 2.5 ft using a split-spoon sampler (or similar) and soil density estimates will be made using blow counts for every sampling interval. Boring logs and as-built diagrams will be prepared to document subsurface explorations; this documentation will be reviewed by a Licensed Geologist for accuracy prior to publication.

Upon completion of logging and sampling, the subsurface explorations will be decommissioned in accordance with the requirements in Chapter 173-160 of the Washington Administrative Code (WAC).

4.1.2 Field Screening and Soil Grab Sampling

Soil samples from borings will be field-screened during lithologic logging (Section 4.1.1). Field-screening techniques include visual inspection for staining, olfactory evaluation for presence and strength of petroleum odors, sheen testing, and soil core/sample scanning using a photoionization detector (PID). Field-screening results will be recorded on boring logs and related field documentation.

Field-screening results will also be used to determine the soil sampling interval in each PRDI soil boring. If field screening indicates the potential presence of contamination, a grab sample will be collected from the 1-ft interval with the strongest evidence of contamination (e.g., presence of sheen, strongest odor, highest PID detection). If field screening *does not* indicate contamination, a grab sample will be collected from the 1-ft interval located at the groundwater table, as indicated by moisture in the soil core. Soil grab samples collected during PRDI activities will be analyzed for gasoline-range TPH (TPH-G) using the Northwest TPH extended-range gasoline analytical method (NWTPH-Gx), diesel-range (TPH-D) using the Northwest TPH extended-range diesel analytical method (NWTPH-Dx), and benzene, toluene, ethylbenzene, and total xylenes (BTEX) using EPA Method 5035/8260; soil samples collected during monitoring well installation activities in the Hilton Avenue subarea will be additionally analyzed for bis(2-ethylhexyl)phthalate by EPA Method 8270E and polycyclic aromatic hydrocarbons (PAHs) by EPA Method 8270E selected ion monitoring (SIM), as shown in Tables 1 and 2.

4.1.3 Groundwater Grab Sampling

Groundwater grab samples will be collected from temporary wells in borings drilled using direct-push methods. These temporary wells will consist of Schedule 40 polyvinyl chloride (PVC) casing with 5-ft PVC screens or stainless-steel wire-wrapped screens attached to downhole tooling (e.g., GeoProbe® SP16 sampler). The target screened interval will be across the water table to evaluate the presence of light non-aqueous phase liquid (LNAPL), as observed in purge water. The groundwater table is estimated to occur at 3 to 14 ft bgs[3] and will be confirmed from the depth to water at the nearest monitoring well and/or the observed depth of soil saturation at the nearest soil boring.

Samples will be collected using low-flow purging methods and analyzed for TPH-G using Method NWTPH-Gx, TPH-D using Method NWTPH-Dx, and BTEX using EPA Method 8260D.

4.1.4 Monitoring Well Installation and Development

Monitoring wells will be installed in borings drilled using hollow-stem auger methods. New wells will be constructed according to the same specifications as recently-installed wells. They will be installed to a maximum depth of 18 ft bgs and constructed using 2-inch-diameter PVC. They will feature 15-ft-long Schedule 40 PVC screens (0.010-inch slot size) and flush-mount protective monuments.

New monitoring wells will be developed using a surge block and centrifugal pump until the purged water runs clear, or until 10 well casing volumes have been removed. For the purposes of development,

[3] Based on the measured depth to water encountered in existing Site monitoring wells (typically screened ranging from 5 to 20 ft bgs).

"clear" means that the measured turbidity in the purged water is approximately 10 nephelometric units or less.

4.1.5 Groundwater Monitoring Well Sampling

Groundwater monitoring wells will be gauged prior to sampling with an oil/water interface probe to determine a) approximate depth to water; b) potential presence of LNAPL petroleum in the well; and c) total well depth (which will be compared to well installation logs [as available] to confirm well construction details and determine if well redevelopment is necessary). Depths-to-water will be measured to the nearest 0.01 ft from the top of the well casing.

Wells will be sampled using peristaltic pumps with dedicated tubing for each well to prevent cross-contamination between wells. Low-flow sampling techniques will be used for purging and sample collection. Additional information on the methods and techniques to be used for groundwater sampling is provided as discussed in the SAP and QAPP documents included in the initial PRDI Project Plan (Landau 2020). Samples will be collected shortly after low tide, to the extent practicable, and will be retained in laboratory-supplied sample containers and put on ice prior to transport to the analytical laboratory.

Based on the area of investigation and as outlined in Table 2, groundwater samples will be analyzed for:

- All PRDI AMD1 wells:
  - Benzene, metals,[4] TPH-G, TPH-D, and TPH-O
  - For waste characterization purposes, toluene, ethylbenzene, xylenes, and metals (arsenic, cadmium, total chromium, copper, lead, nickel, selenium, silver, zinc, and mercury) will also be analyzed.
- Additionally, the Hilton Avenue subarea wells will be analyzed for selected landfill contaminants of concern including:
  - bis(2-ethylhexyl)phthalate
  - PAHs
  - Hexavalent and trivalent chromium
  - Alkalinity.
- C Street subarea wells will be analyzed for EISB assessment parameters including:
  - Dissolved oxygen, pH, oxidation-reduction potential, and temperature (with a YSI field meter)
  - Ferrous (dissolved) iron with field test kits
  - Dissolved (field-filtered) manganese
  - Nitrate/nitrite and sulfate/sulfide

[4] Metals to include arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, and zinc. As noted above, samples from the ASB and Hilton Avenue subarea wells will additionally be analyzed for hexavalent and trivalent chromium.

- Methane
- Total organic carbon
- Alkalinity.

Additionally, groundwater samples will be collected from up to five of the wells in the C Street subarea shortly after high tide to determine the approximate extent and magnitude of tidally-influenced sulfate recharge to Site groundwater from the Whatcom Waterway. These groundwater samples will be analyzed for:

- Chloride
- Total dissolved solids.

Quarterly monitoring of C Street subarea wells is anticipated during the pilot study period, followed by transition to semiannual monitoring after implementation of the final cleanup approach. Hilton Avenue subarea wells will be sampled quarterly during the PRDI AMD 1 activities to evaluate for seasonal flux.

4.1.6 Porewater and Surface Water Sampling

As noted in Section 3.4.3, porewater and surface water samples will be collected along the intertidal shoreline adjacent to the Hilton Avenue subarea to assess the potential effect of identified upland groundwater contamination at concentrations above Site CULs. To collect the porewater samples, a decontaminated stainless-steel porewater sampler will be driven into the sand; perforations in the sampler will allow porewater to enter the sampler. The sample will be retrieved from the sampler with new disposable Teflon® tubing using a peristaltic pump. Sampling locations will be identified that will remain submerged during the tidal cycle at the time of investigation, to the extent practicable.

The surface water samples will be collected from locations as near to the three porewater sampling locations as possible—once at high tide and once at low tide—in order to understand the potential transport mechanisms of contamination along the shoreline. The surface water sampling locations will vary, in an attempt to collect the water from within 6 inches of the top surface of the water, and within 6 inches of the underlying sediment.

As shown in greater detail in Table 3, surface water and porewater samples will be analyzed for TPH-G and TPH-Dx, BTEX, metals,[5] bis(2-ethylhexyl)phthalate, and PAHs.

As noted in Section 3.3.2, regarding the EISB field pilot study in the C Street subarea, and in Appendix A, if nitrate is added to the injection solution as a secondary electron acceptor during the pilot study period, surface water monitoring for nitrate+nitrite will be conducted concurrently with quarterly to semiannual groundwater monitoring.

[5] Metals to include arsenic, cadmium, copper, lead, mercury, nickel, selenium, silver, and zinc, and total, hexavalent, and trivalent chromium.

4.2 Hydraulic Dynamics Investigations

Hydrogeological field methods will be used in the C Street subarea to collect data to further inform the most effective application of EISB treatment in the area and generate a more detailed and accurate understanding of groundwater flow, gradient dynamics, and tidal influences. Similar investigation methods will be used in the Hilton Avenue subarea to collect data to evaluate potential remedial strategies and understand groundwater flow and dynamics proximal to the shoreline and the ASB. Methods and procedures for the planned hydraulic investigations are described in the following subsections.

4.2.1 Groundwater Elevation Measurements

Groundwater elevation measurements will be collected by measuring the depth-to-water and calculating elevation from the well's top-of-casing elevation. Depth-to-water will be measured to the nearest 0.01 ft from the surveyed top-of-casing using a portable water-level meter. If the survey location is not marked on the well casing, the depth-to-water will be measured from the northern side of the casing. The water-level meter will be decontaminated between each monitoring location.

4.2.2 Tidal Studies

Because the Site is adjacent to marine surface water, it is assumed that tidal fluctuations have an impact on the groundwater table, which impacts contaminant fate and transport as well as any potential remedies in each of the respective subareas. According to the National Oceanic and Atmospheric Administration, the mean range between high and low tides in Bellingham Bay is about 8 ft (NOAA; accessed July 21, 2023). The specific influence of tidal fluctuations on the Site's groundwater in all subareas is not known and will be further evaluated as part of this investigation in support of the cleanup action planning process.

Tidal fluctuations and their potential influence on Site groundwater elevations will be evaluated by collecting water-level data in both the uplands and marine areas of the Site. To monitor tide cycles, a pressure transducer will be deployed in a surface water monitoring location adjacent to each subarea, as well as in a selected set of groundwater monitoring wells (detailed in Sections 3.3.4 and 3.4.5). Pressure transducers will monitor groundwater elevations, which will be compared to the marine water levels and predicted tides. A barometer will also be installed in a secure location (such as a locked and vented shed), proximate to the groundwater monitoring wells, to correct pressure transducer data for changing barometric pressure. The duration of the transducer deployment will be approximately 1 week and results will be used to support the groundwater conditions evaluation in the subarea.

The surface water monitoring locations will require installation of a marine pressure transducer via insertion into a screened PVC pipe attached to the existing dock and extended downward into the marine water to the maximum depth practicable or approximately 1 ft above the mudline (i.e., marine sediment surface). The marine and upland transducers will be deployed on the same day and weather conditions (i.e., temperature, wind speed and direction, barometric pressure, precipitation) in the adjacent marine environment will be observed and recorded during the 1-week monitoring period.

4.2.3 Slug Testing

Falling- and/or rising-head slug tests will be conducted using a solid slug (i.e., a long cylinder that can fit within a monitoring well casing and displace a certain volume of water) of known size, a water-level meter, and a submersible, datalogging water-level sensor. The following field measurements are needed to determine hydraulic conductivity from slug tests:

- Inner diameter of well casing (known)
- Inner diameter of well screen (known)
- Borehole radius (known)
- Screen length (known)
- Filter pack material (if present) and its approximate permeability (known or estimated)
- Depth to top of screen from water table (measured)
- Slug radius and length (known)
- Static (pre-test) depth to water in well (measured)
- Estimated saturated thickness of aquifer (known).

Falling-head slug tests will be conducted by rapidly submerging the PVC slug (i.e., adding volume, causing a sudden rise in water level) and monitoring the water level in the well as the displaced water flows into the surrounding formation material. If a significant oscillatory response is observed in a well upon submergence of the slug, or if the water table is within the screen interval, only a rising-head test will be conducted and analyzed. Rising-head slug tests will be conducted after each falling-head slug test by rapidly removing the PVC slug (i.e., removing volume, causing a sudden drop in water level) and monitoring the water level in the well as water flows back into the well casing from the surrounding formation material.

During the planned slug tests, water levels will be measured periodically using the water-level meter and continuously using the submersible, datalogging sensor. Manual water-level meter measurements will be used to validate the sensor data and determine when the test is complete. Each test will last until the water level in the well is 95 percent of its static (pre-test) level (e.g., Butler 1997) . A minimum of three tests will be completed at each well. Continuous sensor data will be analyzed in AQTESOLV or similar program to estimate the local hydraulic conductivity value. An example method of data modeling used by these software programs is the straight-line method (e.g., Bouwer and Rice 1976; Hvorslev 1951), which assumes a quasi-steady-state model by neglecting the compressibility of the aquifer (storativity).

4.2.4 Hydraulic Modeling

The results of the groundwater flow dynamics evaluation field study in the C Street and Hilton Avenue subareas (described in further detail in Sections 3.3.4 and 3.4.5) will be used to develop a simplified three-dimensional numerical groundwater flow model to represent the hydrogeologic conditions present beneath the two subareas of the Site. This model will be used to inform design of groundwater treatment/containment remedies (as appropriate), including the design adaptations to the EISB system in the C Street subarea, and potential treatment or containment strategies in the Hilton Avenue subarea.

The model will be developed using Aquaveo's Groundwater Modeling System (GMS) graphical user interface and solved with the US Geological Survey-developed MODFLOW code (Harbaugh et al. 2000). GMS allows for the graphical representation of the conceptual model of a hydrogeologic system, direct importation of that conceptual model to a three-dimensional MODFLOW grid, and convenient visualization of the model solution. The conceptual model that will be the basis of the numerical model will be developed based on available data, as described above. The datums used for model inputs will be Washington State Plane North (NAD83) for horizontal extent and NAVD88 for vertical extent.

4.3 Geophysical Survey

To better define the extent of landfill refuse within the Hilton Avenue subarea, especially to build upon the current understanding of areas that will require additional consideration during design of the final remedy, Landau will hire a geophysical subconsultant to complete an ERT survey that will include up to five transects (see Figure 5). The ERT technique involves transmitting an electrical current into the ground and measuring the received voltage to identify differences in the electrical properties of subsurface deposits. By calculating the resistivity of the subsurface deposit that the electrical current passes through, it is possible to infer the geologic makeup of the deposit. ERT data are compared with data gathered from subsurface explorations to develop site-specific correlations between soil resistivity and soil type. Typically, soil with a very high moisture content, such as organic deposits or landfill refuse, has a very low resistivity, whereas a mostly mineral soil has a higher resistivity.

4.4 Landfill Gas, Soil Vapor, and Indoor Air

As summarized in Section 3.6, additional information is needed to support the remedial design for mitigating LFG conditions at the Site. The information needed for design includes updating the understanding of the estimated rate of LFG production, completing indoor air assessments in areas inaccessible during initial PRDI efforts, additional characterization data to understand the concentrations of potentially hazardous components of the LFG, and a further refined understanding of the extent of LFG distribution in the subsurface. This section provides further details for conducting the evaluation; sampling and data quality-related information is provided in the SAP and QAPP documents included in the initial PRDI Project Plan (Landau 2020).

4.4.1 Soil Vapor Monitoring and Analyses

LFG monitoring of the 14 existing TGP locations and three monitoring well locations (depending on the current condition of the TGPs at the time the PDRI AMD1 activities are implemented) will be conducted during two discrete field events, separated by a minimum of 2 weeks. The monitoring events will be scheduled to occur when barometric pressure is decreasing to prevent air intrusion into the cover, potentially diluting the sample. The second monitoring event will be conducted to account for the variability in sampling conditions based on changing weather and the logistics of field investigations.

The handheld LFG analyzer will be used during the first monitoring event. At each monitoring location, field personnel will verify an airtight seal at the wellhead, connect the analyzer, and measure static pressure above current atmospheric conditions. Afterwards, the sampling location will be purged of air using the LFG analyzer, removing air that may have accumulated in well casings or within the sampling equipment. No minimum purge volume is required for sampling the temporary monitoring probes, only that the gas concentration readings are stabilized. When concentrations are stable, the data will be recorded onto a field form (initial PRDI SAP; Landau 2020). Field personnel will record the sampling time, purge volume, gas concentrations, and other relevant observations or notes.

During the second monitoring event, the general procedures described above will be repeated for data confirmation and to prevent barometric pressure changes from biasing the monitoring results. Monitoring will be conducted at the temporary LFG monitoring probes and other existing groundwater monitoring wells that might provide useful soil vapor data. In addition to collecting LFG data with the handheld analyzers, soil vapor samples will be collected during this second event and submitted to a certified laboratory for analysis for VOCs. The VOC data will be used to evaluate for the presence of other compounds potentially present in the LFG that could require treatment as part of the final cleanup remedy, and to support future air permitting considerations.

Soil vapor samples (and one additional QA/QC sample of ambient air) will be collected into pre-evacuated Summa canisters, each individually-certified clean of contamination by the laboratory. Samples will be collected using dedicated Teflon tubing through a stainless-steel flow regulator set by the laboratory to collect the sample over a ½-hour period to prevent overdrawing the sampling points and diluting the sample. The ambient air sample will be collected in an upwind location to provide background air quality data for QA purposes.

Selected ion monitoring will be conducted for vinyl chloride to achieve the lowest possible reporting limits. Sampling and analysis procedures are further described in the SAP and QAPP documents included in the initial PRDI Project Plan (Landau 2020).

4.4.2 Indoor Air Monitoring

As noted in Section 3.6.3, indoor air monitoring will be conducted to evaluate for LFG intrusion and to address data gaps in the three buildings that were inaccessible during initial PRDI activities. The indoor air monitoring will include floor-level, breathing-zone, and ceiling monitoring to screen for accumulations in areas of occupied buildings on the Site. The indoor air monitoring will be carried out using a flame ionization detector capable of detecting methane at concentrations as low as 1 part per million.

To monitor the worst-case conditions when LFG intrusion could occur, the monitoring events will be conducted during periods of falling barometric pressure, with heating, ventilation, and air-conditioning systems turned off, and doors and windows closed. Barometric pressure will be recorded on the field forms, and actual barometric pressure from a nearby weather station will accompany the field dataset, confirming monitoring during optimal weather conditions.

Calibration and calibration check procedures for the LFG analyzer will be conducted in accordance with the manufacturer's recommended procedures, as discussed in the SAP and QAPP documents included in the initial PRDI Project Plan (Landau 2020).

4.5 Investigation-Derived Waste

Investigation-derived waste (IDW) from the environmental and geotechnical investigations will be managed as detailed in the initial PRDI SAP (Landau 2020). IDW generated during the installation of Bioremediation Field Pilot Study infrastructure will be managed as detailed in Appendix A. Other IDW, including soil cuttings and water generated during boring advancement, drilling, and sampling, and waste/wastewater generated during sample purge and equipment decontamination, will be collected and managed in 55-gallon steel drums provided by the drilling subcontractors. Drums will be stored at a pre-approved temporary storage location at the Site per direction from the Port. After analytical results are received, Landau will coordinate with the Port to arrange appropriate disposal at a facility licensed by the State of Washington to accept the waste materials.

5.0 INVESTIGATION AND REPORTING SCHEDULE

The table below presents a schedule for implementation of the planned field events included in the PRDI AMD1 activities. As the results of the investigation elements associated with the initial mobilizations will inform the next steps in the investigation process, this schedule has been prepared only to highlight the major steps of the PRDI activities. The actual schedule and sequencing of necessary field activities are likely to change. An updated schedule will be provided in future addenda or separate reporting, as appropriate.

Investigation Element	Field Activities	Duration	Notes
Site Reconnaissance	• Inspect existing PRDI monitoring wells • Inspect existing TGP locations • Evaluate potential access issues • Mark locations for utility locates	1 day	Requires coordination with Port and tenant
Elevation Survey	• Survey top-of-casing and ground surface elevations at all existing monitoring wells • Survey ground surface elevation at proposed surface water monitoring locations	2 days	Conducted by professional surveyor
Surface Conditions Assessment	• Site reconnaissance to evaluate condition, quality, and make-up of existing surface conditions	2 days	
Soil Vapor Evaluation and Indoor Air Quality Evaluation	• Monitor soil vapor from 14 probe locations • Monitor indoor air for intrusion of LFG	3 days	Requires advance tenant coordination Two events, three days each.
C STREET PROPERTIES SUBAREA			
Field Pilot Study Infrastructure Installation	• Excavate six infiltration trenches • Install piping and infrastructure required to conduct field pilot study	15 days	Requires significant coordination with Port and tenant, may require traffic control and utility management
Groundwater and Soil Investigation	• Collect 15 groundwater grab samples • Collect 15 soil grab samples • Total of 15 borings	5 days	
Monitoring Well Installation	• Install three field pilot study groundwater monitoring wells concurrent with three new PRDI wells	3 days	Final locations contingent on underground utilities
Groundwater Evaluation	• Monitor and sample 6 new wells and 11 existing wells	2 days each event	Includes initial baseline assessment and then quarterly during first year of bioremediation pilot test

Investigation Element	Field Activities	Duration	Notes
C STREET PROPERTIES SUBAREA			
Bioremediation Field Pilot Study	• Inject substrate material into each of six infiltration trenches • Sulfate only for 6 months • Nitrate and sulfate for remaining 6 months	4 days each event	Occurs monthly during first year of bioremediation pilot test
Groundwater Hydraulic Dynamics Evaluation	• Conduct groundwater elevation survey at existing PRDI monitoring wells • Install water-level sensors at eight existing PRDI monitoring wells • Install water-level sensor at surveyed surface water monitoring location • Conduct falling- or rising-head slug tests at four existing monitoring wells	9 days	Seven days of continuous logging, two days of slug testing
HILTON AVENUE PROPERTIES SUBAREA AND ASB			
Monitoring Well Installation	• Install four new groundwater monitoring wells	2 days	Final locations contingent on underground utilities
Groundwater Evaluation	• Monitor and sample four new wells and seven existing wells (one Hilton Avenue subarea well and six ASB wells)	2 days	
Tidal Study	• Install water-level sensors at surveyed surface water monitoring location • Install water-level sensors at 11 wells (five Hilton Avenue subarea wells and six ASB wells)	2 weeks	
Porewater and Surface Water Sampling	• Sample porewater and surface water at three locations along subarea border with Bellingham Bay	1 day	Final locations contingent on access to intertidal shoreline area
Geophysical Evaluation	• Conduct up to four ERT transects	2 days	Final locations contingent on underground utilities
Groundwater Hydraulic Dynamics Evaluation	• Conduct groundwater elevation survey at existing PRDI monitoring wells • Install water-level sensors at 11 monitoring wells • Install water-level sensor at surveyed surface water monitoring location • Conduct falling- or rising-head slug tests at three monitoring wells	9 days	Seven days of continuous logging, two days of slug testing

6.0 USE OF THIS PLANNING DOCUMENT

This Amendment No. 1 to the Pre-Remedial Design Investigation Project Plans has been prepared for the exclusive use of the Port of Bellingham for specific application to the Central Waterfront Cleanup Site Remedial Design and Permitting project. No other party is entitled to rely on the information, conclusions, and recommendations included in this document without the express written consent of Landau. Further, the reuse of information, conclusions, and recommendations provided herein for extensions of the project or for any other project, without review and authorization by Landau, shall be at the user's sole risk. Landau warrants that within the limitations of scope, schedule, and budget, our services have been provided in a manner consistent with that level of care and skill ordinarily exercised by members of the profession currently practicing in the same locality under similar conditions as this project. Landau makes no other warranty, either express or implied.

7.0 REFERENCES

Bouwer, H., and R.C. Rice. 1976. "A Slug Test Method for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells." *Water Resources Research* 12 (3):423-428.

Butler, James J. Jr. 1997. *The Design, Performance, and Analysis of Slug Tests*, 1st ed. Boca Raton, FL: CRC Press.

Ecology. 2020. Final Cleanup Action Plan, Central Waterfront Site, Bellingham, Washington. Washington State Department of Ecology. January.

