Supplemental Investigation Work Plan

Gas Works Park Site
Seattle, Washington

for
Puget Sound Energy

March 13, 2013

GeoEngineers
Earth Science + Technology

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March 13, 2013

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1.0 INTRODUCTION

This Supplemental Investigation Work Plan (Work Plan) has been prepared for Puget Sound Energy (PSE) to further assess impacted soil and groundwater associated with former manufactured gas plant (MGP), tar refinery, and other industrial operations located at the City of Seattle Gas Works Park and Harbor Patrol properties. Gas Works Park is located on a 20.5-acre peninsula north of Lake Union, formerly known as Brown's Point (Figure 1).

During previous investigation activities, chemicals of concern were detected in soil and groundwater at the GWPS (uplands) and sediment adjacent to the uplands. This Work Plan has been prepared to provide a framework for obtaining additional data and information to support preparing a site-wide remedial investigation and feasibility study (RI/FS) for the uplands and sediments. This Work Plan has been prepared, and the site-wide RI/FS will be conducted, under a modification of the March 18, 2005 Agreed Order No. DE 2008 between PSE, the City of Seattle (City), and the Washington State Department of Ecology (Ecology) for the Gas Works Park Sediment Site (GWPSS). Under the proposed Agreed Order modification, the GWPSS area of investigation will be expanded to include upland areas that may impact sediments.

1.1. Relationship between Uplands and Sediments

The Gas Works Park Site (GWPS) was defined in the 1999 Consent Decree as the terrestrial areas of Gas Works Park and Harbor Patrol, and did not include areas that are submerged or seasonally submerged by the waters of Lake Union (Ecology 1999). As originally defined in the 2005 Agreed Order DE 2008, the GWPSS includes the sediment adjacent to the GWPS. The 2005 Agreed Order for the GWPSS defined an area of investigation that was further subdivided into an Eastern Study Area (ESA) and Western Study Area (WSA). The ESA and WSA are collectively called the Gas Works Sediment Area (GWSA). RI/FS reports were prepared for GWSA in 2006 and 2007. The RI/FS report for the ESA was prepared for PSE (The RETEC Group 2006), and the RI/FS report for the WSA was prepared for the City (Floyd/Snider 2007).

Uplands investigations and studies have been performed to address source contributions to the GWSA. Investigations in this work plan are proposed to supplement these data to address upland source contributions so the site-wide RI/FS can be completed and a site-wide cleanup action plan can be prepared. The proposed scope of work focuses on upland pathways to sediments, namely soil leaching to groundwater, groundwater migration to sediments, and potential non-aqueous phase liquid (NAPL) migration. Source control activities associated with storm sewers are being address separately from this work plan.

1.2. Regulatory Framework

Environmental investigations at the GWPS have been performed since the 1970s. The GWPS was evaluated for inclusion on the Environmental Protection Agency (EPA) National Priorities List in the 1980s. Instead, in 1996, Ecology and EPA signed a Deferral Agreement that formally provided Ecology with regulatory authority to oversee response actions on the GWPS and GWPSS. Since then, environmental investigations, studies, and remedial actions, have been overseen by Ecology. The following legal instruments govern response actions on the site:

- Deferral Agreement between EPA Region 10 and Ecology, July 17, 1996 (EPA 1996). This document formally defers site regulatory authority to Ecology (Ecology 1996).
- Agreed Order number 97TC-148, August 1, 1997. The 1997 Agreed Order executed by Ecology, the City, and PSE includes procedures and a schedule for preparation of cleanup action planning documents related to contaminated media on the GWPS (Ecology 1997).
- Consent Decree 99-2-52532-9SEA, December 22, 1999. This document establishes the framework for remedial actions on the GWPS (Ecology 1999).
- Amendment 1 to Consent Decree 99-2-52532-9SEA, May 12, 2005. This document incorporated an updated cleanup action plan for the GWPS (Ecology, 2005a).
- Agreed Order DE 2008, March 18, 2005. This document establishes the framework for sediment investigation in Lake Union and established the initial area of investigation for the GWPSS (Ecology 2005b).
- A modification of Agreed Order DE 2008, has been proposed to Ecology to expand the area of investigation defined in the 2005 Agreed Order to incorporate upland areas that may impact sediments (City and PSE 2013).

This supplemental investigation is being performed under Agreed Order DE 2008 (Ecology 2005) between Ecology, PSE, and the City. Proposed upland investigation activities presented in this work plan are within the expanded area of investigation proposed in the Agreed Order modification. The proposed modification is to expand the site boundaries to include Gas Works Park, Seattle Harbor Patrol and the near shore sediments surrounding Gas Works Park and Harbor Patrol. The area of investigation is being expanded to incorporate upland areas that may impact sediments. Although the Agreed Order modification proposes to call the expanded site the “Gas Works Park Site,” the remainder of this document uses the original definitions of the Gas Works Park Site (Gas Works Park and Harbor Patrol upland areas) and Gas Works Park Sediment Site (sediments adjacent to Gas Works Park and Harbor Patrol). The proposed modification is to expand the Site boundaries to include Gas Works Park, Seattle Harbor Patrol and the near shore sediments surrounding the Park and Harbor Patrol.

Environmental actions at the site have been performed by PSE and the City, the primary potentially liable parties for the site. On October 31, 2012, the City and PSE entered into a Settlement, Release, and Cost Allocation Agreement (Settlement Agreement) governing the activities and costs associated with site cleanup. As a result of the Settlement Agreement, PSE has responsibility for directing the remaining investigation and cleanup of the GWPS and GWPSS.

1.3. Purpose and Objectives

The purpose of this supplemental upland investigation is to provide additional data regarding upland areas that may impact sediments and characterize potential sources and migration pathways to sediments to allow completion of a site-wide RI/FS. Objectives of the supplemental investigation include the following:

- Perform an evaluation of primary sources of impacts on the uplands.

- Characterize upland soil in targeted areas to assess potential ongoing sources of groundwater impacts.
- Characterize upland groundwater to address the groundwater to sediment pathway.
- Assess light and dense non-aqueous phase liquid (LNAPL and DNAPL) occurrence and mobility on the uplands, relative to migration to sediment.

1.4. Work Plan Organization

The information and proposed scope of activities presented in this work plan rely on numerous previous investigations and studies performed on the uplands and in the sediments. Documents relevant to the preparation of this Work Plan are listed in Tables 1a and 1b. This work plan includes a summary of planned activities to meet the investigation objectives. Supporting documents including a Sampling and Analysis Plan (SAP, Appendix A), Quality Assurance Project Plan (QAPP, Appendix B), and Health and Safety Plan (HASP, Appendix C) are included. The work plan for proposed geotechnical investigations for Kite Hill is included in Appendix D. Tabulated analytical data are included in Appendix E.

2.0 SITE DESCRIPTION, HISTORY, AND ENVIRONMENTAL SETTING

2.1. Site Description

The GWPS is located on a 20.5-acre peninsula formerly known as Brown's Point. The GWPS consists of Gas Works Park, Harbor Patrol, and a filled portion of Waterway 19, in the northeastern portion of Gas Works Park (Figure 2).

Gas Works Park is owned and maintained by the City of Seattle Department of Parks and Recreation. The Park consists of open grassy areas and landscaping that includes partially dismantled manufactured gas plant (MGP) structures and shoreline bulkhead (prow). The Park includes a parking lot and is accessed by the frequently-used Burke-Gilman bicycle trail. The Park features public events, especially during the summer. The westernmost portion of the GWPS is owned by the Seattle Police Harbor Patrol. The Harbor Patrol includes two over-water boathouses, three floats, a moorage pier, and a service wharf. Historical Waterway 19 is owned by the Washington State Department of Natural Resources (DNR).

Industrial properties are located along the Ship Canal to the west, and to the east and southeast. North of Gas Works Park are the office, warehouse, and residential properties. The Center for Wooden Boats (Chevron/Metro MTCA Site) and the Northlake Shipyard are located west of Gas Works Park. The Gas Works Park Marina is located to the east.

2.2. Site History

The present topography at the Site reflects the expansion of the peninsula over time. Fill material was placed along the shoreline from approximately 1899 to 1929 to increase the area of the peninsula (USGS 1899, Plat of Lake Union Shorelands 1907, Sanborn 1919, USACE 1929),). Substantial cutting and filling occurred during construction of the Park in the 1970s (Haag 1971). The primary industrial operations—gas manufacturing and tar refining—and redevelopment of the property into a municipal park are discussed in the following subsections.

2.2.1. The Manufactured Gas Plant (MGP)

The eastern side of Brown's Point was developed by the Seattle Lighting Company in 1907 with the construction of an MGP on the site. In 1930, it became known as the Seattle Gas Plant. From 1907 to 1937, the plant manufactured gas by coal carbonization. Coal carbonization is the destructive distillation of coal at high temperatures. A hot gas is formed and quenched with cold water to condense tar. Coal tar is a high-quality byproduct that can be refined into a variety of products. In 1937, the coal gas process was replaced with newer oil-gas generators. The coal gas production ended in September 1937 (Brown's 1938).

From 1907 to 1952, carbureted water gas was also produced (Brown's, 1887-1956). In the carbureted water gas process, coke, a by-product of coal carbonization, is heated with steam to release gas (called blue gas or water gas) in a generator. The gas produced from the coke is piped to a carburetor, where a mist of petroleum oil is sprayed and vaporized. The mixture is converted to a gas in a third vessel called a superheater. The resulting gas is quenched to condense out tar in a wash box and scrubbed of impurities before being piped to customers (Middleton 1995; Wyer 1924).

The gas production towers currently located on the GWPS were associated with the oil gas process – the third type of gas production process that operated at the MGP. The MGP produced Pacific Coast Low BTU Oil Gas (500 BTU) from 1937 to 1956. The last of the towers was installed in 1945 when the Seattle Gas Plant was expanded to increase gas production. Like carbureted water gas, the oil gas process generates tar from gas condensing and scrubbing operations. MGP process flow diagrams and utility directory records (Brown's 1933 to 1952) indicate that this oil tar was primarily burned for heat energy in the MGP steam boilers.

Historical MGP features, including overwater structures, are shown on Figure 3. Three docks were present along the eastern shoreline; these are identified from north to south as the lake suction dock, tar dock, and oil dock. The lake suction dock appears to have been constructed by 1919 based on the presence of lake suction lines (Sanborn 1919). The first evidence of the tar dock is a 1927 U.S. Army Corps of Engineers (Corps) "lake conditions" map; revised in 1932 (USACE 1927). Both of these docks are present in a 1936 aerial photograph. In 1937, the MGP received a permit from the Corps to install three dolphins along the eastern shoreline to guide navigation. The permit proposed to extend a catwalk from the shoreline to middle dolphin to support a pipeline to unload oil tankers (USACE 1937). The location of the resulting oil dock is shown on Figure 3.

In 1954, the Trans Mountain Pipeline was opened to Washington, providing natural gas to the Seattle area and decreasing the demand for manufactured gas. This resulted in the plant closing in 1956 (Sabol et al. 1988). The MGP was in stand-by mode from 1956 to approximately 1966; then primarily used for storage until the property was transferred to the City in 1973.

2.2.2. The Tar Refinery

West of the manufactured gas plant, a tar refinery began operating sometime between 1907 and 1912 (Figure 3). The tar refinery operated under the name American Tar Company (ATCO) from approximately 1920 until the mid-1950s, with storage operations into the mid-1960s (USEPA, 1995). The tar refinery operated as the Barrett Company between 1912 and 1920. According to a 1924 Seattle Times article, the tar refinery obtained tar from the adjacent gas plant and from other gas plants throughout the Pacific Northwest. These materials were refined using steam distillation to produce various grades of tar and tar derivatives (Seattle Times 1924). During the tar refinery operation, the Lake Union shoreline was approximately 200 feet closer to the tar refinery. The Lake Union shoreline was extended in this area by filling after 1919 (Sanborn 1919).

2.2.3. Park Construction

In 1971, a master plan for what would become Gas Works Park was completed (Richard Haag and Associates and City of Seattle, 1971). By this time, the MGP had been decommissioned, some MGP facilities had been demolished, and fill material had been imported and stockpiled in the Kite Hill area. Between 1972 and 1976, park development activities were conducted by the architecture firm Richard Haag Associates.

In 1973, the City completed limited improvements to the Great Mound (Kite Hill) so that it could be temporarily opened for public use during development of the remainder of the site. The Great Mound primarily consisted of imported excavation material generated from construction at Interstate 5, the Safeco Building, and possibly other off-site sources (Sabol et al. 1988). Earlier in 1973, the City authorized targeted excavation and demolition throughout the remainder of the Park. Targeted excavation depths extended up to 8 feet below grade and to “water level” near shore. Substantial cutting and stockpiling of impacted soil occurred during these excavation activities. A minimum of 20,000 cubic yards of impacted soil were excavated and temporarily stockpiled on site; however, exact quantities of what was excavated and removed from the site are unknown. By early 1974, most of the demolition of former MGP structures, excavation, and regrading of the majority of the site had occurred. In 1975, the focus was on renovating the former MGP structures to become the Picnic Shelter and Play Barn.

In 1976, another phase of regrading occurred as the site was sculpted into its current topographic form. During this period of regrading, substantial soil was cut from shoreline areas and areas away from the shoreline were filled. Near the end of the redevelopment, a layer of soil, sawdust, dewatered biosolids (as fertilizer) was tilled into the soil to encourage the breakdown of pollutants and control dust (EPA 1995). Two inches of topsoil and hydroseed where used for cover.

Most of the MGP was dismantled. However, MGP facilities, including six oil gas generators or “cracking towers” in the central portion of the park, turbines and other equipment in the “Play Barn”, concrete railroad trestles in the northeastern portion of the park, and other facilities remain and were integrated into the park design. The property was converted to a public park, named Gas Works Park, which opened in 1976. Gas Works Park, including existing historical above-grade MGP structures, was added to the National Register of Historic Places in January 2013 (TCLF 2013).

2.3. Environmental Setting

2.3.1. Topography and Surface Water

Gas Works Park is situated on a peninsula that protrudes southward into Lake Union (Figure 2).The northern part of the Site is relatively flat (40 to 45 feet, Corps datum), and is separated from the remainder of the Park by the Burke-Gilman Trail. Kite Hill (elevation 65 feet, Corps datum) is the most prominent topographic feature of the Site. A portion of the land surface of the Park slopes toward Lake Union (Figure 2).

The Corps maintains the water level in Lake Union by regulating flow through the Hiram M. Chittenden Locks on the western end of Salmon Bay. Lake Union water levels vary approximately 2 feet on a yearly basis, from approximately 20 feet during the winter months to approximately 22 feet during the summer months.

2.3.2. Geology

The following site geology is summarized from the Revised Geologic Conceptual Site Model (CSM) prepared for the site in 2011. Substantial geologic data were evaluated to develop the revised geologic CSM, and resulted in a significantly different interpretation of the geology at GWPS and GWPSS than has been presented in previous studies. These differences are summarized in the Revised CSM Memorandum (GWSA 2011).

Site geology is presented on two cross sections from the revised geologic CSM. Cross section locations are presented on Figure 4. Geologic cross sections are presented on Figure 5 and 6. The primary stratigraphic units in the uplands are the fill, and pre-Fraser Till. These units are the most laterally extensive units in the uplands. Vashon recessional and advance outwash are present on the GWPS and GWPSS, draped over the pre-Fraser Till near the Lake Union shoreline. Recent lacustrine deposits are present offshore. Other stratigraphic units identified on the GWPS and GWPSS are generally thinner and less laterally extensive.

The descriptions provided below include regionally recognized geologic units and also show the observed range of sedimentary characteristics (i.e. sub units) within a larger unit. Site-specific characteristics of each geologic unit are incorporated in the descriptions below. From stratigraphic top (youngest) to bottom (oldest), the site area units include the following:

FILL (AF) – Fill material is present throughout the majority of the GWPS and the shoreline, and is one of the primary stratigraphic units on the uplands. It generally consists of industrial fill material, a combination of soil and industrial fill material, or reworked natural deposits. It typically is a loose to medium dense poorly graded sand with silt, clay, gravel, and debris (ash, cinders, wood, brick fragments, slag, and other anthropogenic debris). Fill pinches out in the northern uplands and extends 10 to 150 feet offshore.

RECENT BEACH AND SHALLOW SHELF DEPOSITS (QB) – Recent beach and shallow shelf deposits have a very limited extent where present, and consist of loose to medium dense, gray to dark gray, sand and gravel deposits at the former shoreline beach, on the shallow wave-cut bench, and on the lake bottom slope below the wave-cut bench. The Qb is a localized deposit and is absent in most areas. For this reason, Qb was grouped with Qvr in the cross-sections. Where present the recent beach and shallow shelf deposits range from 0 to 8 feet thick and are typically 2- to 4-feet thick. Qb often contains scattered wood and organic fragments, thin silty lamina or beds, thin peat beds, and mollusk shell fragments. It generally occurs near or below lake level near the pre-development (1899) shoreline.

RECENT LACUSTRINE DEPOSITS (QL) – Recent lacustrine deposits comprise most of the recent sediment deposited in Lake Union. Recent lacustrine deposits include very soft, reddish brown to black, organic silt and clay with fibrous organic matter and minor sand and rootlets. It is deposited by settling of suspended sediment onto the lake bed. This unit has low shear strength but there is downward "firming" as strength increases (undrained shear strength test results range from 68 to 230 pounds per square foot). The upper recent lacustrine deposits (very soft, black organic silt with minor sand and fresh rootlets as well as various amounts of woody material and/or anthropogenic debris) are separated from the lower recent lacustrine deposits (soft, reddish brown organic silt with decomposing rootlets and a spongy, blocky texture without anthropogenic material) by a thin (<0.25 feet thick) gray silt layer in many areas. Recent lacustrine deposits are currently being deposited in lake-bottom areas at an estimated deposition rate of 0.45 to 1.7 centimeters per year (RETEC 2005). Ql is typically 5 to 15 feet thick and a maximum of up to 50 feet thick within the Gas Works Sediment Area.

VASHON RECESSIONAL GLACIOLACUSTRINE DEPOSITS (Q_{VRL}) – Vashon recessional glacial lake deposits were encountered offshore in two borings and consist of gray, firm to stiff silt and clay with thin interbeds of fine sand. Q_{VRL} may contain scattered dropstones or sandy to gravelly layers, and trace amounts of organic matter. It is locally present below Recent Lacustrine Deposits and within or above recessional outwash. Qvrl in the Gas Works Sediment Area is up to 20 feet thick and was only encountered in two borings, both offshore: one boring penetrated 2.6 feet into the Qvrl, and one boring fully penetrated the Qvrl which was 20 feet thick at that location.

VASHON RECESSIONAL OUTWASH (Q_{VR}) – Vashon recessional glacial outwash is present in the nearshore area of the GWPS. It generally is composed of brown to gray, loose to dense, clean sand-or-gravel, to sand-and-gravel mixtures with variable amounts of silt. Recessional outwash occurs predominantly as a thin, discontinuous blanket on glaciated uplands and as thicker deposits in former glacial meltwater channels in low lying areas. Recessional outwash is generally absent offshore along the southeast-trending glacial till ridge and in the eastern uplands. Recessional outwash is typically 5 to 10 feet thick and a maximum of up to 20 feet thick.

VASHON ADVANCE OUTWASH (Q_{VA}) – Vashon advance outwash present in the nearshore area of the GWPS. Advance glacial outwash is a dense to very dense, gray to brown, poorly graded, slightly silty sand (predominantly fine and medium grained) with interbeds of clean coarser sand, thin silt beds, or sand and gravel mixtures. Advance outwash was deposited in broad proglacial outwash plains or deltaic deposits that were overridden by the advancing glacier. It may include subglacial meltwater channel deposits. The eastern and western flanks of the glacial till ridge are locally overlain with a thin and discontinuous veneer of advance outwash. Advance outwash is not present across most of the uplands. The advance outwash is water bearing where saturated, and is typically 5 to 15 feet thick and a maximum of 20 feet thick.

PRE-FRASER TILL (Q_{PGT}) – Pre-Fraser Till is at least 70 feet thick on the GWPS and is the thickest and most widespread geologic unit at the Park. The pre-Fraser till group primarily consists of glacially overridden, medium dense to very dense diamicts with clayey to silty fine sand matrix with variable gravel content, and scattered cobbles and boulders. The composition of the pre-Fraser glacial till group is vertically and laterally variable and it includes strata that vary in apparent density, degree of weathering, and other properties. In the Uplands, the Pre-Fraser glacial till is characterized by variable density. Color ranges from gray-brown where weathered to gray where un-weathered. Regionally, this unit is typically considered an aquitard and may perch shallow groundwater. This group includes glacial sub units that have recognizable and distinctive characteristics, but are generally too aerially restrictive to be mapped as separate units. Basal till is not a significant component of the Qpgt unit. Distinctive Qpgt subunits are present within the pre-Fraser Till, but do not constitute the majority of the till unit. These subunits include the following:

- **PRE-FRASER GLACIOLACUSTRINE DEPOSITS (QPGL)** - Laminated to massive, gray, very stiff to hard silt, clayey silt, and silty clay deposited in proglacial lakes. May contain scattered dropstones and thin sandy to gravelly lenses. Qpgl offshore is up to 3 feet thick and is locally present (minor unit) off the southern shoreline and farther off the southwestern shoreline. Qpgl has only been observed in one location in the uplands (MW-23, close to the shoreline).
- **PRE-FRASER DIAMICT (QPGD)** - Till-like diamict containing variable amounts of sand and gravel in a silty to clayey matrix that was generally deposited by suspension. Soil behavior ranges from hard and cohesive where the matrix is clayey, to dense or very dense where the matrix is silty to sandy and noncohesive. A gravelly diamict with a fine sand and silt matrix and little or no cohesion comprises the majority of the Qpgd group by volume. Qpgd may also occur as thin lenses within glaciolacustrine deposits. Where present, Qpgd is typically 2 to 12 feet thick and the maximum thickness is greater than 18 feet. This subunit is locally present (minor unit) in sporadic locations on the eastern half of the uplands, and in the southwestern shoreline area.
- **PRE-FRASER SUBGLACIAL MELTOUT TILL (QPGTM)** – Meltout till is composed of interbedded basal till or diamict and lenses to layers of cleaner glaciofluvial sand and gravel. This unit was deposited in meltwater channels and cavities below glacial ice, has been glacially overridden, and is very dense. The color ranges from rusty where oxidized, to gray brown to gray. Where the cleaner layers and lenses are saturated, they can be water bearing, but are often of limited aerial extent and generally poorly interconnected. This subunit appears to be present locally (minor unit) in the area of MW-31.

2.3.3. Hydrogeology

A revised hydrogeologic CSM for the GWPS was prepared in 2010 and 2011 to provide additional hydrogeologic information for a groundwater model prepared in 2012 (Aspect et al. 2012). More than 40 monitoring wells are located on the GWPS (Figure 2). Details regarding monitoring well construction are presented in Table 2. Information from these monitoring wells was used to develop the revised hydrogeologic CSM and groundwater flow model.

Groundwater conditions observed during previous investigations indicate groundwater at the GWPS is primarily unconfined in the fill and outwash deposits. The saturated thickness of the fill and outwash deposits is variable, but generally is thicker near the east and west shorelines where the surface of the till unit is lower. Groundwater conditions observed in the glacial till indicate groundwater is generally unconfined, but may be locally confined because of the heterogeneous nature of the glacial till (GWSA 2011).

Groundwater on the GWPS generally flows radially across the site before discharging to Lake Union (Tech Team 2012). Seasonal variations in groundwater flow are minor. The groundwater table elevation in the glacial till unit appears to be generally controlled by seasonal changes that result from regional recharge. As a result, groundwater elevations in the glacial till tend to be higher in the winter during wet weather and lower in the summer during dry weather. Groundwater elevations in monitoring wells near the shoreline, which primarily monitor fill and outwash deposits, tend to be governed by the elevation of Lake Union, which is maintained at a higher elevation in the summer.

The GWPS is underlain by low-permeability pre-Fraser glacial till. As illustrated on Figure 5 (section R-R'), the surface of the till is highest in the central portion of the GWPS, and slopes toward Lake Union, particularly to the east and west. Higher permeability glacial outwash deposits, including Vashon recessional outwash and Vashon advance outwash, are present beneath the eastern and western shoreline areas above the pre-Fraser till surface. Hydraulic conductivity estimates are presented on Table 3. Approximately 90 percent of recharge that infiltrates the fill or outwash deposits discharges to Lake Union. This direct recharge to fill and outwash deposits is the main source of groundwater from the GWPS to the lake. The average horizontal gradient observed in the uplands during the five recent groundwater monitoring events ranges from approximately 0.01 to 0.02 feet per foot.

Total groundwater discharge to Lake Union is estimated to range from 1,100 to 1,920 cubic feet per day, or approximately 6 to 10 gallons per minute. Greater than 98 percent of the groundwater discharge is estimated to originate from recharge, primarily from precipitation at the Park (Aspect et al. 2012).

2.3.4. Ecological Setting

A Terrestrial Ecological Evaluation (TEE) was prepared for the GWPS (Hart Crowser 2012). An ecological evaluation was also performed as part of a focused feasibility study (Parametrix 1998). As part of that evaluation, the Washington State Department of Fish and Wildlife Priority Habitats and Species Database was queried and no records of endangered or threatened animals or plants or State species of concern were returned for the Site.

Turf grass covers most of the open areas of the GWPS. Some areas are covered by pavement, structures, or compacted gravel paths. Landscape plantings of ornamental tree and shrub species are present along the Lake Union shoreline, bordering the gravel trail, along medians in the parking lot, and scattered elsewhere on the uplands (Hart Crowser 2012).

Wild bird and mammal species observed at Gas Works Park are typical of urban environments and include several introduced species. One mammal species (Eastern Gray Squirrel) was observed on the upland. Signs of past use of the Site by beaver (i.e., old gnaw marks on tree stumps) were observed in the northeast corner of the Park. However, the continuous and intensive use of the Park by humans and their pets, and Park maintenance activities such as periodic mowing and irrigation tend to discourage use of the turf grass areas by birds and mammals. No burrowing animals were observed on the Site during four reconnaissance visits in 2010 (Hart Crowser 2012).

A field survey was conducted on September 23 and 24, 2010, to assess the presence of soil macroinvertebrates. Turf grass areas support diverse and healthy earthworm populations. Both shallow burrowing (endogenic) and deep burrowing (anecic) earthworms were present. Few other macroinvertebrate species were observed during the survey (Hart Crowser 2012).

3.0 SUMMARY OF PREVIOUS INVESTIGATIONS AND REMEDIAL ACTIONS

3.1. Remedial Actions

Several remedial actions have been performed at the site, beginning in the 1970s during Park development. Remedial actions are described in Table 1a. Major remedial action areas are presented on Figure 7. More recent cleanup activities at the GWPS generally have consisted of:

- Covering portions of the Park, including the northwest corner, central meadow, southeast area, and northeast corner with engineered, vegetated soil caps;
- Removing and covering upwelling tar in discrete locations within the Park;
- Implementing institutional controls including fencing, barriers, and signage;
- Placing restrictive covenants that govern actions that disturb contaminated media;
- Installing, operating, and decommissioning an LNAPL recovery system in the southeast portion of the site;
- Installing and operating an air sparging/soil vapor extraction system in the southeast portion of the Park.

The Kite Hill and Cracking Tower areas have not been capped by engineered, vegetated, soil caps. The cracking tower area is fenced, and access to this area by the public is restricted. Because other areas of the Park have been capped, shallow soil samples collected before soil coverings were installed in the northwest area, central meadow, northeast corner, and southeast area are no longer considered representative of surface soil conditions in these areas.

3.2. Previous Investigations

The presence of chemicals of concern at the Park has been investigated and monitored by the City, PSE, EPA, and Ecology through a series of investigations. Early environmental assessments of the subsurface began in 1971. In the 1970s, several soil investigations took place during planning and development of the Park. In the 1980s, multiple soil and groundwater quality investigations were conducted, as concerns regarding potential contamination of the Park were explored. Further investigations took place in the 1990s, 2000s, and 2010s. Descriptions of the major investigations are provided in Table 1b; full details can be found in the investigation documents listed in the reference section. Exploration/sample locations associated with previous investigations are shown on Figure 7. More than 150 soil exploration locations have been made and more than 50 monitoring wells or temporary groundwater monitoring stations have been installed to evaluate environmental conditions on the GWPS. Groundwater monitoring locations on or near the GWPS include or have included the following:

- Monitoring wells MW-1 through MW-31, and MW-3D. Monitoring well MW-4 was never installed.
- Piezometers PZ-1 through PZ-10.
- Observation wells OBS-1 through OBS-3.
- Temporary monitoring stations TMS-1 through TMS-15.

- Monitoring wells TSW-1, TDW-1, TSW-2, TDW-2, TSW-3, and TDW-3.
- Multi-level samplers MLS-1 through MLS-7.
- Recovery well RW-1.
- Monitoring wells DW-4 through DW-7.
- Monitoring well CMP-1

Current soil and groundwater quality conditions at the GWPS, from data generated from investigations summarized on Table 1b, are described in Section 5.

4.0 CLEANUP LEVELS

Cleanup levels for the GWPS were established in Cleanup Action Plan (Parametrix 1999) and incorporated into the 1999 Consent Decree (State of Washington 1999). These cleanup levels were established in conjunction with institutional controls and site use restrictions that exist for the site.

4.1. Soil

Soil cleanup levels established for the GWPS were based on a future residential exposure scenario as a conservative approach that provides an added level of protection to Park users and workers. The majority of the GWPS is covered with vegetated soil caps, paved, or covered by buildings. Institutional controls limit contact with subsurface soil on the GWPS. Chemicals of concern for soil and their cleanup levels are presented on Table 4 (State of Washington 1999).

4.2. Groundwater

Groundwater cleanup levels established for the GWPS are based on the protection of surface water. The results of the groundwater model indicate groundwater flows from the GWPS and discharges into Lake Union (Aspect et al. 2012). Institutional controls, including prohibition of extraction of shallow groundwater beneath the site for purposes other than remediation, prevent the use of chemically-impacted groundwater at any point between the source of hazardous substances and the point(s) of entry of the groundwater into the surface water. Chemicals of concern for groundwater and their cleanup levels are presented on Table 5 (State of Washington 1999).

5.0 EXISTING ANALYTICAL DATA SUMMARY

The following data summary includes soil and groundwater analytical data obtained from the GWPS. Chemicals of concern for soil and groundwater at the GWPS include mono-aromatic hydrocarbon compounds benzene, ethyl benzene, toluene, and total xylenes (BTEXs) and polycyclic aromatic hydrocarbons (PAHs). Analytical data for benzene, naphthalene, and benzo(a)pyrene is presented in this section. Benzene is considered relevant to the investigation because of the presence of benzene in the southeast area of the site and because it is a constituent in coal tar. Naphthalene represents the most commonly detected non-carcinogenic PAH in soil and groundwater on the GWPS (Hart Crowser 2012). Benzo(a)pyrene is the carcinogenic PAH that presents the greatest carcinogenic risk. Arsenic is a chemical of concern in soil.

5.1. Shallow (Surface) Soil

Shallow soil samples, from the ground surface to 3 feet below ground surface, have been collected throughout the GWPS. Shallow soil (0 to 3 feet below ground surface) sample locations and analytical results are presented on Figures 8A through 8D.

The majority of the Park, with the exception of Kite Hill, the Cracking Tower area, and portions of the eastern shoreline, has been covered with engineered, vegetated, soil covers. The cracking tower area is fenced, and access to this area by the public is restricted. Areas of previous cleanup actions, including installation of soil covers, are shown on Figure 7. In areas that have been capped or where soil has been removed, shallow soil samples are no longer considered representative of surface soil.

Benzene and naphthalene were not detected at concentrations greater than their cleanup levels in shallow samples from un-remediated areas of the site. Benzo(a)pyrene was detected in shallow soil samples collected from the uncapped Kite Hill and Cracking Tower areas at concentrations greater than the 0.137 mg/kg cleanup level. Benzo(a)pyrene concentrations ranged from not detected to 289 mg/kg (MW-23 at 3 feet below ground surface) in these uncapped areas. The highest concentrations of benzo(a)pyrene in shallow soil samples that have not been capped or removed were collected from the soil borings for monitoring wells MW-22 and MW-23, located north of the Prow. Arsenic concentrations that exceeded the cleanup level of 20 mg/kg in areas that were not capped include shallow soil samples from two locations near the playbarn and eastern shoreline, which contained concentrations of arsenic ranging from 23.3 mg/kg to 30.4 mg/kg.

5.2. Subsurface Soil

Concentrations of benzene, naphthalene, benzo(a)pyrene, and arsenic in subsurface soil samples (deeper than three feet below ground surface) are presented on Figures 9A through 9D. Benzene was detected at concentrations greater than the reporting limit in subsurface soil samples primarily from the southeast area in the former location of the light oil plant. These data are likely no longer representative of subsurface conditions because recoverable NAPL was removed and an air sparging/soil vapor extraction system was operated in this area from 2001 to 2006 (Hart Crowser 2012). One soil sample from 8 to 9.5 feet below ground surface in soil boring SB-2 in the northeast corner contained 1.7 mg/kg benzene. Naphthalene was detected at concentrations exceeding the 3,200 mg/kg cleanup level in two subsurface soil samples: One sample was collected in the northeast corner from 9 feet below ground surface in boring MW-26 and the second sample was collected in the Harbor Patrol area from 16.5 feet below ground surface in boring B-2-EPRI98. The highest concentrations of benzo(a)pyrene also were detected in soil samples from the northeast corner, Harbor Patrol, and the southeast area. Concentrations of benzo(a)pyrene in subsurface soil samples, exceeded the cleanup level in multiple locations, and ranged from not detected to 510 mg/kg (SB-13 2.5 to 4 feet below ground surface). Arsenic concentrations in subsurface soil samples did not exceed the cleanup level of 20 mg/kg, except in the sample from 4 feet below ground surface in boring GWP-PA-04, in which 70.8 mg/kg arsenic was detected.

5.3. Groundwater

Benzene was detected at concentrations greater than the cleanup level of 43 µg/L in groundwater samples collected from monitoring wells located in the Harbor Patrol area, central meadow, near the Cracking Towers/Kite Hill, and in the southeast area. Recoverable LNAPL was removed and an air sparging/soil vapor extraction system was installed in the southeast area in 1999 and 2000 and operated until 2006 (Hart Crowser 2012). As a result, groundwater analytical data collected before 2006 from monitoring wells installed in the air sparging/soil vapor extraction area are likely no longer representative of the subsurface conditions in that area. Concentrations of benzene in groundwater samples collected in February 2011 from OBS-1, OBS-2, and OBS-3, are less than a hundredth of the concentrations of benzene collected from those monitoring wells in July 2000, before remedial actions were fully implemented.

Naphthalene was detected at concentrations greater than the cleanup level of 9,880 µg/L in groundwater samples collected from the Harbor Patrol/ATCO area. Benzo(a)pyrene also was detected at the highest concentrations in groundwater samples collected from the Harbor Patrol/ATCO area.

Arsenic is not a groundwater chemical of concern because arsenic was detected in upgradient monitoring well MW-3D at a concentration of 4.9 µg/L indicating the presence of arsenic as a natural constituent of groundwater in this area (Parametrix 1998).

5.4. Dense and Light Non-Aqueous Phase Liquids (DNAPL and LNAPL)

Numerous subsurface explorations have been performed to evaluate the presence of visible DNAPL and LNAPL on the GWPS and GWPSS. The conceptual lateral extent and locations of known NAPL occurrence are presented on Figures 10 and 11. Areas where substantial DNAPL has been encountered include Harbor Patrol/ATCO, the northeast corner, and the playbarn area. Recoverable LNAPL was removed and an air sparging/soil vapor extraction system was installed in the light oil plant area in 1999 and 2000 (Hart Crowser 2012) As a result of the LNAPL removal and system operation, LNAPL measurements made in this area before 2006 are likely not representative of current conditions. Visual observations of LNAPL were made during investigations performed east of the playbarn in 2007. This area is outside the extent of the air sparging/soil vapor extraction system.

6.0 CONCEPTUAL SITE MODEL

A conceptual site model (CSM) identifies potential or suspected primary sources of hazardous substances, concentrations of hazardous substances in impacted media (secondary sources), transport mechanisms, actual and potential exposure pathways, and receptors. The CSM discussion in the following sections focuses on physical conditions that may influence the occurrence, fate, and transport of chemicals of concern, primary and secondary sources, and transport mechanisms to frame-up additional data needs. This CSM was prepared using the results of numerous environmental investigations of the uplands that have been performed since the 1970s. The CSM has been developed based on this existing information, is considered dynamic, and will be refined as needed, based on the results of the supplemental investigation.

6.1. Geology and Hydrogeology

The understanding of the geology and hydrogeology of the GWPSS was revised beginning in 2010. Revised geologic CSM and hydrogeologic CSM memos (GWSA 2011a; GWSA 2011c) were prepared that present the current understanding of geologic and hydrogeologic conditions. These reports were used to develop the geology and hydrogeology presented in Section 2.3. In general, the GWPS is underlain by fill material that overlies pre-Fraser age glacial till. Recessional and advance glacial outwash deposits are present above the glacial till on the eastern and western flanks of the GWPS, where the surface of the glacial till is at a lower elevation.

Fill was historically placed along the Lake Union shoreline from the early 1900s to the 1920s to increase the size of the peninsula. The fill generally is thin to absent through the north-central portion of the GWPS, where the glacial till is present at a higher elevation. Fill material is thicker in the western portion of the GWPS, especially at Kite Hill, where fill material is greater than 30 feet thick near the shoreline. The nature of the fill is highly variable, and generally includes substantial anthropogenic material from former MGP and tar refining operations, native soil consisting of silts and sands, and fill materials imported during Park development. Kite Hill, the most prominent topographic feature on the site, is man-made and constructed of imported fill material and excavated or regraded fill soils Construction debris and other manmade debris have been observed in the fill unit throughout the GWPS.

Recessional and advance glacial outwash deposits are present at the eastern and western shorelines on the site. These units are referred to in the geologic CSM as being draped over the glacial till unit in these locations. These units are thicker beneath Lake Union.

Pre-Fraser glacial till comprises the majority of the material underlying the GWPS. The glacial till is present at the ground surface in the north-central portion of the GWPS. The surface of the till slopes toward Lake Union to the west, south, and east.

Groundwater at the GWPS is generally present in unconfined conditions. Groundwater elevations at the GWPS shoreline are primarily influenced by the elevation of Lake Union. The United States Army Corps of Engineers (USACE) maintains the water levels in Lake Washington and Lake Union by regulating flow through the Locks at the western end of Salmon Bay. Lake Union water levels vary roughly 2 feet on a yearly basis, from 20 feet (USACE datum) during the winter months to 22 feet during the summer months.

