INTERIM REMEDIAL ACTION
ALTERNATIVES ANALYSIS

Time Oil Facility 01-169
851 Broadway
Everett, Washington

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EXECUTIVE SUMMARY

Sound Environmental Strategies Corporation (SES) prepared an Interim Remedial Action Alternatives Analysis for the Time Oil Facility 01-169 located at 851 Broadway in Everett, Washington (the site). The purpose of this report is to present the results of an analysis of remediation technologies to address elevated concentrations of gasoline-range petroleum hydrocarbons (GRPH) and benzene that are present in soil and groundwater. These contaminants resulted from a former fueling facility that operated at the site.

Based on a review of site conditions and the results of the technology evaluation, dual-phase extraction is recommended for on property remediation and to prevent the off-property migration of contaminants. Deploying this technology as an interim response action offers the best strategy to achieve the overall interim remedial objectives and potentially a No Further Action (NFA) determination from the Washington Department of Ecology (Ecology).

1.0 INTRODUCTION

Time Oil Company (Time Oil) formerly operated a service station Time Oil Facility 01-169 located at 851 Broadway, in Everett, Washington. The former underground storage tank (UST) system has been abandoned, the main mass of soil contaminated with gasoline-range hydrocarbons (GRPH) was remediated through excavation and thermal desorption, but residual GRPH remains as indicated by the results of compliance soil sampling following the excavation and a subsequent subsurface investigation by Sound Environmental Strategies Corporation (SES). This document presents our understanding of site conditions and an analysis of interim remedial action alternatives that could be implemented to address the residual GRPH contamination.

1.1 SITE HISTORY AND DESCRIPTION

Time Oil formerly owned and operated the property. The property was sold in 2004 but Time Oil retained the associated environmental liability. In late 2003 and early 2004, Time Oil removed four USTs, two fuel dispenser islands, associated distribution piping, and contaminated soil (GeoEngineers, 2004). Approximately 1,460 tons of GRPH were thermally treated off-property at Rinker Materials, in Everett, Washington. Due to the presence of a 48” sewer line in close proximity to the tank excavation and an adjacent sidewalk, GeoEngineers was unable to completely excavate all contaminated soil. The excavation was backfilled with clean fill, compacted and repaved. Currently, the property improvements include a single-story restaurant/store building, which is vacant. The western two-thirds of the site is paved with asphalt, and the eastern (rear) portion of the site is unpaved and covered with a mixture of native grasses.

Time Oil commissioned SES to complete a subsurface investigation in October 2004. The purpose of the investigation was to characterize the residual on-property contaminated soil and groundwater following the UST and soil removal action. The investigation consisted of drilling 12 borings in areas along the perimeter of the former remediation excavation where GRPH-contaminated soil was suspected. Two of the borings were completed as monitoring wells, one of which was dry. Figure 1 presents a site plan showing the location of site improvements, boundaries of the excavation, and the location and analytical results of GeoEngineers’ post-excavation compliance and SES investigation samples.

1.2 SITE CONDITIONS

1.2.1 Topography

The polygonal, 0.43-acre site lies at an elevation of approximately 100 feet above mean sea level. The land surface slopes gently to the southwest toward a shallow depression centered at the intersection of Broadway Avenue North and Tower Street. Development in the immediate vicinity of the site is commercial.

1.2.2 Surface Hydrology

Given the general southwesterly trend of topography in the immediate vicinity of the site, surface runoff flows to the southwest. On a larger scale, surface runoff flows to the northeast, toward the Snohomish River.

1.2.3 Geology and Groundwater Hydrology

The site and surrounding area encompass a gently rolling upland deposited during the Vashon Stade of the last episode of continental glaciation, which ended approximately

13,500 years ago. Review of geologic maps (Newcomb, 1952) indicates that the site is underlain by Vashon Till, which consists of a dense heterogenous mixture of silt, sand, and gravel. The till is typically characterized by relatively low vertical hydraulic conductivity, and may contain lenses of perched groundwater. However, based on our experience with the hydrology of nearby sites located along Broadway Avenue, the depth to groundwater is anticipated to be over 90 feet below ground surface (bgs). Other than “leakage” from water that collects in the former excavation backfill, no groundwater was encountered to the total depth explored at the site (30 feet bgs).

Soil inside the former UST excavation consists of dry sandy gravel pit run material. A thin layer of perched water was noted at approximately 16.5 feet bgs near the base of the pit run backfill in boring MW-1 during drilling. Later measurement of the depth to water after drilling indicated that water is approximately 10 feet bgs in the vicinity of MW-1. Farther to the south within the former excavation in boring B-9, no water was detected. This suggests that the deepest excavated portion of the excavation that extends southwest from the northeastern corner of the backfilled excavation behaves as a “sump” that collects percolating water from adjacent unpaved recharge areas.

A 1- to 2-inch thick layer of water was detected during drilling outside the former excavation along the base of the slag layer in borings B-3, B-6, B-8, B-11, B-12, and in the boring for monitoring well MW-2. Monitoring well MW-2, which was drilled to a depth of approximately 30 feet and screened to prevent influx of water collected in excavation backfill, was dry when checked for water three days after the well had been constructed. The well remained dry when checked one week later. The absence of groundwater at 30 feet bgs suggests that, aside from a localized area of water in the excavation backfill and a thin (1 to 2 inches) localized zone at the base of the slag fill layer that appears to originate from “leakage” from the former excavation, groundwater in the vicinity of the site is over 30 feet bgs.

