



DEPARTMENT OF THE AIR FORCE
HEADQUARTERS 377TH AIR BASE WING (AFMC)

 ENTERED

Colonel Tom D. Miller
377 ABW/CC
2000 Wyoming Blvd SE
Kirtland AFB NM 87117-5600

DEC 23 2014

Mr. Butch Tongate
Deputy Secretary
New Mexico Environment Department (NMED)
1190 St. Francis Drive, Suite N-4050
Santa Fe, New Mexico 87502

RECEIVED

MAR 9 2015

NMED
Hazardous Waste Bureau

Dear Mr. Tongate

Attached please find the *Pilot SVE Shutdown Test Work Plan*. This letter WP will address the respiration and short-term testing, along with the long-term rebound testing, on selected soil vapor monitoring (SVM) wells. Data from this shutdown test will be used in the design of SVE expansion at the BFF site.

Please contact Mr. L. Wayne Bitner at (505) 853-3484 or at ludje.bitner@us.af.mil or Mrs. Victoria Branson at (505) 846-6362 or at victoria.branson@us.af.mil if you have questions.

Sincerely

TOM D. MILLER, Colonel USAF
Commander

Attachment: Pilot SVE Shutdown Test Work Plan

cc:

NMED-HWB (Kieling, Cobrain, Moats, McDonald, Brandwein) w/attch
NMED (McQuillan, Longmire) w/attch
NMED-GWQB (Schoeppner) w/attch
NMED-PSTB (Reuter) w/attch
NMED-OGC (Kendall) w/o attch
EPA Region 6 (King) w/o attch
AFCEC-CZRY (Bodour) w/ attch
Public Info Repository, AR/IR, and File w/attch

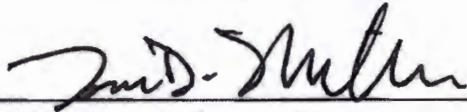
KAFB4228



**40 CFR 270.11
DOCUMENT CERTIFICATION
DECEMBER 2014**

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision according to a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fines and imprisonment for knowing violations.

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TOM D. MILLER, Colonel, USAF
Commander, 377th Air Base Wing

This document has been approved for public release.



KIRTLAND AIR FORCE BASE
377th Air Base Wing Public Affairs

Pilot Soil Vapor Extraction Shutdown Test Work Plan, Bulk Fuels Facility Spill, SWMU ST-106 and SS-111, KAFB, EPS ID# NM9570024423, HWB-KAFB-15 MISC; letter dated February 25, 2015

Comment Response to NMED Conditional Approval Letter

NMED COMMENT	RESPONSE TO COMMENT
<p>1. The first bulleted work plan objective shall be as follows: "Calculated in-situ biodegradation of residual fuel hydrocarbon through respiration testing at selected SVM points. Respiration testing examines oxygen (O₂) utilization to assess aerobic biodegradation occurring throughout the BFF SVE monitoring network. The results will show: areas where residual fuel hydrocarbons are aerobically biodegrading, areas where the volatile fraction of the fuel hydrocarbon has been depleted, or was low to begin with, but biodegradation of the non-volatile jet fuel constituents is continuing, and areas where volatile fuel hydrocarbon fraction is not detectable, where residual fuel contamination may or may not be in proximity, and biodegradation is either not ongoing or is occurring at rates that would not benefit from active aeration."</p>	<p>The bullet has been revised as suggested. First bullet of the work plan objective list now reads: "Calculate in-situ biodegradation of residual fuel hydrocarbon through respiration testing at selected SVM points. Respiration testing examines oxygen (O₂) utilization to assess biodegradation occurring throughout the BFF SVE monitoring network. The results will show: areas where residual fuel hydrocarbons are aerobically biodegrading, areas where the volatile fraction of the fuel hydrocarbon has been depleted, or was low to begin with, but biodegradation of the non-volatile jet fuel constituents is continuing, and areas where volatile fuel hydrocarbon fraction is not detectable, where residual fuel contamination may or may not be in proximity, and biodegradation is either not ongoing or is occurring at rates that would not benefit from active aeration."</p>
<p>2. Vacuum/pressure shall be measured with a vacuum gauge, in accordance with the March 2011 Vadose Zone Investigation Work Plan, Appendix F, rather than with the Horiba instrument.</p>	<p>Comment has been incorporated. Text has been revised to read: "Vacuum/pressure (inches of water column [inches WC]) will be monitored before, during, and after well purging with a vacuum gauge instrument such as a manometer, in accordance with the Vadose Zone Investigation Work Plan (USACE, 2011a)."</p>
<p>3. The Permittee shall, by March 9, 2015, submit a map showing the locations of the 12 soil vapor monitoring wells (with a total of 31 depths to be monitored) that will be used for the long-term rebound testing.</p>	<p>The requested map has been included as Figure 1 in the work plan. Text has been added to reference the Figure: "Hydrocarbon concentrations in the network of 31 SVM points listed in Table 2 will continue to be measured over the 3 months of the shutdown period. The SVM points identified in Table 2 are shown on Figure 1 of this Work Plan."</p>
<p>4. The Permittee shall conduct a detailed (statistical and chemical) comparison of field measurements with laboratory analyses and shall assess the suitability or uncertainty of using field test results for purposes described in the work plan, including any qualifications or limitations of using such data.</p>	<p>The following section has been added to address comparison of field and laboratory analytical data as requested:</p> <p>"2.3 Comparison of Field and Laboratory Analyses</p> <p>Field Horiba measurements and laboratory analytical results will be compared from the Quarter 1 and Quarter 3 CY15 sampling events and results of the comparisons will be included in the Pilot SVE Shutdown Test Report. Field Horiba measurements for TSVH will be compared statistically and chemically to the summed VOC total result from laboratory method TO-15 and APH for Quarter 1 and 3 CY15 data. Horiba measurements for O₂ and CO₂ in soil gas will be statistically compared to laboratory fixed gases analyses for O₂ and CO₂ for Quarter 1 and Quarter 3 CY15 samples. Statistical comparisons will be completed using a statistical analysis program such as JMP™ or similar.</p> <p>Consideration must be given when comparing results from the Horiba instrument to laboratory analytical samples. Key differences in the instruments including detector types, detector ranges, and calibration methods and procedures will by nature produce different results when the same sample is analyzed. However, statistical and chemical comparisons can be used to assess the qualifications and/or limitations of both field and laboratory analyses. Results of the comparison will aid in the assessment of suitability and/or uncertainty of using field analyses and/or a modified laboratory analytical method list for ongoing monitoring of the SVM well network at the BFF site."</p>
<p>5. The Permittee shall submit the final report of the in-situ respiration and rebound testing, complete with all data, interpretations and conclusions, including the field-lab data comparison, within 120 days after resumption of SVE operations.</p>	<p>The following line has been added to Section 3 of the work plan as requested to show submittal of the Report 120 days after SVE operations resume: "Day 155, Resume SVE system operation. Day 275, Submit Pilot Soil Vapor Extraction Shutdown Test Report to NMED"</p>

Additional edits have been made in the Pilot SVE Shutdown Test Work Plan for clarification and to add the complete Quarter 1, 2015 soil vapor sampling event. Horiba readings collected from each SVM point location during the Quarter 1, 2015 sampling event will be used to select the additional 30 SVM points to be included during the SVE Shutdown Test. Baseline Horiba readings will be made on the 61 selected wells prior to the start of the Shutdown Test.



Original December 31, 2014, Revised Version March 6, 2015

Subject: Kirtland Air Force Base Bulk Fuel Facility – Pilot Soil Vapor Extraction Shutdown Test Work Plan

This Kirtland Air Force Base (KAFB) Bulk Fuel Facility (BFF) Soil Vapor Extraction (SVE) Shutdown Testing Letter Work Plan (WP) has been prepared by CB&I Federal Services LLC (CB&I) for the U.S. Army Corps of Engineers (USACE), Albuquerque District, under Contract No. W912DY-10-D-0014. The in-situ respiration and rebound tests will inform the location and design of a more robust remedial strategy for the BFF vadose zone. Details on the additional investigation (Work Plan 2) and system design/installation (Work Plan 3) activities will follow as separate work plans, which will be developed from the results of the SVE shutdown test.

This WP provides details on the approaches and methodologies that will be followed in conducting an in-situ respiration test and short-term and long-term rebound tests, on selected soil-vapor monitoring (SVM) points. In this WP, the reference to “SVM points” is used to refer to discrete SVM well locations and discrete screen depths. The current catalytic oxidizer (CATOX) SVE system will be off for the entire duration of the respiration and rebound tests so that accurate measurements can be made to monitor microbiological activity and hydrocarbon concentration changes under non-flow conditions in the vadose zone.

The objectives of this WP are to collect data to:

- Calculate in-situ biodegradation of residual fuel hydrocarbon through respiration testing at selected SVM points. Respiration testing examines oxygen (O₂) utilization to assess biodegradation occurring throughout the BFF SVE monitoring network. The results will show: areas where residual fuel hydrocarbons are aerobically biodegrading, areas where the volatile fraction of the fuel hydrocarbon has been depleted, or was low to begin with, but biodegradation of the non-volatile jet fuel constituents is continuing, and areas where volatile fuel hydrocarbon fraction is not detectable, where residual fuel contamination may or may not be in proximity, and biodegradation is either not ongoing or is occurring at rates that would not benefit from active aeration.
- Further delineate the distribution of residual hydrocarbons in the vadose zone through rebound testing at selected SVM points. During rebound testing, total soil-vapor hydrocarbon (TSVH) concentrations will be measured over time to monitor the rate, extent, and location of changes in concentration. SVM locations showing rapid and large TSVH concentration increases will indicate the presence of residual contaminant mass to target for treatment.
- Identify potential migration pathways throughout the vadose zone. The rates and extent of rebound will be compared between adjacent monitoring locations throughout the SVM monitoring network in the BFF vadose zone. Patterns of rebound rates will help point toward potential locations of migration pathway.
- Inform the need for and location of additional subsurface investigation. While the BFF SVM network is extensive and data generated to date suggest good coverage of the contamination, the results from the respiration and rebound testing will refine the delineation of vadose zone contamination. However, if rebound trends between adjacent monitoring locations show increasing trends towards a specific monitoring location and that monitoring location is not “bounded” by surrounding monitoring locations that confirm the direction of the trend, an additional SVM points may be needed. Soil-vapor rebound results also will determine the location for continuous soil coring recovery to confirm/correlate the contamination with the TSVH results, and to locate and characterize residual hydrocarbon in the vadose zone. The cores

will be extended approximately 10 to 20 feet below the water table in an attempt to locate, quantify and characterize floating and/or submerged light non-aqueous phase liquid (LNAPL). The details for additional subsurface investigation activities will be provided in a separate work plan to be submitted following the completion of the shutdown test using the test data.

In-situ respiration and rebound test results and additional subsurface investigation data will be used to design an effective and efficient interim measure for the vadose zone that could include any of a number of remediation technologies (i.e., SVE, bioventing, excavation, etc.). While it is desirable to use the existing SVE infrastructure to the extent possible, the objective is to enhance the understanding of the conceptual site model (CSM) and design of an interim measure that removes contaminant mass from the vadose zone effectively. Details on the design and implementation of the optimized interim measure will be provided in follow-on work plan(s) to be submitted after the completion of the additional subsurface investigations.

The following sections of this WP provide details on the SVE shutdown testing methodologies and the data analyses and reporting procedures.

1. SVE SHUTDOWN TESTING SCOPE

The SVE shutdown test provides a unique opportunity to assess the subsurface conditions at the BFF after 12 years of SVE operation. During shutdown, in-situ respiration and short-term rebound monitoring will be performed in tandem on select existing SVM points (see below for SVM point selection logic). In-situ respiration testing will provide data that will be used for calculation of biodegradation rates in the vadose zone. Long-term rebound testing will continue on a subset of the SVM points following the completion of the in-situ respiration and short-term rebound testing. The short-term and long-term rebound test will evaluate soil-vapor concentration recovery after shut down of the CATOX system.

The current CATOX system will be shut down for approximately 3 months to allow sufficient time for the long-term rebound test to be completed and to collect data necessary to optimize the design and operation of the vadose zone remediation system(s).

Prior to SVE shut down, Quarter 1 Calendar Year (CY) 2015 soil vapor samples and baseline sampling will provide information on current vadose zone conditions during SVE operation. O₂ and carbon dioxide (CO₂) data collected after SVE shutdown will allow calculation of the in-situ biodegradation rates throughout the vadose zone. Changes in soil-vapor hydrocarbon concentrations will demonstrate the soil-vapor hydrocarbon rebound potential, and the trends in the concentration increases within individual SVM points and between adjacent SVM points may provide indications of potential fuel migration pathways from the leak points to the water table and the location of residual hydrocarbon mass to target with SVE or other appropriate measures.

In-situ respiration and rebound testing will provide data necessary to make informed decisions for moving the vadose zone remediation effort effectively towards completion. Because excessive soil-vapor purging during sampling can produce erroneous readings, and because over-purging produces no benefit, care must be taken to minimize the volume of soil vapor extracted when conducting respiration testing (EPA, 1995).

Quarter 1 CY15 soil vapor samples will be collected following the revised soil vapor sample procedure in Appendix A prior to the respiration/rebound tests during normal SVE system operation. However, due to the nature of the data driven shutdown testing and need for instantaneous hydrocarbon, O₂, and CO₂ results, KAFB is requesting no quarterly SVM laboratory samples be collected during Quarter 2 CY15 due to the length of the long-term rebound test. At the completion of the long-term rebound test, a complete round of quarterly SVM samples will be collected for the Quarter 3 CY15 event, prior to

resuming SVE operations. Although samples will be collected from the same SVM points included in the quarterly SVM protocol, consideration must be given to the use of the data when comparing the results to previous quarterly SVM events when the SVE system was operational and when historical SV sample protocols were being followed. The Quarter 1 CY15 SV samples will be analyzed in the field for TSVH (ppmv) using the Horiba Model MEXA 584L portable auto emissions analyzer (herein referred to as the Horiba) and samples will be submitted to a laboratory for Method TO-15, Method CARB422 for EDB, Method APH (air-phase petroleum hydrocarbons), and fixed gases analyses. The Horiba readings collected during Quarter 1 SV sampling will be used to select the additional SV points to be included during respiration and short-term rebound testing.

The data collected during the proposed shutdown testing will facilitate an in-depth analysis of the remaining contamination in the vadose zone and the biodegradation rates associated with that contamination. The extended data set from the SVE shutdown test will advance our understanding of the conditions in the BFF vadose zone and will add value to the soil-vapor data that are normally collected during the quarterly sampling events. Having enhanced understanding of subsurface conditions will facilitate effective SVE expansion design and optimal SVE system operation. As such, it would be extremely beneficial to avoid interferences with the tests to ensure that the collected data are of the highest quality possible.

Prior to the Quarter 1 CY15 soil vapor sampling event, baseline sampling, respiration/rebound testing, all SVM and SVE points will be securely capped to prevent soil-vapor points from exhaling soil-vapor gas or inhaling atmospheric air due to barometric pressure increases or decreases. Soil-vapor points in the BFF have been observed to respond to changes in barometric pressure, so preventing these wells from inhaling or exhaling will ensure better accuracy during testing as atmospheric conditions will not be able to influence the deep vadose zone through soil-vapor points. Well caps will be inspected for integrity according to the guidelines in Appendix A before readings or samples are collected from a soil-vapor point.

Barometric pressure gauges and water level transducers will be installed in SVE wells KAFB-106161, KAFB-106160, and one additional well inside the BFF area for the duration of the shutdown test. Barometric pressure gauges will be installed inside the well vault but outside the well cap so that accurate readings of barometric pressure changes can be made. Water level transducers and barometric pressure gauges will be set to record data every hour.

1.1 Baseline Sampling

Once the additional 30 SVM points have been selected based on Horiba readings collected during the Quarter 1 CY15 sample event, baseline measurements will be made on the total 61 selected SVM points while the CATOX system is still operating. Soil-vapor baseline measurements will be collected as described in Appendix A. The sampling system and the soil-vapor sampling method described in Appendix A have been modified from the methodologies outlined in Section 5.3 of the Vadose Zone Investigation Work Plan (USACE, 2011a) and Section 3.0 of the Quality Assurance Project Plan (QAPjP) (USACE, 2011b) to allow for minimal soil-vapor volumes to be withdrawn during the in-situ respiration testing. This will provide more representative data in close proximity to the sampled SVM point. The following parameters will be measured using the Horiba:

- Total hydrocarbons in parts per million by volume (ppmv)
- Percent O₂
- Percent CO₂

Vacuum/pressure (inches of water column [inches WC]) will be monitored before, during, and after well purging with a vacuum gauge instrument such as a manometer, in accordance with the Vadose Zone Investigation Work Plan (USACE, 2011a).