EPA. 1995. Compilation of Air Pollutant Emission Factors. Volume 1: Stationary Point and Area Sources. AP-42. 5th ed. Office of Air Quality Planning and Standards, US Environmental Protection Agency. January. https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emission-factors.

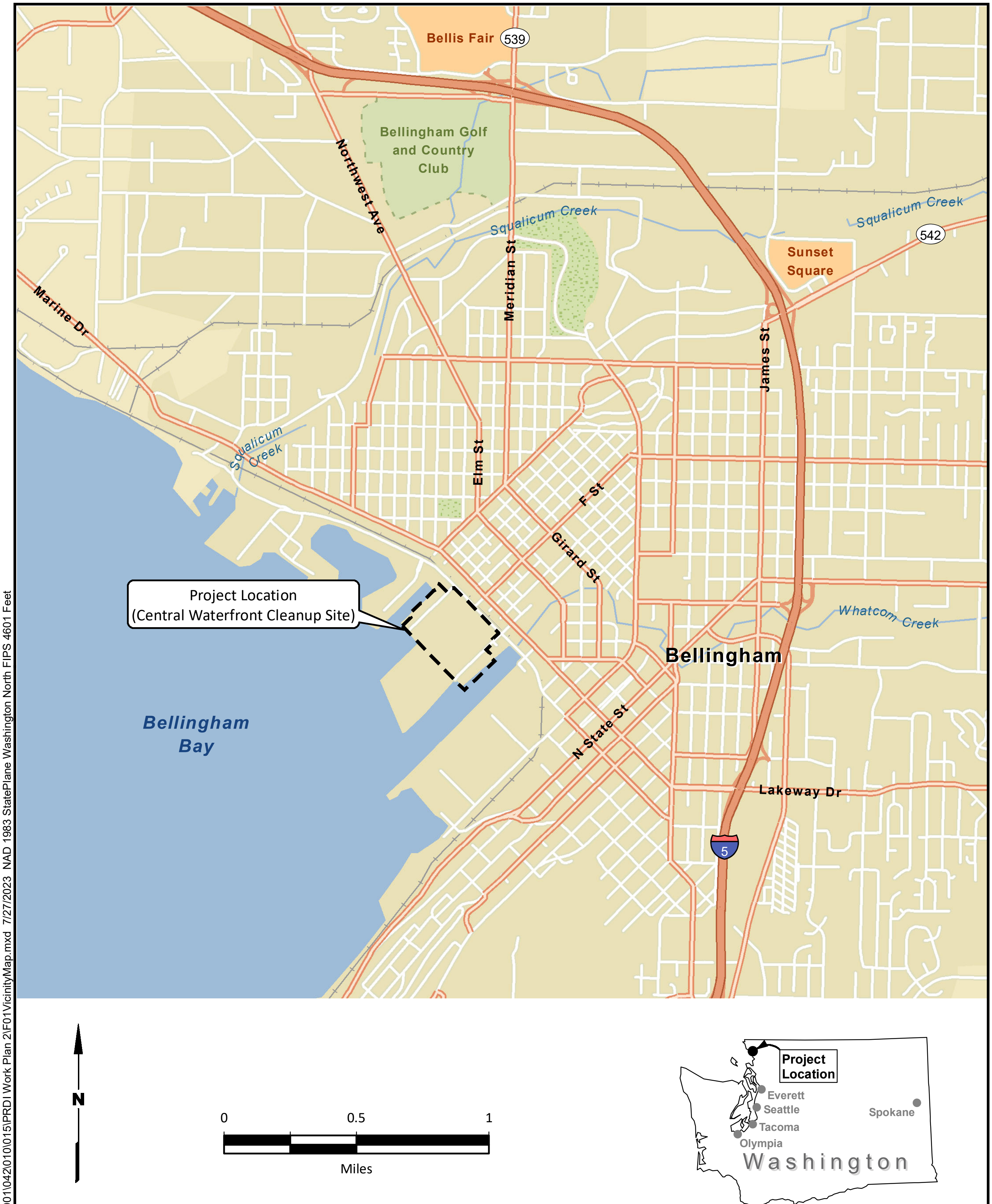
Harbaugh, Arlen W., Edward R. Banta, Mary C. Hill, and Michael G. McDonald. 2000. MODFLOW-2000, The US Geological Survey Modular Ground-Water Model - User Guide to Modularization Concepts and the Ground-Water Flow Process. Open File Report 00-92. US Geological Survey.

Hvorslev, Mikael Juul. 1951. Time Lag and Soil Permeability in Ground-Water Observations. Bulletin No. 36. Waterways Experiment Station, US Army Corps of Engineers. April. https://health.hawaii.gov/heer/files/2021/07/Hvorslev1951.pdf.

Landau. 2020. Report: Pre-Remedial Design Investigation Project Plan, Central Waterfront Cleanup Site, Bellingham, Washington. Landau Associates, Inc. October 14.

Landau. 2022. Agency Review Draft: Engineering Design Report, Central Waterfront Cleanup Site, Bellingham, Washington. Landau Associates, Inc. July 12.

NOAA. Tide Predictions at 9449211: Bellingham, Washington. Tides & Currents, National Oceanic and Atmospheric Administration. https://tidesandcurrents.noaa.gov/noaatidepredictions.html?id=9449211.



Data Source: Esri.

Central Waterfront Cleanup Site Pre-Remedial Investigation Project Plans Amendment No. 1 Bellingham, Washington	**Vicinity Map**	Figure 1

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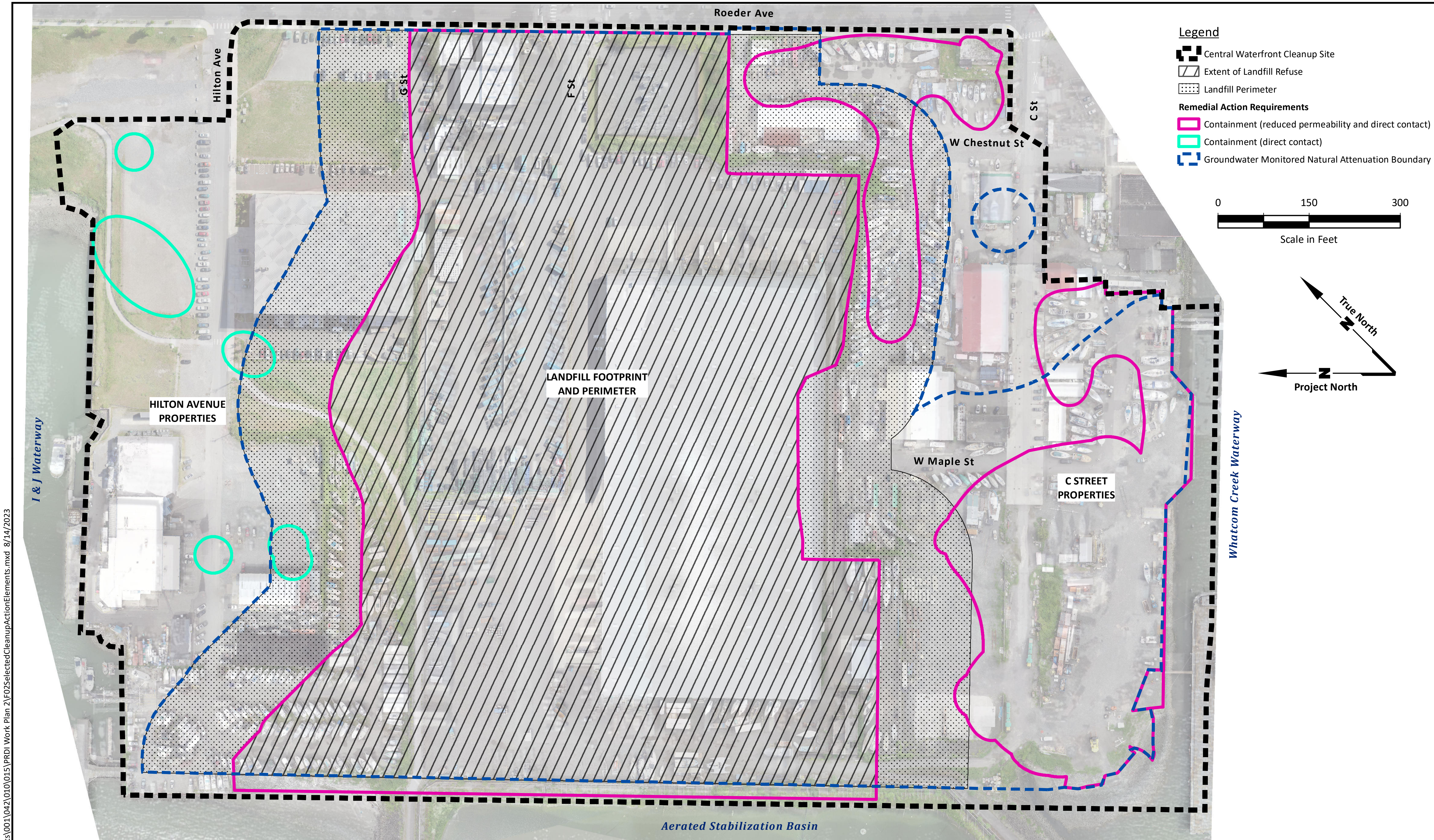
G:\Projects\001\042\010\015\PRDI Work Plan 2\F01VicinityMap.mxd 7/27/2023 NAD 1983 StatePlane Washington North FIPS 4601 Feet



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Note

1. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

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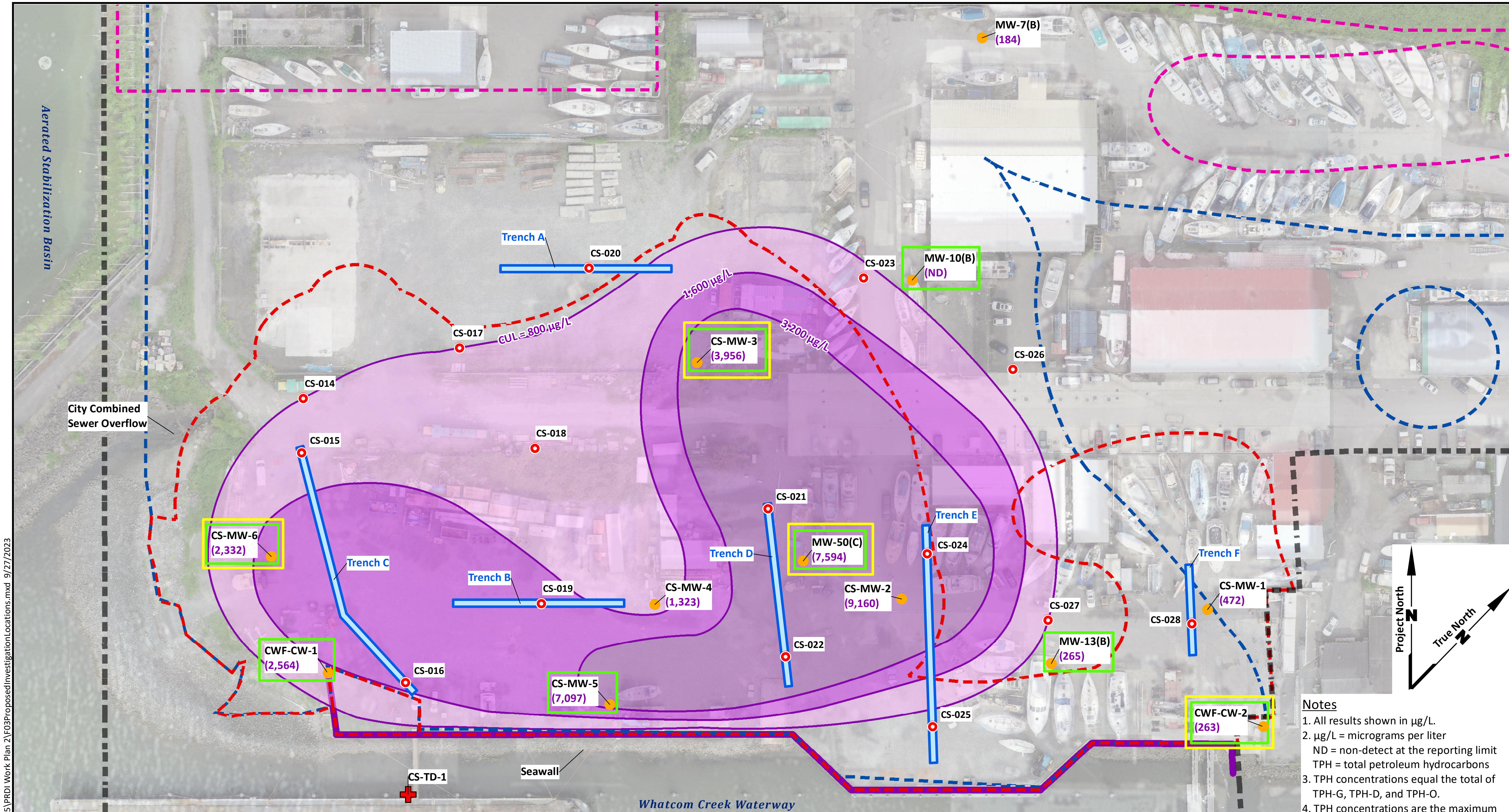
Central Waterfront Cleanup Site
Pre-Remedial Investigation
Project Plans Amendment No. 1
Bellingham, Washington

Selected Cleanup Action Elements

Figure
2



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Legend

- Existing Monitoring Well
- Proposed Direct-Push Boring Location
- Proposed Marine Pressure Transducer
- Proposed Infiltration Trench Location
- Central Waterfront Cleanup Site
- Slug Test Location
- Continuous Groundwater Level Monitoring Location
- Whatcom Waterway Seawall

TPH Concentrations (Approximate)

- >800 µg/L
- >1,600 µg/L
- >3,200 µg/L
- (472) Maximum TPH Concentration in Groundwater (µg/L)

Remedial Action Requirements

- Containment (reduced permeability and direct contact)
- Groundwater Monitored Natural Attenuation Boundary
- C Street Groundwater Treatment Area

Notes

1. All results shown in µg/L.
2. µg/L = micrograms per liter
   ND = non-detect at the reporting limit
   TPH = total petroleum hydrocarbons
3. TPH concentrations equal the total of TPH-G, TPH-D, and TPH-O.
4. TPH concentrations are the maximum concentrations detected in groundwater during 2021 (three monitoring events).
5. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

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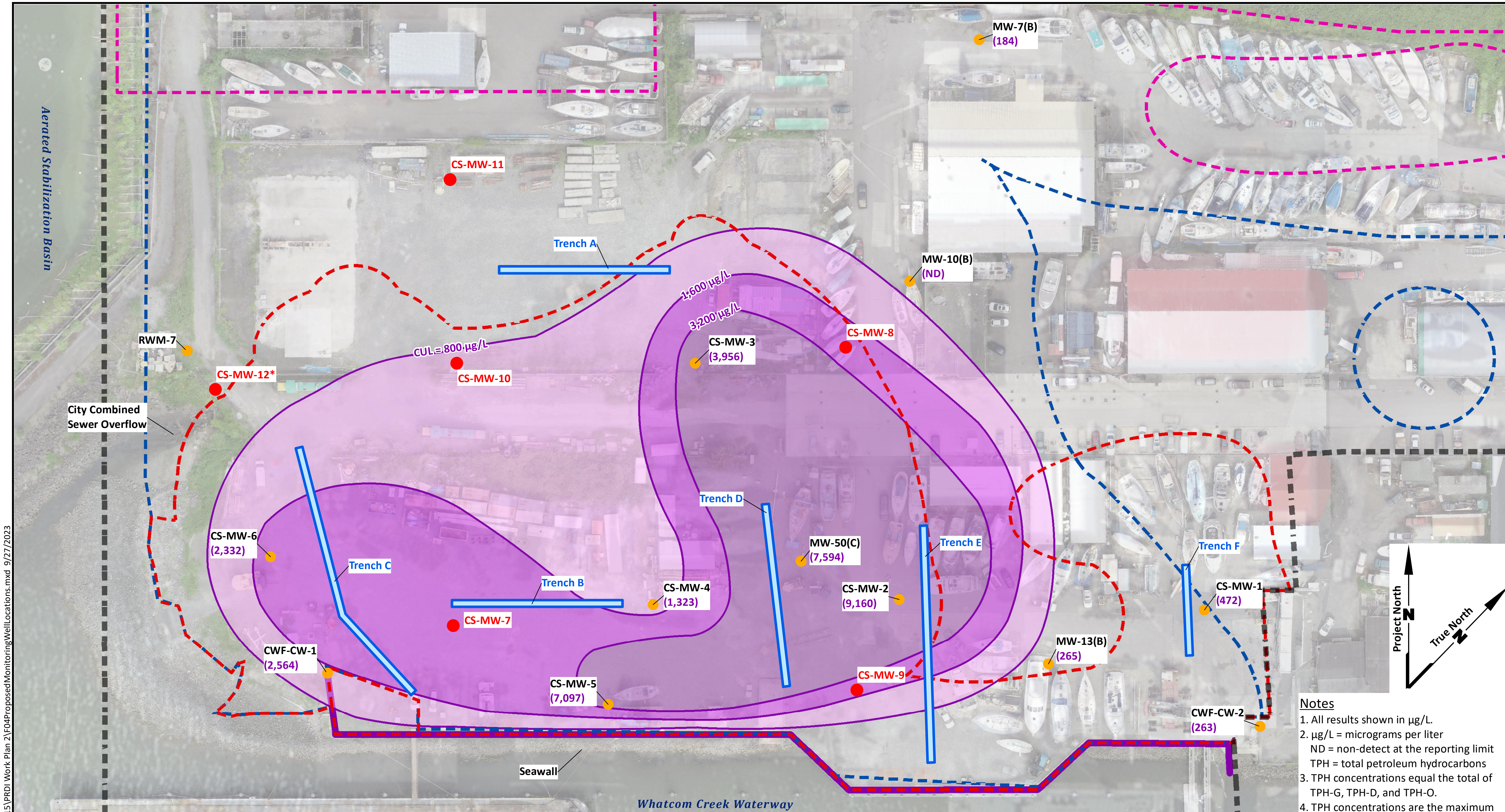
Central Waterfront Cleanup Site Pre-Remedial Investigation Project Plans Amendment No. 1 Bellingham, Washington	**C Street - 2020 PRDI Results and Planned 2023 Investigation Locations**	Figure 3



Legend

- Proposed Monitoring Well Location
- Existing Monitoring Well Location
- Infiltration Trench Location
- Central Waterfront Cleanup Site
- Whatcom Waterway Seawall
- (472) Maximum TPH Concentration in Groundwater (µg/L)
- * Optional Proposed Well - to be installed if RWM-7 cannot be located or is unusable

TPH Concentrations (Approximate)

- >800 µg/L
- >1,600 µg/L
- >3,200 µg/L

Remedial Action Requirements

- Containment (reduced permeability and direct contact)
- Groundwater Monitored Natural Attenuation Boundary
- C Street Groundwater Treatment Area

0 70 140

Scale in Feet

Notes

1. All results shown in µg/L.
2. µg/L = micrograms per liter
   ND = non-detect at the reporting limit
   TPH = total petroleum hydrocarbons
3. TPH concentrations equal the total of TPH-G, TPH-D, and TPH-O.
4. TPH concentrations are the maximum concentrations detected in groundwater during 2021 (three monitoring events).
5. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

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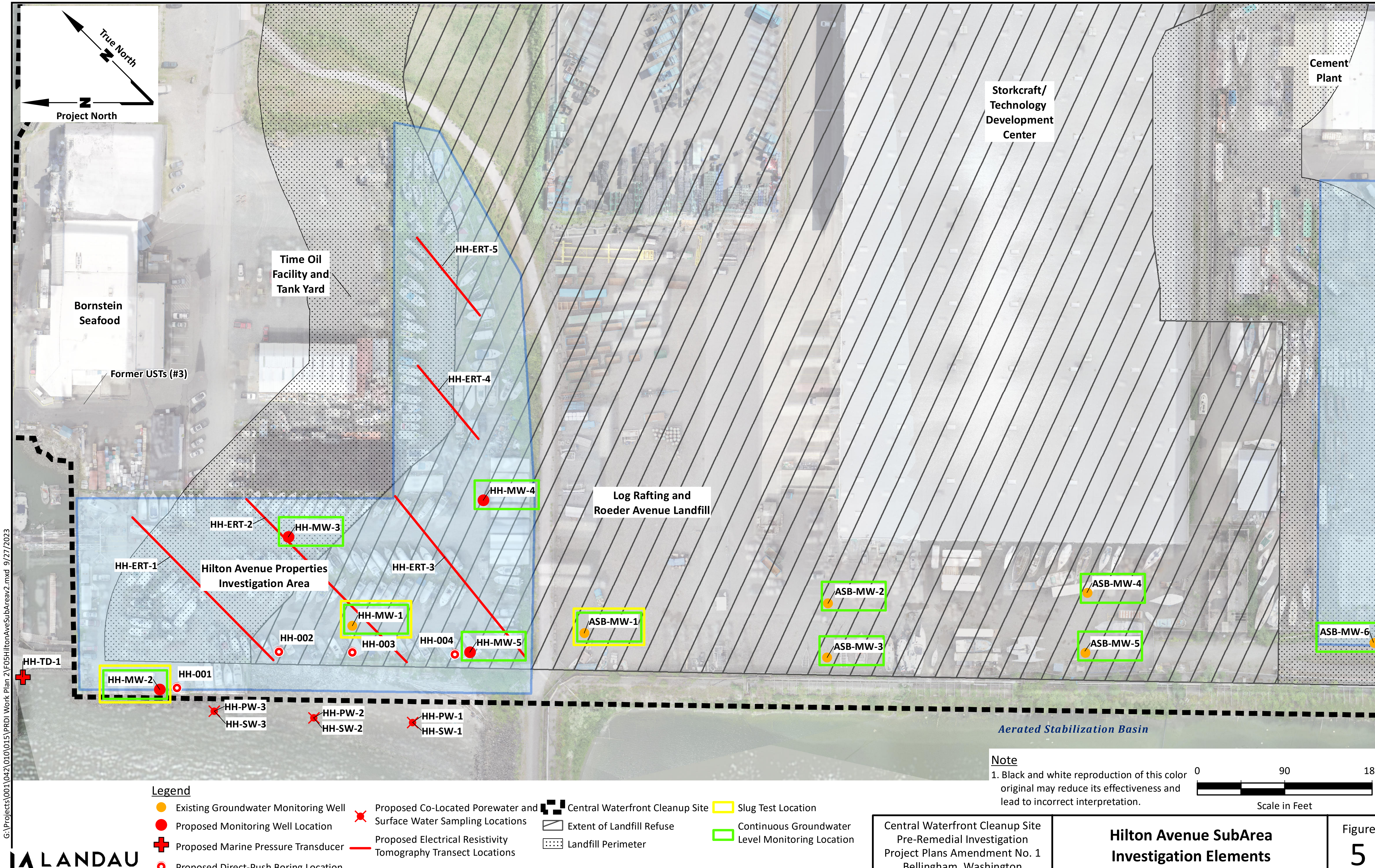
Central Waterfront Cleanup Site Pre-Remedial Investigation Project Plans Amendment No. 1 Bellingham, Washington	**C Street - Proposed Monitoring Well Locations**	Figure 4



