Restarted Soil Vapor Extraction System Optimization and Closure Protocols

Hassayampa Superfund Site
Maricopa County, Arizona

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1. INTRODUCTION

1.1 Terms of Reference

These Restarted Soil Vapor Extraction (SVE) System Optimization and Closure Protocols (Protocols) document the updated soil vapor performance goals that have been developed and describes the planned modifications to and closure protocols for the restarted SVE system at the Hassayampa Landfill Superfund Site (the Site) located in Maricopa County, Arizona. These Protocols were prepared by Geosyntec Consultants (Geosyntec) for the Hassayampa Steering Committee (HSC) for submittal to the United States Environmental Protection Agency, Region 9 (USEPA) and the State of Arizona Department of Environmental Quality (ADEQ).

1.2 Background

At the Hassayampa Site quarterly review meeting on November 6, 2007, the USEPA requested that the Hassayampa Steering Committee (HSC) provide a series of letter work plans to address a number of operations and maintenance (O&M) issues related to the remedy components at the Site and to detail proposed remedy upgrade and optimization tasks. USEPA requested these separate letter work plans specifically in lieu of one comprehensive Phase II Work Plan that had been previously discussed and planned by USEPA/ADEQ and the HSC. In a November 16, 2007 letter, the HSC provided USEPA a listing of the proposed letter work plans and tentative submittal schedules adapted from the draft Phase II Work Plan tasks which were presented at the November 6, 2007 meeting. These Protocols present the content intended for Letter Work Plan #4, “Optimization of the Restarted SVE System.”

1.3 Document Organization

The remainder of this document is organized into the following sections:

- Section 2, “SVE System Modifications,” describes the modifications to the SVE system that are intended to be made at some future time prior to the cessation of SVE at the Site, including the change from off-gas treatment using proprietary pressure/condensation techniques to granular activated carbon;
- Section 3, “Soil Vapor Performance Goals,” describes the updated soil vapor performance goals that have been developed for the Site;
• Section 4, “SVE System Shutdown Protocols,” describes the operation and testing protocols that will be implemented to document compliance with updated soil vapor performance goals and guide shutdown of the SVE system; and

• Section 5, “Summary.”

Referenced tables and figures are included in separate sections at the end of this document.
2. SVE SYSTEM MODIFICATIONS

2.1 General

The objective of the SVE remedy component is to remove VOC mass from the vadose zone beneath the Site to levels that are protective of groundwater quality. Currently, the re-started SVE system is focused on extracting vapors from the fine-grained and sub-basalt vadose zone areas at and near Pit 1, the primary VOC source area at the Site. The off-gas vapors are treated using the GEO Inc. pressure condensation treatment unit (GEO System). An advantage of the GEO System is the system’s ability to cost effectively treat influent vapor with high concentrations of VOCs. As described in the approved Phase I Work Plan [Geosyntec, Hargis, 2005], the HSC intends to replace the GEO System with a vapor-phase carbon system when influent vapor VOC concentrations are reduced to levels that are economically treated by carbon. The carbon system is an ideal off-gas treatment technology for use in pulsed SVE system operation; which is an integral part of the SVE closure plans outlined in Section 4. This section provides details regarding proposed modifications to the SVE system, including the change from off-gas treatment with the GEO System to the carbon system.

2.2 Well Field Modifications

The restarted SVE system has been operating since approximately March 2007 in a focused manner using primarily wells in the vicinity of Pit 1. As the mass extracted from these wells decreases, the SVE well field may be adjusted or expanded as needed to remove VOC mass from the vadose zone in other areas of the Site. Geosyntec will evaluate the need for well field modifications should results of soil vapor monitoring data indicate increasing concentration trends of VOCs in existing soil vapor monitoring wells or indicate that soil vapor performance goals may not be achieved without active extraction.

Specific well field modifications to increase extraction and treatment of soil vapor containing VOCs from the subsurface\(^1\) may include [EPA, 2004]:

- Periodically pulsing (i.e., ceasing and resuming) extraction from one or more individual wells;

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\(^1\) It should be noted that the efficiencies related to pulsed system operation are not applicable to the GEO System and would only be considered for the Site when vapor-phase carbon treatment is used.
• Decreasing or increasing the extraction flow rate from individual extraction wells;
• Adding new extraction wells to the well field or opening additional wells to extraction;
• Closing individual wells to extraction; or
• Converting individual extraction wells to venting wells to allow for introduction of atmospheric air and creation of new flow paths in the subsurface.

Should additional existing wells be added to the SVE system as active extraction wells, well heads and conveyance piping will be constructed and startup testing will be performed consistent with the approach that was used for the addition of sub-basalt wells MW-18UA, MW-19UA, and MW-06UA in August 2007 and fine-grained wells SP-01, SP-02, and coarse-grained well P-01 in October 2008. Well heads will be constructed of Schedule 40 PVC components, including a flow control valve, sample port, and pitot flow measurement port. Conveyance piping will be constructed using 2-inch diameter Schedule 40 PVC. The conveyance piping will be run aboveground and connected to the existing SVE piping network. Upon initial extraction from newly piped SVE wells, step tests will be conducted over a range of applied vacuums for measurements of flow and total VOC concentration.

If performed, details regarding well field modifications will be documented in field logs and as part of quarterly and annual reports. The current SVE extraction well field configuration is shown in Figure 2-1.

2.3 **Carbon System**

2.3.1 **Design and Specifications**

The proposed future carbon system has been designed using data collected during operation of the GEO System and through evaluation of recent vadose zone soil vapor VOC concentrations. The key data that have been used to design and size the carbon system include:

• Number and location of SVE extraction wells;
• Individual well and treatment system flow rates;
• Current vacuum applied at wellheads;
• Influent VOC concentration trends; and
• Predicted carbon usage rates at time of system installation.