After baseline measurements are collected, the CATOX system will be shut down using normal shutdown procedures outlined in Section 6.0 of the SVE System Operations and Maintenance Plan (August 2013). The SVE wells currently connected to the CATOX system (KAFB-106149, KAFB-106150, KAFB-106154, KAFB-106160, and KAFB-106161) will be closed at the well heads prior to shut down of the extraction system to prevent atmospheric air from entering the points and interfering with the initial measurements during the in-situ respiration and short-term rebound testing.

1.2 In-Situ Respiration and Short-Term Rebound Testing

The in-situ respiration and short-term rebound tests will be performed concurrently during the first two weeks of the shutdown period.

The objective of the in-situ respiration and short-term rebound testing is to provide an accurate representation of the biological activity and the residual contamination distribution in the BFF vadose zone. A total of 61 SVM points will be included in the in-situ respiration and short-term rebound testing. Thirty (30) of the SVM points that will be included in the in-situ respiration testing and will be selected based on the results from the Quarter 1 CY15 sampling event using the Horiba readings collected during sampling following the logic described in Table 1. Candidate respiration testing SVM points will be selected to cover a range of subsurface conditions as described in Table 1, and to provide effective coverage of the BFF vadose zone in areas where monitoring is warranted but not covered by the 31 SVM points selected for short and long-term rebound testing, discussed below. Once the Quarter 1 CY15 data are available, a table of the 30 respiration testing points will be provided to the New Mexico Environment Department (NMED) ahead of the shutdown testing for review and approval.

Thirty-one (31) SVM points have already been selected for the rebound testing (Table 2). All 31 of the SVM points selected for the long-term rebound testing will be included in the in-situ respiration and short-term rebound testing (see Section 1.3). The 31 SVM points were selected based on soil-vapor data collected during Fourth Quarter CY 2012 and Second Quarter CY 2014. These two quarters represent the highest historical soil-vapor data and the most recent soil-vapor data, respectively. The SVE system area of influence is defined as the area within the 0.5-inch WC vacuum isopleth, as reported in Appendix L of the Pre-Remedy Quarterly Monitoring Reports.

Following SVE shut down, soil vapor will be sampled from the selected 61 SVM points using the Horiba and the sampling method described in detail in Appendix A. The initial sampling will be initiated within 2 hours after SVE shut down. Subsequent sampling frequencies for each SVM point will be determined based on the observed O₂-utilization rates. SVM points demonstrating a higher O₂-utilization rate will be sampled on a more frequent basis. During the initial 24 hours of post-shutdown monitoring, a crew of six individuals will monitor the SVM points during the day and night. Respiration monitoring will continue until O₂ concentrations decrease to less than 5 percent or 2 weeks is reached, whichever comes first.

Measured O₂ concentrations will be used to create an O₂-utilization curve. A biodegradation rate can then be calculated (see Section 2.1) for the discrete locations represented by the SVM points throughout the vadose zone. The time series of TSVH data from the short-term rebound will be used along with the time series of TSVH data from the long-term rebound test (see Section 2.2) to observe trends in hydrocarbon concentration responses throughout the vadose zone as the subsurface adjusts toward undisturbed conditions (i.e., under SVE-induced vapor flow).

Table 1. Potential Observations Among Hydrocarbon, O₂ and CO₂ Data and the Logic for Soil-vapor Point Selection for Inclusion in the In-situ Respiration and Short Term Rebound Testing	
Data Observations	Implications
High Hydrocarbon (>1,000 ppmv), Depressed O ₂ (<19.5 %), Elevated CO ₂ (>1%)	SVM points with these characteristics may coincide with high-concentration residual fuel, or may be under the influence of nearby residual fuel with a large volatile fraction remaining. The depressed O ₂ combined with elevated CO ₂ is a strong indicator that aerobic biodegradation is occurring during SVE operation. These SVM points would be prime candidates for in-situ respiration, and short-term and long-term rebound testing.
Moderate Hydrocarbon (250 – 1,000 ppmv), Depressed O ₂ (<19.5%), Elevated CO ₂ (>1%)	SVM points with these characteristics may be in proximity to residual fuel contamination with a large or moderately reduced volatile fraction remaining, and aerobic biodegradation is occurring under SVE operation. These SVM points would be prime candidates for in-situ respiration, and short-term and long-term rebound testing.
Low Hydrocarbon (250 – 50 ppmv), Depressed O ₂ (<19.5%), Elevated CO ₂ (>0.5%)	SVM points with these characteristics may be in proximity to residual fuel contamination with a large percentage of the volatile fraction depleted and aerobic biodegradation is occurring during SVE operation. A minimum of five SVM points showing this data signature should be included in the in-situ respiration and long-term rebound testing. If many soil-vapor points are observed in this category, points will be selected to ensure lateral and vertical coverage of the area within the influence of the SVE system. Note that short-term rebound data will be collected during the rebound test, but observation of rapid hydrocarbon rebound is not anticipated.
Very-low Hydrocarbon (<50), Ambient O ₂ (>20%), Ambient CO ₂ (<0.1%)	SVM points with these characteristics may or may not be in proximity of residual fuel contamination. A review of historic vapor data is warranted to determine how these points might be used. If available, a minimum of three SVM points with low hydrocarbon and ambient O ₂ and CO ₂ and previously recorded hydrocarbon concentrations greater than 1,000 ppmv should be included in the in-situ respiration and short-term rebound testing. The results from testing these SVM points will indicate residual fuel contamination that has been depleted of the volatile fraction and that would not show up on the short-term or long-term rebound test, and also will quantify the biodegradation rate of the remaining non-volatile contaminant fraction. One SVM point that matches the data observations without historic hydrocarbon detection should be included in the in-situ respiration testing and will serve to determine the background respiration rate against which the respiration rates at the other 30 SVM points will be compared.

Table 2. SVM Points for Long-Term Rebound Testing		
Well Number	Zone	Monitoring Depths
SVMW-03	Near edge of area influenced by SVE	100
		250
		350
SVMW-06	Inside area influenced by SVE	100
		252
		302
SVMW-10	Outside area influenced by SVE	100
		150
		250
KAFB-106112	Inside area influenced by SVE	250
		350
		450
KAFB-106113	Probably outside area influenced by SVE	350
		450
KAFB-106114	Near edge of area influenced by SVE	350
		450
KAFB-106116	Inside area influenced by SVE	350
		450
KAFB-106117	Inside area influenced by SVE	350
		450
KAFB-106119	Inside area influenced by SVE	150
		250
		350
		450
KAFB-106128	Inside area influenced by SVE	350
		450
KAFB-106129	Possibly influenced by SVE	250
		350
		450
KAFB-106131	Possibly influenced by SVE	350
		450

1.3 Long-Term Rebound Testing

The objective of the long-term rebound testing is to extend the period of rebound monitoring to allow sufficient time for contaminant concentrations in the soil vapor to respond to contaminant that might be held in lower-permeability lithology, which will provide a more accurate representation of the residual contamination distribution in the BFF vadose zone. Hydrocarbon concentrations in the network of 31 SVM points listed in Table 2 will continue to be measured over the 3 months of the shutdown period. The SVM points identified in Table 2 are shown on Figure 1 of this Work Plan.

Following the short-term rebound test, long-term rebound SVM points will be monitored daily for 1 week, weekly for 5 weeks, and then biweekly until TSVH concentrations become asymptotic or for three biweekly sampling events, whichever comes first. These samples will be analyzed using the Horiba following the sampling method described in Appendix A.

1.4 Complete SVM Network Quarterly Sampling After Shutdown Testing

At the conclusion of the shutdown test and before SVE operation resumes, a full round of SVM sampling will be conducted from the network used in the quarterly monitoring sampling program following the sampling methodology described in Appendix A pending discussions with and approval from the NMED.

Samples will be analyzed in the field for TSVH (ppmv) using the Horiba and samples will be submitted to a laboratory for Method TO-15, Method CARB422 for EDB, Method APH (air-phase petroleum hydrocarbons), and fixed gases analyses.

The field and laboratory analyses deployed for BFF vadose zone monitoring are complimentary and not redundant. The analytical instruments used under the different methods employ different detectors and require different dilution factors to keep values in the calibrated range of the respective instrument. As such, the analyses do not provide the same output but rather provide a more in-depth representation of the subsurface conditions. The results from the analyses are used for different purposes and are thus not expected nor needed to replicate values with precision. The field hydrocarbon analyses are an aggregate measurement of the volatile hydrocarbon composition and are used throughout the test to track trends. The laboratory analytical methods provide compound-specific and boiling point split (i.e., hydrocarbon fraction) results, which are useful for effectively assessing remediation effectiveness against the subsurface hydrocarbons.

2. DATA ANALYSIS AND REPORTING

2.1 In-situ Respiration Test

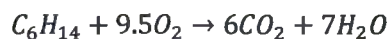
Biodegradation rates in the vadose zone are based on O₂-utilization rates, hydrocarbon oxidation stoichiometry, and relevant soil properties. Following the Bioventing Principles and Practice, Volume II (EPA, 1995), the O₂-utilization rate calculated from the field monitoring data is expressed as a percentage of O₂ as a function of time. O₂-utilization rates will only be calculated for the linear portion of the curve, as it is an indicator that O₂ is not limiting, and is therefore indicative of active biodegradation. The CO₂ data verify that the observed decreases in O₂ are the result of microbiological degradation, and not other oxygen consuming reactions. Increases in CO₂ concentrations that are concurrent with decreasing O₂ concentrations are indicative of biodegradation. (Note that CO₂ data are only used to verify biodegradation and are not used in biodegradation rate calculations because of potential errors associated with geochemical reactions involving CO₂ that can bias the results.)

In the field, soil-vapor O₂ and CO₂ concentrations will be measured using the Horiba. With frequent calibration and calibration checks, the Horiba will provide good-quality data to derive accurate O₂-utilization rates. Comparing the utilization rates between SVM points under the characteristics described in Table 1 will confirm that the measured O₂-utilization is above ambient and due to microbiological degradation of residual fuel hydrocarbons. Laboratory analyses are not required during in-situ respiration testing.

O₂ and CO₂ concentrations will be measured on a percent basis and are expected to change over the duration of the in-situ respiration test as aerobic microorganisms consume O₂ during hydrocarbon degradation and produce CO₂. The O₂ measurements are used to calculate the O₂-utilization rate, which is calculated as the slope of the decrease in O₂ concentrations over time as O₂ concentrations decrease from baseline concentration to 5% O₂. This value is used to calculate the biodegradation rate as shown in Equation 2.

Since the contamination at the BFF project site is fuel hydrocarbon based, hexane is used as the representative hydrocarbon for rate calculations. The stoichiometric relationship used for determination of degradation rates is therefore (EPA, 1995):

Equation 1:



Based on the utilization rates, the biodegradation rate is estimated using the following equation (EPA, 1995):

Equation 2:

$$-k_b = \frac{-\frac{k_o}{100} \theta_a \frac{1L}{1,000cm^3} \rho_{O_2} C}{\rho_k \left\{ \frac{1kg}{1,000g} \right\}} = \frac{-k_o \theta_a \rho_{O_2} C (0.01)}{\rho_k}$$

Where:

k_b = biodegradation rate (milligrams/kilogram-day)

k_o = O_2 -utilization rate (percent/day)

θ_a = gas-filled pore space (volumetric content at the vapor phase, cubic meters gas/cubic centimeter soil)

ρ_{O_2} = density of O_2 (milligrams/liter)

C = mass ratio of hydrocarbons to O_2 required for mineralization (1:3.5)

ρ_k = soil bulk density (grams/cubic centimeter)

The value for k_o will be directly measured during the respiration monitoring as described in Section 1.2. The remaining input values will be based on data obtained from the site, if available, or from industry standards and approved literature. The value for θ_a has the most variability; however, since the respiration testing will be conducted at a low gas-filled porosity, the value can be estimated in accordance with the steps outlined in the EPA manual for Bioventing Principles and Practice, Volume II (EPA, 1995)

2.2 Rebound Test

In the field, TSVH measurements will be made using the Horiba to analyze soil-vapor samples from 61 SVM points during the short-term rebound test and on 31 SVM points during the long-term portion of the rebound test (see Tables 1 and 2 for the SVM point selection logic for the in-situ respiration and short-term rebound testing and the list of 31 pre-selected long-term rebound SVM points, respectively). Using frequent calibration and calibration checks, the Horiba instrument will provide quality data that are sufficient in number to monitor increasing or decreasing TSVH concentrations at each of the 61 SVM points. The data will be used to assess TSVH concentration trends at each SVM point, and to compare the relative concentrations and the trends between the SVM points. The assessment should provide information on the locations and extent of residual contaminant in the vadose zone. The data also will be evaluated to update the CSM for residual hydrocarbon distribution and identify potential migration pathways through the vadose zone, which will inform decisions for additional investigation (Phase 2) and remedial activities (Phase 3) that will be described in future work plans.

The TO-15 and CARB422 analytical data will provide compound-specific delineation within the soil vapor across the monitored network, and will allow for comparison with pre-shutdown compound-specific distributions based on Quarter 1 TO-15 and CARB422 analyses. Data from the APH analyses will be used to evaluate the rebound of gasoline range organics (GRO) and diesel range organics (DRO) along with TO-15 for petroleum-specific hydrocarbons included in the standard method analyte list. The TSVH rebound trends, and locations in combination with the final compound-specific rebound analyses, will inform the decisions on SVE system expansion and operation and/or other vadose zone remediation techniques, as well as the locations for future coring to assess potential LNAPL in the vadose zone and at the water table interface.

2.3 Comparison of Field and Laboratory Analyses

Field Horiba measurements and laboratory analytical results will be compared from the Quarter 1 and Quarter 3 CY15 sampling events and results of the comparisons will be included in the Pilot SVE Shutdown Test Report. Field Horiba measurements for TSVH will be compared statistically and chemically to the summed VOC total result from laboratory method TO-15 and APH for Quarter 1 and 3 CY15 data. Horiba measurements for O₂ and CO₂ in soil gas will be statistically compared to laboratory fixed gases analyses for O₂ and CO₂ for Quarter 1 and Quarter 3 CY15 samples. Statistical comparisons will be completed using a statistical analysis program such as JMP™ or similar.

Consideration must be given when comparing results from the Horiba instrument to laboratory analytical samples. Key differences in the instruments including detector types, detector ranges, and calibration methods and procedures will by nature produce different results when the same sample is analyzed. However, statistical and chemical comparisons can be used to assess the qualifications and/or limitations of both field and laboratory analyses. Results of the comparison will aid in the assessment of suitability and/or uncertainty of using field analyses and/or a modified laboratory analytical method list for ongoing monitoring of the SVM well network at the BFF site.

