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Subject: Submittal of the Interim Measures Progress Report for Soil-Vapor Extraction of Volatile Organic Compounds from Material Disposal Area L, Technical Area 54 and Response to the Approval with Modification for the Interim Measures Progress Report for Soil-Vapor Extraction of Volatile Organic Compounds from Material Disposal Area L, Technical Area 54, dated February 12, 2016

Dear Mr. Kieling:

Enclosed please find two hard copies with electronic files of the Interim Measures Progress Report for Soil-Vapor Extraction of Volatile Organic Compounds from Material Disposal Area L, Technical Area 54. The report summarizes the results from the first year of soil-vapor extraction operation at two vapor-extraction wells at Material Disposal Area L, Technical Area 54, from January 9, 2015, to November 18, 2015. Also enclosed are Los Alamos National Laboratory's responses to the New Mexico Environment Department's (NMED's) comments to the approval with modifications letter, dated February 12, 2016. NMED's comments have been incorporated into the progress report.

If you have any questions, please contact Kent Rich at (505) 665-4272 (krich@lanl.gov) or Ramoncita Massey at (505) 665-7771 (ramoncita.massey@em.doe.gov).

Sincerely,

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Sincerely,

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Enclosures: Two hard copies with electronic files
(1) Interim Measures Progress Report for Soil-Vapor Extraction of Volatile Organic Compounds from Material Disposal Area L, Technical Area 54 (EP2016-0054)
(2) Response to the Approval with Modifications for the Interim Measures Progress Report for Soil-Vapor Extraction of Volatile Organic Compounds from Material Disposal Area L, Technical Area 54 (EP2016-0070)

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EP2016-0054

Interim Measures Progress Report for Soil-Vapor Extraction of Volatile Organic Compounds from Material Disposal Area L, Technical Area 54

Los Alamos
NATIONAL LABORATORY
EST. 1943

Prepared by the Associate Directorate for Environmental Management

EP2016-0054

Interim Measures Progress Report for Soil-Vapor Extraction of Volatile Organic Compounds from Material Disposal Area L, Technical Area 54

May 2016

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EXECUTIVE SUMMARY

This interim measures progress report summarizes the results from the first year of soil-vapor extraction (SVE) operation at two vapor-extraction wells at Material Disposal Area (MDA) L, Technical Area 54. The SVE-West system began operation on January 9, 2015, and the SVE-East system began operation on January 26, 2015. Both the East and West systems were turned off for the winter on November 18, 2015. During the period of operation, the two SVE units removed 553 kg (1217 lb) of total organic vapor mass. The mass was primarily removed from within an approximately 150-ft radius surrounding the extraction wells.

Baseline pore-gas monitoring samples were collected from 185 pore-gas sampling ports in 28 boreholes within and surrounding MDA L in September 2014. Quarterly pore-gas monitoring samples were collected in April, July, and November 2015 from a subset of ports in 14 boreholes located within a 150-ft radius of the SVE units. Pore-gas sampling results confirm SVE operation has reduced the concentrations at the majority of sampling ports to below their baseline values. Data collected during the interim measure will be analyzed further as part of ongoing efforts to support the selection and design of a final remedy for MDA L.

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Appendixes

Appendix A Spreadsheet Containing Dwyer Orifice Plate Calculations (on CD included with this document)

Appendix B Analytical Suites and Results (on CD included with this document)

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Appendix D Field Log Book Entries, Purge Forms, and Chain of Custody Forms for Borehole 54-24399 (on CD included with this document)

Appendix E Flow Rate Data for SVE-West and SVE-East (on CD included with this document)

Appendix F Video Log of Borehole 54-24399 (on DVD included with this document)

Plate

Plate 1 Graphical Summary of Pore-Gas Monitoring Results for MDA L

1.0 INTRODUCTION

This interim measures (IM) progress report summarizes results from the first year of soil-vapor extraction (SVE) operation at two extraction wells at Material Disposal Area (MDA) L, Technical Area 54 (TA-54), within the boundaries of Los Alamos National Laboratory (LANL or the Laboratory). These activities were conducted in accordance with the "Interim Measures Work Plan for Soil-Vapor Extraction of Volatile Organic Compounds from Material Disposal Area L, Technical Area 54, Revision 1" (hereafter, the IMWP) (LANL 2014, 261843). The IMWP was submitted to the New Mexico Environment Department (NMED) on September 15, 2014, in response to requirements in NMED's "Approval with Modifications, Interim Measures Work Plan for Soil-Vapor Extraction of Volatile Organic Compounds from Material Disposal, Area L," dated July 17, 2014 (NMED 2014, 525053). Following 6 mo of operation, a progress report was submitted to NMED on September 28, 2015 (LANL 2015, 600930). On February 12, 2016, LANL received an approval with modifications to the 6 mo report (NMED 2015, 601243). Modifications requested by NMED are included in this progress report. The data in this progress report were collected from August 2014 to November 2015. Although initial plans were to run the SVE IM for a full year, concerns over damage to the system caused by freezing of condensation in the winter months led to modification of the plan and the SVE units were shut down in November 2015.

