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## TECHNICAL MEMORANDUM

**TO:** Mr. Brian Peters, GHD Services, Inc. **DATE:** September 28, 2016

**FROM:** Courtney Schaumberg, SoundEarth Strategies, Inc.

**SUBJECT:** Comments and Recommendations on Proposed Groundwater Extraction and Treatment System

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SoundEarth Strategies, Inc. (SoundEarth) has prepared this Technical Memorandum to provide comments and recommendations on the proposed groundwater extraction (GWE) and treatment system for the Shell-Branded Wholesale Facility located at 1935 North Northgate Way in Seattle, Washington (the Shell Property).

On June 16, 2008, the discovery of a petroleum release from an underground storage tank (UST) fueling distribution system at the Shell Property was reported to the Washington State Department of Ecology (Ecology). Soil and groundwater contamination has migrated onto the property located at 10733 Meridian Avenue North in Seattle, Washington (the Swiss Hotel Property). In addition, measureable light nonaqueous-phase liquid (LNAPL) has been detected on both properties, with thicknesses ranging from 0.10 to 3.42 feet.

According to Ecology's 2008 *Guidelines for Property Cleanups under the Voluntary Cleanup Program*, a site is defined by the nature and extent of contamination associated with one or more releases of hazardous substances (such as the release of gasoline from a leaking UST) prior to any cleanup of that contamination. Based on the information gathered to date, the Site encompasses soil and groundwater contaminated with gasoline-, diesel- and oil-range petroleum hydrocarbons, benzene, toluene, ethylbenzene and total xylenes beneath the central portion of the Shell Property, extending onto the central and eastern portions of the Swiss Hotel Property.

Shell is responsible for the source of the soil, soil gas, and groundwater contamination beneath the Shell Property and the Swiss Hotel Property. Shell is responsible for the installation of a groundwater containment system along the shared property boundary to eliminate future contamination from migrating onto the Swiss Hotel Property. To design the groundwater containment system, GHD Services, Inc. (GHD), the environmental consultants for the Shell Property, conducted a GWE and dual-phase extraction (DPE) pilot test on the Shell Property from March 28 through April 8, 2016. The implementation of the pilot test was based on the conceptual design and work plan presented in GHD's Remedial Investigation Report and Feasibility Study dated February 12, 2016 (2016 RI/FS Report). The results of the pilot test are summarized in GHD's draft Pilot Test Report and Cleanup Action Plan dated May 20, 2016 (2016 Pilot Test and CAP Report).

SoundEarth's comments and recommendations on the capture zone analysis, pilot test data collection, and remediation well design are presented below.

### **CAPTURE ZONE ANALYSIS**

GHD prepared capture zone analyses for groundwater monitoring wells MW-4, MW-8, MW-9R, MW-17, and MW-18 as part of the feasibility study (2016 RI/FS Report). The capture zone analysis was part of the DPE Mass Removal Events as a proposed cleanup action alternative, described in the 2016 RI/FS Report. The GWE objectives of this cleanup action alternative were to provide capture and recovery of LNAPL and dissolved-phase mass and act as a hydraulic control of the dissolved-phase plume. The capture zone analysis was used to evaluate the capture zone for each of the proposed extraction wells and proposed GWE equipment.

Based on SoundEarth's review of the data provided in GHD's documents, groundwater beneath the Site has been observed at elevations ranging from approximately 275 to 302 feet (North American Vertical Datum of 1988 [NAVD88]) and consists of two water-bearing zones; perched groundwater, and a deeper more regional water-bearing zone. The deeper water-bearing zone is located within two distinct soil horizons that appear to be hydraulically connected. The upper soil horizon, is encountered around elevation 300 feet NAVD88, consist of finer grained soils, silt with sand, and silty sand with varying amounts of gravel and appears to be water-bearing near the base of the layer in the north and west portions of the Site, at an elevation of approximately 280 feet NAVD88. This soil horizon appears to thin out along the eastern portion of the Site. The lower soil horizon (lower water-bearing zone) consists of coarser grained soils, poorly graded sand and silty sand. The thickness of the lower water-bearing zone is approximately 30 feet with its base located at an elevation of approximately 251 feet NAVD88 (2016 RI/FS Report; SoundEarth's draft CAP dated September 6, 2016).