Note
1. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

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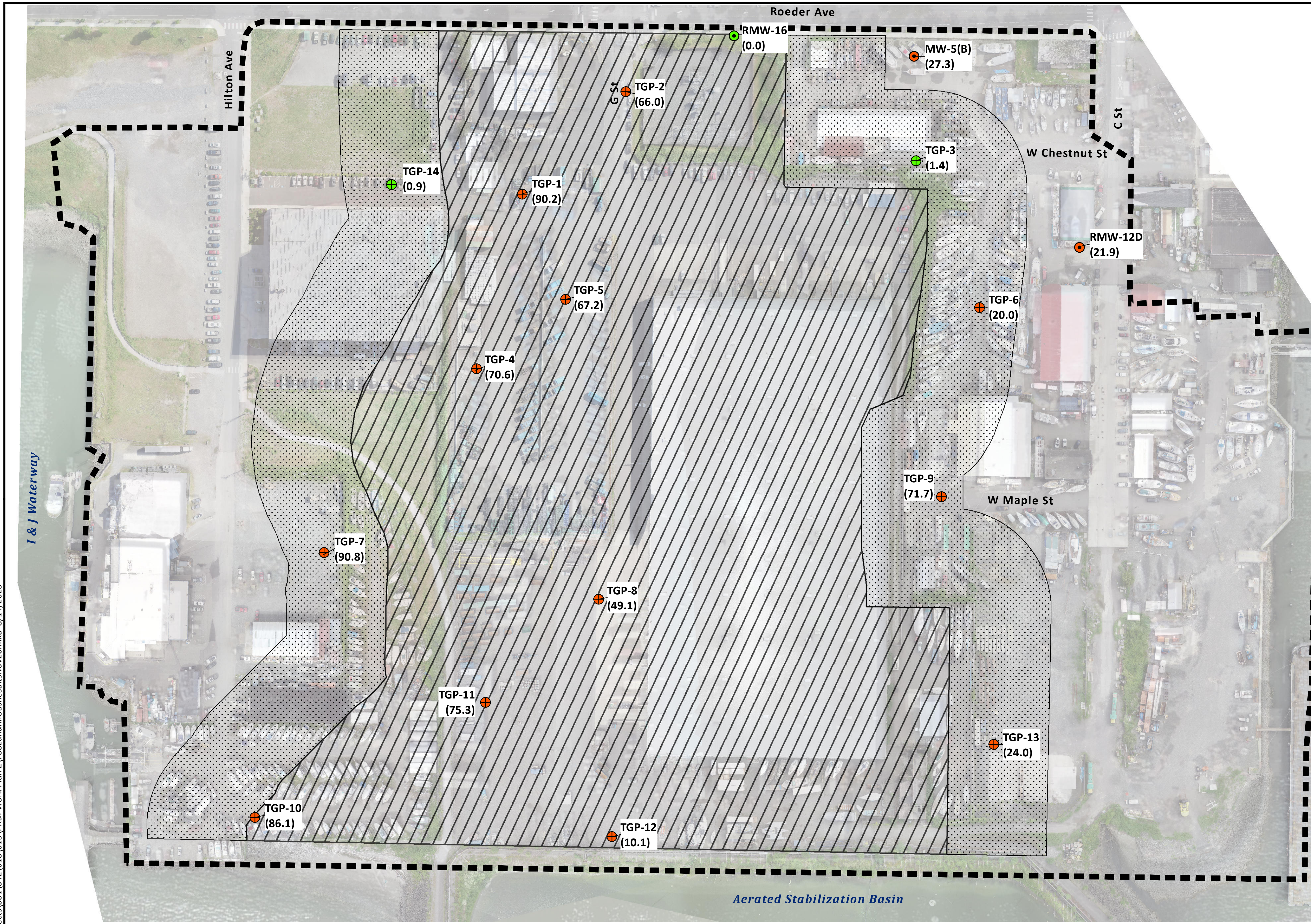
Central Waterfront Cleanup Site
Pre-Remedial Investigation
Project Plans Amendment No. 1
Bellingham, Washington

Hilton Avenue SubArea Investigation Elements

Figure 5



Legend

- Existing Groundwater Monitoring Well
- Temporary Gas Probe
- Methane Concentration Below 5.0%
- Methane Concentration Above 5.0%
- Central Waterfront Cleanup Site
- Extent of Landfill Refuse
- Landfill Perimeter
- **(27.3)** Percent (%) by Volume Methane Detected

0 150 300

Scale in Feet

True North

Project North

Notes

1. 5.0% Methane represents the lower explosive limit (LEL).
2. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

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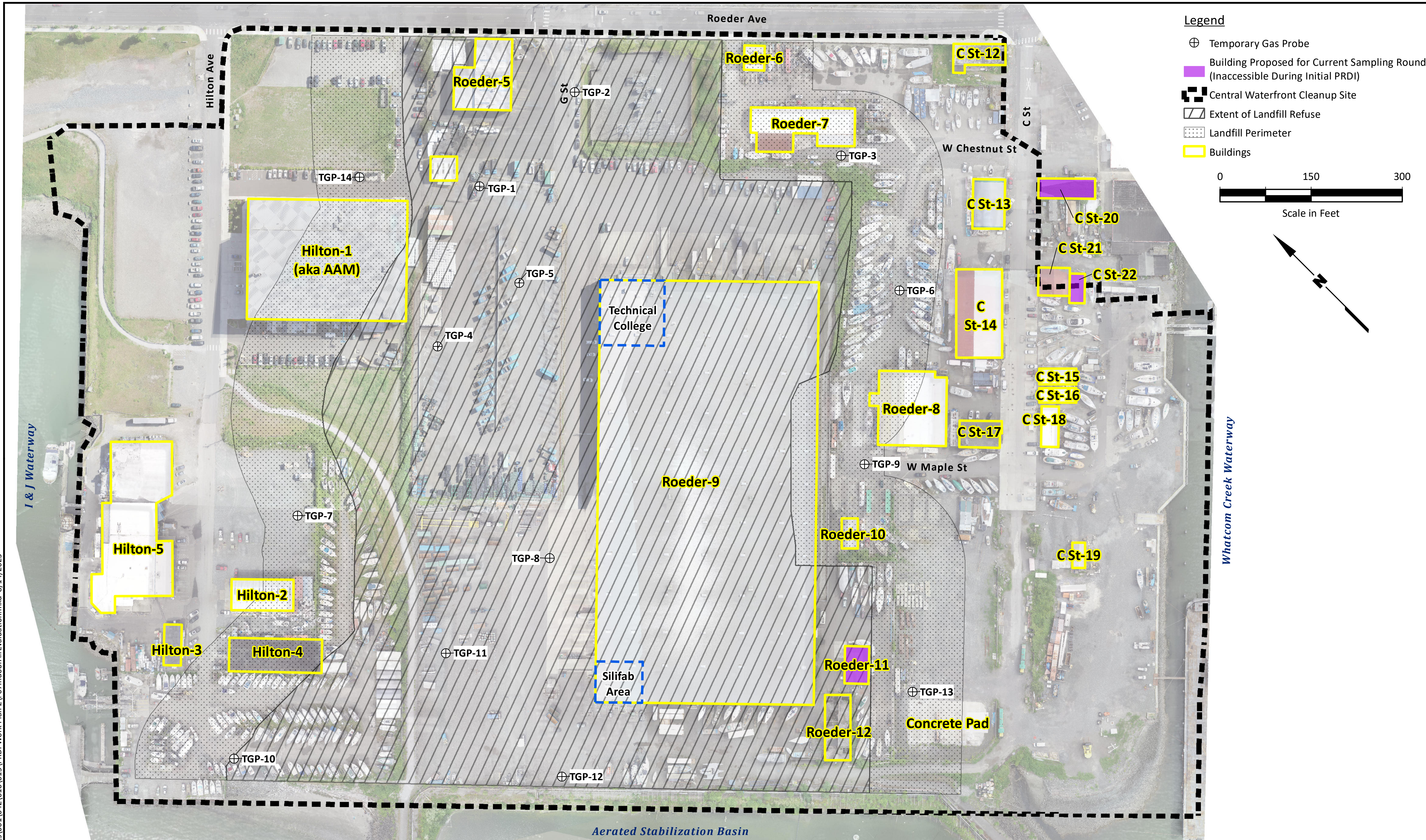
Central Waterfront Cleanup Site Pre-Remedial Investigation Project Plans Amendment No. 1 Bellingham, Washington	**2020 PRDI Landfill Gas Readings and Planned 2023 Landfill Gas Sampling Locations**	Figure 6



Note
1. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

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Central Waterfront Cleanup Site
Pre-Remedial Investigation
Project Plans Amendment No. 1
Bellingham, Washington

Planned 2023 Indoor Air Evaluation Locations

Figure 7

Table 1
Environmental Investigation Summary – Soil Borings
PRDI Project Plans, Amendment No. 1
Central Waterfront Cleanup Site – Bellingham, Washington

Location ID	Subarea	Type	Status	ACTIVITY		SOIL					GROUNDWATER					
				Soil Sampling	Water Sampling	Sample ID Prefix[1]	Sample Interval[2]	TPH-G (NWTPH-Gx)	TPH-D and TPH-O (NWTPH-Dx)	BTEX (EPA Method 5035/8260D)	Sample ID Prefix[1]	Sample Interval[3]	Sampling Frequency	TPH-G (NWTPH-Gx)	TPH-D and TPH-O (NWTPH-Dx)	BTEX (EPA Method 8260D)
CS-014	C Street	Direct Push	Proposed	X	X	CS-014-S	TBD	X	X	X	CS-014-GW	TBD	One-time	X	X	X
CS-015	C Street	Direct Push	Proposed	X	X	CS-015-S	TBD	X	X	X	CS-015-GW	TBD	One-time	X	X	X
CS-016	C Street	Direct Push	Proposed	X	X	CS-016-S	TBD	X	X	X	CS-016-GW	TBD	One-time	X	X	X
CS-017	C Street	Direct Push	Proposed	X	X	CS-017-S	TBD	X	X	X	CS-017-GW	TBD	One-time	X	X	X
CS-018	C Street	Direct Push	Proposed	X	X	CS-018-S	TBD	X	X	X	CS-018-GW	TBD	One-time	X	X	X
CS-019	C Street	Direct Push	Proposed	X	X	CS-019-S	TBD	X	X	X	CS-019-GW	TBD	One-time	X	X	X
CS-020	C Street	Direct Push	Proposed	X	X	CS-020-S	TBD	X	X	X	CS-020-GW	TBD	One-time	X	X	X
CS-021	C Street	Direct Push	Proposed	X	X	CS-021-S	TBD	X	X	X	CS-021-GW	TBD	One-time	X	X	X
CS-022	C Street	Direct Push	Proposed	X	X	CS-022-S	TBD	X	X	X	CS-022-GW	TBD	One-time	X	X	X
CS-023	C Street	Direct Push	Proposed	X	X	CS-023-S	TBD	X	X	X	CS-023-GW	TBD	One-time	X	X	X
CS-024	C Street	Direct Push	Proposed	X	X	CS-024-S	TBD	X	X	X	CS-024-GW	TBD	One-time	X	X	X
CS-025	C Street	Direct Push	Proposed	X	X	CS-025-S	TBD	X	X	X	CS-025-GW	TBD	One-time	X	X	X
CS-026	C Street	Direct Push	Proposed	X	X	CS-026-S	TBD	X	X	X	CS-026-GW	TBD	One-time	X	X	X
CS-027	C Street	Direct Push	Proposed	X	X	CS-027-S	TBD	X	X	X	CS-027-GW	TBD	One-time	X	X	X
CS-028	C Street	Direct Push	Proposed	X	X	CS-028-S	TBD	X	X	X	CS-028-GW	TBD	One-time	X	X	X
HH-001	Hilton	Direct Push	Proposed	X		HH-001-S	TBD	X	X	X	None					
HH-002	Hilton	Direct Push	Proposed	X		HH-002-S	TBD	X	X	X	None					
HH-003	Hilton	Direct Push	Proposed	X		HH-003-S	TBD	X	X	X	None					
HH-004	Hilton	Direct Push	Proposed	X		HH-004-S	TBD	X	X	X	None					
TOTAL				**19**	**15**	**---**	**---**	**19**	**19**	**19**	**---**	**---**	**---**	**15**	**15**	**15**

Table 1
Environmental Investigation Summary – Soil Borings
PRDI Project Plans, Amendment No. 1
Central Waterfront Cleanup Site – Bellingham, Washington

Notes:

(1) Sample IDs for soil and groundwater will contain a depth interval or a date following the prefix shown on the table. For example, the sample ID for a soil sample collected at location CS-014 from 6 to 7 feet bgs would be "CS-014-S-6-7" and a groundwater sample collected at location CS-014 on September 15, 2023 would have a sample ID of "CS-014-GW-20230915."

(2) Sampling interval TBD based on results of field screening. If evidence of contamination is present, samples will be collected from the 1-foot interval with the most evidence (e.g., strongest odor, highest PID detection). If evidence of contamination is not present, samples will be collected from the 1-foot interval that crosses the groundwater table, indicated by the transition from moist to wet soil in the soil core. Additional analysis of metals (arsenic, barium, cadmium, chromium, lead, mercury, nickel, selenium, silver, and zinc) will be conducted at selected locations for waste characterization purposes.

(3) Screened interval will be across the groundwater table to evaluate the presence of LNAPL, as observed in purge water. The groundwater table is estimated to occur at 6 to 8 feet bgs and will be confirmed using the depth-to-water measurements at the nearest monitoring well and/or the observed depth of soil saturation at the nearest soil boring. Additional analysis of total metals (arsenic, barium, cadmium, chromium, lead, mercury, nickel, selenium, silver, and zinc) will be conducted at selected locations for waste characterization purposes.

Abbreviations and Acronyms:

bgs = below ground surface
BTEX = benzene, toluene, ethylbenzene, and total xylenes
EPA = US Environmental Protection Agency
ID = identification
LNAPL = light non-aqueous phase liquid
NWTPH-Dx = Northwest total petroleum hydrocarbon extended-range diesel analytical method
NWTPH-Gx = Northwest total petroleum hydrocarbon extended-range gasoline analytical method
PID = photoionization detector
TBD = to be determined
TPH-D = diesel-range total petroleum hydrocarbons
TPH-G = gasoline-range total petroleum hydrocarbons

Table 2
Environmental Investigation Summary – Groundwater Monitoring Wells and Tidal Study Locations
PRDI Project Plans, Amendment No. 1
Central Waterfront Cleanup Site – Bellingham, Washington

				ACTIVITY						SOIL								GROUNDWATER																		
Location ID	Subarea	Type	Status	Soil Sampling	Water Sampling	Survey	Continuous Water Levels	Slug Tests	Install/Develop	Sample ID Prefix[1]	Sample Interval[2]	TPH-G (NWTPH-Gx)	TPH-D and TPH-O (NWTPH-Dx))	BTEX (EPA Method 5035A/8260D)	Bis(2-ethylhexyl)phthalate (EPA 8270E)	PAHs (EPA 8270E SIM)	Total Metals[3]	Sample ID Prefix[1]	Sample Interval	Sampling Frequency	TPH-G (NWTPH-Gx)	TPH-D and TPH-O (NWTPH-Dx)	BTEX (EPA Method 8260D)	Bis(2-ethylhexyl)phthalate (EPA 8270E)	PAHs (EPA 8270E SIM)	Total and Dissolved Metals[3]	Hexavalent and Trivalent Chromium[4]	YSI Meter (pH, DO, ORP, Temp)	Ferrous (dissolved) Iron (Hach)	Dissolved Manganese (EPA 6020A UCT)	Nitrate, Nitrite, Sulfide, & Sulfate (EPA 300.0)	Methane (RSK-175)	Total Organic Carbon (SM 5310B)	Alkalinity (SM 2320)	Chloride (EPA 300.0)	Total Dissolved Solids (SM 2540)
CS-MW-1	C Street	Monitoring Well	Existing		X	X				None								CS-MW-1-GW	middle of screen	Quarterly	X	X	X			X		X	X	X	X	X	X	X		
CS-MW-2	C Street	Monitoring Well	Existing		X	X				None								CS-MW-2-GW	middle of screen	Quarterly	X	X	X			X		X	X	X	X	X	X	X		
CS-MW-3	C Street	Monitoring Well	Existing		X	X	X	X		None								CS-MW-3-GW	middle of screen	Quarterly	X	X	X			X		X	X	X	X	X	X	X		
CS-MW-4	C Street	Monitoring Well	Existing		X	X				None								CS-MW-4-GW	middle of screen	Quarterly	X	X	X			X		X	X	X	X	X	X	X	X	X
CS-MW-5	C Street	Monitoring Well	Existing		X	X	X			None								CS-MW-5-GW	middle of screen	Quarterly	X	X	X			X		X	X	X	X	X	X	X	X	X
CS-MW-6	C Street	Monitoring Well	Existing		X	X	X	X		None								CS-MW-6-GW	middle of screen	Quarterly	X	X	X			X		X	X	X	X	X	X	X	X	X
CS-MW-7	C Street	Monitoring Well	Proposed	X	X	X			X	CS-MW-7-S	TBD	X	X	X			X	CS-MW-7-GW	middle of screen	Quarterly	X	X	X			X		X	X	X	X	X	X	X		
CS-MW-8	C Street	Monitoring Well	Proposed	X	X	X			X	CS-MW-8-S	TBD	X	X	X			X	CS-MW-8-GW	middle of screen	Quarterly	X	X	X			X		X	X	X	X	X	X	X		
CS-MW-9	C Street	Monitoring Well	Proposed	X	X	X			X	CS-MW-9-S	TBD	X	X	X			X	CS-MW-9-GW	middle of screen	Quarterly	X	X	X			X		X	X	X	X	X	X	X	X	X
CS-MW-10	C Street	Monitoring Well	Proposed	X	X	X			X	CS-MW-10-S	TBD	X	X	X			X	CS-MW-10-GW	middle of screen	Quarterly	X	X	X			X		X	X	X	X	X	X	X		
CS-MW-11	C Street	Monitoring Well	Proposed	X	X	X			X	CS-MW-11-S	TBD	X	X	X			X	CS-MW-11-GW	middle of screen	Quarterly	X	X	X			X		X	X	X	X	X	X	X		
CS-MW-12	C Street	Monitoring Well	Proposed	X	X	X			X	CS-MW-12-S	TBD	X	X	X			X	CS-MW-12-GW	middle of screen	Quarterly	X	X	X			X		X	X	X	X	X	X	X		
CWF-CW-1	C Street	Monitoring Well	Existing		X	X	X			None								CWF-CW-1-GW	middle of screen	Quarterly	X	X	X			X		X	X	X	X	X	X	X		
CWF-CW-2	C Street	Monitoring Well	Existing		X	X	X	X		None								CWF-CW-2-GW	middle of screen	Quarterly	X	X	X			X		X	X	X	X	X	X	X		
MW-7(B)	C Street	Monitoring Well	Existing		X	X				None								None																		
MW-10(B)	C Street	Monitoring Well	Existing		X	X	X			None								MW-10(B)-GW	middle of screen	Quarterly	X	X	X			X		X	X	X	X	X	X	X		
MW-13(B)	C Street	Monitoring Well	Existing		X	X	X			None								MW-13(B)-GW	middle of screen	Quarterly	X	X	X			X		X	X	X	X	X	X	X	X	X
MW-50(C)	C Street	Monitoring Well	Existing		X	X	X	X		None								MW-50(C)-GW	middle of screen	Quarterly	X	X	X			X		X	X	X	X	X	X	X	X	X
HH-MW-1	Hilton	Monitoring Well	Existing		X	X	X	X		None								HH-MW-1-GW	middle of screen	Quarterly	X	X	X	X	X	X	X	X								
HH-MW-2	Hilton	Monitoring Well	Proposed	X	X	X	X	X	X	HH-MW-2-S	TBD	X	X	X	X	X	X	HH-MW-2-GW	middle of screen	Quarterly	X	X	X	X	X	X	X	X								
HH-MW-3	Hilton	Monitoring Well	Proposed	X	X	X	X		X	HH-MW-3-S	TBD	X	X	X	X	X	X	HH-MW-3-GW	middle of screen	Quarterly	X	X	X	X	X	X	X	X								
HH-MW-4	Hilton	Monitoring Well	Proposed	X	X	X	X		X	HH-MW-4-S	TBD	X	X	X	X	X	X	HH-MW-4-GW	middle of screen	Quarterly	X	X	X	X	X	X	X	X								
HH-MW-5	Hilton	Monitoring Well	Proposed	X	X	X	X		X	HH-MW-5-S	TBD	X	X	X	X	X	X	HH-MW-5-GW	middle of screen	Quarterly	X	X	X	X	X	X	X	X								
ASB-MW-1	Hilton/ASB	Monitoring Well	Existing		X	X	X	X		None								ASB-MW-1-GW	middle of screen	Quarterly	X	X	X	X	X	X	X	X								
ASB-MW-2	ASB	Monitoring Well	Existing			X	X			None								None																		
ASB-MW-3	ASB	Monitoring Well	Existing			X	X			None								None																		
ASB-MW-4	ASB	Monitoring Well	Existing			X	X			None								None																		
ASB-MW-5	ASB	Monitoring Well	Existing			X	X			None								None																		
ASB-MW-6	C Street/ASB	Monitoring Well	Existing			X	X			None								None																		
HH-TD-1	Hilton	Surface Water	Proposed			X	X			None	TBD							None																		
CS-TD-1	C Street	Surface Water	Proposed			X	X			None	TBD							None																		
			TOTAL	10	24	31	21	7	10	---	---	10	10	10	4	4	10	---	---	---	23	23	23	6	6	23	6	23	17	17	17	17	17	17	5	5

Table 2
Environmental Investigation Summary – Groundwater Monitoring Wells and Tidal Study Locations
PRDI Project Plans, Amendment No. 1
Central Waterfront Cleanup Site – Bellingham, Washington

Notes:

(1) Sample IDs for soil and groundwater will contain a depth interval or a date following the prefix shown on the table. For example, the sample ID for a soil sample collected at location CS-MW-7 from 6 to 7 feet bgs would be "CS-MW-7-S-6-7" and a groundwater sample collected at location HH-MW-1 on September 15, 2023 would have a sample ID of "HH-MW-1-GW-20230915."

(2) Sampling interval TBD based on results of field screening. If evidence of contamination is present, samples will be collected from the 1-foot interval with the most evidence (e.g., strongest odor, highest PID detection). If evidence of contamination is not present, samples will be collected from the 1-foot interval that crosses the groundwater table, indicated by the transition from moist to wet soil in the soil core.

(3) Metals to include arsenic, cadmium, total chromium, copper, lead, nickel, selenium, silver, and zinc by EPA Method 6020A UCT; and mercury by EPA Method 7470A.

(4) Hexavalent chromium by SM 3500; and trivalent chromium will be quantified through calculation.