1.2.4 Nature and Extent of Contamination

During the UST system excavation, GRPH and associated constituents were determined to be the site chemicals of concern (COC). The October 2004 SES investigation identified soil containing GRPH and benzene in concentrations greater than their respective MTCA Method A cleanup levels along the northern and southwestern edges of the former remediation excavation (along the western sidewall and in the vicinity of the 48-inch sewer line to the southeast). Toluene, ethylbenzene and xylenes concentrations, with one exception, were less than their respective cleanup levels. These results are consistent with the post excavation analyses conducted by GeoEngineers which showed contaminated soil encountered at a depth of approximately 4 to 12 feet bgs in the western sidewall (Samples EX-23-6 had 2,800 mg/kg GRPH and 3.6 mg/kg benzene, EX-24-5 had GRPH at 6,200 mg/kg as shown on Figure 1).

Only monitoring well MW-1, located in the northeastern corner of the former remediation excavation, produced any water. The groundwater sample contained 3,140 µg/L GRPH, which exceeds the 800 µg/L cleanup level. No diesel- or motor oil-range petroleum hydrocarbons were detected in the sample. Naphthalene, detected at a concentration of 19.1 µg/L, was the only SVOC detected in the sample. The naphthalene concentration was less than the 160 µg/L cleanup level and is not considered a COC.

Monitoring well MW-2, which is 30 feet deep and located downgradient from the southwestern corner of the former excavation, produced no groundwater. This suggests that the groundwater in MW-1 is perched within the backfilled excavation, and shallow groundwater is not present outside the UST system backfill. However, visual observations made during drilling suggest that small quantities of water in the excavation backfill may be "leaking" into the coarse grained fraction of the surrounding non-excavation fill. The coarsest non-excavation fill is the slag layer present in several of the borings. In some borings the bottom few inches of the slag layer represented saturated to near saturated conditions adjacent to the former excavation.

1.3 SITE CONCEPTUAL MODEL

The excavation and coarse textured backfill applied to the site have created a "bathtub" effect at the site within the former excavation footprint. This "bathtub" is surrounded by fill likely applied during the construction of Broadway Avenue atop medium dense to dense Vashon Till. GeoEngineers reported a similar but smaller "bathtub" effect was represented by the former tank nest prior to soil excavation activities.

The excavation observations indicate that the southern to southwestern portion of the site was filled prior to construction of the service station. This is evident from the crushed rock that was observed at a depth of approximately 9 feet bgs during excavation activities. In other areas of the site the native soil was described as Vashon Till. No mention of soil densities was made in the report but typically this unit is medium to very dense and hosts perched low yielding groundwater zones. Its low relative permeability can restrict the migration of contamination in soil and in groundwater. Occasionally, thin zones of relatively higher permeability can result in contaminant migration away from the main mass of the plume. Occasionally, secondary permeability via fracture flow (most Vashon Till is highly fractured due to the pressure from thousands of feet of glacial ice and "rebound" following the melting of the ice) can result in some contamination migration and a higher than expected permeability. At many contaminated sites the density and texture of the Vashon Till can preclude the effective application of vapor extraction and air sparging remedial technologies.

The excavation effectively addressed the main mass of the contamination. The report claims that a site-specific Method B soil cleanup level was calculated for the site. All excavation limit soil samples meet this criteria. However, the report also states that the soil-groundwater leaching pathway failed due to benzene concentrations. Therefore, the soil concentrations in the southwestern excavation limit [soil samples EX-23-6 (2,800 mg/kg GRPH and 3.6 mg/kg benzene) and EX-24-5 (6,200 mg/kg GRPH)] will likely be of concern to Ecology. Ecology will be less concerned with the other MTCA Method A Cleanup Level exceedances if these higher concentration locations of residual contamination (Figure 1) are addressed.

GRPH are the only constituents of concern. Subsurface water percolating into the former excavation backfill ponds and becomes contaminated with GRPH. This water represents a media of concern, particularly as a potential migration pathway out of the former excavation to the southwest portion of the site. This subsurface water occurs as a thin discontinuous zone that can be described as subsurface lenticular pools within the deepest portions of the coarse-grained backfill of the former tank cavity. Where the former excavation was less deep, no water collects. The source of this water is likely from surface percolation from nearby unpaved recharge areas during precipitation events or may represent rainwater that accumulated during the UST system removal. Unpaved areas (areas of recharge) lie immediately to the north and east of the former service station/convenience store building. The deeper portions of the former excavation, which is underlain by low permeability native till material, acts to contain the water in a "bathtub" effect.

Based on the total reported depth of the soil confirmation samples taken by GeoEngineers (2004) during the excavation activities, a contour map of the floor of the former excavation was developed (Figure 1). This contour map shows the deepest portion of the excavation trended southwest from the present location of MW-1. There is supporting evidence that the perched zone may drain from the northeast to the southwest portion of the site. Borings in the southwest portion of the property (outside the excavated area) revealed intervals of moist to wet slag fill adjacent to the former excavation. The drainage of contaminated water from the former excavation through the slag fill, sewer line backfill or other media poses a risk for off-property migration of GRPH and benzene from the former excavation. No groundwater was encountered to 30 feet bgs on the southwest side of the former remediation excavation, suggesting that deeper aquifers are unlikely to have been affected by the release.