Provided below are comments and recommendations on the variable inputs used to estimate the capture zones. The comments and recommendations below are based on the GWE design as discussed in 2016 Pilot Test and CAP Report. The GWE design includes converting groundwater monitoring wells MW-9R, MW-17, and MW-18 into extraction wells and installing two new 4-inch-diameter extraction wells to replace the current 2-inch-diameter groundwater monitoring wells, MW-4 and MW-8, which were used in the pilot test.

### **Flow Rate**

The flow rates that were used in the capture zone analysis were based on the average flow rate measured during the development of the wells when they were initially installed (2016 RI/FS Report). It is not clear in the documents provided whether complete drawdown was observed in the groundwater monitoring wells during development. Complete drawdown will be necessary during the system operation to ensure that groundwater levels are low enough to prevent further migration onto the Swiss Hotel Property. In addition, the observed flow rates in MW-9R, MW-17, and MW-18, during the pilot test, were higher than the values used in the capture zone analysis. These groundwater monitoring wells have a deeper bottom of screen and therefore have more screen interval in the lower water-bearing zone. In addition, as discussed further in the Well Design Section, full drawdown was also not observed in MW-9R and MW-18 during the pilot test. This is likely due to a higher hydraulic conductivity in the lower water-bearing zone as discussed in the previous section. Higher flow rates and overall groundwater yield may be necessary to obtain the target capture zones.

### **Hydraulic Conductivity**

The hydraulic conductivity used in the capture zone analysis is based on the observed profile of the upper soil horizon at the Site. GHD has assumed a hydraulic conductivity of  $10^{-3}$  centimeter per second (cm/s) or 0.283 feet per day, which is representative of a glacial till and the observed upper soil horizon with silt and silty sand.

The lower water-bearing zone appears to be significantly more permeable and is likely the primary regional water-bearing zone. Therefore, a higher hydraulic conductivity that is more representative of the lower soil horizon with poorly graded sand (clean sand) should be used to estimate the capture zone for the lower water-bearing zone. SoundEarth recommends using a hydraulic conductivity of  $10^{-2}$  to  $10^{-1}$  cm/s.

### **Hydraulic Gradient**

A hydraulic gradient of 0.04 feet per foot was used in the capture zone analysis, which appears to be the lowest gradient observed from the fourth quarter 2015 monitoring event. Figure 8 of the 2016 RI/FS Report indicates that the hydraulic gradient was approximately 0.07 feet per foot along the shared property boundary and where extraction remediation wells are proposed for hydraulic control. SoundEarth recommends using a hydraulic gradient of 0.07 feet per foot for proposed remediation wells when evaluating the capture zone.

### **Aquifer Thickness**

It is not clear in the documents provided how the aquifer thickness was calculated for each extraction well. Soil boring SB-2 was advanced to a total depth of 66 feet below ground surface (bgs), approximately 245 feet NAVD88. A very stiff, silt layer, in which the water content decreases, was encountered at an elevation of approximately 251 feet NAVD88. This silt layer could be assumed to be a lower confining unit and would indicate that the total aquifer thickness is 30 feet (between approximately 251 and 281 feet NAVD88). SoundEarth understands that this is not the best assumption if the aquifer is not fully penetrated, and drawdown to the bottom of the aquifer is not necessary, but the storage capacity of this 30 foot thick water-bearing zone needs to be accounted for in the design. Please clarify what assumptions GHD used to calculate the thickness. In addition, SoundEarth recommends that extraction wells be installed at a greater depth for hydraulic control, as further discussed in the Groundwater Extraction Well Design section below.