Remediation of the vapor plume by SVE is included as part of the recommended final remedy in the "Corrective Measures Evaluation Report for Material Disposal Area L, Solid Waste Management Unit 54-006, at Technical Area 54, Revision 2" (hereafter, the CME report) to meet the remedial action objective of preventing groundwater from being impacted above a regulatory standard by the transport of volatile organic compounds (VOCs) to groundwater through soil vapor (LANL 2011, 205756). The depth to regional groundwater beneath MDA L is on the order of 285 m (935 ft), whereas the vapor plume is predominantly within the Bandelier Tuff in the upper 90 m (300 ft) of the subsurface. The tuff units beneath the surface at MDA L are underlain by a thick (nearly 150-m [500-ft]) sequence of Cerros del Rio basalts. There is uncertainty regarding the long-term transport of vapors downward through the basalt toward the water table. Therefore, it is desirable to contain the plume above the basalt. The SVE IM is a proactive step to remove VOC mass, to decrease maximum VOC concentrations within the plume, to reduce the current extent of the vapor plume so it remains well contained within the upper tuff units, and to gather design information for a potential final SVE remedy.

1.1 Background

MDA L operated from the early 1960s to 1986 as the designated disposal area for nonradiological liquid chemical wastes, including containerized and uncontainerized liquid wastes; bulk quantities of treated aqueous waste; batch-treated salt solutions and electroplating wastes, including precipitated heavy metals; and small-batch quantities of treated lithium hydride. Waste was disposed of in 1 pit, 3 impoundments, and 34 shafts.

Disposal Shafts 1 through 34 were dry-drilled directly into the Tshirege Member of the Bandelier Tuff. The shafts range from 3 ft to 8 ft in diameter and from 15 ft to 65 ft in depth. The 34 disposal shafts were used to dispose of containerized and uncontainerized liquid chemical wastes and precipitated solids from the treatment of aqueous waste. Before 1982, containerized liquids were disposed of without the addition of absorbents. Small containers were typically dropped into a shaft. Larger drums were lowered by crane and arranged in layers of one drum in a 3- or 4-ft-diameter shaft, 4 to 5 drums in a 6-ft-diameter shaft, or 6 drums in an 8-ft-diameter shaft. The space around the drums was filled with crushed tuff, and a 6-in. layer of crushed tuff was placed between each layer of drums. Uncontainerized liquid wastes were also disposed of in the shafts. Between 1982 and 1985, only containerized wastes (including organic and inorganic liquids, precipitated heavy metals, and stabilized heavy metals) were disposed of in the shafts.

These shafts are the primary source for the subsurface VOC vapor plume that is present beneath MDA L (LANL 2011, 205756).

Soil-vapor monitoring boreholes located within and around MDA L have been used to characterize the nature and extent of the subsurface vapor plume at the site since 1986. Figure 1.1-1 shows the pore-gas monitoring boreholes at MDA L. Concentrations in the subsurface VOC plume are generally highest within 150 ft below ground surface (bgs) and decrease significantly with depth to the top of the Cerros del Rio basalt. Concentrations measured in the basalt are quite low, with values less than 1 ppmv.

The CME report used a two-tiered screening approach to identify the VOCs present at high enough concentrations within the vapor plume to potentially impact groundwater above a regulatory standard if they migrated to groundwater (LANL 2011, 205756). The analysis found vapor concentrations for 1,1,1-trichloroethane (1,1,1-TCA); trichloroethene (TCE); tetrachloroethene (PCE); methylene chloride; 1,2-dichloropropane (1,2-DCP); 1,1-dichloroethene (1,1-DCE); 1,2-dichloroethane (1,2-DCA); and 1,4-dioxane present within the tuff units at concentrations that exceed their Tier II screening levels (LANL 2011, 205756).

The hydrogeologic framework for the contaminated subsurface at MDA L is based on many years of data collection, including results from a 2006 pilot SVE test at the site (LANL 2006, 094152). The current IM uses the same two wells used during the pilot test: SVE-East and SVE-West (Figure 1.1-1). Data gathered in 2006 and subsequent analysis (Stauffer et al. 2007, 097871; Stauffer et al. 2011, 255584) provided IM estimates of expected total mass removal from the two SVE units.

2.0 OPERATION OF SVE UNITS

2.1 Description of SVE Units

The two SVE systems employed during the first 10 mo of SVE operation each have a main blower unit rated to 129 standard cubic feet per minute (scfm) at vacuum equal to 42.5 kPa (120 in. of water), a knock-out trap for liquid, various in-line flow and pressure-measurement instruments, and an off-gas stack to the atmosphere (Figures 2.1-1 and 2.1-2). The SVE blower systems are 11-ft-long × 3-ft-wide skid-mounted Model 4L SVE Blower Package systems provided by Catalytic Combustion Corp. of Bloomer, WI.

The SVE units pull subsurface gas from the open uncased part of the boreholes, 65 ft to 215 ft bgs. Condensed liquid (water) is removed in the SVE unit knock-out tank, and the effluent gas is filtered with a rough particulate filter to protect the blower from large particulate material that may be present. Untreated effluent gas from each SVE unit is then discharged through a stack located 21 ft above ground surface. Samples representative of the extracted gas are collected from a sample port (SP1) located between the blower and the exhaust stack. Each unit is equipped with a manual air dilution valve (V1) that was closed at all times (Figure 2.1-1).

The gas-flow rate is measured at each wellhead using a Dwyer Series PE Orifice Plate Flow Meter (Model PE-H-2) equipped with a Dwyer 0–25 in. of water Magnehelic Differential Pressure Gage. Flow rate is calculated using the measured differential pressure across the orifice plate, line pressure, and temperature using a formula provided by the manufacturer of the flow meter (Appendix A). This calculation is also corrected for a local atmospheric pressure of 80 kPa. Readings from the differential pressure gage, pipeline temperature, and pressure are recorded by the operator and used to calculate the instantaneous flow rate per Detailed Operating Procedure ER-DOP-20242, Soil Vapor Extraction System Setup, Operation, and Monitoring Procedure. During the first 3 wk of operation, each system was monitored 7 d/wk. Following the first 3 wk of operation, each system was inspected and monitored by the operator a minimum of 4 d (Mondays through Thursdays) each week.