Abbreviations & Acronyms:

ASB = Aerated Stabilization Basin
bgs = below ground surface
BTEX = benzene, toluene, ethylbenzene, and total xylenes
PAHs = polyaromatic hydrocarbons
EPA = US Environmental Protection Agency
ID = identification
LNAPL = light non-aqueous phase liquid
NWTPH-Dx = Northwest total petroleum hydrocarbon extended-range diesel analytical method
NWTPH-Gx = Northwest total petroleum hydrocarbon extended-range gasoline analytical method
PID = photoionization detector
SM = Standard Methods
TBD = to be determined
TPH-D = diesel-range total petroleum hydrocarbons
TPH-G = gasoline-range total petroleum hydrocarbons
UCT = universal cell technology

Table 3
Environmental Investigation Summary – Porewater and Surface Water Samples
PRDI Project Plans, Amendment No. 1
Central Waterfront Cleanup Site – Bellingham, Washington

				WATER SAMPLING ANALYSIS																
Location ID	Subarea	Type	Status	Sample ID Prefix[1]	Sample Interval	Sampling Frequency	TPH-G (NWTPH-Gx)	TPH-D and TPH-O (NWTPH-Dx)	BTEX (EPA Method 8260D)	Bis(2-ethylhexyl)phthalate (EPA 8270E)	PAHs (EPA 8270E SIM)	Total and Dissolved Metals[2]	YSI Meter (pH, DO, ORP, Temp)	Ferrous (dissolved) Iron (Hach)	Dissolved Manganese (EPA 6020A UCT)	Nitrate and Sulfate (EPA 300.0)	Methane (RSK-175)	Total Organic Carbon (SM 5310B)	Alkalinity (SM 2320)	Hardness (calculated, EPA 6010C)
HH-PW-1	Hilton	Porewater	Proposed	HH-PW-1	~1 foot bgs	One-time	X	X	X	X	X	X	X	X	X[4]	X[4]	X[4]	X[4]	X[4]	X
HH-PW-2	Hilton	Porewater	Proposed	HH-PW-2	~1 foot bgs	One-time	X	X	X	X	X	X	X	X	X[4]	X[4]	X[4]	X[4]	X[4]	X
HH-PW-3	Hilton	Porewater	Proposed	HH-PW-3	~1 foot bgs	One-time	X	X	X	X	X	X	X	X	X[4]	X[4]	X[4]	X[4]	X[4]	X
HH-SW-1	Hilton	Surface Water	Proposed	HH-SW-1	6 inches from the bottom of the water column	One-time[3]	X	X	X	X	X	X	X	X	X[4]	X[4]	X[4]	X[4]	X[4]	X
HH-SW-2	Hilton	Surface Water	Proposed	HH-SW-2	6 inches from the bottom of the water column	One-time[3]	X	X	X	X	X	X	X	X	X[4]	X[4]	X[4]	X[4]	X[4]	X
HH-SW-3	Hilton	Surface Water	Proposed	HH-SW-3	6 inches from the bottom of the water column	One-time[3]	X	X	X	X	X	X	X	X	X[4]	X[4]	X[4]	X[4]	X[4]	X
			TOTAL	---	---		9	9	9	9	9	9	9	9	9	9	9	9	9	9

Notes:

(1) Sample IDs for surface and porewater will contain a date following the prefix shown on the table. For example, a porewater sample collected at location HH-PW-1 on September 20, 2023 would have the sample ID "HH-PW-1-20230920" and a sample ID of "HH-SW-1-LT-20230920" would be from location HH-SW-1 during low-tide conditions on September 20, 2023.

(2) Metals include arsenic, cadmium, total chromium, copper, lead, nickel, selenium, silver, and zinc by EPA Method 6020A UCT; hexavalent chromium by SM 3500; mercury by EPA Method 7470A; and trivalent chromium will be quantified through calculation.

(3) Two surface water samples to be collected at each location, one at high tide and one at low tide, and on the day of porewater sampling.

(4) Additional porewater and surface water volume will be collected into laboratory-supplied containers and archived at the analytical laboratory for potential follow-on analyses.

Abbreviations and Acronyms:

bgs = below ground surface
BTEX = benzene, toluene, ethylbenzene, and total xylenes
DO = dissolved oxygen
EPA = US Environmental Protection Agency
ID = identification
NWTPH-Dx = Northwest total petroleum hydrocarbon extended-range diesel analytical method
NWTPH-Gx = Northwest total petroleum hydrocarbon extended-range gasoline analytical method
ORP = oxidation-reduction potential
SIM = selected ion monitoring
SM = Standard Methods
Temp = temperature
TPH-D = diesel-range total petroleum hydrocarbons
TPH-G = gasoline-range total petroleum hydrocarbons
UCT = universal cell technology

Table 4
Geotechnical Investigation Summary
PRDI Project Plans, Amendment No. 1
Central Waterfront Cleanup Site – Bellingham, Washington

Sampling Location ID	Location/Rationale	Field Analysis	Laboratory Analysis	Approximate Depth
HH-ERT-1	Determine lateral and vertical extents of landfill refuse	Electrical resistivity tomography	N/A	
HH-ERT-2	Determine lateral and vertical extents of landfill refuse			
HH-ERT-3	Determine lateral and vertical extents of landfill refuse			
HH-ERT-4	Determine lateral and vertical extents of landfill refuse			
HH-ERT-5	Determine lateral and vertical extents of landfill refuse			

APPENDIX A

Bioremediation Field Pilot Study Work Plan

BIOREMEDIATION FIELD PILOT STUDY WORK PLAN

Central Waterfront Cleanup Site
Bellingham, Washington

September 29, 2023

Prepared for

Port of Bellingham
Bellingham, Washington

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Bioremediation Field Pilot Study Work Plan
Central Waterfront Cleanup Site
Bellingham, Washington

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LIST OF ABBREVIATIONS AND ACRONYMS

AN	ammonium nitrate
bgs	below ground surface
C Street Properties subarea	C Street subarea
CAP	Cleanup Action Plan
City	City of Bellingham, Washington
CPOC	conditional point of compliance
CUL	cleanup level
Ecology	Washington State Department of Ecology
EDR	Engineering Design Report
EISB	enhanced *in situ* bioremediation
ft	foot/feet
kg	kilogram
Landau	Landau Associates, Inc.
LNAPL	light non-aqueous phase liquid
MCL	maximum contaminant level
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mg-N/L	milligrams nitrate-as-nitrogen per liter
MNA	monitored natural attenuation
MTCA	Model Toxics Control Act
NAPL	non-aqueous phase liquid
Port	Port of Bellingham
PRDI	pre-remedial design investigation
PVC	polyvinyl chloride
RAO	remedial action objective
redox	reduction-oxidation
Site	Central Waterfront Cleanup Site
TPH	total petroleum hydrocarbons
WAC	Washington Administrative Code

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1.0 INTRODUCTION

This document presents a work plan to conduct a bioremediation field pilot study in the C Street Properties subarea (C Street subarea) within the Central Waterfront Cleanup Site (Site) in Bellingham, Washington. The field pilot study in the C Street subarea will consist of the evaluation of the application of enhanced *in situ* bioremediation (EISB) of total petroleum hydrocarbons (TPH) in groundwater. This work plan has been prepared by Landau Associates, Inc. (Landau) on behalf of the Port of Bellingham (Port) in accordance with the requirements of Agreed Order No. DE 3441, Amendment 4, and the Cleanup Action Plan (CAP; Ecology 2020) issued by the Washington State Department of Ecology (Ecology) in January 2020.

The Site is being cleaned up under the authority of the Model Toxics Control Act (MTCA), Chapter 70.105D of the Revised Code of Washington, and the MTCA Cleanup Regulation, Chapter 173-340 of the Washington Administrative Code (WAC).

1.1 Current C Street Subarea Environmental Conditions Summary

Several environmental investigations were conducted within the C Street subarea prior to developing the CAP. The Remedial Investigation/Feasibility Study Report, finalized in 2018, presents the site conceptual model including the nature and extent of contamination. The summary of Site environmental conditions is based on those prior studies, as presented in the CAP (Ecology 2020). Contaminants of concern within the C Street subarea include petroleum hydrocarbons and associated constituents (i.e., gasoline-, diesel-, and motor oil-range petroleum hydrocarbons, collectively referred throughout this text as total petroleum hydrocarbons [TPH]), benzene, polycyclic aromatic hydrocarbons, and metals in soil and groundwater, TPH in soil gas, and metals in sediments (Ecology 2020).

Two interim cleanup actions have been conducted at the C Street subarea, including underground storage tank decommissioning and petroleum-related contamination cleanup, which removed impacted soils and improved stormwater and utility infrastructure.

The CAP's selected cleanup action for the C Street subarea identified the removal of hotspot soils that exceeded a TPH remediation level of 19,000 milligrams per kilogram (mg/kg). However, initial pre-remedial design investigation (PRDI) sampling activities, which included advancement of 13 soil borings (CS-01 through CS-13) in the hotspot area, resulted in no samples exceeding the remediation level, including those collected proximate to the previous sampling locations with the highest concentrations of TPH. PRDI groundwater sampling results indicated the presence of TPH contaminant concentrations above Site cleanup levels (CULs). Therefore, a groundwater treatment strategy of EISB was developed and presented in the Agency Review Draft Engineering Design Report (EDR) as a more appropriate remedial alternative for the C Street subarea than the identified hotspot excavation. The EISB strategy includes a field pilot study to collect sufficient data to evaluate EISB and develop a final cleanup action for the C Street subarea.

2.0 BIOREMEDIATION PILOT STUDY OBJECTIVES

The EISB field pilot study is being conducted to evaluate the efficacy of an *in situ* bioremediation strategy to accelerate achievement of Site Remedial Action Objective (RAO) No. 6 at the C Street Properties. RAO-6 is to meet groundwater cleanup standards throughout the Site, outside the Landfill and Perimeter subarea footprint (Site-wide).

As described in the Agency Review Draft EDR (Landau 2022), EISB will supplement and enhance ongoing natural attenuation (i.e., anaerobic biodegradation), which is occurring at the Site due to tidal influence and intrusion of marine surface water to groundwater near the shoreline. Marine water contains sulfate, which can be used by naturally-occurring bacteria to obtain energy from the destruction of TPH. The pilot program is being conducted to demonstrate that bioremediation will be stimulated at the Site so that groundwater CULs will be achieved at the designated conditional points of compliance (CPOCs). Monitoring wells CWF-CW-1 and CWF-CW-2, located at the west and east ends of the C Street seawall, respectively (Figure A-3), are considered the CPOCs for groundwater quality in the C Street subarea.

Once the field pilot study program demonstrates that bioremediation can be used effectively to accelerate achieving CULs at the CPOCs, the installed system may be expanded and enhanced (as appropriate, based on performance results) to potentially establish the remedy for groundwater treatment in the C Street subarea. After an extended period of active treatment and achievement of CULs at the CPOCs, bioremediation injections may be suspended with Ecology concurrence and the Site transition to a period of monitored natural attenuation (MNA). MNA will continue until CULs are clearly being achieved at the standard points of compliance for the C Street subarea. Bioremediation injections may be resumed if sustained rebound of TPH concentrations above CULs occurs following transition to MNA. It is anticipated that the field pilot study will demonstrate that CULs can be achieved at the CPOCs within 5 to 10 years of beginning the periodic bioremediation applications described herein.

3.0 FIELD PILOT PROGRAM TECHNOLOGY SELECTION AND DESCRIPTION

This section provides the rationale for the selection of EISB for the planned field pilot study program and further details on the specifics of the treatment process, area of focus, and the basis for study design.

3.1 Enhanced *In Situ* Bioremediation

As described above, EISB will supplement and enhance natural attenuation, which is occurring at the Site due to tidal influence and intrusion of marine surface water to groundwater near the shoreline. This section describes the rational for the selection of the proposed technology and its specific application at the C Street subarea.

EISB consists of enhancing and/or stimulating aerobic or anaerobic biological processes in saturated subsurface soil and groundwater through the introduction of electron acceptors and/or donors. Macronutrients and micronutrients may also be added. Phosphate is a macronutrient that can become a limiting factor over time for continued bioremediation, as phosphate available in the aquifer becomes depleted; ammonium phosphate is commonly applied at 2 pounds per 1,000 gallons of injectate. Yeast extract, providing micronutrients such as trace metals and vitamins, is commonly applied a rate of 1 to 2 pounds per 1,000 gallons of injectate. The introduction of these substrates increases the rate of degradation of contaminants in aquifer soil and groundwater by microbial activity where the natural degradation is limited by the background availability of electron acceptors/donors and nutrients.

Biodegradation occurs through microbially mediated reactions, whereby micro-organisms obtain energy by reduction-oxidation (redox) reactions. Contaminants (e.g., TPH) can be used as the electron donor together with available electron acceptors (oxygen, nitrate, manganese [IV], ferric iron, sulfate, and carbon dioxide) that occur naturally or can be added to stimulate treatment. These redox reactions can be compared to the process whereby humans obtain energy through consumption of food (electron donor) and oxygen (electron acceptor). Bacteria obtain the greatest energy yield by using oxygen as an acceptor, as it is highly oxidized and can be easily reduced. When oxygen is depleted, bacteria use the less-oxidized electron acceptors in the following order: nitrate, manganese (IV), ferric iron, sulfate, and carbon dioxide. Oxygen is naturally depleted in water-bearing zones with high concentrations of natural organic carbon as commonly occurs at marine shoreline sites and sites filled with dredge spoils.

Site data demonstrate that current conditions are anaerobic, specifically nitrate- to sulfate-reducing, with low nitrate and sulfate (electron acceptor) concentrations. TPH biodegradation can be enhanced by addition of these electron acceptors. Sulfate is readily available at the Site in the surrounding marine surface water and is present in tidally-influenced groundwater within about 200 feet (ft) of the Site shoreline. Use of filtered marine surface water for injection of sulfate to the TPH-impacted aquifer is a sustainable and easy application. Nitrate may be used as a secondary electron acceptor to accelerate TPH cleanup.

Bioremediation relies on addition of electron acceptor substrates by various means including injection into vertical wells or infiltration trenches/galleries. Infiltration trenches or galleries are recommended for the Site because of expected slow infiltration rates due to silty aquifer soils and access limitations that make the use of numerous individual injection wells problematic. Infiltration is also preferred due to the low hydraulic conductivity anticipated in the finer silty sands in the C Street subarea. Use of infiltration trenches allows for relatively quick injection of substrates to granular trench backfill, followed by slower infiltration to native soils. The use of infiltration trenches improves distribution of reagents to the interbedded sands and silts that are intercepted by the trench.

3.2 Pilot Program Treatment Description

Data collected from monitoring wells in the C Street subarea indicate anaerobic conditions with detections of sulfate electron acceptor extending some distance inland from the south shoreline. Sulfate concentrations greater than 10 milligrams per liter (mg/L) extend approximately 200 ft inland due to tidal mixing of seawater with groundwater (seawater contains sulfate at a concentration of approximately 2,800 mg/L). Sulfate concentrations decrease with increased inland distance due to a combination of less tidal influence and utilization of sulfate by bacteria for TPH degradation. Injection of sulfate, and potentially nitrate, to upland groundwater is likely to enhance the biodegradation of TPH at the Site. The sulfate concentration injected will match the sulfate concentration of seawater (approximately 2,800 mg/L). Nitrate, if used, may be applied at a similar or higher concentration as sulfate (up to 4,500 milligrams nitrate-as-nitrogen per liter [mg-N/L] has been applied by Landau Associates at other sites in Washington).

Anaerobic biodegradation of TPH is the preferred approach (over aerobic biodegradation) for the Site, consistent with its application at other cleanup sites with reduced aquifers (Wiedemeier et al. 1999). Sulfate and nitrate can be used together or independently as electron acceptors for anaerobic bioremediation of TPH (Cunningham et al. 2001). Sulfate and nitrate are not substantially depleted as oxygen is by natural organic carbon. Nitrate is typically a more effective acceptor and is preferred by aquifer bacteria as it provides more energy than sulfate and is often depleted in areas of TPH contamination. Groundwater monitoring data from recently installed wells indicate that nitrate concentrations in the treatment area are very low to not detected, indicating that added nitrate would be effectively used by Site bacteria for degradation of TPH. The decrease of sulfate concentrations in groundwater with distance inland suggests that additional sulfate would improve the degradation of TPH.

Sulfate-containing seawater from the adjacent Whatcom Waterway will be the primary source of electron acceptor injected at the Site for bioremediation. This is a very low-cost and sustainable approach to provide electron acceptor farther inland at the Site. As described in the following section, minimal labor and processing are required to use sulfate in seawater for bioremediation. Furthermore, injected seawater will move toward and eventually discharge to the waterway with utilization of sulfate occurring all along the flow path. A surface water discharge limit for sulfate is not a concern because the discharge of sulfate sourced from the receiving water body will not exceed the natural concentration of the water body. Increased salinity in the C Street subarea of the Site is not a concern, as Site groundwater is non-potable and has a highest beneficial use of discharge to marine surface water.

Seawater levels of salinity do not inhibit the desired biodegradation of TPH; TPH biodegradation in seawater has been well documented following oil spills and at natural oil seeps.

While sulfate-containing seawater is anticipated to be the primary source of electron acceptor applied during the EISB Field Pilot Study at the C Street subarea, the ongoing performance results of the study will also be used to evaluate if the effectiveness of the EISB program would be enhanced through the additional use of nitrate. Nitrate may be used as a secondary electron acceptor added to seawater injection fluid if monitoring results over the course of treatment indicate that TPH degradation is not proceeding as quickly as desired. The rate of TPH degradation varies by site due to various factors, including contaminant solubility and distribution, and hydrogeology. Rebound in TPH occurs following injections as long as significant TPH mass remains in sorbed or non-aqueous phase liquid (NAPL) phases. Monitoring results will be evaluated and potential addition of nitrate discussed with Ecology. At other Washington sites, Landau applies nitrate at concentrations ranging from 225 to 4,500 mg-N/L for TPH bioremediation. Although a drinking water maximum contaminant level (MCL) exists for nitrate at 10 mg-N/L, drinking water is not a beneficial use of shallow groundwater at the Site and, therefore, the MCL does not apply. The highest beneficial use for Site groundwater is the discharge to the marine surface water; however, no marine surface water criteria are established for nitrate.

Landau is currently conducting nitrate injections to enhance TPH biodegradation at a Port site at Blaine Marina in Blaine, Washington. At that site, 20 mg-N/L is used as the benchmark limit for nitrogen in marine surface water from the combined contributions of nitrate and nitrite (i.e., 20 mg-N/L of nitrate and nitrite). Nitrate and nitrite are monitored in marine surface water adjacent to Blaine Harbor and results have consistently been well below the benchmark. A similar nitrate+nitrite limit in marine surface water is recommended for the C Street subarea bioremediation program.

Electron acceptor injection will be accomplished using a series of infiltration trenches located approximately perpendicular to the groundwater flow direction. The benefits of infiltration trenches at the Site are described in Section 3.1.

3.3 Treatment Area

The locations and extent of the planned infiltration trenches are shown on Figure A-3 in association with the maximum 2021 TPH concentrations. A cross section of the proposed trench construction is shown on Figure A-4.

Trenches will be located upgradient of, and within, maximum TPH concentration areas to treat and intercept contaminated groundwater flow; Site groundwater flows south toward the shoreline and then east and west around the seawall. Trenches A, D, and E will target the central area with the highest 2021 TPH concentrations in groundwater. Trenches B and C will treat TPH moving past the west end of the seawall and CPOC CWF-CW-1. Trench F will treat TPH moving past the east end of the seawall and CPOC CWF-CW-2. Sulfate infiltration at these trenches will enhance the treatment already occurring up to 200 ft from the shoreline based on sulfate concentrations ranging from 10 to 100 mg/L resulting from tidal influence/seawater intrusion.

Groundwater flow in the C Street subarea is dynamic and complex. The dominant groundwater flow is to the south discharging to the waterway, but the seawall forces groundwater to flow west and east to discharge near CWF-CW-1 and CWF-CW-2. Furthermore, higher tide conditions cause temporary gradient reversals near the shoreline, with localized groundwater flow to the north (inland) near CWFCW-1. The pilot program infiltration trenches will be oriented approximately perpendicular to the variable groundwater flow directions so that groundwater flows through one or more lines of treatment before discharging to the waterway near the ends of the seawall. Injected sulfate will be transported by groundwater flow to create treatment zones hydraulically downgradient of each infiltration trench.

The spacing between infiltration rows will be based, in part, on the distance that groundwater is estimated to travel in 1 year or less. This is based on estimated groundwater average seepage velocity of 0.3 to 1 ft/day (about 100 to 300 ft/year).[1] Seepage velocity estimates and final infiltration trench placement will be refined once top-of-casing elevations and aquifer slug test data are obtained in advance of pilot program installation and start-up.

3.4 Design Criteria, Assumptions, and Calculations

Six infiltration trenches will be constructed across the C Street treatment area at the approximate locations shown on Figure A-3. Trenches will be excavated approximately 5 ft wide using a standard bucket excavator. Details of trench construction are described in Section 4.2.

The estimated injection volume (per injection event) is 45,250 gallons, based on the estimated pore volumes for the six infiltration trenches. The lengths of the infiltration trenches (see Figure A-3) will range from 125 to 200 ft, with individual trench volumes ranging from 5,750 to 9,250 gallons. Each infiltration trench injection volume is based on a design trench width of 5 ft and estimated freeboard of 5 ft above the groundwater table at the time of injection (based on the average depth to groundwater). Filling the infiltration trenches to just below pavement base course with injection fluid is desired to contact the highest portion of the TPH-impacted soils (i.e., smear zone) and to provide a driving head to distribute injection fluid into the surrounding native soil. Volume calculations are provided in Table A-1.

Seawater from Bellingham Bay will provide sulfate, the electron acceptor for TPH degradation, at a concentration of approximately 2,800 mg/L. Seawater will be pumped from a suspended drop tube in the bay (e.g., attached to dock piling) and passed through a dual-bag filter (10 to 40 microns) to remove algae that could be detrimental to the performance of the infiltration trenches.

Multiple injections of sulfate are anticipated to complete treatment of TPH mass present in the aqueous phase (dissolved) and adsorbed to aquifer soil particles. Based on stoichiometry, it takes approximately 4.6 kilograms (kg) of sulfate to degrade 1 kg of TPH/benzene, toluene, ethylbenzene, and total xylenes if sulfate is fully used for TPH degradation; stoichiometric calculations are provided in Table A-2. Based on stoichiometric calculations, the anticipated volume of each injection event (45,250 gallons) will deliver 480 kg of sulfate capable of supporting biodegradation of 104 kg of TPH, or approximately 71 liters

[1] Seepage velocity estimates will be refined once top-of-casing elevation and aquifer slug test data are obtained for the monitoring wells in the C Street subarea.

(19 gallons) of TPH pure product equivalent. Injection events are anticipated to occur at a frequency of monthly potentially transitioning to quarterly, depending on monitoring results.

Although a groundwater quality standard exists for sulfate (250 mg/L; WAC 173-200-040), drinking water is not a beneficial use of shallow groundwater at the Site; therefore, the standard does not apply. As described in the CAP (Ecology 2020), the highest beneficial use for Site groundwater is discharge to the marine surface water of Bellingham Bay. The average sulfate concentration in marine water (Pacific Ocean) is 2,800 mg/L (Mackenzie et al. 2020). No marine surface water criteria are established for sulfate. Per WAC 173-201A-260(1)(a), "It is recognized that portions of many water bodies cannot meet the assigned criteria due to the natural conditions of the water body. When a water body does not meet its assigned criteria due to natural climatic or landscape attributes, the natural conditions constitute the water quality criteria." As seawater will be the source of sulfate for injection, the maximum concentration that can be applied to groundwater and, therefore, could reach surface water is the same as the receiving water body.