Using the above information, the carbon system is designed to consist of the following primary components:

• A condensate knockout pot with a 1-Horsepower (HP) transfer pump;
• Particulate air filters;
• Three 10,000-pound vessels loaded with virgin coconut shell vapor-phase carbon and connected in series;
• A 10-HP positive displacement blower (8 – 12” Hg vacuum capable);
• A 5-HP heat exchanger at system’s influent; and
• Associated instrumentation and controls.

The number and size of the carbon vessels may be modified based on actual VOC concentrations at the time of system installation or as conditions change as the carbon system is operated. A process flow diagram of the carbon adsorption treatment system is shown on Figure 2-2. The knockout pot, blower, heat exchanger, and control panel will be housed on a skid. During a carbon changeout, the carbon vessel with the fresh carbon (previously in the lead position) will be placed in the lag position. Likewise, the carbon vessels with partially spent carbon (previously in the lag positions) will be placed in the lead positions. At this point, the system is started back on line with what were the lag vessels now in the lead positions and the previous lead bed, which was just rebelled with fresh carbon, are put into the lag position. The lag vessels should have the freshest, most highly regenerated media in it at the end of a new carbon changeout. Appropriate quick connect hose connections will be made between the skid and the carbon vessels to allow for lead/lag configuration flexibility for the individual carbon vessels during spent carbon changeouts. The existing 4-inch PVC header piping from the well field will be connected to the influent of the carbon system. The carbon system will be located on the lined equipment pad in the same location currently occupied by the GEO System. Instrumentation for the carbon adsorption treatment system will consist of a National Electrical Manufactures Association (NEMA) control panel and system telemetry. The system will be equipped with telemetry components to allow for shutdown alarms to be automated and remote start and stop capabilities. The carbon
system will not require as much electrical service as the GEO System, and therefore, electrical modifications will be minimal.

The carbon system will be permitted with the Maricopa County Air Quality Department (MCAQD). Depending on the requirements of the MCAQD, the existing permit equivalent will be modified or new permit equivalent documents will be filed. Startup of the carbon system will be conducted over a one to two-week period (Section 2.3.2). Following the startup period, it is anticipated that the treatment system will be fully operational and will be purposefully shut down only for routine O&M, carbon change-outs, pulsed operation or SVE system closure (see Sections 4.2 through 4.5).

2.3.2 Startup Procedures

Startup of the carbon system will be conducted over a one to two-week period. The following field data will be collected during startup of the vapor-phase carbon SVE system:

- Total VOC concentrations measured using a PID;
- Flow rates at individual extraction wells over a range of applied vacuums;
- Condensate production rates with time;
- Chemical quality of condensate with time, and
- Total VOC concentrations, measured using a PID, at the influent and effluent monitoring locations at each of the carbon vessels.

Data from these field tests will be used to balance individual SVE well flow rates, adjust system dilution air settings, assess condensate disposal options, and evaluate the timing for carbon vessel changeouts. As performed, details regarding startup testing for the carbon treatment system will be documented as part of the quarterly and annual reports.

2.3.3 Operation, Maintenance, and Monitoring

A preventative maintenance program will be utilized to reduce process downtime, provide greater VOC recovery efficiency, and reduce utility costs for system operation.
A site visit will be conducted every two weeks, during which the following maintenance tasks will be conducted:

- Inspect gaskets and seals for leaks;
- Inspect the stream valves for leaks;
- Check process dilution air flows and adjust if necessary;
- Inspect indicating lamps on the control panel;
- Check pressure gauges for proper calibration;
- Observe condensate knockout pot to verify proper operation; and
- Preventative maintenance of system components (e.g., greasing blower bearings and changing the oil, inspecting belts for condition, etc.) at frequencies dictated by manufacturer’s recommendations.

The carbon treatment system operation will be monitored during the biweekly site visits wherein the following monitoring tasks will be conducted:

- Monitoring flow rate and vacuum at the system influent;
- Monitoring flow rate, vacuum and concentrations (using a PID) of total VOC concentrations at individual extraction wells;
- Monitoring total VOC concentrations using a PID at the influent and effluent of each carbon vessel;
- Monitoring condensate production rates; and
- Monitoring system runtime.

Site visit frequencies may be adjusted in consideration of future system operation protocols. Vapor effluent sampling will be conducted in accordance with the MCAQD permit.

Operational data will be used to evaluate the performance of the SVE treatment system and will be documented as part of the quarterly and annual reports. Adjustments will be made to the system configuration to increase extraction and treatment of soil vapor containing VOCs from the subsurface. Adjustments may include:

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2 Additional routine maintenance of the carbon system may be conducted in accordance with the manufacturers’ specifications.
• Decreasing or increasing the extraction flow rate from individual extraction wells to focus on wells with the highest VOC concentrations;

• Opening individual extraction wells to be used as venting wells (closed to system extraction, but sample port remains open to allow for introduction of atmospheric air and creation of new flow paths in the subsurface);

• Adding new extraction wells to the well field, opening additional wells to extraction or closing certain wells based on changes in soil vapor monitoring data; or

• Adjusting the amount of dilution air entering the system over time as influent VOC concentrations decrease.

The system will operate as noted above; however additional modifications may be made periodically to increase the system’s effectiveness. As performed, adjustments made to the system configuration will be documented as part of the quarterly and annual reports. After substantial mass removal and demonstrated reduction in the concentration of VOCs in influent samples, the closure protocols described in Section 4 will be implemented.