Groundwater conditions farther upland appear to be more influenced by seasonal and regional changes in groundwater elevation. Regional recharge to the pre-Fraser till is greater in the winter months when the weather is wetter and lesser in the summer months when the weather is drier. The majority of groundwater that discharges from the GWPS to Lake Union is generated from precipitation and irrigation at the Park.

6.2. Contaminant Sources and Media

The potential primary sources of hazardous substances consist of raw materials, products, or byproducts produced by gas manufacturing and tar refining such as coal tar and light aromatic oils. Primary sources on the GWPS are mostly associated with MGP and tar refining facilities. Other primary sources of chemical impacts may exist on the GWPS, based on past site activities. Primary sources are often used to identify areas of potential contribution to secondary sources. However, primary sources at the GWPS may not reflect the current location of COCs for the following reasons:

- Primary sources have been removed from the GWPS during facility demolition and remedial actions.
- MGP and tar refining operations on the GWPS operated more than 50 years ago. COCs have likely migrated by natural transport mechanisms.
- Impacted soil and anthropogenic materials from gas manufacturing and tar refining were excavated and transported off site during plant demolition and park development.
- Fill was imported during park development.
- Substantial relocation of soils impacted by gas manufacturing and tar refining byproducts occurred during development of Gas Works Park, as a result of extensive cutting and filling of soil that occurred during Park development (see Section 2.2.3).

Chemicals of concern resulting from these MGP and tar refining raw materials, products, and byproducts include polycyclic aromatic hydrocarbons (PAHs) and benzene, ethyl benzene, toluene, and total xylenes (BTEXs). Light aromatic compounds (BTEXs) are mostly associated with the light oil plant that operated in the southeast portion of the GWPS; however, BTEXs are also a component of coal tar. PAHs are considered the primary chemicals of concern and have been detected throughout the GWPSS.

Non-aqueous phase liquid (NAPL) is present beneath portions of the GWPS and GWPSS. Dense NAPL (DNAPL) occurs in the fill material, recessional outwash, and advance outwash on the GWPS. Unrefined MGP, refinery, and other historically sourced raw materials, products, and byproducts, including tar, exist as part of the fill unit. Based on previous explorations, DNAPL impacts on the GWPS occur in the western portion of the GWPS near Harbor Patrol, and are associated with the former ATCO plant. Additional DNAPL impacts have been identified on the eastern shoreline of the GWPS near the former MGP operations. LNAPL impacts, located on the eastern portion of the site, are mostly associated with the light oil plant that operated on the southeastern portion of the GWPS. Secondary sources include impacted media (i.e., soil, groundwater, sediment, and NAPL). In addition, there is a localized area of exposed soil and weathered tar in the northeast corner, at the "tar mound" shown on Figure 10. Investigations have been focused on evaluating the presence of NAPL in these areas of the GWPS.

6.3. Transport Pathways

Primary sources have resulted in releases to surface and subsurface soil, groundwater, and Lake Union sediment. These impacted media function as secondary sources of site contaminants that may be transported from the upland to aquatic environments as a result of groundwater transport or upland soil erosion. The transport pathways that will be reconsidered as the CSM is refined after completing the supplemental investigation described in this work plan include the following:

- Wind erosion and dispersion of impacted soil to outdoor air;
- Volatilization of chemicals of concern from impacted media indoor and outdoor air;

- Erosion of impacted soil and subsequent storm water or surface water transport to sediment and surface water;
- Leaching of chemicals of concern from impacted soil and dissolved groundwater transport to surface water and sediment; and
- Mobile NAPL transport to surface water and sediment.

A comparison of observed chemical concentrations in surface soil indicates chemicals of concern are present at concentrations exceeding cleanup levels. However, buildings, paved areas, and clean vegetated soil caps installed on most of the GWPS prevent Park visitors from directly contacting these impacted soils. Exposure to impacted soils in the Cracking Tower area is prevented by the presence of vegetation and a tall, locked, chain-link fence that surrounds it. An interim action, consisting of installation of an engineered soil cap is planned for the Kite Hill area of the Park that is not covered by an engineered cap.

In addition to the Cracking Tower and Kite Hill areas, there is a localized area of exposed soil and weathered tar in the northeast corner, at the “tar mound.” This area is surrounded by a chain-link fence with signage. Erosion and transport of impacted soil/weathered tar (secondary source) is a transport mechanism that will be considered in this area of the Park.

Erosion and dispersion of impacted soil at the Gas Work Park site is likely to be minimal given the presence of an extensive and well-maintained vegetative cap and an automated irrigation system. Although the Cracking Tower area is not watered, this area is covered by vegetation, pavement, or other hard surfaces. Volatilization appears to be incomplete or minor pathway based on a study conducted by the City to evaluate impacts to indoor air and ambient air quality (Hart Crowser 2012). Erosion of impacted soil and transport by surface water or storm water (through storm drains) are considered viable transport mechanisms. Additional assessment of surface soil runoff and storm drains will be performed to evaluate these potential sources of sediments recontamination.

Potential receptors and exposure pathways for groundwater are limited at the GWPS. Shallow groundwater beneath the GWPS does not currently serve as a drinking water source. Based on the results of pumping tests conducted at the Site, the shallow groundwater zone beneath the GWPS is not capable of producing water of sufficient quantity to support use as a future water supply. Specifically, groundwater is not present in sufficient quantity to yield greater than 0.5 gallon per minute on a sustainable basis (per WAC 173-340-720[2]). Therefore, drinking water ingestion is not considered a complete exposure pathway at the GWPS (Hart Crowser 2012, Parametrix 1999). Seeps, where direct contact could occur, are limited to the shore face directly east of the prow after Lake Union water levels have been lowered in late fall/early winter. This seep has been analyzed for PAHs and did not contain PAHs at concentrations greater than the detection limits (ThermoRetec 2001).

The primary transport mechanisms of concern and the focus of investigation activities are leaching of chemicals of concern from impacted soil, dissolved groundwater transport, and mobile NAPL transport. The transport pathways of potential concern for dissolved groundwater and mobile NAPL is discharge to Lake Union sediment and surface water. The supplemental investigation described in Section 7.0 will include activities specifically intended to provide information related to these pathways.

7.0 SUPPLEMENTAL WORK PLAN ELEMENTS

This section describes the supplemental field investigations that will be performed to provide qualitative and quantitative information on the upland to support a site-wide remedial investigation and feasibility study. Data collected during the supplemental investigation will be used to further characterize transport pathways identified in the CSM (Section 6.0) and will be presented in a site-wide RI. The supplemental data also will be used to support the development and evaluation of remedial alternatives in a site-wide feasibility study.

Detailed information regarding exploration and sampling locations and depths, field procedures, and analytical methods for the supplemental investigation are presented in the Sampling and Analysis Plan (SAP, Appendix A). Quality control procedures and data quality objectives are presented in the Quality Assurance Project Plan (QAPP, Appendix B), and health and safety procedures are presented in the Health and Safety Plan (HASP, Appendix C).

In general, laboratory analytical methods used during the supplemental investigation will have reporting limits that do not exceed the soil and groundwater cleanup levels (Tables 4 and 5). The analytical laboratories will achieve the lowest sample-specific reporting limits consistent with the analytical method and analytical constraints such as matrix interference or elevated analyte concentrations requiring sample dilutions. Target reporting limits for the proposed analytical methods are presented in the QAPP (Appendix B).

7.1. General Approach

The proposed field investigation scope presented in this Work Plan was prepared using information obtained from a detailed historical review of the MGP and tar refinery, review of previous investigations and studies, and a review of existing soil and groundwater data. The results of the historical and analytical data reviews are summarized in Sections 2 and 5 of this Work Plan. Previous investigations and studies are summarized in Section 3. The field investigation will include the following general work elements:

- **MONITORING WELL SURVEY.** Existing monitoring wells will be located and inspected to determine their usability for ground water monitoring. Monitoring wells may be repaired or redeveloped as necessary before including them in the current monitoring well network. In cases where a monitoring well is considered not repairable, it will be abandoned.
- **GEOPHYSICAL SURVEYS.** Non-intrusive magnetic/gradiometer and electromagnetic conductivity surveys will be performed to provide information regarding the presence and location of potential buried MGP structures that may be primary sources. This information will be used to focus soil explorations in areas of potential concern.
- **"TARGOST®" LASER INDUCED FLUORESCENCE EXPLORATION.** TarGOST® will be used in selected areas of the site to provide a rapid, qualitative method of identifying the presence of or delineating the extent of tar or NAPL. TarGOST® may be used to assess potential primary sources of tar and NAPL identified during the geophysical surveys.

- **SOIL BORINGS**. Soil borings will be drilled in selected locations based on the results of the geophysical surveys and TarGOST® screening. Soil samples will be selected for chemical analysis of BTEXs, PAHs, and arsenic. Soil samples will also be collected for chemical analysis from monitoring well borings. Soil borings may also be drilled for collection of samples for UV photography and petrophysical testing.
- **MONITORING WELL INSTALLATION**. Additional monitoring wells will be installed near the shoreline to provide data for input into a groundwater model and to evaluate the concentrations of chemicals of concern in groundwater.
- **INITIAL GROUNDWATER MONITORING**. Usable current and proposed monitoring wells will be sampled to assess concentrations of chemicals of concern in groundwater and to select wells for future groundwater monitoring.
- **GROUNDWATER MONITORING.** One round of groundwater monitoring from proposed and selected existing monitoring wells will be performed to provide data for input into a groundwater model and to provide an overall understanding of groundwater conditions at the GWPS shoreline.
- **NAPL TESTING**. NAPL baildown tests may be performed to evaluate the potential mobility of NAPL.
- **GEOTECHNICAL EXPLORATION OF KITE HILL**. The geotechnical stability of Kite Hill will be evaluated in anticipation of placing an engineered, vegetated soil cap in that area. Details regarding the geotechnical explorations are presented in Appendix D.
- **AQUIFER TESTING**. Selected proposed monitoring wells will be slug tested. Hydraulic conductivity of the water bearing unit at each tested location will be estimated.

The monitoring well survey and the results of the geophysical surveys will be used to evaluate and modify, as necessary, the locations of proposed TarGOST® Laser Induced Fluorescence exploration. As a result, TarGOST® locations will be explored after the results of the well survey and geophysical surveys have been evaluated. TarGOST® exploration results will be used to refine the locations of monitoring wells and soil borings to focus these explorations to achieve the project objectives

7.2. Monitoring Well Survey

A monitoring well survey will be performed to identify current, usable, monitoring wells on the GWPS, and to evaluate their condition before being sampled. Up to 47 monitoring wells may be present on site. Current monitoring wells including location, construction, and groundwater information at each monitoring well are listed in Table 2 and shown on Figure 2. Methodology for performing the proposed activities is presented in the SAP (Appendix A). The monitoring well survey will include the following activities:

- Performing field reconnaissance to locate existing monitoring wells. Unless already marked, each monitoring well located will be marked with the monitoring well number, photographed relative to surroundings, and the location recorded on a GPS unit.
- Inspecting the condition of each monitoring well by visually observing the monitoring well completion and the condition of the monitoring well riser at the ground surface.

- Testing for the presence of both LNAPL and DNAPL using an oil/water interface probe or similar device in each monitoring well.
- Measuring the depth to ground water and total depth in each monitoring well.
- Collecting samples of LNAPL and DNAPL from monitoring wells, if present, as discussed in Section 7.13.

Monitoring wells requiring repair will be noted, and the necessary repairs will be performed by field crews or a licensed well driller, depending on the nature of the repair. Repairs to monitoring wells will be performed before groundwater monitoring begins. Monitoring wells considered not repairable will be abandoned according to State regulations. If a monitoring well is abandoned, the location will be evaluated relative to the overall monitoring program.

Seven multi-level samplers (MLSs) are also present on the GWPS, near Harbor Patrol/ATCO (Figure 2, Table 2). These MLSs provide discrete groundwater monitoring points at multiple depths in one location. MLS samplers will be located, visually inspected, and evaluated for sampling during the monitoring well survey. Water levels will not be obtained from the MLSs.

7.3. Geophysical Surveys

Selected areas of the former MGP will be explored using non-intrusive, surface magnetic and electromagnetic (EM) geophysical methods to provide information regarding potential subsurface structures associated with the former MGP (Figure 12). The primary objective of the geophysical surveys is to evaluate broad areas of former MGP operations for potential buried structures. Information obtained from the geophysical surveys will be used to target soil borings in those areas where potential buried MGP structures may exist. The geophysical surveys may also provide information regarding areas, such as active storm drains or utilities, to avoid with intrusive explorations.

Magnetic and EM conductivity surveys can provide information regarding the location of potential buried structures. Magnetic surveys are performed using a magnetometer, which measures disturbances in the earth's natural magnetic field caused by magnetic materials. Most soils have negligible magnetization, so most magnetic disturbances from shallow sources can be attributed to iron or steel objects

EM conductivity surveys induce a time-varying electric current in subsurface soils. Man-made metallic objects are substantially more conductive than natural soils. Therefore, the electric currents induced in the ground by EM instruments will be affected by the presence of man-made metallic objects or other objects with significant contrasts in conductivity. By looking for anomalous signals that cannot be attributed to natural soils, buried objects can be identified (Zonge 2010).

The presence of significant surface structures such as large metallic tanks, piping, machinery, and reinforced concrete can interfere with the proposed geophysical survey methods and present challenges to data interpretation. Consequently, it is possible that limited or no useful information will be obtained near areas where such surface structures exist, including the cracking towers and the prow. The play barn area will be excluded from the geophysical surveys due to the substantial number, size, and mass of surface structures in this area that would interfere with the surveys.

7.4. TarGOST® Laser Induced Fluorescence Probing

The Tar-specific Green Optical Screening Tool (TarGOST®) is a laser-induced fluorescence (LIF) screening tool that is designed to detect non-aqueous phase liquids (NAPL) in the subsurface. TarGOST® uses a green laser to excite higher molecular weight PAHs that are typically present in NAPL at MGP sites. It responds to NAPL by sensing the fluorescence of the high molecular weight PAHs within the NAPL. It has a very limited response, if any, to lower molecular weight PAHs with less than four carbon rings or volatile organic compounds (Dakota 2010). Areas on the GWPS where DNAPL and tar have been encountered will be targeted with TarGOST®.

The primary objective of TarGOST® exploration is to evaluate selected areas of former MGP operations where DNAPL and tar have been encountered to further delineate the upland extent of DNAPL and tar. TarGOST® will also be used in other areas where data on the potential presence of DNAPL and tar is needed and as potential primary source evaluation for site reconnaissance, where it may further project objectives. The TarGOST® system uses a probe that is advanced into the subsurface using direct push technology (DPT). The probe sends a laser light through a fiber optic cable strung within the DPT rods. As the probe is advanced, the soil is exposed to pulses of laser light. If NAPL containing PAHs is present, the PAHs in NAPL absorb some of the light and fluorescence. Some of this fluorescence, along with a portion of the reflected laser light, are collected and returned to the TarGOST® instrument for detection. The result of the laser induced fluorescence testing is a graphical representation of depth versus the fluorescence response of PAHs in the soil encountered in the direct push probing (GeoProbe). These results can be used to identify subsurface zones that contain NAPL and tar versus zones that do not contain NAPL or tar, and may provide a qualitative indication of the magnitude of NAPL present.

Proposed areas of TarGOST® exploration and TarGOST® probing locations are presented on Figure 13. Rationale for selecting these locations for TarGOST® probing is provided in Table 6. In general, the field team will begin with TarGOST® probing locations that are most likely to encounter DNAPL or tar. Based on the real-time results of the TarGOST® probe, additional probing locations will be conducted to define the lateral extent of NAPL contamination in each area. Seven specific areas of the site with known or suspected DNAPL or tar will be explored with TarGOST®. TarGOST® exploration is anticipated to be performed over 5 days. The goal is to advance approximately (40) TarGOST® probings.

The proposed TarGOST® probing locations shown in the northeast corner were selected based on visual observations of DNAPL and PAHs detected in soil samples from these areas. Proposed TarGOST® locations in the Harbor Patrol area were selected to delineate areas where DNAPL has accumulated in monitoring wells. TarGOST® exploration is proposed in these locations to delineate DNAPL and tar, and to provide additional information to locate soil borings and soil samples for chemical analysis.

The proposed TarGOST® exploration area west of the play barn, near monitoring well MW-09 was selected based on visual observations of DNAPL and PAHs detected in soil samples from MW-09. The proposed TarGOST® exploration in this location is proposed to provide additional information on the extent of subsurface NAPL around monitoring well MW-09 without drilling through impervious surfaces. The results from this TarGOST® investigation will be used to locate one or more additional soil borings and soil samples for chemical analysis in these areas.

The TarGOST® exploration areas in the southeast and Cracking Tower areas were selected because limited explorations have been performed in these areas. The TarGOST® investigation in this area will be used to locate proposed soil borings and soil samples for chemical analysis.

7.5. Soil Borings and Sampling

TarGOST® probing results will be used to target the locations of soil borings and soil samples for chemical analyses in those areas where potential DNAPL or tar are more likely to exist. Direct push probe soil cores will be logged and samples will be collected to provide field confirmation of TarGOST® results (i.e., the presence of NAPL) and soil lithology. Soil cores may be submitted for chemical analysis, UV light photography and petrophysical testing as described below. The review of visual NAPL observations, distribution of subsurface exploration points, and previous soil analytical data indicate that there are some areas of the GWPS where additional data are needed to evaluate potential soil impacts. The objective of the soil sampling program will be to evaluate chemicals of concern in soil for the soil leaching to groundwater transport pathway and to characterize the occurrence and potential mobility of NAPL.

7.5.1. Soil Borings

Five (5) supplemental soil borings (GEI-1 through GEI-5; Figure 13) will be completed to characterize chemicals of concern in selected areas. In addition to these supplemental borings, additional soil borings will be drilled in areas where TarGOST® exploration indicates NAPL impacts to soil. Soil borings will be drilled to perform field screening and geologic logging, and to obtain soil samples for chemical analysis in areas where NAPL or tar were identified using TarGOST®. These soil borings will be compared to TarGOST® results from these locations to evaluate fluorescence response relative to observed conditions in the boring. Soil samples will also be collected from proposed monitoring well borings. Soil samples for chemical analysis will be focused on subsurface soil because most areas of the GWPS have been covered by a vegetated soil cap. Soil sample collection rationale, methodology, and chemical analyses are summarized on Table 6.

7.5.2. Visible Light and Ultraviolet Light Imaging

Continuous soil cores for digital imaging will be collected at borings located in areas of known NAPL impacts to evaluate the nature of NAPL occurrence such as residual NAPL in finer grained matrices, pore space NAPL saturation, and the potential for NAPL mobility. Cores will be collected in up to five locations, based on the results of TarGOST® exploration, for visible light photography and ultraviolet photography (UV). The cores will be collected within NAPL areas, as determined during the examination and geologic description of soil cores collected from adjacent borings. The visible light photography will provide a permanent record of the relative variation of impacts in different lithologies within the core interval. The UV light photography will provide the NAPL fluorescence of the core interval to identify the most heavily impacted portion of each core and visible variation in impact between lithologies in the core.

7.5.3. Petrophysical Testing

Petrophysical testing refers to the analysis of physical properties that define the behavior of NAPL. Soil samples for petrophysical testing will be selected after reviewing the digital images obtained from the UV light and visible light photography. Soil samples that are representative of the most visibly impacted depth interval will be tested. The petrophysical testing includes measuring the specific gravity and viscosity of NAPL and Free Product Mobility testing of soils. Free Product Mobility testing involves centrifuging samples and quantifying the volumetric percent saturation of air/oil/water in the samples at various pressures that represent gravity drainage to approximately 1,000 times the force of gravity.

The test results will be used to evaluate whether NAPL present in the samples is mobile and, if so, what the residual saturation is after the mobile NAPL is removed from the sample. The residual saturation values representative of gravity drainage will be used to evaluate the vertical and lateral extent of soil that could still generate mobile NAPL.

7.6. Geotechnical Evaluation

A geotechnical soil sampling program has been prepared to evaluate the stability of Kite Hill. Three additional borings GEO-1 through GEO-3 will be drilled as part of the geotechnical evaluation. Soil boring GEO-1 will also be used for installation of monitoring well MW-32D. The work plan for geotechnical soil exploration is presented in Appendix D.

7.7. Monitoring Well Installation

Twelve monitoring wells will be installed near the shoreline of the GWPS to obtain additional information regarding groundwater conditions (Figure 14). Planned monitoring well depths, target stratigraphic units, screen lengths, and rationale are summarized in Table 7. Information from these monitoring wells will be used for the following purposes to evaluate the groundwater to sediment pathway and potential NAPL mobility:

- Groundwater depths will be measured to obtain groundwater elevations and gradients.
- Groundwater analytical data from these monitoring wells will be used to further evaluate the vertical and lateral extent of chemicals of concern at the shoreline and to estimate flux at the Lake Union shoreline.
- Monitoring wells will be used to evaluate the potential presence of DNAPL and LNAPL by measuring with an interface probe.
- If NAPL is encountered and sufficient volume is available, NAPL may be removed for chemical and physical testing (Section 7.13).
- Selected monitoring wells will be used for slug testing.

Borings for groundwater monitoring wells will be installed using hollow stem auger or sonic drilling techniques as specified in the SAP. Monitoring wells will be installed and completed as specified in the SAP (Appendix A). The new groundwater monitoring wells will be installed by a Washington-licensed driller in accordance with the requirements of the Washington State well construction standards (Minimum Standards for Construction and Maintenance of Wells; WAC 173-160). These standards require that Ecology be notified of the intent to begin monitoring well construction (i.e., Start Card submittal) at least 72 hours before starting work (WAC 173-160-151). Following installation, monitoring wells will be developed as specified in the SAP.

7.8. Initial Groundwater Monitoring

Groundwater will be sampled from usable existing monitoring wells and new monitoring wells not containing NAPL to evaluate chemicals of concern. Usable existing monitoring wells will be identified during the monitoring well survey. Construction details for current monitoring wells are summarized in Table 2. We anticipate as many as 47 current monitoring wells, including MLSs, may be included in initial groundwater monitoring. It is anticipated that the initial groundwater monitoring event, planned for April will represent conditions under higher groundwater gradients as groundwater levels should be relatively high away from the shoreline and Lake Union water levels will have been drawn down. Before the monitoring wells are sampled, groundwater levels will be measured and the wells will be tested for the presence of LNAPL and DNAPL using an oil/water interface probe or similar device. If measurable LNAPL or DNAPL is encountered in a monitoring well, a groundwater sample will not be collected from that location. If greater than 1 foot of LNAPL or DNAPL is encountered in a monitoring well, a sample of the NAPL will be collected and submitted for testing, as discussed in Section 7.11. Groundwater samples will be collected from the monitoring wells using low-flow purging and sampling techniques, as described in the SAP (Appendix A). The groundwater samples collected during the initial event will be analyzed for the following constituents:

- Field parameters (e.g. salinity and/or conductivity/specific conductance, pH, temperature, dissolved oxygen, redox potential, and turbidity);
- Benzene, ethylbenzene, toluene, and total xylenes (BTEXs) (SW-846 Method 8260), and
- Polycyclic aromatic hydrocarbons (PAHs) (SW-846 Method 8270).

The results of initial groundwater monitoring will be used to define the groundwater monitoring network for groundwater monitoring. Seasonal trends and Lake Union elevation will be considered in developing the monitoring program.

7.9. Groundwater Monitoring

A second round of groundwater monitoring will be performed to enhance the overall understanding of groundwater conditions at the shoreline. This second round of sampling will be conducted in late summer to early fall when groundwater gradients should be lower due to lower water levels away from the shoreline (end of dry season—reduced recharge) and the rising Lake Union water levels. Groundwater samples will be submitted for analysis of BTEXs and PAHs. The twelve newly-installed wells will be sampled along with select existing monitoring wells. Existing monitoring wells will be selected for subsequent groundwater monitoring based on the results of initial groundwater monitoring and the following criteria:

- Groundwater analytical data from that location are necessary to provide an adequate understanding of the lateral and vertical distribution of dissolved-phase chemicals of concern at the shoreline.

- Groundwater analytical data from that location are necessary to provide an understanding of potential source locations upland from the shoreline and to establish dilution attenuation factors for that area of the GWPS.
- Monitoring wells do not contain measurable thicknesses of LNAPL or DNAPL.

7.10. Aquifer Testing

Hydraulic characteristics of the water bearing units will be estimated by performing slug tests on up to ten (10) newly installed monitoring wells. Slug tests provide data to estimate the hydraulic conductivity of the screened interval. Slug tests will be performed in selected newly installed monitoring wells based on well screen length, lithology of the screened interval, and well construction details. The monitoring wells proposed for slug testing are presented in Table 7.

7.11. LNAPL and DNAPL Testing

Information to evaluate NAPL mobility will be obtained by collecting samples of NAPL for chemical and physical property testing and performing NAPL bail down tests, if possible, on existing and new monitoring wells where NAPL has accumulated. A description of these tests is presented in the following subsections. In addition, information to evaluate NAPL mobility will be obtained by performing petrophysical testing on soil cores from selected new borings, and submitting selected soil samples for expanded PAH analysis.

7.11.1. Chemical and Physical NAPL Testing

If measureable DNAPL and LNAPL are recoverable from monitoring wells, two 1-liter samples of groundwater, DNAPL, and LNAPL will be obtained and submitted to PTS laboratories. Testing will be performed for density, specific gravity, and kinematic viscosity based on ASTM D1217, D1481, and D445 methods. Chemical analyses may also be performed on NAPL samples and may include extended PAH analysis (SW-846 Method 8270) and BTEXs (SW-846 Method 8260).

7.11.2. NAPL Bail-Down Tests

NAPL bail-down tests may be used to estimate the transmissivity of DNAPL and LNAPL. These transmissivity estimates will be used to evaluate NAPL mobility and recoverability. The tests require at least one foot of measurable NAPL to be present in the well. Existing monitoring wells where NAPL bail-down testing may be possible will be evaluated during the monitoring well survey. Previous NAPL measurements in existing wells indicate monitoring wells DW-5 and MW-09 may contain a sufficient thickness of NAPL for bail-down testing. Proposed groundwater monitoring wells may also be tested if at least one foot of NAPL accumulates following monitoring well development.

7.12. Permits

A "Revocable Permit to Use or Occupy Park Property" (RUP) is required by Seattle Department of Parks and Recreation before performing intrusive investigations including TarGOST® probing, soil borings, and monitoring well installation at the Park. A RUP is not required for non-intrusive planned activities including geophysical surveys, monitoring well survey, groundwater monitoring, and aquifer or NAPL testing. However, non-intrusive field activities will be coordinated with the Parks Department.

7.13. Historical Resources

Gas Works Park including existing historical above grade MGP structures was added to the National Register of Historic Places in January 2013 (TCLF 2013). Field investigation activities will be coordinated with the Parks Department to ensure field activities are performed consistent with requirements associated with National Register listing. Care will be taken to preserve the condition of the historical structures when working near them. If damage occurs to the structures during supplemental investigation activities, the Parks Department will be notified.

8.0 REPORTING

Following review and validation of the data generated during the supplemental upland field investigation, a site-wide Remedial Investigation Report will be prepared and transmitted to Ecology. The Expanded RI is anticipated to be a compilation of site-wide data including the results of upland and sediment studies.

Supplemental upland sampling data will be submitted to Ecology and EPA. Electronic data will be submitted via Ecology's Environmental Information Management (EIM) system as provided in WAC 173-340-840(5). Submittal of reports and data will confirm to EPA's electronic document submittal requirements to the extent practicable.

9.0 SCHEDULE

The proposed schedule for the supplemental upland field investigation is presented on Figure 15. The anticipated target completion dates represent an expedited schedule, so that field activities can be completed during the Park's off-season (between approximately November and April). Adherence to this schedule will require accelerated agency review.

The timing of field activities will be coordinated with the Seattle Department of Parks and Recreation. In general, field investigation activities will be limited to when Park use is low, generally November through April. This schedule will be revised as necessary based on work plan review schedule, field conditions, Park schedule, and discussions with Ecology and other stakeholders.

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TABLES

Table 1a

Previous Remedial Actions

Gas Works Park Site

Seattle, Washington

Year	Remedial Action Description	Who Remediated	Location	Reference
1971 / 1972	SOIL COVER. In 1971 or 1972, the City learned about a large oil spill that occurred over approximately one-third of the Site in January 1969 (City of Seattle 1971; EPA 1995). Washington Natural Gas covered it with a thin layer of fill. Test holes 7, 8 and 10 were located within the spill and cover area.	WNG	South Central Area	City of Seattle 1971; EPA 1995
1973	EXCAVATION. Targeted areas were identified for removal to depths ranging from 1.5- to 8-feet below grade or to water level during plant demolition and initial regrading for park development.	City	South Central; Central; Southeast; Northwest; Northeast Area	Haag 1973
1976	"CLEAN" SOIL COVER. Park regraded with net removal near shoreline and net fill away from shoreline. A cover layer of biosolids mixed with sawdust and other organic materials was placed over the Site. This material was mixed with imported fill and/or excavated soil and graded and/or tilled into the upper surface soil layer (HDR 1988b; Sabol 1988). Kite Hill was created by mounding 20,000 cubic yards of excavation materials and covering the mound with thousands of yards of imported fill (Parametrix and Key 1998). Excavated material and debris was covered with as much as 6 feet of clean soil during the construction of Kite Hill (HDR 1988h).	City	Site-Wide	HDR 1988b; Sabol 1988; Ongerth 1985; Parametrix and Key 1998; HDR 1988h; WNG 1981
1984	CLEAN SOIL COVER. Approximately 1-foot-thick clean soil cover was placed over the most impacted areas of the park.	City	Site-Wide	HDR 1988b; Sabol 1998
1985	ASPHALT CAPPING OF TAR. In 1985, tar was observed seeping up through the asphalt sidewalk in the northwest section of the park, south of the railroad right-of-way. This area is in the general vicinity of the old tar refinery originally located on the Site. The City attempted to pave (seal) some of the larger seeps (5 or 6 inches in diameter). However, the seeps continued to penetrate the asphalt, particularly during the warmer months.	City	Northwest Area	TetraTech 1985
1997	REMOVAL AND TREATMENT OF RESIDUAL UPWELLING TAR. Characterization of known and suspected tar seeps was conducted in October 1997 using backhoe test pits. With concurrence from Ecology, the City and Puget Sound Energy made the decision during the tar characterization work to define the extent of the shallow tar with the backhoe, remove as much tar as practicable, and backfill the excavations with clean fill. Tar was removed from the Site. Twenty-two drums of semi-solid tar were removed in October 1997; one drum from TP-6 and 21 drums from TP-10, TP-11, and TP-12. Also, approximately 24 cubic yards of tar-contaminated soil were removed from the TP-1 excavation (Parametrix and Key 1998).	City/PSE	North of Kite Hill; Southeast Corner	Parametrix 1999; Parametrix and Key 1998
1997	PRODUCT REMOVAL FROM TANK. As part of an assessment of soil quality within the Cracking Tower area, HWA Geosciences discovered a partially buried tank beneath the two relief-holder scrubbers. Approximately 2,500 gallons of viscous tarry liquid was present in the tank. Most of the product was removed. The remaining non-pumpable product was left in the tank. The tank access covers were replaced and secured (Parametrix and Key 1998).	Seattle Parks Department	Cracking Tower Area	Parametrix and Key 1998
1998	FENCING, BARRIERS, SIGNAGE. Maintenance of fencing around the cracking towers, barriers to public access in the northwest corner, and signs warning park users not to eat dirt, or drink from, wade, or swim in Lake Union. The fence is inspected weekly.	City/PSE	Cracking Towers; Northwest Corner	Parametrix 1999
1998	LNAPL RECOVERY. Prior to installation of the AS/ SVE system, an Interim Remedial Action was conducted in 1998. This action included installation of a network of recovery wells in the southeastern corner of the park. A vacuum truck was used to recover oil and groundwater from the wells (Parametrix 1999).	City/PSE	Southeast Corner	Parametrix 1999
1999	RESTRICTIVE COVENANTS. A restrictive covenant was recorded that restricts actions that disturb contaminated soil or groundwater.	Seattle Parks Department	Site-Wide	Parametrix 1999
1998-2000	CLEAN SOIL COVER. 1500 to 2000 cubic yards of clean fill from another City of Seattle project was moved to NW Corner and later spread to create a level surface. The thickness of this fill layer was estimated to be approximately 1 foot (Parametrix, 2004).	City	Northwest Corner	Parametrix, 2004
1999-Present	TAR REMOVAL/COVERING. Seattle Parks Department does periodic inspections for upwelling tar. Recent communications with Seattle Parks Department personnel indicate that surface seepage of tar is infrequent and generally involves covering “button-sized” or “thread-like” occurrences with clean soil. Residual upwelling tar is removed when discovered.	Seattle Parks Department	Site-Wide	Floyd|Snider 2008a
2000-2001	CLEAN SOIL COVER. A 12- to 18-inch-thick vegetative soil cover was placed on approximately 5.7 acres of the Site in the north-central and southeastern portions of the park. These areas were scarified and rough graded to a depth of 4-6 inches below ground surface. Soil cover consists of grass turf layer, 12 inches of sandy loose soil, and a geogrid identifier layer (ThermoRetec, 2001). The soil cover is inspected weekly.	City/PSE	North Central; Southeast Area	ThermoRETEC 2001
2001-2006	AIR SPARGE/SOIL VAPOR EXTRACTION. Installation of an in situ groundwater air sparging and soil vapor extraction (AS/SVE) treatment system of the southeastern corner of the park. The AS/ SVE treatment system operated in the southeast corner of the park, from 2001 until December 2006 (EcoCompliance 2007).	City/PSE	Southeast Corner	EcoCompliance 2007
2001-2010	MONITORED NATURAL ATTENUATION. Monitored natural attenuation of PAHs in groundwater in the western portion of the park. A detailed study conducted by EPRI of the tar-impacted area near the Seattle Harbor Patrol facility confirmed that tar impacts extended from the former ATCO plant toward Lake Union. Monitored natural attenuation was selected as the remedy for this area (Parametrix 1999). Portions of this remedial action were further described and implemented in the Construction Completion Report (ThermoRETEC 2001).	City/PSE	Harbor Patrol; Southwest Corner	Parametrix 1999; ThermoRETEC 2001
2005	SOIL COVER. In 2005, the Consent Decree and Cleanup Action Plan were amended to allow installation of a vegetated soil cover in the northwestern corner of the Site. This area was recontoured and geotextile fabric and 1 foot of topsoil were added following the installation of an irrigation system.	City	Northwest Corner	NW Corner Improvements; As-built plan set, 2005
2007	TAR REMOVAL/COVERING. Two tar occurrences were removed by the Seattle Parks Department from the seasonally submerged areas along the eastern shoreline in January 2007. An additional occurrence was observed in May 2007 in the northeastern area of the uplands (AECOM 2007a). This tar occurrence was partially removed, covered with geotextile fabric, and covered with clean fill (Floyd Snider 2008a).	Seattle Parks Department	Eastern Shoreline; Northeast Corner	AECOM 2007a; Floyd|Snider 2008a
2008	TAR REMOVAL/COVERING. In August 2008, Seattle Parks Department partially removed tar seeps observed in the eastern shoreline and in the valley west of the cracking towers. A total of four seeps were identified. Excavated areas were backfilled.	Seattle Parks Department	Eastern Shoreline; Cracking tower	Floyd|Snider 2008a
2012	SOIL COVER. In November 2012, the Northeast corner was capped with clean soil by Ecology.	Ecology	NE Corner	Hart Crowser 2012