2.2 Data Collection Methods and Results

SUMMA canisters were used for both SVE gas effluent and subsurface pore-gas sampling. All SUMMA samples were analyzed by an independent analytical laboratory, Eurofins Air Toxics, Inc., using U.S. Environmental Protection Agency (EPA) Method TO-15. Eurofins Air Toxic is a National Environmental Laboratory Accreditation Program–certified laboratory. The data are entered into the Environmental Information Management (EIM) database and undergo a secondary validation. EIM is the official database for environmental data collected by both the Laboratory and NMED. Table 2.2-1 lists the organic compounds analyzed by EPA Method TO-15 from samples collected from the effluent streams of the active SVE units and subsurface pore-gas sampling ports. Analytical results from samples collected during the first 10 mo of SVE operation are presented in Appendix B (on CD).

All data analyzed by Eurofins Air Toxics using the EPA Method TO-15 are reported to the Laboratory in units of ppbv. To convert from ppbv to ppmv, one divides by 1000 as: $C_{ppmv} = C_{ppbv}/1000$. Both ppmv and ppbv are used in this report. Concentrations expressed as ppmv or ppbv are independent of temperature or pressure. Further, NMED has requested that the Laboratory provide concentrations in μg/m^3, and these units are included in Appendix B. To convert between the two units, one must know the molecular weight of the contaminant and that of air as well as the density of air, which is a function of temperature and pressure. Air is a mixture of many gases but can be approximated as having a molecular weight of 29 g/mol. The primary VOC at MDA L, TCA, has a molecular weight of 133 g/mol. Assuming the density of air on the mesa (top elevation, average atmospheric pressure, and temperature of 2072 m, 80 kPa, and 10°C: 6800 ft, 11.6 psi, and 50°F) is approximately 1 kg/m^3, a concentration of 1000 ppmv TCA can be converted to μg/m^3 as follows:

$$1000 \text{ ppmv} = 1000 \text{ moles TCA}/1\text{e}6 \text{ moles air}$$

$$1000 \text{ moles TCA} * 133 \text{ g/mol} * 1\text{e}6\ \mu\text{g/g} = 133.\text{e}9\ \mu\text{g TCA}$$

$$1\text{e}6 \text{ moles Air} * 29 \text{ g/mol} * 1 \text{ m}^3\text{/kg} = 29{,}000 \text{ m}^3$$

Yielding

$$133.\text{e}9\ \mu\text{g}/29{,}000 \text{ m}^3 = 4.6\text{e}6\ \mu\text{g/m}^3$$

Within Laboratory databases, units of ppbv provided by the analytical laboratory are converted to μg/m^3 using the assumption of constant gas density at standard pressure and temperature (101.325 kPa, 25°C) with conversion factors for each compound based on individual molecular weights. Because the actual pressures and temperatures are not constant for each measured sample, this required assumption of the conversion from ppbv to μg/m^3 introduces an error into the μg/m^3 values that could be up to 20% (Stauffer et al. 2007, 097871).

2.2.1 Effluent Gas from SVE Units

Effluent gas from each SVE system was sampled in accordance with the sampling plan outlined in the IMWP (LANL 2014, 261843). Section 12[2] of ER-DOP-20242 outlines the steps taken to collect the gas sample from sampling port SP1 on each unit (Figure 2.1-1). Data were collected by connecting tubing from port SP1 to the SUMMA canister. The SP1 was then opened, followed by opening of the SUMMA canister valve. The SUMMA vacuum is audible and when the sound associated with filling the canister stops, the SUMMA valve is closed. Samples were collected in SUMMA canisters more frequently early in the operation of the system. As operation of the system continued and the vapor concentrations of VOCs were observed to level out, the sampling frequency decreased. Section 2.3.1 of this report presents the SVE effluent sampling schedule.

2.2.2 Calculation of Mass Removal from SVE Effluent and Gas Flow Rate

Calculation of mass removal is based on two principles: numerical integration of the flow and concentration data and interpolation of the results to the desired date. Numerical integration is based on the trapezoid method and the interpolation is always linear. No results are extrapolated beyond the last measurement.

The first step in the numerical integration is the calculation of the volume of the gas pumped. The flow versus time curves are integrated, producing two curves of volume pumped versus time: one each for the West and East SVE units. Total pumped volume versus time is produced by adding West and East curves. The addition process includes interpolation of the results from the West volume versus time curve to the time from the East curve. This is necessary because the West and East values are not measured at exactly the same time.

In the second step, concentration versus time columns are (virtually) constructed, transferred to the concentration versus volume scale (using volume pumped values from the first step) and numerically integrated, producing total mass removed. The “concentration” in this process may be a concentration of the individual compound or a total concentration (sum of all concentrations). Finally, the West and East mass removal curves are added together using interpolation. Example calculations for effluent mass removal are included in Appendix C.

VOC concentrations from SUMMA samples are reported by the analytical laboratory in ppbv units. Laboratory values are stored in the EIM database as “Laboratory Result.” The EIM database recalculates the ppbv concentrations to $\mu g/m^3$ values using molar mass, and standard temperature and pressure (101.325 kPa, 25°C). Recalculated values (in $\mu g/m^3$) are stored by the database as “Reported result,” and these data were used to calculate total mass removed.