Spent carbon will be profiled and disposed of under manifest per applicable requirements by a licensed waste disposal contractor. Replacement carbon will consist of virgin coconut shell vapor-phase carbon only. Depending on the chemical profile, condensate may be blended with extracted groundwater and treated using the existing air stripper at the Site or transported off-site for disposal under manifest per applicable requirements by a licensed waste disposal contractor. The proposed method of condensate disposal will be presented to USEPA and ADEQ for approval following initial startup testing.
3. SOIL VAPOR PERFORMANCE GOALS

3.1 General

Prior to the construction and operation of the original SVE system, soil vapor performance goals were developed for the Site in 1994 using computer modeling (SESOIL coupled with groundwater mixing cell model MIXMODEL and the HELP model) [EM, 2001]. Following shutdown of the original SVE system in accordance with the aforementioned 1994 soil vapor performance goals, VOC concentrations exhibited increasing trends in soil vapor and in several Unit A groundwater monitoring wells, including upgradient well MW-11UA. Further investigation performed in 2006 supported an updated Site Conceptual Model (SCM) that identified dissolution of VOCs from soil vapor into groundwater as a significant migration pathway to Unit A groundwater [Geosyntec and Hargis, 2007]. Considering the updated SCM and the above noted trends, it can be concluded that the 1994 soil vapor performance goals require updating.

3.2 Technical Approach

Site-specific groundwater performance standards (Table 3-1) have been established for the Site. The standards are a combination of Federal or State Maximum Contamination Levels (MCLs) and Health Based Guidance Levels (HBGLs) identified by ADEQ or the Arizona Department of Health Services (ADHS). This section describes the development of soil vapor performance goals for each VOC that has a groundwater performance standard; this approach is based on the premise that the ultimate remedial objective the SVE remedy component is to protect groundwater quality.

The updated 2009 soil vapor performance goals for these VOCs were developed using a combination of the following:

- Regulatory standards; and
- Agency guidance that provides a process for calculating concentrations of specific analytes that may be left in soil that would not result in an exceedance of a target or specified groundwater concentration. For the application detailed in this document, the target groundwater concentrations are the site-specific groundwater performance standards (Table 3-1).
When available, the regulatory standards that were utilized were the Arizona Minimum Groundwater Protection Levels (GPLs) for organic contaminants from the ADEQ document “A Screening Method to Determine Soil Concentrations Protective of Groundwater Quality” [ADEQ, 1996]. However, because Arizona Minimum GPLs are not published for every VOC analyte targeted for soil vapor performance goal development, soil vapor performance goals were calculated for remaining compounds in accordance with the methods described by the soil screening guidance tool developed by USEPA in 1996. This guidance provides a methodology to calculate site-specific Soil Screening Levels (SSLs) [EPA, 1996].

It should be noted that both the Arizona GPLs and the USEPA methods used to develop site-specific SSLs yield allowable total soil concentrations. Additional calculations were performed to convert the soil concentrations to soil vapor concentrations at equilibrium conditions, which are then presented as the updated 2009 soil vapor performance goals for the Site.

The updated soil vapor performance goals will be used to guide operation of the SVE system and provide a set of criteria from which to evaluate when shutdown of the system is appropriate. Details regarding the development of the soil vapor performance goals using the Arizona Minimum GPLs and USEPA SSL methodology are provided in the following sections.

3.3 Arizona Groundwater Protection Levels

Where available, Minimum GPLs were used to derive soil vapor performance goals for targeted VOC analytes. Minimum GPLs were obtained from the ADEQ document “A Screening Method to Determine Soil Concentrations Protective of Groundwater Quality” [ADEQ, 1996]. In September 1994, the ADEQ’s Cleanup Standards Task Force developed a contaminant fate-and-transport model to calculate potential impacts on groundwater quality due to residual soil contamination. Based on this model, Minimum GPLs for organic contaminants were developed using federal maximum contaminant levels (MCLs) as a groundwater threshold.

Minimum GPLs were developed as conservative levels for groundwater protection. Minimum GPLs represent soil concentrations protective of groundwater quality in a “worst-case” situation, where the entire soil profile is contaminated from surface to just above the groundwater surface. The input model parameters used to develop the Minimum GPLs provide for very conservative protection levels. “If a pre-determined or
site-specific soil cleanup standard is not protective of groundwater quality, a Minimum GPL can be used to ensure groundwater protection” [ADEQ 1996, Page v].

It should be noted that the Minimum GPLs are likely more conservative than values derived from site-specific contaminant fate and transport modeling. Table 3-2 lists the target VOC analytes with published Minimum GPLs and their corresponding soil concentration values.

If an Arizona Minimum GPL was not published for VOC analytes targeted for soil vapor performance goal development, a value was calculated using the USEPA Soil Screening Guidance tool (Section 3.4).

3.4 USEPA Soil Screening Levels

In July 1996, the USEPA developed the “Soil Screening Guidance: User’s Guide” to help standardize the evaluation and cleanup of contaminated soils at sites and provide a methodology to calculate site-specific SSLs [EPA, 1996]. The guidance provides a step-by-step methodology to calculate site-specific SSLs from specified groundwater performance standards using a series of equations described in this section.