Residual soil contamination in the western/southwestern sidewall and in the vicinity of the sewer line represent another media of concern (Figure 1). The residual GRPH soil contamination could not be excavated due to its close proximity to the sidewalk and sewer line. Based on the SES investigation, approximately 180 to 200 tons of GRPH-contaminated soil remain in place and must be addressed to achieve the remedial action objectives for the site.

1.4 CURRENT AND FUTURE LAND USE

1.4.1 Land Use

The site is currently zoned commercial. No short-term changes to site use are anticipated. Site improvements include a vacant single story restaurant/store building and asphalt paving on the western 2/3 of the property.

1.4.2 Groundwater Use

Currently, the site and surrounding community are provided water by the City of Everett Public Works Department. According to the Washington Department of Ecology (Ecology) Well Logs website, no private or public drinking water supply wells exist within a ¼ mile radius of the site.

Institutional controls limit the future likelihood of developing shallow drinking water supply wells in the vicinity of the site. These controls include requirements for high yield, water rights permitting, drinking water quality regulations, Department of Ecology public water system rules and regulations, and setback requirements for well construction.

2.0 REMEDIAL ACTION OBJECTIVES

Remedial Action Objectives (RAOs) form the basis for evaluating the areas requiring remediation and the appropriate remedial action for these areas. They are also useful in identifying remedial technologies capable of eliminating, reducing, or controlling a particular exposure pathway, and form the basis for evaluating the need for long-term monitoring.

The overall remedial objective is to obtain, if feasible, an unrestricted No Further Action (NFA) determination for the site from Ecology. To achieve the overall objective, the following component objectives are identified.

1. **Address the On-Property Source** – Under the working conceptual model, the sources include: 1) saturated backfill and perched water within the tank cavity ”bathtub” and

2) residual GRPH and BTEX soil concentrations adjacent to the former excavation. The interim action goal will seek to reduce source concentrations of GRPH and benzene to levels below the contaminant specific risk-based cleanup levels and ensure no rebound in water (within the excavation backfill) concentrations above the cleanup levels.

2. **Address Any Affected Off-Property Media To the Extent Practical From On-Property Locations** – Reduce COC concentrations in soil and groundwater located adjacent to the southern and western limits of the former excavation to levels below the contaminant specific risk-based cleanup levels.

3. **Eliminate the Potential for OFF-PROPERTY Migration of COCs** – Implement remedial actions on property to ensure no future off-property migration of COCs in concentrations exceeding cleanup levels.

4. **Monitor Remedial Effectiveness** – During and after remedial action, collect performance and compliance monitoring data to evaluate cleanup effectiveness and completeness.

2.1 EXPOSURE ANALYSIS

RAO development is based on an evaluation of COCs, exposure routes, receptors, site conditions, and threats to human health and the environment. The site is currently a vacant commercial property located in a commercial setting, and will likely remain in that land use for the foreseeable future. Thus, MTCA Method A and/or Method B cleanup levels apply. Previous investigations concluded that soil and groundwater exceeded MTCA Method A or B cleanup levels for GRPH and benzene.

Potential threats to human health were evaluated based on the findings of recent investigation efforts and the site conditions described above. This evaluation compared the observed and measured soil and water within the former excavation backfill conditions against cleanup levels. This analysis concludes that:

- COCs detected in shallow soil and water within the former excavation are present at concentrations above published risk thresholds for human health via the direct contact pathway. However, the site is predominantly capped or covered with asphalt or concrete surfaces, which limits or prevents soil and water contact. Therefore, direct contact with soil and groundwater are only complete pathways for site excavation/construction workers, or utility personnel who occasionally maintain site and City of Everett utilities.

- Since the site is predominantly paved with asphalt and concrete and this condition will continue into the foreseeable future, storm water infiltration and soil leaching are limited. However, elevated concentrations of COCs in soil are in direct contact with perched shallow water that ponds in the former excavation backfill. Elevated concentrations of COCs in soil will continue to serve as a residual source of contamination to this ponding water. Therefore, soil leaching to groundwater will continue to be considered a complete pathway until the source area has been treated or removed.

- Downward vertical migration of petroleum-impacted water within the excavation backfill into deeper and potentially more productive aquifers is limited by the presence of low permeability glacial till found beneath the site. Coarse-grained granular fill associated with the former tank excavation, sewer line, sidewalk and roadway are present in the southwestern portion of the site but are shallow, discontinuous and very low yielding water bearing zones. Therefore, shallow groundwater as a source of drinking water is not considered a complete pathway. These fill materials may; however, present a pathway for migration of on-property contaminated perched water off property.

- It can be demonstrated that the highest beneficial use of the shallow groundwater in this area is regional discharge to the south and east that eventually contributes to surface water flow into Puget Sound. Area hydrogeologic conditions suggest that such migration is unlikely. Therefore, discharge to surface water is not considered a complete pathway.