Table 1b

Previous Investigations

Gas Works Park Site

Seattle, Washington

Year	Investigation Description	Location	Location IDs	Type of Exploration	Analytical Collected	Reference
1971	Cole and Machno summarized the subsurface conditions at the park for the City. They found oil in the water table and oil-soaked ground in the southeast corner of the park and several other areas. Hydrocarbon wastes, ashes, cinders, and oil were found in the majority of the 20 soil borings.	site-wide	#1 to #20 (NOT ON PREVIOUS SAMPLE LOCATION WORK PLAN FIGURE)	soil borings	--	City of Seattle 1971; Cole and Machno 1971
1972	In 1972, two surface soil samples were collected and analyzed for arsenic. Results showed levels of arsenic from "under the old filter" and from "15 feet around the periphery." There are no maps showing the locations of the soil arsenic samples. "Under the old filter" could be interpreted to mean underneath the former Kelly filter area to the south of the playbarn.	unknown - Kelly filter?	A and B (NOT ON PREVIOUS SAMPLE LOCATION WORK PLAN FIGURE)	surface soil samples	soil (NOT IN DATABASE)	Chemithon 1972
1973	Thirty-one backhoe test pits (referred to as "borings") were dug; encountered foundations, pipes, gas plant waste materials, and native soils.	site-wide	A, A-A, A-1, B, B-B, C, D, E, Trench F, G, H, I, J, K, L, M, N, O, P, Q, R, S, T, T-1, T-2, U, V, W, X, Y, Z (NOT ON PREVIOUS SAMPLE LOCATION WORK PLAN FIGURE)	test pits	--	City of Seattle 1973a
1973	Five test pits and three borings were installed along a proposed sewer line in December 1973; noted fill and some oily wastes.	site-wide	MH1 to MH5; A, B, C (NOT ON PREVIOUS SAMPLE LOCATION WORK PLAN FIGURE)	test pits and borings	--	City of Seattle 1973b
1984	In April 1984, Ecology and Environment (E&E) conducted a soil sampling investigation of the Site, collecting and analyzing 72 composite samples from 0 to 0.5 feet and 0 to 3 feet depths at 24 locations. Seven additional soil samples were collected from apparent "hotspots" on the east side of the park and under the pier.	site-wide	84EPA... series; EPA1 to EPA24	soil sampling	soil	E&E 1984; EPA 1984; Ongerth 1985
1984	Surface soil samples (upper inch) were collected from the Site in May 1984 and evaluated for PAHs.	site-wide	UW... series	surface soil samples	soil	UW 1984; Ongerth 1985
1984	Air and soil samples were collected in June 1984 to evaluate off-site release of volatile organic compounds (VOCs) and determine PAH compounds in dust.	site-wide	P1 to P5; S1 to S5; V1 to V9 (NOT ON PREVIOUS SAMPLE LOCATION WORK PLAN FIGURE)	air and soil sampling	air and soil (NOT IN DATABASE)	PSAPCA 1984; Ongerth 1985
1985	Additional testing was conducted in 1985, which included surface soil, tar samples, and groundwater samples. This investigation consisted of collecting 21 surface soil samples (upper 2 inches) and six tar samples; 34 soil samples and associated field replicates were analyzed for PAHs and one location was analyzed for cyanide.	site-wide	B.., C..., D..., E..., F..., G..., H..., I..., J..., K..., L..., M..., N..., P... series	surface soil, tar, and groundwater samples	soil	TetraTech 1985c
1986-1987	The Seattle Parks Department and US Geological Survey (USGS) conducted an investigation in 1986 and 1987 to evaluate groundwater quality under the park and potential discharge of contaminants to Lake Union. This included the installation of 16 groundwater monitoring wells, borehole sampling (10 soil samples), groundwater sampling and testing, investigation of subsurface stratigraphy, soil gas sampling (28 samples), groundwater elevation, and hydraulic transmissivity testing. Soil cores were obtained from the well borings and analytical testing for organic compounds was conducted on ten soil samples. Groundwater samples were collected and analyzed for PAHs, VOCs, metals, cyanide, polychlorinated biphenyls (PCBs), and pesticides. Results from the groundwater analyses indicated that the southeast corner had elevated levels of VOCs. The northwest corner had elevated levels of oil and tar wastes. Soil results indicated the presence of a number of PAH compounds associated with coal tar wastes. Several volatile organic compounds were detected in soil gas including benzene, toluene, ethylbenzene, xylene, and naphthalene.	site-wide	MW-01 to MW-16 (SOIL GAS LOCATIONS NOT ON PREVIOUS SAMPLE LOCATION WORK PLAN FIGURE)	monitoring wells, groundwater, soil, and soil gas sampling	groundwater, soil, and soil gas	TetraTech 1987a; TetraTech 1987b
1988	In February 1988, air, soil, and asbestos testing from the Play Barn area were conducted for protection of workers prior to renovation. Results from this testing showed low levels of PAHs in the soils, low levels of VOCs in the air, and the presence of friable asbestos in pipe lagging, though no airborne asbestos fibers were detected above the reporting limit.	Playbarn	PB-S-1 to PB-S-4	air, soil, and asbestos testing	air and soil	HDR 1988c
1988	A focused field investigation was conducted in June and July 1988 to continue ongoing monitoring of the park and assess plans for an irrigation system. Collected groundwater samples from 15 temporary monitoring wells and tested for VOCs; installed one permanent monitoring well (MW-17) and tested for VOCs, PAHs, and metals; tested six soil samples for cyanide.	NE Corner	MW-1 to MW-17; TMS1 to TMS15; S23 to S29	monitoring well, groundwater, and surface soil sampling	groundwater and soil	HDR 1988h
1989	Installation of four permanent monitoring wells and groundwater sampling for VOCs and PAHs; geophysics study in former tar refinery area.	site-wide	MW-18 to MW-21	monitoring wells and groundwater sampling	groundwater	HDR 1989b
1995	In 1995, EPA conducted an Expanded Site Inspection, where two samples from the shoreline, one upland soil sample, and two surface water samples were collected. Evaluation of the results indicated elevated levels of PAHs and other contaminants existed in the shoreline, soil, and water samples collected.	NE Corner; SE Corner shoreline	95EPA... series	soil and surface water sampling	soil and surface water	EPA 1995
1997	In 1997, in response to the Agreed Order work scope, groundwater monitoring wells were sampled and ten surficial soil samples were collected as part of the Focused Feasibility Study/Cleanup Action Plan (FFS/CAP). Known and suspected tar seeps were characterized. Twelve test pits were excavated and three tar samples were collected.	site-wide	MW-1 to MW-21; S-1 to S-10; TP-1 toTP-12	test pits, groundwater, surface soil, and tar sampling	groundwater, soil, and tar	Parametrix and Key 1998

Year	Investigation Description	Location	Location IDs	Type of Exploration	Analytical Collected	Reference
1997 -1998	Also as part of the Agreed Order, soil and groundwater quality was investigated at the Harbor Patrol area and the area directly east of Kite Hill. Data generated from soil borings, monitoring wells, and piezometers were used to develop cross-sections of the Site, measure groundwater flow gradients, and evaluate the nature and extent of NAPL occurrences. Fate and transport modeling was used to predict downgradient attenuation of dissolved PAHs as part of the conceptual site model. A total of two soil boring were completed and nineteen wells/piezometers were installed.	Harbor Patrol area	B-1-EPRI; B-2- EPRI; DW-4 to DW-7; PZ-1 to PZ-10; RW-01; MLS-1 to MLS-7; MW-13; MW-14, MW-22 to MW-25	soil borings, monitoring wells, piezometers, pump test, soil and groundwater sampling	groundwater and soil	EPRI 1998
1998	Field investigations of the southeastern area were conducted in 1998 to evaluate the feasibility of an air sparging system. Thirty-four geoprobe borings were advanced and soil and groundwater samples were collected. Elevated benzene concentrations were detected in soil and groundwater samples, and were delineated as two separate plumes, one near the shoreline and one further upgradient. Analytical results from LNAPL samples collected indicated that light oil was the source of the benzene in the shoreline plume.	southeastern area mostly; one location NW corner	B-1 to B-34	soil borings, groundwater, soil and LNAPL sampling	groundwater, soil, and LNAPL	Retec 1998; Parametrix and Key 1998; Retec 2001
2000	Installation of four monitoring wells: OBS-1 to OBS-3 were installed as part of benzene cleanup action as performance monitoring wells; CMP-1 was installed as part of groundwater monitoring compliance.	SE Corner; Harbor Patrol	CMP-1; OBS-1 to OBS-3	monitoring wells	--	Retec 2000; Retec 2001 (aka HC Reference "Thermoretec 2001")
2004	In 2004, the northwest corner of the park was investigated in order to allow the City to remove the existing physical barriers and allow public access to that area. Thirteen test pits were excavated and sixteen surficial soil samples collected and analyzed.	northwest area	NWSS-... series	test pits and surface soil sampling	surface soil	Parametrix 2004a; Parametrix 2004b
2005	A soil quality investigation was conducted within the fenced Cracking Towers area in July 2005. Six soil samples were collected at depths of 0.5 to 1.5 feet below ground surface. The samples were analyzed for PAHs, VOCs, PCBs, and metals (including arsenic, lead, and mercury). Elevated concentrations of PAHs were detected in all six soil samples. No PCBs or VOCs were detected in the samples. Metals concentrations were generally not detected or were well below MTCA Method A unrestricted cleanup levels.	cracking towers	GWP-TP1 to GWP-TP6	test pits and soil sampling	soil	Corvus 2005
2006	In September 2006, an investigation of the western shoreline was conducted to delineate the presence and assess the mobility of DNAPL in the subsurface. Nine soil borings were advanced, and permanent and temporary monitoring wells installed. Soil samples were collected and analyzed for petrophysical properties, and slug tests were performed to determine hydrogeologic properties.	western shoreline	TDW-1 to TDW-3; TSW-1 to TSW-3; TSB-1 to TSB-3	soil borings and monitoring wells	soil (petrophysical and geotechnical)(NOT IN DATABASE)	Floyd|Snider 2007a
2007	In August 2007, a soil gas survey was conducted in the northeastern portion of the park to identify locations for further exploration.	northeast corner	SG-01 to SG-54 (NOT ON PREVIOUS SAMPLE LOCATION WORK PLAN FIGURE)	soil gas survey	soil gas (NOT IN DATABASE)	Floyd|Snider 2008a
2007	In 2007, two separate but complementary investigations of the northeastern meadow and eastern shoreline area were conducted by PSE, the City of Seattle, and Ecology. In September 2007, 34 soil borings were advanced, and soil samples were collected and analyzed. LNAPL and DNAPL were observed most frequently in the southern section of the investigation area. Chemical tests were conducted on selected samples for SVOCs, VOCs, total petroleum hydrocarbons, and Synthetic Precipitation Leaching Procedure (SPLP) analysis for SVOCs.	northeast corner/eastern shoreline	GP1 to GP14; HA1 to HA9; SB 1 to SB 13	soil borings and soil sampling	soil	Floyd|Snider 2008a; Floyd|Snider 2008c; AECOM 2008
2007	In October 2007, a NAPL sample was collected from monitoring well MW-9, and was found to contain elevated concentrations of PAHs.	MW-9	MW-9	MW Sampling	NAPL	Floyd|Snider 2008b
2007-2008	Air quality was evaluated using three quarterly monitoring events conducted from spring 2007 to winter 2008. Air samples were collected from five locations within the Park (Cracking Towers, Prow Upwind, Weather Station Location, East Shore, and Play Barn Basement) and Harbor Patrol facility. The quarterly results showed that the detected concentrations of VOCs, benzene and naphthalene in particular do not exceed the park user scenario; and do not exceed OSHA occupational standards (PEL) that would be applicable to Park and Harbor Patrol employees.	site-wide	HP, CT, PUP, WSL, ES, PBB (NOT ON PREVIOUS SAMPLE LOCATION WORK PLAN FIGURE)	air sampling	air (NOT IN DATABASE)	Floyd|Snider 2008e
2008-2011	Annual groundwater sampling.	SE Corner; Harbor Patrol; W Kite Hill	CMP-1; OBS-1 to OBS-3; MLS-5; MLS-6; MW-17; MW-19	groundwater sampling	groundwater	EcoCompliance 2008; EcoCompliance 2009; Amec Geomatrix 2010; Amec 2011
2010	In June 2010, six surface soil samples were collected from the WW No.19 storm drain ditch as part of storm drain source control evaluation.	NE Corner	WW19-01 to WW19-06	surface soil sampling	surface soil	Floyd|Snider 2010b
2010	In September 2010, a hydrogeologic investigation was conducted to collect additional hydrogeological data in support of a site-wide, three-dimensional numerical groundwater flow model. This investigation included a survey of groundwater levels from existing monitoring wells, advancing soil borings to provide stratigraphic information, completion of monitoring wells slug and pump tests. Ecology obtained split soil samples from the well borings and submitted 19 of the samples for chemical analysis of metals and SVOCs.	site-wide	MW-26 to MW-31	monitoring wells and soil sampling	soil	GeoEngineers 2010; Aspect 2012a
2011	Ecology sampled surface soil on Kite Hill.	Kite Hill	KH-1 to KH-7	surface soil grab sampling	soil	Ecology (Maura O'Brien) email, 7-26-11
2011	For Seattle Structural and Seattle Police Department, HartCrowser sampled geotechnical boring B-1 and sinkhole location for environmental COCs as part of bulkhead structural review and assessment.	Harbor Patrol area	B-1; sinkhole	soil sampling	soil	Seattle Structural 2011
2012	Proposed play area soil sampling, and asbestos and lead paint sampling of playbarn structure.	Playbarn	GWP-PA-01 to GWP-PA-04	hand auger and soil sampling	soil	Amec 2012

Note:

Storm drain investigations and associated sampling not included.

Table 2

Summary of Well Construction Details

Gas Works Park Site

Seattle, Washington

Well ID	Well Location*		Well Construction Information in Feet								
	Northing	Easting	Approximate Ground Surface Elevation (at Time of Installation)	Approximate Ground Surface Elevation (Current)*	Approximate Stickup	Approximate Measuring Point (TOC) Elevation*	Screen Interval Depth BGS at Time of Installation: Top	Screen Interval Depth BGS at Time of Installation: Bottom	Geologic Unit of Screen Interval**	Approximate Screen Interval Elevation: Top	Approximate Screen Interval Elevation: Bottom
Gas Works Park Property											
TDW-1	239245	1269574	24.90	24.90	-0.30	24.60	37.5	42.5	Qva	-12.6	-17.6
TSW-1	239252	1269587	25.77	25.77	-0.33	25.44	5.3	10.3	Fill	20.5	15.5
TDW-2	238940	1269755	24.84	24.84	-0.32	24.52	34.5	39.5	Qva	-9.7	-14.7
TSW-2	238956	1269763	27.53	27.53	-0.30	27.23	7.0	12.0	Fill	20.5	15.5
TDW-3	238766	1269989	27.13	27.13	-0.21	26.92	34.5	39.5	Qva	-7.4	-12.4
TSW-3	238772	1269991	27.53	27.71	-0.33	27.38	6.0	11.0	Fill	21.5	16.5
MLS-1-1	239315	1269896	36.75	40.08	-0.37	--	21.3	22.3	Till	15.5	14.5
MLS-1-2	239315	1269896	36.75	40.08	-0.37	--	16.8	17.8	Qvr	20.0	19.0
MLS-1-3	239315	1269896	36.75	40.08	-0.37	--	12.3	13.3	Qvr	24.5	23.5
MLS-2-1	239232	1269827	34.22	34.67	-0.34	--	23.0	24.0	Qva	11.2	10.2
MLS-2-2	239232	1269827	34.22	34.67	-0.34	--	18.5	19.5	Qva	15.7	14.7
MLS-2-3	239232	1269827	34.22	34.67	-0.34	--	14.0	15.0	Qvr	20.2	19.2
MW-01	240139	1270317	84.94	84.52	--	--	24.8	34.8	-	60.1	50.1
MW-02	239459	1269803	38.81	43.01	--	--	3.9	13.9	-	34.9	24.9
MW-03	239454	1270269	38.69	38.69	-0.47	38.22	1.6	10.6	Till	37.1	28.1
MW-03D	239460	1270281	38.93	38.93	-0.54	38.39	54.6	57.6	Till	-15.7	-18.7
MW-05	239238	1269874	36.03	36.70	--	--	8.3	18.3	-	27.7	17.7
MW-06	239339	1270434	33.98	33.93	--	--	1.9	9.9	-	32.1	24.1
MW-07	239174	1270144	36.14	39.29	--	--	7.1	17.1	-	29.0	19.0
MW-08	239211	1270333	36.70	38.00	--	--	9.5	19.5	-	27.2	17.2
MW-09	239136	1270552	34.35	34.35	-0.47	33.88	10.8	20.8	Till	23.6	13.6
MW-10	238982	1270112	32.42	32.42	-0.49	31.93	5.3	15.3	Fill	27.1	17.1
MW-11	238982	1270480	38.33	37.30	--	--	19.9	29.9	-	18.4	8.4
MW-12	238960	1270699	25.55	28.10	--	--	1.3	9.6	-	24.3	16.0
MW-13	238831	1269892	32.86	32.86	-0.44	32.42	7.3	17.3	Fill	25.6	15.6
MW-14	238795	1270177	27.22	27.22	-0.38	26.84	2.5	9.5	Fill	24.7	17.7
MW-15	238858	1270244	38.07	38.07	-0.46	37.61	9.5	19.5	Fill	28.6	18.6
MW-16	238807	1270617	23.38	24.32	-0.48	--	2.5	10.5	-	20.9	12.9
MW-17	239090	1269812	33.07	33.07	-0.20	32.87	6.5	16.5	Fill	26.6	16.6
MW-18	239330	1269777	38.51	38.51	-0.31	38.20	-	-	-	-	-
MW-19	239212	1269917	39.39	39.39	-0.22	39.17	-	-	-	-	-
MW-20	239138	1270542	34.37	34.09	--	--	-	-	-	-	-
MW-21	238949	1270704	24.73	27.60	--	--	-	-	-	-	-
MW-22	238720	1270113	24.69	24.69	-0.44	24.25	24.0	34.0	Qva	0.7	-9.3
MW-23	238717	1270181	23.79	23.79	-0.43	23.36	22.0	32.0	Till	1.8	-8.2
MW-24	238718	1270116	24.64	24.64	-0.49	24.15	5.0	15.0	Qvr	19.6	9.6
MW-25	238713	1270183	23.69	23.69	-0.47	23.22	5.0	15.0	Qvr	18.7	8.7
MW-26	239414	1270609	32.94	32.94	-0.51	32.43	9.0	12.6	Till	23.9	20.3
MW-27	239268	1270426	35.42	35.42	-0.27	35.15	12.0	15.0	Till	23.4	20.4
MW-28	238800	1270458	37.60	37.60	-0.21	37.39	17.0	27.0	Till	20.6	10.6
MW-29	238996	1270119	31.53	31.53	-0.22	31.31	13.0	23.0	Till	18.5	8.5
MW-30	238987	1270115	31.91	31.91	-0.23	31.68	12.0	22.0	Till	19.9	9.9
MW-31	239409	1269784	41.33	41.33	-0.45	40.88	35.0	45.5	Till	6.3	-4.2
PZ-2	239269	1269770	34.40	35.16	0.00	--	5	20	Fill	29.4	14.4
PZ-3	239232	1269812	34.81	34.81	-0.23	34.58	5	20	Qvr	29.8	14.8
PZ-9	239322	1269844	36.76	39.32	-0.52	38.80	12.5	22.5	Qvr	24.3	14.3
PZ-10	239316	1269815	36.97	38.72	-0.27	38.45	12.5	22.5	Qvr	24.5	14.5
RW-1	239317	1269857	36.91	39.55	-0.29	39.26	12.5	22.5	Qvr	24.4	14.4
OBS-1	238946	1270753	23.13	23.13	0.39	23.52	2	11.7	Fill	21.1	11.4
OBS-2	238962	1270739	26.46	26.46	-0.32	26.14	2	11.7	Till	24.5	14.8
OBS-3	238984	1270678	29.60	29.60	-0.27	29.33	2	11.7	Fill	27.6	17.9
Harbor Patrol Property											
CMP-1	239055	1269720	25.24	25.24	-0.41	24.83	6.5	21.5	Fill	18.7	3.7
DW-4	239159	1269736	25.86	25.86	-0.53	25.33	32.0	37.0	Till	-6.1	-11.1
DW-5	239141	1269718	25.44	25.44	-0.34	25.10	24.0	29.0	Qva	1.4	-3.6
DW-6	239095	1269676	25.04	25.04	-0.50	24.54	37.0	42.0	Qva	-12.0	-17.0
DW-7	239055	1269726	25.35	25.35	-0.12	25.23	37.5	42.5	Qva	-12.2	-17.2
MLS-3-1	239193	1269778	33.60	33.73	-0.4	--	26.3	27.3	Qva	7.3	6.3
MLS-3-2	239193	1269778	33.60	33.73	-0.4	--	21.8	22.8	Qva	11.8	10.8
MLS-3-3	239193	1269778	33.60	33.73	-0.4	--	17.3	18.3	Qvr	16.3	15.3
MLS-3-4	239193	1269778	33.60	33.73	-0.4	--	12.8	13.5	Qvr	20.8	20.1
MLS-3-5	239193	1269778	33.60	33.73	-0.4	--	8.3	9.3	Fill	25.3	24.3
MLS-4-1	239167	1269731	25.34	25.34	-0.33	--	23	24	Qva	2.3	1.3
MLS-4-2	239167	1269731	25.34	25.34	-0.33	--	18.5	19.5	Qva	6.8	5.8
MLS-4-3	239167	1269731	25.34	25.34	-0.33	--	14	15	Qva	11.3	10.3
MLS-4-4	239167	1269731	25.34	25.34	-0.33	--	9.5	10.5	Qvr	15.8	14.8
MLS-4-5	239167	1269731	25.34	25.34	-0.33	--	5	6	Fill	20.3	19.3
MLS-5-1	239156	1269715	25.06	25.06	-0.23	--	24	25	Qva	1.1	0.1
MLS-5-2	239156	1269715	25.06	25.06	-0.23	--	19.5	20.5	Qva	5.6	4.6
MLS-5-3	239156	1269715	25.06	25.06	-0.23	--	15	16	Qvr	10.1	9.1

Well ID	Well Location*		Well Construction Information in Feet								
			Approximate Ground Surface Elevation (at Time of Installation)	Approximate Ground Surface Elevation (Current)*	Approximate Stickup	Approximate Measuring Point (TOC) Elevation*	Screen Interval Depth BGS at Time of Installation		Geologic Unit of Screen Interval**	Approximate Screen Interval Elevation	
	Northing	Easting					Top	Bottom		Top	Bottom
MLS-5-4	239156	1269715	25.06	25.06	-0.23	--	10.5	11.5	Qvr	14.6	13.6
MLS-5-5	239156	1269715	25.06	25.06	-0.23	--	6	7	Fill	19.1	18.1
MLS-6-1	239098	1269673	24.64	24.64	-0.32	--	24	25	Qva	0.6	-0.4
MLS-6-2	239098	1269673	24.64	24.64	-0.32	--	19.5	20.5	Qvr	5.1	4.1
MLS-6-3	239098	1269673	24.64	24.64	-0.32	--	15	16	Fill	9.6	8.6
MLS-6-4	239098	1269673	24.64	24.64	-0.32	--	10.5	11.5	Fill	14.1	13.1
MLS-6-5	239098	1269673	24.64	24.64	-0.32	--	6	7	Fill	18.6	17.6
MLS-7-1	239057	1269724	24.94	24.94	-0.29	--	24	25	Qva	0.9	-0.1
MLS-7-2	239057	1269724	24.94	24.94	-0.29	--	19.5	20.5	Qvr	5.4	4.4
MLS-7-3	239057	1269724	24.94	24.94	-0.29	--	15	16	Fill	9.9	8.9
MLS-7-4	239057	1269724	24.94	24.94	-0.29	--	10.5	11.5	Fill	14.4	13.4
MLS-7-5	239057	1269724	24.94	24.94	-0.29	--	6	7	Fill	18.9	17.9
PZ-1	239205	1269609	25.62	25.62	-0.51	25.11	3.0	13.0	Qvr	22.6	12.6
PZ-4	239169	1269801	33.73	30.11	--	--	10.0	30.0	Qvr/Qva	23.7	3.7
PZ-5	239013	1269790	27.74	30.26	--	--	3.0	18.0	Fill	24.7	9.7
PZ-6	239074	1269773	27.16	28.97	--	--	5.0	20.0	Fill	22.2	7.2
PZ-7	239073	1269710	24.53	26.68	--	--	5.0	20.0	Fill	19.5	4.5
PZ-8	239157	1269715	25.66	25.66	-0.36	25.30	5.0	20.0	Qvr	20.7	5.7

Notes:

Horizontal Datum: NAD83 WA State Plane North.

Vertical Datum: Corps of Engineers (USACE).

* Existing well locations as well as ground surface and TOC elevations will be confirmed using professional survey as part of Supplemental Investigation.

** Some screen intervals cross more than one geologic unit. Units listed here are the same as those assigned by Aspect in their groundwater modeling report (Aspect, 2012).

Gray shading indicates wells that no longer exist or are presumed to no longer exist.

Table 3

Hydrostratigraphic Units and Hydraulic Conductivities

Gas Works Park Site

Seattle, Washington

Hydrostratigraphic Units	Geologic Units	Hydraulic Conductivity Range (k) (cm/sec)
Fill	Fill (Af)	3×10^{-3}
Lake Sediments	Recent Lacustrine Deposits (Ql)	4×10^{-4}
	Vashon Recessional Glaciolacustrine Deposits (Qvrl)	
Glacial Outwash Deposits	Recent Beach and Shallow Shelf Deposits (Qb)	1×10^{-3} to 2×10^{-2}
	Vashon Recessional Outwash (Qvr)	
	Vashon Advance Outwash (Qva)	
Till and Till-like Deposits	Pre-Fraser Till (Qpgt)	1×10^{-5} to 7×10^{-4}
	Pre-Fraser Glaciolacustrine Deposits (Qpgl)	
	Pre-Fraser Diamict (Qpgd)	
	Pre-Fraser Subglacial Meltout Till (Qpgtm)	

Table 4

Soil Cleanup Levels

Gas Works Park Site

Seattle, Washington

Chemicals of Concern	Sediment Cleanup Level[1] (mg/kg)
Inorganic Chemicals	
Arsenic	20(1)
Carcinogenic PAHs	
Benzo(a)anthracene	0.137
Benzo(b)fluoranthene	0.137
Benzo(k)fluoranthene	0.137
Benzo(a)pyrene	0.137
Chrysene	0.137
Dibenzo(a,h)anthracene	0.137
Indeno(1 ,2,3-cd)pyrene	0.137
Other PAHs	
Naphthalene	3,200
Pyrene	2,400
Fluoranthene	3,200

Note:

[1]Cleanup levels established in Cleanup Action Plan based on MTCA Method B.

mg/kg = milligrams per kilogram

PAH = Polycyclic aromatic hydrocarbon

Table 5

Groundwater Cleanup Levels

Gas Works Park Site

Seattle, Washington

Chemicals of Concern	Cleanup Level[3] (µg/L)
Carcinogenic PAHs	
Benzo(a)anthracene	0.0296
Benzo(b)fluoranthene	0.0296
Benzo(k)fluoranthene	0.0296
Benzo(a)pyrene	0.0296
Chrysene	0.0296
Dibenz(a,h)anthracene	0.0296
Indeno(1,2,3-cd)pyrene	0.0296
Other PAHs	
Fluoranthene	90.2
Fluorene	3,460
Naphthalene	9,880
Pyrene	2,590
Volatile Organic Chemicals	
Benzene	43
Ethylbenzene	6,910
Toluene	48,500

Notes:

[1]MacKay et al. 1992

[2]EPRI 1998; from solubility leaching tests

[3]Cleanup level established in Cleanup Action Plan based on MTCA Method B surface water levels.

µL = micrograms per liter

N/A = not available

PAH – Polycyclic Aromatic Hydrocarbon

U = undetected at the given detection limit

Table 6

Soil Sample Collection Objective, Rationale and Analyses

Gas Works Park Site

Seattle, Washington

TarGOST and Soil Boring Target Area	Exploration Location	Objective	Anticipated Boring Depth (feet below ground surface)	Anticipated Number of Samples to be Analyzed[2] (per boring)	Methodology for Sample Selection for Analysis
Northeast Corner	GEI-01	Investigate former transformer area.	10	1 - 2	Select one soil sample at the approximate location of the former ground surface, if possible. If the former ground surface is not discernable, one composite soil sample will collected from 0-3 feet below the existing ground surface. One additional soil sample may be collected based on visual observations.
	TarGOST Explorations	Investigate the northern, southern, and western extent of observed NAPL in this area.	15	N/A	Up to 7 TarGOST explorations will be advanced to evaluate the lateral and vertical extent of NAPL observed in previous borings in this area. TarGOST explorations will be advanced through the fill unit and at least 3 feet below the deepest NAPL response OR to probe refusal, whichever is shallower.
	Soil Borings TBD	Investigate the areas of greatest TarGOST response.	15	2-3	Soil borings will be drilled at locations selected based on the evaluation of TarGOST results in the northeast corner. At least one soil boring will be drilled adjacent to the TarGOST exploration location with the greatest NAPL response to compare TarGOST response to visual observations and/or obtain soil cores for UV photography and potential petrophysical testing. Drill soil boring through the fill material at least 3 feet into native soil and until there is no field screening evidence of impacts. Select soil samples for chemical analysis of BTEXs and PAHs based on TarGOST responses, with the goal of collecting samples above, within, and below the depth of visible NAPL impact.
Southeast Corner	MW-16 TarGOST Target Area	Investigate the area of former monitoring well MW-16 to evaluate the extent of observed tar in this area.	25	N/A	TarGOST explorations will be advanced to evaluate the lateral extent of NAPL observed in boring MW-16 in this area. TarGOST explorations will be advanced through the fill unit and at least 3 feet below the deepest NAPL response OR to probe refusal, whichever is shallower.
	Soil Borings TBD	Investigate the areas of greatest TarGOST response.	25	3-4	Soil borings will be drilled at locations selected based on the evaluation of TarGOST results in the MW-16 target area. At least one soil boring will be drilled adjacent to the TarGOST exploration location with the greatest NAPL response to compare TarGOST response to visual observations and/or obtain soil cores for UV photography and potential petrophysical testing. Drill soil boring through the fill material at least 3 feet into native soil and until there is no field screening evidence of impacts. Select soil samples for chemical analysis of BTEXs and PAHs based on TarGOST responses, with the goal of collecting samples above, within, and below the depth of visible NAPL impact.
Play Barn/Central Meadow	GEI-03	Investigate the extent of observed NAPL detected in previous soil samples in this area, and potential arsenic source area.	25	3-4	Soil boring will be drilled through the fill material at least 3 feet into native soil and until there is no field screening evidence of impacts. Select soil samples for chemical analysis of BTEXs, PAHs, and arsenic at approximate 5-foot intervals, with the goal of collecting samples above, within, and below the depth of visible NAPL impact.
	GEI-04	Investigate the extent of observed NAPL detected in previous soil samples in this area, and potential arsenic source area.	25	3-4	Soil boring will be drilled through the fill material at least 3 feet into native soil and until there is no field screening evidence of impacts. Select soil samples for chemical analysis of BTEXs, PAHs, and arsenic at approximate 5-foot intervals, with the goal of collecting samples above, within, and below the depth of visible NAPL impact.
	GEI-05	Investigate the extent of observed NAPL detected in previous soil samples in this area, and potential arsenic source area.	25	3-4	Soil boring will be drilled through the fill material at least 3 feet into native soil and until there is no field screening evidence of impacts. Select soil samples for chemical analysis of BTEXs, PAHs, and arsenic at approximate 5-foot intervals, with the goal of collecting samples above, within, and below the depth of visible NAPL impact.
	MW-09 TarGOST Target Area	Investigate the northern, southern, and western extent of observed NAPL in MW-09 in this area, and potential arsenic source area.	25	N/A	TarGOST explorations will be advanced to evaluate the lateral and vertical extent of NAPL observed in monitoring well MW-09 in this area. TarGOST explorations will be advanced through the fill unit and at least 3 feet below the deepest NAPL response OR to probe refusal, whichever is shallower.
	Soil Borings TBD	Investigate the areas of greatest TarGOST response.	25	3-4	Soil borings will be drilled at locations selected based on the evaluation of TarGOST results in the MW-09 target area. At least one soil boring will be drilled adjacent to the TarGOST exploration location with the greatest NAPL response to compare TarGOST response to visual observations and/or obtain soil cores for UV Photography and potential petrophysical testing. Drill soil boring through the fill material at least 3 feet into native soil and until there is no field screening evidence of impacts. Select soil samples for chemical analysis of BTEXs, PAHs, and arsenic based on TarGOST responses, with the goal of collecting samples above, within, and below the depth of visible NAPL impact.

TarGOST and Soil Boring Target Area	Exploration Location	Objective	Anticipated Boring Depth (feet below ground surface)	Anticipated Number of Samples to be Analyzed[2] (per boring)	Methodology for Sample Selection for Analysis
Historical Structures (cracking towers)	GEI-02	Investigate the location of the former MGP structures in this area.	10-15	2-3	Soil boring will be drilled through the fill material into native soil and until there is no field screening evidence of impacts. Select soil samples at approximate 5-foot intervals, based on field evidence of greatest impact. Submit soil samples for BTEX and PAH analysis.
	Downgradient of Cracking Tower TarGOST Target Area	Investigate the extent of NAPL in this area.	10-15	N/A	TarGOST explorations will be advanced to evaluate the lateral and vertical extent of potential NAPL downgradient of the cracking towers. TarGOST explorations will be advanced through the fill unit and at least 3 feet below the deepest NAPL response OR to probe refusal, whichever is shallower.
	MW-15 TarGOST Target Area	Investigate the extent of NAPL in this area.	10-15	N/A	TarGOST explorations will be advanced to evaluate the lateral and vertical extent of NAPL observed in soil boring MW-15 in this area. TarGOST explorations will be advanced through the fill unit and at least 3 feet below the deepest NAPL response OR to probe refusal, whichever is shallower.
	Historical Structure TarGOST Target Area	Investigate the extent of NAPL in this area.	10-15	N/A	TarGOST explorations will be advanced to evaluate the lateral and vertical extent of potential residual NAPL that may be associated with former MGP structures in this area. TarGOST explorations will be advanced through the fill unit and at least 3 feet below the deepest NAPL response OR to probe refusal, whichever is shallower.
	Soil Borings TBD	Investigate the areas of greatest TarGOST response.	10-15	3-4	Soil borings will be drilled at locations selected based on the evaluation of TarGOST results in the cracking tower, MW-15, and historical structure target areas. At least one soil boring will be drilled adjacent to the TarGOST exploration location with the greatest NAPL response to compare TarGOST response to visual observations. Drill soil boring through the fill material at least 3 feet into native soil and until there is no field screening evidence of impacts. Select soil samples for chemical analysis of BTEXs and PAHs based on TarGOST responses, with the goal of collecting samples above, within, and below the depth of visible NAPL impact.
Harbor Patrol	TarGOST Explorations	Investigate the extent of observed NAPL in borings and monitoring wells in the Harbor Patrol Area.	40-45	N/A	Up tp 4 TarGOST explorations will be advanced to evaluate the lateral and vertical extent of NAPL observed in monitoring wells and soil borings in this area. TarGOST explorations will be advanced through the fill unit and at least 3 feet below the deepest NAPL response OR to probe refusal, whichever is shallower.
	Soil Borings TBD	Investigate the areas of greatest TarGOST response.	40-45	3-4	Soil borings will be drilled at locations selected based on the evaluation of TarGOST results in the Harbor Patrol area. At least one soil boring will be drilled adjacent to the TarGOST exploration location with the greatest NAPL response to compare TarGOST response to visual observations and/or obtain soil cores for UV photography and potential petrophysical testing. Drill soil boring through the fill material at least 3 feet into native soil and until there is no field screening evidence of impacts. Select soil samples for chemical analysis of BTEXs and PAHs based on TarGOST responses, with the goal of collecting samples above, within, and below the depth of visible NAPL impact.
Shoreline Monitoring Wells[1]	MW-32D	Soil borings for monitoring well installation at the shoreline downgradient of Kite Hill.	47	2	Drill soil boring for monitoring well installation. Select soil samples for chemical analysis of BTEXs and PAH with the goal of collecting samples above, within, and below the depth of visible NAPL impact.
	MW-33S	Soil boring for monitoring well installation at the shoreline downgradient of the Cracking Towers.	17	2	Drill soil boring for monitoring well installation. Select soil samples for chemical analysis of BTEXs and PAH with the goal of collecting samples above, within, and below the depth of visible NAPL impact.
	MW-34S	Soil boring for monitoring well installation at the shoreline in the southeast area.	13	2	Drill soil boring for monitoring well installation. Select soil samples for chemical analysis of BTEXs and PAH with the goal of collecting samples above, within, and below the depth of visible NAPL impact.
	MW-35S	Soil boring for monitoring well installation at the shoreline in the southeast area near the former MW-16 area.	12	2	Drill soil boring for monitoring well installation. Select soil samples for chemical analysis of BTEXs, PAHs and arsenic, with the goal of collecting samples above, within, and below the depth of visible NAPL impact.
	MW-36D	Soil borings for monitoring well installation at the shoreline downgradient of monitoring well MW-09 and in an area of observed NAPL impact at GP-11 and GP-12.	37	2	Drill soil boring for monitoring well installation. Select soil samples for chemical analysis of BTEXs, PAHs and arsenic, with the goal of collecting samples above, within, and below the depth of visible NAPL impact.

TarGOST and Soil Boring Target Area	Exploration Location	Objective	Anticipated Boring Depth (feet below ground surface)	Anticipated Number of Samples to be Analyzed[2] (per boring)	Methodology for Sample Selection for Analysis
Shoreline Monitoring Wells[1]	MW-37S	Soil boring for monitoring well installation at the shoreline in the area of observed NAPL impact at GP-9.	14	2	Drill soil boring for monitoring well installation. Select soil samples for chemical analysis of BTEXs, PAHs and arsenic, with the goal of collecting samples above, within, and below the depth of visible NAPL impact.
	MW-38S	Soil boring for monitoring well installation at the shoreline in an area where NAPL impacts were not identified.	13	2	Drill soil boring for monitoring well installation. Select soil samples for chemical analysis of BTEXs, PAHs and arsenic, with the goal of collecting samples above, within, and below the depth of visible NAPL impact.
	MW-39D	Soil borings for monitoring well installation at the shoreline near the tar mound and observed NAPL impacts.	22	2	Drill soil boring for monitoring well installation. Select soil samples for chemical analysis of BTEXs and PAH with the goal of collecting samples above, within, and below the depth of visible NAPL impact.
	MW-40S	Soil boring for monitoring well installation at the shoreline near the northern site boundary.	13	2	Drill soil boring for monitoring well installation. Select soil samples for chemical analysis of BTEXs and PAH with the goal of collecting samples above, within, and below the depth of visible NAPL impact.

Notes:

Soil Borings TBD = Soil borings, number and location to be determined. Approximately 15 additional soil borings will be drilled on the GWPS based on the results of TarGOST exploration.

N/A = Not applicable. Soil samples for chemical analysis cannot be obtained from TarGOST explorations.

[1]Monitoring well installation rationale is presented on Table 7.

[2]Soil samples will be analyzed for BTEXs and PAHs. Selected soil samples will be analyzed for arsenic. Soil samples from GEI-01 will be analyzed for PCBs. See SAP Table A-1 for details.

[3]Soil borings will be sampled continuously for visual observation, PID, and field screening.