The methodology for developing SSLs for the migration to groundwater pathway is based on rather conservative, simplified assumptions about the release and transport of contaminants in the subsurface. The soil screening guidance tool uses a simple linear equilibrium soil/water partition equation that relates concentrations of adsorbed soil contaminants to soil leachate concentrations in the zone of contamination. It also uses a water balance equation to calculate a Dilution Attenuation Factor (DAF) to account for reduction of soil leachate concentrations due to localized mixing in an aquifer. An estimated mixing zone depth (d) of 1.62 meters (Equation 1) is used along with other site-specific variables to calculate the DAF value (Equation 2) from the mixing zone equation [EPA, 1996]. The mixing zone equation, derived from a water-balance relationship, was used to calculate a site-specific DAF of 938 using site-specific aquifer and soil data.

The soil/water partition equation calculates SSLs corresponding to a target soil leachate contaminant concentration, $C_w$. In this document, $C_w$ values are the site-specific groundwater performance standards for each VOC analyte multiplied by the DAF (Equation 3).
Table 3-2 lists the VOC analytes and the calculated SSLs in units of total soil concentration. Values for chemical specific variables for VOC analytes used in Equation 1 are listed in Table 3-3. Values and references for site-specific variables used in the following equations are listed in Table 3-4. The step-by-step methodology used to calculate the SSL for an example VOC (Acetone) is shown below.

**Calculating Mixing Zone Depth (d)**

\[
d := \left( \frac{0.0112}{L_a} \right)^2 + d_a \left( 1 - e^{- \frac{L_a}{K_i d_a}} \right)
\]

where  
- \( L_a \) = Source Length Parallel to Groundwater Flow = 15.24 m  
- \( d_a \) = Aquifer Thickness = 10.7 m  
- \( I \) = Infiltration Rate = 0.0018 \( \cdot P^2 \) (where \( P = 0.217 \text{ m/yr} \)) = 8.5 \times 10^{-5} \text{ m/yr}  
- \( K \) = Aquifer Hydraulic Conductivity = 238.3 \text{ m/yr}  
- \( i \) = Hydraulic Gradient = 3.15 \times 10^{-3} \text{ m/m}

From Equation 1,

\[
d = \left[ 0.0112(15.24\text{ m})^2 \right]^{0.5} + (10.7\text{ m}) \left( 1 - e^{- \frac{15.24\text{ m}}{238.3\text{ m/yr} \cdot 3.15 \times 10^{-3} \text{ m/m} \cdot 10.7\text{ m}}} \right) 
\]

\[
d = 1.62\text{ m}
\]

**Calculating Site-Specific Dilution Attenuation Factor (DAF)**

\[
DAF := 1 + \frac{K_i d}{I L_a}
\]

From Equation 2,

\[
DAF = 1 + \frac{238.3\text{ m/yr} \cdot 3.15 \times 10^{-3} \text{ m/yr} \cdot (1.62\text{ m})}{8.5 \times 10^{-5} \cdot (15.24\text{ m})}
\]

\[
DAF = 938
\]
Calculating Target Soil Leachate Contaminant Concentration for Acetone \((C_w)\)

\[ C_w = \text{Acetone Site Specific Groundwater Performance Standard} \times \text{DAF} \quad (3) \]

where
- Site Specific Groundwater Performance Standard for Acetone = 700 µg/L
- DAF = 938 (from Equation 2)

From Equation 3,

\[ C_w = \left( \frac{.7 \text{ mg}}{\text{ L}} \right) \times 938 \]

\[ C_w = 657 \text{ mg/L} \]

Calculating Soil Screening Level for Acetone \((SSL)\)

\[ \text{SSL} = C_w \left[ K_{oc} f_{oc} + \left( \frac{\theta_w + \theta_a H_c}{\rho_b} \right) \right] \quad (4) \]

where
- \(K_{oc}\) = Organic Carbon Partition Coefficient = 0.575 L/kg
- \(f_{oc}\) = Fraction Organic Carbon in Soil = 0.001 (unitless)
- \(\theta_w\) = Volumetric Water Content = 0.15 (unitless)
- \(\theta_a\) = Air-Filled Soil Porosity = 0.15 (unitless)
- \(H_c\) = Henry's Law Constant = 0.00159 (unitless)
- \(\rho_b\) = Dry Soil Bulk Density = 1.3 kg/L

From Equation 4,

\[ \text{SSL} = \left( \frac{657 \text{ mg}}{\text{ L}} \right) \left[ \left( \frac{166 \text{ L}}{\text{ kg}} \right) \times (0.001) + \left( \frac{0.15}{1.3 \text{ kg/L}} \right) \right] \]

\[ \text{SSL} = 76.3 \text{ mg/kg} \]
3.5 **Updated Soil Vapor Performance Goals**

To derive the updated soil vapor performance goals, the soil concentrations developed using Minimum GPLs and SSLs were expressed as equivalent soil vapor concentrations at equilibrium. The use of soil vapor performance goals is preferred over soil-based values given the extensive existing soil vapor monitoring network installed in the coarse-grained, fine-grained, and sub-basalt vadose zones of the Site. Additionally, soil vapor data can be collected on a frequent basis and with greater ease than soil data, especially given the presence of the geomembrane liner over a majority of the Site.

The soil concentrations derived from the Minimum GPLs and calculated SSLs were converted to equilibrium vapor concentrations using Equation 5. The methodology used to calculate the equilibrium vapor concentration for acetone from the site-specific SSL (calculated from Equation 4) is shown below.