3. SCHEDULE

Approximate durations for specific tasks associated with shutdown testing are provided below:

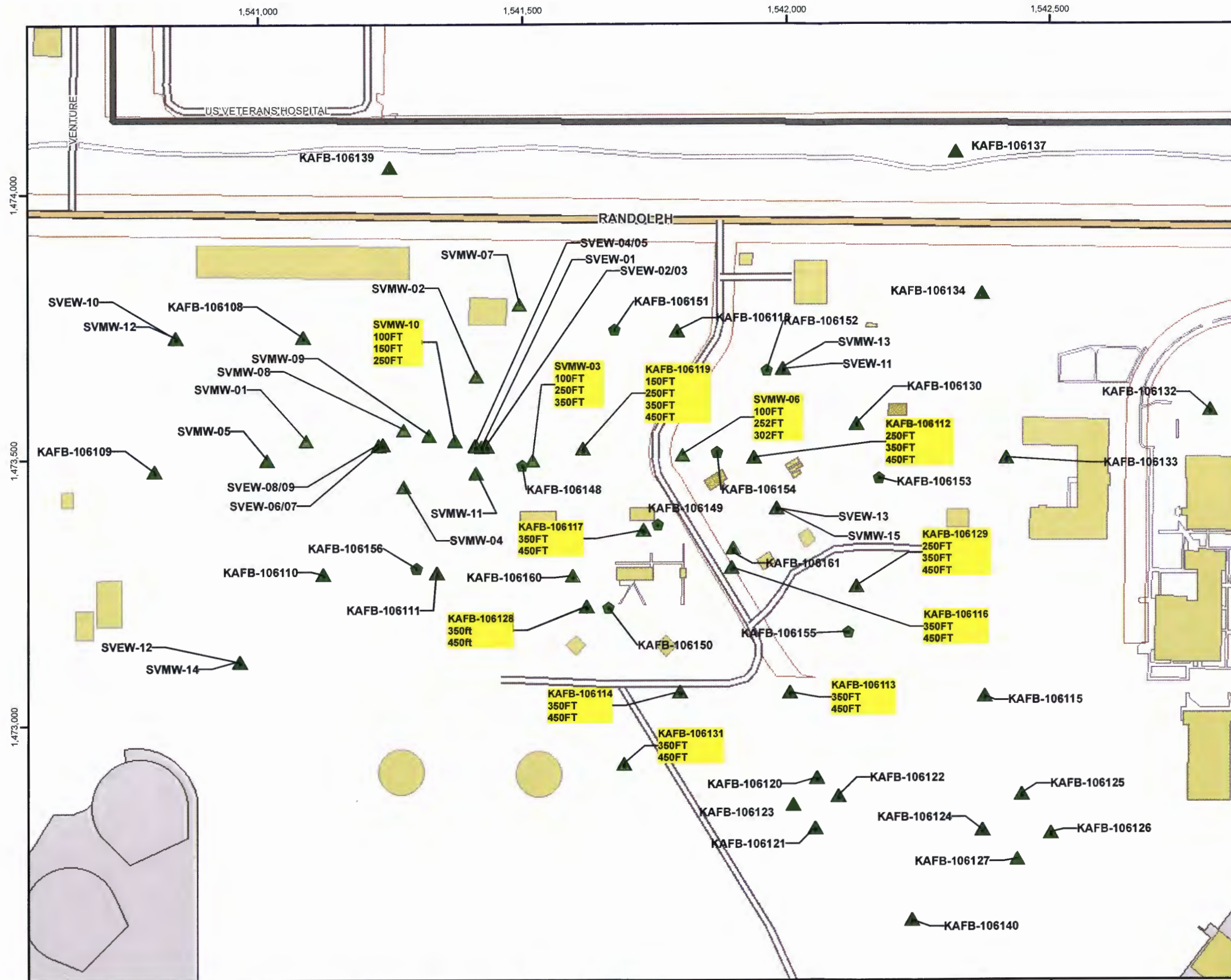
Quarterly sampling (approximately 33 days)	Quarter 1 CY15 complete SVM network quarterly sampling event. Select additional 30 SV points from Quarterly Horiba measurements.
Pre-shutdown (2-3 days)	Conduct baseline measurements using the Horiba Model MEXA 584L on the 61 selected SV points for respiration and short-term rebound testing
Day 0	Shut down the SVE system
Day 0-14	Perform respiration monitoring (at frequencies based on real time data as described above) using the Horiba Model MEXA 584L.
Day 0-14	Short-term rebound monitoring (at frequencies based on real time data as described above) using the Horiba Model MEXA 584L.
Day 15-21	Daily rebound monitoring using the Horiba Model MEXA 584L.
Day 22-56	Weekly rebound monitoring using the Horiba Model MEXA 584L.
Day 57-98	Biweekly rebound monitoring using the Horiba Model MEXA 584L.
Day 99-154	Complete SVM network quarterly sampling event.
Day 155	Resume SVE system operation.
Day 275	Submit Pilot Soil Vapor Extraction Shutdown Test Report to NMED

4. REFERENCES

EPA. 1995. *Manual, Bioventing Principles and Practice, Volume II: Bioventing Design*. September.

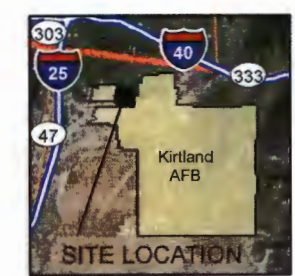
USACE. 2011a. *Vadose Zone Investigation Work Plan, Bulk Fuels Facility (BFF) Spill, Solid Waste Management Units ST-106 and SS-111, Kirtland Air Force Base, Albuquerque, New Mexico*. Prepared by Shaw Environmental & Infrastructure, Inc., for the USACE Albuquerque District under USACE Contract No. W912DY-10-D-0014, Delivery Order 0002. March.

USACE. 2011b. *Quality Assurance Project Plan, Bulk Fuels Facility (BFF) Spill, Solid Waste Management Units ST-106 and SS-111, Kirtland Air Force Base, Albuquerque, New Mexico*. Prepared by Shaw Environmental & Infrastructure, Inc., for the USACE Albuquerque District under USACE Contract No. W912DY-10-D-0014, Delivery Order 0002. April.



Legend

- ◆ Pneulog Cluster
 - ▲ SVE Extraction Well
 - ▲ SVM Cluster
 - Structure
 - ▬ Paved Road
 - ▬ Unpaved Road
 - ▭ Installation Boundary
- SVMW-03 Selected Well Location IDs and Proposed Monitoring Depths**
- 100 FT
 - 250 FT
 - 350 FT



Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Revision Date: 02/27/15

Projection : NAD83 State Plane New Mexico Central FIPS3002 Feet

SVE PILOT SHUTDOWN TEST WORK PLAN
 BULK FUELS FACILITY
 KIRTLAND AIR FORCE BASE, NEW MEXICO

FIGURE 1

SVM WELL LOCATIONS SELECTED FOR RESPIRATION, SHORT-TERM AND LONG-TERM REBOUND TESTING

APPENDIX A

SOIL-VAPOR SAMPLING AND FIELD ANALYTICAL METHODS

Soil Vapor Sampling and Field Analysis Procedure, revised February 2015

1.1 Introduction

All field personnel collecting soil-vapor samples are required to be trained and fully understand the sampling procedure outlined in this document. Any and all questions will be addressed prior to the start of sampling. Prior to the start of the soil-vapor sampling in 2015, all SVM points and SVE wells will be capped and sealed to minimize barometric-pumping interferences on sampling and analyses. Sealing the points/wells will be done by securing an air-tight cap onto each point/well head and adding a pneumatic quick connect fitting to each point/well that will serve as a sampling port for ease of access and to ensure that an air-tight seal is maintained. Each well port will be examined by the field personnel to confirm the integrity of each fitting and to immediately address and mitigate any problems or replace any defective parts.

1.2 Pre-Sampling Steps

1.2.1 Horiba Model MEXA 584L Calibration

It should be noted that the Horiba instrument can effectively measure petroleum hydrocarbons, O₂ and CO₂, which are the three parameters of concern for monitoring the effectiveness of vadose zone remediation technologies such as SVE and bioventing. However, the Horiba is sold as an engine exhaust monitoring instrument and the use for soil-vapor monitoring is different than the manufacturer's intended purpose. While not the primary selling point of the instrument, the Horiba's sampling ability and the non-dispersive infrared detector (NDIR) and chemical cell detector make it a good instrument for total soil-vapor hydrocarbons (reported as hydrocarbons (HC) by the Horiba), CO₂ and O₂ analyses.

Various engine exhaust and leak detection instruments are routinely used in the field for soil-vapor monitoring, but their use is often tailored to provide more representative data. CB&I evaluated the Horiba manufacturer's calibration procedure, which was developed for engine exhaust monitoring, and determined that a modified calibration method was in order to better ready the instrument for measuring soil-vapor petroleum hydrocarbon, O₂ and CO₂ concentrations. The manufacturer's calibration procedure can be found in the instruction manual for the instrument. The modified calibration method will outperform the manufacturer's process for soil-vapor monitoring, and includes a more representative calibration/calibration-check gas, more frequent calibration than specified by the manufacturer, frequent calibration checks (HC, O₂ and CO₂) during daily Horiba usage, and real-time data analysis to look for indicators of potential calibration deviations. At the start, middle and end of each work day including night shifts, the Horiba will be calibrated for petroleum hydrocarbons, O₂ and CO₂ against a calibration standard of known concentrations in a premixed gas cylinder. The same calibration gas cylinder will be used to calibrate every Horiba instrument and the same person will complete calibration each day to ensure consistent calibrations. The calibration gas consists of 1,600 ppmv propane, 13.0% CO₂, and the remaining volume will consist of nitrogen. This calibration gas mixture was selected to accurately calibrate the horiba for the gases that are present in the vadose zone during SV sampling and respiration/rebound testing, specifically, CO₂ and HC (calibrated as propane).

The instrument will be calibrated by applying the premixed gas into the calibration port located on top of the instrument. The calibration steps listed in the Horiba manual for applying the calibration gas and the sequence of key strokes listed will be followed to complete calibration. After calibration, HC and CO₂ concentrations should be within 5% of the known calibration gas values.

As stated before, the initial calibration will be done by following the procedure laid out in the Horiba Instruction Manual. This manual goes through the calibration of each compound. During the calibration of HC, the Horiba will display three numbers as shown in the Horiba Instruction Manual. The top number is the known value of the calibration gas (propane at 1,600 ppmv). The middle number will be constant

for a particular instrument but will vary from instrument to instrument; this number is the factory calibration setting for that instrument that corresponds to the input value of the calibration gas. The bottom number will change as the calibration gas is applied and read by the instrument. Both the middle and bottom numbers are reporting the gas as hexane rather than propane; hexane is the standard for HC for the Horiba instrument. The conversion between hexane and propane for the Horiba is approximately one half. Thus, a reading of 800 ppmv reported as Hexane by the detector is the equivalent of 1,600 ppmv as Propane. Once the gas is applied, the bottom HC number on the display should read within 5% of the middle number. A value of approximately 800 ppmv HC is expected after the Horiba instrument is calibrated.

After calibration is confirmed, the same calibration gas will be used to fill a 3L Tedlar[®] gas sampling bag. The customized sampling system shown in Figure 1 will be used to complete the calibration as follows.

Step 1 – Disconnect all quick connect pneumatic fittings from sampling system with the exception of the stainless steel hose. This ensures the system is sealed from all points except through the hose.

Step 2 – Visually check that the red drain separator O-ring (approximately 2-inches in diameter) is visible at the opening of the sample inlet port, which is located on the front of the Horiba and to the right of the screen display. Insert the male pneumatic fitting on the end of the Horiba sampling tube to the female quick connect on the sampling system and ensure a secure fit.

Step 3 - Ensure that the sampling system is purged according to the steps listed below under Section 1.2.2 Cross Contamination Purging for Sampling System.

Step 4 - Once within the given values, attach the Tedlar[®] bag to the male pneumatic fitting at the end of the braided stainless steel tubing.

Step 5 - Open the Tedlar[®] bag valve to allow the calibration gas to be pulled through the sampling system.

Step 6 – Record the instrument readouts when the instrument has stabilized and compare the results to the calibration gas concentrations.

If the values for HC, O₂ and CO₂ are within 5% of the calibration values made using the calibration port, the calibration process is complete. As stated previously, the Horiba readouts for HC are reported as Hexane. A value of approximately 800 ppmv HC is expected. All other gas composition values should match the calibration gas values. If values are outside of this range, perform a leak check as described in Section 1.2.4 and follow the calibration process again.

If at any point during sampling, a reading for HC, O₂ or CO₂ reaches an unreasonable value (e.g., an O₂ concentration greater than 22%) or if a data value falls outside the trend indicated by previous readings at a given SVM point, a calibration check will be triggered. The expected range of values for HC is from 0 to 10,000 ppmv, 0% to 22% for percent O₂ and 0% to 10% for percent CO₂. If any readings are outside of this range, a calibration check must be made and if necessary the instrument will need to be recalibrated.

During respiration testing, O₂ readings could fall to near zero; however, tracking to 5% is all that is needed for calculating biodegradation rates and 5% is within the Horiba's detectable range.

1.2.2 Cross Contamination Purging for Sampling System

The sampling system must be purged with ambient air before being attached to a SVM point sample port to minimize the potential for cross contamination between sample collections. To ensure the entire sample train is thoroughly purged, attach the pump to the setup and flush air through each quick connect port and the stainless steel tubing. All quick connect pneumatic fittings are to be opened during this process by placing a male end into the female fitting to allow for flow. Monitor the purging effectiveness using the Horiba to ensure no contaminants are still present and ambient air is being read by the Horiba. Values for ambient air are less than 5 ppmv hydrocarbons, between 20% to 22% for percent O₂, and 0% for percent CO₂. Purging must be done after sampling each SVM point.

1.2.3 Leak Check of Sample System

At the beginning of each day, the sampling system will be leak checked by using the pump to apply vacuum to the sampling system as follows.

- Step 1. Cap the male pneumatic fitting on the end of the braided stainless steel tubing with a spare female quick disconnect fitted to a vacuum/pressure gauge (see Figure 2).
- Step 2. Connect the SVM point purging/sampling pump to one of the quick disconnect fittings on the sample system and evacuate the air from the sample system to establish a vacuum.
- Step 3. Disconnect the pump and immediately record the vacuum reading from the pressure/vacuum gauge.
- Step 4. After 10 minutes have elapsed, check and record the vacuum reading on the gauge.
- Step 5. Verify that the starting and ending vacuum matches to ensure that the sampling system is not leaking.
- Step 6. If the two vacuum readings do not match, check the conditions of the seals and repeat the leak test until the sampling system is confirmed to be air tight.

1.3 Sampling Procedures

1.3.1 Sample Train Setup

The Horiba must be turned on, warmed up, and calibrated according to the section above and then attached to the sampling system. The Horiba is turned on for the first time at the beginning of the day and then remains in the on position throughout the day. The Horiba is plugged into the 12V DC outlet in the truck using an AC inverter. All other equipment will be powered by generator and can be powered off in-between wells. The pump is attached and sealed to the setup by a quick connect fitting. It is important that no pneumatic fittings besides the tubing to the well port be attached prior to turning on the pump.

1.3.2 Static Pressure Measurement

Before taking the static pressure reading, the manometer instrument must be zeroed to atmospheric pressure. The screen should read "0.00 in WC". After confirming that the manometer is zeroed, the following procedure is used to connect the sampling system to the SVM points, measure the static (also called baseline) pressure, and to ready for purging and sampling.

- Step 1. Connect the manometer to the quick connect on the side of the sampling system opposite of the Bottle-Vac™ sample collection port (see Figure 1).
- Step 2. Verify that the manometer reads 0.00 inches of WC.
- Step 3. Insert the male quick connect fitting on the end of the braided stainless steel tubing to the female quick disconnect fitting on the top of the SVM point and ensure a secure connection.
- Step 4. Monitor the change in manometer readings over time and record the pressure/vacuum reading when the meter stabilizes.

Note: Static pressure readings have typically ranged from +2.00 in (pressure) to -12.00 in WC (vacuum) at each well port. In deeper well ports, the vacuums were generally greater during SVE operation. During SVE shutdown, pressures in the vadose zone should change and may fall outside the typical range. In additions, plugging of the SVM points and groundwater monitoring wells may have an impact on the barometric impacts on vadose zone pressures, causing additional deviation from the previously-measured pressures. It will be important to use the baseline static pressure from the baseline sampling and compared it to the static pressure measured following SVE shutdown to show that the SVM point was within the influence of the SVE extraction well network. The data from subsequent static pressure measurement made on each SVM point during in situ respiration and rebound testing will provide verification of sample system connection integrity. Deviations between measurements require attention to ensure proper connections before purging and sample collection.

1.3.3 Well Purging

Stagnant vapor is purged from the SVM point as follows.

Step 1. Turn on the SVM point sampling pump, verify the operation of the flow rotameter, and check for potential leaks as necessary.

Step 2. Consult the Purge Table (see Attachment 1) for the initial purge volume.

Step 3. Connect the female quick disconnect on the terminal end of the sampling system to the male quick connect on the vacuum side of the SVM sampling pump and start timing the purge cycle. Note the flow rate on the rotameter and use the pre-calculated purge volume to quickly calculate the purge length time. *

Step 4. After purging to the appropriate time, quickly disconnect the sampling system from the vacuum pump and immediately record the manometer reading. **(Note: the sampling system is to remain connected to the SVM point for the duration of sampling.)**

Step 5. Allow the manometer reading to return to within 0.05 in WC of the static pressure reading before moving to the next step in the sampling procedure.

*The purge time is determined by the well port diameter, well depth, and flow rate of the pump; all of which are known before sampling with the exception of the flowrate. The amount of vapor needed to be removed is based on one well casing volume.

1.3.4 Horiba Readings

Once the SVM point has been purged, the following procedure is used to take and record HC, O₂ and CO₂ measurements using the calibrated Horiba.

Step 1. Ensure that the Horiba is turned on and functioning properly.

Step 2. Record the manometer reading.

Step 3. Insert the male quick connect fitting into the female quick connect fitting on the terminal side of the sampling system and ensure a tight connection. Check the manometer reading. A slight and consistent increase in vacuum between sampling events on each SVM point is indicative of a good seal.

Step 4. Observe the Horiba O₂ reading for stability or for a maximum of one minute, whichever comes first.

Step 5. Record the O₂, CO₂ and HC readings and quickly disconnect the Horiba.

1.3.5 Bottle-Vac™ Sampling

The following procedure will be used when collecting Bottle-Vac™ samples for laboratory analyses.