2.2.3 Subsurface Pore-Gas Sampling

Subsurface pore-gas sampling was performed in accordance with the current version of Standard Operating Procedure EP-ERSS-SOP-5074, Sampling Subsurface Vapor. Baseline samples were collected from pore-gas sampling ports in 28 boreholes (Table 2.2-2). Quarterly samples were collected from a subset of ports in 14 boreholes located within a 150-ft radius of the SVE units (Table 2.2-3). At location 54-24399, a packer system is used to collect pore-gas samples from an open borehole interval.

Sampling involves a set of steps for each well and port. This process begins when a well is opened, and a radiological control technician (RCT) monitors the well for radioactivity. If the activity levels are less than 20 $\mu Ci/m^3$, each port is opened and the RCT monitors the area above each port within 2 in. of the opening. If any ports are found to be higher than 20 $\mu Ci/m^3$, the port is allowed to breath and then is monitored again. Next, the sampling team records static subsurface pressure with a handheld digital manometer. Once static pressure has been measured, the sample port is connected to the sample train shown in Figure 2.2-1.

A dedicated packer system and sampling line are used to collect samples at borehole 54-24399. The packer and air-line fittings are tested for leaks before the packer system is sent downhole. A drill rig is used for lowering and raising the packer system into the borehole. Once the packer is positioned at the correct depth, it is inflated with pure nitrogen (99.99%) to the desired inflation pressure according to the manufacturer’s specification. The sampling line is then connected at the surface to the sample train.

The sample train consists of tubing that connects the sample port to a pair of isolation valves. The isolation valves allow the SUMMA canister to be bypassed during purging. The sample train continues past the isolation valves into a Sierra Instruments Top-Trak Mass Flow Meter that displays the purge rate and total purge volume in standard liters per minute. The flow meter is connected to a Brailsford & Company single-head portable pump that produces a flow rate of 4 to 5 L/min. Exhaust from the pump is routed through a Geotech MultiRAE portable screening instrument that measures CH_4, O_2, VOC, and CO_2. The MultiRAE is the final piece of the sample train, and exhaust from this instrument is allowed to vent to the atmosphere.

After the sampling train is assembled, the isolation valves are opened (SUMMA is closed at this point), and the sample port is purged for 10 min at a flow rate of 4 to 5 L/min. At the beginning of purge, the ambient surface air concentrations of CH_4, O_2, VOC, and CO_2 are recorded on a purge form. After 10 min, CH_4, O_2, VOC, and CO_2 readings are taken and recorded every minute for 3 min. If readings are stable and within 10% of one another, the pump is turned off and the isolation valves are closed. Next, the valve on the SUMMA canister is opened and the vacuum pressure is checked to ensure the SUMMA canister is at the required initial vacuum. The isolation valve on the sample port side of the sampling train is then opened to allow subsurface gas to flow into the SUMMA canister. Once the pressure gauge equilibrates back to ambient pressure from the lower SUMMA suction pressure, the SUMMA valve is closed. The time of the sample collection is recorded in the log book, on the purge form, on the chain of custody, and on the identification tag of the sample. Log book entries, purge forms, and chain-of-custody forms for borehole 54-24399 are included in Appendix D. At the completion of each sampling day, the SUMMA samples are taken to the Laboratory's Sample Management Office (SMO) for shipment to the analytical laboratory.

In some cases, sample ports were determined to be either fully blocked or partially blocked. In an effort to ensure data quality, ports that are either fully or partially blocked on two consecutive sampling events are assumed to be adversely impacted and are subsequently removed from the sampling plan.

2.3 Data Collection Schedule

2.3.1 Effluent Data from SVE Units

Gas samples were collected in SUMMA canisters from the two SVE systems effluent sample port (SP1) according to the following schedule:

1. Day 1 and Day 2 of operation: Four samples were collected each day.
2. Next 3 wk: One sample was collected each day (closure of the Laboratory prevented collection of one sample daily during this period).
3. Next 9 to 11 wk: One sample was collected weekly (generally on Wednesday of each week).
4. Beginning April 15, 2015, for SVE-West and May 6, 2015, for SVE-East: One sample was collected monthly on the first Wednesday of each month.
5. Monthly sampling of the SVE system effluent continued until the SVE units were shut down in November 2015.

2.3.2 Subsurface Pore-Gas Data

Subsurface pore-gas samples were collected from a round of baseline sampling (referred to as Baseline 2014 or September 2014) from late August to early October 2014, and three quarters of sampling from boreholes located within a 150-ft radius of the SVE units in April and May 2015, July 2015, and November 2015. The baseline data collection was repeated in February 2016. However, because of time requirements for analytical laboratory turnaround and data validation, only the results of Baseline 2014 and sampling during the three quarters are presented in this report. Analytical results are included in

Appendix B (on CD). Blockages and radiological screening results prevented sampling at some ports during annual and quarterly sampling. Tables 2.2-2 and 2.2-3 show the ports from wells sampled during each round, and notes are included to indicate why certain samples could not be collected. If a port failed because of blockage or partial blockage for two quarters in a row, the port was removed from the sampling plan.

2.4 Summary of SVE System Operations

The SVE-West system operated from January 9, 2015, to November 18, 2015, at an average flow rate of 99.3 scfm. During this period, the system was operational 99.0% of the available time. The system shut down five times: on January 24, 2015, because of a sitewide power failure; on February 23, 2015, because of ice buildup in the water knock-out tank; and on August 8, October 21, and October 22, 2015, when lightning caused power outages in the area. The SVE-West system was also shut down for very short periods for maintenance.

The SVE-East system operated from January 26, 2015, to November 18, 2015, at an average flow rate of 97.5 scfm. During this period, the system was operational 99.0% of the available time. The system shut down four times: on February 23, 2015, because of ice buildup in the water knock-out tank; and on August 8, October 21, and October 22, 2015, when lightning caused power outages in the area. The SVE-East system was also shut down for very short periods for maintenance.