Table 7

Proposed Monitoring Well Installation Summary

Gas Works Park Site

Seattle, Washington

Area	Monitoring Well	Target Zone	Geologic Unit for Well Screen	Approx. Ground Surface[1] (ft.)	Approx. Screen Interval (ft. bgs)	Screen Interval Elevation	Closest Boring(s) or Well(s)	Rationale
Kite Hill	MW-32S	Potentially impacted zone of uppermost water-bearing unit	Fill	27	15.5 to 30.5	11.5 to -3.5	TSB-1/MW-13	- To evaluate the lateral extent of DNAPL from Harbor Patrol and the potential presence of DNAPL downgradient of Kite Hill at this location. - To evaluate the concentrations of chemicals of concern in groundwater in the fill unit at shoreline downgradient of Kite Hill. - To provide information to estimate the vertical groundwater gradient at this location.
Kite Hill	MW-32D	Below base of impacts; Advance Outwash at top of Glacial Till; match screen interval of TDW-2 and TDW-3	Advance Outwash and Glacial Till	27	42 to 47	-15 to -20	TSB-1/MW-13	- To evaluate the lateral extent of DNAPL from Harbor Patrol at this location. - To evaluate the concentrations of chemicals of concern in groundwater in the advance outwash unit downgradient of Kite Hill. - To provide information to estimate the vertical groundwater gradient at this location.
Cracking Towers	MW-33S	Water Table	Fill and Recessional Outwash	32	7 to 17	25 to 15	MW-23/MW-25	- To evaluate the concentrations of chemicals of concern in groundwater above the glacial till downgradient of the cracking towers. - To evaluate the presence of DNAPL downgradient of the cracking towers.
Southeast Area	MW-34S	Water Table	Fill and Glacial Till Surface	28	3 to 13	25 to 15	MW-28	- To evaluate the concentrations of chemicals of concern in groundwater above the glacial till near the shoreline in this area. - To evaluate the presence of DNAPL near the shoreline in this area.
Southeast Area	MW-35S	Water Table	Fill	24	2 to 12	22 to 12	MW-16/OBS-1	- To obtain soil and groundwater information at the former monitoring well MW-16 area. - To evaluate the concentrations of chemicals of concern in groundwater above the glacial till in this area. - To evaluate the presence of tar or DNAPL in this area.
Southeast Area/Playbarn	MW-36S	Water Table	Fill	27	3 to 23	24 to 4	GP-11/GP-12	- To evaluate the concentrations of chemicals of concern in groundwater within the fill in this area, downgradient of monitoring well MW-9. - To evaluate the presence of LNAPL in this area. - To provide information to estimate the vertical groundwater gradient at this location.
Southeast Area/Playbarn	MW-36D	Below base of impacts; Recessional Outwash at Top of Glacial Till	Recessional Outwash	27	32 to 37	-5 to -10	GP-11/GP-12	- To obtain soil and groundwater information near the southeast corner of the playbarn, downgradient of monitoring well MW-9, and in the area of observed NAPL impacts. - To evaluate DNAPL and the concentrations of chemicals of concern in groundwater within the recessional and advance outwash deposits in this area. - To provide information to estimate the vertical groundwater gradient at this location.
Playbarn	MW-37S	Water Table	Fill	27	4 to 14	23 to 13	GP-9	- To obtain soil and groundwater information east of the playbarn in the area of observed NAPL impact at GP-11 and GP-12. - To evaluate the concentrations of chemicals of concern in groundwater within the fill unit. - To evaluate the presence of LNAPL and DNAPL in this area near boring GP-9.
Playbarn	MW-38S	Water Table	Fill	26	3 to 13	23 to 13	GP-8	- To obtain soil and groundwater information east of the playbarn in an area where NAPL impacts were not observed. - To evaluate the concentrations of chemicals of concern in groundwater within the fill unit. - To evaluate the presence of DNAPL in this area near boring GP-8.
Northeast Corner	MW-39S	Water Table	Fill	27	4 to 14	23 to 13	GP-6	- To obtain soil and groundwater information in the northeast corner. - To evaluate the concentrations of chemicals of concern in groundwater within the fill unit near the tar mound. - To evaluate the presence of DNAPL in this area. - To provide information to estimate the vertical groundwater gradient at this location.

Area	Monitoring Well	Target Zone	Geologic Unit for Well Screen	Approx. Ground Surface[1] (ft.)	Approx. Screen Interval (ft. bgs)	Screen Interval Elevation	Closest Boring(s) or Well(s)	Rationale
Northeast Corner	MW-39D	Below base of Impacts; Advance Outwash at top of Glacial Till	Advance Outwash	27	17 to 22	10 to 5	GP-6	- To obtain soil and groundwater information in the northeast corner. - To provide information regarding the geology at this location. - To evaluate the concentrations of chemicals of concern in groundwater within the advance outwash at the surface of the glacial till near the tar mound. - To evaluate the presence of DNAPL in this area. - To provide information to estimate the vertical groundwater gradient at this location.
Northeast Corner	MW-40S	Water Table	Fill	26	3 to 13	23 to 13	GP-1	- To obtain soil and groundwater information in the northern portion of the northeast corner. - To evaluate the concentrations of chemicals of concern in groundwater within the fill unit in the northeast corner. - To evaluate the presence of DNAPL in this area. - To provide information regarding the northern extent of identified DNAPL and dissolved phase groundwater impacts near the shoreline.

Notes:

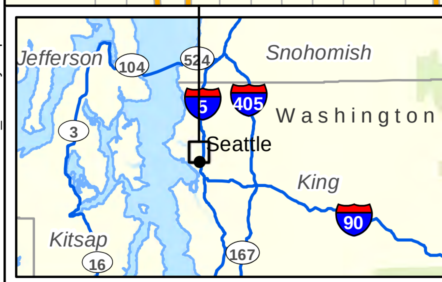
[1]Current Elevation of Approximate Ground Surface

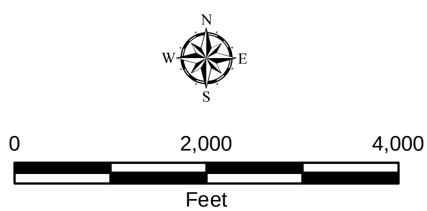
Approx. = Approximate

bgs = below ground surface

GW = Groundwater

FIGURES





Vicinity Map

Gas Works Park Sediment Site
Seattle, Washington
Supplemental Investigation Work Plan

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Figure 1

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

Path: \\seal\projects\0\0186846\GIS\MXD\Phase01\018684601_VicinityMap.mxd

Map Revised: 13 March 2013 amanza

Legend

- Current Monitoring Well
- Impervious Surface
- Buildings and Structures
- Upland DNR Property (Waterway 19)
- Surface Runoff Extent

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

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Site Layout

Gas Works Park Sediment Site
Seattle, Washington
Supplemental Investigation Work Plan

GeoEngineers

2

Path: \\sea\Projects\0\0186846\GIS\MXD\Phase01\018684601_WorkPlan_SiteLayout.mxd Map Revised: 13 February 2013 amanza

Legend

- Historical Railroad Features
- Current Shoreline
- Former MGP Structure
- Former Tar Refinery Footprint

Notes:
1. Reference: Historical structures provided by Floyd|Snider, 2012.
2. Site structures delineated as shown in the General Plan, Lake Station, Seattle Gas Company, April 1949, revised in June 1953, the 1950 Oil Lines, Seattle Gas Co. Map, and a 1956 aerial photograph.
3. Historical railroad features shown as delineated in General Plan, Lake Station, Seattle Gas Co., June 1938.
4. Structure labels shown in *( ) indicate previous MGP operational uses (pre-1946).
5. The locations of all features shown are approximate.
6. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

N W E S

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Historical Structures

Gas Works Park Sediment Site
Seattle, Washington
Supplemental Investigation Work Plan

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3

Path: \\sea\projects\0\0186846\GIS\MXD\Phase01\0186846_01_WorkPlan_HistoricalStructures.mxd   Map Revised: 13 March 2013   amanza

Legend

Cross Section

Upland Symbols

▲ Soil Boring

Monitoring Well

Sediment Symbols

▲ Core

▼ Diver Core

■ SPT

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

N W E S

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Feet

Cross Section Locations

Gas Works Park Sediment Site
Seattle, Washington
Supplemental Investigation Work Plan

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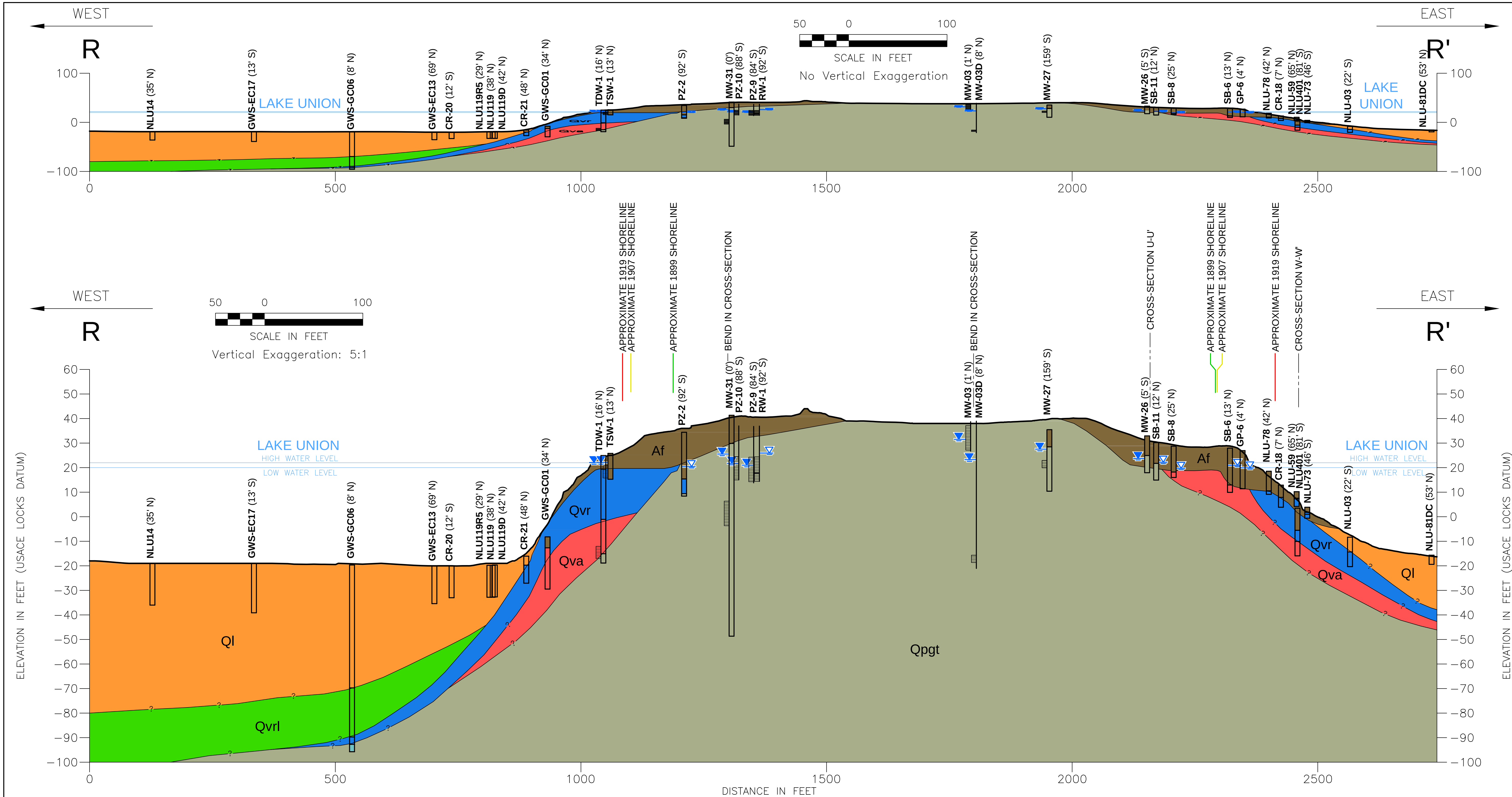
4

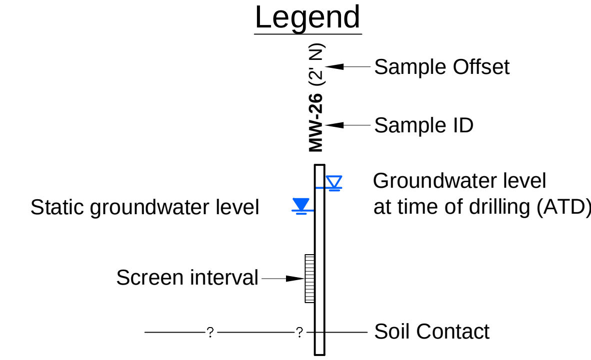
Path: \\sea\projects\0\0186846\GIS\MXD\Phase01\018684601_WorkPlan_CrossSections.mxd Map Revised: 13 March 2013 amanza



Geologic Units

- Af - Fill
- Ql - Recent Lacustrine Deposits
- Qvrl - Vashon Recessional Glaciolacustrine Deposits
- Qvr - Vashon Recessional Outwash (includes Qb)
- Qva - Vashon Advance Outwash
- Qpgt - Pre-Fraser Till (includes Qpgtm [Pre-Fraser Meltout Till], Qpgd [Pre-Fraser Diamict], and Qpgl [Pre-Fraser Glaciolacustrine Deposits])

Legend



Notes
1. Modified from GWSA Tech Team 2011a (Revised Geologic CSM).
2. MW-03 and MW-03D were not used to interpret lithology.
3. The locations of all features shown are approximate.
4. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Geologic Cross-Section R-R'

Gas Works Park Sediment Site
Seattle, Washington
Supplemental Investigation Work Plan

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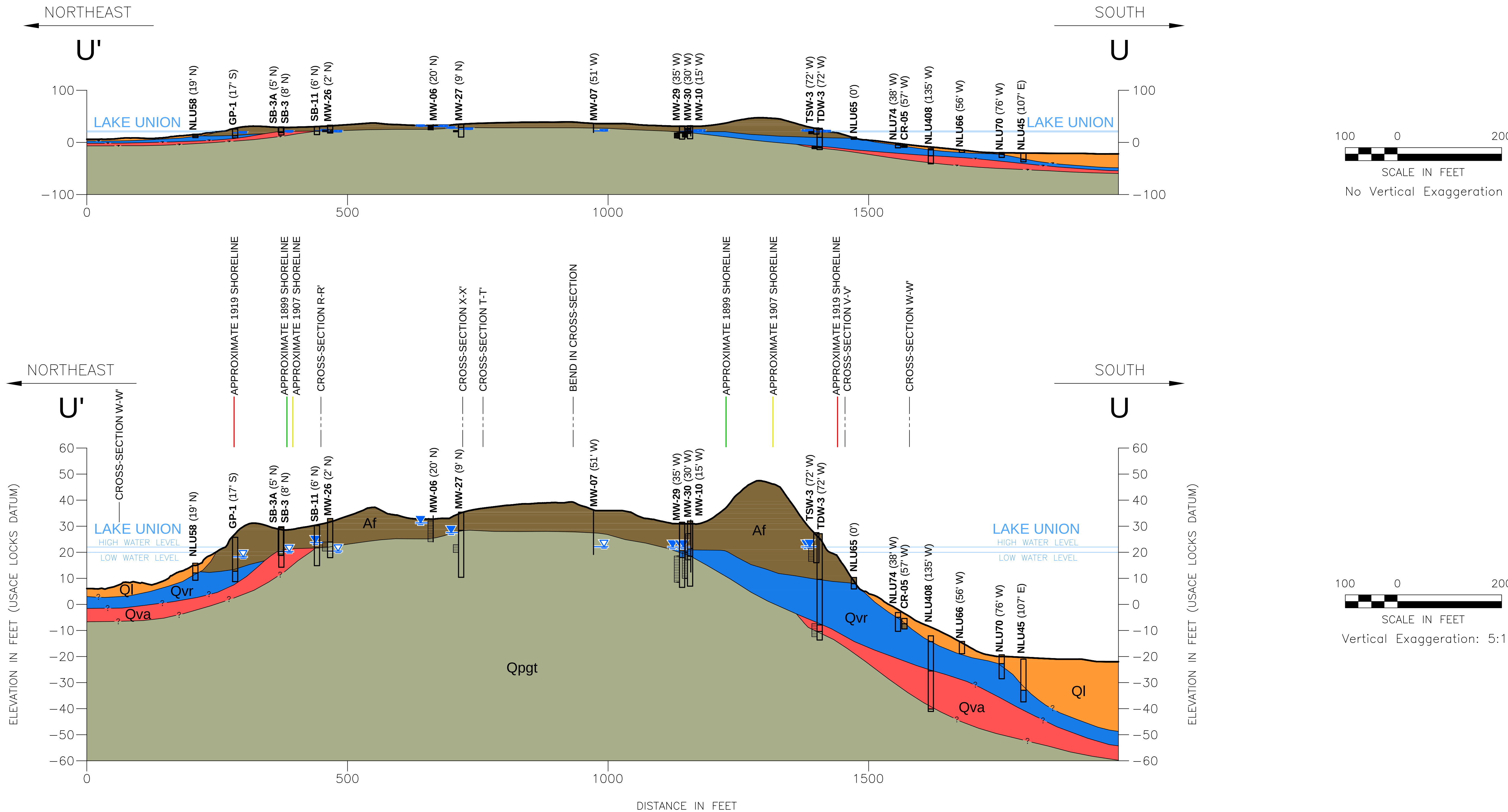
Figure 5

P:\0\0186846\01\CAD\0186864-01 Work Plan Geologic X-Sections R-X.dwg\TAB:R modified by tmichaud on Mar 13, 2013 - 11:02



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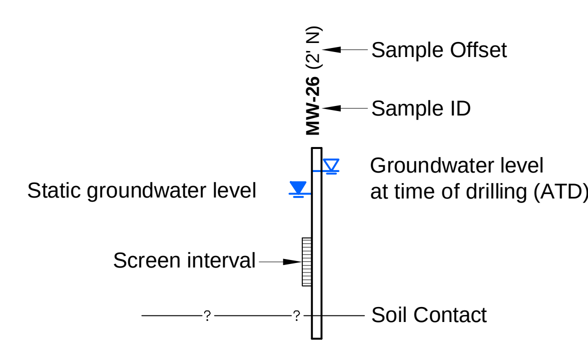

Geologic Units

- Af - Fill
- Ql - Recent Lacustrine Deposits
- Qvr - Vashon Recessional Outwash (includes Qb)
- Qva - Vashon Advance Outwash
- Qpgt - Pre-Fraser Till (includes Qpgtm [Pre-Fraser Meltout Till], Qpgd [Pre-Fraser Diamict], and Qpgl [Pre-Fraser Glaciolacustrine Deposits])

Notes

1. Modified from GWSA Tech Team 2011a (Revised Geologic CSM).
2. MW-10, MW-06, and MW-07 were not used to interpret lithology.
3. The locations of all features shown are approximate.
4. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Geologic Cross-Section U-U'

Gas Works Park Sediment Site
Seattle, Washington
Supplemental Investigation Work Plan

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Figure 6

Legend

- Shallow Exploration
- Exploration Partially Penetrates Fill
- Exploration Fully Penetrates Fill
- Exploration Fully Penetrates Fill and Terminates in Till (Qpgt)
- 1984: Approximate area of tar removal.
- 1997: Approximate area of tar removal.
- 2006-2011: Approximate location of tar removal.
- Engineered Soil Cap
- AS/SVE Impervious Cover

Mapping Rationale:
1. Exploration logs not available for MW-18 to MW-21.
2. TP-11 and TP-12 are in same approximate location as TP-10 (Parametrix, 1998).

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

0 100 200
Feet

Previous Upland Explorations and Remedial Action Areas

Gas Works Park Sediment Site
Seattle, Washington
Supplemental Investigation Work Plan

GEOENGINEERS

7

Path: \\sea\projects\0\0186846\GIS\MXD\Phase01\0186846-01_WorkPlan_PreviousInvestigations.mxd Map Revised: 13 March 2013 amanza

Legend

Date Sampled	Sample Depth (ft)	Benzene Concentration (mg/kg)
4/16/98	8-9.5	1700

No cover since sample collected

Sample location has been covered since collection

U = Not detected at reporting limit

JT = Analyte present but below minimum quantifiable limit

NS = Not specified

Bold = Detected concentration exceeds the current MTCA Method B direct contact soil cleanup level of 18 mg/kg

* = According to Hart Crowser RI, sample location excavated and covered with clean fill

** = According to Hart Crowser RI, sample location reportedly covered with clean soil by City of Seattle in 1985

Mapping Rationale:

1. Based on the 1999 Consent Decree, benzene was not listed as a constituent of concern for soil (just groundwater). For comparison purposes, benzene concentrations are shown relative to the current MTCA Method B direct contact cleanup level of 18 mg/kg.
2. Shaded samples collected prior to 2001 represent soil conditions at the depth indicated before capping and regrading of the site.

N W E S

100 0 100

FEET

Notes

1. Reference: Map prepared from Uplands RI figure provided by Hart Crowser, 2012.
2. Source: Base map prepared from aerial photo by City of Seattle, 2005.
3. The locations of all features shown are approximate.
4. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Benzene Concentrations in Soil Depths 0-3 Feet

Gas Works Park Sediment Site
Seattle, Washington
Supplemental Investigation Work Plan

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Figure 8A

Legend

Date Sampled	Sample Depth (ft)	Naphthalene Concentration (mg/kg)
4/16/98	8-9.5	1200

No cover since sample collected

Sample location has been covered since collection

U = Not detected at reporting limit

ND = Not detected

J = Estimated Value

Bold = Detected concentration exceeds the MTCA Method B direct contact soil cleanup level of 3200 mg/kg referenced in the 1999 Consent Decree

* = According to Hart Crowser RI, sample location excavated and covered with clean fill

** = According to Hart Crowser RI, sample location reportedly covered with clean soil by City of Seattle in 1985

Mapping Rationale:

1. If multiple samples were taken from one location the concentrations are presented as a range from minimum to maximum values for that location.
2. Shaded samples collected prior to 2001 represent soil conditions at the depth indicated before capping and regrading of the site.

N W E S

100 0 100

FEET

Notes

1. Reference: Map prepared from Uplands RI figure provided by Hart Crowser, 2012.
2. Source: Base map prepared from aerial photo by City of Seattle, 2005.
3. The locations of all features shown are approximate.
4. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Naphthalene Concentrations in Soil Depths 0-3 Feet

Gas Works Park Sediment Site
Seattle, Washington
Supplemental Investigation Work Plan

GeoEngineers

Figure 8B

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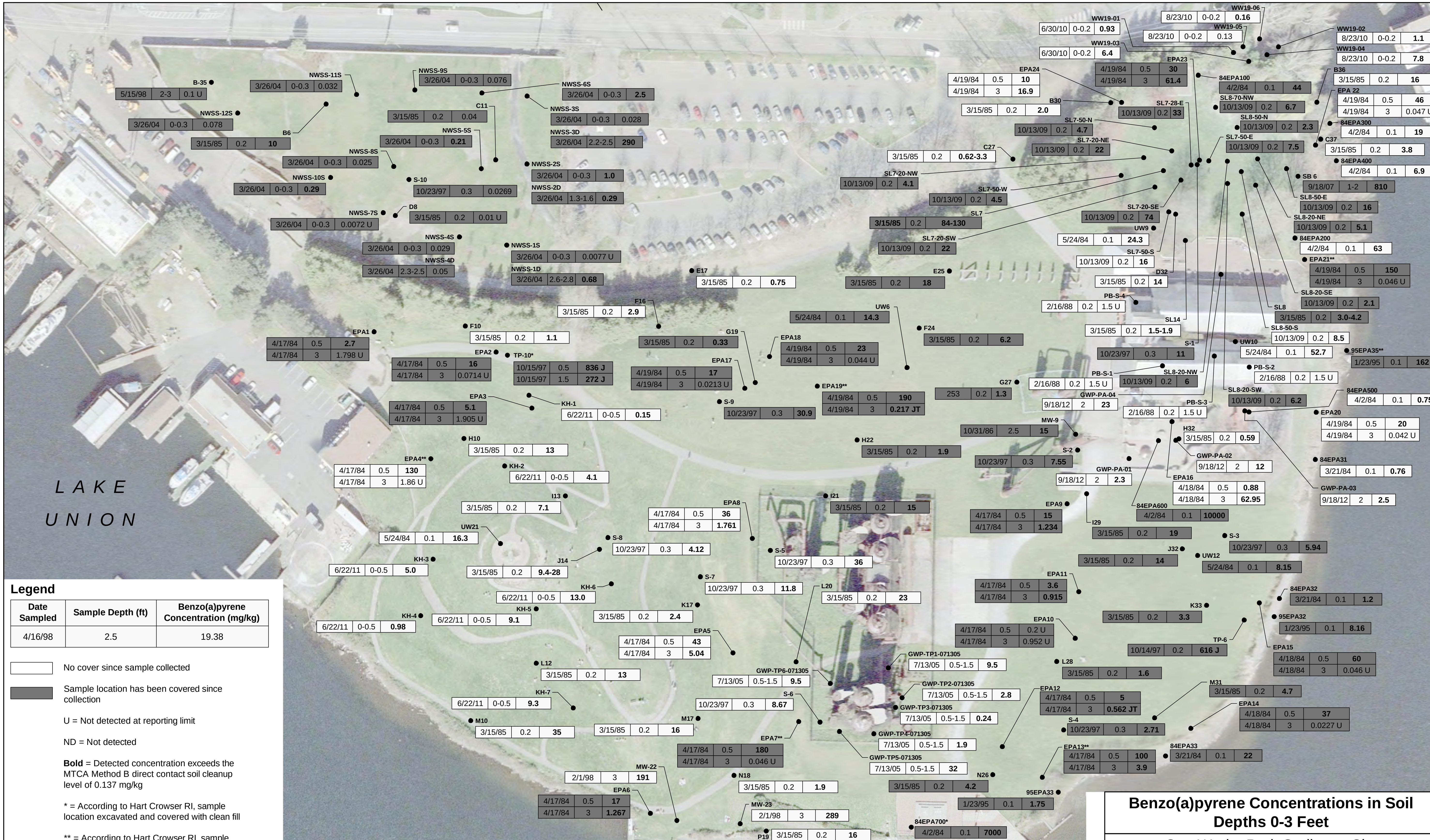

Legend

Date Sampled	Sample Depth (ft)	Benzo(a)pyrene Concentration (mg/kg)
4/16/98	2.5	19.38

No cover since sample collected

Sample location has been covered since collection

U = Not detected at reporting limit

ND = Not detected

Bold = Detected concentration exceeds the MTCA Method B direct contact soil cleanup level of 0.137 mg/kg

* = According to Hart Crowser RI, sample location excavated and covered with clean fill

** = According to Hart Crowser RI, sample location reportedly covered with clean soil by City of Seattle in 1985

Mapping Rationale:

1. If multiple samples were taken from one location the concentrations are presented as a range from minimum to maximum values for that location.
2. Shaded samples collected prior to 2001 represent soil conditions at the depth indicated before capping and regrading of the site.

Notes

1. Reference: Map prepared from Uplands RI figure provided by Hart Crowser, 2012.
2. Source: Base map prepared from aerial photo by City of Seattle, 2005.
3. The locations of all features shown are approximate.
4. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Benzo(a)pyrene Concentrations in Soil Depths 0-3 Feet

Gas Works Park Sediment Site
Seattle, Washington
Supplemental Investigation Work Plan

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Figure 8C

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Legend

Date Sampled	Sample Depth (ft)	Arsenic Concentration (mg/kg)
4/16/98	3	7

No cover since sample collected

Sample location has been covered since collection

U = Not detected at reporting limit

Bold = Detected concentration exceeds the MTCA soil cleanup level of 20 mg/kg

** = According to Hart Crowser RI, sample location reportedly covered with clean soil by City of Seattle in 1985

Mapping Rationale:

1. Shaded samples collected prior to 2001 represent soil conditions at the depth indicated before capping and regrading of the site.

N W E S

100 0 100

FEET

Notes

1. Reference: Map prepared from Uplands RI figure provided by Hart Crowser, 2012.
2. Source: Base map prepared from aerial photo by City of Seattle, 2005.
3. The locations of all features shown are approximate.
4. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Arsenic Concentrations in Soil Depths 0-3 Feet

Gas Works Park Sediment Site
Seattle, Washington
Supplemental Investigation Work Plan

GEOENGINEERS

Figure 8D

P:\0\0186864\01\CAD\0186864-01 Fig 8D.dwg\TAB:11x17 - H modified by tmichaud on Mar 13, 2013 - 11:14

Legend

Date Sampled	Sample Depth (ft)	Benzene Concentration (mg/kg)
4/16/98	8-9.5	1700

Sample location remediated since collection

U = Not detected at reporting limit

JT = Analyte present but below minimum quantifiable limit

Bold = Detected concentration exceeds the current MTCA Method B direct contact soil cleanup level of 18 mg/kg

Mapping Rationale:

1. Based on the 1999 Consent Decree, benzene was not listed as a constituent of concern for soil (just groundwater). For comparison purposes, benzene concentrations are shown relative to the current MTCA Method B direct contact cleanup level of 18 mg/kg.
2. Samples collected prior to 2001 represent soil conditions at the depth indicated before capping and regrading of the site.

Notes

1. Reference: Map prepared from Uplands RI figure provided by Hart Crowser, 2012.
2. Source: Base map prepared from aerial photo by City of Seattle, 2005.
3. The locations of all features shown are approximate.
4. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Benzene Concentrations in Soil Depths 3+ Feet

Gas Works Park Sediment Site
Seattle, Washington
Supplemental Investigation Work Plan

GEOENGINEERS

Figure 9A

P:\01\0186846\01\CAD\0186864-01 Fig 9A.dwg\TAB:11x17 - H Modified by THichaud on Mar 13, 2013 - 11:15

Legend

Date Sampled	Sample Depth (ft)	Naphthalene Concentration (mg/kg)
4/16/98	8-9.5	1200

U = Not detected at reporting limit

ND = Not Detected

T = Value is between the MDL and the RL

J = Estimated value

Bold = Detected concentration exceeds the MTCA Method B direct contact soil cleanup level of 3200 mg/kg referenced in the 1999 Consent Decree

Mapping Rationale:

1. Samples collected prior to 2001 represent soil conditions at the depth indicated before capping and regrading of the site.

N
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FEET

Notes

1. Reference: Map prepared from Uplands RI figure provided by Hart Crowser, 2012.
2. Source: Base map prepared from aerial photo by City of Seattle, 2005.
3. The locations of all features shown are approximate.
4. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Naphthalene Concentrations in Soil Depths 3+ Feet

Gas Works Park Sediment Site
Seattle, Washington
Supplemental Investigation Work Plan

GEOENGINEERS

Figure 9B

P:\0\0186864\01\CAD\0186864-01 Fig 9B.dwg\TAB:11x17 - H modified by tmichaud on Mar 13, 2013 - 11:19

Legend

Date Sampled	Sample Depth (ft)	Benzo(a)pyrene Concentration (mg/kg)
9/19/07	10-11.5	1.5

U = Not detected at reporting limit

ND = Not detected

J = Estimated value

Bold = Detected concentration exceeds the MTCA Method B direct contact soil cleanup level of 0.137 mg/kg

Mapping Rationale:

1. Samples collected prior to 2001 represent soil conditions at the depth indicated before capping and regrading of the site.

N W E S

100 0 100

FEET

Notes

1. Reference: Map prepared from Uplands RI figure provided by Hart Crowser, 2012.
2. Source: Base map prepared from aerial photo by City of Seattle, 2005.
3. The locations of all features shown are approximate.
4. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Benzo(a)pyrene Concentrations in Soil Depths 3+ Feet

Gas Works Park Sediment Site
Seattle, Washington
Supplemental Investigation Work Plan

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Figure 9C

P:\0\0186864\01\CAD\0186864-01 Fig 9C.dwg\TAB:11x17 - H modified by tmichaud on Mar 13, 2013 - 11:23

Legend

Date Sampled	Sample Depth (ft)	Arsenic Concentration (mg/kg)
4/16/98	3	7

Bold = Detected concentration exceeds the MTCA soil cleanup level of 20 mg/kg

U = Not detected at reporting limit

Mapping Rationale:

1. Samples collected prior to 2001 represent soil conditions at the depth indicated before capping and regrading of the site.

N W E S

100 0 100

FEET

Notes

1. Reference: Map prepared from Uplands RI figure provided by Hart Crowser, 2012.
2. Source: Base map prepared from aerial photo by City of Seattle, 2005.
3. The locations of all features shown are approximate.
4. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Arsenic Concentrations in Soil Depths 3+ Feet

Gas Works Park Sediment Site
Seattle, Washington
Supplemental Investigation Work Plan

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Figure 9D

P:\0\0186846\01\CAD\0186864-01 Fig 9D.dwg\TAB:11x17 - H modified by tmichaud on Mar 13, 2013 - 11:26

Legend

NAPL Occurrence

- Tar.
- Heavy sheen with NAPL.
- Heavy sheen and/or trace NAPL.
- Slight to moderate sheen.
- Staining and/or odor.
- No impacts.
- Conceptual Extent of LNAPL
- Conceptual Extent of DNAPL
- Observations of Contiguous Near-surface Tar

NAPL Line Type

- Inferred Lateral Extent of Multiple Location NAPL or Tar in Sediment
- Estimated Lateral Extent of Multiple Location NAPL or Tar in Uplands
- Estimated Lateral Extent of Multiple Location NAPL or Tar in Sediment
- Air Sparging System
- Site Boundary
- Approximate 1907 Shoreline
- Shoreline

Mapping Rationale:
1. Where both Tar and Heavy Sheen with NAPL were observed in an exploration, the exploration is shown as Tar-impacted.
2. Mapping intends to show areas where Tar or NAPL have been interpreted to exist at multiple adjacent sample locations.

Notes:
1. Modified from figure provided by Floyd|Snider, 2012.
2. NAPL data presented in this figure was sourced from a table jointly produced by Floyd|Snider and GeoEngineers.
3. Observations of contiguous near-surface tar in the offshore delineated by diver probe.
4. The 1907 shoreline shown as delineated in the Plat of Lake Union Shore Lands, 1907.
5. The locations of all features shown are approximate.
6. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

N S E W

0 125 250
Feet

Conceptual Extent of NAPL and Tar

Gas Works Park Sediment Site
Seattle, Washington
Supplemental Investigation Work Plan

GeoEngineers

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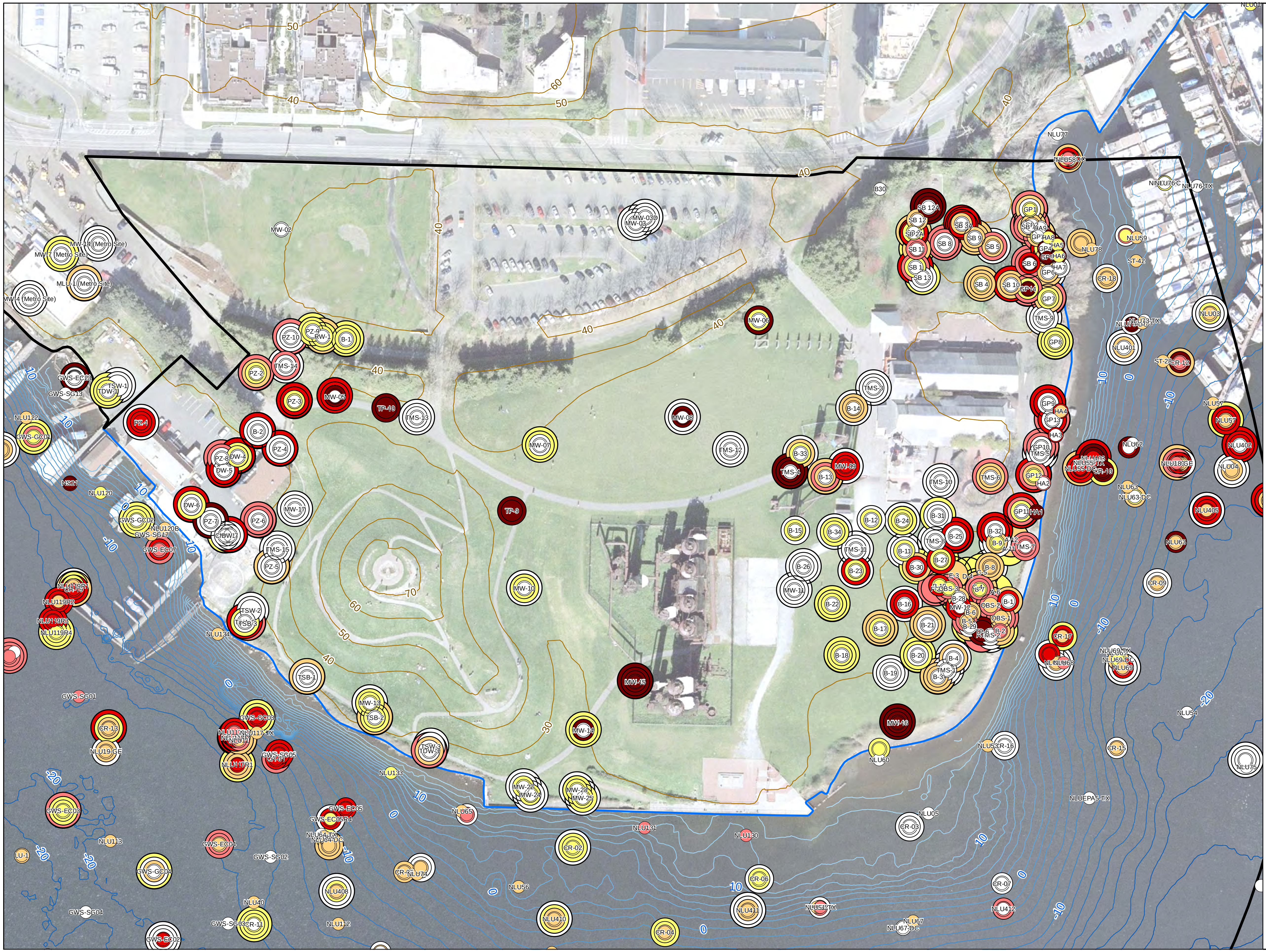
Path: \\seal\projects\0\0186846\GIS\MXD\Phase01\0186846 01_WorkPlan_FS_ConceptualExtent_NAPL_Tar.mxd Map Revised: 13 March 2013 amanza



Legend

NAPL Occurrence

- Tar.
- Heavy sheen with NAPL.
- Heavy sheen and/or trace NAPL.
- Slight to moderate sheen.
- Staining and/or odor.
- No impacts.

Data Depth Intervals:

- 0 - 0.5 ft. Below Mudline/Ground Surface
- 0.5 - 3.0 ft. Below Mudline/Ground Surface
- 3.0 - 6.0 ft. Below Mudline/Ground Surface
- 6.0 - 10.0 ft. Below Mudline/Ground Surface
- 10 - 100 ft. Below Mudline/Ground Surface

- Bathymetric Contour (ft, USACE Locks Datum)
- Topographic Contour (ft, USACE Locks Datum)
- Site Boundary
- Shoreline

Mapping Rationale:

1. Drawing order is from shallow to deep, such that symbols belonging to shallower intervals overlie symbols belonging to deeper intervals. The query statements will allow for the same sample to occur in more than one interval but the drawing order will ensure that the shallower occurance of that sample will take precedence.
2. Symbol levels have been assigned to the samples captured by the query language for each interval such that the following drawing hierarchy is maintained within each interval:
   Tar
   Heavy sheen with NAPL
   Heavy sheen and/or trace NAPL
   Slight to moderate sheen
   Staining and/or odor
   No impacts

Notes:

1. Modified from figure provided by Floyd|Snider, 2012.
2. NAPL data presented in this figure was sourced from a table jointly produced by the City of Seattle and Puget Sound Energy, transmitted to Ecology in March 2010.
3. The locations of all features shown are approximate.
4. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

N W E S

0 125 250
Feet

NAPL Occurrence Map

Gas Works Park Sediment Site
Seattle, Washington
Supplemental Investigation Work Plan

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Path: \\seal\projects\0\0186846\GIS\MXD\Phase01\018684601_WorkPlan_FS_NAPL_Occurrence.mxd Map Revised: 13 March 2013 amanza

Legend

- Building or Structure
- Impervious Surface
- AS/SVE Impervious Cover
- Proposed Area of Magnetic and Electromagnetic Survey
- Former MGP Structure
- Former Tar Refinery Footprint

Notes:
1. Reference: Historical structures provided by Floyd|Snider, 2012.
2. Site structures delineated as shown in the General Plan, Lake Station, Seattle Gas Company, April 1949, revised in June 1953, the 1950 Oil Lines, Seattle Gas Co. Map, and a 1956 aerial photograph.
3. Historical railroad features shown as delineated in General Plan, Lake Station, Seattle Gas Co., June 1938.
3. The locations of all features shown are approximate.
4. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

N W E S

0 100 200
Feet

Proposed Geophysical Survey Area

Gas Works Park Sediment Site
Seattle, Washington
Supplemental Investigation Work Plan

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Path: \\sea\projects\0\0186846\GIS\MXD\Phase01\018684601_WorkPlan_GeophysicalSurvey.mxd Map Revised: 13 March 2013 amanza

Legend

AS/SVE Impervious Cover
Conceptual Extent of LNAPL
Conceptual Extent of DNAPL
Observations of Contiguous Near-surface Tar

NAPL Line Type

Inferred Lateral Extent of Multiple Location NAPL in Sediment
Estimated Lateral Extent of Multiple Location NAPL in Uplands
Estimated Lateral Extent of Multiple Location NAPL in Sediment

Proposed Exploration Locations

Proposed Soil Boring
Proposed Geotechnical Boring
Proposed TarGOST Exploration
TarGOST Target Area

Previous Deep Explorations

Deep Exploration: Exploration Fully Penetrates Fill
Deep Exploration: Exploration Fully Penetrates Fill and Terminates in Till (Qpgt)

Mapping Rationale:

1. NAPL extent mapping intends to show areas where NAPL has been interpreted to exist at multiple adjacent sample locations.