Step 1. Check the vacuum in a Bottle-Vac™ prior to sampling by taking a vacuum reading using a lab supplied vacuum gauge. The gauge is connected to the bottle through a quick connect set in the same way that the bottle is connected to the sampling system. (Note: Bottles are required to have between 24 and 26 inches of Mercury (in Hg) of vacuum. If a lower vacuum is measured, do not use the Bottle-Vac™ for sample collection.)

Step 2. With the braided stainless steel tubing still connected to the well port, record the static pressure indicated on the manometer readout.

Step 2. Connect the Bottle-Vac™ to the specialized female pneumatic connection on the sample system (see Figure 1) and note any change in the manometer reading. Connecting the bottle should show a slight change based on the bottle vacuum and volume.

Step 3. Disconnect the Bottle-Vac™ after two minutes or once the manometer reading returns to static pressure, whichever comes first.

Step 4. Check the vacuum in the Bottle-Vac™ after removing from the sampling system. (Note: The vacuum should read 0.0 in Hg of vacuum. If there is still a positive vacuum reading, re-attach the

Bottle-Vac™ to the sampling system for two additional minutes before checking the pressure once more; repeat as necessary.)

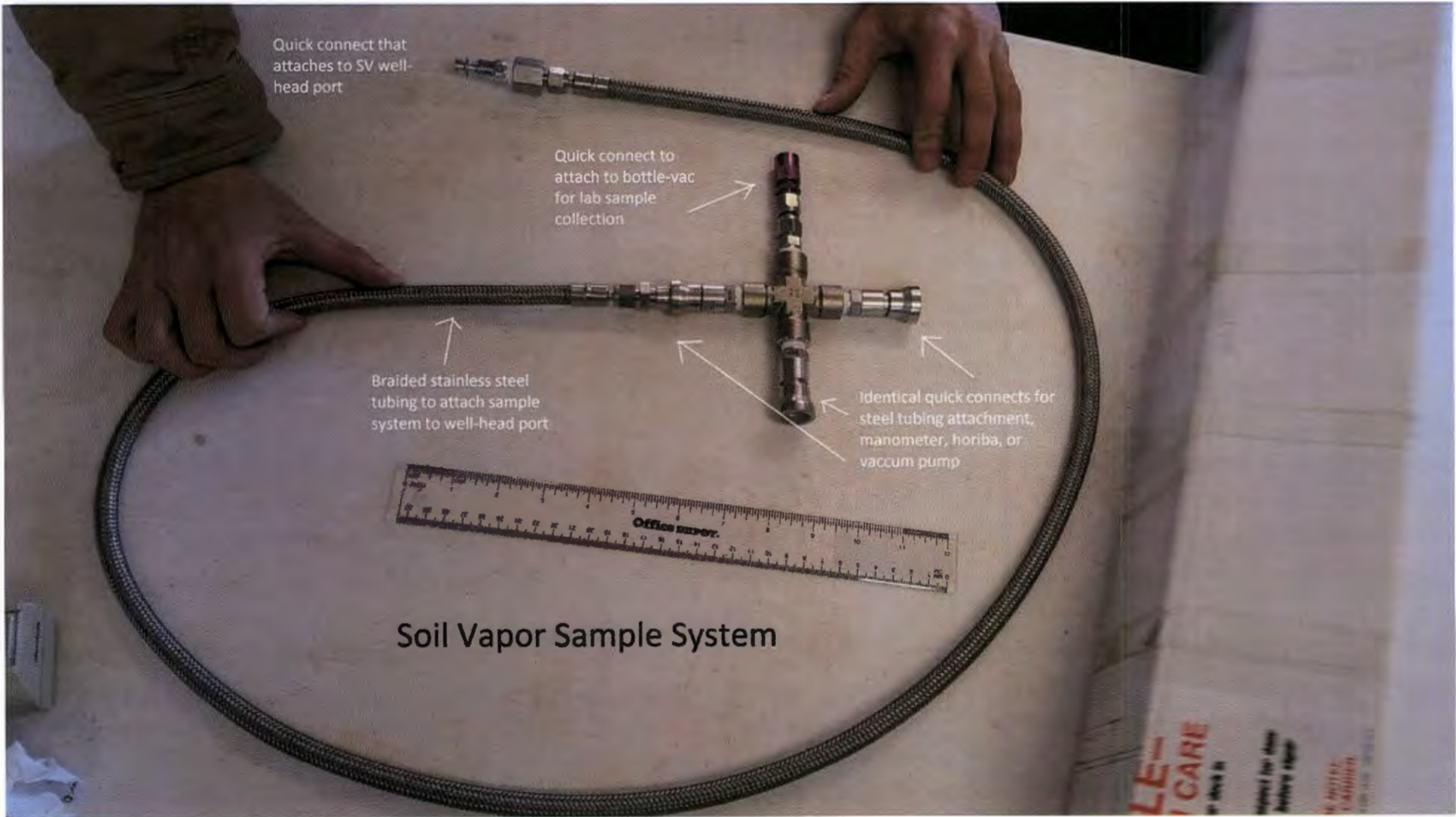


Figure 1: Soil-Vapor Sample System

Vaccum Gauge connected to SV Sample System to perform leak test on system.

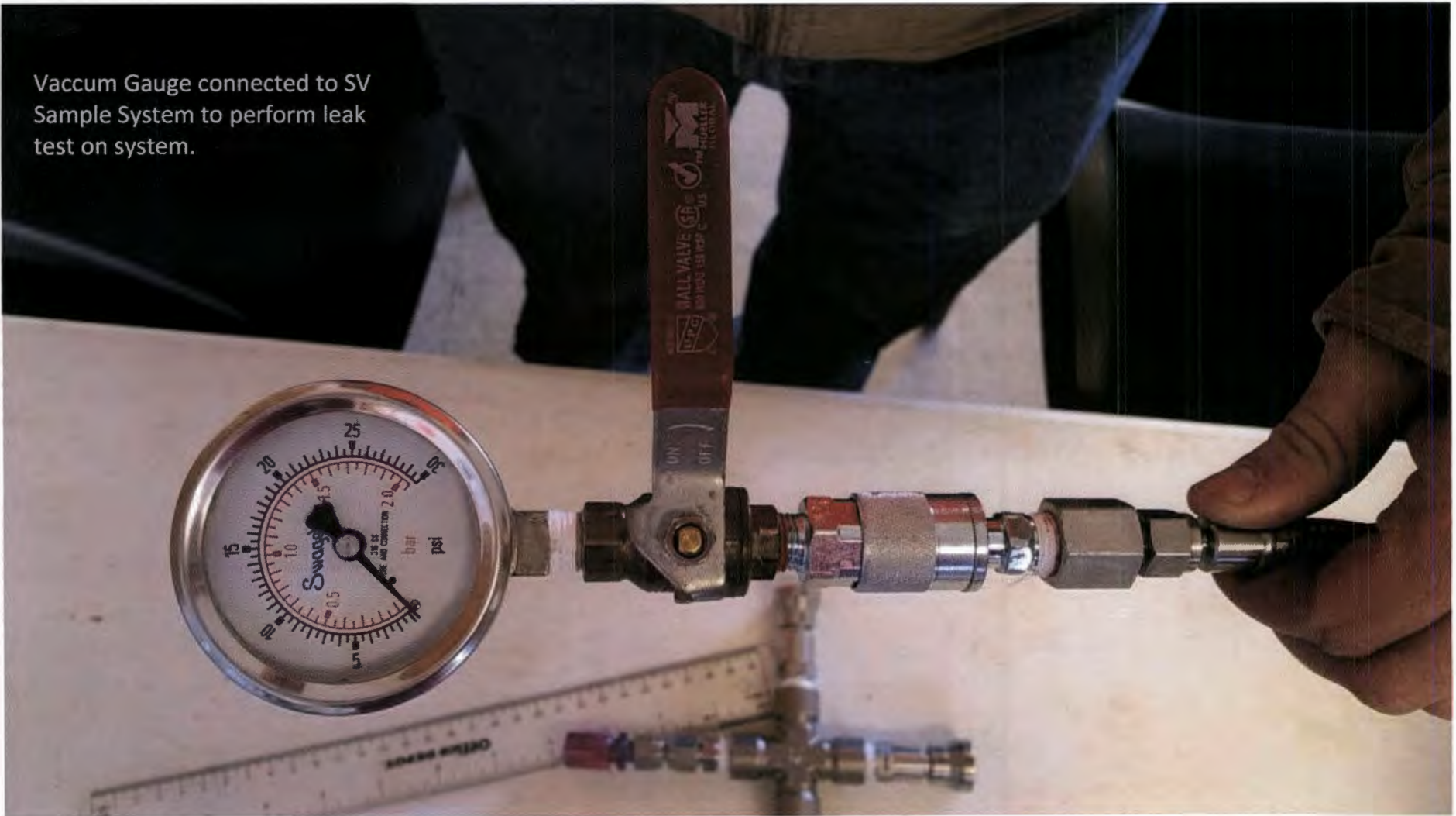


Figure 2: Vacuum Gauge connected to sample system via the stainless steel tubing for leak testing

Attachment 1. SV Well Construction Parameters and Pre-calculated Purge Volumes

Sample Location	Unique Database ID	Screened Interval (ft)		Well Diameter (in)	Casing Area (sq ft)	Filter Pack Volume (cu ft) *	Purge Volume (cu ft)
		Top	Bottom				
SVMW-01	SVMW-01-050	50	52.5	1/2	0.00136	0.409	0.481
	SVMW-01-100	100	102.5	1/2	0.00136	0.409	0.549
	SVMW-01-250	250.7	253.2	1/2	0.00136	0.409	0.754
	SVMW-01-300	308.5	310	1/2	0.00136	0.2454	0.668
SVMW-02	SVMW-02-050	50	52.5	1/2	0.00136	0.409	0.481
	SVMW-02-100	97	99.5	1/2	0.00136	0.409	0.545
	SVMW-02-150	150	152.5	1/2	0.00136	0.409	0.617
SVMW-03	SVMW-03-050	50	52.5	1/2	0.00136	0.409	0.481
	SVMW-03-100	100	102.5	1/2	0.00136	0.409	0.549
	SVMW-03-250	250	252.5	1/2	0.00136	0.409	0.753
	SVMW-03-300	300	302.5	1/2	0.00136	0.409	0.821
SVMW-04	SVMW-04-050	50	52.5	1/2	0.00136	0.409	0.481
	SVMW-04-100	98	100.5	1/2	0.00136	0.409	0.546
	SVMW-04-250	250	252.5	1/2	0.00136	0.409	0.753
	SVMW-04-300	297.5	300	1/2	0.00136	0.409	0.818
SVMW-05	SVMW-05-050	50	52.5	1/2	0.00136	0.409	0.481
	SVMW-05-100	100	102.5	1/2	0.00136	0.409	0.549
	SVMW-05-230	229.5	231	1/2	0.00136	0.2454	0.560
	SVMW-05-290	287.5	290	1/2	0.00136	0.409	0.804
SVMW-06	SVMW-06-050	50	52.5	1/2	0.00136	0.409	0.481
	SVMW-06-100	99.5	102	1/2	0.00136	0.409	0.548
	SVMW-06-252	252	254.5	1/2	0.00136	0.409	0.756
	SVMW-06-302	302.5	305	1/2	0.00136	0.409	0.825
SVMW-07	SVMW-07-050	49.5	52	1/2	0.00136	0.409	0.480
	SVMW-07-100	95.5	98	1/2	0.00136	0.409	0.543
	SVMW-07-150	147.5	150	1/2	0.00136	0.409	0.614
SVMW-08	SVMW-08-050	50	52.5	1/2	0.00136	0.409	0.481
	SVMW-08-100	100	102.5	1/2	0.00136	0.409	0.549
	SVMW-08-250	250	252.5	1/2	0.00136	0.409	0.753
	SVMW-08-266	266	268.5	1/2	0.00136	0.409	0.775
SVMW-09	SVMW-09-050	50	52.5	1/2	0.00136	0.409	0.481
	SVMW-09-100	100	102.5	1/2	0.00136	0.409	0.549
	SVMW-09-250	250	252.5	1/2	0.00136	0.409	0.753
	SVMW-09-266	266	268.5	1/2	0.00136	0.409	0.775
SVMW-10	SVMW-10-050	50	52.5	1/2	0.00136	0.409	0.481
	SVMW-10-100	100	102.5	1/2	0.00136	0.409	0.549
	SVMW-10-150	150	152.5	1/2	0.00136	0.409	0.617
	SVMW-10-250	250	252.5	1/2	0.00136	0.409	0.753
SVMW-11	SVMW-11-050	50	52.5	1/2	0.00136	0.409	0.481
	SVMW-11-100	100	102.5	1/2	0.00136	0.409	0.549

Attachment 1. SV Well Construction Parameters and Pre-calculated Purge Volumes

Sample Location	Unique Database ID	Screened Interval (ft)		Well Diameter (in)	Casing Area (sq ft)	Filter Pack Volume (cu ft) *	Purge Volume (cu ft)
		Top	Bottom				
	SVMW-11-250	250	252.5	1/2	0.00136	0.409	0.753
	SVMW-11-260	260	262.5	1/2	0.00136	0.409	0.767
SVMW-12	SVMW-12-150	150	152.5	1/2	0.00136	0.409	0.617
	SVMW-12-250	250	252.5	1/2	0.00136	0.409	0.753
	SVMW-12-350	350	352.5	1/2	0.00136	0.409	0.890
	SVMW-12-450	450	452.5	1/2	0.00136	0.409	1.026
SVMW-13	SVMW-13-150	150	152.5	1/2	0.00136	0.409	0.617
	SVMW-13-250	250	252.5	1/2	0.00136	0.409	0.753
	SVMW-13-350	350	352.5	1/2	0.00136	0.409	0.890
	SVMW-13-450	450	452.5	1/2	0.00136	0.409	1.026
SVMW-14	SVMW-14-150	150	152.5	1/2	0.00136	0.409	0.617
	SVMW-14-250	250	252.5	1/2	0.00136	0.409	0.753
	SVMW-14-350	350	352.5	1/2	0.00136	0.409	0.890
	SVMW-14-450	450	452.5	1/2	0.00136	0.409	1.026
SVMW-15	SVMW-15-150	150	152.5	1/2	0.00136	0.409	0.617
	SVMW-15-250	250	252.5	1/2	0.00136	0.409	0.753
	SVMW-15-350	350	352.5	1/2	0.00136	0.409	0.890
	SVMW-15-450	450	452.5	1/2	0.00136	0.409	1.026
KAFB-106028	KAFB-106028-150	148.75	151.25	1/2	0.00136	0.409	0.615
	KAFB-106028-250	248.75	251.25	1/2	0.00136	0.409	0.752
	KAFB-106028-350	348.75	351.25	1/2	0.00136	0.409	0.888
	KAFB-106028-450	448.75	451.25	1/2	0.00136	0.409	1.024
SVEW-01	SVEW-01-260	245	260	2	0.02182	2.454	8.126
SVEW-02/03	SVEW-02-060	45	60	2	0.02182	2.454	3.763
SVEW-02/03	SVEW-03-160	145	160	2	0.02182	2.454	5.945
SVEW-04/05	SVEW-04-313	298	313	2	0.02182	2.454	9.283
SVEW-04/05	SVEW-05-460	445	460	2	0.02182	2.454	12.490
SVEW-06/07	SVEW-06-060	45	60	2	0.02182	2.454	3.763
SVEW-06/07	SVEW-07-160	145	160	2	0.02182	2.454	5.945
SVEW-08/09	SVEW-08-260	245	260	2	0.02182	2.454	8.126
SVEW-08/09	SVEW-09-460	443	457	2	0.02182	2.2904	12.261
SVEW-10	SVEW-10-410	400	410	2	0.02182	1.636	10.581
SVEW-11	SVEW-11-410	400	410	2	0.02182	1.636	10.581
SVEW-12	SVEW-12-410	400	410	2	0.02182	1.636	10.581
SVEW-13	SVEW-13-410	400	410	2	0.02182	1.636	10.581
KAFB-106108	KAFB-106108-025	15.3	25.3	3/4	0.00307	1.636	1.714
	KAFB-106108-050	40	50	3/4	0.00307	1.636	1.789
	KAFB-106108-150	140.2	150.2	3/4	0.00307	1.636	2.097
	KAFB-106108-250	240.3	250.3	3/4	0.00307	1.636	2.404
	KAFB-106108-350	340.3	350.3	3/4	0.00307	1.636	2.711