Water has condensed in the knock-out tank of both systems during periods of cold weather. Generally, water vapor in extracted pore gas condenses and is captured in the knock-out tank when the ambient air temperature drops below freezing for an extended period of time. More water was generated in the SVE-West unit probably because it is shaded in winter and does not warm from exposure to the sun. Approximately 200 gal. of condensed water was generated through November 2015 from the operation of both SVE units. The condensed water was characterized as nonradioactive and nonhazardous and was disposed of at the Laboratory's Sanitary Wastewater System Consolidation treatment facility.

3.0 SUMMARY OF SUBSURFACE PORE-GAS BASELINE RESULTS

Baseline pore-gas samples were collected in August and September 2014 from 185 individual gas sampling ports in 28 boreholes within and surrounding MDA L. These data were used to estimate the total plume mass of two primary constituents: TCE and 1,1,1-TCA. These constituents were selected because they have historically constituted more than 60% of the estimated plume mass (Stauffer et al. 2005, 090537; Stauffer et al. 2007, 097871; LANL 2011, 205756; Stauffer et al. 2011, 255584). The mass of 1,1,1-TCA and TCE was calculated using three-dimensional (3-D) data-interpolation techniques described more fully by Weston Solutions, Inc. (Weston 2015, 600886). Assumptions in this technique include fixed subsurface water saturation within each geological unit, fixed Henry's Law partitioning into subsurface pore water, fixed sorption parameters, and a small component (0.05%) of organic carbon within the subsurface. Given these assumptions, the baseline 1,1,1-TCA plume mass in September 2014 was estimated to be 740 kg (1628 lb), while the TCE plume mass was estimated to be 343 kg (755 lb). The baseline plume is discussed further in section 4.

4.0 SUMMARY OF SVE RESULTS

4.1 Effluent Mass Removal

From January 9, 2015, to November 18, 2015, the combined VOC mass removal from the two SVE units is calculated to be 553 kg (1217 lb). Figure 4.1-1 shows the cumulative mass removal versus time for both SVE units as well as the cumulative volume of soil-gas pumped from the subsurface by both SVE units. The slopes of both the mass removal and volume pumped curves change when the SVE-East unit became active on January 26, 2015.

Figure 4.1-2 shows the rate of mass removal for the combined extraction from both SVE units in pounds per week. The activation of SVE-East on January 26, 2015, resulted in an increase in mass removal from 35 lb/wk to nearly 60 lb/wk. The mass-removal rate then decreases over time to 23 lb/wk in July 2015. By November 2015, the rate decreased to about 17 lb/wk. The long tail in the mass removal curve shows the SVE systems continue to be effective after 10 mo of operation.

Table 4.1-1 lists the mass removed for each detected organic compound during SVE operations. Out of 62 analytes measured using the TO-15 panel, only 24 have reported detections in the SVE effluent. Of the total 1217 lb removed, 1,1,1-TCA was the highest constituent at over 44% (541 lb); TCE comprised 21% of the mass extracted (259 lb); Freon-113 (1,1,2-trichloro-1,2,2-trifluoroethane) was third at 10% (117 lb); and PCE was the fourth most prevalent component in the effluent at 9% (110 lb). Other significant mass removals include 1,2-DCA (46 lb); 1,1-DCE (34 lb); 1,2-DCP (29 lb); and chloroform (24 lb). Together these constituents comprised 95% of the total extracted mass.

Tables 4.1-2 and 4.1-3 list the flow rates for SVE-West and SVE-East, respectively. These flow rates were calculated using observed wellhead pressures and orifice plate pressure differentials as described in Section 2.1. Flow rate data for SVE-West and SVE-East are included in Appendix E (on CD).

4.2 Concentrations in the SVE Effluent

Concentration reductions in the effluent from the two SVE units are presented in Figure 4.2-1. The five analytes with the greatest mass removal (TCA, TCE, PCE, Freon-113, and 1,2-DCA) were selected to illustrate the decreases in concentrations in the effluent with time. Effluent concentrations from both systems decrease with time for all analytes, with larger decreases in concentrations seen for SVE-West. On both east and west sides of the site, PCE concentrations are reduced by smaller fractions of their initial values than are other constituents. The larger reduction in all concentrations on the west side of MDA L is likely because the SVE-West system is located closer to the western source region than is the SVE-East system to the eastern source region and because the total plume on the west side is smaller (Figures 1.1-1 and 4.3-2).

Figure 4.2-2 shows how the molar ratios of these compounds evolved during the 10 mo of SVE operation. Molar ratio is defined as the number of moles of a given compound divided by the total number of moles of organics measured in the TO-15 suite. Because ppbv is a measure of molar volumetric concentration (volume fraction per total volume) and volume is directly proportional to the number of moles, molar ratio is derived by dividing the ppbv of a given analyte by the sum of all measured analytes in ppbv at a given port (see Appendix B for the lists of analytes found at each port). Initially, for SVE-West, TCE decreased rapidly as a mole fraction of the plume while PCE increased. Beginning in around August 2015, TCE reached a steady percentage while TCA began to drop with a further increase of PCE molar fraction. For SVE-East, small changes occurred in the percentages of the major constituents, with TCA decreasing and TCE, 1,2-DCA, and PCE increasing while Freon-113 appeared to maintain a relatively constant mole fraction.