- The inhalation pathway is potentially complete for residential or commercial worker exposure to COCs in indoor and ambient air, and construction worker exposure to soil gas under plausible current and future use scenarios. The vapor inhalation pathway will be evaluated both under current site conditions and future conditions as part of the detailed evaluation of a selected remedial alternative.

2.2 CLEANUP LEVELS

The proposed cleanup levels are based on the MTCA regulations/guidelines as well as the exposure assessment described above. These cleanup levels are protective of a cumulative excess cancer risk of 1×10^{-6} and are compiled below for air/vapor, groundwater and soil.

Cleanup Level	RAO
AIR/VAPOR • 0.321 µg/m3 – Benzene	Prevent future residential, commercial worker and construction worker inhalation of vapors above the Method B cleanup level.
GROUNDWATER • 800 µg/L – GRPH • 5 µg/L – Benzene	Prevent construction worker direct contact exposure or discharge of contaminated groundwater to surface water above the Method A cleanup level.
SOIL • 30 mg/kg – GRPH • 0.03 mg/kg – Benzene	Attain soil concentrations that are protective of groundwater and human receptor inhalation of vapors above the Method A cleanup level.

2.3 POINTS OF COMPLIANCE

The objective of the interim remedial action is to achieve the cleanup levels in all media of the site Remedial effectiveness at negotiated points of compliance will be evaluated following the source control action and any subsequent soil and groundwater remedial actions, in accordance with the proposed implementation schedule and constraints.

3.0 REMEDIAL TECHNOLOGY SCREENING

3.1 POTENTIALLY APPLICABLE TECHNOLOGIES

The following technologies have been identified as potentially applicable for remediation of petroleum-contaminated vapor, soil, and groundwater at the site:

- Monitored Natural Attenuation;
- Containment;

- Excavation with Off-PropertyTreatment / Disposal;
- Dual Phase Fluid (groundwater and soil vapor) Extraction and Treatment;
- In Situ Chemical Oxidation;
- Soil Vapor Extraction; and
- Enhanced Bioremediation Technologies.

3.2 TECHNOLOGY DESCRIPTIONS

3.2.1 Monitored Natural Attenuation

Natural attenuation depends on intrinsic environmental factors to reduce contaminant concentrations over time, through such processes as biodegradation, adsorption, and dispersion.

Monitored natural attenuation is often the default technology for that portion of a site that cannot be cost-effectively remediated by active means. It is also used as a polishing technology after an active technology has reduced contaminant concentrations but is unable to achieve cleanup levels. Monitoring is required to evaluate the effectiveness of natural attenuation and to document the achievement of cleanup levels. Monitored natural attenuation may be appropriate in combination with other on-property and, if necessary, off-property remedial technologies.

3.2.2 Containment

Containment consists of installing physical barriers that isolate the media of concern from potential receptors and/or reduce the potential for migration of COCs. A vertical barrier, such as a sheet-pile wall or grout curtain, can be used to prevent migration of COCs away from the source area. Since contaminants are not physically removed or destroyed, a long-term groundwater monitoring program would be required to demonstrate the continued effectiveness of the containment, and institutional controls would be needed to prevent future exposure.

A horizontal barrier (i.e., a cap) can be used to impede surface water infiltration through impacted vadose zone soil, thus reducing leaching of COCs to groundwater. The existing pavement already serves as a horizontal barrier over the former tank cavity.

3.2.3 Excavation with Off-Property Treatment/Disposal

Excavation and off-site treatment/disposal of the source area, including the perched groundwater in the tank cavity is feasible to implement. Excavation of the contaminated soil located adjacent to the 48” sewer main is considered difficult and risky to implement due to the shoring requirements and risk of damage to the utility. Use of standard excavation methods (e.g., a track excavator) is an option, as the shallow groundwater has restricted the source area to depths no greater than 15 to 17 feet bgs. Excavated soil would be characterized for transportation and disposal purposes.

3.2.4 Dual Phase (Soil Vapor and Groundwater) Extraction and Treatment

Dual-phase extraction (DPE), also known as bioslurping, involves recovering both contaminated soil vapor and groundwater for aboveground treatment. This technology is effective by recovering the volatile compounds in both the vapor and aqueous phases and providing oxygen to the subsurface to enhance further in situ biological degradation of the compounds not recovered by physical removal. High vacuum pressure is applied in a DPE well to recover both vapor and groundwater simultaneously. Both media are recovered and treated separately in aboveground treatment units. Implementation of this technology would be feasible for the source area, contaminated soil located on the edge of the former excavation, and to a certain extent, off-property contamination, if present.

3.2.5 In Situ Chemical Oxidation

In situ chemical oxidation involves injecting chemicals into the subsurface to oxidize contaminants. In situ treatment of impacted soil and groundwater would be possible using this technology. The oxidants most commonly used are potassium permanganate, ozone, and hydrogen peroxide. Fenton's reagent, an aggressive form of chemical oxidation currently in practice, would involve injection of concentrated hydrogen peroxide along with ferrous iron. Source area chemical oxidation can be completed in a relatively short timeframe. As with other in situ treatment technologies, however, it is generally unable to achieve 100 percent removal/destruction of contaminant mass. The residual mass typically continues to act as a source of groundwater contamination, thus requiring additional injection events.