As discussed in Section 3.2, nitrate may be introduced as a secondary electron acceptor to enhance the EISB process depending on the ongoing performance results of the field pilot study. If nitrate is used as a secondary electron acceptor in addition to sulfate, a benchmark limit of 20 mg-N/L is proposed for combined nitrate and nitrite (i.e., 20 mg-N/L of nitrate + nitrite). This is the limit used at a similar shoreline site in Blaine, Washington (Section 3.2). Ongoing monitoring for nitrate and nitrite would be conducted in marine surface water adjacent to the Site.

4.0 CONSTRUCTION AND IMPLEMENTATION

This section describes construction of infiltration trenches and installation of monitoring wells; injection to trenches; monitoring; waste disposal; and adaptive management.

4.1 Utility Locates

Prior to trenching or monitoring well installation, Landau will mark the proposed locations on the ground using white spray paint. Landau will be responsible for utility clearance for monitoring wells. The excavation contractor will be responsible for utility clearance for trench construction.

Landau and the contractor will contact the public one-call utility locating service to identify public utilities in the investigation area. Additionally, a private utility locating service will be subcontracted to mark private utilities within the work area. A Landau representative will be on Site during the marking of private utilities. If utilities are identified in the locations where subsurface work is anticipated, adjustments will be made to avoid impacting utilities, to the extent practicable.

4.2 Trench Construction

As described in Section 3.4, six infiltration trenches will be constructed to facilitate the application of electron acceptor substrate in the locations shown on Figure A-3. Trench excavation will occur during the dry season (lowest seasonal groundwater). Infiltration trenches will be constructed approximately 5 ft wide and extend an average of 8 ft deep to intersect as much of the TPH smear zone as can be achieved without dewatering. Trenches will be excavated using trench boxes to prevent sloughing of the sidewalls. The length of open trench will be minimized, with placement of the infiltration pipe and risers, observation standpipes, and gravel backfill as excavation progresses. Details of trench construction are as follows:

- Each trench will feature a 3- or 4-inch-diameter, rigid high-density polyethylene or polyvinyl chloride (PVC) perforated pipe for horizontal distribution of the injected substrate along the entire length of the trench. The horizontal perforated pipe will be placed on top of 2 ft of 1.5-inch washed drain rock placed in the bottom of the trench to prevent the pipe from silting up with disturbed soil.
- Non-perforated vertical risers for injection and cleanout will be installed at both ends of the horizontal perforated pipe using cleanout sweeps. Risers will be contained within traffic-rated vaults at the surface to allow future access for monitoring and injection, while minimizing aboveground obstructions to Site use.
- Also installed at the end of each trench and extending into the vault will be 4-inch-diameter PVC observation standpipes to be used for water-level monitoring during and after injection and for groundwater sampling, as needed. The observation standpipes will extend to the bottom of the trench and be constructed with a 4-ft-long slotted well screen (0.010-inch slot size).
- Trenches will be wrapped with a separation geotextile (non-woven geotextile Mirafi® 140N or equivalent) prior to placement of 1.5-inch washed drain rock to within 1.5 ft of grade. The ends of the geotextile wrap will be folded over the top of drain rock before placement of crushed surfacing base course to grade.

- The vault penetrations for observation standpipes and injection risers will be sealed with non-shrink cement grout. Injection risers will be completed with female pipe thread adapters and threaded plugs to facilitate connection to injection hoses. All connections and fittings must be solvent-welded.
- At the seawall, trench alignments and depths will be modified, as needed, to avoid the wall tiebacks; tiebacks may be as shallow as 4 ft below ground surface (bgs) at the wall and increase in depth to approximately 15 ft bgs at their inland terminus.

4.3 Groundwater Well Installation

Three new monitoring wells (i.e., CS-MW-7 through CS-MW-9) will be installed in the C Street subarea to provide additional locations for performance monitoring of the EISB field pilot study. Planned new groundwater well locations are shown on Figure A-5. It is anticipated that these wells will be installed after the infiltration trenches to avoid damage to wells during trench construction.

An additional three new monitoring wells (CS-MW-10 through CS-MW-12) will be installed in the C Street subarea to provide additional locations to evaluate groundwater flow and contaminant levels to aid in ongoing evaluation and potential enhancement of the EISB remedy (i.e., to determine if additional trenches or increased/decreased rate of substrate application is warranted). Optimal locations for these additional wells will be determined following evaluation of additional PRDI results, including laboratory analyses of soil and groundwater from direct-push borings, detailed in the PRDI Project Plan, Amendment No. 1.

Well installation and development procedures for the six new C Street area groundwater wells will be as follows:

- Monitoring wells will be installed in borings drilled using hollow-stem auger methods.
- New wells will be constructed according to the same specifications of previously-installed wells in the C Street subarea.
- Wells will be installed to a maximum depth of 20 ft bgs and constructed using 2-inch-diameter PVC piping. Each well will feature 15-ft-long (5 to 20 ft bgs) Schedule 40 PVC screens (0.010-inch slot size) and traffic-rated, flush-mount protective monuments.
- Monitoring wells will be developed using a surge block and centrifugal pump until the purged water runs clear. For the purposes of development, "clear" means that the measured turbidity in the purged water is approximately 10 nephelometric units or less.

4.4 Injection Procedures

A 3-inch, gasoline-powered, centrifugal injection pump capable of approximately 300 gallons per minute maximum flow rate will be used for injection. Seawater will be pumped from a suspended pipe in the bay (i.e., attached to dock piling) and passed through a dual-bag filter (10 to 40 microns) to remove algae that could be detrimental to the performance of the infiltration trenches. A totalizer will measure the volume injected to each trench.

Each trench will be injected one at a time. Injection risers on either end of each infiltration trench will be injected simultaneously for even distribution of injection solution within the trench. Injection flow rates will be regulated by adjusting the throttle and a valve on the pump. The trench water level will be monitored in trench standpipes during injection to maintain the fluid level below ground surface. Nearby utility corridors, catch basins, and surface water will be monitored for potential short-circuiting of injection solution.

In the event that nitrate is added as a secondary electron acceptor, a concentrated solution of ammonium nitrate (AN) will be added with the filtered seawater injected to the trenches. AN solution will be added through an additional drop tube on the suction side of the pump or may be added to trench risers prior to injection of seawater. Prior to the use of nitrate, a Field Pilot Study Work Plan addendum would be prepared for Ecology review and approval. The addendum will provide the details of AN dosing and surface water sampling for nitrate.

4.5 Groundwater Monitoring

Groundwater monitoring will be conducted during the EISB period to assess treatment progress and inform potential modifications to subsequent injection events. Monitoring will be conducted at the 17 monitoring wells within and near the treatment area (see Figure A-5); upgradient well MW-7(B) will not be included as it is outside and upgradient of the treatment area. Monitoring parameters will include redox and electron acceptor parameters (dissolved oxygen, nitrate, ferrous iron, and sulfate) and gasoline- and diesel-range TPH. An initial baseline monitoring event will be conducted prior to the initial injection event, and quarterly monitoring of C Street subarea wells is anticipated thereafter during the field pilot study period. A transition to semiannual monitoring may be implemented following the field pilot study, depending on the field pilot study results.

If nitrate is added to injection solution as a secondary electron acceptor, surface water monitoring for nitrate+nitrite will be conducted concurrent with quarterly to semiannual groundwater monitoring.

As noted above, once CULs are consistently achieved at the CPOCs, EISB injections will be suspended and the Site will transition to a period of MNA, which will continue until CULs are achieved throughout the Site (i.e., at the standard points of compliance). MNA groundwater monitoring is anticipated to include a reduced number of wells, frequency (annual), and parameters (TPH only), to be described in a subsequent work plan.

4.6 Waste Management

It is anticipated that some volume of pavement rubble, surface gravel, and excavated soils will be generated during installation of the infiltration trenches. With construction occurring in the dry season, dewatering is not anticipated. Pavement rubble, gravel, and waste soil will be disposed of as follows:

- Pavement rubble will be disposed of at an inert waste landfill or municipal solid waste landfill (Resource Conservation Recovery Act Subtitle D facility).
- Excavated soil and surface gravel will be characterized using existing or new analytical data as appropriate, and categorized accordingly for transport and disposal at one or more facilities

licensed by the State of Washington to accept the waste materials. Assuming a 10 percent volume explanation factor for excavated soil, approximately 1,589 cubic yards (2,542 tons) is anticipated for disposal. Clean overburden may be segregated through field screening and confirmation sampling for reuse on Site, if appropriate, though it is not anticipated that soils will be reused in the construction of the trenches in order to maximize the volume of substrate that can be injected into the subsurface.

In the event that a significant amount of light non-aqueous phase liquid (LNAPL) accumulates in open trenches, LNAPL will be recovered using a vactor truck and/or sorbent pads. Recovered fluids will be treated or disposed of at an approved facility. Sorbent pads will be drummed and disposed of at an approved facility.

4.7 Adaptive Management

Adaptive management will be a key element of the bioremediation field pilot study, with potential modifications anticipated for subsequent injections based on observations and performance monitoring data. Potential modifications are anticipated to include:

- Injection frequency, and/or injection volume will likely be modified to optimize treatment based on injection observations and monitoring data, indicating TPH treatment effects and the distribution/longevity of injected sulfate.
- Nutrients may be added to optimize treatment. This includes the macronutrients nitrate and phosphorus and micronutrients provided by yeast extract.
- Additional infiltration trenches may be added if treatment coverage or the extent of TPH impacts is not as anticipated.
- As described above, nitrate may be added as a complementary electron acceptor in addition to sulfate. Nitrate is typically a more effective acceptor because it is more energetically favorable to micro-organisms for TPH degradation but results in additional costs for materials and labor/equipment (i.e., onsite mixing). A range of likely nitrate application concentrations and a benchmark limit for nitrogen in marine surface water (20 mg-N/L) are described in Section 3.2. Nitrate use would be described in a work plan addendum for Ecology review.
- The EISB field pilot study is intended to collect sufficient information to evaluate if EISB will be effective as a final cleanup remedy to address the highest concentrations of TPH present at the C Street subarea. A subsequent period of MNA is anticipated to achieve cleanup standards, as described in the CAP (Ecology 2020).

5.0 SCHEDULE AND REPORTING

The table below presents a schedule for implementation of the planned field events included in this Bioremediation Field Pilot Study Work Plan. The actual schedule and sequencing of necessary field activities are likely to change, depending on the results of periodic monitoring and sampling. Ongoing performance results will be reported to and reviewed with Ecology during monthly status meetings. As necessary, updated schedules will be provided in future addenda or separate reporting.

Pilot Study Element	Field Activities	Duration	Notes
Utility Locates	• Oversee utility locates and positioning of trench and well locations	1 day	Requires coordination with Port and tenant
Trench Installation	• Excavate six trenches 5 ft wide, averaging 8 ft deep (1 to 2 ft below the encountered water table. • Trenches will range between 125 and 200 ft long.	14 days	Approximately 2 days per trench plus mobilization and demobilization; final locations dependent on access/utilities
Groundwater Monitoring Well Installation	• Three performance monitoring wells installed as part of the field pilot study	1 day	Installed concurrently with three additional PRDI wells proximal to the study area; final locations dependent on access/utilities
Groundwater Evaluation	• Monitor and sample 6 new wells and 11 existing wells	2 days	One two-day baseline event prior to substrate injections; quarterly two-day events thereafter
Substrate Injections	• Injection of substrate material into each of six trenches • Sulfate only for 6 months • Nitrate and sulfate for remaining 6 months, pending initial performance results	2 days	2-day events occur monthly during first year of bioremediation field pilot study

6.0 USE OF THIS WORK PLAN

This Bioremediation Field Pilot Study Work Plan has been prepared for the exclusive use of the Port of Bellingham for specific application to the Central Waterfront Cleanup Site Remedial Design and Permitting project, as an appendix to the Pre-Remedial Design Investigation Project Plan, Amendment No. 1 prepared by Landau. No other party is entitled to rely on the information, conclusions, and recommendations included in this document without the express written consent of Landau. Further, the reuse of information, conclusions, and recommendations provided herein for extensions of the project or for any other project, without review and authorization by Landau, shall be at the user's sole risk. Landau warrants that within the limitations of scope, schedule, and budget, the services have been provided in a manner consistent with that level of care and skill ordinarily exercised by members of the profession currently practicing in the same locality under similar conditions as this project. Landau makes no other warranty, either express or implied.

7.0 REFERENCES

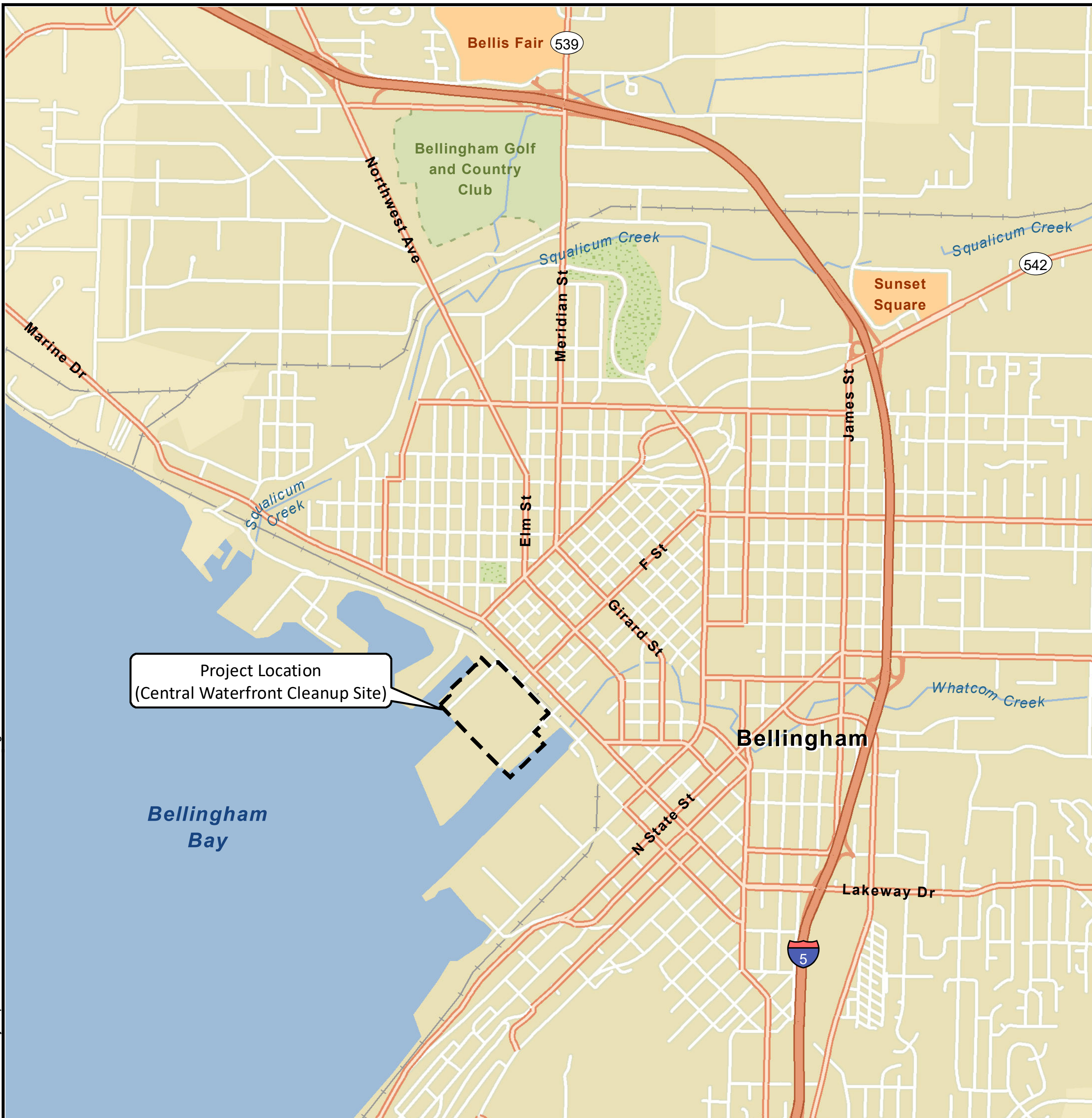
Cunningham, Jeffrey A., Halla Rahme, Gary D. Hopkins, Carmen Lebron, and Martin Reinhard. 2001. "Enhanced In Situ Bioremediation of BTEX-Contaminated Groundwater by Combined Injection of Nitrate and Sulfate." *Environmental Science & Technology.* 35 (8):1663-1670. doi: 10.1021/es001722t. April 15.

Ecology. 2020. Final Cleanup Action Plan, Central Waterfront Site, Bellingham, Washington. Washington State Department of Ecology. January.

Landau. 2022. Agency Review Draft: Engineering Design Report, Central Waterfront Cleanup Site, Bellingham, Washington. Landau Associates, Inc. July 12.

Mackenzie, Fred T., Robert Howard Byrne, and Alyn C. Duxbury. 2020. "seawater." Encyclopedia Britannica. November 5. https://www.britannica.com/science/seawater.

Wiedemeier, Todd H., John T. Wilson, Donald H. Kampbell, Ross N. Miller, and Jerry E. Hansen. 1999. Technical Protocol for Implementing Intrinsic Remediation with Long-Term Monitoring for Natural Attenuation of Fuel Contamination Dissolved in Groundwater. Technology Transfer Division, US Air Force Center for Environmental Excellence. March 8.



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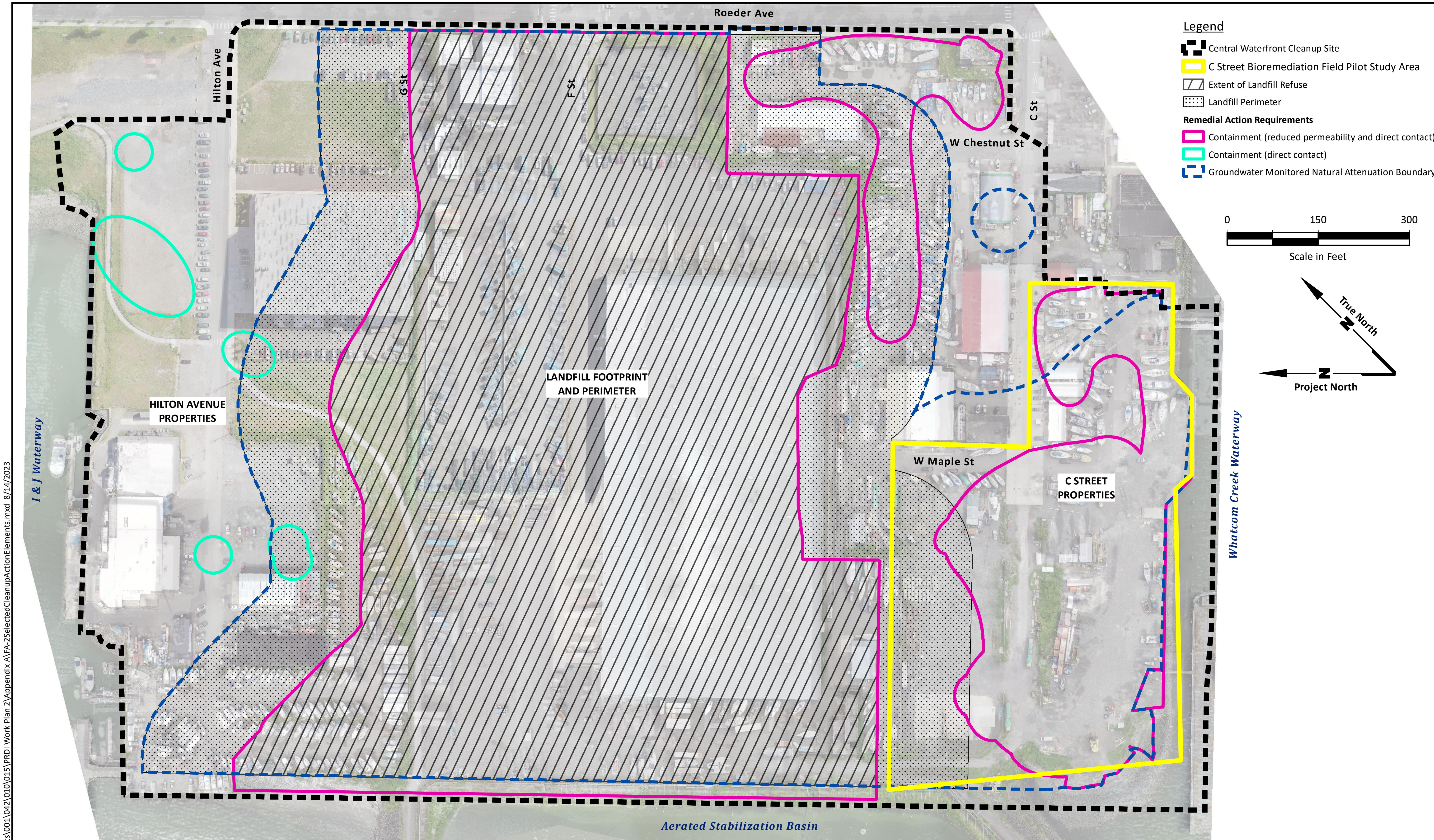
Central Waterfront Cleanup Site Bioremediation Field Pilot Study Work Plan Bellingham, Washington	**Vicinity Map**	Figure A-1