4.3 Subsurface Plume Changes Relative to Baseline 2014

Samples for the first quarter of 2016 were collected between November 4 and 12, 2015, from 44 sampling ports in 14 boreholes that lie within approximately 45.7-m (150-ft) radius of each of the SVE units. Table 2.3-1 shows that the number of ports sampled was reduced in this quarter because of a combination of port plugging and radiological screening, thus preventing samples from being collected during certain events. Plate 1 presents color bars for the main constituents at each of the 2015 quarterly sampling locations compared with Baseline 2014 data at a range of depths. The sum of each color segment is the total ppmv of a given sample. Most of the concentration plots have the same maximum scale (600 ppmv), allowing for comparison of relative plume concentrations. The maximum scale for wells 54-02089 and 54-24238 are 1200 ppmv because of the increases in concentrations observed in July and November 2015. On the east side of the site, boreholes 54-02002, 54-24243, and 54-24241 show large decreases in measured total organics as a result of SVE operations. On the west side, boreholes 54-24240, 54-27641, and 54-02001 show the strongest decreases in concentration from SVE operations. Boreholes 54-02089 and 54-24238, located in the east source region, both show increases in concentrations. The Laboratory is investigating why concentrations at these locations are increasing.

Figure 4.3-1a plots concentrations for seven analytes from each borehole around SVE-East and SVE-West that were sampled for both the Baseline 2014 and November 2015 (553 points in total). Data in this plot are for 1,1,1-TCA; TCE; PCE; 1,2-DCA; 1,1-DCE; 1,2-DCP; and methylene chloride. Dashed black lines above and below the red 1:1 line show typical ±30% uncertainty in reproducibility of subsurface gas concentration measurements. Baseline 2014 concentrations are plotted on the horizontal axis, while November 2015 concentrations are plotted on the vertical axis. Figure 4.3-1a shows the decreasing trend in concentrations that occurred during the first 10 mo of SVE operation. If the SVE system had no impact on subsurface concentrations, the data would plot on or close to the 1:1 line shown in red in the figure. However, most of the points fall below the 1:1 line, indicating the SVE system has reduced the concentrations at the majority of sample ports below their baseline values. Points are colored by borehole, indicating the boreholes that are the most impacted. Figure 4.3.1b shows how the subsurface surrounding the SVE system responded over three quarters of sampling. The green points from April 2015 have slightly more scatter around the 1:1 line, while July 2015 and November 2015 both show the majority of the measurements to be well below the 2014 baseline sampling concentrations. Again, a few points in boreholes 54-02089 and 54-23238 show increases above background, with an increasing trend for each of the three quarters presented. These points lie above the 1:1 line, having the same background concentration value (x-coordinate), and progress from green upward to purple and finally to yellow. The Laboratory is investigating why concentrations at these locations are increasing.

4.3.1 Weston Data Interpolations

Figures 4.3-2 and 4.3-3 show 1,1,1-TCA plume images generated by data interpolation for the Baseline 2014 and third quarter 2015 data, respectively (from Weston 2015, 600887). Data are shown with dots, while the interpolation is shown on a contoured color scale with both color contour lines and contour shading. The contour intervals are based on multiples of Tier I screening values used in the CME report (LANL 2011, 205756). Tier I screening uses only Henry's Law partitioning to determine if a given vapor concentration exceeds groundwater standards, assuming the vapor is in contact with groundwater. The post-SVE image (Figure 4.3-3) shows a decrease in both the spatial extent of most individual concentration contours and the overall magnitude of the 1,1,1-TCA plume.

Figures 4.3-4 and 4.3-5 show similar information for TCE (from Weston 2015, 600887). Again, the extent of a given contour is reduced, and maximum concentration contours are also reduced. For example, the highest concentration of TCE in Figure 4.3-4 on the west side of the site is well into the 250 times (red) color shading, while in third quarter 2015 (Figure 4.3-5) the maximum concentration contour shading is reduced to 100 times (orange).

Using the data interpolation techniques, a comparison of the third quarter 2015 data and corresponding models and mass estimates to those of the Baseline 2014 suggests substantial (~30%) SVE-induced mass reductions in both the 1,1,1-TCA and TCE plumes.

The Weston analysis was not performed with the data collected from the two later quarters; however, another interpolation will be performed after data from the larger-scale annual sampling in February 2016 (second quarter 2016) are returned, and the updated analysis will be included in the next SVE IM progress report.

4.3.2 Effectiveness of SVE at Selected Boreholes

In Figures 4.3-6 through 4.3-14, data from a subset of nine boreholes are presented showing concentration versus depth for 1,1,1-TCA; TCE; PCE; and 1,2-DCE for each of the three quarters after the start of SVE compared with Baseline 2014 data. In all of the depth-dependent plots, Baseline 2014 data are shown in dark blue, while lighter colors show the quarterly data collected while the SVE system was running.

SVE-West

Figures 4.3-6 and 4.3-7 show concentration data from boreholes 54-27641and 54-24240, respectively, both within a 30-ft radius of SVE-West. These boreholes both show similar concentration reductions within 150 ft bgs, and mass removal appears to be especially effective in the top 50 ft bgs, with drops of close to 2 orders of magnitude at this depth range. This region may be impacted by flow of fresh air from the atmospheric boundary being pulled toward the low-pressure region created by the SVE system. The effectiveness of the SVE is observed to decrease with depth in borehole 54-27641, especially at depths below 150 ft. The data from April 2015 (third quarter 2015) show an anomalous increase in concentration at 340-ft depth; however, this anomaly is not observed in the next two quarters of data, where concentrations return to values in the pre-SVE baseline sampling.