3.2.6 Soil Vapor Extraction

Soil vapor extraction (SVE) is a proven technology for recovering volatile petroleum hydrocarbons from unsaturated zone soil. The technology is implemented by installing vertical or horizontal wells within the zone of contamination. Vacuum pressure is applied to recover contaminants in the vapor phase for subsequent treatment and disposal. This technology is not suitable for the recovery of contaminated groundwater. Since one of the sources at this site consists primarily of contaminated perched water, SVE is not applicable for source treatment. However, SVE may be feasible for treating contaminated vadose zone soil located near the sewer line and, if necessary, off property. Vapor treatment, likely using activated carbon would be required prior to release to the atmosphere. In this treatment process, contaminants are removed from the soil vapor via adsorption onto the carbon.

3.2.7 Enhanced Bioremediation Technologies

Bioremediation of residual concentrations of petroleum hydrocarbons in the saturated zone is most effective and sustainable under aerobic (i.e., elevated dissolved oxygen) conditions. The rate and effectiveness of intrinsic aerobic bioremediation of COCs are controlled by and generally limited by the lack of sufficient dissolved oxygen (DO) available to native microbes.

Increasing the availability and concentration of DO in the impacted groundwater by artificial methods enhances the subsurface conditions to promote natural degradation of COCs. Several proven methods exist to increase the DO concentration in the saturated zone, including injection of chemical reactants that produce elemental oxygen (hydrogen or magnesium peroxide [ORC]) or sparging oxygen gas or compressed air (via in-situ oxygen curtain [ISOC] technology) directly into the water-bearing zone. The increased DO concentration resulting from these enhancements will produce an increased and sustained rate of natural degradation of the dissolved COCs. Limitations to the technology are subsurface heterogeneities and low groundwater transmissivity, conditions that translate to poor distribution and migration of the DO.

3.2.8 Dewatering (Pump and Treat)

This technology involves removing dissolved contaminants in groundwater by pumping. The recovered groundwater is either treated on property or stored on property for eventual off-property transportation and disposal. Pump and treat is similar to DPE except that contaminated soil vapor is not recovered; therefore it is generally less effective than DPE. This technology is partially effective for the recovery of aqueous (dissolved) phase hydrocarbons, but is prone to result in rebounding concentrations of contaminants in groundwater due to inherent mass transfer limitations from soil to groundwater. It is considered because of its lower relative cost compared to DPE and the likelihood of a finite quantity of contaminated groundwater in the former excavation “bathtub”.

3.3 TECHNOLOGY SCREENING RESULTS

The results of the remedial technology screening, in terms of overall effectiveness on the site-specific COCs, relative cost, and relative implementability, are summarized on Table 1. The effectiveness evaluation focuses on the technical ability of the technology to remove and/or destroy the COCs in the environment. Implementability is a measure of whether the technology is practical at the site based on subsurface conditions, site operations, system construction, and potential regulatory constraints. Cost is ranked as high, medium or low, mostly to allow comparison between technologies with similar effectiveness and implementability. Based on this information, the following technologies were retained for detailed evaluation and consideration as part of the full-scale interim remedial alternative evaluation:

- Monitored Natural Attenuation;
- Dual Phase Extraction and Treatment;
- In situ Chemical Oxidation;
- Soil Vapor Extraction; and
- Enhanced Bioremediation Techniques.

4.0 REMEDIAL ALTERNATIVE SELECTION

The purpose of the alternatives analysis is to identify a technology or combination of technologies that are feasible to implement, effective in achieving the RAOs, and reasonable from a cost perspective. The screening of technologies, documented in Section 3.3 and summarized in Table 1, identify the short list of potential interim remedial action technologies that meet these criteria. This section describes how retained technologies would be implemented alone or in combination with other technologies as interim remedial action alternatives to achieve the overall RAO and component objectives restated below:

Overall Remedial Objective: Unrestricted NFA under the Model Toxics Control Act.

Component Objectives:

1. Address the on property sources.
2. Address any off property affected media from on property locations.
3. Eliminate the potential for off-property migration of COCs in concentrations exceeding cleanup levels.
4. Monitor remedial effectiveness.

Monitored natural attenuation is an important complementary technology for each interim action alternative described below and is therefore not included in the alternative description. Following implementation of an interim remedial action technology, periodic monitoring will be performed to verify that natural attenuation processes are effective at preventing rebounding concentrations and whether cleanup levels are permanently achieved. If monitoring indicates that natural attenuation is not effective at maintaining COC concentrations below cleanup levels, then additional remedial action would be necessary to achieve the RAOs.

4.1 INTERIM ACTION SOURCE CONTROL ALTERNATIVES

4.1.1 In Situ Chemical Oxidation of Bathtub

This alternative consists of inoculating the thin perched zone with a strong chemical oxidant such as hydrogen peroxide solution to reduce the concentrations of GRPH and benzene to levels below the cleanup levels. A hydrogen peroxide solution of 17% has been demonstrated to be effective for reducing dissolved phase GRPH concentrations. Hydrogen peroxide may also be injected in combination with reduced iron under acid conditions (Fenton's Reaction) to generate a strong and vigorous oxidation reaction, but this process is more costly. In situ chemical oxidation requires no air permits, wastewater discharge authorizations, or other aboveground treatment or control instruments.