Notes:

1. MLS = multi-level sampler.
2. * Soil boring will be completed following approval from Washington State Department of Archaeology and Historical Preservation.
3. The locations of all features shown are approximate.
4. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

0 100 200
Feet

Proposed Soil Borings and TarGOST Exploration Areas

Gas Works Park Sediment Site
Seattle, Washington
Supplemental Investigation Work Plan

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Path: \\sea\projects\0\0186846\GIS\MXD\Phase01\018684601_WorkPlan_ProposedSoilBoring_TarGOST.mxd Map Revised: 13 March 2013 amanza

Legend

- AS/SVE Impervious Cover
- Conceptual Extent of LNAPL
- Conceptual Extent of DNAPL
- Observations of Contiguous Near-surface Tar

NAPL Line Type

- Inferred Lateral Extent of Multiple Location NAPL in Sediment
- Estimated Lateral Extent of Multiple Location NAPL in Uplands
- Estimated Lateral Extent of Multiple Location NAPL in Sediment

Proposed Exploration Locations

- Existing Monitoring Well
- Existing Monitoring Well to be Sampled (initial sampling)
- Proposed Monitoring Well

Previous Deep Explorations

- Deep Exploration: Exploration Fully Penetrates Fill
- Deep Exploration: Exploration Fully Penetrates Fill and Terminates in Till (Qpgt)

Mapping Rationale:
1. NAPL extent mapping intends to show areas where NAPL has been interpreted to exist at multiple adjacent sample locations.
2. Some existing monitoring wells are not proposed for sampling due to history of NAPL in well.

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

Proposed Monitoring Wells

Gas Works Park Sediment Site
Seattle, Washington
Supplemental Investigation Work Plan

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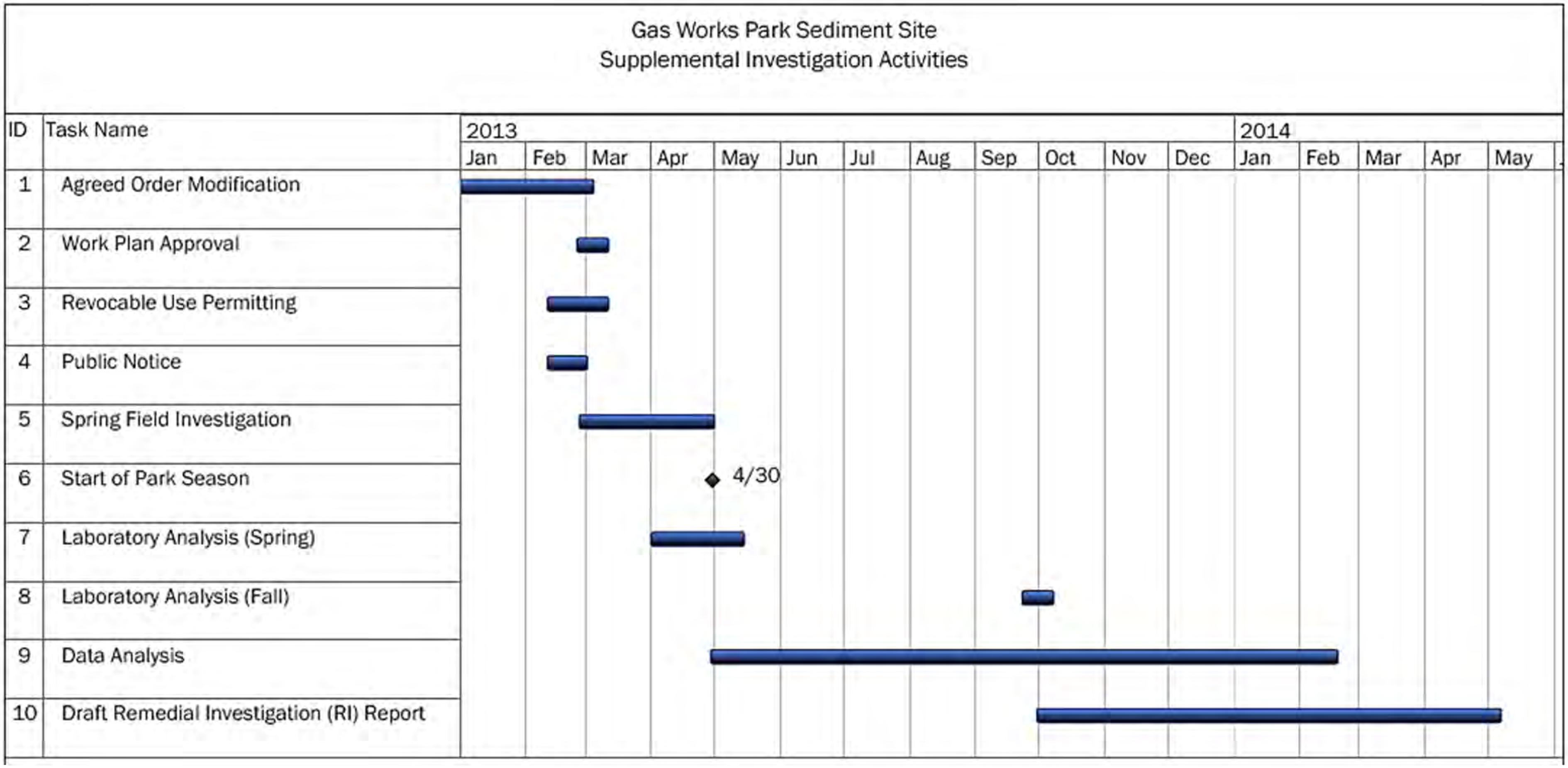
Path: \\seal\projects\0\0186846\GIS\MXD\Phase01\018684601_WorkPlan_ProposedMonitoringWells.mxd   Map Revised: 13 March 2013   amanza https://projects.geoengineers.com/sites/0018684600/Draft/Upland%20Work%20Plan/Work%20Plan%20Figures CD 02/25/13



Notes:

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

Schedule

Gas Works Park Sediment Site
Seattle, Washington
Supplemental Investigation Work Plan

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Figure 15

APPENDICES

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APPENDIX A
Sampling and Analysis Plan

Appendix A
Sampling and Analysis Plan

Supplemental Upland Investigation
Gas Works Park Site
Seattle, Washington

for
Puget Sound Energy

March 13, 2013

GeoEngineers

Plaza 600 Building
600 Stewart Street, Suite 1700
Seattle, Washington 98101
206.728.2674

Table of Contents

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

This Sampling and Analysis Plan (SAP) describes the investigation methods that will be used to implement the Work Plan for Supplemental Investigation (Work Plan) for the Gas Works Park Sediment Site (GWPSS or Site) (Figure A-1). The planned sampling activities will supplement existing data and information from previous environmental investigations. These data will be used to evaluate uplands impacts on sediments and support completion of a site-wide remedial investigation and feasibility study for the expanded Gas Works Park Sediment Site (GWPSS). This SAP has been prepared in general accordance with the Model Toxics Control Act (MTCA), Chapter 173-340-820 of the Washington Administrative Code.

The purpose of the SAP is to define the specific requirements for sample collection and analytical activities for soil, groundwater, and non-aqueous phase liquid (NAPL), and to ensure they are conducted in accordance with technically acceptable protocols such that results meet data quality objectives.

The supplemental investigation will be conducted in accordance with the Work Plan and its appendices including this SAP (Appendix A), Quality Assurance Project Plan (QAPP, Appendix B), and Health and Safety Plan (HASP, Appendix C). This SAP provides a basis for conducting upland field activities and a mechanism for complying with quality assurance requirements.

2.0 OVERALL INVESTIGATION DESIGN

The supplemental investigation will be completed as described in the Work Plan. General work elements include:

- Monitoring well survey,
- Geophysical surveys,
- TarGOST® Laser Induced Fluorescence (LIF) exploration (TarGOST®),
- Soil borings and soil sampling for chemical analysis,
- Ultraviolet light photography and petrophysical testing,
- Soil borings and soil sampling for geotechnical testing,
- Monitoring well installation,
- Initial groundwater monitoring,
- Aquifer testing,
- NAPL testing (if sufficient NAPL is available) and
- Groundwater monitoring (1 round of sampling).

Proposed investigation locations are illustrated on Figures A-2 through A-4. A summary of proposed activities and sample locations is presented in Table A-1. Where applicable, investigation elements described in this SAP will be performed in general accordance with Ecology Publication Number 94-49, Guidance on Sampling and Data Analysis Methods dated January 1995.

2.1. Investigation Flow

The proposed investigation activities at GWPSS have been designed to be modifiable based on the results of previous investigation elements. Geophysical surveys will be performed early in the investigation, so that the results of the surveys can be evaluated to refine subsequent investigation activities to meet project objectives. The TarGOST® exploration program will provide real-time data that will be evaluated in the field so that data from initial TarGOST® probing locations in a target area will be used to select subsequent TarGOST® probing locations in that area. The results of the geophysical survey and TarGOST® explorations, will be used to modify the locations of proposed monitoring wells and soil borings to focus these explorations to achieve the project objectives. As a result, soil borings will be drilled and monitoring wells will be installed after the results of these initial surveys and explorations have been evaluated.

The monitoring well survey may be performed before or concurrently with the geophysical survey and TarGOST® probing.

2.2. Investigation Numbering System

2.2.1. TarGOST® Exploration Numbers

Each TarGOST® exploration number will begin with TG, to differentiate these explorations from proposed borings for soil sampling, and from soil borings or samples previously obtained from the GWPSS. Each TarGOST® exploration location will be sequentially numbered as the investigation progresses. Single digit numbers preceded by a leading zero will be used for the numeric portion of the boring number. So, the first TarGOST® boring will be designated TG-01, the second TarGOST® boring will be designated TG-02, and so on.

2.2.2. Soil Boring and Sample Numbers

Soil samples for chemical analysis will be assigned a unique sample identifier that will include the following components.

- Each soil boring number will begin with GEI (GeoEngineers, Inc.), to differentiate proposed borings from the numerous borings previously drilled on the GWPSS.
- Each soil boring number will have a sequential number, beginning with one (1). Single digit numbers will be preceded by a leading zero.
- Following the soil boring number, the depth of the sample (in feet, preceded by one leading zero) will be included.

For example, a soil sample collected from 6 to 8 feet below ground surface (bgs) from the first boring will be numbered GEI01-06-08.

For soil samples collected from soil borings drilled for monitoring well installation, the soil boring and sample number will consist of the following components:

- The soil boring number will begin with MW to correspond to the proposed monitoring well. The monitoring wells will be numbered beginning with MW-32 to continue the primary numbering system. An S or D is included in the monitoring well number to designate whether the well is considered shallow or deep.
- The alpha-numeric portion of the soil boring number will correspond to the monitoring well number.
- Following the monitoring well number, the depth of the sample (in feet, preceded by one leading zero), will be included.

For example, a soil sample collected from 2 to 4 feet below ground surface from the boring for monitoring well MW-32S would be numbered MW32S-02-04.

The sample number will be placed on the sample label, Field Report form, and Chain of Custody form.

2.2.3. Groundwater Sample Numbers

The groundwater samples collected from monitoring wells will be assigned a unique sample number that will include the components listed below.

- The monitoring well prefix which will consist of MW for proposed monitoring wells and the existing monitoring wells' prefix for previously installed monitoring wells,
- The well number, and
- The date in the YYMMDD format.

For example, the groundwater sample collected from monitoring well TDW-2 on March 10, 2013, would be numbered TDW2-130310. If a sample of nonaqueous phase liquid is collected from a monitoring well, the same sample numbering will be used, and will be supplemented with either a –LNAPL or –DNAPL suffix. The sample identification number will be recorded in the field notes, on the sample label and on the Chain of Custody form.

3.0 FIELD METHODOLOGY

The following sections summarize procedures for implementing the planned field activities. Planned sampling and analysis requirements are summarized in Table A-1.

3.1. Permit Requirements

A "Revocable Permit to Use or Occupy Park Property" (RUP) is required by Seattle Department of Parks and Recreation before performing many of the proposed investigation activities at the Park. The RUP will be obtained before intrusive investigations are performed at the Park.

Based on conversations with the Parks Department, a RUP is not required for non-intrusive planned activities including geophysical surveys, monitoring well survey, groundwater monitoring, and aquifer or NAPL testing. However, these field activities are explained in the RUP application, and will be coordinated with the Parks Department.

3.2. Underground Utilities Clearance

Before beginning intrusive activities, such as drilling or probing, exploration locations will be evaluated, and modified if necessary based on results from the geophysical survey. Exploration locations will then be marked in the field using white marking paint. At least one week before drilling, GeoEngineers will meet with Parks Department staff on site to review and mark utilities based on the City's maps/utility plans. Utilities to be identified include natural gas, electric power, water, sewer, and irrigation lines. In addition, a One-Call and private utility locate will be arranged by GeoEngineers after meeting in the field with Parks Department staff and before drilling. Hand auger or hand excavation methods will be used to approximately 2 feet below ground surface at each location before drilling to minimize the potential for encountering unmarked utilities.

3.3. Monitoring Well Survey

A monitoring well survey will be performed to identify current, usable, monitoring wells on the GWPSS, and to evaluate their condition before being sampled. Up to 40 monitoring wells and 7 multi-level sampler locations may be present on site. Current monitoring wells and the location, construction, and groundwater information at each monitoring well are listed in Work Plan Table 2 and shown on Figure A-4. The monitoring well survey will include the following activities:

- Wells will be located using site maps and GPS and coordinates. Unless already marked, each monitoring well located will be marked with the monitoring well number, photographed relative to surroundings, and the location recorded on a GPS unit. GPS surveying procedures are presented in Section 3.14.1.
- Inspecting the condition of each monitoring well by visually observing the monitoring well completion and the condition of the monitoring well riser at the ground surface
- Testing for the presence of both LNAPL and DNAPL using an oil/water interface probe or similar device in each monitoring well, as summarized in Section 3.12.2.
- Measuring the depth to ground water and total depth in each monitoring well, as summarized in Section 3.12.1.
- Collecting a sample of NAPL if it can be recovered and submitting for testing, as discussed in Section 3.12.4.

Monitoring wells requiring repair will be noted, and the necessary repairs will be performed by field crews or a licensed well driller, as appropriate and depending on the nature of the repair. Repairs to monitoring wells will be performed before initial groundwater monitoring is performed. Monitoring wells considered not repairable or unusable will be abandoned according to State regulations.

3.4. Geophysical Surveys

The areas proposed for non-intrusive surface geophysical surveys are presented on Figure A-2. Proposed geophysical methods include magnetometer and electromagnetic conductivity surveys. The information obtained during the geophysical surveys will be used to target soil borings in those areas where potential buried manufactured gas plant structures may exist and also provide information regarding areas to avoid, such as active storm drains or utilities, with intrusive explorations.

Geophysical surveys will be performed by an experienced geophysical subconsultant using industry-accepted protocols for these types of surveys. A 10-foot spacing between traverses is proposed for the 5.5-acre area.

3.5. TarGOST® Laser Induced Fluorescence Probing

The TarGOST® system uses a laser-induced fluorescence probe that is advanced into the subsurface using direct push technology (DPT), such as a GeoProbe®. The result of a TarGOST® investigation is a graphical representation of the fluorescence of PAHs in the soil, indicating the potential presence of NAPL.

The objective of TarGOST® explorations is to evaluate selected exploration locations and target areas (Figure A-3) where LNAPL, DNAPL, or tar have been encountered to further delineate the upland extent of these substances and in areas where there are potential sources of NAPL and insufficient subsurface data. TarGOST® probing at these selected locations or target areas will provide qualitative data to support refinement of the conceptual site model and inform decisions for further soil exploration including soil borings, soil samples for chemical analysis, and monitoring well locations. In general, for each TarGOST® exploration target area, the field team will begin with TarGOST® probing at the location(s) where LNAPL, DNAPL, or tar have been encountered or where probings are considered most likely to encounter LNAPL, DNAPL, or tar based on existing information. These are defined as the first priority locations. Based on the real-time results of the TarGOST® probings, additional TarGOST® probings may be performed to evaluate the lateral extent of NAPL or tar in each area.

The TarGOST® exploration program will be limited to five working days (estimated 30 to 40 TarGOST® probings), because of to the rigid scheduling requirements of the TarGOST® equipment, and prioritized in the following order.

- First priority probings will be located near the areas of known NAPL or tar impacts that require additional delineation. These exploration locations include proposed TarGOST® probing locations in the northeast corner and Harbor Patrol, and NAPL identified in boring MW-15, boring MW-16, and boring MW-09. Additional locations will be stepped-out to attempt to delineate the lateral extent of NAPL in these locations.
- Second priority locations include areas where suspected NAPL sources exist, based on limited subsurface data. In these locations, the investigation approach will consist of reconnaissance at wider spacing and investigation of potential NAPL source targets, and step-out/fill-in explorations as necessary to delineate the lateral extent of NAPL or tar.

The TarGOST® probe will be advanced using a GeoProbe® drill rig. The probe will be advanced from the surface to approximately 10 to 40 feet below ground surface depending on the location. In general, TarGOST® probing will be advanced through the fill unit and at least three feet below the deepest NAPL response or where the probe hits refusal, whichever is shallower. Table 6 in the Work Plan provides the specific rationale and approximate depths for TarGOST® probing for each exploration target area. Dakota Technologies will be onsite to provide setup and calibration of the TarGOST® instrumentation and real-time results from the TarGOST® probing activities.

TarGOST® field confirmation will be conducted at approximately 10 percent of the TarGOST® probe locations by advancing direct push probe soil cores and collecting samples. These direct push soil cores will be located within approximately 1 to 2 feet of TarGOST® probe locations and will be used to visually observe the presence of NAPL and soil lithology. Some of these soil cores may also be submitted for petrophysical testing.

3.6. Borehole Drilling and Lithologic Logging

Soil borings will be drilled for the following purposes:

- Monitoring well installation,
- To collect soil samples for visual observation, field screening, and chemical analyses,
- To collect soil samples for soil physical properties testing to support geotechnical evaluations, and
- To collect soil samples for petrophysical testing.

Drilling methods anticipated to be used include direct push, hollow stem auger, mud rotary, and sonic rotary (sonic) drilling methods. Drilling activities will conform to State and local regulations including WAC 173-160, Minimum Standards for Construction and Maintenance of Wells.

The drill rig will be visually inspected by the field geologist or engineer before drilling activities begin to confirm that it has been cleaned before entering the GWPSS, to prevent potential cross-contamination from other sites. Any fluid leaks found on the drill rig will be repaired before starting or resuming drilling activities.

Management of investigation-derived waste (IDW) generated during drilling is discussed in Section 3.17.

3.6.1. Direct Push Borings

The direct push boring method will be used to obtain soil samples from each soil exploration location where other drilling methods are not required. The direct push boring method will use four-foot long hydraulically driven rods lined with a disposable acetate sleeve. Lithologic logging and field screening will be conducted on the recovered soil and recorded on the boring logs. Soil samples will be obtained as summarized in Table A-1. Soil samples to be submitted for chemical analysis will be removed from the acetate sleeve and placed into laboratory-supplied containers.

3.6.2. Hollow Stem Auger Borings

The hollow stem auger borings will be drilled to obtain soil core samples for ultraviolet photography and petrophysical testing and at other potential locations as considered necessary by the field team. Soil samples will be collected from the hollow stem borings using a decontaminated split-barrel sampler. Lithologic logging and field screening will be conducted and recorded in the boring logs. The split-barrel sampler (SPT or Dames and Moore) will be driven into soil by a 140 pound or

300-pound hammer falling a vertical distance of approximately 30 inches. The number of hammer blows required to advance the sampler the final 18 inches will be recorded on the boring logs.

Reusable equipment used to obtain soil samples (e.g., split-barrel samplers) will be decontaminated as described in Section 3.15.

3.6.3. Mud Rotary Borings

The mud rotary drilling method advances the boring by rotating steel drilling rods attached to a rotary bit into the ground. Drilling fluid consisting of water and bentonite is circulated down through the drilling rod and up through the boring to remove the soil cuttings and maintain hydraulic pressure in the borehole. Soil samples are collected by removing the rotary bit from the rods, replacing it with a soil sampler (SPT or Dames and Moore), and driving the sampler as discussed in Section 3.6.2.

3.6.4. Sonic Borings

The sonic rotary (sonic) drilling method advances the boring by vibrating a steel casing and an internal sample barrel into the ground. Sonic drilling will provide a continuous sample representative of subsurface conditions by advancing an inner sample barrel into the formation ahead of the casing. The core is then extruded from the sample barrel for logging and storage.

3.7. Field Screening

Soil samples will be field-screened for evidence of possible chemical impacts. Field screening methods that may be used and documented: (1) visual and olfactory screening, (2) NAPL shake test screening (3) visual NAPL sheen screening, and (4) headspace vapor screening. Field screening results will be recorded on the field logs and the results will be used as a general guideline to identify areas of possible chemical impacts and select locations of soil samples for chemical analysis. Screening results will be used with other information to support selection of soil samples that will be submitted for chemical analysis.

3.7.1. Visual and Olfactory Screening

Indications of chemical impacts including odors, color or staining, or the presence of tar or NAPL that may be indicative of contamination will be noted on the boring and field logs.

3.7.2. NAPL Shake Test Screening

NAPL shake testing will be performed on select samples where NAPL is suspected or observed to evaluate the presence, nature (i.e., DNAPL or LNAPL), and amount of NAPL present. A small volume of soil (5-10 grams) is removed from the sampler and placed in a small glass vial (typical VOA). Water is added to fill the vial approximately 2/3 full. The vial is vigorously shaken until NAPL that may be present is displaced from the core matrix. The vial with the soil/NAPL/water solution is observed and recorded on the field log for each sample/location as to whether the oil is DNAPL or LNAPL. If possible, the vial may be retained for later observation.

3.7.3. NAPL Sheen Screening

Water sheen screening is a qualitative field screening method that can help identify the presence or absence of NAPL. A portion of the soil sample will be placed in a pan containing distilled water. The water surface will be observed for signs of sheen. The following sheen classifications will be used:

Identifier	Description
No Sheen (NS)	No visible sheen on the water surface
Slight Sheen (SS)	Light, colorless, dull sheen; spread is irregular, not rapid; sheen dissipates rapidly
Moderate Sheen (MS)	Light to heavy sheen; may have some color/iridescence; spread is irregular to flowing, may be rapid; few remaining areas of no sheen on the water surface
Heavy Sheen (HS)	Heavy sheen with color/iridescence; spread is rapid; entire water surface may be covered with sheen

3.7.4. Headspace Vapor Screening

Headspace vapor screening can help identify the presence or absence of volatile chemicals. As soon as possible after collecting a soil sample, a portion of the sample will be placed in a re-sealable plastic bag for headspace vapor screening. Ambient air is captured in the bag; the bag is sealed, left for approximately 5 minutes, and then gently shaken or crushed for approximately 10 seconds to expose the soil to the air trapped in the bag. Vapors present within the sample bag's headspace are measured by inserting the probe of a photoionization detector (PID) through a small opening in the bag or piercing the bag with the probe. A PID measures the concentration of organic vapors ionizable by a 10.6 electron volt lamp (standard) in parts per million (ppm) and quantifies organic vapor concentrations in the range between 0.1 ppm and 2,000 ppm (isobutylene-equivalent) with an accuracy of 1 ppm between 0 ppm and 100 ppm. The maximum ppm value will be recorded on the field report for each sample screened. The PID will be calibrated to 100 ppm isobutylene.

3.8. Soil Sampling

Soil samples will be collected for lithologic logging, field screening, chemical analysis, UV photography, and petrophysical testing. Proposed soil sampling locations, frequencies, and depths are summarized in Table A-1. The following subsections describe each type of soil sampling.

3.8.1. Soil Samples for Chemical Analysis

Soil samples will be collected for laboratory analyses to meet the objectives of the supplemental investigation. Proposed soil boring and monitoring well locations are shown on Figure A-3. Soil samples for chemical analysis will be collected from up to twenty (20) soil borings and twelve (12) soil borings for monitoring well installation completed using direct push, hollow stem auger, mud rotary, or sonic drilling methods. A summary of proposed soil borings, depths, sampling intervals, rationale, and methodology are included in Table A-1.

Soil samples to be submitted for chemical analysis will be removed from the sampler, placed into laboratory-supplied containers, lightly packed, and capped with a plastic lid (with the exception of sample aliquots for VOCs analysis, which will be collected using EPA Method 5035A). The sand-sized and finer fractions of the soil will be targeted for collection. The sample containers will be retained on ice and delivered under chain-of-custody (COC) to the analytical laboratory. Soil samples for UV photography and petrophysical testing will be collected and handled as discussed in Section 3.8.2.

3.8.2. Soil Samples for Ultra Violet Photography and Petrophysical Testing

Soil core samples may be obtained and submitted to PTS Laboratories for UV photography and petrophysical testing. Specific locations will be determined based on the presence of NAPL encountered during the investigation, but generally will be focused in shoreline areas. Before obtaining the cores, PTS laboratories will be contacted to arrange for shipping and to confirm collection procedures.

The soil core samples will be co-located with an existing or planned boring location with lithologic and visual NAPL information. Soil core samples will be collected using a decontaminated split-barrel sampler with sleeves. The cores will be maintained in the sleeves in a vertical position corresponding to their in situ orientation and removed from the sampler as soon as possible. Any void space in a sleeve should be covered by saran wrap. The sleeves should be wrapped with saran wrap, secured with clear box tape, and each sleeve labeled with boring name, and beginning and end depth to the tenth of a foot accuracy. The prepared cores should immediately be placed upright in a cooler containing dry ice. Soil cores will be shipped the same day they are collected to the extent practical. In addition, one 1-liter groundwater sample and, available, one 1-liter of NAPL sample will be obtained and submitted to PTS laboratories. Tests to be conducted by PTS laboratories will likely include:

- Digital core photography using white light and UV light based on core photography methods listed in ASTM D 5079-90 and API RP40. The UV photography will indicate relative hydrocarbon distribution in the soil cores.
- NAPL mobility testing by centrifugal method will be performed based on based on a modification of ASTM Method D425. The samples for this test will be selected by GeoEngineers based on a review of the results from the UV photography, to represent NAPL within different stratigraphic units as observed at the time of sample collection.

3.8.3. Soil Samples for Physical Testing

Selected soil samples will be submitted for grain size analysis to confirm soil types recorded on boring logs. Testing results will be compared to lithologic descriptions within each interval.

3.9. Soil Borings for Geotechnical Testing

Soil samples for geotechnical testing will be collected from soil borings MW-32D/GEO-1, GEO-2, and GEO-3, to obtain information to evaluate the geotechnical stability of Kite Hill (Figure A-3). Soil samples for chemical analyses will be obtained from boring MW-32D/GEO-1. Boring MW-32D/GEO-1 will also be completed as a shoreline monitoring well. The detailed scope for the geotechnical investigation is presented in Appendix D of the Work Plan.

3.10. Monitoring Well Construction

Monitoring wells will be installed using sonic or mud rotary drilling methods at the locations shown on Figure A-4. The proposed monitoring well locations near the shoreline have been selected to provide information regarding groundwater quality near the shoreline. Monitoring well construction details will be recorded on the monitoring well construction logs. Notices of intent to construct wells (start cards) will be submitted to Ecology before installing monitoring wells. Specific monitoring well construction elements are discussed below.

3.10.1. Soil Borings for Monitoring Well Installation

Soil borings for monitoring well installation will be advanced using rotary sonic (sonic) or mud rotary methods. Alternatively, a hollow stem auger drilling rig may be used, in which case, driven samples of soil will be collected for geologic logging purposes. Final drilling methods will be based on the selected drilling contractor and their available tooling and access considerations.

Soil borings drilled through visible NAPL to less-impacted, deeper lithologic units will be advanced through NAPL impacted intervals using double-cased drilling methods to limit the chance for carry-down of NAPL. A conductor casing will be installed into the top of the competent underlying unit. The conductor casing will then be lifted approximately one foot so that bentonite chips may be placed and allowed to hydrate for 12-hours to form a confining “plug”. Once the plug is complete, the conductor casing will stay in place while a smaller diameter drill casing is telescoped through the conductor casing and bentonite plug to complete the boring, and construct the well. If a permanent conductor casing is not used, the inner casing will be withdrawn and annular space sealed with bentonite before withdrawing the temporary conductor casing. The annular space created by the temporary conductor casing will also be sealed with grout.

3.10.2. Well Casing

The monitoring wells will be constructed using 2-inch diameter, Schedule 40, threaded, polyvinyl chloride (PVC) casing that meets the following requirements:

- Casing will be new and will be decontaminated if necessary as described in Section 3.15;
- Casing sections will be joined by tightening threaded couplings. No glue or adhesives will be used to join casing sections; and
- Casing will be straight and plumb.

3.10.3. Well Screen

The proposed target zone, geologic unit, well screen elevations, and well screen depths are summarized in Work Plan Table 2. Well screen lengths and depth intervals may be adjusted at the time of drilling based on the observed stratigraphy and NAPL impacts in each boring. Well screens will consist of 2-inch diameter, Schedule 40, 0.010-inch machine slotted, PVC well screens. PVC end caps will be installed on the bottom of the well screens.

- Shallow monitoring wells will generally be screened to monitor groundwater at the water table. The proposed screened intervals for shallow monitoring wells range from 10 to 20 feet.
- Deep monitoring wells will generally be screened within deeper Vashon recessional or advance outwash deposits just above the underlying pre-Fraser glacial till to monitor for the presence of DNAPL. The screened interval for these proposed monitoring wells ranges from 5 to 10 feet. Each deep monitoring well will be located adjacent to a nearby a shallow well so that vertical concentration and hydraulic gradients can be estimated.

Well screen lengths and depth intervals may be adjusted at the time of drilling based on the observed lithology in each well location.

3.10.4. Sand Filter

The filter for the monitoring wells will consist of commercially prepared 10-20 silica sand. The sand filter will extend from the bottom of the well screen to no more than 3-feet above, but at least 1 foot above, the top of the well screen. In areas where the groundwater table is very shallow, the sand filter may extend less than 1 foot above the top of the well screen, to accommodate the installation of the annular seal and surface completion.

3.10.5. Annular Seal

The annular seal will consist of a minimum 3-foot thick layer of hydrated bentonite pellets or chips installed between the filter pack and the concrete surface seal, except in shallow monitoring wells where the depth of the top of the monitoring well screen is too shallow to install a 3 foot thick layer of bentonite pellets. In these cases, the bentonite pellet seal will extend from the top of the sand filter to the base of the concrete surface seal, approximately 1.5 feet below ground surface.

3.10.6. Surface Completion

Monitoring well surface completions will be flush with the ground surface. The well casing will be cut approximately 3 inches below the rim of the surface completion, and a locking "J"-plug compression-type or similar cap will be installed to prevent surface water from entering the well. The monitoring well protective cover will be installed in a concrete surface seal. Where vehicular traffic may pass over the well, the concrete surface seal and well monument will be constructed to meet the strength requirements of surrounding surfaces.

Monitoring wells will be secured with corrosion-resistant locks as soon as possible after drilling. Wherever possible, keyed-alike locks will be used.

3.11. Monitoring Well Development

New monitoring wells will be developed to remove water introduced into the well during drilling (if any), stabilize the filter pack and formation materials surrounding the well screen, and to restore the hydraulic connection between the well screen and the surrounding soil. Well screen intervals will be gently surged with a decontaminated bailer or surge block and the wells will be purged of water. Development will continue until a minimum of five casing volumes of water have been removed and turbidity of the purge water is relatively low. The target turbidity of less than 5 nephelometric turbidity units (NTU) may not be achieved in all wells. Turbidity and the volume of groundwater removed will be recorded during well development. Depths to water in the monitoring wells will be measured before and after development. At least 48 hours will be allowed to pass after monitoring well development before the first round of sampling is performed to allow the surrounding groundwater-bearing zone to stabilize following monitoring well development.

Existing monitoring wells will be redeveloped as necessary, using the methodology described above, as determined in the field using professional judgment and the following general criteria:

- Substantial sediment has accumulated in the base of the monitoring well.
- The groundwater depth measurement appears anomalous based on previous measurements.
- Foreign material is present in the well.
- The monitoring well was damaged or breached in such a way that foreign material may have entered the monitoring well.

3.12. Groundwater Monitoring

Two groundwater monitoring events will be performed to obtain chemical analytical data to support a site-wide remedial investigation. Groundwater samples will be analyzed for BTEXs and PAHs as presented in the QAPP (Work Plan Appendix B) and Table A-1. Monitoring well locations are shown on Figure A-4. The initial groundwater monitoring event will include the following:

- Current monitoring wells identified during the monitoring well survey. Approximately forty (40) current monitoring wells are anticipated to be present and usable.
- Current MLS locations identified during the monitoring well survey. Seven MLSs, each consisting of three to five individual sampling ports (31 total ports), are anticipated to be present and usable.
- Twelve proposed shoreline monitoring wells to be installed during the supplemental investigation.

Existing monitoring well construction and groundwater elevation data are included in Work Plan Table 2. Groundwater samples will not be collected from monitoring wells that contain DNAPL or LNAPL. DNAPL and LNAPL samples may be collected from these monitoring wells, as discussed in Section 3.12.4.

One subsequent round of groundwater monitoring will be performed and include the 12 new shoreline supplemental investigation monitoring wells and up to 13 previously installed monitoring wells. Proposed and existing monitoring well locations are shown on Figure A-4. Monitoring well construction information and ground water depths and elevations are presented in Work Plan Table 2. Proposed monitoring well installation depths, screen intervals, and rationale are presented in Work Plan Table 7. In addition to collecting groundwater samples for chemical analysis, selected groundwater monitoring wells may be used for aquifer testing.

Groundwater monitoring activities will be recorded in field reports and on groundwater sampling forms. The following sections describe the activities to be conducted during each groundwater monitoring event.

3.12.1. Groundwater Depth Measurements

During each groundwater monitoring event, water level measurements will be measured and recorded at least once within a single 12-hour period, in all monitoring wells located on the Park to be sampled, to determine the elevation of the groundwater table and provide the data needed to prepare groundwater surface contours for each monitoring event. If monitoring wells located on Harbor Patrol cannot be accessed during this 12-hour period, Harbor Patrol wells and select Park monitoring wells from the western side of the Park will be measured as close as possible to the Park wells. Known conditions (e.g., unusually low or high barometric pressure) that may affect groundwater levels will be recorded.

Standing water inside the monitoring well protective cover will be removed before opening the monitoring well, to prevent surface water from entering the monitoring well. Monitoring wells will be opened and allowed to vent for at least 10 minutes before groundwater level measurement.

Depth to groundwater will be measured to the nearest 0.01-foot using a decontaminated electronic sounding device from a permanent mark located at the top of the well casing. Following water level measurement, the total depth of the well from the top-of--casing will be measured using a weighted measuring tape or electronic sounding device and recorded. The depth to groundwater from the top-of-casing will be subtracted from the surveyed top-of-casing elevation to determine the groundwater elevation at each monitoring well. Evidence of NAPL observed during groundwater depth measurements will be recorded, and these monitoring wells evaluated for depth to LNAPL and DNAPL using an interface probe. Depth to groundwater will not be measured at MLS locations.

3.12.2. LNAPL and DNAPL Depth Measurements

A decontaminated interface probe will be used to check for the presence of LNAPL and DNAPL during each groundwater monitoring event, at those monitoring wells where evidence of NAPL has been observed. The depth to LNAPL, groundwater, and DNAPL in the well will be measured to the nearest 0.1 foot from a permanent mark located at the top of the well casing and recorded.

3.12.3. Groundwater Sampling

Groundwater samples will be obtained using low-flow/low-turbidity sampling techniques to minimize the suspension of sediment in the samples. The pump intake will be placed near the middle of the monitoring well screen interval and the wells will be purged and groundwater samples will be obtained from the wells using submersible well pumps or a peristaltic pump, and dedicated or disposable polyethylene tubing. Target groundwater purge rate will be 0.5 liters per minute, however lower flows may be used if recharge is slow. A Horiba U-22 (or similar) water quality measuring system with a flow-through cell will be used to monitor the following water quality parameters during purging: electrical conductivity, dissolved oxygen, pH, salinity, total dissolved solids, oxidation-reduction potential, and temperature. Turbidity will be measured using a Hach turbidimeter (or similar). Samples will be collected from the wells after these parameters vary by less than 10 percent on three consecutive measurements and turbidity is relatively low. Target "low turbidity" will be less than 5 NTU, however samples may be collected if three well volumes have been removed and parameters generally vary by less than 10 percent on three consecutive measurements. The field measurements will be documented on the field log.

Following well purging, the flow-through cell will be disconnected and groundwater samples will be collected in laboratory-prepared containers. The samples will be placed into a cooler with ice and logged on the chain-of-custody form using procedures described below. Samples will be submitted to an Ecology-certified laboratory for analyses of BTEXs and PAHs.

Required sample containers, preservation methods, volumes, and holding times are summarized in the QAPP (Work Plan Appendix B). Reusable sampling equipment will be decontaminated before sampling, and between wells, as discussed in Section 3.15. In addition to collecting groundwater samples for chemical analysis, select groundwater monitoring wells may be used for slug testing and LNAPL bail-down testing as discussed in Section 3.13.2.