**Calculating Soil Vapor Equivalent for Acetone (Cv)**

\[
C_v = \frac{C_s \cdot \rho_b}{K_{oc} \cdot f_{oc} \cdot P_b \cdot \frac{H_c}{H_c} + \frac{\theta_w}{H_c} + (\theta_T - \theta_w)} \tag{5}
\]

where \( C_s = \) Soil Concentration (Acetone SSL) = 76.3 mg/kg or 7.63 \times 10^4 \text{ ug/kg}  \\
\( \theta_T = \) Total Porosity = 0.3 (unitless)

From Equation 5,

\[
C_v = \left( \frac{7.63 \times 10^4 \text{ ug}}{\text{kg}} \right) \cdot \left( \frac{1.3 \text{ kg}}{L} \right) \cdot \left( \frac{.575 \frac{L}{kg}}{.00159} \right) \cdot \left( \frac{1.3 \text{ kg}}{L} \right) \cdot \left( .15 \right) + \left( .3 - .15 \right)
\]

\[
C_v = 1040 \frac{\mu g}{L}
\]
The resulting soil vapor concentrations, which constitute the updated soil vapor performance goals, are summarized on Table 3-2. Values for chemical specific variables for VOC analytes are listed in Table 3-3. Values for site-specific variables are listed in Table 3-4. The updated soil vapor performance goals will be used to guide operation of the SVE system and provide a set of criteria from which to evaluate when shutdown of the system is appropriate using the protocols presented in Section 4.
4. SVE SYSTEM SHUTDOWN PROTOCOLS

4.1 Technical Approach

This section describes operational and testing protocols to be implemented in conjunction with comparison of measured soil vapor VOC concentrations to the updated soil vapor performance goals to define when shutdown of the SVE system is appropriate. These protocols include periodically ceasing and resuming extraction of individual wells or the system as whole to allow for potential rebound of VOCs when mass removal data indicate approaching asymptotic conditions. Rebound tests will be performed using a combination of field and laboratory tests. When rebound testing results of individual wells indicate that VOC concentrations are below the updated soil vapor performance goals, the well will be closed to extraction. The entire SVE remedy will be shutdown and deemed complete when all SVE wells have been closed and the results of annual soil vapor monitoring events indicate that soil vapor concentrations have remained below the performance goals for a period of at least one year. Details regarding rebound testing and system shutdown criteria are described in the following sections.

4.2 Rebound Testing

Operational data will be used to monitor the rate and cumulative mass of VOCs being extracted and treated by the SVE system. Typically for SVE systems, the rate of mass removal is generally fast during early phases of operation and gradually becomes progressively slower until it approaches a relatively consistent, flat-lined trend, referred to as an asymptote. Figure 4-1 represents the relationship between concentration reduction and mass removal typical of asymptotic behavior. Figure 4-2 is a plot of both cumulative and quarterly VOC mass removal for the SVE system at the Site. Based on the cumulative mass removal data shown on Figure 4-2, asymptotic conditions have not yet been reached. The SVE system will continue to be operated until asymptotic behavior is observed.

Once it appears that an asymptote has been reached at a SVE well, rebound testing and shutdown protocols will be implemented as illustrated in the flow chart included as Figure 4-3. When asymptotic behavior is first observed at a SVE well, extraction at that well will be ceased for a period of at least one month to evaluate rebound. Just prior to shutdown, the VOC concentration at the well will be measured using a PID under dynamic (active extraction) conditions. Following the shutdown period, rebound VOC concentrations will be measured using a PID under static (prior to resumed extraction)
and dynamic (within the first few hours of resumed extraction) conditions. The PID data will be used to assess whether or not a sample should be collected for laboratory testing. Samples for laboratory testing will not be collected when significant rebound is measured or if data suggest VOC concentrations are greater than the soil vapor performance goals.

When the rebound testing PID data suggest the concentrations of VOCs are at or below the soil vapor performance goals, a sample will be collected for laboratory testing in a SUMMA canister under static conditions (no active vapor extraction) following a one month rebound period. The sample will be analyzed for VOCs by EPA Method TO-15. Samples for laboratory testing will either be collected just prior to resuming extraction and rebound testing following the initial one month rebound period, or following a successive one-month rebound period after the dynamic rebound testing is conducted.

If VOC concentrations from one month rebound samples are below soil vapor performance goals (Table 3-2), extraction at the individual well will remain discontinued for an additional two month rebound period at which time a three month soil vapor rebound sample will be collected for laboratory testing (Figure 4-3). If soil vapor VOC concentrations remain below soil vapor performance goals after the three month rebound period, the SVE well will be closed and monitored as part of the next annual soil vapor sampling event. Data collected from annual soil vapor sampling events will be used to support shutdown of the SVE system (Section 4.5).

If soil vapor VOC concentrations are greater than soil vapor performance goals, extraction will be resumed and the rebound testing process will start over. It should be noted that if results of successive rebound testing cycles do not result in significant increases in VOC concentrations and soil vapor concentrations remain greater than the soil vapor performance goals, a point of technical impracticability for the SVE remedy may be reached. Should these conditions occur, an evaluation of alternative vadose zone remedial actions may be warranted.

Rebound testing results will be documented as part of quarterly and annual monitoring reports as the rebound testing is performed and the field and laboratory data are collected.
4.3 **Sub-Basalt Vapor Conditions**

The updated SCM [Geosyntec and Hargis, 2007] identified dissolution of VOCs from soil vapor as a significant migration pathway to Unit A groundwater. As concentrations of soil vapor VOCs are reduced in the sub-basalt vadose zone through operation of the SVE system, equilibrium is reversed and VOC vapors will off-gas from groundwater back into the sub-basalt vadose zone.