Borehole 54-02022, shown in Figure 4.3-8, is located more than 150 ft from SVE-West. This borehole shows concentration decreases to a depth of 200 ft. Data from the April 2015 are again anomalous, showing concentration increases above the pre-SVE baseline at depths below 150 ft; however, both the July 2015 and November 2015 sampling rounds show decreases in all four analytes at all depths. The strong decreases of both TCA and TCE at 200 ft bgs suggest the radius of influence (ROI) for the SVE West extraction well may be greater than 150 ft.

SVE-East

Figures 4.3-9 and 4.3-10 show data for boreholes 54-24243 and 54-24241, located 54 ft and 83 ft radially from SVE-East. Both show strong impacts from SVE, with concentration decreases between 3 times to 100 times in many ports. However, borehole 54-24243 shows the stronger impacts nearer to the surface while 54-24241 shows the strongest impacts between 100 ft to 200 ft bgs. One explanation for these differences is that borehole 54-24243 is in an area with no asphalt where infiltration of atmospheric air through the surface can occur, while 54-24241 is near the center of the paved portion of MDA L. One anomaly in the data is for 1,2-DCA in borehole 54-24241, where concentrations have risen at ports lying vertically above 100 ft bgs, and no explanation for this increase has been ascertained.

The deepest borehole at MDA L, 54-24399, lies very close to borehole 54-24241; however, this well is cased from the surface to a depth of 565.5 ft bgs. Samples from this well are shown in Figure 4.3-11, with concentrations of all analytes dropping significantly from the pre-SVE baseline. The large drop in concentrations at this depth is not expected based on the conceptual model of flow and transport at the site, where the pressure perturbation from the SVE units is not expected to propagate to depths much below 250 ft bgs. The original plan to collect data from a 1-ft interval at the top of the uncased section (568–569 ft bgs) using a dual-packer system was abandoned after the April 2015 sampling event after the lower packer was shredded when it came in contact with vesicular basalt. Subsequently, video logs of the open hole were generated showing a short section of massive basalt near the top of the uncased section followed by vesicular basalt, some having large voids and very sharp rock formations (Appendix F on DVD). The depths indicated in the video are inaccurate because of issues with the camera equipment. The depth to the bottom of the casing was also revised from 568 ft to 565.5 ft bgs after further review of the original drilling log (LANL 2005, 092591). Because of the risk of damage to packers from sampling the uncased section of the borehole below the casing, sampling with the dual-packer system was removed from the sampling plan.

Borehole 54-27642 is located about 130 radial feet from SVE-East and shows reductions in concentration with greater efficiency at shallow depths (Figure 4.3-12). Borehole 54-27642 is located near the edge of the paved portion of the site and shows appreciable reductions in concentration to 150 ft bgs, with less impact observed at greater depths. The large reductions in concentration in this borehole also suggest that the 150-ft ROI may be conservative with respect to design of a corrective measures SVE system as discussed in the CME report (LANL 2011, 205756).

Boreholes 54-02089 and 54-24238 are approximately 70 ft and 100 ft from the SVE-East extraction well and are fairly close to the eastern disposal shafts (Figure 1.1-1). Many of the ports in these wells show increased concentrations for all analytes, particularly at the deepest 89 ft ports (Figures 4.3-13 and 4.3-14). Only in the shallowest ports are concentrations reduced and only for certain analytes (TCA in both holes, and all four analytes shown in 54-02089). The Laboratory continues to analyze these data and has not determined the cause for the increases in concentration.

Figure 4.3-15 shows measured air permeability relative to the approximate geologic units mapped at MDA L. Of note are the changes in permeability at the geologic contacts between units Qbt 1g and Qbt 1v and between subunits Qbt 1v-c and 1v-u. This figure indicates possible impacts of geological structure on VOC concentrations measured in the subsurface.

Gradient Reversals

In section 3.3.1 of the IMWP (LANL 2014, 261843), it was hypothesized that

> [with] maximum concentrations lower in the source regions, vapor transport will reverse direction, and VOCs will diffuse from deeper in the plume back toward the surface. This reversal of the diffusion gradient would limit deeper migration into the underlying basalt and potentially toward groundwater.

Borehole 54-27641 clearly demonstrates such a reversal in concentration gradient. Figure 4.3-6 shows that before SVE operations, concentrations were highest near the surface with lower concentrations at depth, a situation that would tend to move mass to depth from high to low concentrations via diffusion. Thus, in Figure 4.3-6, TCA mass at 150 ft bgs would diffuse downward along the concentration gradient. However, this trend has been reversed by the impacts of the SVE system. At the end of the active SVE operation in November 2015, when the primary mass transport mechanism switches from advection back to diffusion, the concentration gradient (from high to low concentration) at 150 ft bgs has reversed to an upward direction, meaning that diffusion will transport mass at 150 ft bgs following the concentration gradient toward the surface and will aid in remediation. Similar gradient reversals have been observed in borehole 54-24240 at 100 ft bgs and in borehole 54-24243 at 80 ft bgs. However, reversal of the concentration gradient is not ubiqitous, and boreholes 54-27642, 54-02022, and 54-24241 show concentration reductions at all depths without reversals of their concentration gradients.

4.4 Differential Pressure Measurements

Subsurface differential pressure measurements were made at pore-gas sampling ports in boreholes sampled during SVE operations. Measurements were made during the baseline sampling in August and September 2014, in April 2015, in July 2015, and in November 2015. For these measurements, one input on a digital manometer is connected to a subsurface gas sampling port, while the other input is left open to the atmosphere. The manometer then records the difference in pressure between the subsurface port and the atmosphere. Table 4.3-1 shows the results of the pressure measurements for 189 ports in the 28 boreholes for the baseline and a subset of these for the three quarterly sampling events (April 2015, July 2015, and November 2015).