Note

1. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

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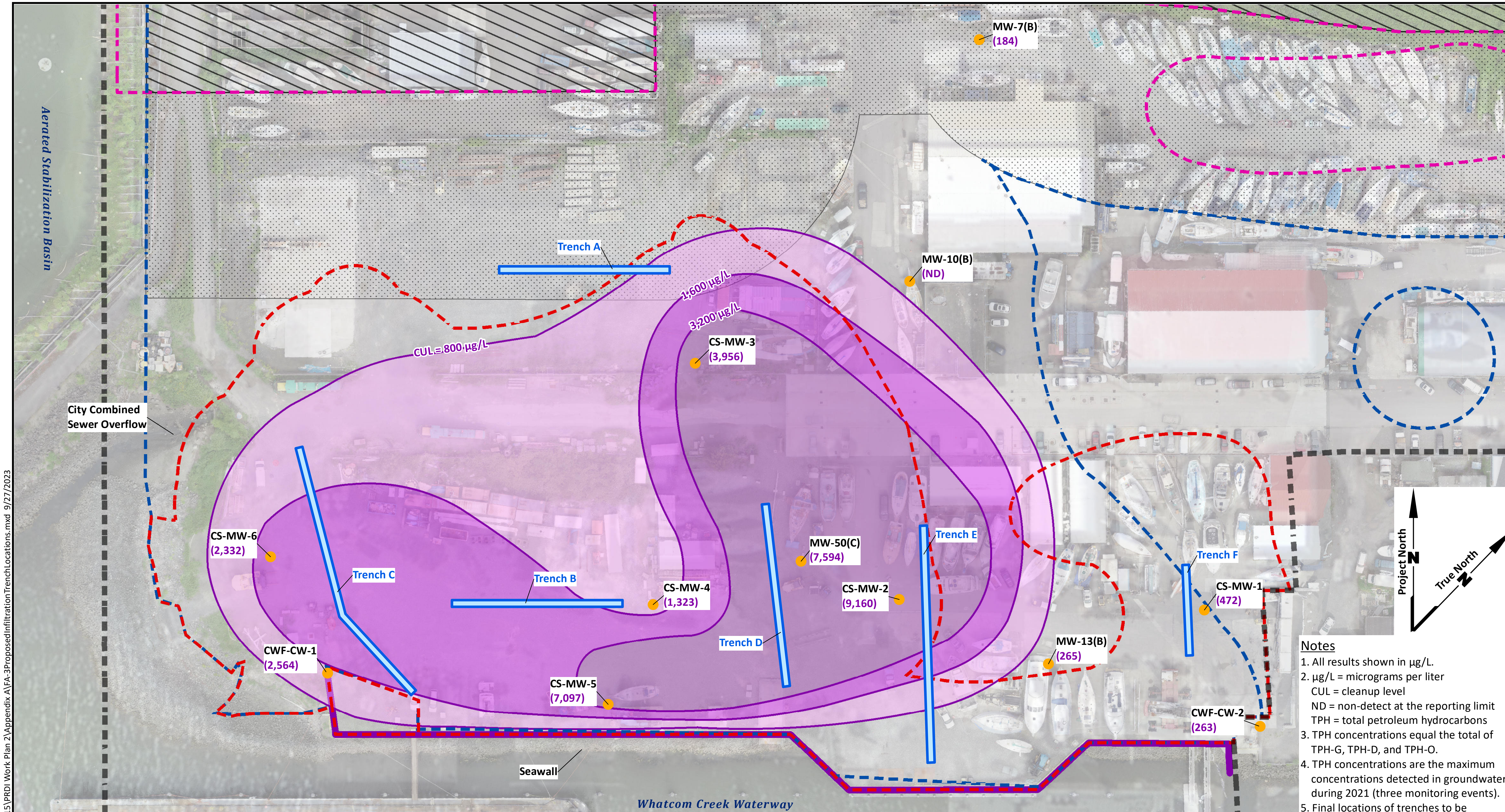
Central Waterfront Cleanup Site Bioremediation Field Pilot Study Work Plan Bellingham, Washington	**Selected Cleanup Action Elements**	Figure A-2



Legend

- Existing Monitoring Well
- Infiltration Trench Location
- Central Waterfront Cleanup Site
- Extent of Landfill Refuse
- Landfill Perimeter
- Whatcom Waterway Seawall
- (472) Maximum TPH Concentration in Groundwater (µg/L)

TPH Concentrations (Approximate)

- >800 µg/L
- >1,600 µg/L
- >3,200 µg/L

Remedial Action Requirements

- Containment (reduced permeability and direct contact)
- Groundwater Monitored Natural Attenuation Boundary
- C Street Groundwater Treatment Area

0 70 140

Scale in Feet

Notes

1. All results shown in µg/L.
2. µg/L = micrograms per liter
   CUL = cleanup level
   ND = non-detect at the reporting limit
   TPH = total petroleum hydrocarbons
3. TPH concentrations equal the total of TPH-G, TPH-D, and TPH-O.
4. TPH concentrations are the maximum concentrations detected in groundwater during 2021 (three monitoring events).
5. Final locations of trenches to be established in the field based on site access and tenant considerations.
6. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

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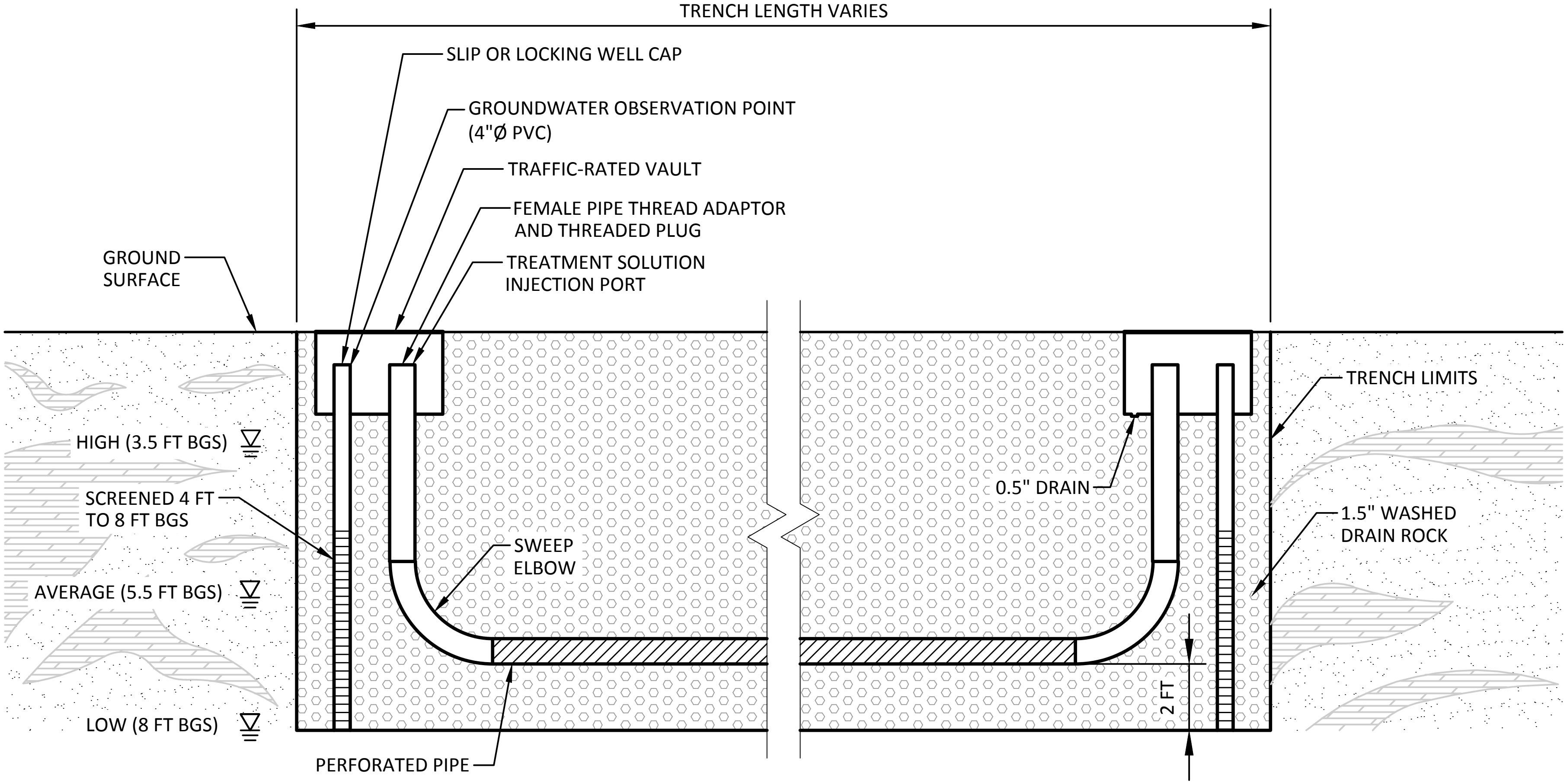
Central Waterfront Cleanup Site Bioremediation Field Pilot Study Bellingham, Washington	C Street - Total TPH Concentrations and Proposed Trench Locations	Figure A-3



PROFILE VIEW

NOT TO SCALE

Notes

1. Profile view along the length of a trench.
2. FT = feet
   BGS = below ground surface
3. The excavated trenches will be wrapped with a separation geotextile (non-woven geotextile Mirafi 140N or equivalent) prior to placement of drain pipe surrounded by 1.5" washed drain rock. Ends of the geotextile wrap will be folded over the top of emplaced drain rock before placement of crushed base course to grade.

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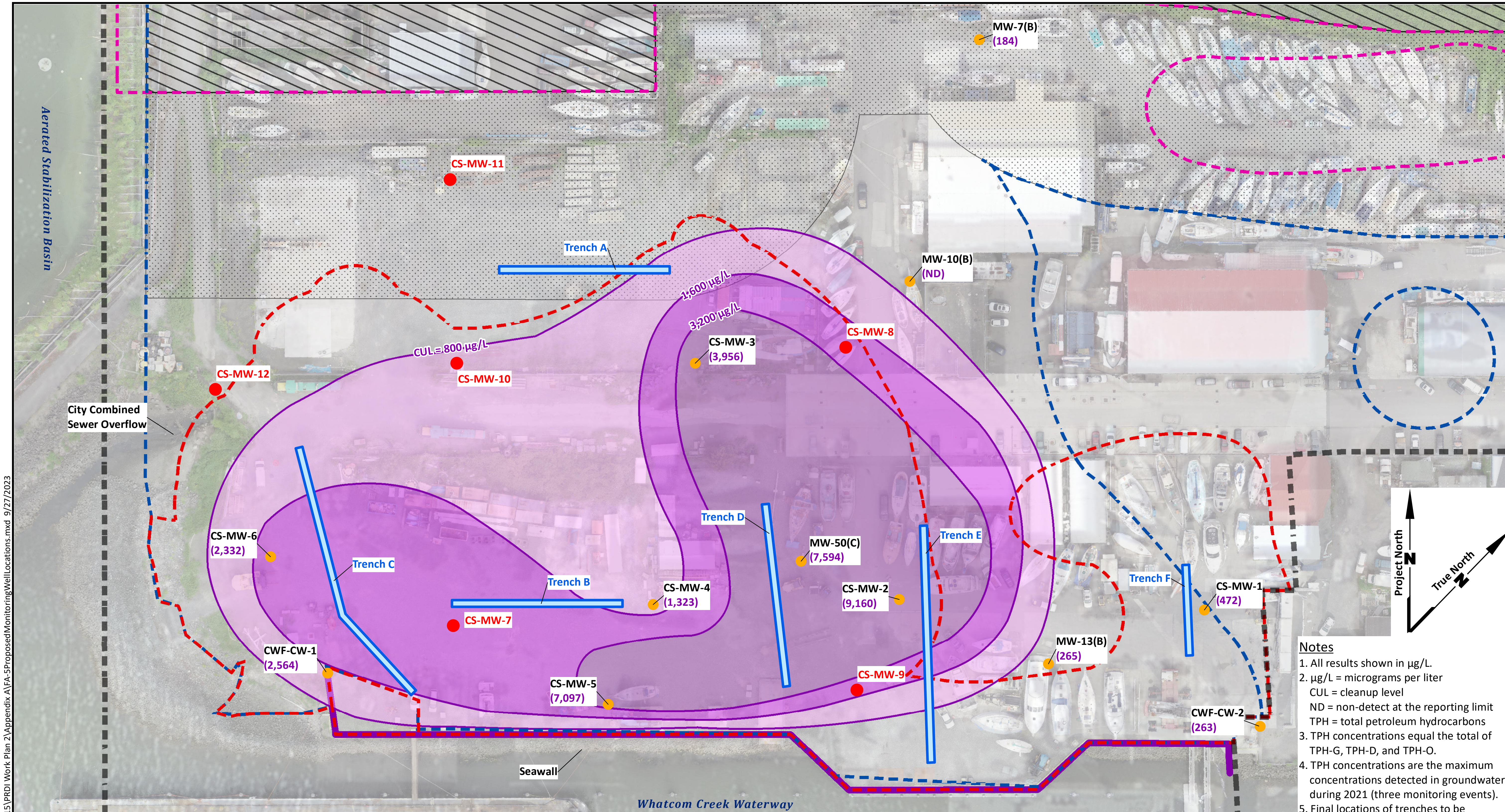
Central Waterfront Cleanup Site
Bioremediation Field Pilot Study
Work Plan
Bellingham, Washington

Infiltration Trench Conceptual Cross Section

Figure A-4



Legend

- Proposed Monitoring Well Location
- Existing Monitoring Well
- Infiltration Trench Location
- Central Waterfront Cleanup Site
- Extent of Landfill Refuse
- Landfill Perimeter
- Whatcom Waterway Seawall
- (472) Maximum TPH Concentration in Groundwater (µg/L)

TPH Concentrations (Approximate)

- >800 µg/L
- >1,600 µg/L
- >3,200 µg/L

Remedial Action Requirements

- Containment (reduced permeability and direct contact)
- Groundwater Monitored Natural Attenuation Boundary
- C Street Groundwater Treatment Area

0 70 140

Scale in Feet

Notes

1. All results shown in µg/L.
2. µg/L = micrograms per liter
   CUL = cleanup level
   ND = non-detect at the reporting limit
   TPH = total petroleum hydrocarbons
3. TPH concentrations equal the total of TPH-G, TPH-D, and TPH-O.
4. TPH concentrations are the maximum concentrations detected in groundwater during 2021 (three monitoring events).
5. Final locations of trenches to be established in the field based on site access and tenant considerations.
6. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

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Central Waterfront Cleanup Site Bioremediation Field Pilot Study Bellingham, Washington	**C Street - Proposed Monitoring Well Locations**	Figure A-5

Table A-1
Injection Volume Estimates
Groundwater Treatment Design Parameters
Central Waterfront Cleanup Site – Bellingham, Washington

Trench ID	Length (ft)	Width (ft)	Freeboard (ft)	Total Volume (ft^3)	Total Volume (gal)	Rounded Volume (gal)	Pore Volume (gal) Low (n = 0.25)	Pore Volume (gal) Average (n = 0.325)	Pore Volume (gal) High (n = 0.40)	Max Sulfate Applied (kg) Low (n = 0.25)	Max Sulfate Applied (kg) Average (n = 0.325)	Max Sulfate Applied (kg) High (n = 0.40)	Max TPH Treated (kg) Low (n = 0.25)	Max TPH Treated (kg) Average (n = 0.325)	Max TPH Treated (kg) High (n = 0.40)
A	125	5	5	3,125	23,377	23,000	5,750	7,475	9,200	61	79	98	13	17	21
B	125	5	5	3,125	23,377	23,000	5,750	7,475	9,200	61	79	98	13	17	21
C	200	5	5	5,000	37,403	37,000	9,250	12,025	14,800	98	127	157	21	28	34
D	200	5	5	5,000	37,403	37,000	9,250	12,025	14,800	98	127	157	21	28	34
E	175	5	5	4,375	32,727	33,000	8,250	10,725	13,200	87	114	140	19	25	30
F	150	5	5	3,750	28,052	28,000	7,000	9,100	11,200	74	96	119	16	21	26
						Totals	45,250	58,825	72,400	480	623	767	104	136	167

↓

Treatment Estimates per Injection	Pore volume	45,250	gal	[Assume low pore volume]
	Max sulfate applied	480	kg	[Assume low pore volume]
	Max TPH treated	104	kg	[Assume low pore volume]
Treatment Zone Characteristics	Approximate area	200,000	ft^2	[Google Earth estimate]
	Treatment length	30	ft	[Maximum depth of visual evidence of contamination from boring logs]
	Treatment zone	6,000,000	ft^3	
		44,883,120	gal	
	Total pore space	14,587,014	gal	[Assume average porosity for gravel]
	Max TPH concentration	9,160	µg/L	[Maximum measured in new wells]
		0.000035	kg/gal	
	Total TPH mass	506	kg	[Assume maximum concentration throughout all pore space]
	Total sulfate required	2,327	kg	[4.6 kg sulfate per kg TPH]

Notes:

Typical low, average, and high porosity (n) values for gravel used to estimate pore volume.
Freeboard (i.e., void space above the water table) calculated using average depth to water measurements across the Site.
Low porosity estimate used for conservative sulfate application and TPH degradation calculations.

Abbreviations and Acronyms:

ft = feet
ft^2 = square feet
ft^3 = cubic feet
gal = gallons
kg = kilograms
µg/L = micrograms per liter
n = porosity
TPH = total petroleum hydrocarbons

Table A-2
Stoichimetry of Total Petroleum Hydrocarbon Biodegradation with Sulfate
Groundwater Treatment Design Parameters
Central Waterfront Cleanup Site – Bellingham, Washington

The stoichiometry of approach to estimate sulfate mass applied during treatment is based on the stoichiometry of anaerobic sulfate reduction.

If fully used for total petroleum hydrocarbon (TPH) degradation, it takes approximately 4.6 lbs of sulfate to degrade 1 lb of TPH/benzene, toluene, ethylbenzene, and xylenes (BTEX), as follows. The reaction for benzene mineralization using sulfate as the terminal electron acceptor (Eq. 1) is used to estimate the mass of sulfate required for degradation of TPH components.

(Eq. 1)
$$8C_6H_6 + 30SO_4^{2-} + 24H_2O \rightarrow 15H_2S + 15HS^- + 48HCO_3^- + 3H^+$$

As indicated in the formula above, 30 moles of sulfate are necessary to degrade eight moles of benzene. Using the molecular weights of each species in the mineralization reaction (Eq. 1), the sulfate: TPH mass ratio of 4.6 g sulfate per 1 g of benzene can be developed (Eq. 2).

$$Benzene = C_6H_6 = 78\ g/mol \qquad Sulfate = SO_4^{2-} = 96\ g/mol$$

(Eq. 2)
$$\left(\frac{30\ mol\ SO_4^{2-}}{8\ mol\ C_6H_6}\right)\left(\frac{96\ g\ SO_4^{2-}}{mol\ SO_4^{2-}}\right)\left(\frac{mol\ C_6H_6}{78\ g\ C_6H_6}\right) = 4.6\ g\ SO_4^{2-}/g\ C_6H_6$$

The stoichiometry (Eq. 1) and the mass ratio (Eq. 2) can be used to estimate the maximum TPH mass that can be degraded per injection of sulfate (Eq. 3). The proposed injection volume is 52,750 gallons and calculations assume that all sulfate is used to degrade TPH and none is consumed by other microbiological processes. Calculations also assume the average concentration of sulfate in seawater of 2,800 mg/L.

(Eq. 3)
$$52{,}750\ gal\left(\frac{3.78\ L}{gal}\right)\left(\frac{2.8\times10^6\ \mu g\ SO_4^{2-}}{L\ seawater}\right)\left(\frac{mg\ SO_4^{2-}}{1000\ \mu g\ SO_4^{2-}}\right)\left(\frac{g\ SO_4^{2-}}{1000\ mg\ SO_4^{2-}}\right) \times\left(\frac{kg\ SO_4^{2-}}{1000\ g\ SO_4^{2-}}\right)\left(\frac{kg\ TPH}{4.6\ kg\ SO_4^{2-}}\right) = 122\ kg\ TPH$$

Using 0.85 kg/L, or 3.2 kg/gal, as the approximate density of diesel fuel, the 122 kg of TPH degraded is equivalent to 38 gallons. Considering the past usage of the treatment area, this is a relatively small volume. This supports the assumption that multiple sulfate injections will be required to achieve cleanup levels in the treatment area.

APPENDIX B

Sampling and Analysis Plan/ Quality Assurance Project Plan

SAMPLING AND ANALYSIS PLAN/ QUALITY ASSURANCE PROJECT PLAN

Central Waterfront Cleanup Site
Bellingham, Washington

September 29, 2023

Prepared for

Port of Bellingham
Bellingham, Washington

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Sampling and Analysis Plan/Quality Assurance Project Plan
Central Waterfront Cleanup Site
Bellingham, Washington

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Quality Reviewer

Date: September 29, 2023
Project No.: 0001042.010
File path: P:\001\042\R\PRDI Work Plan, Amendment No. 1 – 2023\Appendix B SAP QAPP Addendum
Project Coordinator: Christopher C. Young

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FIGURE

TABLES

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LIST OF ABBREVIATIONS AND ACRONYMS

ALS	Analytical Laboratory Services, Inc.
AR	Analytical Resources, LLC
ASTM	ASTM International
BEHP	bis(2-ethylhexyl)phthalate
DQI	data quality indicator
Ecology	Washington State Department of Ecology
EPA	US Environmental Protection Agency
GPS	Global Positioning System
HSA	hollow-stem auger
Landau	Landau Associates, Inc.
LFG	landfill gas
MS	matrix spike
MSD	matrix spike duplicate
PID	photoionization detector
Port	Port of Bellingham
PRDI	Pre-Remedial Design Investigation
PRDI AMD 1	Amendment No. 1 of the PRDI Project Plans
QAPP	Quality Assurance Project Plan
QC	quality control
SAP	Sampling and Analysis Plan
SIM	selected ion monitoring
SM	standard method
Site	Central Waterfront Cleanup Site
TPH	total petroleum hydrocarbons
UCT	universal cell technology
USCS	Unified Soil Classification System
VOC	volatile organic compound

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1.0 INTRODUCTION

Landau Associates, Inc. (Landau) prepared this combined Sampling and Analysis Plan and Quality Assurance Project Plan (SAP/QAPP) for the Port of Bellingham (Port) in support of the Amendment No. 1 (PRDI AMD 1) of the Pre-Remedial Design Investigation (PRDI) Project Plans for the Central Waterfront Cleanup Site (Site), located in Bellingham, Washington. This SAP/QAPP provides additional information regarding sample collection and analysis, data quality objectives, and quality assurance procedures as they relate specifically to PRDI AMD 1 implementation. The information provided in this SAP/QAPP should be used in conjunction with the original PRDI Project Plan SAP and QAPP documents that were prepared for the initial PRDI investigation in 2020 (Landau 2020).

At the request of the Washington State Department of Ecology (Ecology), the Port plans to implement additional PRDI work prior to proceeding with designing the Site cleanup action. The additional activities are detailed in the PRDI AMD 1, to which this SAP/QAPP is an appendix. PRDI AMD 1 activities are planned for multiple subareas at the Site and are related to the investigation elements presented in the PRDI AMD 1. In general, the investigation elements include implementing a groundwater treatment field pilot study in the C Street Properties subarea, groundwater quality and hydraulic evaluation in the C Street Properties and Hilton Avenue Properties subareas, groundwater hydraulic evaluation near the Aerated Stabilization Basin, a Site-wide Surface Condition Assessment, and landfill gas (LFG) assessments (Figure B-1).

Procedures and methods for the following planned PRDI AMD 1 activities are detailed in the 2020 version of the SAP and QAPP (Landau 2020):

- Direct-push drilling
- Subsurface soil sample collection
- Low-flow groundwater sampling
- Groundwater well installation and development
- Groundwater-level measurements
- Laboratory analyses for field-measured and/or sampled parameters for soil, groundwater, landfill gas, and indoor air monitoring.

One laboratory method target reporting limit, for bis(2-ethylhexyl)phthalate (BEHP), has been updated for groundwater samples collected at the Site and an updated table showing target reporting limits is included in this SAP/QAPP.

Procedures and methods for the following activities were not included in previous documentation and are included in this SAP/QAPP:

- Semi-continuous water-level monitoring
- Slug testing
- Surface water sample collection

- Porewater sample collection
- Hollow-stem auger (HSA) drilling.

Procedures for construction for the bioremediation field pilot study in the C Street subarea are provided in Appendix A of the PRDI AMD 1.

No additional analytical tests are planned for the PRDI AMD 1 beyond what was already presented in the 2020 PRDI SAP and QAPP documents. This combined SAP/QAPP focuses on procedures required for semi-continuous water-level monitoring, slug testing, surface water and porewater sample collection, and HSA drilling.