If concentrations of VOCs in the sub-basalt vadose zone are found to rebound above performance standards, an evaluation of the potential contribution from groundwater off-gassing will be conducted. If it is concluded that off-gassing from groundwater is the likely cause of the soil vapor rebound, the affected sub-basalt SVE wells will be operated on an extended rebound schedule while a focused remedy evaluation is conducted. Depending on the specific groundwater and soil vapor conditions at the time, an evaluation of alternative vadose zone or groundwater remedial actions may be warranted. Long term, continued operation of an SVE system to solely capture vapors generated by groundwater off-gassing is not practical.

4.4 **System Shutdown**

Shutdown or longer-term rebound soil vapor data will be obtained as part of annual soil vapor monitoring events. Should results of annual soil vapor monitoring indicate concentrations of VOCs greater than performance standards, vapor extraction will be resumed in the subject area and the rebound testing process described in Section 4.2 will be repeated. The SVE system will be shut down once concentrations of VOCs in soil vapor are demonstrated to remain below performance goals at each extraction well and monitoring probe after a rebound period of at least one year.

The status of the SVE system and associated monitoring and testing data will be documented as part of future quarterly and annual reports. Upon reaching the conditions for system shutdown, a close-out report will be prepared for submittal to USEPA and ADEQ.
5. SUMMARY

At the Hassayampa Site quarterly review meeting on November 6, 2007, the USEPA requested that the HSC provide a series of letter work plans to address a number of remedy O&M, upgrade and optimization tasks. This document details the development of updated soil vapor performance goals and describes the proposed modifications to and closure protocols for the restarted SVE system at the Site.

SVE System Modifications

Currently, the re-started SVE system is primarily focused on extracting vapors from the fine-grained and sub-basalt vadose zone areas at and nearby Pit 1, the primary VOC source area at the Site. The extracted vapors are treated using the GEO Inc. pressure condensation treatment unit. As described in the approved Phase I Work Plan [Geosyntec, Hargis, 2005], the HSC intends to replace the GEO System with a vapor-phase carbon system when influent vapor VOC concentrations are reduced to levels that are economically treated by carbon. The carbon treatment system will consist of a condensate knockout pot, particulate air filters, three 10,000-pound carbon vessels with virgin coconutchell carbon, a positive displacement blower, heat exchanger, and associated instrumentation and controls. Following installation, startup testing will be performed. Routine O&M and associated waste disposal protocols have been developed. In addition, the SVE well field will be modified (decreased or expanded) as needed to remove VOC mass from the vadose zone in areas of the Site where data indicated soil vapor performance goals may not be achieved without active extraction.

Updated Soil Vapor Performance Goals

Increasing concentrations of VOCs in select Unit A groundwater wells in the late 1990s and thereafter following shutdown of the initial SVE system in 1998 indicated that soil vapor performance goals developed in 1994 require updating. Given the Site remedy objective of protecting groundwater quality, soil vapor performance goals were developed for each VOC analyte that has a site-specific groundwater performance standard. Updated 2009 soil vapor performance goals were developed using a combination of regulatory approved standards, Arizona Minimum GPLs, and agency guidance for developing site-specific SSLs.

Where available, Arizona Minimum GPLs for organic contaminants were used. When an Arizona Minimum GPL was not published for a VOC targeted for soil vapor performance goal development, the soil vapor performance goal was calculated in
accordance with the methods described in the “Soil Screening Guidance: User’s Guide” developed by USEPA in 1996. Arizona Minimum GPLs and the calculated site-specific SSL soil concentrations were then expressed as equivalent equilibrium vapor concentrations for the updated soil vapor performance goals.

**SVE System Shutdown Protocols**

A series of operational and testing protocols have been developed which will be implemented, in conjunction with comparison of measured soil vapor VOC concentrations to the updated soil vapor performance goals, to define when shutdown of the SVE system is appropriate based on the goals set forth. These protocols include periodically ceasing and resuming extraction of individual wells or the system as whole to allow for rebound testing protocols to be utilized when mass removal data indicate that the influent data trends are approaching asymptotic conditions. When rebound testing results of individual wells indicate that the VOC concentrations are below the updated soil vapor performance goals, the well will be closed to extraction. The SVE remedy will be shutdown and deemed complete when all SVE wells have been closed and the results of annual soil vapor monitoring events indicate that soil vapor concentrations have remained below the performance goals for a period of at least one year.
REFERENCES


TABLES
# Table 3-1
Groundwater Performance Standards
Hassayampa Landfill
Maricopa County, Arizona

<table>
<thead>
<tr>
<th>Volatile Organic Compound</th>
<th>Groundwater Performance Standard (µg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetone</td>
<td>700</td>
</tr>
<tr>
<td>Benzene</td>
<td>5</td>
</tr>
<tr>
<td>2-Butanone</td>
<td>170</td>
</tr>
<tr>
<td>Chlorobenzene</td>
<td>100</td>
</tr>
<tr>
<td>Dichlorofluoromethane</td>
<td>1400</td>
</tr>
<tr>
<td>1,2-Dichloroethane</td>
<td>5</td>
</tr>
<tr>
<td>1,1-Dichloroethene</td>
<td>7</td>
</tr>
<tr>
<td>1,2-Dichloroethene (cis)</td>
<td>70</td>
</tr>
<tr>
<td>1,2-Dichloroethene (trans)</td>
<td>100</td>
</tr>
<tr>
<td>1,2-Dichloropropane</td>
<td>5</td>
</tr>
<tr>
<td>Methylene Chloride</td>
<td>5</td>
</tr>
<tr>
<td>Tetrachloroethene</td>
<td>5</td>
</tr>
<tr>
<td>Toluene</td>
<td>1000</td>
</tr>
<tr>
<td>1,1,1-Trichloroethane</td>
<td>200</td>
</tr>
<tr>
<td>Trichloroethene</td>
<td>5</td>
</tr>
<tr>
<td>Trichlorofluoromethane</td>
<td>2100</td>
</tr>
<tr>
<td>Trichlorotrifluoroethane (Freon 113)</td>
<td>210000</td>
</tr>
<tr>
<td>Vinyl Chloride</td>
<td>2</td>
</tr>
<tr>
<td>Xylene (total)</td>
<td>10000</td>
</tr>
</tbody>
</table>
### Table 3-2
Soil Vapor Performance Standards
Hassayampa Landfill
Maricopa County, Arizona