3.12.4. NAPL Sample Collection

If measureable DNAPL or LNAPL are recoverable, two 500-mililiter samples of groundwater, DNAPL, and LNAPL will be obtained and submitted for physical testing and chemical analysis. Samples will be collected by using a disposable, bottom-filling bailer and transferring the NAPL to laboratory-supplied containers. Water incidentally recovered during NAPL sample collection will not be included in the sample to the extent practicable. NAPL testing will be performed for density, specific gravity, and kinematic viscosity based on ASTM D1217, D1481, and D445 methods. Chemical analyses may be performed using SW-846 Method 8270 SIM, using an expanded PAH analyte list (43 alkyl-PAHs).

3.13. Aquifer Testing

Aquifer testing may be performed in selected monitoring wells, as summarized on Table A-1.

3.13.1. Slug Tests

The slug tests will include a rising head test at each monitoring well to evaluate the hydraulic conductivity of specific water-bearing geologic units along the shoreline of the site. Falling head tests may be performed on monitoring wells screened below the ground water table. An electronic pressure transducer will be placed into each monitoring well tested to measure and record water pressure, which corresponds to the height of ground water above the transducer, and will be used to calculate rising groundwater level in response to the removal of a slug in the well. In addition, the depth to groundwater in each monitoring well tested will be measured manually using an electronic water level meter before and after each slug test.

Slug tests will be performed as follows:

1. Measure the static groundwater level before inserting a pressure transducer into the well.
2. Insert a pressure transducer into the well and secure it at a depth approximately 6 inches above the bottom of the well. Allow the groundwater level to return to the approximate static level measured in Step 1. Water level measurements will be recorded at approximately 0.1- to 15-second intervals during the tests.
3. Insert a clean slug (weighted length of sealed PVC casing) of known volume into the well and measure the groundwater level until it falls to the approximate static level.

4. Conduct the rising-head test by rapidly removing the slug from the well and recording the groundwater level using the transducer until it rises to the approximate static level.
5. Observe the transducer data on the laptop to verify that adequate data have been recorded and are usable for calculating hydraulic analysis.
6. Remove the pressure sensor/data logger from the well.

3.13.2. LNAPL Bail-Down Tests

NAPL bail-down tests will be performed in monitoring wells where greater than 1.0 foot of NAPL is encountered. It is anticipated that one location for LNAPL and up to three locations for DNAPL may be tested. Bail-down tests will be used to measure NAPL transmissivity and estimate potential recovery rates.

Each LNAPL and DNAPL bail-down test will be completed using either a decontaminated, stainless steel, or dedicated bailer or peristaltic pump with dedicated polyethylene tubing to remove as much NAPL as possible while minimizing the amount of groundwater withdrawn from the well. Care will be taken to minimize the volume of water removed from the monitoring well during the NAPL bail-down test. After NAPL has been removed from the monitoring well to the maximum extent practicable, an electronic oil-water interface probe or electronic pressure transducer will be used to measure the depth to water and product thickness at regular intervals until at least 80 percent of the initial thickness of LNAPL measured in the well has recovered or 6 hours has elapsed.

3.14. Surveying

Exploration locations including TarGOST® probings, soil borings, and new and existing monitoring wells will be surveyed by a professional land surveyor. Surveying may be performed by field crews to obtain information to locate explorations before surveying is completed by the professional land surveyor.

3.14.1. Surveying by Professional Land Surveyor

Exploration locations including soil borings, TarGOST® probings, and monitoring wells will be marked using flagging or whiskers to allow surveying of the locations by a Washington-licensed professional land surveyor. The surveyors will measure and record the vertical and horizontal coordinates or each exploration location. Elevations will be measured to the nearest 0.01 foot, referenced to U. S. Army Corps of Engineers (Locks) datum. Horizontal coordinates will be measured to the nearest 0.10 foot, referenced to the NAD 83, Washington State Plane North coordinate system. The ground surface elevation and top-of-casing elevation will be measured at each monitoring well location, including current monitoring wells located during the well survey.

3.15. Decontamination Procedures

To prevent cross-contamination of collected samples, reusable equipment used to collect samples will be decontaminated before sample collection using the following procedures. Deviations from these procedures, if any, will be documented in the field report.

3.15.1. Drilling Equipment

Large pieces of drilling equipment (such as augers, drill rods, drill bits), will be decontaminated between borings and upon completion of drilling activities. To decontaminate this equipment a pressure-washer will be used and, if necessary, components will be scrubbed to remove visible dirt, grime, grease, oil, loose paint, rust flakes, etc. The equipment will then be rinsed with potable water. If visible tar or NAPL remains adhered to the equipment following decontamination, the equipment will be scrubbed with isopropyl alcohol to remove all visible evidence of contamination, and re-decontaminated as presented above.

Soil and groundwater sampling devices (e.g., split-barrel soil sampler) will be cleaned using an aqueous Alconox® or Liqui-Nox® solution and a distilled water rinse before each sample is collected. If visible tar or NAPL remains adhered to the equipment following decontamination, the equipment will be scrubbed with isopropyl alcohol to remove all visible evidence of contamination, and re-decontaminated.

3.15.2. Reusable Sampling Equipment

Before and in between sample collection, reusable sampling equipment that comes in contact with soil, groundwater, or NAPL will be decontaminated. Reusable sampling equipment may include split-barrel soil samplers, groundwater sampling pumps, interface probes, sounding tapes, surface water samplers, trowels, spoons, and other hand tools or sampling/measuring devices.

For soil sampling equipment, excess soil will first be removed from the equipment. The equipment will then be pressure-washed or washed using an aqueous Alconox® or Liqui-Nox® detergent solution and a brush. Detergent will be used to clean surfaces of sampling tools that directly contact samples (e.g., split-barrel core sampler). Following washing, the equipment will be rinsed with distilled water. If visible tar or NAPL remains adhered to the equipment following decontamination, the equipment will be scrubbed with isopropyl alcohol to remove all visible evidence of contamination, and re-decontaminated. Decontaminated equipment will be temporarily stored on clean plastic sheeting, wrapped or covered with aluminum foil, and/or stored in a clean, dry place.

Oil-water interface probes and electronic water level indicators/well sounders used for well gauging will be decontaminated before and after use at each well. Decontamination will be performed as follows:

1. Wipe off any visible tar or NAPL with disposable towels.
2. Clean measurement probe and tape with an aqueous Alconox® or Liqui-Nox® solution.
3. Rinse with distilled water.
4. If necessary to ensure complete removal of residual NAPL, measuring devices may also be cleaned with acetone or isopropyl alcohol at this stage. If acetone or isopropyl is used, steps 2 and 3 (with fresh solutions) will be repeated.

If submersible (centrifugal) or bladder-type groundwater purging and sampling pumps are used, they will be decontaminated before and after each use by washing the exterior with an aqueous Alconox® or Liqui-Nox® solution and a brush. The interior of the pump and may be cleaned by first pumping an aqueous Alconox® or Liqui-Nox® solution through the system, followed by distilled water. Dedicated pumps, if used, will not be decontaminated.

3.15.3. Monitoring Well Casing/Screen and Well Development Equipment

Unless brought to the work site in sealed plastic wrappers, new, visually-clean well casings and screens will be pressure-washed before they are installed. In addition, well development equipment (surge block, development pump) will be pressure-washed before use at each well.

3.15.4. Sample Containers

Precleaned sample bottles and jars will be supplied by the subcontracted analytical laboratory. The sample containers will be protected from contact with dust, dirt, and other potential sources of cross-contamination. Sample containers will not be reused.

3.15.5. Used Decontamination Water

Used decontamination water will be stored in labeled 55-gallon drums for subsequent characterization and off-property disposal at a permitted facility. IDW management is discussed in Section 3.17.

3.16. Field Documentation

Three primary types of field documentation will be used for this project: field reports (and field forms), sample container labels, and chain-of-custody (COC) forms. A description of each of these documentation methods is provided in the following sections.

3.16.1. Field Reports

Field reports are intended to provide a sufficient record of observations and data to enable participants to reconstruct events that occur during project field activities. They contain factual, detailed, and objective information.

Field reports will be used by field representatives to document the field and sampling activities performed at the project site for each day of field work. Field reports will include the date, time, description of field activities performed, names of personnel and site visitors, equipment present, down time, type and quantities of materials used, weather conditions, areas where photographs were taken (if applicable), and any other data pertinent to the project. Field reports will also contain sample collection and identification information and (if appropriate) a drawing of each area sampled, along with the locations (coordinates) where samples were collected. Sample data recorded in field reports will include the sample date, time, location, identification number, matrix, collection method, analyses to be performed, any comments, and the sampler's name. Locations and unique identification of soil samples collected from excavations or stockpiles will be recorded in the field report or an attached site map, or other appropriate form. Field reports will also document any safety issues; quality control samples collected (e.g., duplicate samples, equipment rinsate blanks); calibration checks of field monitoring and measuring instruments (e.g., PID, water quality meter); field measurements; and IDW disposition (e.g., number of drums generated and their contents and location). At the end of each day of drilling, the drilling supervisor shall complete a daily drilling log and provide a copy to the field representative for inclusion with the field report.

Soil boring and well installation information will be recorded on boring logs and well logs attached to the field report. Groundwater sampling and monitoring well development records will be used for each well to record the information collected during ground water sampling and well development.

Following review by the project manager, the original field records will be kept in the project file.

3.16.2. Boring Logs

The lithology/stratigraphy encountered in drilled borings will be logged by the field geologist or engineer on boring and well completion field forms. At drilled boring locations, unconsolidated samples for lithologic description, physical testing, and chemical analysis will be obtained at depths specified in Table A-1 during drilling. Information on boring logs will include the exploration location; general information about drilling/excavation field activities; sampling information such as sample intervals/depths, sample recoveries (for drilled borings), and drilling hammer blow counts; and sample description information. Soil will generally be described in accordance with ASTM D2488 Standard Practice for Description and Identification of Soils (Visual-Manual Procedure). In addition, the Unified Soil Classification System (USCS) group symbol will be recorded on the field logs.

In addition to the information noted above, depth to groundwater/saturated soil, the presence of heaving sand, changes in drilling rate, and other noteworthy observations or conditions, such as the apparent depths of stratigraphic contacts will be recorded on the logs.

Well installation information will be recorded on boring logs and attached to the field report.

3.16.3. Sample Labels

Sample containers will be clearly labeled with waterproof black ink at the time of sampling. Sample labels will include the following information:

- Company Name;
- Project/site name/number;
- Sampling date;
- Sampling time;
- Sample identification number, as discussed in Section 2.2;
- Preservation used, if any; and
- Initials of sampler.

The same information entered on the sample label will be recorded on the COC form and in the field report.

3.16.4. Chain-of-Custody Forms

Samples will be retained in the field crew's custody until samples are delivered to the analytical laboratory, courier, or commercial carrier. After samples have been collected and labeled, they will be maintained under COC procedures. These procedures provide documentation of the transfer of custody of samples from the field to the laboratory. Each sample sent to the laboratory for analysis will be recorded on a COC form.

The COC form includes sample names, dates, times, and analyses to be performed for each sample, as well as documentation of transfers of sample custody from the field to the analytical laboratory. The COC form will be completed using waterproof ink. Any corrections will be made by drawing a line through and initialing and dating the change, then entering the correct information.

When transferring custody of samples, the individuals relinquishing and receiving them will sign, date, and note the time on the COC form. Sample coolers shipped by common carrier will have the COC form enclosed in a re-sealable plastic bag and placed in the sample cooler before sealing the cooler for shipping. Custody seals will be used on sample coolers that are shipped by common carrier or delivered by courier to the laboratory. The sample shipping receipt will be retained in the project files as part of the COC documentation. The shipping company will not sign the COC forms as a receiver; instead the laboratory will sign as a receiver when the samples are received. Internal laboratory records will document custody of the samples from the time they are received through final disposition.

3.17. Investigation- Derived Waste (IDW)

Soil cuttings and water generated during field activities will be contained in 55-gallon steel drums provided by the driller. The drums will be transferred by the driller (using a tracked Bobcat) to the fenced storage area east of the cracking towers at the end of each day of fieldwork (Figure A-1). The containers will remain in the fenced area pending waste characterization for subsequent off-property disposal at a permitted facility. IDW will be managed and disposed according to applicable local, State, and Federal regulations.

3.17.1. Soil

Soil cuttings from borings will be placed in 55-gallon drums marked with the contents, date, and contact information. The drums will be temporarily staged in the fenced area pending characterization and identification of appropriate disposal options. Soil cuttings will be disposed of at an appropriate permitted facility. Soil cuttings that appear to be substantially impacted, will be segregated from less visibly impacted material as practical.

3.17.2. Groundwater and Decontamination Water

Well development and purge water from monitoring wells, and decontamination water generated during sampling activities will be placed in 55-gallon drums marked with the contents, date, and contact information. The drums will be temporarily staged in a secure location on site pending characterization and identification of appropriate disposal options.

3.17.3. Incidental Waste

Incidental waste generated during field activities includes items such as disposable personal protective clothing, gloves, and sampling supplies such as aluminum foil, paper towels, plastic bags/sheeting, and similar discarded materials. These materials are considered de-minimis and will be placed in plastic garbage bags or other appropriate containers. Incidental waste will be disposed of as municipal waste at a local trash receptacle or county disposal facility.

4.0 SAMPLE HANDLING PROCEDURES

4.1. Sample Containers and Preservation

Requirements for sample containers, sample preservation, and sample holding times for the planned laboratory analyses are discussed in the QAPP (Work Plan Appendix B).

4.2. Sample Packaging and Shipping

Each sample submitted for laboratory analysis will be assigned a unique identification number, and will be labeled and recorded on field forms and the COC form, as discussed in Section 2.2. Labels for sample containers will be filled out completely with all appropriate information. Samples will then be packed on ice in a cooler for delivery to the analytical laboratory. Instructions for samples submitted for petrophysical testing are presented in Section 3.8.2. The samples will be either hand-delivered to the laboratory by field personnel or courier, or shipped via a commercial carrier. Custody seals will be used on sample coolers that are not hand-delivered by field personnel.

Upon receipt of the sample coolers at the laboratory, the custody seals will be broken, the condition and temperature of the samples will be recorded, and the COC forms will be signed to document transfer of sample custody. The COC forms will be used internally in the laboratory to track sample handling and final disposition.

5.0 LABORATORY ANALYTICAL METHODS

The analytical methods to be used for sample analysis are listed in Table A-1. Details regarding analytical methods, sample containers, sample preservatives, and sample holding times are discussed in the QAPP (Appendix B of the Work Plan).

6.0 QUALITY ASSURANCE AND QUALITY CONTROL REQUIREMENTS

The QAPP (Work Plan Appendix B) discusses quality assurance and quality control (QA/QC) requirements in detail.

Field QC samples will be used to evaluate the effectiveness of equipment decontamination procedures, potential cross-contamination of samples during transport to the laboratory, reproducibility of laboratory results, and sample heterogeneity. Field QC samples will consist of equipment rinsate blanks, trip blanks, and field duplicates, and will be documented in the field report. Details regarding the field QC samples to be collected and analyzed are provided in the QAPP.

Table A-1

Field Investigation Summary[1]

Gas Works Park Site

Seattle, Washington

Site Area	Planned Activities	Number of Sampling Locations	Sample Location ID	Anticipated Boring Depth (feet bgs)	Boring Method	Boring Requirements	Sample Collection	Number of Samples to Submit for Chemical Analysis	Monitoring Well Screen Interval (feet bgs)	Misc. Notes	Physical Testing				Chemical Analyses [2]				
											Sieve Analysis	Geotechnical Properties	NAPL Properties[4]	Photos & Petrophysical	BTEX	Extended PAHs	PAHs	Arsenic	PCBs
											ASTM D422	See Note 3	ASTM D 1481 and D 445	ASTM & API Procedures[6]	EPA Method 8260 (Low level)	EPA Method 8270 SIM	EPA Method 8270 SIM (Low level)	EPA Method 200.8	EPA 8082- (Low level)
Site-wide	Well Survey	Up to 47	Existing wells and multi-level samplers (MLSs)	N/A	N/A	N/A	Samples of LNAPL and DNAPL may be collected from monitoring wells containing more than 1 foot of measurable NAPL.	TBD	Various	Locate, visually inspect, check for the presence of LNAPL/DNAPL, and measure the depth to groundwater. If LNAPL/DNAPL is present, samples may be obtained for TarGOST fluorescence response evaluation.	–	–	X	–	–	X	–	–	–
	Geophysical Survey	N/A	N/A	N/A	N/A	N/A	None.	N/A	N/A	Magnetometer and Electromagnetic surveys to be performed.	–	–	–	–	–	–	–	–	–
	Initial Groundwater Monitoring (including existing monitoring wells, MLSs, and new monitoring wells)	Up to 83	New wells, existing wells and multi-level samplers (MLSs)	N/A	N/A	N/A	Obtain groundwater samples per the SAP and analytical requirements.	Up to 83 plus QA/QC samples	Various	Wells or sample locations that contain NAPL will not be sampled.	–	–	–	–	X	–	X	–	–
	Additional Groundwater Monitoring (including 12 new monitoring wells and up to 13 existing monitoring wells)	25[5]	New wells and selected existing wells and MLSs	N/A	N/A	N/A	Obtain groundwater samples per the SAP and analytical requirements.	TBD	Various	Wells or sample locations that contain NAPL will not be sampled. Existing monitoring wells to be sampled will be determined following review of initial groundwater monitoring results.	–	–	–	–	X	–	X	–	–
	Petrophysical Soil Core Sampling	TBD	TBD	TBD	HSA	Collect Soil Cores for Petrophysical Testing	Obtain soil core samples in NAPL-impacted areas based on previous data, geophysics surveys, TarGOST results.	TBD	N/A	Soil cores must be maintained in an upright position relative to their location in the ground before removal, handled with minimal disturbance, sealed and placed immediately on dry ice.	–	–	–	X	–	–	–	–	–
	NAPL Sampling	TBD	TBD	N/A	N/A	N/A	Obtain NAPL samples from wells.	TBD	Various	NAPL samples may be submitted for chemical analysis and physical testing, or submitted for TarGOST fluorescence response evaluation.	–	–	X	–	–	X	X	–	–

Site Area	Planned Activities	Number of Sampling Locations	Sample Location ID	Anticipated Boring Depth (feet bgs)	Boring Method	Boring Requirements	Sample Collection	Number of Samples to Submit for Chemical Analysis	Monitoring Well Screen Interval (feet bgs)	Misc. Notes	Physical Testing				Chemical Analyses [2]				
											Sieve Analysis	Geotechnical Properties	NAPL Properties[4]	Photos & Petrophysical	BTEX	Extended PAHs	PAHs	Arsenic	PCBs
											ASTM D422	See Note 3	ASTM D 1481 and D 445	ASTM & API Procedures[6]	EPA Method 8260 (Low level)	EPA Method 8270 SIM	EPA Method 8270 SIM (Low level)	EPA Method 200.8	EPA 8082- (Low level)
Site-wide	Slug Testing	TBD	Selected new monitoring wells.	N/A	N/A	N/A	None.	N/A	Various	Rising head method	–	–	–	–	–	–	–	–	–
	Bail-Down Testing	TBD	TBD	N/A	N/A	N/A	NAPL samples may be retained from the wells tested, however, the purpose of the test is to evaluate NAPL transmissivity.	TBD	Various	At least one-foot of NAPL within the well is required for bail down testing.	–	–	–	–	–	X	–	–	–
Harbor Patrol	TarGOST Explorations	3	TBD	40-45	DP	TarGOST locations may be adjusted based on utility locations. Advance boring to the anticipated top of till material or until refusal.	None.	None.	N/A	–	–	–	–	–	–	–	–	–	–
	Soil Borings (Chemical)	TBD	TBD	40-45	DP or HSA	Boring locations will be selected based on TarGOST. Advance boring to target depth.	Continuous field screening. Obtain soil samples at approximately 5-foot intervals based on field evidence of greatest impact.	TBD	N/A	–	–	–	–	–	X	–	X	–	–
Kite Hill	Install New Monitoring Well(s)	2	MW-32S	20	Sonic	Install monitoring well	None.	0	15.5 to 30.5	–	–	–	–	–	–	–	–	–	–
			MW-32D/GEO-1	46	Mud Rotary	Install monitoring well. Soil borings will be drilled to obtain soil data for geotechnical evaluation. Soil samples for chemical analysis will be collected.	Continuous field screening. Obtain soil samples for geotechnical testing per Work Plan Appendix D. Obtain two soil samples for chemical analysis based on field evidence of greatest impact. Collect continuous soil samples across the screen interval for sieve analysis.	2	42 to 47	–	X	X	–	–	X	–	X	–	–
	Geotechnical Borings	2	GEO-2	40-50	Mud Rotary	Soil borings will be drilled to obtain soil data for geotechnical evaluation. Soil samples for chemical analysis may be collected.	Obtain soil samples at 5-foot intervals for geotechnical analysis per Work Plan Appendix D. Chemical sampling to be determined based on field screening results.	TBD	N/A	–	–	X	–	–	–	–	–	–	–
			GEO-3	20-30	Mud Rotary	Soil borings will be drilled to obtain soil data for geotechnical evaluation. Soil samples for chemical analysis may be collected.	Obtain soil samples at 5-foot intervals for geotechnical analysis per Work Plan Appendix D. Chemical sampling to be determined based on field screening results.	TBD	N/A	–	–	X	–	–	–	–	–	–	–
Cracking Towers	TarGOST Exploration	TBD	TBD	10-15	DP	Boring location may be adjusted based on geophysical survey. Advance boring to the anticipated top of till material or until refusal.	None.	N/A	N/A	Cracking Tower Target Area MW-15 Target Area Historical Structure Target Area	–	–	–	–	–	–	–	–	–

Site Area	Planned Activities	Number of Sampling Locations	Sample Location ID	Anticipated Boring Depth (feet bgs)	Boring Method	Boring Requirements	Sample Collection	Number of Samples to Submit for Chemical Analysis	Monitoring Well Screen Interval (feet bgs)	Misc. Notes	Physical Testing				Chemical Analyses [2]				
											Sieve Analysis	Geotechnical Properties	NAPL Properties[4]	Photos & Petrophysical	BTEX	Extended PAHs	PAHs	Arsenic	PCBs
											ASTM D422	See Note 3	ASTM D 1481 and D 445	ASTM & API Procedures[6]	EPA Method 8260 (Low level)	EPA Method 8270 SIM	EPA Method 8270 SIM (Low level)	EPA Method 200.8	EPA 8082- (Low level)
Cracking Towers	Install New Monitoring Well(s)	1	MW-33S	17	Sonic	Install monitoring well	Continuous field screening. Obtain two soil samples for chemical analysis based on field evidence of greatest impact. Collect continuous samples across the screen interval for sieve analysis.	2	7 to 17	Water Table Well	X	--	--	--	X	--	X	X	--
Cracking Towers	Soil Borings (Chemical)	TBD	GEI-02	15-20	HSA or DP	Boring location may be adjusted based on geophysical survey. Drill through the fill material into native soil until no field screening evidence of impacts.	Continuous field screening. Obtain soil samples at approximately 5-foot intervals based on field evidence of greatest impact.	3-4	N/A	Installing GEI-02 at the proposed location is dependent on timely approval from DAHP. If timely approval is not received, the boring will be relocated or not installed.	--	--	--	--	X	--	X	--	--
Cracking Towers	Soil Borings (Chemical)	TBD	TBD	15-20	HSA or DP	Drill through the fill material into native soil until no field screening evidence of impacts.	Continuous field screening. Obtain soil samples at the ground surface and approximately 5-foot intervals based on field evidence of greatest impact.	3-4	N/A	--	--	--	--	--	X	--	X	--	--
Southeast Area	TarGOST Exploration	TBD	TBD	10-20[5]	DP	Advance probing to the anticipated top of till material or until refusal.	None.	None	N/A	MW-16 Target Area	--	--	--	--	--	--	--	--	--
Southeast Area	Install New Monitoring Well(s)	2	MW-34S	13	Sonic	Install monitoring well	Continuous field screening. Obtain two soil samples for chemical analysis based on field evidence of greatest impact. Collect continuous geotechnical samples across the screen interval for sieve analysis.	2	3 to 13	Water Table Well	X	--	--	--	X	--	X	--	--
Southeast Area	Install New Monitoring Well(s)	2	MW-35S	23	Sonic	Install monitoring well	Continuous field screening. Obtain two soil samples for chemical analysis based on field evidence of greatest impact. Collect continuous geotechnical samples across the screen interval for sieve analysis.	2	2 to 12	Water Table Well	X	--	--	--	X	--	X	--	--
Southeast Area	Soil Borings (Chemical)	TBD	TBD	25	HSA or DP	Based on the results of TarGOST exploration.	Continuous field screening. Sample intervals to be based on TarGOST results and field evidence of greatest impact.	3-4	--	--	--	--	--	--	X	--	X	--	--

Site Area	Planned Activities	Number of Sampling Locations	Sample Location ID	Anticipated Boring Depth (feet bgs)	Boring Method	Boring Requirements	Sample Collection	Number of Samples to Submit for Chemical Analysis	Monitoring Well Screen Interval (feet bgs)	Misc. Notes	Physical Testing				Chemical Analyses [2]				
											Sieve Analysis	Geotechnical Properties	NAPL Properties[4]	Photos & Petrophysical	BTEX	Extended PAHs	PAHs	Arsenic	PCBs
											ASTM D422	See Note 3	ASTM D 1481 and D 445	ASTM & API Procedures[6]	EPA Method 8260 (Low level)	EPA Method 8270 SIM	EPA Method 8270 SIM (Low level)	EPA Method 200.8	EPA 8082- (Low level)
Playbarn	TarGOST Exploration	TBD	TBD	25	DP	Boring location may be adjusted based on geophysical survey. Advance boring to the anticipated top of till material or until refusal.	None.	N/A	N/A	MW-09 Target Area	–	–	–	–	–	–	–	–	–
	Install New Monitoring Well(s)	3	MW-36S	23	Sonic	Install monitoring well	None.	0	3 to 23	Water Table Well	–	–	–	–	–	–	–	X	–
			MW-36D	37	Sonic	Install monitoring well	Continuous field screening. Obtain two soil samples for chemical analysis based on field evidence of greatest impact. Collect continuous geotechnical samples across the screen interval for sieve analysis.	2	32 to 37	–	X	–	–	–	X	–	X	–	–
			MW-37S	14	Sonic	Install monitoring well	Continuous field screening. Obtain two soil samples for chemical analysis based on field evidence of greatest impact. Collect continuous geotechnical samples across the screen interval for sieve analysis.	2	4 to 14	Water Table Well	X	–	–	–	X	–	X	X	–
	Soil Borings (Chemical)	3	GEI-03, GEI-04, GEI-05	25	HSA or DP	Drill through the fill material into native soil until no field screening evidence of impacts.	Continuous field screening. Obtain soil samples at approximately 5-foot intervals based on field evidence of greatest impact.	3-4	N/A	–	–	–	–	–	X	–	X	X	–
			TBD	25	HSA or DP	Drill through the fill material into native soil until no field screening evidence of impacts.	Continuous field screening. Obtain soil samples at approximately 5-foot intervals based on field evidence of greatest impact.	3-4	N/A	–	–	–	–	–	X	–	X	X	–
Northeast Corner	TarGOST Exploration	7	TBD	15	DP	Boring locations may be adjusted based on geophysical survey.	None.	N/A	N/A	–	–	–	–	–	–	–	–	–	–
	Install New Monitoring Well(s)	4	MW-38S	14	Sonic	Install monitoring well	Continuous field screening. Obtain two soil samples for chemical analysis based on field evidence of greatest impact. Collect continuous geotechnical samples across the screen interval for sieve analysis.	2	3 to 13	Water Table Well	X	–	–	–	X	–	X	X	–

Site Area	Planned Activities	Number of Sampling Locations	Sample Location ID	Anticipated Boring Depth (feet bgs)	Boring Method	Boring Requirements	Sample Collection	Number of Samples to Submit for Chemical Analysis	Monitoring Well Screen Interval (feet bgs)	Misc. Notes	Physical Testing				Chemical Analyses [2]				
											Sieve Analysis	Geotechnical Properties	NAPL Properties[4]	Photos & Petrophysical	BTEX	Extended PAHs	PAHs	Arsenic	PCBs
											ASTM D422	See Note 3	ASTM D 1481 and D 445	ASTM & API Procedures[6]	EPA Method 8260 (Low level)	EPA Method 8270 SIM	EPA Method 8270 SIM (Low level)	EPA Method 200.8	EPA 8082- (Low level)
Northeast Corner	Install New Monitoring Well(s)	4	MW-39S	12	Sonic	Install monitoring well	None.	0	4 to 14	Water Table Well	–	–	–	–	–	–	–	X	–
			MW-39D	22	Sonic	Install monitoring well	Continuous field screening. Obtain two soil samples for chemical analysis based on field evidence of greatest impact. Collect continuous geotechnical samples across the screen interval for sieve analysis.	2	17 to 22	–	X	–	–	–	X	–	X	–	–
			MW-40S	15	Sonic	Install monitoring well	Continuous field screening. Obtain two soil samples for chemical analysis based on field evidence of greatest impact. Collect continuous geotechnical samples across the screen interval for sieve analysis.	2	3 to 13	Water Table Well	X	–	–	–	X	–	X	–	–
	Soil Borings (Chemical)	TBD	GEI-01	10	HSA or DP	Drill through the fill material into native soil until no field screening evidence of impacts.	Continuous field screening. Obtain one soil sample at the approximate former ground surface. If not discernible, one composite soil sample from 0 to 3 feet will be collected.	1-2	N/A	–	–	–	–	–	X	–	X	–	X
			TBD	15	HSA or DP	Drill through the fill material at least 3-feet into native soil until no field screening evidence of impacts.	Continuous field screening. Obtain soil samples at approximately 5-foot intervals based on field evidence of greatest impact.	2-3	N/A	–	–	–	–	–	X	–	X	–	–

Notes:

TBD = To be determined based on results of preceding investigation phases.

NAPL= Non-aqueous phase liquid

LNAPL= Light non-aqueous phase liquid

DNAPL= Dense non-aqueous phase liquid

HSA= hollow-stem auger

DP= direct push

BTEX= benzene, toluene, ethylbenzene, total xylenes

PAHs =Polycyclic aromatic hydrocarbons

PCBs = Polychlorinated biphenyls

bgs = Below ground surface

Misc. = Miscellaneous

MW= monitoring well

[1]Investigation locations are shown on Figures A-2, A-3, and A-4.

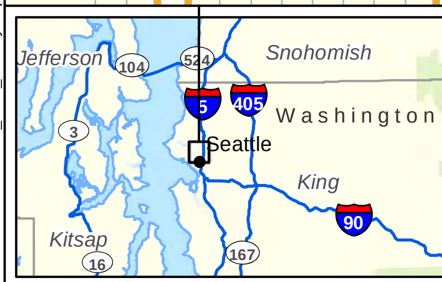
[2]Target Practical Quantitation Limits (PQLs) are listed in the QAPP.

[3]Geotechnical properties include physical testing for moisture content (ASTM D 2216), grain-size distribution (ASTM D 422), Atterberg limits (ASTM D 4318), and percent fines (ASTM D 1140).

[4]LNAPL/DNAPL physical testing includes density and specific gravity (ASTM D 1481) and kinematic viscosity (ASTM D 445).

[5]Up to thirteen existing wells will be selected, in addition to the 12 new monitoring wells, for one additional round of sampling based on results from the well survey and initial groundwater monitoring results.

[6]UV Photography using ASTM D 5079-90 and API RP40. Petrophysical testing (Free Product Mobility) using modified ASTM D 425.



N
W E
S

0 2,000 4,000

Feet

Vicinity Map

Gas Works Park Sediment Site
Seattle, Washington
Supplemental Investigation Sampling and Analysis Plan

GEOENGINEERS

Figure A-1

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

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Legend

- Building or Structure
- Impervious Surface
- AS/SVE Impervious Cover
- Proposed Area of Magnetic and Electromagnetic Survey
- Former MGP Structure
- Former Tar Refinery Footprint

Notes:
1. Reference: Historical structures provided by Floyd|Snider, 2012.
2. Site structures delineated as shown in the General Plan, Lake Station, Seattle Gas Company, April 1949, revised in June 1953, the 1950 Oil Lines, Seattle Gas Co. Map, and a 1956 aerial photograph.
3. Historical railroad features shown as delineated in General Plan, Lake Station, Seattle Gas Co., June 1938.
3. The locations of all features shown are approximate.
4. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

N
W E
S

0 100 200
Feet

Proposed Geophysical Survey Area

Gas Works Park Sediment Site
Seattle, Washington
Supplemental Investigation
Sampling and Analysis Plan

GeoEngineers

A-2

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Legend

- AS/SVE Impervious Cover
- Conceptual Extent of LNAPL
- Conceptual Extent of DNAPL
- Observations of Contiguous Near-surface Tar

NAPL Line Type

- Inferred Lateral Extent of Multiple Location NAPL in Sediment
- Estimated Lateral Extent of Multiple Location NAPL in Uplands
- Estimated Lateral Extent of Multiple Location NAPL in Sediment

Proposed Exploration Locations

- Proposed Soil Boring
- Proposed Geotechnical Boring
- Proposed TarGOST Exploration
- TarGOST Target Area

Previous Deep Explorations

- Deep Exploration: Exploration Fully Penetrates Fill
- Deep Exploration: Exploration Fully Penetrates Fill and Terminates in Till (Qpgt)

Mapping Rationale:

1. NAPL extent mapping intends to show areas where NAPL has been interpreted to exist at multiple adjacent sample locations.

Notes:

1. MLS = multi-level sampler.
2. * Soil boring will be completed following approval from Washington State Department of Archaeology and Historical Preservation.
3. The locations of all features shown are approximate.
4. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Proposed Soil Borings and TarGOST Exploration Areas

Gas Works Park Sediment Site
Seattle, Washington
Supplemental Investigation
Sampling and Analysis Plan

GeoEngineers

A-3

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Legend

- AS/SVE Impervious Cover
- Conceptual Extent of LNAPL
- Conceptual Extent of DNAPL
- Observations of Contiguous Near-surface Tar

NAPL Line Type

- Inferred Lateral Extent of Multiple Location NAPL in Sediment
- Estimated Lateral Extent of Multiple Location NAPL in Uplands
- Estimated Lateral Extent of Multiple Location NAPL in Sediment

Proposed Exploration Locations

- Existing Monitoring Well
- Existing Monitoring Well to be Sampled (initial sampling)
- Proposed Monitoring Well

Previous Deep Explorations

- Deep Exploration: Exploration Fully Penetrates Fill
- Deep Exploration: Exploration Fully Penetrates Fill and Terminates in Till (Qpgt)

Mapping Rationale:

1. NAPL extent mapping intends to show areas where NAPL has been interpreted to exist at multiple adjacent sample locations.
2. Some existing monitoring wells are not proposed for sampling due to history of NAPL in well.

Notes:

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

N W E S

0 100 200

Feet

Proposed Monitoring Wells

Gas Works Park Sediment Site
Seattle, Washington
Supplemental Investigation
Sampling and Analysis Plan

GEOENGINEERS

A-4

Path: \\seal\projects\0\0186846\GIS\MXD\Phase01\018684601_SAP_ProposedMonitoringWells.mxd Map Revised: 13 March 2013 amanza

APPENDIX B
Quality Assurance Project Plan

Appendix B
Quality Assurance Project Plan (QAPP)

Supplemental Upland Investigation
Gas Works Park Site
Seattle, Washington

for
Puget Sound Energy

March 13, 2013

GeoEngineers

Plaza 600 Building
600 Stewart Street, Suite 1700
Seattle, Washington 98101
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1.0 PROJECT DESCRIPTION

This Quality Assurance Project Plan (QAPP) has been prepared for the Gas Works Park Sediment Site (GWPSS or Site). During previous investigation activities, chemicals of potential concern were detected in soil, groundwater, and sediment samples from the site. The purpose of the proposed supplemental sampling is to supplement these data on the upland portion of the Site. This QAPP serves as the primary guide for the integration of quality assurance (QA) and quality control (QC) functions into field activities. It presents the objectives, procedures, organization, functional activities, and specific QA/QC activities designed to achieve data quality objectives (DQOs) established for the project. This QAPP is based on guidelines specified in the Washington State Model Toxics Control Act Cleanup Regulation (Washington Administrative Code [WAC] Chapter 173-340) and on Ecology guidance contained in Ecology Publication #04-03-030, *Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies* (Ecology, 2004).

Throughout the project, environmental measurements will be conducted to produce data that are scientifically valid, of known and acceptable quality, and meet established objectives. QA/QC procedures will be implemented so that the precision, accuracy, representativeness, completeness, and comparability (PARCC) of the data generated meet the specified DQOs to the maximum extent possible.

1.1 Site Description and Background

The GWPSS is located on a 20.5-acre peninsula formerly known as Brown's Point. The GWPSS consists of the municipal park, Harbor Patrol located adjacent to and west of the park, and adjacent aquatic lands within Lake Union.

The park is located on the site of a former manufacturing gas plant (MGP) and tar refinery. From 1907 to 1937, the MGP manufactured gas by coal carbonization. In 1937, the coal gas plant was replaced with newer oil-gas generators to produce manufactured gas. Carbureted water gas was also produced from 1907 to 1952. West of the manufactured gas plant, a tar refinery operated from approximately 1912 until the mid-1950s with storage operations into the mid-1960s. In 1956, the MGP and tar refinery stopped operations. The property was purchased by the City of Seattle from Washington Natural Gas (WNG) in 1962, the title to and possession of the property was transferred to the City in 1973. From 1962 to 1973, storage and maintenance operations, plant decommissioning and demolition were conducted by WNG. Between 1973 and 1976, park development activities were conducted by the City. In 1976 Gas Works Park was officially opened to the public. Select former MGP structures were preserved and remain standing. The park is listed on the National Register of Historic Places. Further information about the Upland Study Area, including potential chemical releases and associated contamination, is presented in the Work Plan and Uplands RI (Hart Crowser 2012).

1.2 Objectives

The purpose of this supplemental upland investigation is to supplement existing upland data to complete a site-wide RI/FS. Objectives of the supplemental investigation include the following:

- Perform an evaluation of primary sources of impacts and the nature and extent of secondary impacts on the uplands.
- Characterize upland soil in targeted areas to assess potential ongoing sources of groundwater impacts.
- Characterize upland groundwater to address the groundwater to sediment pathway.
- Assess non-aqueous phase liquid (NAPL) occurrence and mobility on the uplands relative to migration to sediment and surface water.

Project activities, findings, and results will be governed by this QAPP and will be documented accordingly. Significant changes to the QAPP will be provided to Ecology for review, with the opportunity to comment on and approve revisions.