## **GROUNDWATER EXTRACTION PILOT TEST DATA COLLECTION AND ANALYSIS**

The hydraulic radius of influence and capture zone(s) of individual or combination of extraction test wells is difficult to assess and confirm based on the existing data presentation in the 2016 Pilot Test and CAP Report. SoundEarth noted in Table 3 of the 2016 Pilot Test and CAP Report that water level measurements in observation wells were not allowed to equilibrate and return to their initial static groundwater level before pumping commenced in the next extraction well. The data indicate that some of the individual extraction wells did not cause significant drawdown on their surrounding observation wells. For example, the depth to water measurements in observation wells MW-8, MW-9R, MW-10, and MW-18 decreased, indicating that the groundwater level was rising, while extraction was occurring individually in well MW-17 on March 28, 2016. This observation is likely a result of the observation wells recharging to their static groundwater level after the completion of extraction from well MW-18, which

occurred immediately prior to the extraction in well MW-17. This example and observation of water levels increasing in adjacent monitoring wells also indicates that the drawdown and applied extraction rate (pumping rate) from well MW-17 did not influence surrounding observation wells and the capture zones at this location may be significantly reduced more than prior estimates due to the well screen location.

The final rows of Table 3 in the 2016 Pilot Test and CAP Report summarize the maximum drawdown in an observation well as a result of pumping from a single extraction well. These results are biased high because they include observations from when multiple extraction wells were pumping. Presenting the maximum drawdown measured at each observation well provides a conceptual understanding of how the proposed GWE system may operate when multiple extraction wells are pumping at their current screen intervals. The actual drawdown at an individual observation well cannot be determined due to inconsistencies associated with the extraction operations (not allowing the formation to stabilize to static water levels prior to pumping from another well) and data collection during the GWE pilot test. In addition, the drawdown and recovery data were not collected at intervals useful to assess the hydraulic properties of the two water-bearing zones. Please clarify whether or not pressure transducers were used to document groundwater draw down and recovery in extraction and observation wells.

Slug testing is recommended at wells MW-4, MW-8, MW-15, and MW-16, or newly installed wells fully screened in the lower water-bearing zone, to assist with a better understanding of the hydraulic properties of the water-bearing zone, including hydraulic conductivity, and well design and pump specifications for the proposed GWE system. A pumping test may be warranted for the lower water-bearing zone if slug test results confirm recovery time of displaced water is too fast for a slug test due to the presence of highly permeable soils.

## **GROUNDWATER EXTRACTION WELL DESIGN**

GHD's current plan includes five extraction wells; four wells along the shared property boundary, and one well in a more central location on the Shell Property, near the source. The proposed design involves converting three 4-inch-diameter groundwater monitoring wells, MW-9R, MW-17, and MW-18, into extraction wells and installing two new 4-inch-diameter extraction wells to replace the current 2-inch-diameter groundwater monitoring wells, MW-4 and MW-8, which were used in the pilot test.

Provided below are recommendations for well locations, diameters, and screen intervals and elevations for the GWE system based on the results of the pilot test and field observations.

### **Well Locations**

SoundEarth recommends installing three additional 6-inch-diameter extraction wells in addition to the replacements for MW-4 and MW-8. The three additional extraction wells should be installed along the shared property boundary; one well should be installed to the west of MW-8, and two wells should be installed to the east of MW-9R and south and southeast of MW-1. These additional extraction wells are necessary to provide a sufficient capture zone from the GWE system operations to address the observed groundwater contamination migrating onto the Swiss Hotel Property, in the vicinity of MW-8, as wells as contamination observed along the northeast property boundary of the Swiss Hotel Property (i.e., north of MW12).