Attachment 1. SV Well Construction Parameters and Pre-calculated Purge Volumes

Sample Location	Unique Database ID	Screened Interval (ft)		Well Diameter (in)	Casing Area (sq ft)	Filter Pack Volume (cu ft) *	Purge Volume (cu ft)
		Top	Bottom				
	KAFB-106108-450	440	450	3	0.04909	1.636	23.725
KAFB-106109	KAFB-106109-025	15.2	25.2	3/4	0.00307	1.636	1.713
	KAFB-106109-050	40.1	50.1	3/4	0.00307	1.636	1.790
	KAFB-106109-150	140	150	3/4	0.00307	1.636	2.096
	KAFB-106109-250	240.2	250.2	3/4	0.00307	1.636	2.404
	KAFB-106109-350	340.6	350.6	3/4	0.00307	1.636	2.712
	KAFB-106109-450	440	450	3	0.04909	1.636	23.725
KAFB-106110	KAFB-106110-025	15	25	3/4	0.00307	1.636	1.713
	KAFB-106110-050	40.1	50.1	3/4	0.00307	1.636	1.790
	KAFB-106110-150	140.3	150.3	3/4	0.00307	1.636	2.097
	KAFB-106110-250	240	250	3/4	0.00307	1.636	2.403
	KAFB-106110-350	340.2	350.2	3/4	0.00307	1.636	2.710
	KAFB-106110-450	440	450	3	0.04909	1.636	23.725
KAFB-106111	KAFB-106111-025	15.2	25.2	3/4	0.00307	1.636	1.713
	KAFB-106111-050	40.1	50.1	3/4	0.00307	1.636	1.790
	KAFB-106111-150	140.3	150.3	3/4	0.00307	1.636	2.097
	KAFB-106111-250	240.3	250.3	3/4	0.00307	1.636	2.404
	KAFB-106111-350	340.4	350.4	3/4	0.00307	1.636	2.711
	KAFB-106111-450	440.3	450.3	3	0.04909	1.636	23.740
KAFB-106112	KAFB-106112-025	15	25	3/4	0.00307	1.636	1.713
	KAFB-106112-050	40	50	3/4	0.00307	1.636	1.789
	KAFB-106112-150	140	150	3/4	0.00307	1.636	2.096
	KAFB-106112-250	240	250	3/4	0.00307	1.636	2.403
	KAFB-106112-350	339	349	3/4	0.00307	1.636	2.707
	KAFB-106112-450	439	449	3	0.04909	1.636	23.676
KAFB-106113	KAFB-106113-020	10	20	3/4	0.00307	1.636	1.697
	KAFB-106113-050	40	50	3/4	0.00307	1.636	1.789
	KAFB-106113-150	140	150	3/4	0.00307	1.636	2.096
	KAFB-106113-250	240	250	3/4	0.00307	1.636	2.403
	KAFB-106113-350	340	350	3/4	0.00307	1.636	2.710
	KAFB-106113-450	440	450	3	0.04909	1.636	23.725
KAFB-106114	KAFB-106114-025	15	25	3/4	0.00307	1.636	1.713
	KAFB-106114-050	40	50	3/4	0.00307	1.636	1.789
	KAFB-106114-150	140	150	3/4	0.00307	1.636	2.096
	KAFB-106114-250	235	245	3/4	0.00307	1.636	2.388
	KAFB-106114-350	340	350	3/4	0.00307	1.636	2.710
	KAFB-106114-450	439.6	449.6	3	0.04909	1.636	23.706
KAFB-106115	KAFB-106115-025	14.6	24.6	3/4	0.00307	1.636	1.711
	KAFB-106115-050	39.6	49.6	3/4	0.00307	1.636	1.788
	KAFB-106115-150	144.6	154.6	3/4	0.00307	1.636	2.110

Attachment 1. SV Well Construction Parameters and Pre-calculated Purge Volumes

Sample Location	Unique Database ID	Screened Interval (ft)		Well Diameter (in)	Casing Area (sq ft)	Filter Pack Volume (cu ft) *	Purge Volume (cu ft)
		Top	Bottom				
	KAFB-106115-250	239.6	249.6	3/4	0.00307	1.636	2.402
	KAFB-106115-350	339.6	349.6	3/4	0.00307	1.636	2.709
	KAFB-106115-450	439.6	449.6	3	0.04909	1.636	23.706
KAFB-106116	KAFB-106116-025	10	19.45	3/4	0.00307	1.54602	1.606
	KAFB-106116-050	40	49.45	3/4	0.00307	1.54602	1.698
	KAFB-106116-150	140	149.45	3/4	0.00307	1.54602	2.005
	KAFB-106116-250	240	249.45	3/4	0.00307	1.54602	2.311
	KAFB-106116-350	340	349.45	3/4	0.00307	1.54602	2.618
	KAFB-106116-450	440	448.95	3	0.04909	1.46422	23.502
KAFB-106117	KAFB-106117-025	15	25	3/4	0.00307	1.636	1.713
	KAFB-106117-050	40	50	3/4	0.00307	1.636	1.789
	KAFB-106117-150	140	150	3/4	0.00307	1.636	2.096
	KAFB-106117-250	240	250	3/4	0.00307	1.636	2.403
	KAFB-106117-350	340	350	3/4	0.00307	1.636	2.710
	KAFB-106117-450	440	450	3	0.04909	1.636	23.725
KAFB-106118	KAFB-106118-025	15	25	3/4	0.00307	1.636	1.713
	KAFB-106118-050	40	50	3/4	0.00307	1.636	1.789
	KAFB-106118-160	150	160	3/4	0.00307	1.636	2.127
	KAFB-106118-265	255	265	3/4	0.00307	1.636	2.449
	KAFB-106118-350	340	350	3/4	0.00307	1.636	2.710
	KAFB-106118-450	440	450	3	0.04909	1.636	23.725
KAFB-106119	KAFB-106119-025	15	25	3/4	0.00307	1.636	1.713
	KAFB-106119-050	40	50	3/4	0.00307	1.636	1.789
	KAFB-106119-150	140	150	3/4	0.00307	1.636	2.096
	KAFB-106119-250	240	250	3/4	0.00307	1.636	2.403
	KAFB-106119-350	340	350	3/4	0.00307	1.636	2.710
	KAFB-106119-450	440	450	3	0.04909	1.636	23.725
KAFB-106120	KAFB-106120-025	15	25	3/4	0.00307	1.636	1.713
	KAFB-106120-050	40	50	3/4	0.00307	1.636	1.789
	KAFB-106120-150	140	150	3/4	0.00307	1.636	2.096
	KAFB-106120-250	240	250	3/4	0.00307	1.636	2.403
	KAFB-106120-350	340	350	3/4	0.00307	1.636	2.710
	KAFB-106120-450	434	444	3	0.04909	1.636	23.431
KAFB-106121	KAFB-106121-025	15	25	3/4	0.00307	1.636	1.713
	KAFB-106121-050	40	50	3/4	0.00307	1.636	1.789
	KAFB-106121-145	135	145	3/4	0.00307	1.636	2.081
	KAFB-106121-250	240	250	3/4	0.00307	1.636	2.403
	KAFB-106121-350	340	350	3/4	0.00307	1.636	2.710
	KAFB-106121-440	434	444	3	0.04909	1.636	23.431
KAFB-106122	KAFB-106122-025	15	25	3/4	0.00307	1.636	1.713

Attachment 1. SV Well Construction Parameters and Pre-calculated Purge Volumes

Sample Location	Unique Database ID	Screened Interval (ft)		Well Diameter (in)	Casing Area (sq ft)	Filter Pack Volume (cu ft) *	Purge Volume (cu ft)
		Top	Bottom				
	KAFB-106122-050	40	50	3/4	0.00307	1.636	1.789
	KAFB-106122-150	140	150	3/4	0.00307	1.636	2.096
	KAFB-106122-250	240	250	3/4	0.00307	1.636	2.403
	KAFB-106122-350	340	350	3/4	0.00307	1.636	2.710
	KAFB-106122-450	434	444	3	0.04909	1.636	23.431
KAFB-106123	KAFB-106123-025	15	25	3/4	0.00307	1.636	1.713
	KAFB-106123-050	40	50	3/4	0.00307	1.636	1.789
	KAFB-106123-150	140	150	3/4	0.00307	1.636	2.096
	KAFB-106123-250	240	250	3/4	0.00307	1.636	2.403
	KAFB-106123-350	340	350	3/4	0.00307	1.636	2.710
	KAFB-106123-450	432	442	3	0.04909	1.636	23.333
KAFB-106124	KAFB-106124-025	15.1	25	3/4	0.00307	1.61964	1.696
	KAFB-106124-050	40.1	50	3/4	0.00307	1.61964	1.773
	KAFB-106124-150	140.1	150	3/4	0.00307	1.61964	2.080
	KAFB-106124-250	240.1	250	3/4	0.00307	1.61964	2.387
	KAFB-106124-350	340.1	350	3/4	0.00307	1.61964	2.693
	KAFB-106124-450	440.1	450	3	0.04909	1.61964	23.709
KAFB-106125	KAFB-106125-025	15.2	25	3/4	0.00307	1.60328	1.680
	KAFB-106125-050	40.2	50	3/4	0.00307	1.60328	1.757
	KAFB-106125-150	140.2	150	3/4	0.00307	1.60328	2.063
	KAFB-106125-250	240.2	250	3/4	0.00307	1.60328	2.370
	KAFB-106125-350	340.2	350	3/4	0.00307	1.60328	2.677
	KAFB-106125-450	440.2	450	3	0.04909	1.60328	23.693
KAFB-106126	KAFB-106126-025	15.1	25	3/4	0.00307	1.61964	1.696
	KAFB-106126-050	40.1	50	3/4	0.00307	1.61964	1.773
	KAFB-106126-150	140.1	150	3/4	0.00307	1.61964	2.080
	KAFB-106126-250	240.1	250	3/4	0.00307	1.61964	2.387
	KAFB-106126-350	340.1	350	3/4	0.00307	1.61964	2.693
	KAFB-106126-450	440.2	450	3	0.04909	1.60328	23.693
KAFB-106127	KAFB-106127-025	15	25	3/4	0.00307	1.636	1.713
	KAFB-106127-050	40	50	3/4	0.00307	1.636	1.789
	KAFB-106127-150	140	150	3/4	0.00307	1.636	2.096
	KAFB-106127-250	240	250	3/4	0.00307	1.636	2.403
	KAFB-106127-350	340	350	3/4	0.00307	1.636	2.710
	KAFB-106127-450	440	450	3	0.04909	1.636	23.725
KAFB-106128	KAFB-106128-025	15.04	25.04	3/4	0.00307	1.636	1.713
	KAFB-106128-050	40.07	50.07	3/4	0.00307	1.636	1.790
	KAFB-106128-150	140.19	150.19	3/4	0.00307	1.636	2.097
	KAFB-106128-250	240.29	250.29	3/4	0.00307	1.636	2.404
	KAFB-106128-350	340.39	350.39	3/4	0.00307	1.636	2.711

Attachment 1. SV Well Construction Parameters and Pre-calculated Purge Volumes

Sample Location	Unique Database ID	Screened Interval (ft)		Well Diameter (in)	Casing Area (sq ft)	Filter Pack Volume (cu ft) *	Purge Volume (cu ft)
		Top	Bottom				
	KAFB-106128-450	440.06	450.06	3	0.04909	1.636	23.728
KAFB-106129	KAFB-106129-025	15.1	25.1	3/4	0.00307	1.636	1.713
	KAFB-106129-050	39.7	49.7	3/4	0.00307	1.636	1.788
	KAFB-106129-150	140.2	150.2	3/4	0.00307	1.636	2.097
	KAFB-106129-250	240.1	250.1	3/4	0.00307	1.636	2.403
	KAFB-106129-350	337.4	347.4	3/4	0.00307	1.636	2.702
	KAFB-106129-450	440.7	450.7	3	0.04909	1.636	23.760
KAFB-106130	KAFB-106130-025	15	25	3/4	0.00307	1.636	1.713
	KAFB-106130-050	40	50	3/4	0.00307	1.636	1.789
	KAFB-106130-150	150	160	3/4	0.00307	1.636	2.127
	KAFB-106130-250	240	250	3/4	0.00307	1.636	2.403
	KAFB-106130-350	340	350	3/4	0.00307	1.636	2.710
	KAFB-106130-450	440	450	3	0.04909	1.636	23.725
KAFB-106131	KAFB-106131-025	15	25	3/4	0.00307	1.636	1.713
	KAFB-106131-055	45	55	3/4	0.00307	1.636	1.805
	KAFB-106131-150	140	150	3/4	0.00307	1.636	2.096
	KAFB-106131-245	235	245	3/4	0.00307	1.636	2.388
	KAFB-106131-350	340	350	3/4	0.00307	1.636	2.710
	KAFB-106131-450	430	440	3	0.04909	1.636	23.234
KAFB-106132	KAFB-106132-025	15	25	3/4	0.00307	1.636	1.713
	KAFB-106132-050	40	50	3/4	0.00307	1.636	1.789
	KAFB-106132-175	164	174	3/4	0.00307	1.636	2.170
	KAFB-106132-250	240	250	3/4	0.00307	1.636	2.403
	KAFB-106132-350	340	350	3/4	0.00307	1.636	2.710
	KAFB-106132-450	440	450	3	0.04909	1.636	23.725
KAFB-106133	KAFB-106133-025	15	25	3/4	0.00307	1.636	1.713
	KAFB-106133-050	40	50	3/4	0.00307	1.636	1.789
	KAFB-106133-170	160	170	3/4	0.00307	1.636	2.158
	KAFB-106133-250	240	250	3/4	0.00307	1.636	2.403
	KAFB-106133-350	339	349	3/4	0.00307	1.636	2.707
	KAFB-106133-450	439	449	3	0.04909	1.636	23.676
KAFB-106134	KAFB-106134-025	15	25	3/4	0.00307	1.636	1.713
	KAFB-106134-050	40	50	3/4	0.00307	1.636	1.789
	KAFB-106134-170	160	170	3/4	0.00307	1.636	2.158
	KAFB-106134-250	240	250	3/4	0.00307	1.636	2.403
	KAFB-106134-350	340	350	3/4	0.00307	1.636	2.710
	KAFB-106134-450	440	450	3	0.04909	1.636	23.725
KAFB-106135	KAFB-106135-025	15	25	3/4	0.00307	1.636	1.713
	KAFB-106135-050	40	50	3/4	0.00307	1.636	1.789
	KAFB-106135-150	140	150	3/4	0.00307	1.636	2.096

Attachment 1. SV Well Construction Parameters and Pre-calculated Purge Volumes

Sample Location	Unique Database ID	Screened Interval (ft)		Well Diameter (in)	Casing Area (sq ft)	Filter Pack Volume (cu ft) *	Purge Volume (cu ft)
		Top	Bottom				
	KAFB-106135-250	240	250	3/4	0.00307	1.636	2.403
	KAFB-106135-350	340	350	3/4	0.00307	1.636	2.710
	KAFB-106135-450	440	450	3	0.04909	1.636	23.725
KAFB-106136	KAFB-106136-025	15	25	3/4	0.00307	1.636	1.713
	KAFB-106136-050	40	50	3/4	0.00307	1.636	1.789
	KAFB-106136-150	140	150	3/4	0.00307	1.636	2.096
	KAFB-106136-250	240	250	3/4	0.00307	1.636	2.403
	KAFB-106136-350	340	350	3/4	0.00307	1.636	2.710
	KAFB-106136-450	440	450	3	0.04909	1.636	23.725
KAFB-106137	KAFB-106137-025	15	25	3/4	0.00307	1.636	1.713
	KAFB-106137-050	40	50	3/4	0.00307	1.636	1.789
	KAFB-106137-150	140	150	3/4	0.00307	1.636	2.096
	KAFB-106137-250	240.1	250.1	3/4	0.00307	1.636	2.403
	KAFB-106137-350	340.5	350.5	3/4	0.00307	1.636	2.711
	KAFB-106137-450	440	450	3	0.04909	1.636	23.725
KAFB-106138	KAFB-106138-025	15	25	3/4	0.00307	1.636	1.713
	KAFB-106138-050	40	50	3/4	0.00307	1.636	1.789
	KAFB-106138-150	140	150	3/4	0.00307	1.636	2.096
	KAFB-106138-250	240	250	3/4	0.00307	1.636	2.403
	KAFB-106138-350	340	350	3/4	0.00307	1.636	2.710
	KAFB-106138-450	440	450	3	0.04909	1.636	23.725
KAFB-106139	KAFB-106139-025	15	25	3/4	0.00307	1.636	1.713
	KAFB-106139-050	40	50	3/4	0.00307	1.636	1.789
	KAFB-106139-150	140	150	3/4	0.00307	1.636	2.096
	KAFB-106139-250	240	250	3/4	0.00307	1.636	2.403
	KAFB-106139-350	340	350	3/4	0.00307	1.636	2.710
	KAFB-106139-450	440	450	3	0.04909	1.636	23.725
KAFB-106140	KAFB-106140-025	15	25	3/4	0.00307	1.636	1.713
	KAFB-106140-050	40	50	3/4	0.00307	1.636	1.789
	KAFB-106140-150	141.8	151.8	3/4	0.00307	1.636	2.102
	KAFB-106140-250	240	250	3/4	0.00307	1.636	2.403
	KAFB-106140-350	340	350	3/4	0.00307	1.636	2.710
	KAFB-106140-450	440	450	3	0.04909	1.636	23.725
KAFB-106141	KAFB-106141-025	15	25	3/4	0.00307	1.636	1.713
	KAFB-106141-050	50	60	3/4	0.00307	1.636	1.820
	KAFB-106141-170	160	170	3/4	0.00307	1.636	2.158
	KAFB-106141-250	240	250	3/4	0.00307	1.636	2.403
	KAFB-106141-350	340	350	3/4	0.00307	1.636	2.710
	KAFB-106141-450	440	450	3	0.04909	1.636	23.725
KAFB-106142	KAFB-106142-030	20	30	3/4	0.00307	1.636	1.728