2.0 ENVIRONMENTAL DATA QUALITY ASSURANCE OBJECTIVES

Quality assurance objectives for the project data include the qualitative guidelines listed in the original PRDI Project Plan SAP and QAPP, as well as quantitative determinations of the data quality indicators (DQIs). A summary of these quality-control parameters for porewater and surface water sampling, and their associated measurement quality objectives, are provided in Table B-1.

Surface water and porewater samples will be collected for laboratory analysis as described in Section 3. To help achieve these data quality objectives, the following DQIs s will be evaluated throughout the course of this project:

- Reporting limits
- Data precision
- Data accuracy
- Representativeness
- Comparability and completeness.

These quality-assessment parameters are described in greater detail in the following subsections.

2.1 Reporting Limits

One laboratory method target reporting limit (for BEHP) has been updated from the 2020 version of the SAP and QAPP (Landau 2020) for groundwater samples collected at the Site. The amended analytical methods and target laboratory reporting limits for soil and groundwater are provided in Table B-2a.

Analytical methods and target laboratory reporting limits for surface water and porewater are provided in Table B-2b. The reporting limits will be observed for laboratory analyses conducted during this project, except where matrix interferences and high concentrations of target and non-target compounds increase the reporting detection limits.

2.2 Data Precision

Precision is typically determined by examining the relative percent difference between duplicate analyses of field-collected duplicate samples. However, there are no field duplicates planned for surface water or porewater samples. Information regarding precision evaluation for groundwater samples is provided in Section 3.1.1 of the original PRDI Project Plan SAP (Landau 2020).

2.3 Data Accuracy

Accuracy is defined as the degree of agreement between a measurement and an accepted reference of true concentration. Accuracy is determined by spiking samples with a known concentration of standard compounds and comparing the analytical results with the known value. Data accuracy will be assessed by determining the percent recovery of a spiked compound. Percent recovery (%R) is determined by the equation:

$$\%R = \frac{(C_1 - C_0)}{C_S} \times 100$$

where:

C_1	=	measured concentration in the spiked sample
C_o	=	measured concentration in the unspiked sample
C_s	=	concentration at which the sample was spiked.

The concentration at which the sample was spiked (C_s) is calculated, using the following equation:

$$C_S = \frac{(C_{spike} \times V_{spike})}{V_{sample} + V_{spike}}$$

where:

C_s	=	concentration at which the sample was spiked
C_{spike}	=	spike concentration
V_{spike}	=	volume of spike
V_{sample}	=	volume of sample.

The laboratory objective for accuracy is to generate percent recoveries that fall within established control limits for the analytical method employed.

Surrogate and matrix spiking compounds and sample selection for spiking are determined by current US Environmental Protection Agency (EPA) SW-846 methodologies. Percent recoveries indicate the actual performance of the analytical method on real-world samples. Surrogate spikes, matrix spikes, matrix spike duplicates (MS/MSDs), and quality control (QC) spikes will be analyzed using standard laboratory methods. Spike analysis may be conducted at the discretion of the analytical laboratory, as needed for the laboratory to demonstrate internal accreditation requirements. Field sampling for potential laboratory-required MS/MSDs is not planned during porewater and surface water sample collection.

2.4 Representativeness

Representativeness is the degree to which data accurately and precisely represent a characteristic population, a process control, or an environmental condition. Appropriate sampling procedures will be implemented so that the samples are representative of the environmental matrices from which they were obtained. To obtain representative porewater and surface water samples, field personnel should follow the procedures described in Section 3.2.

2.5 Comparability and Completeness

Comparability is achieved using analytical methods similar to ones that were used previously, through use of trained personnel and by following all applicable SAP/QAPPs. Completeness is a measure of the amount of valid data obtained from a measurement system compared to the amount that was expected to be obtained under normal conditions. The minimum completeness goal is 90 percent.

3.0 ENVIRONMENTAL SAMPLING ACTIVITIES AND PROCEDURES

The following activities and procedures are required to implement the PRDI AMD 1 elements and should be executed in conjunction with the 2020 PRDI Project Plans SAP and QAPP. Specific information regarding porewater and surface water sampling containers, preservatives, and hold times; field quality control samples; and field equipment calibration and frequency requirements are provided in Tables B-3 through B-5.

3.1 Semi-Continuous Water-Level Monitoring and Slug Testing

Non-sampling activities such as semi-continuous water-level monitoring and slug testing require the use of specialized equipment and involve *in situ* data collection and observations. Non-dedicated equipment, such as submersible dataloggers, water-level meters, or steel slug rods, will be decontaminated before and after use, and according to the decontamination procedures outlined in Section 4.11 of the original PRDI Project Plan SAP.

Semi-continuous water-level measurement activities should be conducted in accordance with Section 4.8.3.2 of the original PRDI Project Plan SAP.

Slug testing will be conducted in accordance with ASTM International (ASTM) standard D4044/D4044M-15 with perturbation and recovery tolerance levels set to at least 95 percent.

3.2 Surface Water and Porewater Sampling

Surface water samples will be collected from the marine waters of Bellingham Bay, at three locations adjacent to and west of the Hilton Properties subarea. The samples will be collected during falling tide and rising tide (for a total of six samples) by lowering clean jars into the water from the shoreline, submerging the jars just below the surface of the water using an extendable pole, and retrieving the sample. The timing of sample collection will attempt to allow collection of the samples from about 0 to 6 inches below the water surface, and about 6 inches from the top of the underlying sediment. Surface water sampling coordinate locations will be recorded using a handheld global positioning system (GPS) device, as directed by the original PRDI Project Plan SAP.

In addition to the surface water samples, porewater samples will be collected to further investigate the potential for contaminant transport through the shoreline, from upland groundwater toward the marine environment. Porewater sampling locations will be co-located with surface water sampling locations and collected using decontaminated, temporary well screens. The perforated stainless-steel well screens will be driven to a depth of approximately 1 to 3 feet below the mudline. Final depths will be determined at the time of sampling and may be influenced by the presence of large cobbles or boulders, or other marine obstacles not visible from the sandy surface. A peristaltic pump and disposable tubing will be used to collect a porewater sample from within the stainless-steel screen. Decontamination procedures for non-dedicated sampling equipment are provided in Section 4.11 of the 2020 PRDI Project Plan SAP.

Surface water and porewater samples will be collected into or carefully poured into the laboratory-supplied sample containers. The containers will be labeled, and the samples will be maintained in a cooler with ice under chain-of-custody procedures, and submitted to the laboratory for the following analyses:

- Gasoline-range total petroleum hydrocarbons (TPH) by the Northwest TPH extended-range gasoline analytical method
- Diesel- and motor oil-range TPH by the Northwest TPH-extended-range diesel analytical method
- Benzene, toluene, ethylene, and total xylenes by EPA Method 8260D
- Bis(2-ethylhexyl)phthalate by EPA Method 8270E
- Polycyclic aromatic hydrocarbons by EPA Method 8270E with selected ion monitoring (SIM)
- Total and dissolved metals (i.e., arsenic, cadmium, total chromium, copper, lead, nickel, selenium, silver, and zinc by EPA Method 6020A universal cell technology [UCT]; hexavalent chromium by Standard Method [SM] 3500; mercury by EPA Method 7470A; and trivalent chromium will be quantified through calculation).

Additional volume will be collected from each of the porewater and surface water sampling locations for the following potential follow-up analyses:

- Dissolved manganese by EPA 6020A UCT
- Nitrate and sulfate by EPA 300.0
- Methane by RSK-175
- Total organic carbon (SM 5310B)
- Alkalinity (SM 2320)
- Hardness (EPA 6010C).

Target reporting limits for each analysis are provided in Table B-2b. If adequate volume is present in the porewater sampling device after samples are collected, the field measurements for ferrous iron, pH, dissolved oxygen, oxidation reduction potential, and temperature will be collected.

3.3 Hollow-Stem Auger Drilling

Borings will be completed by a driller licensed in the State of Washington and will be monitored by a Landau environmental professional. Soil will be described and classified in accordance with the Unified Soil Classification System (USCS). Prior to initiation of drilling or any other intrusive subsurface activity, the locations of each proposed exploration will be checked in the field by reviewing information from the Port to locate aboveground and/or underground utilities and/or physical obstructions that would prevent drilling at the proposed location. In addition, a public utility locate service will be contacted to locate underground utilities at the perimeter of the Site and a private utility locate service will be retained to survey the exploration locations and mark underground utilities. A Landau representative will be on Site during the marking of private utilities. If utilities are identified in the locations where subsurface work is anticipated, adjustments will be made to avoid impacting utilities, to the extent practicable. The specific locations planned for subsurface soil sample collection and the associated analyses are provided in figures and tables in the PRDI AMD 1. The final location for each borehole will be selected based on the findings of the field check and the utility locating and marking.

During drilling, soil samples will be collected at each soil boring location to classify soil lithology in accordance with the USCS. For soil borings advanced using an HSA rig, the soil samples will be obtained using a 3-inch-diameter, 1.5-foot-long, split-spoon sampler. A record of the soil and groundwater conditions observed during drilling will be recorded on a Log of Exploration form. The boring log will also show soil types encountered; evidence of contamination based on field screening; and other pertinent information. Procedures for screening and processing soil samples are described in detail in Sections 3.3.1 and 3.3.2.

3.3.1 Field Screening

Soil will be field-screened for evidence of environmental impact. Field-screening techniques may include visually inspecting the soil or water for staining, discoloration, and other evidence of environmental impact; observation of odors; and sheen testing. Volatile organic compound (VOC) monitoring for soil will be conducted using headspace analysis and will be conducted by first measuring VOC levels along the length of freshly exposed soil in recovered soil cores (e.g., split-spoon sampler) using a photoionization detector (PID). Field-screening results will be recorded and entered in the comments section of the soil boring logs. Additionally, PID readings over 5 parts per million will be noted on the chain-of-custody form to communicate the potential for contamination to the laboratory. Sheen testing will be conducted by agitating a small volume of soil in a decontaminated stainless-steel bowl or disposable cup with clean tap water to see if a sheen is generated.

3.3.2 Soil Sampling

Soil sampling during HSA drilling activities will be conducted in accordance with the original PRDI Project Plan SAP and QAPP (Landau 2020). Collection of soil samples from split-spoon samplers during HSA drilling is similar to soil sample collection from core liners during direct-push drilling, except that the split-spoon sampling devices are not disposable and need to be decontaminated between sampling intervals. Section 3.0 of the PRDI AMD 1 includes a discussion of soil sampling locations, sampling intervals, and analytical methods for the Site subareas and for each investigation location.

Subsurface soil samples analyzed for volatile constituents (e.g., gasoline, benzene, toluene, ethylbenzene, and xylenes) will be collected following Method 5035A procedures. Field QC sample requirements are provided in Table B-4. Samples will then be handled according to the procedures specified in the original PRDI Project Plan QAPP and submitted to a certified laboratory for analysis.

4.0 ANALYTICAL PROCEDURES

Analytical testing will be in accordance with the methodologies established in Test Methods for Evaluating Solid Waste: Physical/Chemical Methods (SW-846; EPA; accessed July 27, 2020), Standard Methods for the Examination of Water and Wastewater (Baird et al. 2017), or approved ASTM standard methods.

4.1 Analytical Laboratories

Analytical Resources, LLC (AR) will conduct the laboratory chemical analysis of soil and water. LFG samples will be analyzed by Analytical Laboratory Services, Inc. (ALS). Environmental laboratories conducting work under this SAP will maintain current accreditation through Ecology for applicable methods and analytes. If geotechnical analyses are required, analyses will be managed by Landau at its internal soils laboratory. Contact information for the primary consultant and laboratories are provided below.

Contact	Responsibility
AR 4611 South 134th Place, Suite 100 Tukwila, WA 98168 Telephone: (206) 695-2600	Chemical analysis (Soil and water)
ALS 2655 Park Center Drive, Suite A Tukwila, WA 98168 Telephone: (805) 577-2086	Chemical analysis (Soil vapor)
Landau Geotechnical Laboratory 500 Columbia Street NW, Suite 110 Olympia, WA 98501 Telephone: (360) 791-3178	Geotechnical testing

5.0 USE OF THIS PLANNING DOCUMENT

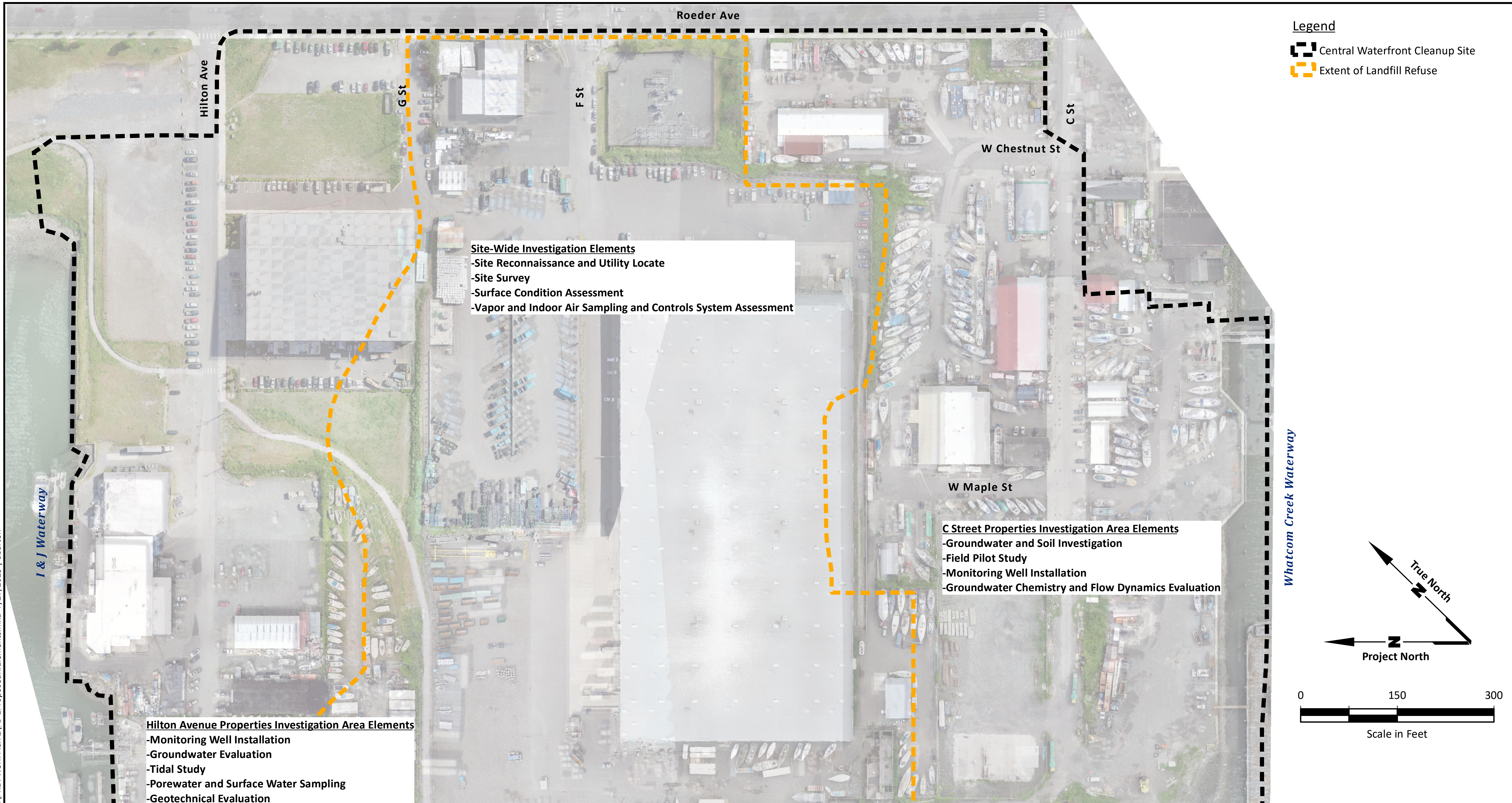
This Sampling and Analysis Plan and Quality Assurance Project Plan has been prepared for the exclusive use of the Port of Bellingham for specific application to the Central Waterfront Cleanup Site Remedial Design and Permitting project, as an appendix to the Pre-Remedial Design Investigation Project Plan, Amendment No. 1 prepared by Landau. No other party is entitled to rely on the information, conclusions, and recommendations included in this document without the express written consent of Landau. Further, the reuse of information, conclusions, and recommendations provided herein for extensions of the project or for any other project, without review and authorization by Landau, shall be at the user’s sole risk. Landau warrants that within the limitations of scope, schedule, and budget, the services have been provided in a manner consistent with that level of care and skill ordinarily exercised by members of the profession currently practicing in the same locality under similar conditions as this project. Landau makes no other warranty, either express or implied.

6.0 REFERENCES

Baird, Roger B., Andrew D. Eaton, and Eugene W. Rice, eds. 2017. *Standard Methods for the Examination of Water and Wastewater, 23rd Edition*. American Public Health Association, American Water Works Association, and Water Environment Federation. January 1.

EPA. *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods*. Third Edition Final Updates I (1993), II (1995), IIA (1994), IIB (1995), III (1997), IIIA (1999), IIIB (2005), IV (2008), and V (2015). SW-846. US Environmental Protection Agency. https://www.epa.gov/hw-sw846.

Landau. 2020. Report: Pre-Remedial Design Investigation Project Plan, Central Waterfront Cleanup Site, Bellingham, Washington. Landau Associates, Inc. October 14.



Notes

1. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

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LANDAU ASSOCIATES

Central Waterfront Cleanup Site Pre-Remedial Design Investigation Bellingham, Washington	**Proposed Investigation Elements**	Figure B-1

Table B-1
Measurement Quality Objectives for Porewater and Surface Water
Pre-Remedial Design Investigation SAP/QAPP, Amendment No. 1
Central Waterfront Cleanup Site – Bellingham, Washington

DQI	QC Sample or Activity Used to Assess MQO	MQO	Frequency	Sampling or Analytical DQI
Porewater/Surface Water Samples Analyzed for Gasoline-Range Petroleum Hydrocarbons by Method NWTPH-Gx				
Representativeness	Cooler Temperature	< 6°C	All project samples	S
Bias	Surrogates	Recoveries within laboratory-specified control limits	All project and QA samples	A
Accuracy	LCS/LCSD	Recoveries within laboratory-specified control limits	1 per 20 samples or one per analytical batch	A
Precision	LCS/LCSD and MS/MSD	RPDs within laboratory-specified control limits	1 per 20 samples or one per analytical batch	A
Method performance for matrix, bias	MS/MSD	Recoveries within laboratory-specified control limits	1 per 20 samples or one per analytical batch	S&A
Bias/Contamination	Method Blank, Trip Blank	Target analytes not detected at concentrations > 1/2 the RL	1 method blank per 20 samples, 1 every 12 hours, or 1 per analytical batch	S&A
Representativeness	Number of usable (not rejected) results out of total number of results	90%	N/A	S&A
Field Completeness	Number of samples collected out of planned samples	90%	N/A	S
Porewater/Surface Water Samples Analyzed for TPH-D and TPH-O by Method NWTPH-Dx				
Representativeness	Cooler Temperature	< 6°C	All project samples	S
Bias	Surrogates	Recoveries within laboratory-specified control limits	All project and QA samples	A
Accuracy	LCS/LCSD	Recoveries within laboratory-specified control limits	1 per 20 samples or one per analytical batch	A
Precision	LCS/LCSD and MS/MSD	RPDs within laboratory-specified control limits	1 per 20 samples or one per analytical batch	A
Method performance for matrix, bias	MS/MSD	Recoveries within laboratory-specified control limits	1 per 20 samples or one per analytical batch	S&A
Bias/Contamination	Method Blank	Target analytes not detected at concentrations > 1/2 the RL	1 method blank per 20 samples, 1 every 12 hours, or 1 per analytical batch	S&A
Analytical Completeness	Number of usable (not rejected) results out of total number of results	90%	N/A	S&A
Field Completeness	Number of samples collected out of planned samples	90%	N/A	S

Table B-1
Measurement Quality Objectives for Porewater and Surface Water
Pre-Remedial Design Investigation SAP/QAPP, Amendment No. 1
Central Waterfront Cleanup Site – Bellingham, Washington

DQI	QC Sample or Activity Used to Assess MQO	MQO	Frequency	Sampling or Analytical DQI
Porewater/Surface Water Samples Analyzed for SVOCs, PAHs by EPA 8270E, EPA 8270E SIM				
Representativeness	Cooler Temperature	< 6°C	All project samples	S
Bias	Surrogates	Recoveries within laboratory-specified control limits	All project and QA samples	A
Accuracy	LCS/LCSD	Recoveries within laboratory-specified control limits	1 per 20 samples or one per analytical batch	A
Precision	LCS/LCSD and MS/MSD	RPDs within laboratory-specified control limits	1 per 20 samples or one per analytical batch	A
Method performance for matrix, bias	MS/MSD	Recoveries within laboratory-specified control limits	1 per 20 samples or one per analytical batch	S&A
Bias/Contamination	Method Blank	Target analytes not detected at concentrations > 1/2 the RL	1 method blank per 20 samples, 1 every 12 hours, or 1 per analytical batch	S&A
Analytical Completeness	Number of usable (not rejected) results out of total number of results	90%	N/A	S&A
Field Completeness	Number of samples collected out of planned samples	90%	N/A	S
Porewater/Surface Water Samples Analyzed for Total or Dissolved Metals by EPA Methods 6020A UCT, 7470A, SM 3500				
Representativeness	Cooler Temperature	< 6°C	All project samples	S
Accuracy	LCS	Recoveries within laboratory-specified control limits	1 per 20 samples or one per analytical batch	A
Precision	LCS and MS/Laboratory Duplicate	RPDs within laboratory-specified control limits	1 per 20 samples or one per analytical batch	A
Method performance for matrix, bias	MS/Laboratory Duplicate	Recoveries within laboratory-specified control limits	1 per 20 samples or one per analytical batch	S&A
Precision	Field Duplicates	RPD <20%	1 per 20 samples or one per analytical group	S&A
Bias/Contamination	Method Blank	Target analytes not detected at concentrations > 1/2 the RL	1 method blank per 20 samples, 1 every 12 hours, or 1 per analytical batch	S&A
Analytical Completeness	Number of usable (not rejected) results out of total number of results	90%	N/A	S&A
Field Completeness	Number of samples collected out of planned samples	90%	N/A	S

Table B-1
Measurement Quality Objectives for Porewater and Surface Water
Pre-Remedial Design Investigation SAP/QAPP, Amendment No. 1
Central Waterfront Cleanup Site – Bellingham, Washington