1.3 Sampling Design and Schedule

The proposed schedule for the supplemental upland field investigation is presented in the Work Plan. The project schedule will be revised, as appropriate, as details of the field program are developed. Details of the investigation design, including locations and frequency of sampling, are presented in the Work Plan and the Sampling and Analysis Plan (SAP; Appendix A of the Work Plan).

2.0 PROJECT ORGANIZATION AND RESPONSIBILITIES

Key positions associated with project quality are described as follows.

2.1 Principal-in-Charge and Project Manager

The Principal-in-Charge has overall responsibility for executing the project in accordance with contractual requirements. Dan Baker is the Principal-in-Charge. The Project Manager is responsible for coordinating and scheduling project activities, implementing the terms and conditions of this QAPP, interfacing with Ecology and other agency personnel, selecting project team members, assigning and coordinating project tasks, determining subcontractor participation, establishing and adhering to budgets and schedules, providing technical oversight, and coordinating production and review of project deliverables. Zanna Satterwhite and Jim Roth are the co-Project Managers.

2.2 Field Coordinator

The Field Coordinator is responsible for the daily management of activities in the field. Specific responsibilities include:

- Provides technical direction to the field staff.
- Develops schedules and allocates resources for field tasks.
- Coordinates data collection activities to be consistent with information requirements.
- Supervises the compilation of field data and laboratory analytical results.
- Assures that data are correctly and completely reported.

- Implements and oversees field sampling in accordance with project plans.
- Supervises field personnel.
- Coordinates work with on-site subcontractors.
- Schedules sample shipment with the analytical laboratory.
- Monitors that appropriate sampling, testing, and measurement procedures are followed.
- Coordinates the transfer of field data, sample tracking forms, and log books to the Project Manager for data reduction and validation.
- Participates in QA corrective actions as required.

Paul Robinette or an alternate designee will be the Field Coordinator.

2.3 Quality Assurance Leader

The QA Leader is responsible for coordinating QA/QC activities as they relate to the acquisition of field data. Specific responsibilities include the following:

- Serves as the official contact for laboratory data QA concerns.
- Reviews and approves the laboratory QA Plan.
- Responds to laboratory data QA needs, answers laboratory requests for guidance and assistance, and resolves issues.
- Monitors laboratory compliance with data quality requirements.
- Ensures that appropriate sampling, testing, and analysis procedures are followed and that proper QC checks are implemented.
- Reviews the implementation of the QAPP and the overall quality of the analytical data generated.
- Maintains the authority to implement corrective actions as necessary.
- Ensures proper implementation of this QAPP.
- Ensures that GeoEngineers and subcontractor personnel have been properly trained as applicable.
- Reviews project policies, procedures, and guidelines and reviews the project activities to ensure the QA program is being properly implemented.
- Responsible for project-related quality aspects related to the collection and chemical analysis of samples, as delegated by the Project Manager.
- Provides oversight of the data development and review process and of subcontracting laboratories.
- Develops detailed scopes of work for the subcontracting laboratories that incorporate the DQOs described in Section 3.0.
- Conducts laboratory audits, as necessary, and data validation activities.

- Enters data into Ecology's Environmental Information Management (EIM) system.

Mark Lybeer is the QA Leader.

2.4 Laboratory Management

The subcontracted laboratories conducting sample analyses for this project are required to obtain approval from the QA Leader before the initiation of sample analysis to assure that the laboratory QA plan complies with the project QA objectives. The Laboratory QA Coordinator administers the Laboratory QA Plan and is responsible for QC. Specific responsibilities of the Laboratory QA Coordinator include:

- Ensure implementation of the laboratory QA plan.
- Serve as the laboratory point of contact.
- Activate corrective action as necessary when analytical control limits are exceeded.
- Issue the final laboratory QA/QC report.
- Administer QA sample analysis.
- Comply with the specifications established in the project plans as related to laboratory services.
- Participate in QA audits and compliance inspections.

The Laboratory's QA Coordinator will be determined once an Ecology-accredited laboratory is chosen.

2.5 Health and Safety

The site-specific Health and Safety Plan (HASP) for the project is contained in Appendix C of the Work Plan. The requirements for health and safety precautions are described in the HASP, including daily health and safety tailgate meetings before the start of work. Tailgate meetings will be documented in the field reports.

The Field Coordinator will be responsible for implementing the HASP during sampling activities. The Project Manager will discuss health and safety issues with the Field Coordinator on a routine basis during the completion of field activities.

The Field Coordinator will terminate any GeoEngineers work activities that do not comply with the HASP. Companies providing services for this project on a subcontracted basis will be responsible for developing and implementing their own HASP.

3.0 DATA QUALITY OBJECTIVES

The overall DQO for the project is to collect environmental sampling data of known, acceptable, and documentable quality. The specific objectives established for the project are:

- Implement the procedures outlined in the SAP and this QAPP for field sampling, sample custody, equipment operation and calibration, laboratory analysis, and data reporting to ensure consistency and thoroughness of data generated.
- Achieve the level of QA/QC required to produce scientifically valid analytical data of known and documented quality. This will be accomplished by establishing criteria for data precision, accuracy, representativeness, completeness, and comparability, and by evaluating project data against these criteria.

The sampling design, field procedures, laboratory procedures, and QC procedures established for this project were developed to provide defensible data. Specific data quality factors that may affect data usability include quantitative factors (precision, bias, accuracy, completeness, and reporting limits) and qualitative factors such as representativeness and comparability. The specific DQOs associated with these data quality factors are discussed below. Method-specific DQOs for laboratory analyses are presented in Tables B-1 and B-2.

3.1 Analytes and Matrices of Concern

Samples of soil, groundwater, and NAPL (if present) will be collected during field activities. Tables B-1 and B-2 summarize the analyses to be performed for soil and groundwater.

The constituents of potential concern (COPCs) for this project include:

- Polychlorinated aromatic hydrocarbons (PAHs), analyzed by EPA Method 8270-SIM;
- Benzene, toluene, ethylbenzene, xylenes (BTEX), analyzed by EPA Method 8021 (8021-Low level for groundwater);
- Arsenic, analyzed by EPA Methods 200.8;
- Polychlorinated biphenyls (PCBs), analyzed by EPA method 8082-Low level; and,
- Non-aqueous phase liquid (NAPL), analyzed for PAHs by EPA Method 8270-SIM.

3.2 Analytical Detection Limits

Analytical methods have quantitative limitations at a given statistical level of confidence that are often expressed as the method detection limit (MDL). Individual instruments often can detect but not accurately quantify compounds at limits lower than the MDL, referred to as the instrument detection limit (IDL). Although results reported near the MDL or IDL provide insight regarding site conditions, QA dictates that analytical methods achieve a consistently reliable level of detection known as the practical quantitation limit (PQL). The contract laboratory will provide numerical results for all analytes and report them as detected above the PQL or not detected at or above the PQL.

Achieving a stated detection limit and quantitation limit for a given analyte is necessary in providing statistically useful data. Intended data uses, such as direct comparison to numerical criteria or the involvement in risk assessment equations, typically rely on project target reporting limits (TRLs) to fulfill the stated DQOs for the project. The TRLs for site COPCs will serve as the target laboratory PQLs for this project, presented in Tables B-1 and B-2. It may be possible for the laboratory to achieve PQLs less than the TRLs under ideal conditions. Conversely, there may be occasions when the laboratory's ability to achieve a stated TRL is impeded by unforeseen characteristics in the sample matrix. As several factors may influence the PQLs across samples, the TRLs are considered to be static targets for the purposes of the project. In cases where a given analyte PQL exceeds the TRL, professional judgment must be used in determining whether the data point is applicable to the project or not. Data users must be aware that elevated PQLs can bias statistical data summaries, and careful interpretation is required when using data sets with PQLs exceeding TRLs.

For example, high moisture content or high organic content in the sample matrix of soil samples can affectively raise the PQLs to be greater than the TRLs. Also, analytical procedures may require sample dilutions in order to accurately quantify a particular analyte with a high concentration above the linear range of the instrument. The effect of this is that other analytes of lesser concentrations could be reported as not detected but reporting a PQL greater than a specified TRL. In these situations, it may be acceptable to use the data points even though the PQLs exceed the TRLs.

3.3 Precision

Precision is the measure of mutual agreement among replicate or duplicate measurements of an analyte from the same sample and applies to field duplicate or split samples, replicate analyses, and duplicate spiked environmental samples (matrix spike duplicates). The closer the measured values are to each other, the more precise the measurement process. Precision error may affect data usefulness. Good precision is indicative of relative consistency and comparability between different samples. Precision will be expressed as the relative percent difference (RPD) for spike sample and field duplicate comparisons of various matrices. The RPD is calculated as:

$$RPD(\%) = \frac{|D_1 - D_2|}{(D_1 + D_2)/2} X\ 100,$$

Where

D_1 = Concentration of analyte in primary sample.

D_2 = Concentration of analyte in duplicate sample.

The RPD will be calculated for samples and compared to the project RPD QC control limits. Project RPD QC control limits are listed in Tables B-1 and B-2. The RPD QC control limits listed in Tables B-1 and B-2 are only applicable if the primary and duplicate sample concentrations are greater than five times the PQL. For results less than five times the PQL, the difference between the primary and duplicate samples should be less than two times the PQL for soil samples and one times the PQL for water samples.

3.4 Accuracy

Accuracy is a measure of bias in the analytical process. The closer the measurement value is to the true value, the greater the accuracy. Accuracy is typically evaluated by adding a known spike concentration of a target or surrogate compound to a sample before analysis. The detected concentration or percent recovery (%R) of the spiked compound reported in the sample provides a quantitative measure of analytical accuracy. Since most environmental data collected represent single points spatially and temporally rather than an average of values, accuracy is generally more important than precision in assessing the data. In general, if %R values are low, non-detect results may be reported for compounds of interest when in fact these compounds are present (i.e., false negative results), and results for detected compounds may be biased low. The reverse is true when %R values are high. In this case, non-detect values are considered accurate, whereas detected values may be higher than true values.

For this project, accuracy will be expressed as the %R of a known surrogate spike, matrix spike, or laboratory control sample (blank spike), concentration:

$$Recovery\,(\%R) = \frac{Spiked\ Result - Unspiked\ Result}{Known\ Spike\ Concentration}\ X\ 100$$

Accuracy (%R) criteria for surrogate spikes, matrix spikes, and laboratory control samples (blank spikes) are presented in Tables B-1 and B-2.

3.5 Representativeness, Completeness, and Comparability

Representativeness expresses the degree to which data accurately and precisely represent the actual site conditions. Representativeness of the data will be evaluated by:

- Comparing actual procedures to those specified in this QAPP.
- Reviewing analytical results for field duplicates to determine the variability in the analytical results.
- Invalidating non-representative data or identifying data to be classified as questionable or qualitative in nature. Only representative data will be used in subsequent data reduction, validation, and reporting activities.

Completeness establishes whether a sufficient amount of valid measurements were obtained to meet project objectives. The number of samples and results expected establishes the comparative basis for completeness. The completeness goal is 90% useable data for the samples/analyses planned. If the completeness goal is not achieved, an evaluation will be performed to determine if the data are adequate to meet study objectives.

Comparability expresses the confidence with which one set of data can be compared to another. Although numeric goals do not exist for comparability, a statement on comparability will be prepared to assess overall usefulness of data sets generated during the project, following the evaluation of precision and accuracy.

3.6 Holding Times

Holding times are defined as the time between sample collection and extraction, sample collection and analysis, or sample extraction and analysis. Some analytical methods specify a recommended holding time for analysis only. For many methods, recommended holding times may be extended by sample preservation techniques in the field. If a sample exceeds a recommended holding time, then the results may be biased low. For example, if the extraction holding time for volatile analysis of soil samples is exceeded, then the possibility exists that some of the organic constituents may have volatilized from the sample or degraded. Results for that analysis would be qualified as estimated to indicate that the reported results may be lower than actual site conditions. Recommended holding times are presented in Table B-4.

3.7 QC Blank Samples

According to the *National Functional Guidelines for Organic Data Review* (EPA, 2008), "The purpose of laboratory (or field) blank analysis is to assess the existence and magnitude of contamination resulting from laboratory (or field) activities. The criteria for evaluation of blanks apply to any blank associated with the samples (e.g., method blanks, instrument blanks, trip blanks, and equipment blanks)." Trip blanks are placed with samples during shipment; method blanks are created during sample preparation and follow samples throughout the analysis process.

QC blanks are discussed further in Section 7.0. Analytical results for QC blanks will be interpreted in general accordance with EPA's *National Functional Guidelines for Organic and Inorganic Data Review* and professional judgment.

4.0 SAMPLE COLLECTION, HANDLING, AND CUSTODY

The SAP (Appendix A of the Work Plan) discusses sample collection, handling, and custody procedures. Topics addressed in the SAP include, but are not limited to, sampling equipment to be used; equipment decontamination procedures; field screening procedures; sample containers and labeling; sample storage; sample delivery to the analytical laboratory; chain-of-custody procedures; laboratory custody procedures; and field documentation.

5.0 CALIBRATION PROCEDURES

5.1 Field Instrumentation

Field instrument calibration and calibration checks facilitate accurate and reliable field measurements. The calibration of the instruments will be checked and adjusted as necessary in general accordance with manufacturers' recommendations. Methods and frequency of calibration checks and instrument maintenance will be based on the type of instrument, stability characteristics, required accuracy, intended use, and environmental conditions. The basic calibration check frequencies are described below.

If a photoionization detector (PID) is used for headspace vapor screening, its calibration will be checked at the start of each day it is used. If necessary (based on the calibration check results), the instrument will be calibrated in general accordance with the manufacturer's specifications. Calibration check and calibration results will be recorded in the field report.

The calibration of the water quality meter (e.g., Horiba U-22) will be checked, and if necessary, the instrument will be calibrated, before each water sampling event. The instrument will be calibrated in general accordance with the manufacturer's specifications. Calibration check and calibration results will be recorded in the field report.

5.2 Laboratory Instrumentation

For chemical analytical testing, calibration procedures will be performed in general accordance with the analytical methods used and the laboratory's Standard Operating Procedures (SOPs). Calibration documentation will be retained at the laboratory.

6.0 LABORATORY DATA REPORTING AND DELIVERABLES

Laboratories will report data in formatted hardcopy and electronic form to the Project Manager and QA Leader. Upon completion of analyses, the laboratory will prepare electronic deliverables for data packages in accordance with the specifications in the agreed-upon *Special Conditions for Lab Analysis* document. The laboratory will provide electronic data deliverables (EDDs) within two business days after GeoEngineers' receipt of printed-copy analytical results, including the appropriate QC documentation. Analytical laboratory measurements will be recorded in standard formats that display, at a minimum, the client/field sample identification, the laboratory sample identification, reporting units, analytical methods, analytes tested, analytical results, extraction and analysis dates, quantitation limits, and data qualifiers. Each sample delivery group will be accompanied by sample receipt forms and a case narrative identifying data quality issues.

GeoEngineers will establish EDD requirements with the contract laboratory. In general, EQuIS four-file format EDDs will be required.

7.0 QUALITY CONTROL SAMPLES AND PROCEDURES

QC samples will be analyzed to ensure the precision, accuracy, representativeness, comparability, and completeness of the data. Table B-3 summarizes the types and frequency of QC samples to be analyzed during the investigation, including both field QC and laboratory QC samples.

7.1 Field Quality Control Samples

Field QC samples serve as a control and check mechanism to monitor the consistency of sampling methods and the influence of off-site factors on environmental samples. Examples of potential off-site factors include airborne VOCs and potable water used in drilling activities. As shown in Table B-3, three types of field QC samples will be processed: trip blanks, field duplicates, and equipment rinsate blanks. The field duplicates and equipment rinsate blanks are collected in the field, and the trip blanks are provided by the analytical laboratory. Descriptions of these types of QC samples are provided in the following subsections.

7.1.1 Field Duplicates

Field duplicates serve as measures for precision. They are created by placing aliquots of the collected sample in separate containers, and identifying one of the aliquots as the primary sample and the other as the duplicate sample. With the exception of samples for BTEX analyses, sample samples should be homogenized in the field before primary and duplicate aliquots are placed in the laboratory-supplied containers. Field duplicates measure the precision and consistency of laboratory analytical procedures and methods, as well as the consistency of the sampling techniques used by field personnel and/or the relative homogeneity of sample matrices.

The duplicate sample is submitted to gain precision information on sample homogeneity, handling, shipping, storage and preparation, and analysis. Field duplicates will be analyzed for the same parameters as the associated primary samples.

For the supplemental upland data collection field investigation, one field duplicate will be collected for every twenty primary soil samples and every twenty primary water samples (i.e., a frequency of 5% for each matrix). The duplicate samples will be collected at the same locations and as close as possible to the same times as the associated primary samples.

7.1.2 Equipment Rinsate Blanks

Equipment rinsate blanks will be used to evaluate the effectiveness of decontamination procedures for preventing possible cross-contamination of project samples. Equipment rinsates are the final rinse waters from the equipment decontamination procedure. The rinsate blanks will be collected by slowly pouring the distilled water used for sampling equipment decontamination over or through the decontaminated equipment (such as split-barrel core samplers) and collecting the rinsate in appropriate sample containers for analysis. Rinsate blanks will be analyzed for the same parameters as the associated project samples.

For the supplemental upland data collection field investigation, one rinsate blank will be collected for every twenty primary soil samples and every twenty primary water samples (i.e., a frequency of 5% for each matrix). A minimum of one equipment rinsate blank will be collected for each day of sampling activities.

7.1.3 Trip Blanks

Trip blanks are samples of reagent (analyte-free) water taken from the laboratory to the sampling site and returned to the laboratory with the samples to be analyzed for VOCs. Trip blanks accompany samples for VOC analysis during field sampling and delivery to the laboratory. One trip blank will accompany each cooler containing samples that will be submitted for BTEX analysis. The trip blanks are used to assess potential VOC contamination of project samples related to sample preservation, packing, shipping, and storage procedures.

7.1.4 Other QC Samples

Discretionary QC samples include field blanks. Field blanks will be used at the discretion of the QA Leader if there is a reason to suspect contamination introduced by ambient conditions in the field. Field blanks are samples of distilled water poured directly into sample containers in the field. Field blanks are analyzed for the same parameters as the associated project samples.

7.2 Laboratory Quality Control

The analytical laboratory will follow standard analytical method procedures that include specified QC monitoring requirements. These requirements will vary by method, but generally include:

- Method blanks;
- Internal standards;
- Instrument calibrations;

- Matrix spikes/matrix spike duplicates (MS/MSDs);
- Laboratory control samples/laboratory control sample duplicates (LCS/LCSDs);
- Laboratory replicates or duplicates; and
- Surrogate spikes.

7.2.1 Laboratory Blanks

Laboratory procedures employ the use of several types of blanks but the most commonly used blanks for QA/QC assessments are method blanks. Method blanks are laboratory QC samples that consist of either a soil-like material that has undergone a contaminant destruction process, or a sample of reagent water. Method blanks are extracted and analyzed with each batch of environmental samples undergoing analysis. Method blanks are particularly useful during volatiles analysis since VOCs can be transported in the laboratory through the vapor phase. If a substance is found in the method blank, it indicates that one (or more) of the following occurred:

- Measurement apparatus or containers were not properly cleaned and contained contaminants.
- Reagents used in the analytical process were contaminated with a substance(s) of interest.
- Contaminated analytical equipment was not properly cleaned.
- Volatile substances in the air with high solubility or affinities toward the sample matrix contaminated the samples during preparation or analysis.

It is difficult to determine which of the above scenarios took place if method blank contamination occurs. However, it is assumed that the conditions that affected the blanks also likely affected the project samples. If method blank contamination occurs, validation guidelines assist in determining which substances detected in associated project samples are likely truly present in the samples and which ones are likely attributable to the analytical process.

7.2.2 Matrix Spikes/Matrix Spike Duplicates

MS/MSDs are used to assess influences or interferences caused by the physical or chemical properties of the sample itself. For example, extreme pH can affect the results of SVOC analyses. Or, the presence of a particular analyte in a sample may interfere with accurate quantitation of another analyte. MS/MSD data are reviewed in combination with other QC monitoring data to evaluate matrix effects. In some cases, matrix effects cannot be determined due to dilution or high concentrations of related substances in the sample. An MS is created by spiking a known amount of one or more of the target analytes into a project sample, ideally at a concentration at least 5 to 10 times higher than the concentration in the un-spiked sample. A %R value is calculated by subtracting the un-spiked sample result from the spiked sample result, dividing by the spike amount, and multiplying by 100.

The samples designated for MS/MSD analysis should be obtained from a boring or sampling location that is suspected to not be highly contaminated. A sample from an area of low-level contamination is needed because the objective of MS/MSD analyses is to assess possible matrix interferences, which can best be achieved with low levels of contaminants. For the supplemental upland data collection field investigation, additional sample volume will be collected for MS/MSD analysis for every twenty primary soil samples and every twenty primary water samples (i.e., a frequency of 5% for each matrix) or as determined as necessary by the analytical laboratory.

7.2.3 Laboratory Control Spikes/ Laboratory Control Spike Duplicates

Also known as blank spikes, laboratory control spikes (LCS) and laboratory control spike duplicates (LCSDs) are similar to MS/MSD samples in that a known amount of one or more of the target analytes is spiked into a prepared medium and a %R value is calculated for the spiked substance(s). The primary difference between an MS and LCS is that the LCS spike medium is considered “clean” or contaminant-free. For example, reagent water is typically used for LCS water analyses. The purpose of an LCS is to help assess the overall accuracy and precision of the analytical process including sample preparation, instrument performance, and analyst performance. LCS data must be reviewed in context with other laboratory QC data to determine if corrective action is necessary for laboratory control limit exceedances.

7.2.4 Laboratory Replicates/Duplicates

Laboratories often utilize MS/MSDs, LCS/LCSDs, and/or replicates to assess precision. Replicates are a second analysis of a field-collected environmental sample. Replicates can be split at varying stages of the sample preparation and analysis process, but most commonly consist of a second analysis on the extracted media.

7.2.5 Surrogate Spikes

Surrogate spikes are used to verify the accuracy of the analytical instrument and extraction procedures used. Surrogates are substances similar to the target analytes. A known concentration of surrogate is added to each project sample and passed through the instrument, noting the surrogate recovery. Each surrogate used has an acceptable range of %R. If a surrogate recovery is low, sample results may be biased low, and, depending on the %R value, a possibility of false negatives may exist. Conversely, when surrogate recoveries are above the specified range of acceptance, a possibility of false positives exists, although non-detected results are considered accurate.

7.2.6 Instrument Calibrations

Several types of instrument calibrations are used, depending on the method, to determine whether the methodology is ‘in control’ by verifying the linearity of the calibration curve and to assure that the sample results reflect accurate and precise measurements. This is performed by verifying that the percent relative standard deviations (%RSD) and/or the correlation coefficients are within the control limits specified in the validation documents. The main calibrations used are initial calibrations, daily calibrations, and continuing calibration verification.

8.0 PETROPHYSICAL TESTING, GEOPHYSICAL METHODS AND TARGOST

This section describes the process for petrophysical testing, geophysical methods and TarGOST analysis.

8.1 Petrophysical Testing

Petrophysical testing will be performed by PTS Laboratories (PTS) located in Santa Fe Springs, California. These tests are specialty tests that are a combination of ASTM and American Petroleum Association (API) approved procedures and propriety methods developed by PTS. PTS has internal quality assurance procedures established for these specialty tests.

8.2 Geophysical Methods

Non-intrusive, surface magnetic and electromagnetic (EM) geophysical methods will be performed to provide information regarding potential subsurface structures. Magnetometers used for buried object detection measure the gradient of the magnetic field between two sensors separated vertically by two or three feet. A 10-foot line spacing will be used, recording continuously (0.5 interval) along the lines. A sub-meter real-time differential GPS unit will be used for position guidance and control. The contractor will include an interpreted geophysical summary plot with a narrative discussion of the interpretation.

8.3 TarGOST

The Tar-specific Green Optical Screening Tool (TarGOST) is a laser-induced fluorescence (LIF) screening tool that is specifically designed to detect NAPL in the subsurface. TarGOST testing will be performed by Dakota Technologies, Inc (Dakota). These tests are specialty tests that have been utilized in case studies recognized by EPA. Dakota has internal quality assurance procedures established for these specialty tests.

9.0 DATA REDUCTION AND ASSESSMENT PROCEDURES

This section describes the process for generating and checking data, as well as the process for producing reports for field and analytical laboratory data.

9.1 Data Reduction

Data reduction involves the conversion or transcription of field and analytical data to a useable format. The laboratory personnel will reduce the analytical data for review by the QA Leader and Project Manager. This will involve both hard-copy forms and EDDs. Both forms of data will be compared with each other to verify that the data are reliable and error-free.

9.2 Review of Field Documentation and Laboratory Receipt Information

Documentation of field sampling data will be reviewed periodically for conformance with project QC requirements described in this QAPP. At a minimum, field documentation will be checked for proper documentation of the following:

- Sample collection information (date, time, location, matrices, etc.);
- Field instruments used and calibration data;
- Sample collection protocol;
- Sample containers, preservation, and volume;
- Field QC samples collected at the frequency specified;

- Chain-of-custody protocols; and
- Sample shipment information.

Sample receipt forms provided by the laboratory will be reviewed for QC exceptions. The final laboratory data package will describe (in the case narrative) the effects that any identified QC exceptions have on data quality. The laboratory will review transcribed sample collection and receipt information for correctness prior to delivering the final data package.

9.3 Data Verification/Validation

Project decisions, conclusions, and recommendations will be based upon verified (validated) data. The purpose of data verification is to ensure that data used for subsequent evaluations and calculations are scientifically valid, of known and documented quality, and legally defensible. Field data verification will be used to eliminate data not collected or documented in accordance with the protocols specified in the SAP. Laboratory data verification will be used to eliminate data not obtained using prescribed laboratory procedures.

The QA Leader will validate data collected during the supplemental upland data collection field investigation to ensure that the data are valid and usable. Data will be validated in general conformance with EPA functional guidelines for data validation (EPA, 2004, and 2008). At a minimum, the following items will be reviewed to verify the data as applicable:

- Documentation that a final review of the data was completed by the Laboratory QA Coordinator;
- Documentation of analytical and QC methodology;
- Documentation of sample preservation and transport;
- Sample receipt forms and case narratives; and
- The following QC parameters:
    - Holding times and sample preservation
    - Method blanks
    - MS/MSDs
    - LCS/LCSDs
    - Surrogate spikes
    - Duplicates/replicates

When sample analytical data are received from the analytical laboratory, they will undergo a QC review by the QA Leader. The accuracy and precision achieved will be compared to the laboratory's analytical control limits. Example control limits are presented in Tables B-1 and B-2. Calculations of RPDs will follow standard statistical conventions and formulas as presented in Section 3.0. Additional specifications and professional judgment by the QA Leader may be incorporated when appropriate data from specific matrices and field samples are available.

A data quality assessment will be prepared to document the overall quality of the data relative to the DQOs. The major components of the data quality assessment are as follows:

- **Data Validation Summary.** Summarizes the data validation results for all sample delivery groups by analytical method. The summary identifies any systematic problems, data generation trends, general conditions of the data, and reasons for any data qualification.
- **QC Sample Evaluation.** Evaluates the results of QC sample analyses, and presents conclusions based on these results regarding the validity of the project data.
- **Assessment of DQOs.** An assessment of the quality of data measured and generated in terms of accuracy, precision, and completeness relative to objectives established for the project.
- **Summary of Data Usability.** Summarizes the usability of data, based on the assessment performed in the three preceding steps.

The data quality assessment will help to achieve an acceptable level of confidence in the decisions that are to be made based upon the project data. The project analytical data will be submitted to Ecology's EIM system after the data quality assessment is completed.

10.0 REFERENCES

Ecology 2004. Washington State Department of Ecology (Ecology), Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies, July 2004.

Environmental Protection Agency, 2008. U.S. Environmental Protection Agency (EPA), Contract Laboratory Program National Functional Guidelines for Superfund Organic Methods Data Review, EPA-540-R-08-01. June 2008.

Environmental Protection Agency, 2004. U.S. Environmental Protection Agency (EPA), Contract Laboratory Program National Functional Guidelines for Inorganic Data Review, OSWER 9240.1-45, EPA-540-R-04-004. October 2004.

Hart Crowser 2012. Gas Works Park Uplands Remedial Investigation. Seattle, Washington. February 1, 2012.

Table B-1

Target Practical Quantitation Limits
And Quality Control Limits for Soil Samples

Gas Works Park Site
Seattle, Washington

Analyte	CAS Number	Target Practical Quantitation Limits for Soil	Quality Control Limits for Soil	
			RPD*	% R
Polycyclic Aromatic Hydrocarbons by EPA 8270D-SIM- Low Level (ug/kg)				
Acenaphthene	83-32-9	5	0-30	31 - 100
Acenaphthylene	208-96-8	5	0-30	26 - 102
Anthracene	120-12-7	5	0-30	30 - 117
Benzo(a)anthracene	56-55-3	5	0-30	36 - 125
Benzo(a)pyrene	50-32-8	5	0-30	33 - 122
Benzo(b)fluoranthene	205-99-2	5	0-30	42 - 124
Benzo(g,h,i)perylene	191-24-2	5	0-30	27 - 107
Benzo(k)fluoranthene	207-08-9	5	0-30	37 - 129
Chrysene	218-01-9	5	0-30	42 - 115
Dibenzo(a,h)anthracene	53-70-3	5	0-30	30 - 128
Fluoranthene	206-44-0	5	0-30	43 - 119
Fluorene	86-73-7	5	0-30	33 - 106
Indeno(1,2,3-cd)pyrene	193-39-5	5	0-30	29 - 126
Naphthalene	91-20-3	5	0-30	27 - 107
Phenanthrene	85-01-8	5	0-30	38 - 108
Pyrene	129-00-0	5	0-30	36 - 122
BTEX by EPA Method 8260-Low level (ug/kg)				
Benzene	71-43-2	1.4	0-30	80 - 126
Ethylbenzene	100-41-4	25	0-30	80 - 134
Toluene	108-88-3	25	0-30	79 - 120
Xylenes (Total)	1330-20-7	3	NA	NA
Metals by EPA Methods 200.8 (mg/kg)				
Arsenic	7440-38-2	0.1	0-20	75-125
PCBs by EPA 8082-Low level (mg/kg)				
Aroclor 1016	12674-11-2	0.004	0-30	30-160
Aroclor 1221	11104-28-2	0.004	NA	NA
Aroclor 1232	11141-16-5	0.004	NA	NA
Aroclor 1242	53469-21-9	0.004	NA	NA
Aroclor 1248	12672-29-6	0.004	NA	NA
Aroclor 1254	11097-69-1	0.004	NA	NA
Aroclor 1260	11096-82-5	0.004	0-30	30-160
Total PCBs (sum of Aroclors)	12767-79-2	0.004	NA	NA

Notes:

CAS = Chemical Abstract Services

RPD = Relative percent difference

% R = Percent recovery

* Listed RPD is for laboratory replicates and duplicate spiked samples; RPD goal for field duplicates is 0-50.

mg = Milligrams

ug = Micrograms

kg = Kilograms

NA = Not applicable

PAH = Polycyclic Aromatic Hydrocarbons

TEC = Toxic equivalent concentration; PQL calculated as prescribed in WAC 173-340 using one-half the PQL for individual non-detected constituents.

Table B-2

Target Practical Quantitation Limits
And Quality Control Limits for Groundwater Samples

Gas Works Park Site

Seattle, Washington

Analyte	CAS Number	Target Practical Quantitation Limits for Water	Quality Control Limits for Water	
			RPD*	% R
Polycyclic Aromatic Hydrocarbons by EPA 8270D-SIM -Low level (ug/L)				
Acenaphthene	83-32-9	0.01	0-30	33 - 114
Acenaphthylene	208-96-8	0.01	0-30	25 - 104
Anthracene	120-12-7	0.01	0-30	18 - 113
Benzo(a)anthracene	56-55-3	0.01	0-30	31 - 125
Benzo(a)pyrene	50-32-8	0.01	0-30	10 - 109
Benzo(b)fluoranthene	205-99-2	0.01	0-30	31 - 134
Benzo(g,h,I)perylene	191-24-2	0.01	0-30	17 - 133
Benzo(k)fluoranthene	207-08-9	0.01	0-30	39 - 128
Chrysene	218-01-9	0.01	0-30	50 - 121
Dibenzo(a,h)anthracene	53-70-3	0.01	0-30	30 - 126
Fluoranthene	206-44-0	0.01	0-30	37 - 135
Fluorene	86-73-7	0.01	0-30	42 - 112
Indeno(1,2,3-cd)pyrene	193-39-5	0.01	0-30	32 - 124
Naphthalene	91-20-3	0.01	0-30	31 - 111
Phenanthrene	85-01-8	0.01	0-30	46 - 118
Pyrene	129-00-0	0.01	0-30	36 - 132
BTEX by EPA Method 8260-Low level (ug/L)				
Benzene	71-43-2	0.45	0-30	73 - 120
Ethylbenzene	100-41-4	0.42	0-30	71 - 128
Toluene	108-88-3	0.48	0-30	74 - 120
Xylenes (Total)	1330-20-7	0.78	NA	NA
Water Quality by EPA Method 300.0 (mg/L)				
Nitrate	NA	NA	NA	NA
Sulfate	14808-79-8	NA	NA	NA
Total Organic Carbon	NA	NA	NA	NA
Dissolved Inorganic Carbon	NA	NA	NA	NA

Notes:

CAS = Chemical Abstract Services

RPD = Relative percent difference

% R = Percent recovery

* Listed RPD is for laboratory replicates and duplicate spiked samples; RPD goal for field duplicates is 0-35.

ug = Micrograms

NA = Not applicable

cPAH = Carcinogenic Heavy Polycyclic Aromatic Hydrocarbons

TEC = Toxic equivalent concentration; PQL calculated as prescribed in WAC 173-340 using one-half the PQL for individual non-detected constituents.

Table B-3

Quality Control Samples Type and Minimum Frequency

Gas Works Park Site

Seattle, Washington

Parameter	Field QC Samples			Laboratory QC Samples			
	Field Duplicates	Trip Blanks	Equipment Rinsate Blanks	Method Blanks	LCS or OPR	MS/MSD	Lab Duplicates
PAHs by EPA 8270-SIM-Low Level	1 per 20 primary groundwater/soil samples	NA	1 per 20 primary groundwater/soil samples (1 per day minimum)	1 per batch*	1 per batch*	1 per batch*	NA
BTEX by EPA 8260-Low Level		NA		1 per batch*	1 per batch*	1 per batch*	NA
PCBs by EPA 8082-Low Level		NA		1 per batch*	1 per batch*	1 per batch*	NA

Notes:

*An analytical batch is defined as a group of samples taken through a preparation procedure and sharing a method blank, LCS, and MS/MSD (or MS and lab duplicate). No more than 20 field samples are contained in one batch.

BTEX = Benzene, toluene, ethylbenzene, and xylenes

LCS = Laboratory control sample

OPR = Ongoing precision and recovery

PAHs = Polycyclic Aromatic Hydrocarbons

PCBs = Polychlorinated Biphenyls

MS = Matrix spike

MSD = Matrix spike duplicate

NA = Not applicable

Table B-4

Soil, Water and NAPL Test Methods, Sample Containers, Preservatives and Holding Times

Gas Works Park Site

Seattle, Washington

Analysis	Method	Minimum Sample Size		Sample Containers		Sample Preservatives		Sample Holding Times[1]	
		Soil	Water	Soil	Water	Soil	Water	Soil	Water
PAHs	EPA 8270SIM	30 g	500 mL	(2) 8 oz glass widemouth with Teflon-lined lid	Two 500 mL amber glass with Teflon-lined lid	Cool ≤6°C	Cool ≤6°C	14 days to extraction (1 year if frozen), 40 days from extraction to analysis	7 days to extraction 40 days from extraction to analysis
BTEX	EPA 8260B	50 g	120 mL	2 oz glass widemouth with Teflon-lined septa lid	3 - 40 mL VOA Vials	Cool ≤6°C	Cool ≤6 °C, HCl to pH < 2	14 days	14 days
Arsenic	EPA 200.8	100 g	500 mL	4 or 8 oz glass widemouth with Teflon-lined lid	1 L HDPE	Cool ≤6°C	Cool ≤6 °C, HNO_3 to pH < 2 (Dissolved metals preserved after filtration)	180 days to digestion, 180 days to analysis	180 days to digestion, 180 days to analysis
PCBs	EPA 8082	50 g	--	8 oz glass widemouth with Teflon-lined lid	--	Cool ≤6°C	--	14 days to extraction (1 year if frozen), 40 days from extraction to analysis	--
Petrophysical Testing	Various	--	--	Frozen core, maximum length of 2.5 feet.	--	Freeze	--	Send to PTS Laboratory within two days of collection	--

Notes:

[1]Holding times are based on elapsed time from date of sample collection.

BTEX = benzene, toluene, ethylbenzene, xylenes

VOA = Volatile organic analysis

HCl = Hydrochloric Acid

HDPE = High density polyethylene

HNO_3 = nitric acid

PAHs = Polycyclic Aromatic Hydrocarbons

PCBs = Polychlorinated Biphenyls

oz = ounce

mL = milliliter

L = liter

g = gram

APPENDIX C
Health and Safety Plan

Appendix C
Site Health and Safety Plan

Supplemental Upland Investigation
Gas Works Park Site
Seattle, Washington

for
Puget Sound Energy

March 13, 2013

GeoEngineers

Plaza 600 Building
600 Stewart Street, Suite 1700
Seattle, Washington 98101
206.728.2674

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GEOENGINEERS, INC.
SITE HEALTH AND SAFETY PLAN
GAS WORKS PARK SEDIMENT SITE SUPPLEMENTAL UPLAND INVESTIGATION
FILE NO. 0186-846-01

This checklist is to be used in conjunction with the GeoEngineers Safety Program Manual. Together, the program and this checklist constitute the site safety plan for this site. This plan is to be used by GeoEngineers personnel working on this site during site exploration activities. If the work entails potential exposures to other substances or unusual situations, additional safety and health information will be included and the updated plan will be approved by the GeoEngineers Health and Safety Manager. All plans are to be used in conjunction with current standards and policies outlined in the GeoEngineers Health and Safety Program Manual.

Liability Clause: If requested by subcontractors, this site safety plan may be provided for informational purposes only. In this case, Form C-3 shall be signed by the subcontractor. Please be advised that this Site Safety Plan is intended for use by GeoEngineers Employees only. Nothing herein shall be construed as granting rights to GeoEngineers' subcontractors or any other contractors working on this site to use or legally rely on this Site Safety Plan. GeoEngineers specifically disclaims any responsibility for the health and safety of any person not employed by them.