Attachment 1. SV Well Construction Parameters and Pre-calculated Purge Volumes

Sample Location	Unique Database ID	Screened Interval (ft)		Well Diameter (in)	Casing Area (sq ft)	Filter Pack Volume (cu ft) *	Purge Volume (cu ft)
		Top	Bottom				
	KAFB-106142-050	40	50	3/4	0.00307	1.636	1.789
	KAFB-106142-170	160	170	3/4	0.00307	1.636	2.158
	KAFB-106142-250	240	250	3/4	0.00307	1.636	2.403
	KAFB-106142-350	340	350	3/4	0.00307	1.636	2.710
	KAFB-106142-450	440	450	3	0.04909	1.636	23.725
KAFB-106160	KAFB-106160-530	490	525	6	0.19635	5.726	108.809
KAFB-106161	KAFB-106161-530	490	525	6	0.19635	5.726	108.809
KAFB-106149	KAFB-106149-250	24	194	3	0.04909	27.812	37.335
	KAFB-106149-350	199	349	3	0.04909	24.54	41.671
	KAFB-106149-484	354	484	3	0.04909	21.268	45.026
KAFB-106150	KAFB-106150-250	25	200	3	0.04909	28.63	38.447
	KAFB-106150-350	206	350	3	0.04909	23.5584	40.739
	KAFB-106150-484	355	484	3	0.04909	21.1044	44.863
KAFB-106154	KAFB-106154-250	28	197	3	0.04909	27.6484	37.319
	KAFB-106154-350	201	350	3	0.04909	24.3764	41.557
	KAFB-106154-484	355	484	3	0.04909	21.1044	44.863

*the borehole casing factor = $((10 \text{ inch diameter}/12 \text{ inches})^2)(3.14159/4)(0.3 \text{ porosity}) = 0.1636$



DEPARTMENT OF THE AIR FORCE
HEADQUARTERS 377TH AIR BASE WING (AFMC)

ENTERED

Colonel Tom D. Miller
377 ABW/CC
2000 Wyoming Blvd SE
Kirtland AFB NM 87117-5600

DEC 23 2014

Mr. Butch Tongate
Deputy Secretary
New Mexico Environment Department (NMED)
1190 St. Francis Drive, Suite N-4050
Santa Fe, New Mexico 87502

RECEIVED

FEB 12 2015

NMED
Hazardous Waste Bureau

Dear Mr. Tongate

Attached please find the *Pilot SVE Shutdown Test Work Plan*. This letter WP will address the respiration and short-term testing, along with the long-term rebound testing, on selected soil vapor monitoring (SVM) wells. Data from this shutdown test will be used in the design of SVE expansion at the BFF site.

Please contact Mr. L. Wayne Bitner at (505) 853-3484 or at ludie.bitner@us.af.mil or Mrs. Victoria Branson at (505) 846-6362 or at victoria.branson@us.af.mil if you have questions.

Sincerely

TOM D. MILLER, Colonel USAF
Commander

Attachment: Pilot SVE Shutdown Test Work Plan

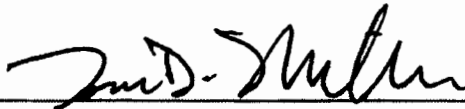
cc:

NMED-HWB (Kieling, Cobrain, Moats, McDonald, Brandwein) w/attach
NMED (McQuillan, Longmire) w/attach
NMED-GWQB (Schoeppner) w/attach
NMED-PSTB (Reuter) w/attach
NMED-OGC (Kendall) w/o attach
EPA Region 6 (King) w/o attach
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TOM D. MILLER, Colonel, USAF
Commander, 377th Air Base Wing

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CB&I Federal Services LLC
2440 Louisiana Blvd. NE, Suite 300
Albuquerque, NM 87110
Tel: +1 505 262 8800
Fax: +1 505 262 8855
www.CBI.com

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Subject: Kirtland Air Force Base Bulk Fuel Facility – Pilot Soil Vapor Extraction Shutdown Test Work Plan

This Kirtland Air Force Base (KAFB) Bulk Fuel Facility (BFF) Soil Vapor Extraction (SVE) Shutdown Testing Letter Work Plan (WP) has been prepared by CB&I Federal Services LLC (CB&I) for the U.S. Army Corps of Engineers (USACE), Albuquerque District, under Contract No. W912DY-10-D-0014. The in-situ respiration and rebound tests will inform the location and design of a more robust remedial strategy for the BFF vadose zone. Details on the additional investigation (Work Plan 2) and system design/installation (Work Plan 3) activities will follow as separate work plans, which will be developed from the results of the SVE shutdown test.

This WP provides details on the approaches and methodologies that will be followed in conducting an in-situ respiration test and short-term and long-term rebound tests, on selected soil-vapor monitoring (SVM) points. In this WP, the reference to “SVM points” is used to refer to discrete SVM well locations and discrete screen depths. The current catalytic oxidizer (CATOX) SVE system will be off for the entire duration of the respiration and rebound tests so that accurate measurements can be made to monitor microbiological activity and hydrocarbon concentration changes under non-flow conditions in the vadose zone.

The objectives of this WP are to collect data to:

- Calculated in-situ biodegradation of residual fuel hydrocarbon through respiration testing at selected SVM points. Respiration testing examines oxygen (O₂) utilization to assess biodegradation occurring throughout the BFF SVE monitoring network. The results will show: areas where residual volatile fuel hydrocarbons are aerobically biodegrading, areas where the volatile fraction of the fuel hydrocarbon has been depleted but biodegradation of the non-volatile jet fuel constituents is continuing, and areas where volatile fuel hydrocarbon fraction is not measured and biodegradation is either not ongoing or is occurring at rates that would not benefit from active aeration.
- Further delineate the distribution of residual hydrocarbons in the vadose zone through rebound testing at selected SVM points. During rebound testing, total soil-vapor hydrocarbon (TSVH) concentrations will be measured over time to monitor the rate, extent, and location of changes in concentration. SVM locations showing rapid and large TSVH concentration increases will indicate the presence of residual contaminant mass to target for treatment.
- Identify potential migration pathways throughout the vadose zone. The rates and extent of rebound will be compared between adjacent monitoring locations throughout the SVE monitoring network in the BFF vadose zone. Patterns of rebound rates will help point toward potential locations of migration pathway.
- Inform the need for and location of additional subsurface investigation. While the BFF SVM network is extensive and data generated to date suggest good coverage of the contamination, the results from the respiration and rebound testing will refine the delineation of vadose zone contamination. However, if rebound trends between adjacent monitoring locations show increasing trends towards a specific monitoring location and that monitoring location is not “bounded” by surrounding monitoring locations that confirm the direction of the trend, an additional SVM points may be needed. Soil-vapor rebound results also will determine the location for continuous soil coring recovery to confirm/correlate the contamination with the TSVH results, and to locate and characterize residual hydrocarbon in the vadose zone. The cores

will be extended approximately 10 to 20 feet below the water table in an attempt to locate, quantify and characterize floating and/or submerged light non-aqueous phase liquid (LNAPL). The details for additional subsurface investigation activities will be provided in a separate work plan to be submitted following the completion of the shutdown test using the test data.

In-situ respiration and rebound test results and additional subsurface investigation data will be used to design an effective and efficient interim measure for the vadose zone that could include any of a number of remediation technologies (i.e., SVE, bioventing, excavation, etc.). While it is desirable to use the existing SVE infrastructure to the extent possible, the objective is to enhance the understanding of the conceptual site model (CSM) and design of an interim measure that removes contaminant mass from the vadose zone effectively. Details on the design and implementation of the optimized interim measure will be provided in follow-on work plan(s) to be submitted after the completion of the additional subsurface investigations.

The following sections of this WP provide details on the SVE shutdown testing methodologies and the data analyses and reporting procedures.

1. SVE SHUTDOWN TESTING

The SVE shutdown test provides a unique opportunity to assess the subsurface conditions at the BFF after 12 years of SVE operation. During shutdown, in-situ respiration and short-term rebound monitoring will be performed in tandem on select existing SVM points (see below for SVM point selection logic). In-situ respiration testing will provide data that will be used for calculation of biodegradation rates in the vadose zone. Long-term rebound testing will continue on a subset of the SVM points following the completion of the in-situ respiration and short-term rebound testing. The short-term and long-term rebound test will evaluate soil-vapor concentration recovery after shut down of the CATOX system.

The current CATOX system will be shut down for approximately 3 months to allow sufficient time for the long-term rebound test to be completed and to collect data necessary to optimize the design and operation of the vadose zone remediation system(s).

Prior to SVE shut down, baseline sampling will provide information on current vadose zone conditions during SVE operation. O₂ and carbon dioxide (CO₂) data collected after SVE shutdown will allow calculation of the in-situ biodegradation rates throughout the vadose zone. Changes in soil-vapor hydrocarbon concentrations will demonstrate the soil-vapor hydrocarbon rebound potential, and the trends in the concentration increases within individual SVM points and between adjacent SVM points may provide indications of potential fuel migration pathways from the leak points to the water table and the location of residual hydrocarbon mass to target with SVE or other appropriate measures.

In-situ respiration and rebound testing will provide data necessary to make informed decisions for moving the vadose zone remediation effort effectively towards completion. Because excessive soil-vapor purging during sampling can produce erroneous readings, and because overpurging produces no benefit, care must be taken to minimize the volume of soil vapor extracted when conducting respiration testing (EPA, 1995). Due to the potential for regular SVM activities to impact the quality and accuracy of the data collected during shutdown testing, KAFB is requesting no quarterly SVM samples be collected for the first two Quarters of Calendar Year (CY) 2015 due to the length and timing of the long-term rebound test. At the completion of the long-term rebound test, a complete round of quarterly SVM samples will be collected as a quarterly sampling event, prior to resuming SVE operations. Although samples will be collected from the same SVM points included in the quarterly SVM protocol, consideration must be given to the use of the data when comparing the results to previous quarterly SVM events when the SVE system was operational.

The data collected during the proposed shutdown testing will facilitate an in-depth analysis of the remaining contamination in the vadose zone and the biodegradation rates associated with that contamination. The extended data set from the SVE shutdown test will advance our understanding of the conditions in the BFF vadose zone and will add value to the soil-vapor data that are normally collected during the quarterly sampling events. Having enhanced understanding of subsurface conditions will facilitate effective SVE expansion design and optimal SVE system operation. As such, it would be extremely beneficial to avoid interferences with the tests to ensure that the collected data are of the highest quality possible.

Prior to baseline sampling and respiration/rebound testing, all SVM and SVE points will be securely capped to prevent soil-vapor points from exhaling soil-vapor gas or inhaling atmospheric air due to barometric pressure increases or decreases. Soil-vapor points in the BFF have been observed to respond to changes in barometric pressure, so preventing these wells from inhaling or exhaling will ensure better accuracy during testing as atmospheric conditions will not be able to influence the deep vadose zone through soil-vapor points. Well caps will be inspected for integrity according to the guidelines in Appendix A before readings or samples are collected from a soil-vapor point.

Barometric pressure gauges and water level transducers will be installed in SVE wells KAFB-106161, KAFB-106160, and one additional well inside the BFF area for the duration of the shutdown test. Barometric pressure gauges will be installed inside the well vault but outside the well cap so that accurate readings of barometric pressure changes can be made. Water level transducers and barometric pressure gauges will be set to record data every hour.

1.1 Baseline Sampling

Baseline measurements will be made on all of the 287 SVM points while the CATOX system is still operating. Soil-vapor baseline measurements will be collected as described in Appendix A. The sampling system and the soil-vapor sampling method described in Appendix A have been modified from the methodologies outlined in Section 5.3 of the Vadose Zone Investigation Work Plan (USACE, 2011a) and Section 3.0 of the Quality Assurance Project Plan (QAPjP) (USACE, 2011b) to allow for minimal soil-vapor volumes to be withdrawn during the in-situ respiration testing. This will provide more representative data in close proximity to the sampled SVM point. The following parameters will be measured using a Horiba Model MEXA 584L portable auto emissions analyzer (herein referred to as the Horiba):

- Total hydrocarbons in parts per million by volume (ppmv)
- Percent O₂
- Percent CO₂
- Vacuum/pressure (inches of water column [inches WC])

After baseline measurements are collected, the CATOX system will be shut down using normal shutdown procedures outlined in Section 6.0 of the SVE System Operations and Maintenance Plan (August 2013). The SVE wells currently connected to the CATOX system (KAFB-106149, KAFB-106150, KAFB-106154, KAFB-106160, and KAFB-106161) will be closed at the well heads prior to shut down of the extraction system to prevent atmospheric air from entering the points and interfering with the initial measurements during the in-situ respiration and short-term rebound testing.

1.2 In-Situ Respiration and Short-Term Rebound Testing

The in-situ respiration and short-term rebound tests will be performed concurrently during the first two weeks of the shutdown period.

The objective of the in-situ respiration and short-term rebound testing is to provide an accurate representation of the biological activity and the residual contamination distribution in the BFF vadose zone. A total of 61 SVM points will be included in the in-situ respiration and short-term rebound testing. Thirty (30) of the SVM points that will be included in the in-situ respiration testing and will be selected based on the results from the baseline testing following the logic described in Table 1. Candidate respiration testing SVM points will be selected to cover a range of subsurface conditions as described in Table 1, and to provide effective coverage of the BFF vadose zone in areas where monitoring is warranted but not covered by the 31 SVM points selected for the selected for short and long-term rebound testing, discussed below. Once the baseline data are available, a table of the 30 respiration testing points will be provided to the New Mexico Environment Department (NMED) ahead of the shutdown testing for review and approval.

Thirty-one (31) SVM points have already been selected for the rebound testing (Table 2). All 31 of the SVM points selected for the long-term rebound testing will be included in the in-situ respiration and short-term rebound testing (see Section 1.3). The 31 SVM points were selected based on soil-vapor data collected during Fourth Quarter CY 2012 and Second Quarter CY 2014. These two quarters represent the highest historical soil-vapor data and the most recent soil-vapor data, respectively. The SVE system area of influence is defined as the area within the 0.5-inch WC vacuum isopleth, as reported in Appendix L of the Pre-Remedy Quarterly Monitoring Reports.

Following SVE shut down, soil vapor will be sampled from the selected 61 SVM points using the Horiba and the sampling method described in detail in Appendix A. The initial sampling will be initiated within 2 hours after SVE shut down. Subsequent sampling frequencies for each SVM point will be determined based on the observed O₂-utilization rates. SVM points demonstrating a higher O₂-utilization rate will be sampled on a more frequent basis. During the initial 24 hours of post-shutdown monitoring, a crew of six individuals will monitor the SVM points during the day and night. Respiration monitoring will continue until O₂ concentrations decrease to less than 5 percent or 2 weeks is reached, whichever comes first.

Measured O₂ concentrations will be used to create an O₂-utilization curve. A biodegradation rate can then be calculated (see Section 2.1) for the discrete locations represented by the SVM points throughout the vadose zone. The time series of TSVH data from the short-term rebound will be used along with the time series of TSVH data from the long-term rebound test (see Section 2.2) to observe trends in hydrocarbon concentration responses throughout the vadose zone as the subsurface adjusts toward undisturbed conditions (i.e., under SVE-induced vapor flow).