Injection wells would be installed in a grid pattern and screened within and slightly above and below the saturated zone. The number of wells and well spacing would be sufficient to ensure treatment of the entire bathtub area. More than one injection event would likely be necessary to reduce COC concentrations to below cleanup levels for the COCs. Treatment effectiveness would be evaluated by post treatment groundwater monitoring shortly after injection events and at prescribed intervals (e.g. monthly or quarterly) to evaluate potential rebound effects.

The potential limitation of this and other source control alternatives is the uncertainty with respect to the effectiveness of the treatment to reduce source concentrations sufficiently to maintain post-treatment concentrations below cleanup levels (i.e. preventing rebound effects).

4.1.2 Dual Phase Extraction and Treatment

Dual phase extraction would be implemented in the former excavation to recover both contaminated groundwater and soil vapor for aboveground treatment of both media. This alternative would be implemented by installing dual phase extraction piping in existing MW-1 and drilling and installing additional DPE wells in the bathtub area. Approximately five DPE wells should be sufficient to cover the former excavation area. Wells would be connected to the vacuum pump via buried pipe. Treatment equipment would be placed in a trailer or shed on the site. The treatment area must be compatible with the new owner's land use plans. Assuming there is a small and finite quantity of water to be recovered from the former excavation area, recovered water would be stored on property for subsequent off-property disposal. Based on the relatively low contaminant concentrations in the groundwater, recovered vapor would be treated adequately and cost-effectively using vapor phase granular activated carbon. Treated vapor would be discharged to the atmosphere. Treatment effectiveness would be evaluated by shutting down the system temporarily, measuring the depth to water and evaluating groundwater quality after a period of pressure equalization in the subsurface.

This alternative is expected to be more effective compared to other source control technologies in the time needed to achieve cleanup levels and in minimizing the potential for rebound. The basis for this assessment is the fact that DPE will recover a significant mass of GRPH and benzene already dissolved in groundwater. Mass transfer from aqueous to vapor phase will continue as the formerly saturated zone is subjected to constant air flow. Contaminant mass still remaining after dewatering and air flow would be reduced by aerobic biological degradation, the rate of which would not be hindered due to lack of oxygen.

4.1.3 Enhanced Bioremediation

The conceptual design of an enhanced bioremediation system includes the installation of several injection probes in the excavation area. For this analysis, a series of ISOC gas bubblers will be installed in each of the injection probes, which will be equipped with pressurized oxygen gas tanks and controlled with manifold valves and control equipment. All gas lines, probes, and connectors will be installed just below the asphalt paving. Pressurized oxygen tanks (three total) will be replaced every quarter until groundwater monitoring wells have reached a stabilized asymptotic state, at which time the interim remedial action will convert to a monitored natural attenuation stage.

4.2 ON- AND OFF-PROPERTY AFFECTED MEDIA ALTERNATIVES

Soil and potentially perched water contamination require remediation in the southwestern portion of the site adjacent to the sidewalk and sewer line. In situ interim action treatment technologies are the only ones considered feasible. This section presents alternatives to address this contamination.

4.2.1 In Situ Chemical Oxidation

This alternative consists of using direct push methods to install several well points in a grid pattern in the area of soil contamination. Potable water would be injected in the well points to saturate the treatment area before injecting hydrogen peroxide solution to oxidize the contaminants. A minimum of two injection events would be conducted. Treatment effectiveness would be evaluated following the second injection event by collecting soil samples in a grid pattern between the injection points.

4.2.2 Dual Phase or Soil Vapor Extraction

Dual phase extraction of the soil contamination near the sewer main could be implemented together with the source control remediation within the former excavation. Although there is no significant groundwater identified in the area outside the former excavation, DPE would be effective in addressing both perched water and soil contamination. If DPE is not selected as the preferred technology for the former excavation area, a lower pressure and lower cost soil vapor extraction blower could be employed to focus only on the soil contamination. This technology would be implemented by installing dual phase or soil vapor extraction wells screened in the slag intervals and applying vacuum to recover the perched water and contaminated soil vapor. Treatment effectiveness would be determined by collecting pre- and post-treatment soil samples and comparing concentrations to cleanup levels for that medium.

4.3 PREVENTION OF OFF-PROPERTY CONTAMINATION

In order to maximize the opportunity to obtain an unrestricted NFA for the site as a result of an interim action, it must be demonstrated to Ecology that site-related contamination does not extend off-property or threaten adjacent properties. There is no evidence to date that contamination has migrated off-property. However, the working site conceptual model suggests the potential for off-property contamination via drainage of contaminated perched water through slag fill and extension of the residual western and southwestern sidewall soil contamination in the southwestern portion of the property. Therefore the selected on-property remedial response should include a component designed to prevent off-property migration of COCs. Potential alternatives that address this objective are described below.

4.3.1 Dual Phase or Soil Vapor Extraction

In combination with other on property site remedial measures, dual phase extraction or soil vapor extraction deployed in the southwest corner of the site would prevent off-property migration of COCs. If there is significant perched water in the slag fill near the property boundary, DPE would be required; otherwise soil vapor extraction would effectively control the migration of COCs. To implement either technology, extraction wells would be installed on property near the property boundary. The wells would be screened over the slag fill and connected to a vacuum pump located on property. Recovered water would be stored on property for eventual off-property disposal. Recovered vapor would be treated by vapor-phase granular activated carbon.