This HASP will be updated as appropriate as additional field activities occur. Additional scopes of work may be covered by an addendum to this existing HASP.

1.0 GENERAL PROJECT INFORMATION

Project Name:	Gas Works Park Sediment Site Supplemental Upland Investigation
Project Number:	00186-846-01, T0900
Type of Project:	Remedial Investigation (Exploratory Boring, Soil and Groundwater Sampling, NAPL measurements/sampling, Well Drilling, Installation, and Development, laser induced fluorescence explorations, geophysical studies, and ground surveying)
Start/Completion:	Likely March 2013/October 2013
Subcontractors:	To be determined

2.0 SCOPE OF WORK

The general scope of work is as follows:

1. Borings:

   a. Oversee drilling of environmental and geotechnical soil borings and monitoring well borings using hollow-stem auger, geoprobe, sonic, and mud rotary drill rigs to depths of up to 50 feet below ground surface.
   b. Sample soil for logging purposes using field screening techniques including visual observation, PID vapor testing, and water sheen testing.
   c. Soil samples to be collected for chemical analysis depending on boring type and location.
2. Well Installation:
   a. Oversee and log the installation of monitoring wells.
3. Well Development:
   a. Develop new wells and/or redevelop existing wells by pumping/bailing and surging/swabbing. Measure water quality parameters during well development.
4. Groundwater Sampling:
   a. Obtain groundwater samples and/or monitor groundwater quality parameters from new and existing wells.
   b. Measure NAPL thickness in selected wells and collect samples of NAPL for chemical analysis.
5. Work with direct-push driller and TarGOST contractor to complete NAPL evaluation.
6. Geophysical Survey.

3.0 PERSONNEL/CONTACT INFORMATION PHONE NUMBERS

Chain of Command	Title	Name	Telephone Numbers
1	Project Manager	Zanna Satterwhite	o: 206.239.3231 c: 206.499.7588
2	Site Safety and Health Supervisor*, Field Activity Manager	Field Eng./Geologist with oversight by Zanna Satterwhite	o: 206.239.3231 c: 206.499.7588
3	Principal	Dan Baker	o: 206.239.3232
4	Health and Safety Program Manager	Wayne Adams	o: 253.722.2793 c: 253.350.4387
5	Field Engineer/Geologist	Paul Robinette Andrew Johnson Claudia de la Via John Peters	c: 253.278.0273 c: 206.455.5238 c: 571.232.1040 c: 360.790.8570
	Current Owner	John Rork, PSE	c: 425.456.2228

* **Site Safety and Health Supervisor** – The individual present at a hazardous waste site responsible to the employer and who has the authority and knowledge necessary to establish the site-specific health and safety plan and verify compliance with applicable safety and health requirements.

4.0 EMERGENCY INFORMATION

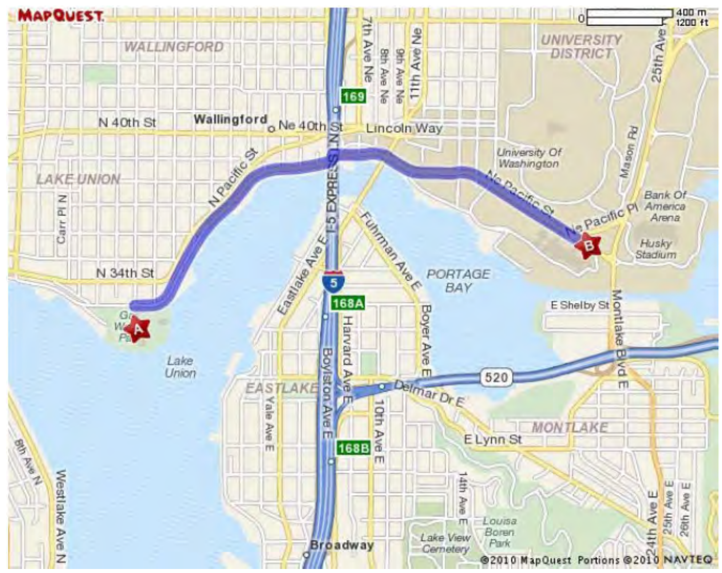
Hospital Name and Address: University of Washington Medical Center
1959 NE Pacific Street
Seattle, Washington 98195

Phone Numbers (Hospital ER): Phone: **206.598.3300**

Distance: 2 miles

Route to Hospital:

1. Head east on N Northlake Way toward Meridian Avenue N
2. Continue onto NE Pacific Street
3. Hospital will be on your right



Ambulance:	9-1-1
Poison Control:	Seattle (206) 253-2121; Other (800) 732-6985
Police:	9-1-1
Fire:	9-1-1
Location of Nearest Telephone:	Cell phones are carried by field personnel.
Nearest Fire Extinguisher:	Located in the GeoEngineers vehicle on-site.
Nearest First-Aid Kit:	Located in the GeoEngineers vehicle on-site.

4.1 Standard Emergency Procedures

1. Get help -
   - Send another worker to phone 911 (if necessary)
   - As soon as feasible, notify GeoEngineers' project manager
2. Reduce risk to injured person -
   - Turn off equipment
   - Move person from injury location (if possible)

- Keep person warm
- Perform CPR (if necessary)

3. Transport injured person to medical treatment facility (if necessary) -
   - By ambulance (if necessary) or GeoEngineers vehicle
   - Stay with person at medical facility
   - Keep GeoEngineers manager apprised of situation and notify human resources manager of situation

5.0 LIST OF FIELD PERSONNEL AND TRAINING

Name of Employee on Site	Level of HAZWOPER Training (24-/40-hr)	Date of 8-Hr Refresher Training	Date of HAZWOPER Supervisor Training	First Aid/ CPR	Date of Respirator Fit Test
Jim Roth	6/14/1989	12/21/2007*	12/22/2000	NR	NR
Dan Baker	10/20/1989	Estimated completion date 2/26/2013	11/20/1995	9/21/2010	NR
Zanna Satterwhite	7/10/2000	Estimated Completion date 2/26/2013	8/25/2004	9/21/2010	Estimated Completion Date 2/26/2013
Paul Robinette	5/22/1997	4/20/2012	12/4/2002	12/21/2011	8/9/2012
Claudia de la Via	9/20/2011	9/24/2012	NR	10/26/2011	9/25/2012
John Peters	4/27/2012	4/27/2012	NR	8/22/2012	5/1/2012
Andrew Johnson	9/3/2004	2/19/2013	NR	10/26/2011	11/2012

* = Employee will not be in exclusion or decontamination zone.

6.0 KNOWN (OR ANTICIPATED) HAZARDS

Note: A hazard assessment will be completed at every site prior to beginning field activities. Updates will be included in the daily log. This list is a summary of hazards listed on the form.

6.1 Physical Hazards

X	Drill rigs
X	Well development rig
	Backhoe
	Trackhoe
	Crane
	Front End Loader (Tracked Bobcat)
	Excavations/trenching (1.5:1 slopes for site soils)

	Shored/braced excavation if vertical cuts greater than 4 feet of depth (sheet pile wall anticipated around portion of UST-remedial excavation).
X	Overhead hazards/power lines
X	Tripping/puncture hazards (debris on-site, steep slopes or pits)
X	Traffic hazard (MW-3D)

6.2 Physical Hazard Mitigation Measures or Procedures

- Use traffic cones, candles, and caution tape to delineate active work area/exclusion zone around boring locations in the Park. The exclusion zone will be an approximate 50-foot radius around each boring in the Park. For borings in areas where space is limited, such as the Harbor Patrol Area, the exclusion zone will be an approximate 10 foot distance outward from the perimeter of the working area. Personnel will wear blaze orange vests for increased visibility by vehicle and equipment operators.
- Field personnel will be aware constantly of the location and motion of heavy equipment. A safe distance will be maintained between personnel and the equipment. Personnel will be visible to the operator at all times and will remain out of the swing and/or direction of the equipment apparatus. Personnel will approach operating heavy equipment only when they are certain the operator has indicated it is safe to do so.
- Heavy equipment and/or vehicles used on this site will not work within 20 feet of overhead utility lines without first ensuring that the lines are not energized. This distance may be reduced to 10 feet depending on the client and the use of a safety watch.
- Keep a safe distance from energized parts which is a minimum of 10 feet for 50 kV and under. The minimum distance will be more for higher voltages (above 50kV). The only exception is for trained and qualified electrical workers using insulated tools designed for high voltage lines.
- Personnel will avoid tripping hazards, steep slopes, pit and other hazardous encumbrances. If it becomes necessary to work within 6 feet of the edge of a pit, oversteepened slope, pier or other potentially hazardous area, appropriate fall protection measures will be implemented by the Site Safety and Health Supervisor in accordance with OSHA/WISHA regulations and the GEI Safety Program manual.
- Care should be used to avoid falling accidents and to maintain good house-keeping. By keeping tools and equipment picked up and out of working area walkways, Personnel will take care when walking on slippery park surfaces, such as wet grass, and on sloped ground surfaces and embankments.
- Exclusion zones will be made around work areas and open holes with fences, traffic cones, caution tape barricades, etc. to limit public access.
- All field personnel will adhere to general safety rules including wearing appropriate PPE, hard hats and safety vests. Eating, drinking, and/or use of tobacco or cosmetics will be restricted in all work areas. Personnel will prevent splashing of liquids containing chemicals and minimize emissions of dust.

- Hard hats will be worn by all personnel at all times during drilling, where overhead obstructions are present, and while working in traffic-accessible areas.
- Nitrile safety gloves will be worn to protect the hands from dust, chemicals, and while using equipment. Proper tools and equipment will be used to avoid hand or finger pinching or trauma resulting from inappropriate use of tools or equipment.
- Safety glasses or face shields will be worn during sample collection and decontamination activities, and other instances when appropriate.
- Use proper lifting techniques.
- Workers will ensure adequate hydration, shade, and breaks when temperatures are elevated.
- Work will proceed during daylight hours only, or under sufficient artificial light.
- Noise: Excessive levels of noise (exceeding 85 dBA) may be experienced during drilling. Personnel potentially exposed will wear ear plugs or muffs with a noise reduction rating (NRR) of at least 25 dB whenever it becomes difficult to carry on a conversation 6 feet away from a co-worker or whenever noise levels become bothersome. (Increasing the distance from the source will decrease the noise level noticeably.) See Section 10.0 for more information on noise monitoring.
- Overhead Power Line Clearance Safety: Working equipment around overhead power lines requires distance and a spotter. Before a job begins, call the utility company and find out voltage in lines. Have the equipment de-energized if possible. Ensure that the equipment remains de-energized by using some type of lockout and tag procedure, and ensure that the electrician uses grounding lines when they are required.

Engineering controls:

______	Trench shoring and excavation wall sloping (1.5:1 slope for most Site soils)
X	Locate work spaces upwind when possible/wind direction monitoring
______	Other soil covers (as needed)
X	Other: Traffic cones, caution tape; steel fencing around rig if left in Park overnight.
______	

6.3 Chemical Hazards (potentially present at site)

6.3.1 Petroleum Hydrocarbons:

X	Benzene, ethylbenzene, toluene, xylenes
______	Gasoline
______	Diesel fuel
______	Other petroleum fuels:_________

6.3.2 Hazards from Other Organic Compounds (present or potentially present at site):

______	Chlorinated hydrocarbons (Polychlorinated biphenyls) and PCE. Breakdown products of PCE have not been

	detected at the site.
X	PAHs (polycyclic aromatic hydrocarbons)
	Pesticides/Herbicides
	Semi-volatile organic compounds SVOC
X	Naphthalenes

6.3.3 Metals (potentially present at site)

	Lead
X	Other metals (arsenic)

6.3.4 Historical Sampling

In general, site soil, sediment and groundwater have been characterized during multiple phases of environmental studies. The contaminants of concern for the Gas Works Park site include naphthalenes, total polycyclic aromatic hydrocarbons (TPAHs), BETX and arsenic. Short-term exposure to large amounts of naphthalene and TPAH can cause mild symptoms, or serious illness. Mild symptoms may include skin or eye irritation, headache, confusion, and blurry vision. Serious effects may include degenerative changes in the kidneys, liver, thymus, or spleen, dermatitis, or conjunctivitis.

Known chemical characteristics (maximum/approximate average concentrations):

Analytes	Soil Chemistry (mg/kg)	Water Chemistry (µg/l)
Arsenic	47.5	60
Benzo(a)anthracene	3,000	4,500
Benzo(b)fluoranthene	4,000	2,000
Benzo(k)fluoranthene	61.2	3,600
Benzo(a)pyrene	10,000	2,200
Chrysene	6,000	4,200
Dibenz(a,h)anthracene	2,000	45
Indeno(1,2,3-cd)pyrene	11,000	1,900
Fluoranthene	8,000	41,000
Fluorene	N/A	20,000
Naphthalene	13,000	170,000
Pyrene	18,000	32,000
Benzene	2,900	642,000
Ethylbenzene	1,250	20,800
Toluene	9,220	222,000
Xylenes (total)	11,400	251,000

Note: Additional information applicable to the site: Shallow contaminated soils have been capped with approx. 2 feet of clean fill soil. In-situ cleanup of benzene plume was completed in NE portion of Park in vicinity of the Playbarn.

6.3.5 Summary of Chemical Hazards

Compound/ Description	Exposure Limits/IDLH[b]	Exposure Routes	Toxic Characteristics[d]
Polycyclic aromatic hydrocarbons (PAH) as coal tar pitch volatiles	PEL 0.2 mg/m³ TLV 0.2 mg/m³ REL 0.1 mg/m³ IDLH 80 mg/m³	Inhalation, ingestion, skin and/or eye contact	Dermatitis, bronchitis, potential carcinogen
Benzene	OSHA PEL 1 ppm Short term PEL: 5 ppm ACGIH PEL 0.5 ppm	Inhalation, skin absorption, ingestion, skin and/or eye contact	Irritated eyes, skin, nose, respiratory system; dizziness; headache, nausea, staggered gait; anorexia, lassitude (weakness, exhaustion); dermatitis; bone marrow depression; [potential occupational carcinogen]
Arsenic	PEL 0.01 mg/m³ TLV 0.01 mg/m³ Ceiling 0.002 mg/m³ IDLH 5 mg/m³	Inhalation, skin absorption, ingestion, skin and/or eye contact	Ulcerated nasal septum, dermatitis, gastrointestinal disturbances, peripheral neuropathy, respiratory irritation, hyperpigmentation of skin, potential carcinogen

6.4 Chemical Hazard Mitigation Measures or Procedures

Air monitoring will be conducted for VOC vapors as discussed in Section 9.0. A PID will be used on site during any soil disturbance activity, or well development or groundwater/NAPL sampling.

- Level D PPE will be worn at all times on site. Potentially exposed personnel will wash gloves, hands, face, and other pertinent items to prevent hand-to-mouth contact. This will be done prior to hand-to-mouth activities including eating, smoking, etc.
- Adequate personnel and equipment decontamination will be used to decrease potential ingestion and inhalation.
- Field personnel will visually inspect air quality for the presence of dust in the work area to ensure that personnel are not exposed to contaminants through inhalation. Continuous visual monitoring will be used to identify the potential need for dust controls, or monitoring, as described below:
    - If dust is observed and sustained for more than five minutes in any work area, dust controls will be implemented including slower rate or work and applying water for dust control. If dust controls are effective, a normal rate of work will be resumed.

- If dust is not controlled, the area will be evacuated, and exposure will be controlled by evacuation or the work area.

6.5 Biological Hazards

______	Poison Ivy or other vegetation
______	Insects or snakes
X	Used hypodermic needles or other infectious hazards
______	Others

6.6 Biological Hazard Mitigation Measures or Procedures

Site personnel shall avoid contact with or exposures to potential biological hazards encountered.

Additional Hazards: None anticipated

6.7 Additional Hazards (Update in Daily Log)

Include evaluation of:

- *Physical Hazards* (excavations and shoring, equipment, traffic, tripping, heat stress, cold stress and others)
- *Chemical Hazards* (odors, spills, free product, airborne particulates and others present)
- *Biological Hazards* (snakes, spiders, other animals, discarded needles, poison ivy and others present)

7.0 LIST OF FIELD ACTIVITIES

Check the activities to be completed during the project

X	Site reconnaissance
X	Exploratory borings
______	Construction monitoring
X	Geophysical Survey
______	Test pit exploration
X	Monitor well installation
X	Monitor well development
X	Soil logging
X	Field screening of soil samples
X	Vapor measurements
X	Groundwater sampling
X	Groundwater depth and free product measurement
X	NAPL measurements/sample collection

______	Soil stockpile testing
______	Remedial excavation
______	Underground storage tank (UST) removal monitoring
______	Remediation system monitoring
______	Recovery of free product

8.0 SITE DESCRIPTION

8.1 Site History

Gas Works Park (site) is located along the north shore of Lake Union, north of downtown Seattle. From the early 1900s until 1956, gas companies operated a plant at the site that converted coal and oil into manufactured gas. The American Tar Company operated nearby, manufacturing tar from coal by-products. Releases and wastes from the gas works and tar production facilities contaminated the soil and groundwater as well as sediments in Lake Union. Contaminated soil capping and an in-situ cleanup of a benzene-impacted area in the NE portion of the Park have been completed since 2000.

Address/Location:	Gas Works Park - 2101 N. Northlake Way, Seattle, Washington 98103
Site topography:	Varies. Generally rolling hills
Predominant wind direction:	Southwest
Site drainage:	

X	Municipal drain
X	Surface water drainage –direction of flow South to Lake Union
X	Engineered site drains
	Other

Utility check complete:	Private and public (one-call) utility locate to be arranged by GeoEngineers prior to fieldwork. Will also meet in the field with Parks staff who have knowledge of Site utilities.
Traffic or vehicle access control plans:	
Site access control (exclusion zone) defined by:	

X	Temporary chain-link fence (only areas left overnight with equipment). Fence cannot penetrate ground surface.
X	Caution tape
X	Traffic cones, barricades or candles
	Other

HOT ZONE/EXCLUSION ZONE:

As part of site control measures to protect the public and restrict access drilling operations, an exclusion zone of approximately 50-foot radius around the drill rigs will be established around each boring in the Park. For borings in areas where space is limited, such as the Harbor Patrol Area, the exclusion zone will be an approximate 10 foot distance outward from the perimeter of the working area. The exclusion zone will be clearly marked by GeoEngineers staff with fencing, rope, barriers, tape, or other obvious marking methods. Inside the exclusion zone, workers will be required to have current hazardous materials training and meet all other health and safety requirements, as stated in this HASP. Exclusion zone controls including working upwind and air monitoring will be implemented to limit the potential for chemical exposure associated with site activities. Access to the exclusion zone will be controlled by GeoEngineers. Only authorized personnel shall be permitted access to the exclusion zone, and staff will stop work if members of the public insist on entering.

CONTAMINATION REDUCTION/DECONTAMINATION ZONE:

The contamination reduction/decontamination zone for the site includes all areas outside the hot zone/exclusion zone area.

8.2 Personal Protective Equipment

Personal Protective Equipment (PPE). Minimum level of protective equipment for this Site is Level D. After the initial and/or daily hazard assessment has been completed, select the appropriate protective gear (PPE) to preserve worker safety. Task-specific levels of PPE shall be reviewed with field personnel during the pre-work briefing conducted prior to the start of drilling/well development activities.

Check applicable personal protection gear to be used as appropriate:

__X__ Hardhat
__X__ Steel-toed boots
__X__ Safety glasses
__X__ Hearing protection (if it is difficult to carry on a conversation 6 feet away)
__X__ Rubber boots (if wet conditions)

Gloves (specify):

__X__ Nitrile
______ Latex
______ Liners
______ Leather
______ Other (specify) ________________________________

Protective clothing:

______ Tyvek (If dermal protection in addition to gloves is required. If dry conditions are encountered, Tyvek is sufficient.)

______ Saranex (personnel shall use Saranex if liquids are handled or splash may be an issue)

__X__ Layered warm clothing (as needed)

__X__ Rain gear (as needed)

Inhalation hazard protection:

__X__ Level D. None.

______ Level C. Respirators with organic vapor filters/P100 filters will always be onsite with workers in the event that conditions warrant upgrading respiratory protection.

If additional dermal or respiratory protection is required, the following will be added to Level D PPE as appropriate:

Protective clothing:

__X__ Tyvek (Required only if additional dermal protection other than gloves is required).

Inhalation hazard protection:

__X__ Respirators with organic vapor filters/P100 filters will be onsite with workers in the event that conditions warrant upgrading to Level C respiratory protection.

LIMITATIONS OF PROTECTIVE CLOTHING

PPE clothing ensembles designated for use during site activities shall be selected to provide protection against known or anticipated hazards. However, no protective garment, glove, or boot is entirely chemical-resistant, nor does any PPE provide protection against all types of hazards. To obtain optimum performance from PPE, site personnel shall be trained in the proper use and inspection of PPE. This training shall include the following:

- Inspect PPE before and during use for imperfect seams, non-uniform coatings, tears, poorly functioning closures, or other defects. If the integrity of the PPE is compromised in any manner, proceed to the contamination reduction zone and replace the PPE.
- Inspect PPE during use for visible signs of chemical permeation such as swelling, discoloration, stiffness, brittleness, cracks, tears, or other signs of punctures. If the integrity of the PPE is compromised in any manner, proceed to the contamination reduction zone and replace the PPE.
- Disposable PPE should not be reused after breaks unless it has been properly decontaminated.

RESPIRATOR SELECTION, USE, AND MAINTENANCE

GeoEngineers has developed a written respiratory protection program in compliance with OSHA requirements contained in 29 CFR 1910.134. Site personnel shall be trained on the proper use, maintenance, and limitations of respirators. Site personnel that are required to wear respiratory protection shall be medically qualified to wear respiratory protection in accordance with 29 CFR 1910.134. Site personnel that will use a tight-fitting respirator must have passed a qualitative or quantitative fit test conducted in accordance with an OSHA-accepted fit test protocol. Fit testing must be repeated annually or whenever a new type of respirator is used.

RESPIRATOR CARTRIDGES

If site personnel are required to wear air-purifying respirators, the appropriate cartridges shall be selected to protect personnel from known or anticipated site contaminants. The respirator/cartridge combination shall be certified and approved by NIOSH. A cartridge change-out schedule shall be developed based on known site contaminants, anticipated contaminant concentrations, and data supplied by the cartridge manufacturer related to the absorption capacity of the cartridge for specific contaminants. Site personnel shall be made aware of the cartridge change-out schedule prior to the initiation of site activities. Site personnel shall also be instructed to change respirator cartridges if they detect increased resistance during inhalation or detect vapor breakthrough by smell, taste, or feel although breakthrough is not an acceptable method of determining the change-out schedule. Cartridges should be changed a minimum of once daily.

RESPIRATOR INSPECTION AND CLEANING

The Site Safety and Health Supervisor shall periodically (i.e., weekly) inspect respirators at the project site. Site personnel shall inspect respirators prior to each use in accordance with the manufacturer's instructions. In addition, site personnel wearing a tight-fitting respirator shall perform a positive and negative pressure user seal check each time the respirator is donned to ensure proper fit and function. User seal checks shall be performed in accordance with the GeoEngineers respiratory protection program or the respirator manufacturer's instructions.

Respirators shall be hygienically cleaned as often as necessary to maintain the equipment in a sanitary condition. At a minimum, respirators shall be cleaned at the end of each work shift. Respirator cleaning procedures shall include an initial soap/water cleaning, a water rinse, a sanitizing soaking, and a final water rinse. One capful of bleach per one gallon of water can be used to create the sanitizing soak solution. When not in use, respirators shall be stored to protect against damage, hazardous chemicals, sunlight, dust, excessive temperatures, and excessive moisture. In addition, respirators shall be stored to prevent deformation of the face piece and exhalation valve.

FACIAL HAIR AND CORRECTIVE LENSES

Site personnel with facial hair that interferes with the sealing surface of a respirator shall not be permitted to wear respiratory protection or work in areas where respiratory protection is required. Normal eyeglasses cannot be worn under full-face respirators because the temple bars interfere with the sealing surface of the respirator. Site personnel requiring corrective lenses will be provided with spectacle inserts designed for use with full-face respirators. Contact lenses should not be worn with respiratory protection.

9.0 AIR MONITORING PLAN

Air monitoring will be performed prior to drilling to measure background conditions, every hour in the breathing zone during drilling/well development/groundwater-NAPL sampling and every two hours during drilling activities at the perimeter of the exclusion zone using a photo ionization detector (PID). The PID will be used to measure parts per million (ppm) of organic vapors. PID measurements from the perimeter of the exclusion zone during drilling will be recorded in a field log and compared to background concentrations measured prior to drilling or to additional background measurements that are taken concurrent with drilling in areas of the park clearly separated from potential drilling impacts. If the PID registers a measurable concentration in the breathing zone, air monitoring frequencies and personal protection shall be modified per the "Air Monitoring Action Levels" table below. If air monitoring results at the exclusion zone boundary are greater than the background concentrations, the exclusion zone area will be increased.

Work will be conducted upwind if at all possible. The PID will not measure/respond to PAHs; however if VOCs areas present, the PID will detect these chemicals.

AIR MONITORING PLAN

Check instrumentation to be used:

__X__ PID (Photoionization Detector)

_____ Other (i.e., detector tubes): other consultant on site(Aspect) will be monitoring with PID

Check monitoring frequency/locations: and type (specify: work space, borehole, breathing zone):

_____ 15 minutes - Continuous during soil disturbance activities or handling samples

_____ 15 minutes

_____ 30 minutes

__X__ Hourly (in breathing zone during drilling, well development, groundwater-NAPL sampling)

__X__ Every 2 hours (at perimeter of exclusion zone during drilling)

The workspace will be monitored using a photoionization detector (PID). These instruments must be properly maintained, calibrated and charged (refer to the instrument manuals for details). Zero this meter in the same relative humidity as the area it will be used in and allow at least a 10-minute warm-up prior to zeroing. Do not zero in a contaminated area. The PID can be tuned to read chemicals specifically if there are not multiple contaminants on site. It can be tuned to detect one chemical with response factor entered into the equipment, but the PID picks up all volatile organic compounds (VOCs) present. Ionization potential (IP) of chemical has to be less than lamp (11.7/ 10.6eV). The ppm readout on the instrument is relative to the IP of isobutylene (calibration gas), so conversion must be made in order to estimate ppm of the chemical on-site.

An initial vapor measurement survey of the site should be conducted to detect "hot spots" if contaminated soil is exposed at the surface. Vapor measurement surveys of the workspace should be conducted at least hourly.

Additional personal air monitoring for specific chemical exposure:

AIR MONITORING ACTION LEVELS

Contaminant	Activity	Monitoring Device	Frequency of Monitoring Breathing Zone	Action Level	Action
Organic Vapors	Environmental Remedial Actions	PID	Start of shift; prior to excavation entry; every 30 to 60 minutes and in event of odors	Background to 2.5 parts per million (ppm) in breathing zone	Use Level D or Modified Level D PPE
Organic Vapors	Environmental Remedial Actions	PID	Start of shift; prior to excavation entry; every 30 to 60 minutes and in event of odors	2.5 to 25 ppm in breathing zone	Upgrade to Level C respiratory protection OR Temporarily step away from the area and allow the vapors to dissipate.
Organic Vapors	Environmental Remedial Actions	PID	Start of shift; prior to excavation entry; every 30 to 60 minutes	> 25 ppm in breathing zone	Stop work and evacuate the area. Contact Health and Safety Manager (HSM) for guidance.
Combustible Atmosphere	Environmental Remedial Actions	PID/TLV	Start of shift; prior to excavation entry; every 30 to 60 minutes	<10% LEL or <1000 ppm	Depends on contaminant. The PEL is usually exceeded before the LEL.
Combustible Atmosphere	Environmental Remedial Actions	PID/TLV Or 4 gas meter	Start of shift; prior to excavation entry; every 30 to 60 minutes	>10% LEL or >1000 ppm	Stop work and evacuate the site. Contact HSM for guidance.
Oxygen Deficient/Enriched Atmosphere	Environmental Remedial Actions Confined Spaces	Oxygen meter Or 4 gas meter	Start of shift; prior to excavation entry; every 30 to 60 minutes	>19.5<23.5%	Continue work if inside range. If outside range, exit area and contact HSM.

10.0 NOISE MONITORING PLAN

In order to meet the noise requirements of Chapter 173-60 WAC and Seattle Municipal Code Chapter 25.08, noise monitoring will be performed every two hours during drilling operations at the perimeter of the exclusion zone using a sound level meter. Sound level measurements will be compared to the maximum permissible sound levels (MPSL) for drilling in a residential area

(80 decibels). This decibel (dBA) value was confirmed with Jeff Stalter of the City's Noise Abatement Program. Mr. Stalter stated that the City's noise code is more restrictive than the noise standards in WAC 173-60. If sound levels are greater than the MPSL, the exclusion zone area will be increased so that the MPSL is not exceeded at the perimeter of the exclusion zone, unless it can be shown by noise measurements that the MPSL exceedance is being generated by other background sources of noise.

11.0 DECONTAMINATION PROCEDURES

Decontamination consists of washing soiled boots and gloves using bucket and brush provided on-site in the contamination reduction zone. Inner gloves will then be removed, and respirator (if used), hands and face will be washed in either a portable wash station or a bathroom facility in the support zone. Employees will perform decontamination procedures and wash prior to eating, drinking or leaving the site. **Used PPE to be placed in on-site drum/dumpster.**

12.0 WASTE DISPOSAL OR STORAGE

Investigation-derived waste (IDW) will be generated during field activities. The IDW that is generated during the sampling, including soil cuttings, development and decontamination water, will be contained in 55-gallon drums and temporarily stored on site. Drums will be transferred by the driller to this temporary storage area at the end of each day of fieldwork. The solid IDW and decontamination water and well development water will be disposed at a permitted disposal facility after waste characterization is completed. Liquid and solid waste shall be contained in separate 55-gallon drums to the greatest extent possible, to reduce potential increases in disposal costs.

PPE disposal (specify):

__X__ On-site, pending analysis and further action

_____ Secured (list method) ____

_____ Other (describe destination, responsible parties): _______________________

13.0 DOCUMENTATION EXPECTED TO BE COMPLETED

The Field Log is to contain the following information:

- Updates on hazard assessments, field decisions, and conversations with subs, client or other parties;
- Sampling/monitoring log;
- Air monitoring/calibration results; personnel, locations monitored, activity at the time of monitoring;
- Actions taken;
- Action level for upgrading PPE and rationale; and

- Meteorological conditions (temperature, wind direction, wind speed, humidity, rain, snow, etc.).

Required forms:

- Field Log
- Health and Safety Plan acknowledgment by GEI employees (Form C-2)
- Contractors Health and Safety Plan Disclaimer (Form C-3)
- Conditional forms available at GeoEngineers office: Accident Report (Form C-4)

14.0 APPROVALS

1. Plan Prepared	Sandy Smith Signature	February 2013 Date
2. Plan Approval	Jim Roth PM Signature	February 2013 Date
3. Health & Safety Officer	Wayne Adams Health & Safety Program Manager	February 2013 Date

FORM C-1
HEALTH AND SAFETY PRE-ENTRY BRIEFING
GAS WORKS PARK SEDIMENT SITE SUPPLEMENTAL UPLAND INVESTIGATION
FILE NO. 0186-846-01

Inform employees, contractors and subcontractors or their representatives about:

- The nature, level and degree of exposure to hazardous substances they're likely to encounter;
- All site-related emergency response procedures; and
- Any identified potential fire, explosion, health, safety or other hazards.

Conduct briefings for employees, contractors and subcontractors, or their representatives as follows:

- A pre-entry briefing before any site activity is started; and
- Additional briefings, as needed, to make sure that the Site-specific HASP is followed.

Make sure all employees working on the Site are informed of any risks identified and trained on how to protect themselves and other workers against the Site hazards and risks

Update all information to reflect current sight activities and hazards.

All personnel participating in this project must receive initial health and safety orientation. Thereafter, brief tailgate safety meetings will be held as deemed necessary by the Site Safety and Health Supervisor.

The orientation and the tailgate safety meetings shall include a discussion of emergency response, Site communications and site hazards.

Company Employee

Date	Topics	Attendee	Name	Initials

FORM C-2
SITE SAFETY PLAN – GEOENGINEERS' EMPLOYEE ACKNOWLEDGMENT
GAS WORKS PARK SEDIMENT SITE SUPPLEMENTAL UPLAND INVESTIGATION
FILE NO. 0186-846-01

(All GeoEngineers' Site workers shall complete this form, which should remain attached to the Safety Plan and filed with other project documentation).

I hereby verify that a copy of the current Safety Plan has been provided by GeoEngineers, Inc., for my review and personal use. I have read the document completely and acknowledge an understanding of the safety procedures and protocol for my responsibilities on site. I agree to comply with all required, specified safety regulations and procedures.

Print Name	Signature	Date

FORM C-3
SUBCONTRACTOR AND SITE VISITOR SITE SAFETY FORM
GAS WORKS PARK SEDIMENT SITE SUPPLEMENTAL UPLAND INVESTIGATION
FILE NO. 0186-846-01

I verify that a copy of the current Site Safety Plan has been provided by GeoEngineers, Inc. to inform me of the hazardous substances on Site and to provide safety procedures and protocols that will be used by GeoEngineers' staff at the Site. By signing below, I agree that the safety of my employees is the responsibility of the undersigned company.

Print Name	Signature	Firm	Date

APPENDIX D
Kite Hill Geotechnical Scope

APPENDIX D
PSE KITE HILL GEOTECHNICAL SCOPE

Numerous explorations have been completed around the perimeter of Kite Hill, primarily for environmental and hydrogeological purposes. The subsurface conditions represented by these explorations are illustrated in Cross-sections S-S', U-U' and V-V' (GWSA Tech Team, 2011). These cross-sections show a considerable thickness of loose fill soils below the south portion of Kite Hill. The fill soils are up to about 30 feet in thickness along the Kite Hill portion of the Lake Union shoreline. The exploration programs completed previously included laboratory testing to determine certain geologic and engineering characteristics of the fill and underlying native soils. However, additional explorations and laboratory testing will be completed to provide sufficient information for engineering analyses.

The purpose of GeoEngineers' initial design services will be to further explore the subsurface soil and groundwater conditions in the area of Kite Hill to supplement existing exploration information and provide the basis for developing final geotechnical recommendations and design criteria for the project. We expect that the primary design objectives will be directed toward 1) evaluating the stability of Kite Hill where it is in close proximity to the shoreline, especially with regard to seismic considerations (liquefaction and soil strength loss), 2) developing recommendations for improving the stability, including consideration of buttresses and retaining walls, as required, and 3) providing recommendations for placement of a soil cap across Kite Hill.

The City of Seattle Building Code (SBC) Section 1803, 5.11.1 requires that slope stability analyses for steep slope environmentally critical areas (slopes steeper than 40 percent and more than 10 feet in height) be completed in accordance with Chapter 16 of the SBC and Section 11.4.5 of ASCE 7 using ground motion with 2/3 times the value identified by the building code for an event with a 2 percent probability of exceedance in 50 years. The stability of Kite Hill will be completed using this code specified seismic ground motion. Based on our preliminary review of the available subsurface information, liquefaction and seismic instability of Kite Hill under the design seismic event appear likely.

Based on the available subsurface information for the nearby portions of the site and in the Kite Hill area, an exploration program consisting of three borings will be appropriate to supplement the existing information and develop geotechnical design recommendations for this project. One of these explorations, labeled MW-32D/GEO-1 on Work Plan Figure 13, which is to be completed for environmental purposes will also be completed as a geotechnical boring. This boring will include continuous soil sampling to provide sufficient soil samples for geotechnical laboratory testing and chemical analyses. The two other proposed geotechnical borings are labeled GEO-2 and GEO-3 on Work Plan Figure 13.

GeoEngineers' specific scope of services will include the following:

1. Complete two borings (MW-32D/GEO-1 and GEO-2 along the shoreline to depths ranging from 40 to 50 feet. MW-32D/GEO-1 will also be completed as a monitoring well as part of our environmental services. We will also drill one boring (GEO-3) to a depth of 20 to 30 feet on the north side of Kite Hill. The proposed boring locations are shown on Work Plan Figure 13.

The borings will be completed using mud rotary drilling equipment and sampled using D&M and SPT split-barrel samplers. The locations and elevations of the borings will be determined in the field by pacing or measuring from existing features such as buildings, hardscape, and site improvements shown on plans provided by the project team. The drilling will generate excess soil that will not be replaced in the boreholes. Soil cuttings will be drummed and left temporarily on site (discussed in the Sampling and Analysis Plan). The borings will be backfilled in accordance with the Department of Ecology's requirements.

2. Evaluate pertinent physical and engineering characteristics of the site soils based on laboratory tests completed on samples obtained from the borings. The laboratory tests will include moisture content, grain-size distribution, Atterberg limits and percent fine contents, as appropriate. The soils will be returned to the site and placed in the drums with the other soil cuttings for proper disposal.
3. Complete liquefaction analyses using previous borings in the immediate vicinity of Kite Hill with blow count information and borings completed for this study.
4. Complete slope stability analyses using the commercially available Slope W program for both static and seismic considerations, including the effects of soil strength loss (liquefaction) during a design seismic event.
5. Develop options for mitigating the risk of slope instability such as the use of buttresses to contain the soil cap or shoring walls to provide stability, as appropriate.
6. Prepare a draft geotechnical report for Ecology's review that will include the results of our field explorations and laboratory testing, boring logs, site plan showing the borings locations, and conclusions and recommendations for the geotechnical design elements. GeoEngineers' report will also include the following:
   - Description of the geologic materials and depth to groundwater encountered in the explorations.
   - The results of soil strength determinations for soils encountered in the explorations.
   - Recommendations for seismic considerations including seismic design criteria per the 2009 Seattle Building Code (SBC).
   - Preliminary geotechnical assessment and recommendations including the following, as appropriate:
     - Recommended methods for improving the stability of Kite Hill, including retaining walls and buttresses where appropriate;
     - Recommendations for placement and stabilization of a soil cap on Kite Hill; and
     - Construction considerations for placement of the soil cap and retaining wall construction, as appropriate.
7. Prepare a final geotechnical report after receiving and responding to review comments and finalizing design recommendations for selected stabilization methods.

REFERENCE

GWSA Tech Team 2011. Gas Works Sediment Area (GWSA) Technical Team, 2011. Letter by Peter Rude, Seattle Public Utilities, and John Rork, Puget Sound Energy, to John Keeling, WA State Department of Ecology. Revised Geologic Conceptual Site Model, Gas Works Sediment Area. Includes figures by GeoEngineers. April 4, 2011.

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