<table>
<thead>
<tr>
<th>Volatile Organic Compound</th>
<th>Arizona GPLs(^1) (mg/kg)</th>
<th>Site Specific SSLs(^2) (mg/kg)</th>
<th>Vapor Equivalent Soil Vapor Performance Standards(^3) (µg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetone</td>
<td>-</td>
<td>76.260</td>
<td>1.04E+03</td>
</tr>
<tr>
<td>Benzene</td>
<td>0.71</td>
<td>-</td>
<td>8.07E+02</td>
</tr>
<tr>
<td>2-Butanone</td>
<td>-</td>
<td>19.159</td>
<td>3.64E+02</td>
</tr>
<tr>
<td>Chlorobenzene</td>
<td>-</td>
<td>33.010</td>
<td>1.43E+04</td>
</tr>
<tr>
<td>Dichlorofluoromethane</td>
<td>-</td>
<td>2682.030</td>
<td>2.15E+07</td>
</tr>
<tr>
<td>1,2-Dichloroethane</td>
<td>0.21</td>
<td>-</td>
<td>6.13E+01</td>
</tr>
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<td>1,1-Dichloroethene</td>
<td>0.81</td>
<td>-</td>
<td>2.85E+03</td>
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<tr>
<td>1,2-Dichloroethene (cis)</td>
<td>4.9</td>
<td>-</td>
<td>4.81E+03</td>
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<td>1,2-Dichloroethene (trans)</td>
<td>8.4</td>
<td>-</td>
<td>1.52E+04</td>
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<td>1,2-Dichloropropane</td>
<td>0.28</td>
<td>-</td>
<td>1.87E+02</td>
</tr>
<tr>
<td>Methylene Chloride</td>
<td>-</td>
<td>0.645</td>
<td>4.21E+02</td>
</tr>
<tr>
<td>Tetrachloroethene</td>
<td>1.3</td>
<td>-</td>
<td>2.74E+03</td>
</tr>
<tr>
<td>Toluene</td>
<td>400</td>
<td>-</td>
<td>3.31E+05</td>
</tr>
<tr>
<td>1,1,1-Trichloroethylene</td>
<td>1.0</td>
<td>-</td>
<td>2.30E+03</td>
</tr>
<tr>
<td>Trichloroethene</td>
<td>0.61</td>
<td>-</td>
<td>7.80E+02</td>
</tr>
<tr>
<td>Trichlorofluoromethane</td>
<td>-</td>
<td>1318.402</td>
<td>7.80E+06</td>
</tr>
<tr>
<td>Trichlorotrifluoroethane</td>
<td>-</td>
<td>541710.152</td>
<td>3.86E+09</td>
</tr>
<tr>
<td>Vinyl Chloride</td>
<td>-</td>
<td>0.492</td>
<td>2.08E+03</td>
</tr>
<tr>
<td>Xylene (total)</td>
<td>2200</td>
<td>-</td>
<td>1.14E+06</td>
</tr>
</tbody>
</table>

**Notes:**

\[
SSL = C_w \left[ K_{oc} f_{oc} \theta_a + \frac{(\theta_w + \theta_a H_c)}{P_b} \right]
\]

\[
C_w = \text{Site Specific Groundwater Performance Standard (Table 3-1)} \times DAF
\]

\[
DAF = 1 + \frac{K_{ul}}{K_{il}}
\]

\[
d = (0.0112 \cdot L^2)^5 + d_a (11 - e^{-\frac{L}{K_{al}}})
\]

(3) Calculated from soil concentrations

\[
C_v = \frac{C_s \cdot P_b}{K_{oc} f_{oc} h_c + \theta_w h_c + (\theta_T - \theta_w)}
\]
### Table 3-3
Chemical Specific Variables
Hassayampa Landfill
Maricopa County, Arizona