4.3.2 In Situ Chemical Oxidation

In situ chemical oxidation of the saturated slag fill before it drains off-property would be an effective response to prevent off-property contaminant migration. This would be implemented by installing injection wells with screen sections spanning the entire saturated thickness of the fill material. Hydrogen peroxide solution would then be injected into the saturated zone to affect chemical oxidation of the organic contaminants. A minimum of two injection events would be conducted. Treatment effectiveness would be evaluated by collecting water samples from the injection wells following the second injection event and periodically thereafter to confirm that no rebound has occurred.

5.0 RECOMMENDATIONS

A variety of viable technologies were evaluated that could potentially achieve the interim remedial action objectives. However, to most effectively address the contamination in the former excavation and minimize the potential for recontamination, DPE appears to be the best alternative. This recommendation is based on the ability of the technology to remove contaminants through physical as well as biochemical means. This technology will remove contaminants dissolved in groundwater and in soil vapor within unsaturated soil pores. Contaminant mass would be further reduced by increasing oxygen concentrations in the formerly saturated backfill to enhance the rate of intrinsic biodegradation. DPE can also be used to effectively treat other on property soil contamination and to prevent off-property migration of contaminants in saturated slag fill. This technology probably involves a higher initial capital investment compared with other alternatives; however, these capital costs would be offset by using existing Time Oil Company equipment and avoiding the protracted treatments necessary for alternative technologies.

6.0 LIMITATIONS

The services described in this report were performed consistent with generally accepted professional consulting principles and practices. No other warranty, express or implied, is made. These services were performed consistent with our agreement with our client. This report is solely for the use and information of our client unless otherwise noted. Any reliance on this report by a third party is at such party's sole risk.

Opinions and recommendations contained in this report apply to conditions existing when services were performed and are intended only for the client, purposes, locations, time frames, and project parameters indicated. We are not responsible for the impacts of any changes in environmental standards, practices, or regulations subsequent to performance of services. We do not warrant the accuracy of information supplied by others, or the use of segregated portions of this report.

7.0 REFERENCES

GeoEngineers, March 22, 2004, *UST Removal Site Assessment, Time Oil Facility #01-169*.

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Table 1
Remedial Technology Screening Summary
Time Oil Facility No. 01-169
851 Broadway, Everett, Washington
SES Project No. 0440-002-01

Remedial Technology	Effectiveness for			Implementability	Cost	Screening Result
	Soil Vapor	Soil	Groundwater			
Monitored Natural Attenuation (1)	Medium	Medium	Medium	High	Low	Retained as a secondary or tertiary technology.
Containment (2)	Low	Medium	Low	Low	Medium	Not retained for further evaluation.
Excavation with Off-Site Treatment/Disposal	High	High	Medium(3)	Low	High	Not retained based on implementability and cost
Dual Phase Extraction and Treatment	High	Medium	High	High	Medium	Retained as an onsite source and onsite and offsite affected media control technology.
In Situ Chemical Oxidation	Medium	Medium	High	Medium	Medium	Retained as soil and groundwater treatment technology.
Soil Vapor Extraction	High	Medium	Low	High	Medium	Retained as potentially applicable for soil contamination only
Enhanced Bioremediation Techniques (4)	Low	Medium	Medium	High	Medium	Retained as soil and groundwater treatment technology.
Dewatering (Pump and Treat)	Low	Low	Medium	High	Medium	Not retained; DPE more effective