## Well Diameter

The current well design in the 2016 Pilot Test and CAP Report states that 4-inch-diameter well screen will be utilized for the GWE wells. According to the results from the pilot test, extraction wells MW-9R and MW-18 did not reach complete drawdown due to high water yield. It is likely that the extraction wells screened in the lower water-bearing zone will sustain significantly higher pumping rates than presented in the pilot test due to the presence of highly permeable soils. It is recommended that 6-inch-diameter well screens be installed for new extraction wells to handle the likely higher pumping rates necessary for hydraulic control at the Site.

## Well Screen Intervals and Elevations

The three groundwater monitoring wells, MW-9R, MW-17, and MW-18, that are being considered for extraction as part of the GWE system are screened across the upper and lower soil horizons. The bottom of the screen intervals for proposed extraction wells MW-9R, MW-17, and MW-18 range from 2.37 to 6.94 feet below the deepest portion of the planned remedial excavation on the Swiss Hotel Property (275 feet elevation). The results from the 2016 Pilot Test and CAP Report indicate that proposed extraction wells MW-9R and MW-18 did not reach complete drawdown due to high water yield.

In addition, the maximum drawdown observed in wells along the shared property boundary ranged from 0.20 to 1.93 feet, or groundwater elevations that ranged from 278.76 to 301.23 feet NAVD88. These groundwater elevations are above the deepest limits of the remedial excavation. Therefore, deeper screen intervals are necessary to provide for full hydraulic control of contamination present at the Shell Property and to prevent recontamination of the Swiss Hotel Property after the planned redevelopment. It is recommended that the bottom of the well screens for the extraction wells be placed in the lower water-bearing zone at a minimum elevation of 265 feet NAVD88 or lower.

**Summary of Existing and Recommended Extraction Well Construction Details**

Well ID	Well Diameter (inches)	Top of Casing Elevation (feet NAVD88)	Total Depth (feet bgs)	Elevation of Well Screen Interval (feet NAVD88)
<b>Existing Wells Details<sup>(1)</sup></b>				
MW-4	2	310.63	36.50	275.63–295.63
MW-8	2	311.60	35.50	276.60–296.60
MW-9R	4	313.48	45.00	268.48–288.48
MW-17	4	313.06	45.00	268.06–288.06
MW-18	4	312.63	40.00	272.63–292.63
<b>Recommended Well Construction Details<sup>(2)</sup></b>				
N/A	6	312.28 <sup>(3)</sup>	52.28 <sup>(4)</sup>	260–280 <sup>(5)</sup>

**NOTES:**

bgs = below ground surface

N/A = not applicable

NAVD88 = North American Vertical Datum of 1988

<sup>(1)</sup>Existing Well Construction Data from Table 4 of GHD Services, Inc. Remedial Investigation Report and Feasibility Study dated February 12, 2016.

<sup>(2)</sup>Proposed Well Construction Details are approximate and may change based on the results of a slug test results (site-specific hydraulic conductivity) and observations made at the time of drilling (bottom of upper soil horizon).

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<sup>(3)</sup>Recommended top of casing elevation obtained from averaging the top of casing elevation of the four existing wells along the shared property boundary (MW-8, MW-9R, MW-17, and MW-18). Top of casing of future well is dependent on the location the wells are installed.

<sup>(4)</sup>Recommended total depth is based off of a hypothetical top of casing elevation of 312.28 feet NAVD88. Total depth is dependent on the location the wells are installed.

<sup>(5)</sup>Recommended elevation of well screen interval will be based on field observation made at the time of drilling. Top of screen should be placed just below the bottom of the upper soil horizon.

## **CLOSING**

Overall, the pilot test data indicate that the proposed GWE system can provide an effective hydraulic control to prevent recontamination of the Swiss Hotel Property if the GWE wells are screened within the lower water-bearing zone at a sufficient depth.

SoundEarth appreciates the opportunity to provide comments and recommendations on the capture zone analysis, pilot test data collection, and extraction well design provided by GHD. Please let us know if we can provide any additional information.

cc: Faizel Kassam, Legacy Hospitality  
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