<table>
<thead>
<tr>
<th>Volatile Organic Compound</th>
<th>$H_C$ (EPA) (unitless)</th>
<th>$K_{OC}$ (EPA) (L/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetone</td>
<td>0.00159&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.575&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Benzene</td>
<td>0.228&lt;sup&gt;a&lt;/sup&gt;</td>
<td>58.9&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>2-Butanone</td>
<td>0.00228&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.5&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Chlorobenzene</td>
<td>0.152&lt;sup&gt;a&lt;/sup&gt;</td>
<td>219&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Dichlorofluoromethane</td>
<td>16.40&lt;sup&gt;b&lt;/sup&gt;</td>
<td>34.67&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>1,2-Dichloroethane</td>
<td>0.0401&lt;sup&gt;a&lt;/sup&gt;</td>
<td>17.4&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>1,1-Dichloroethene</td>
<td>1.07&lt;sup&gt;a&lt;/sup&gt;</td>
<td>65&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>1,2-Dichloroethene (cis)</td>
<td>0.167&lt;sup&gt;a&lt;/sup&gt;</td>
<td>35.5&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>1,2-Dichloroethene (trans)</td>
<td>0.385&lt;sup&gt;a&lt;/sup&gt;</td>
<td>52.5&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>1,2-Dichloropropane</td>
<td>0.115&lt;sup&gt;a&lt;/sup&gt;</td>
<td>43.7&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Methylene Chloride</td>
<td>0.0898&lt;sup&gt;a&lt;/sup&gt;</td>
<td>11.7&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Tetrachloroethene</td>
<td>0.754&lt;sup&gt;a&lt;/sup&gt;</td>
<td>155&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Toluene</td>
<td>0.272&lt;sup&gt;a&lt;/sup&gt;</td>
<td>182&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>1,1,1-Trichloroethane</td>
<td>0.705&lt;sup&gt;a&lt;/sup&gt;</td>
<td>110&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Trichloroethene</td>
<td>0.422&lt;sup&gt;a&lt;/sup&gt;</td>
<td>166&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Trichlorofluoromethane</td>
<td>3.96&lt;sup&gt;b&lt;/sup&gt;</td>
<td>93.32&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>Trichlorotrifluoroethane</td>
<td>19.61&lt;sup&gt;b&lt;/sup&gt;</td>
<td>371.54&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>Vinyl Chloride</td>
<td>1.11&lt;sup&gt;a&lt;/sup&gt;</td>
<td>18.6&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Xylene (total)</td>
<td>0.276&lt;sup&gt;a&lt;/sup&gt;</td>
<td>386.33&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
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</table>

**References:**

Table 3-4
Site-Specific Variables
Hassayampa Landfill
Maricopa County, Arizona

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
<th>Reference(1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$f_{OC}$ - Fraction Organic Carbon in Soil (unitless)</td>
<td>0.001</td>
<td>[Hargis, 2007A]</td>
</tr>
<tr>
<td>$P_b$ - Dry Soil Bulk Density</td>
<td>1.3 kg/L</td>
<td>[Hargis, 2007A]</td>
</tr>
<tr>
<td>$\theta_w$ - Volumetric Water Content (unitless)</td>
<td>0.15</td>
<td>[Hargis, 2007A]</td>
</tr>
<tr>
<td>$\theta_T$ - Total Porosity (unitless)</td>
<td>0.3</td>
<td>[Hargis, 2007A]</td>
</tr>
<tr>
<td>$\theta_a$ - Air-Filled Soil Porosity (unitless)</td>
<td>0.15</td>
<td>[Hargis, 2007A]</td>
</tr>
<tr>
<td>$K$ - Aquifer Hydraulic Conductivity</td>
<td>238.3 m(/)yr</td>
<td>[Hargis, 2008]</td>
</tr>
<tr>
<td>$i$ - Hydraulic Gradient</td>
<td>3.15E-03 m/m</td>
<td>[Hargis, 2007B]</td>
</tr>
<tr>
<td>$I$ - Infiltration Rate(2)</td>
<td>8.5E-05 m/year</td>
<td>$I = 0.0018P^2$, where $P = 0.217$ m/yr</td>
</tr>
<tr>
<td>$L$ - Source Length Parallel to Groundwater Flow</td>
<td>15.24 m</td>
<td>Approximate width of Pit 1</td>
</tr>
<tr>
<td>$d_a$ - Aquifer Thickness</td>
<td>10.7 m</td>
<td>[Hargis, 2008]</td>
</tr>
</tbody>
</table>

Notes:
(1) References


(2) Based on Phoenix mean annual precipitation data. Calculation from Texas Risk Reduction Program, Tier 2 PCL equations. TCEQ Texas Risk Reduction Program (TRRP) Rule (30 TAC 350).
FIGURES
FIGURE 2-1
SVE LAYOUT AND VAPOR PROBES
HAZAYAMPA LANDFILL SUPERFUND SITE

Explanation
- Sub-Basalt Vapor Monitoring Point
- Soil Vapor Vent Well
- Soil Vapor Monitor Well (Course and Fine Grained Zone)
- Soil Vapor Extraction Well (Course and Fine Grained Zone)
- Soil Vapor Extraction Well (Fine Grained Zone)
- Soil Vapor Extraction Well (Sub-Basalt)
- Waste Disposal Pit (Approximate Location)
- Soil Vapor Extraction System Pipeline
- Vapor Treatment Equipment
- Fence
- Approximate Property Boundary

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SOLID WASTE LANDFILL

Project No. HR0933
Date: December 2006
Figure 4-1: Typical Relationship Between Concentration Reduction and Mass Removal

Source: How to Evaluate Alternative Cleanup Technologies for Underground Storage Tanks – Chapter II: Vapor Extraction. USEPA, 2004

Project No.: HR0933-12
Date: December 2008
Figure 4-2: SVE System Mass Removal Curve
Hassayampa Landfill Site

Cumulative VOC Mass Removal (lbs)

Quarterly VOC Mass Removal (lbs)

Feb-06 Jun-06 Sep-06 Dec-06 Mar-07 Jul-07 Oct-07 Jan-08 May-08 Aug-08

25% System Up Time for Quarter
FIGURE 4-3
Flow Chart
SVE Rebound Testing and Shutdown Protocols

Well turned off to evaluate rebound

Resume soil vapor extraction and continue rebound testing process

Significant rebound measured (PID)?

YES

NO

Collect soil vapor sample for laboratory testing after 1 month rebound period

Concentrations below soil vapor performance standards?

YES

NO

Collect soil vapor sample for laboratory testing after 3 month rebound period

Concentrations below soil vapor performance standards?

YES

NO

Close SVE well & monitor as part of annual soil vapor sampling event

Initiate system shutdown and prepare closure report

Each monitoring point & well below soil vapor performance standards >1 yr?