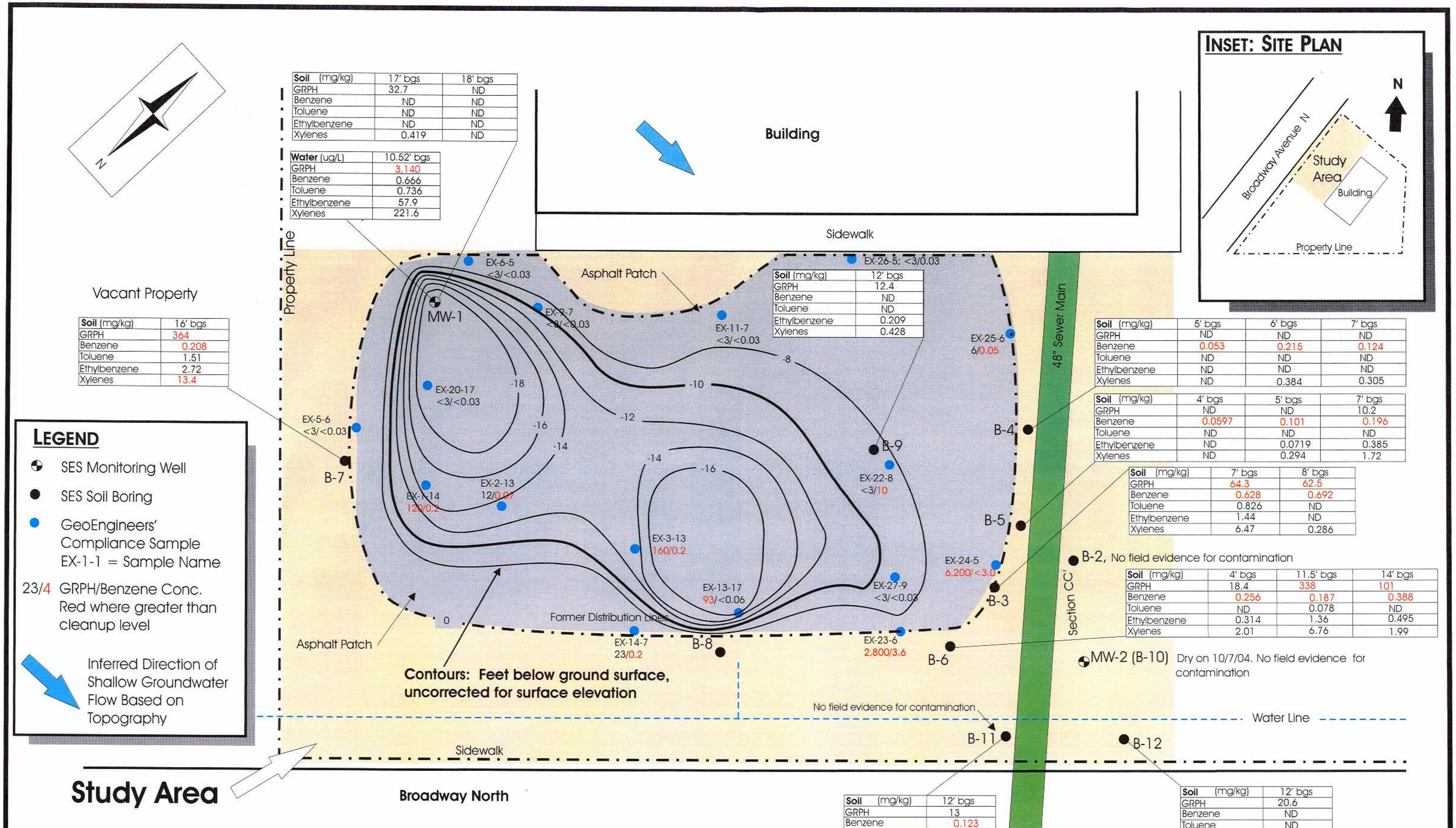
Notes:

1) Monitored natural attenuation is a slow process, but can be effective over time if groundwater concentrations are reduced to low levels and unacceptable exposures are prevented (e.g. through institutional and engineered controls).

2) These technologies can be effective in preventing or isolating unacceptable exposures, but do nothing to reduce subsurface contamination.

3) Excavation is generally not applicable to groundwater remediation; however, complete source removal/control is necessary to effectively initiate and expedite groundwater treatment.

4) Bioremediation techniques are effective at relatively lower soil/groundwater concentrations; rate of treatment increases with increased treatment costs (i.e., increased enhancement by oxygenation and nutrient addition).



Soil (mg/kg)	17' bgs	18' bgs
GRPH	32.7	ND
Benzene	ND	ND
Toluene	ND	ND
Ethylbenzene	ND	ND
Xylenes	0.419	ND

Water (ug/L)	10.52' bgs
GRPH	3,140
Benzene	0.666
Toluene	0.736
Ethylbenzene	57.9
Xylenes	221.6

Soil (mg/kg)	16' bgs
GRPH	364
Benzene	0.208
Toluene	1.51
Ethylbenzene	2.72
Xylenes	13.4

Soil (mg/kg)	12' bgs
GRPH	12.4
Benzene	ND
Toluene	ND
Ethylbenzene	0.209
Xylenes	0.428

Soil (mg/kg)	5' bgs	6' bgs	7' bgs
GRPH	ND	ND	ND
Benzene	0.053	0.215	0.124
Toluene	ND	ND	ND
Ethylbenzene	ND	ND	ND
Xylenes	ND	0.384	0.305

Soil (mg/kg)	4' bgs	5' bgs	7' bgs
GRPH	ND	ND	10.2
Benzene	0.0597	0.101	0.196
Toluene	ND	ND	ND
Ethylbenzene	ND	0.0719	0.385
Xylenes	ND	0.294	1.72

Soil (mg/kg)	7' bgs	8' bgs
GRPH	64.3	62.5
Benzene	0.628	0.692
Toluene	0.826	ND
Ethylbenzene	1.44	ND
Xylenes	6.47	0.286

Soil (mg/kg)	4' bgs	11.5' bgs	14' bgs
GRPH	18.4	338	101
Benzene	0.256	0.187	0.388
Toluene	ND	0.078	ND
Ethylbenzene	0.314	1.36	0.495
Xylenes	2.01	6.76	1.99

Soil (mg/kg)	12' bgs
GRPH	13
Benzene	0.123
Toluene	0.832
Ethylbenzene	0.112
Xylenes	0.298

Soil (mg/kg)	12' bgs
GRPH	20.6
Benzene	ND
Toluene	ND
Ethylbenzene	0.107
Xylenes	0.120

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Time Oil Facility (#01-169)
851 Broadway
Everett, WA

Date: 10/05
Drawn by: WHR
Chk by: BQH
SES project No:440-2

FIGURE 1
SITE PLAN, SOIL/GROUNDWATER CHEMISTRY AND FORMER EXCAVATION DEPTH CONTOURS

0 10 20 40
SCALE (FEET)