DQI	QC Sample or Activity Used to Assess MQO	MQO	Frequency	Sampling or Analytical DQI
Porewater/Surface Water Samples Analyzed for Volatile Organic Compounds or BTEX by EPA Method 8260C				
Representativeness	Cooler Temperature	< 6°C	All project samples	S
Bias	Surrogates	Recoveries within laboratory-specified control limits	All project and QA samples	A
Accuracy	LCS/LCSD	Recoveries within laboratory-specified control limits	1 per 20 samples or one per analytical batch	A
Precision	LCS/LCSD and MS/MSD	RPDs within laboratory-specified control limits	1 per 20 samples or one per analytical batch	A
Method performance for matrix, bias	MS/MSD	Recoveries within laboratory-specified control limits	1 per 20 samples or one per analytical batch	S&A
Bias/Contamination	Method Blank, Trip Blank	Target analytes not detected at concentrations > 1/2 the RL	1 method blank per 20 samples, 1 every 12 hours, or 1 per analytical batch	S&A
Analytical Completeness	Number of usable (not rejected) results out of total number of results	90%	N/A	S&A
Field Completeness	Number of samples collected out of planned samples	90%	N/A	S
Porewater/Surface Water Samples Analyzed for Alkalinity by Method SM2320B				
Representativeness	Cooler Temperature	< 6°C	All project samples	S
Accuracy	LCS	Recoveries within laboratory-specified control limits	1 per 20 samples or one per analytical batch	A
Precision	LCS and MS/Laboratory Duplicate	RPDs within laboratory-specified control limits	1 per 20 samples or one per analytical batch	A
Method performance for matrix, bias	MS/Laboratory Duplicate	Recoveries within laboratory-specified control limits	1 per 20 samples or one per analytical batch	S&A
Bias/Contamination	Method Blank	Target analytes not detected at concentrations > 1/2 the RL	1 method blank per 20 samples or 1 per analytical batch	S&A
Analytical Completeness	Number of usable (not rejected) results out of total number of results	90%	N/A	S&A
Field Completeness	Number of samples collected out of planned samples	90%	N/A	S

Table B-1
Measurement Quality Objectives for Porewater and Surface Water
Pre-Remedial Design Investigation SAP/QAPP, Amendment No. 1
Central Waterfront Cleanup Site – Bellingham, Washington

DQI	QC Sample or Activity Used to Assess MQO	MQO	Frequency	Sampling or Analytical DQI
Porewater/Surface Water Samples Analyzed for Anions by EPA Method 300.0				
Representativeness	Cooler Temperature	< 6°C	All project samples	S
Accuracy	LCS	Recoveries within laboratory-specified control limits	1 per 20 samples or one per analytical batch	A
Precision	LCS and MS/Laboratory Duplicate	RPDs within laboratory-specified control limits	1 per 20 samples or one per analytical batch	A
Method performance for matrix, bias	MS/Laboratory Duplicate	Recoveries within laboratory-specified control limits	1 per 10 samples or two per analytical batch	S&A
Bias/Contamination	Method Blank	Target analytes not detected at concentrations > 1/2 the RL	1 method blank per 20 samples or 1 per analytical batch	S&A
Analytical Completeness	Number of usable (not rejected) results out of total number of results	90%	N/A	S&A
Field Completeness	Number of samples collected out of planned samples	90%	N/A	S
Porewater/Surface Water Samples Analyzed for Total Organic Carbon by Method SM 5310B				
Representativeness	Cooler Temperature	< 6°C	All project samples	S
Accuracy	LCS	Recoveries within laboratory-specified control limits	1 per 20 samples or one per analytical batch	A
Precision	LCS and MS/Laboratory Duplicate	RPDs within laboratory-specified control limits	1 per 20 samples or one per analytical batch	A
Method performance for matrix, bias	MS/Laboratory Duplicate	Recoveries within laboratory-specified control limits	1 per 10 samples or two per analytical batch	S&A
Bias/Contamination	Method Blank	Target analytes not detected at concentrations > 1/2 the RL	1 method blank per 20 samples or 1 per analytical batch	S&A
Analytical Completeness	Number of usable (not rejected) results out of total number of results	90%	N/A	S&A
Field Completeness	Number of samples collected out of planned samples	90%	N/A	S

Table B-1
Measurement Quality Objectives for Porewater and Surface Water
Pre-Remedial Design Investigation SAP/QAPP, Amendment No. 1
Central Waterfront Cleanup Site – Bellingham, Washington

DQI	QC Sample or Activity Used to Assess MQO	MQO	Frequency	Sampling or Analytical DQI
Porewater/Surface Water Samples Analyzed for Total Dissolved Solids by Method SM 2540C				
Accuracy	LCS	Recoveries within laboratory-specified control limits	1 per 20 samples or one per analytical batch	A
Precision	LCS and MS/Laboratory Duplicate	RPDs within laboratory-specified control limits	1 per 20 samples or one per analytical batch	A
Method performance for matrix, bias	MS/Laboratory Duplicate	Recoveries within laboratory-specified control limits	1 per 20 samples or one per analytical batch	S&A
Bias/Contamination	Method Blank	Target analytes not detected at concentrations > 1/2 the RL	1 method blank per 20 samples or 1 per analytical batch	S&A
Analytical Completeness	Number of usable (not rejected) results out of total number of results	90%	N/A	S&A
Field Completeness	Number of samples collected out of planned samples	90%	N/A	S

Acronyms/Abbreviations:

°C = degrees Celsius
A = analytical
BTEX = benzene, toluene, ethylbenzene, xylene
DQI = data quality indicator
EPA = US Environmental Protection Agency
LCS = laboratory control spike
LCSD = laboratory control spike duplicate
MQO = measurement quality objective
MS = matrix spike
MSD = matrix spike duplicate
N/A = not applicable
NWTPH-Dx = Northwest Total Petroleum Hydrocarbon diesel extended
NWTPH-Gx = Northwest Total Petroleum Hydrocarbon gasoline extended
QA = quality assurance
QC = quality control
RL = reporting limit
RPD = relative percent difference
S = sampling
SIM = selected ion monitoring
TPH-D = diesel-range total petroleum hydrocarbons
TPH-O = oil-range total petroleum hydrocarbons
UCT = universal cell technology

Table B-2a
Amended Target Reporting Limits for Soil and Groundwater
Pre-Remedial Design Investigation SAP/QAPP, Amendment No. 1
Central Waterfront Project – Bellingham, Washington

Analyte	CAS No.	Soil		Groundwater	
		Method	Reporting Limit (mg/kg)	Method	Reporting Limit (µg/L)
Volatile Organic Compounds					
Benzene	71-43-2	EPA 8260D	0.050	EPA 8260D	1.00
Toluene	108-88-3	EPA 8260D	0.050	EPA 8260D	1.00
Ethylbenzene	100-41-4	EPA 8260D	0.050	EPA 8260D	1.00
Total Xylenes	1330-20-7	EPA 8260D	0.100	EPA 8260D	2.00
Petroleum Hydrocarbons					
TPH-G (NWTPH-Gx)	N/A	NWTPH-Gx	5.00	NWTPH-Gx	100
TPH-D (NWTPH-Dx)	N/A	NWTPH-Dx	5.00	NWTPH-Dx	100
TPH-O (NWTPH-Dx)	N/A	NWTPH-Dx	10.0	NWTPH-Dx	200
TPH (calculation)	N/A	Calculation	(a)	Calculation	(a)
Semivolatile Organic Compounds					
bis(2-Ethylhexyl)phthalate	117-81-7	--	--	EPA 8270E	0.50
PAHs					
Naphthalene	91-20-3	--	--	EPA 8270E SIM	0.01
2-Methylnaphthalene	91-57-6	--	--	EPA 8270E SIM	0.01
1-Methylnaphthalene	90-12-0	--	--	EPA 8270E SIM	0.01
2-Chloronaphthalene	91-58-7	--	--	EPA 8270E SIM	0.01
Biphenyl	92-52-4	--	--	EPA 8270E SIM	0.01
2,6-Dimethylnaphthalene	581-42-0	--	--	EPA 8270E SIM	0.01
Acenaphthylene	208-96-8	--	--	EPA 8270E SIM	0.01
Acenaphthene	83-32-9	--	--	EPA 8270E SIM	0.01
Dibenzofuran	132-64-9	--	--	EPA 8270E SIM	0.01
2,3,5-Trimethylnaphthalene	2245-38-7	--	--	EPA 8270E SIM	0.01
Fluorene	86-73-7	--	--	EPA 8270E SIM	0.01
Dibenzothiophene	132-65-0	--	--	EPA 8270E SIM	0.01
Phenanthrene	85-01-8	--	--	EPA 8270E SIM	0.01
Anthracene	120-12-7	--	--	EPA 8270E SIM	0.01
Carbazole	86-74-8	--	--	EPA 8270E SIM	0.01
Fluoranthene	206-44-0	--	--	EPA 8270E SIM	0.01
Pyrene	129-00-0	--	--	EPA 8270E SIM	0.01
1-Methylphenanthrene	832-69-9	--	--	EPA 8270E SIM	0.01
Benzo(a)anthracene	56-55-3	--	--	EPA 8270E SIM	0.01
Chrysene	218-01-9	--	--	EPA 8270E SIM	0.01
Benzo(b)fluoranthene	205-99-2	--	--	EPA 8270E SIM	0.01
Benzo(k)fluoranthene	207-08-9	--	--	EPA 8270E SIM	0.01
Benzo(j)fluoranthene	205-82-3	--	--	EPA 8270E SIM	0.01
Benzofluoranthenes, Total	N/A	--	--	EPA 8270E SIM	0.01
Benzo(e)pyrene	197-97-2	--	--	EPA 8270E SIM	0.01
Benzo(a)pyrene	50-32-8	--	--	EPA 8270E SIM	0.01
Perylene	1985-5-0	--	--	EPA 8270E SIM	0.01
Indeno(1,2,3-cd)pyrene	193-39-5	--	--	EPA 8270E SIM	0.01
Dibenzo(a,h)anthracene	53-70-3	--	--	EPA 8270E SIM	0.01
Benzo(g,h,i)perylene	191-24-2	--	--	EPA 8270E SIM	0.01

Table B-2a
Amended Target Reporting Limits for Soil and Groundwater
Pre-Remedial Design Investigation SAP/QAPP, Amendment No. 1
Central Waterfront Project – Bellingham, Washington

Analyte	CAS No.	Soil		Groundwater	
		Method	Reporting Limit (mg/kg)	Method	Reporting Limit (µg/L)
Conventionals					
Sulfate	14808-79-8	--	--	EPA 300.0	100
Sulfide	18496-25-8	--	--	EPA 300.0	50
Nitrate	14797-55-8	--	--	EPA 300.0	100
Nitrite	14797-65-0	--	--	EPA 300.0	100
Chloride	7647-14-5	--	--	EPA 300.0	100
Methane	74-82-8	--	--	RSK-175	0.654
Total Organic Carbon	N/A	--	--	SM 5310B	500
Total Dissolved Solids	N/A	--	--	SM 2540	5,000
Alkalinity, Total (µg/L CaCO3)	N/A	--	--	SM 2320	1,000
Total/Dissolved Metals					
Arsenic	7440-38-2	EPA 6010C	5.00	EPA 6020A UCT	0.200
Barium	7440-39-3	EPA 6010C	0.300	N/A	--
Cadmium	7440-43-9	EPA 6010C	0.200	EPA 6020A UCT	0.100
Chromium, Total	7440-47-3	EPA 6010C	0.500	EPA 6020A UCT	0.500
Chromium, Hexavalent (SM 3500)	18540-29-9	--	--	SM 3500	10.0
Chromium, Trivalent (calculated)	16065-83-1	--	--	Calculation	N/A
Copper	7440-50-8	--	--	EPA 6020A UCT	0.500
Hardness (calculated)	N/A	--	--	EPA 6010C	N/A
Iron	7439-89-6	--	--	EPA 6020A UCT	20.0
Lead	7439-92-1	EPA 6010C	2.00	EPA 6020A UCT	0.100
Manganese	7439-96-5	--	--	EPA 6020A UCT	0.500
Mercury	7439-97-6	EPA 7471B	0.025	EPA 7470A	0.0200
Nickel	7440-02-0	--	--	EPA 6020A UCT	0.500
Selenium	7782-49-2	EPA 6010C	5.00	EPA 6020A UCT	0.500
Silver	7440-22-4	EPA 6010C	0.300	EPA 6020A UCT	0.200
Zinc	7440-66-6	--	--	EPA 6020A UCT	4.00

Notes:

(a) TPH will be calculated as the sum of detections.

Acronyms/Abbreviations:

CaCO3 = calcium carbonate
CAS = Chemical Abstracts Service
EPA = US Environmental Protection Agency
µg/L = micrograms per liter
mg/kg = miligrams per kilogram
N/A = not applicable
-- = not scheduled for analysis
NWTPH-Dx = Northwest Total Petroleum Hydrocarbon diesel extended
NWTPH-Gx = Northwest Total Petroleum Hydrocarbon gasoline extended
RL = reporting limit
SM = Standard Methods
TPH = total petroleum hydrocarbons
TPH-D = diesel-range total petroleum hydrocarbons
TPH-O = oil-range total petroleum hydrocarbons
UCT = universal cell technology

Table B-2b
Target Reporting Limits for Porewater and Surface Water
Pre-Remedial Design Investigation SAP/QAPP, Amendment No. 1
Central Waterfront Cleanup Site – Bellingham, Washington

Analyte	CAS No.	Porewater/Surface Water	
		Method	Reporting Limit (µg/L)
Volatile Organic Compounds			
Benzene	71-43-2	EPA 8260D	1.00
Toluene	108-88-3	EPA 8260D	1.00
Ethylbenzene	100-41-4	EPA 8260D	1.00
Total Xylenes	1330-20-7	EPA 8260D	2.00
Petroleum Hydrocarbons			
TPH-G (NWTPH-Gx)	N/A	NWTPH-Gx	100
TPH-D (NWTPH-Dx)	N/A	NWTPH-Dx	100
TPH-O (NWTPH-Dx)	N/A	NWTPH-Dx	200
TPH (calculation)	N/A	Calculation	(a)
Semivolatile Organic Compounds			
bis(2-Ethylhexyl)phthalate	117-81-7	EPA 8270E	0.50
PAHs			
Naphthalene	91-20-3	EPA 8270E SIM	0.01
2-Methylnaphthalene	91-57-6	EPA 8270E SIM	0.01
1-Methylnaphthalene	90-12-0	EPA 8270E SIM	0.01
2-Chloronaphthalene	91-58-7	EPA 8270E SIM	0.01
Biphenyl	92-52-4	EPA 8270E SIM	0.01
2,6-Dimethylnaphthalene	581-42-0	EPA 8270E SIM	0.01
Acenaphthylene	208-96-8	EPA 8270E SIM	0.01
Acenaphthene	83-32-9	EPA 8270E SIM	0.01
Dibenzofuran	132-64-9	EPA 8270E SIM	0.01
2,3,5-Trimethylnaphthalene	2245-38-7	EPA 8270E SIM	0.01
Fluorene	86-73-7	EPA 8270E SIM	0.01
Dibenzothiophene	132-65-0	EPA 8270E SIM	0.01
Phenanthrene	85-01-8	EPA 8270E SIM	0.01
Anthracene	120-12-7	EPA 8270E SIM	0.01
Carbazole	86-74-8	EPA 8270E SIM	0.01
Fluoranthene	206-44-0	EPA 8270E SIM	0.01
Pyrene	129-00-0	EPA 8270E SIM	0.01
1-Methylphenanthrene	832-69-9	EPA 8270E SIM	0.01
Benzo(a)anthracene	56-55-3	EPA 8270E SIM	0.01
Chrysene	218-01-9	EPA 8270E SIM	0.01
Benzo(b)fluoranthene	205-99-2	EPA 8270E SIM	0.01
Benzo(k)fluoranthene	207-08-9	EPA 8270E SIM	0.01
Benzo(j)fluoranthene	205-82-3	EPA 8270E SIM	0.01
Benzofluoranthenes, Total	N/A	EPA 8270E SIM	0.01
Benzo(e)pyrene	197-97-2	EPA 8270E SIM	0.01
Benzo(a)pyrene	50-32-8	EPA 8270E SIM	0.01
Perylene	1985-5-0	EPA 8270E SIM	0.01
Indeno(1,2,3-cd)pyrene	193-39-5	EPA 8270E SIM	0.01
Dibenzo(a,h)anthracene	53-70-3	EPA 8270E SIM	0.01
Benzo(g,h,i)perylene	191-24-2	EPA 8270E SIM	0.01

Table B-2b
Target Reporting Limits for Porewater and Surface Water
Pre-Remedial Design Investigation SAP/QAPP, Amendment No. 1
Central Waterfront Cleanup Site – Bellingham, Washington

Analyte	CAS No.	Porewater/Surface Water	
		Method	Reporting Limit (µg/L)
Conventionals			
Sulfate	14808-79-8	EPA 300.0	100
Nitrate	14797-55-8	EPA 300.0	100
Chloride	7647-14-5	EPA 300.0	100
Methane	74-82-8	RSK-175	0.654
Total Organic Carbon	N/A	SM 5310B	500
Total Dissolved Solids	N/A	SM 2540	5,000
Alkalinity, Total (µg/L CaCO3)	N/A	SM 2320	1,000
Total/Dissolved Metals			
Arsenic	7440-38-2	EPA 6020A UCT	0.200
Barium	7440-39-3	N/A	--
Cadmium	7440-43-9	EPA 6020A UCT	0.100
Chromium, Total	7440-47-3	EPA 6020A UCT	0.500
Chromium, Hexavalent (SM 3500)	18540-29-9	SM 3500	10.0
Chromium, Trivalent (calculated)	16065-83-1	Calculation	N/A
Copper	7440-50-8	EPA 6020A UCT	0.500
Hardness (calculated)	N/A	EPA 6010C	N/A
Iron	7439-89-6	EPA 6020A UCT	20.0
Lead	7439-92-1	EPA 6020A UCT	0.100
Manganese	7439-96-5	EPA 6020A UCT	0.500
Mercury	7439-97-6	EPA 7470A	0.0200
Nickel	7440-02-0	EPA 6020A UCT	0.500
Selenium	7782-49-2	EPA 6020A UCT	0.500
Silver	7440-22-4	EPA 6020A UCT	0.200
Zinc	7440-66-6	EPA 6020A UCT	4.00

Notes:

(a) TPH will be calculated as the sum of detections.

Acronyms/Abbreviations:

-- = not scheduled for analysis
CaCO3 = calcium carbonate
CAS = Chemical Abstracts Service
EPA = US Environmental Protection Agency
µg/L = micrograms per liter
N/A = not applicable
NWTPH-Dx = Northwest TPH extended-range diesel analytical method
NWTPH-Gx = Northwest TPH extended-range gasoline analytical method
QAPP = Quality Assurance Project Plan
RL = reporting limit
SAP - Sampling and Analysis Plan
SM = Standard Methods
RL = reporting limit
SAP - Sampling and Analysis Plan
SM = Standard Methods
TPH = total petroleum hydrocarbons
TPH-D = diesel-range TPH
TPH-O = oil-range TPH
UCT = universal cell technology

Table B-3
Sample Containers, Preservatives, and Holding Times - Environmental
Pre-Remedial Design Investigation SAP/QAPP, Amendment No. 1
Central Waterfront Cleanup Site – Bellingham, Washington

Matrix	Analyte	Method	Container	Preservative	Holding Time (a)	Laboratory
Porewater/ Surface Water	TPH-G	NWTPH-Gx	2 x 40 mL vial	Cool to < 6°C, HCl	14 days preserved 7 days unpreserved	AR
Porewater/ Surface Water	TPH-D, TPH-O	NWTPH-Dx	2 x 500 mL Amber	Cool to < 6°C	7 days	AR
Porewater/ Surface Water	BTEX	EPA 8260D	2 x 40 mL vial	Cool to < 6°C, HCl	14 days preserved 7 days unpreserved	AR
Porewater/ Surface Water	SVOCs	EPA 8270E	2 x 500 mL Amber	Cool to < 6°C, HCl	7 days/40 days	AR
Porewater/ Surface Water	PAHs	EPA 8270E SIM	2 x 500 mL Amber	Cool to < 6°C, HCl	7 days/40 days	AR
Porewater/ Surface Water	Total and Dissolved Metals	EPA 6020A UCT	500 mL HDPE	Cool to < 6°C HNO3 (b)	6 months	AR
Porewater/ Surface Water	Total and Dissolved Mercury	EPA 7470A	500 mL HDPE	Cool to < 6°C HNO3 (b)	28 days	AR
Porewater/ Surface Water	Hexavalent Chromium	SM 3500	500 mL HDPE	Cool to < 6°C, buffer to pH 9.3 to 9.7	28 days 24 hours (c)	AR
Porewater/ Surface Water	Anions	EPA 300.0	500 mL HDPE	Cool to < 6°C	48 hrs (nitrate) 28 days (sulfate) (chloride)	AR
Porewater/ Surface Water	Dissolved Gases	RSK-175	3 x 40 mL vial	Cool to < 6°C	14 days	AR
Porewater/ Surface Water	Alkalinty	SM 2320B	500 mL HDPE	Cool to < 6°C	14 days	AR
Porewater/ Surface Water	Total Organic Carbon	SM 5310B	250 mL glass	Cool to < 6°C, pH <2 H2SO4	28 days	AR
Porewater/ Surface Water	Total Dissolved Solids	SM 2540C	1 Liter HDPE	Cool to < 6°C	7 days	AR

Notes:

(a) Time from sample collection to extraction/time from sample extraction to analysis.
(b) Total metals or field-filtered samples only.
(c) If buffer is not used.

Table B-3
Sample Containers, Preservatives, and Holding Times - Environmental
Pre-Remedial Design Investigation SAP/QAPP, Amendment No. 1
Central Waterfront Cleanup Site – Bellingham, Washington

Acronyms/Abbreviations:

^{o}C = degrees Celsius
AR = Analytical Resources, LLC
BTEX = benzene, ethylbenzene, toluene, total xylenes
EPA = US Environmental Protection Agency
H2SO4 = sulfuric acid
HCl = hydrochloric acid
HDPE = high-density polyethylene
HNO3 = nitric acid
mL = milliliter
NWTPH-Dx = Northwest TPH extended-range diesel analytical method
NWTPH-Gx = Northwest TPH extended-range gasoline analytical method
PAH = polycyclic aromatic hydrocarbon
SIM = selected ion monitoring
SM = Standard Methods
TPH = total petroleum hydrocarbons
TPH-D = diesel-range TPH
TPH-G = gasoline-range TPH
TPH-O = oil-range TPH

Table B-4
Field Quality Control Sample Summary for Porewater and Surface Water
Pre-Remedial Design Investigation SAP/QAPP, Amendment No. 1
Central Waterfront Cleanup Site – Bellingham, Washington

Matrix	Collection Frequency Trip Blanks
Porewater/ Surface Water	1 per each cooler containing samples scheduled for volatile analyses

Table B-5
Equipment Calibration Requirements
Pre-Remedial Design Investigation SAP/QAPP, Amendment No. 1
Central Waterfront Cleanup Site – Bellingham, Washington

Instrument	Calibration Procedure	Calibration Frequency
pH meter	Three-point calibration with pH buffers 7, 4, and 10, as appropriate	Daily
Conductivity meter	One-point calibration with 1,500 microSiemen/centimeter (µS/cm) standard solution for non-saline water, or 2,880 µS/cm standard solution for saline waters	Daily
Dissolved Oxygen meter	100% saturation using tap water exposed to ambient air, in accordance with manufacturer's specifications.	Daily and/or when weather (pressure and/or temperature) changes are significant
Redox meter	None	N/A
Thermometer	Check with ohm meter or standard thermomter	Annually
Electric water-level probe	Test probe in tap water; check tape against known length	Probe; as needed if malfunctions; tape length: annually
Photoionization detector (PID)	Isobutylene gas and bump test	Daily
Flame ionization detector (FID)	Calibrate per manufacturer's recommendations and bump test	Daily