Table 1. Potential Observations Among Hydrocarbon, O₂ and CO₂ Data and the Logic for Soil-vapor Point Selection for Inclusion in the In-situ Respiration and Short Term Rebound Testing	
Data Observations	Implications
High Hydrocarbon (>1,000 ppmv), Depressed O ₂ (<19.5 %), Elevated CO ₂ (>1%)	SVM points with these characteristics may coincide with high-concentration residual fuel, or may be under the influence of nearby residual fuel with a large volatile fraction remaining. The depressed O ₂ combined with elevated CO ₂ is a strong indicator that aerobic biodegradation is occurring during SVE operation. These SVM points would be prime candidates for in-situ respiration, and short-term and long-term rebound testing.
Moderate Hydrocarbon (250 – 1,000 ppmv), Depressed O ₂ (<19.5%), Elevated CO ₂ (>1%)	SVM points with these characteristics may be in proximity to residual fuel contamination with a large or moderately reduced volatile fraction remaining, and aerobic biodegradation is occurring under SVE operation. These SVM points would be prime candidates for in-situ respiration, and short-term and long-term rebound testing.
Low Hydrocarbon (250 – 50 ppmv), Depressed O ₂ (<19.5%), Elevated CO ₂ (>0.5%)	SVM points with these characteristics may be in proximity to residual fuel contamination with a large percentage of the volatile fraction depleted and aerobic biodegradation is occurring during SVE operation. A minimum of five SVM points showing this data signature should be included in the in-situ respiration and long-term rebound testing. If many soil-vapor points are observed in this category, points will be selected to ensure lateral and vertical coverage of the area within the influence of the SVE system. Note that short-term rebound data will be collected during the rebound test, but observation of rapid hydrocarbon rebound is not anticipated.
Very-low Hydrocarbon (<50), Ambient O ₂ (>20%), Ambient CO ₂ (<0.1%)	SVM points with these characteristics may or may not be in proximity of residual fuel contamination. A review of historic vapor data is warranted to determine how these points might be used. If available, a minimum of three SVM points with low hydrocarbon and ambient O ₂ and CO ₂ and previously recorded hydrocarbon concentrations greater than 1,000 ppmv should be included in the in-situ respiration and short-term rebound testing. The results from testing these SVM points will indicate residual fuel contamination that has been depleted of the volatile fraction and that would not show up on the short-term or long-term rebound test, and also will quantify the biodegradation rate of the remaining non-volatile contaminant fraction. One SVM point that matches the data observations without historic hydrocarbon detection should be included in the in-situ respiration testing and will serve to determine the background respiration rate against which the respiration rates at the other 30 SVM points will be compared.

Table 2. SVM Points for Long-Term Rebound Testing		
Well Number	Zone	Monitoring Depths
SVMW-03	Near edge of area influenced by SVE	100
		250
		350
SVMW-06	Inside area influenced by SVE	100
		252
		302
SVMW-10	Outside area influenced by SVE	100
		150
		250
KAFB-106112	Inside area influenced by SVE	250
		350
		450
KAFB-106113	Probably outside area influenced by SVE	350
		450
KAFB-106114	Near edge of area influenced by SVE	350
		450
KAFB-106116	Inside area influenced by SVE	350
		450
KAFB-106117	Inside area influenced by SVE	350
		450
KAFB-106119	Inside area influenced by SVE	150
		250
		350
		450
KAFB-106128	Inside area influenced by SVE	350
		450
KAFB-106129	Possibly influenced by SVE	250
		350
		450
KAFB-106131	Possibly influenced by SVE	350
		450

1.3 Long-Term Rebound Testing

The objective of the long-term rebound testing is to extend the period of rebound monitoring to allow sufficient time for contaminant concentrations in the soil vapor to respond to contaminant that might be held in lower-permeability lithology, which will provide a more accurate representation of the residual contamination distribution in the BFF vadose zone. Hydrocarbon concentrations in the network of 31 SVM points listed in Table 2 will continue to be measured over the 3 months of the shutdown period.

Following the short-term rebound test, long-term rebound SVM points will be monitored daily for 1 week, weekly for 5 weeks, and then biweekly until TSVH concentrations become asymptotic or for three biweekly sampling events, whichever comes first. These samples will be analyzed using the Horiba following the sampling method described in Appendix A.

1.4 Complete SVM Network Quarterly Sampling

At the conclusion of the shutdown test and before SVE operation resumes, a full round of SVM sampling will be conducted from the network used in the quarterly monitoring sampling program following the

sampling methodology described in Appendix A pending discussions with and approval from the NMED. Samples will be analyzed in the field for TSVH (ppmv) using the Horiba and samples will be submitted to a laboratory for Method TO-15, Method CARB422 for EDB, Method APH (air-phase petroleum hydrocarbons), and fixed gases analyses.

The field and laboratory analyses deployed for BFF vadose zone monitoring are complimentary and not redundant. The analytical instruments used under the different methods employ different detectors and require different dilution factors to keep values in the calibrated range of the respective instrument. As such, the analyses do not provide the same output but rather provide a more in-depth representation of the subsurface conditions. The results from the analyses are used for different purposes and are thus not expected nor needed to replicate values with precision. The field hydrocarbon analyses are an aggregate measurement of the volatile hydrocarbon composition and are used throughout the test to track trends. The laboratory analytical methods provide compound-specific and boiling point split (i.e., hydrocarbon fraction) results, which are useful for effectively assessing remediation effectiveness against the subsurface hydrocarbons.

2. DATA ANALYSIS AND REPORTING

2.1 In-situ Respiration Test

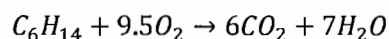
Biodegradation rates in the vadose zone are based on O₂-utilization rates, hydrocarbon oxidation stoichiometry, and relevant soil properties. Following the Bioventing Principles and Practice, Volume II (EPA, 1995), the O₂-utilization rate calculated from the field monitoring data is expressed as a percentage of O₂ as a function of time. O₂-utilization rates will only be calculated for the linear portion of the curve, as it is an indicator that O₂ is not limiting, and is therefore indicative of active biodegradation. The CO₂ data verify that the observed decreases in O₂ are the result of microbiological degradation, and not other oxygen consuming reactions. Increases in CO₂ concentrations that are concurrent with decreasing O₂ concentrations are indicative of biodegradation. (Note that CO₂ data are only used to verify biodegradation and are not used in biodegradation rate calculations because of potential errors associated with geochemical reactions involving CO₂ that can bias the results.)

In the field, soil-vapor O₂ and CO₂ concentrations will be measured using the Horiba. With frequent calibration and calibration checks, the Horiba will provide good-quality data to derive accurate O₂-utilization rates. Comparing the utilization rates between SVM points under the characteristics described in Table 1 will confirm that the measured O₂-utilization is above ambient and due to microbiological degradation of residual fuel hydrocarbons. Laboratory analyses are not required during in-situ respiration testing.

O₂ and CO₂ concentrations will be measured on a percent basis and are expected to change over the duration of the in-situ respiration test as aerobic microorganisms consume O₂ during hydrocarbon degradation and produce CO₂. The O₂ measurements are used to calculate the O₂-utilization rate, which is calculated as the slope of the decrease in O₂ concentrations over time as O₂ concentrations decrease from baseline concentration to 5% O₂. This value is used to calculate the biodegradation rate as shown in Equation 2.

Since the contamination at the BFF project site is fuel hydrocarbon based, hexane is used as the representative hydrocarbon for rate calculations. The stoichiometric relationship used for determination of degradation rates is therefore (EPA, 1995):

Equation 1:



Based on the utilization rates, the biodegradation rate is estimated using the following equation (EPA, 1995):

Equation 2:

$$-k_b = \frac{-\frac{k_o}{100} \theta_a \frac{1L}{1,000cm^3} \rho_{O_2} C}{\rho_k \left\{ \frac{1kg}{1,000g} \right\}} = \frac{-k_o \theta_a \rho_{O_2} C (0.01)}{\rho_k}$$

Where:

k_b = biodegradation rate (milligrams/kilogram-day)

k_o = O₂-utilization rate (percent/day)

θ_a = gas-filled pore space (volumetric content at the vapor phase, cubic meters gas/cubic centimeter soil)

ρ_{O_2} = density of O₂ (milligrams/liter)

C = mass ratio of hydrocarbons to O₂ required for mineralization (1:3.5)

ρ_k = soil bulk density (grams/cubic centimeter)

The value for k_o will be directly measured during the respiration monitoring as described in Section 1.2. The remaining input values will be based on data obtained from the site, if available, or from industry standards and approved literature. The value for θ_a has the most variability; however, since the respiration testing will be conducted at a low gas-filled porosity, the value can be estimated in accordance with the steps outlined in the EPA manual for Bioventing Principles and Practice, Volume II (EPA, 1995)

2.2 Rebound Test

In the field, TSVH measurements will be made using the Horiba to analyze soil-vapor samples from 61 SVM points during the short-term rebound test and on 31 SVM points during the long-term portion of the rebound test (see Tables 1 and 2 for the SVM point selection logic for the in-situ respiration and short-term rebound testing and the list of 31 pre-selected long-term rebound SVM points, respectively). Using frequent calibration and calibration checks, the Horiba instrument will provide quality data that are sufficient in number to monitor increasing or decreasing TSVH concentrations at each of the 61 SVM points. The data will be used to assess TSVH concentration trends at each SVM point, and to compare the relative concentrations and the trends between the SVM points. The assessment should provide information on the locations and extent of residual contaminant in the vadose zone. The data also will be evaluated to update the CSM for residual hydrocarbon distribution and identify potential migration pathways through the vadose zone, which will inform decisions for additional investigation (Phase 2) and remedial activities (Phase 3) that will be described in future work plans.

The TO-15 and CARB422 analytical data will provide compound-specific delineation within the soil vapor across the monitored network, and will allow for comparison with pre-shutdown compound-specific distributions based on prior TO-15 and CARB422 analyses. Data from the 8015D analyses will be used to evaluate the rebound of gasoline range organics (GRO) and diesel range organics (DRO) along with petroleum-specific hydrocarbons included in the standard method analyte list. The TSVH rebound trends, and locations in combination with the final compound-specific rebound analyses, will inform the decisions on SVE system expansion and operation and/or other vadose zone remediation techniques, as well as the locations for future coring to assess potential LNAPL in the vadose zone and at the water table interface.

3. SCHEDULE

Approximate durations for specific tasks associated with shutdown testing are provided below:

Pre-shutdown (3-5 days)	Conduct baseline sampling
Day 0	Shut down the SVE system
Day 0-14	Perform respiration monitoring (at frequencies based on real time data as described above) using the Horiba Model MEXA 584L.
Day 0-14	Short-term rebound monitoring (at frequencies based on real time data as described above) using the Horiba Model MEXA 584L.
Day 15-21	Daily rebound monitoring using the Horiba Model MEXA 584L.
Day 22-56	Weekly rebound monitoring using the Horiba Model MEXA 584L.
Day 57-98	Biweekly rebound monitoring using the Horiba Model MEXA 584L.
Day 99-154	Complete SVM network quarterly sampling event.
Day 155	Resume SVE system operation.

4. REFERENCES

EPA. 1995. *Manual, Bioventing Principles and Practice, Volume II: Bioventing Design*. September.

USACE. 2011a. *Vadose Zone Investigation Work Plan, Bulk Fuels Facility (BFF) Spill, Solid Waste Management Units ST-106 and SS-111, Kirtland Air Force Base, Albuquerque, New Mexico*. Prepared by Shaw Environmental & Infrastructure, Inc., for the USACE Albuquerque District under USACE Contract No. W912DY-10-D-0014, Delivery Order 0002. March.

USACE. 2011b. *Quality Assurance Project Plan, Bulk Fuels Facility (BFF) Spill, Solid Waste Management Units ST-106 and SS-111, Kirtland Air Force Base, Albuquerque, New Mexico*. Prepared by Shaw Environmental & Infrastructure, Inc., for the USACE Albuquerque District under USACE Contract No. W912DY-10-D-0014, Delivery Order 0002. April.

APPENDIX A

SOIL-VAPOR SAMPLING AND FIELD ANALYTICAL METHODS

Soil Vapor Sampling and Field Analysis Procedure, revised February 2015

1.1 Introduction

All field personnel collecting soil-vapor samples are required to be trained and fully understand the sampling procedure outlined in this document. Any and all questions will be addressed prior to the start of sampling. Prior to the start of the soil-vapor sampling in 2015, all SVM points and SVE wells will be capped and sealed to minimize barometric-pumping interferences on sampling and analyses. Sealing the points/wells will be done by securing an air-tight cap onto each point/well head and adding a pneumatic quick connect fitting to each point/well that will serve as a sampling port for ease of access and to ensure that an air-tight seal is maintained. Each well port will be examined by the field personnel to confirm the integrity of each fitting and to immediately address and mitigate any problems or replace any defective parts.

1.2 Pre-Sampling Steps

1.2.1 Horiba Model MEXA 584L Calibration

It should be noted that the Horiba instrument can effectively measure petroleum hydrocarbons, O₂ and CO₂, which are the three parameters of concern for monitoring the effectiveness of vadose zone remediation technologies such as SVE and bioventing. However, the Horiba is sold as an engine exhaust monitoring instrument and the use for soil-vapor monitoring is different than the manufacturer's intended purpose. While not the primary selling point of the instrument, the Horiba's sampling ability and the non-dispersive infrared detector (NDIR) and chemical cell detector make it a good instrument for TSVH, CO₂ and O₂ analyses.

Various engine exhaust and leak detection instruments are routinely used in the field for soil-vapor monitoring, but their use is often tailored to provide more representative data. CB&I evaluated the Horiba manufacturer's calibration procedure, which was developed for engine exhaust monitoring, and determined that a modified calibration method was in order to better ready the instrument for measuring soil-vapor petroleum hydrocarbon, O₂ and CO₂ concentrations. The modified calibration method will outperform the manufacturer's process for soil-vapor monitoring, and includes a more representative calibration/calibration-check gas, more frequent calibration than specified by the manufacturer, frequent calibration checks (TSVH, O₂ and CO₂) during daily Horiba usage, and real-time data analysis to look for indicators of potential calibration deviations. At the start, middle and end of each work day, the Horiba will be calibrated for petroleum hydrocarbons, O₂ and CO₂ against a calibration standard of known concentrations in a premixed gas cylinder. The same calibration gas cylinder will be used to calibrate every Horiba instrument at the same time and by the same person to ensure consistent calibrations. This calibration gas will consist of 1,600 ppmv propane, 13.0% CO₂, and the remaining volume will consist of nitrogen.

The instrument will be calibrated by applying the premixed gas into the calibration port located on top of the instrument (see the Horiba Instruction Manual for assistance in identifying this port). After calibration is confirmed, the same gas will be used to fill a 3L Tedlar[®] bag. The customized sampling system shown in Figure 1 will be used to complete the calibration as follows.

- Step 1 - Close all valves on the sampling system.
- Step 2 - Connect the Horiba to the sampling system.
- Step 3 - Open the valve on the Horiba port and ensure that the sampling system is purged according to the steps listed below under Section 1.2.2 Cross Contamination Purging for Sampling System.
- Step 4 - Once within the given values, attach the Tedlar[®] bag to the male pneumatic fitting at the bottom of the sampling system.

Step 5 - Open the Tedlar[®] bag valve to allow the calibration gas to be pulled through the sampling system.

Step 6 – Record the instrument readouts when the instrument has stabilized and compare the results to the calibration gas concentrations.

If the values for TSVH, O₂ and CO₂ are within 5% of the calibration values made using the calibration port, the calibration process is complete. If values are outside of this range, perform a leak check as described in Section 1.2.4 and follow the calibration process again.

If at any point during sampling, a reading for petroleum hydrocarbons, O₂ or CO₂ reaches an unreasonable value (e.g., an O₂ concentration greater than 21%) or if a data value falls outside the trend indicated by previous readings at a given SVM point, a calibration check will be triggered. The expected range of values for petroleum hydrocarbons is from 0 to 10,000 ppmv, 0% to 22% for percent O₂ and 0% to 10% for percent CO₂. If any readings are outside of this range, a calibration check must be made and if necessary the instrument will need to be recalibrated.

During respiration testing, O₂ readings could fall to near zero; however, tracking to 5% is all that is needed for calculating biodegradation rates and 5% is within the Horiba's detectable range.

1.2.2 Cross Contamination Purging for Sampling System

The sampling system must be purged with ambient air before being attached to a SVM point sample port to minimize the potential for cross contamination between sample collections. To ensure the entire sample train is thoroughly purged, attach the pump to the setup and flush air through each opening and valve. All valves are to be opened during this process. Monitor the purging effectiveness using the Horiba to ensure no contaminants are still present and ambient air is being read by the Horiba. Values for ambient air are less than 5 ppmv hydrocarbons, between 20% to 22% for percent O₂, and 0% for percent CO₂. Purging must be done after sampling each SVM point.

1.2.4 Leak Check

At the beginning of each day, the sampling system can be leak checked by using the pump to apply pressure to the system. Simply reverse the pump intake and exhaust with the valve open to allow air into the system. Apply a Snoop[®] solution (or similar soapy leak detection solution) to any and all joints and look for indications of leaks. If any leaks are present, address immediately before sampling. The system will also be tested for leaks during the static pressure measurement at each well as described below.

1.3 Sampling Procedures

1.3.1 Sample Train Setup

The Horiba must be turned on, warmed up, and calibrated and then attached to the sampling system. The Horiba is turned on for the first time at the beginning of the day and then remains in the on position throughout the day. The Horiba is plugged into the 12V DC outlet in the truck using an AC inverter. All other equipment will be powered by generator and can be powered off in-between wells. The pump is attached and sealed with clamps to the setup. It is important that no valves be open prior to turning on the pump.

1.3.2 Static Pressure Measurement

Before taking the static pressure reading, the manometer instrument must be zeroed to atmospheric pressure. The screen should read "0.00 in WC". Using the static pressure adapter (Figure 2), which includes a sample-port adapter and manometer, take and record the static pressure of the well in inches of

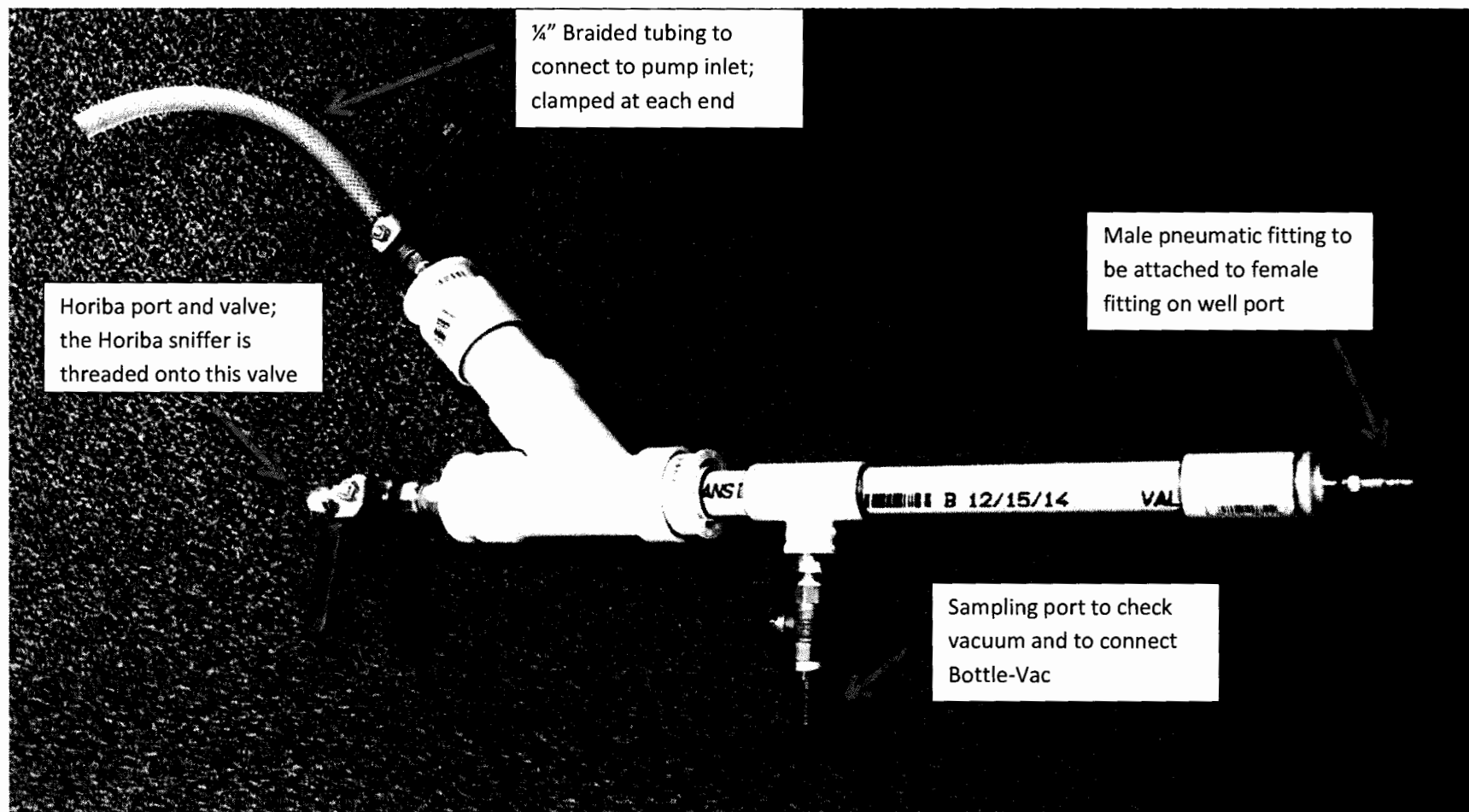


Figure 1. Soil Vapor Sampling System



Figure 2. Static Pressure Adapter



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NMED
Hazardous Waste Bureau

DEC 23 2014

Colonel Tom D. Miller
377 ABW/CC
2000 Wyoming Blvd SE
Kirtland AFB NM 87117-5600

Mr. Butch Tongate
Deputy Secretary
New Mexico Environment Department (NMED)
1190 St. Francis Drive, Suite N-4050
Santa Fe, New Mexico 87502

Dear Mr. Tongate

Attached please find the *Pilot SVE Shutdown Test Work Plan*. This letter WP will address the respiration and short-term testing, along with the long-term rebound testing, on selected soil vapor monitoring (SVM) wells. Data from this shutdown test will be used in the design of SVE expansion at the BFF site.

Please contact Mr. L. Wayne Bitner at (505) 853-3484 or at ludie.bitner@us.af.mil or Mrs. Victoria Branson at (505) 846-6362 or at victoria.branson@us.af.mil if you have questions.

Sincerely

TOM D. MILLER, Colonel USAF
Commander

Attachment: Pilot SVE Shutdown Test Work Plan

cc:

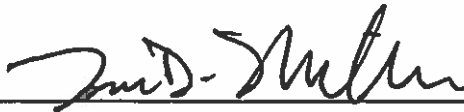
NMED-HWB (Kieling, Cobrain, Moats, McDonald, Brandwein) w/atth
NMED (McQuillan, Longmire) w/atth
NMED-GWQB (Schoeppner) w/atth
NMED-PSTB (Reuter) w/atth
NMED-OGC (Kendall) w/o atth
EPA Region 6 (King) w/o atth
AFCEC-CZRY (Bodour) w/ atth
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DECEMBER 2014**

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision according to a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fines and imprisonment for knowing violations.



TOM D. MILLER, Colonel, USAF
Commander, 377th Air Base Wing

This document has been approved for public release.



KIRTLAND AIR FORCE BASE
377th Air Base Wing Public Affairs



CB&I Federal Services LLC
2440 Louisiana Blvd. NE, Suite 300
Albuquerque, NM 87110
Tel: +1 505 262 8800
Fax: +1 505 262 8855
www.CBI.com

December 31, 2014

Subject: Kirtland Air Force Base Bulk Fuel Facility – Pilot Soil Vapor Extraction Shutdown Test Work Plan

This Kirtland Air Force Base (KAFB) Bulk Fuel Facility (BFF) Soil-Vapor Extraction (SVE) Shutdown Testing Letter Work Plan (WP) has been prepared by CB&I Federal Services LLC (CB&I) for the U.S. Army Corps of Engineers (USACE), Albuquerque District, under Contract No. W912DY-10-D-0014. This letter WP will address the respiration and short-term testing, along with the long-term rebound testing, on selected soil vapor monitoring (SVM) wells. Data from this shutdown test will be used in the design of SVE expansion at the BFF site.

1. SVE SHUTDOWN TESTING

During the shutdown test, respiration and rebound monitoring will be performed in tandem on select existing SVM wells. Respiration testing will provide data that will be used for accurate calculation of biodegradation rates in the vadose zone. Rebound testing is being conducted to evaluate soil vapor concentration recovery following the shutting down of the catalytic oxidizer (CATOX) system. The current CATOX system will be shut down for the approximate 3-month duration of rebound testing.

Due to the potential for regular SVM activities to impact the quality and accuracy of the data collected during shutdown testing, KAFB is requesting no quarterly SVM samples be collected in First Quarter and Second Quarter Calendar Year (CY) 2015. The data that will be collected during the proposed shutdown testing will facilitate an in-depth analysis of the remaining contamination in the vadose zone and the biodegradation rates associated with that contamination. The extended data set from the SVE shutdown test will advance our understanding of the conditions in the BFF vadose zone and will add value to the soil vapor data that are normally collected during the quarterly sampling events. That enhanced understanding of subsurface conditions will facilitate effective SVE expansion design and optimal SVE system operation. As such, it would be extremely beneficial to avoid interferences with the tests to ensure that the collected data are of the highest quality possible.

1.1 Baseline Sampling

Baseline measurements will be collected from each of the 287 SVM ports. Soil vapor baseline measurements will be collected in accordance with the methodologies outlined in Section 5.3 of the Vadose Zone Investigation Work Plan (USACE, 2011a) and Section 3.0 of the Quality Assurance Project Plan (QAPjP) (USACE, 2011b). The following parameters will be measured:

- Total hydrocarbons in parts per million by volume (ppmv)
- Percent oxygen (O₂)
- Percent carbon dioxide
- Vacuum/pressure (inches of water column [in. WC])

The CATOX system will be shut down using normal shutdown procedures outlined in Section 6.0 of the SVE System Operations and Maintenance Plan (August 2013). The wells currently connected to the CATOX system (KAFB-106149, KAFB-106150, KAFB-106154, KAFB-106160, and KAFB-106161) will be closed at the well heads prior to shutdown of the treatment system to prevent atmospheric air from

entering the wells and interfering with the initial measurements during the in situ respiration and short-term rebound testing.

1.2 In Situ Respiration and Short-Term Rebound Testing

The objective of the in situ respiration and short-term rebound testing is to provide an accurate representation of the biological activity and the residual contamination distribution in the BFF vadose zone. A total of 60 SVM wells will be included in the respiration and short-term rebound testing. All 30 of the SVM wells selected for the long-term rebound testing will be included in the respiration testing (see Section 1.3). An additional 30 SVM wells will be selected based on the results from the baseline testing. Candidate SVM wells will be selected to represent areas of high total petroleum hydrocarbon (TPH) [i.e., greater than 1,000 ppmv] and depressed oxygen concentrations (i.e., less than 19 percent), as well as areas with low TPH (i.e., less than 1,000 ppmv) and elevated oxygen concentrations (i.e., closer to ambient).

Following SVE shutdown, soil vapor will be sampled from the selected 60 SVM wells using the current sampling method in Section 5.3 of the Vadose Zone Investigation Work Plan (USACE, 2011a) and Section 3.0 of the QAPjP (USACE, 2011b). The initial sampling will be initiated 2 hours after SVE shutdown. Subsequent sampling frequencies for each SVM well will be determined based on the observed oxygen utilization rate. Any SVM wells demonstrating a higher oxygen utilization rate will be sampled on a more frequent basis. During the initial 24 hours of post-shutdown monitoring, a crew of three individuals will monitor the SVM wells during the day and night. Respiration monitoring will continue until oxygen concentrations decrease to less than 5 percent or 2 weeks is reached, whichever comes first.

The measured O₂ concentration will be used to create an oxygen utilization curve. An accurate biodegradation rate can then be calculated for the vadose zone. The TPH data from the short-term rebound will be utilized in the long-term rebound assessment (see Section 1.3).

1.3 Long-Term Rebound Testing

The objective of the long-term rebound testing is to allow sufficient time for contaminant concentrations in soil vapor to equilibrate from lower permeability lithology to provide accurate representation of the residual contamination distribution in the BFF vadose zone. A network of 30 SVM wells (Table 1) has been selected for the long-term rebound testing. The SVM wells were selected based on vapor data collected during Fourth Quarter CY 2012 and Second Quarter CY 2014, as these quarters represent the highest historical vapor data and the most recent vapor data, respectively. The SVE system area of influence is defined as the area within the 0.5-in. WC) vacuum isopleths, as reported in Appendix L of the Pre-Remedy Quarterly Monitoring Reports.

Table 1. Soil Vapor Monitoring Wells for Long-Term Rebound Testing

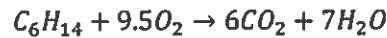
Well Number	Zone	Monitoring Depths
SVMW-03	Near edge of area influenced by soil vapor extraction (SVE)	100
		250
		350
SVMW-06	Inside area influenced by SVE	100
		252
		302
SVMW-10	Outside area influenced by SVE	100
		150
		250
KAFB-106112	Inside area influenced by SVE	250
		350
		450
KAFB-106113	Probably outside area influenced by SVE	350
		450
KAFB-106114	Near edge of area influenced by SVE	350
		450
KAFB-106116	Inside area influenced by SVE	350
		450
KAFB-106117	Inside area influenced by SVE	350
		450
KAFB-106119	Inside area influenced by SVE	150
		250
		350
		450
KAFB-106128	Inside area influenced by SVE	350
		450
KAFB-106129	Possibly influenced by SVE	250
		350
		450
KAFB-106130	Possibly influenced by SVE	350
		450

Following the short-term rebound test, long-term rebound SVM wells will be monitored daily for 1 week, weekly for 5 weeks and then biweekly until TPH concentrations become asymptotic or for three biweekly sampling events, whichever comes first. These samples will be analyzed for TPH (ppmv) using a Horiba Model MEXA 584 L portable auto emissions analyzer using the current sampling method in the Vadose Zone Investigation Work Plan (USACE, 2011a) and Section 3.0 of the QAPjP (USACE, 2011b). During the final bi-weekly monitoring event, soil vapor samples will be collected from each of the wells being monitored. Samples will be submitted to a laboratory for Method TO-15 analysis.

2. DATA ANALYSIS AND REPORTING

Biodegradation rates in the vadose zone are based on oxygen utilization rates, hydrocarbon oxidation stoichiometry, and relevant soil properties. Following the Bioventing Principles and Practice, Volume II (EPA, 1995), the oxygen utilization rate calculated from the field monitoring data is expressed as a percentage of oxygen as a function of time. Oxygen utilization rates will only be calculated for the linear portion of the curve, as it is an indicator that oxygen is not limiting, and is therefore indicative of active biodegradation.

Since the contamination at the BFF project site is hydrocarbons, hexane is used as the representative hydrocarbon for rate calculations. The stoichiometric relationship used for determination of degradation rates is therefore (EPA, 1995):



Based on the utilization rates, the biodegradation rate is estimated using the following equation (EPA, 1995):

$$-k_b = \frac{-\frac{k_o}{100} \theta_a \frac{1L}{1,000cm^3} \rho_{O_2} C}{\rho_k \left\{ \frac{1kg}{1,000g} \right\}} = \frac{-k_o \theta_a \rho_{O_2} C (0.01)}{\rho_k}$$

Where:

- k_b = biodegradation rate (milligrams/kilogram-day)
- k_o = oxygen utilization rate (percent/day)
- θ_a = gas-filled pore space (volumetric content at the vapor phase, cubic meters gas/cubic centimeter soil)
- ρ_{O_2} = density of oxygen (milligrams/liter)
- C = mass ratio of hydrocarbons to oxygen required for mineralization (1:3.5)
- ρ_k = soil bulk density (grams/cubic centimeter)

The value for k_o will be directly measured during the respiration monitoring as described in Section 1.2. The remaining input values will be based on data obtained from the site, if available, or from industry standards and approved literature. The value for θ_a has the most variability; however, since the respiration testing will be conducted at a low gas-filled porosity, the value can be estimated in accordance with the steps outlined in the EPA manual for Bioventing Principles and Practice, Volume II (EPA, 1995)

3. SCHEDULE

The anticipated dates for shutdown testing are as follows:

- Respiration and short-term rebound testing (begin mid-February 2015)
- Long-term rebound testing (March through June 2015)

4. REFERENCES

EPA. 1995. *Manual, Bioventing Principles and Practice, Volume II: Bioventing Design*. September.

USACE. 2011a. *Vadose Zone Investigation Work Plan, Bulk Fuels Facility (BFF) Spill, Solid Waste Management Units ST-106 and SS-111, Kirtland Air Force Base, Albuquerque, New Mexico*. Prepared by Shaw Environmental & Infrastructure, Inc., for the USACE Albuquerque District under USACE Contract No. W912DY-10-D-0014, Delivery Order 0002. March.

USACE. 2011b. *Quality Assurance Project Plan, Bulk Fuels Facility (BFF) Spill, Solid Waste Management Units ST-106 and SS-111, Kirtland Air Force Base, Albuquerque, New Mexico*. Prepared by Shaw Environmental & Infrastructure, Inc., for the USACE Albuquerque District under USACE Contract No. W912DY-10-D-0014, Delivery Order 0002. April.