To understand the potential usefulness of these data, it is helpful to first review measurements made at MDA L in the 1990s. Neeper (2002, 098639) presents atmospheric and differential subsurface pressure data from boreholes near MDA L. These data show that the atmosphere can change pressure by more than 1.5 kPa over the span of a few days (Neeper 2002, 098639, Figure 3). Subsurface pressure changes in response to atmospheric pressure; however, pressure changes in the subsurface are shifted in time and reduced in amplitude, based on their ability to connect to the atmosphere. The amplitude of subsurface pressures within the Bandelier Tuff decreases, and maximum deviations from average pressure are shifted to later times with increasing depth. Neeper (2002, 098639) presents data collected from a borehole located 100 m (328 ft) to the east of the site that show almost no pressure difference between the atmosphere and a port at the depth of 11 m (36 ft). However, at depths of 77 m and 103 m (250 ft and 338 ft), the amplitude of the pressure wave is depressed, and the phase is shifted such that maximum differential pressure between atmospheric pressure and downhole pressure varies between +0.6 kPa and −0.6 kPa, with the maximum downhole deviation from average pressure occurring up to 0.33 d after the maximum atmospheric deviation.

Given the variability expected in subsurface differential pressure, it is difficult to attribute many of the measured values presented in Table 4.3-1 to the SVE systems. However, some ports at boreholes 54-24240, 54-24241, and 54-27641 show strong signals that are likely impacted by the SVE suction. Additionally, some of the shallower pressure measurements should be less impacted by shifts in magnitude and phase, allowing smaller pressure differences to be attributed to the SVE units. Further analysis using daily pressure variations at the time of the sampling could allow more refined estimates of the extent of pressure propagation from the SVE units and may reduce unexpected variability observed in data collected between third quarter 2015 and first quarter 2016. Such analysis requires the use of layered permeability models to separate out the effects of natural-phase shift and amplitude reduction from those caused by SVE at individual ports.

5.0 NUMERICAL ANALYSIS

This section presents results from simulations of the SVE interim measure. This section begins with a brief review of previous work on modeling in support of decision analysis undertaken at MDA L. Next is a description of the generation of an initial pre-SVE simulated plume corresponding to the period just before the IM was initiated in January 2015, after which simulation results generated in December 2014 are presented for predicted plume behavior, comparing the predicted results to those obtained during the SVE IM. Finally, differences between predicted and observed behavior are discussed and with emphasis on how these differences impact previous recommendations for long-term corrective measures.

5.1 MDA L Vapor Plume Modeling Review

A 3-D numerical model of the VOC vapor plume in the subsurface at MDA L is developed using a site-scale numerical model. The porous flow simulator Finite Element Heat- and Mass-Transfer (FEHM) is used for all calculations (Zyvoloski et al. 1997, 070147). The numerical simulations account for diffusion, advection, partitioning between liquid and vapor, variable saturation and porosity, an atmospheric boundary, two discrete source release locations, an asphalt cover, and topography. Figure 5.1-1 shows the numerical 3-D model domain and the site boundary of MDA L. The numerical domain contains more than 140,000 finite volume elements with a lateral spacing of 25 ft. The domain extends from the topographic surface to the water table and contains two high-resolution regions around the SVE boreholes.

The site-scale numerical model has evolved over many years (1999–2016) and has been used to evaluate the nature and extent of the subsurface plume at MDA L associated with waste disposal. As a surrogate for the entire plume, the contaminant with the highest subsurface concentrations (1,1,1-TCA) was selected to reduce the complexity of the simulations. The numerical model includes a 2006 SVE pilot test of less than 1-mo duration that was used to calibrate permeability at MDA L by matching flow rate versus pressure drop simultaneously with concentrations in the exhaust gas (Vrugt et al. 2008, 104951). The calibrated model parameters were then used to initiate model validation that started from the pre-SVE test in 2006 and was used to predict plume concentrations in the year 2010. Results from this effort yielded a data/model correlation coefficient (r^2) for over 150 data model pairs of greater than 90%. The ability of the model to align with data after 4 yr that include two active SVE demonstration tests provided confidence that the model captures the dominant physical transport processes at this site. The validated numerical model was next used to explore scenarios related to the possible role of SVE as a corrective measure at MDA L (LANL 2011, 205756; Stauffer et al. 2011, 255584). Previous analysis showed that SVE has the potential to effectively remove significant quantities of VOCs from the subsurface (Stauffer et al. 2007, 104950; Stauffer et al. 2007, 097871). Suggestions regarding sampling frequency and location were made based on these results to allow for rapid detection of any sudden changes in the plume (Stauffer et al. 2007, 097871). Estimates of the ROIs of the SVE pilot test wells (~37 m [120 ft]) were given and a suggested SVE system for long-term plume control was presented (LANL 2011, 205756). To judge the quality of the model throughout the modeling process, spatially dependent TCA concentration data from the site and the predicted (modeled) concentrations are compared through linear regression.

5.2 November 2014 Base Simulation

The last model update, before the current SVE interim measure, was performed in 2011 for the MDA L CME (LANL 2011, 205756). To generate an updated model that represents the subsurface TCA plume, the output of the 2011 CME model, which correlated well with the 2011 plume data, was used as the starting point. The two source regions were then assumed to leak with fixed concentrations until 2014. During the fixed leakage simulations, diffusion is assumed to be the only process moving mass in the subsurface. Figure 5.2-1 shows predicted concentrations for three simulations with fixed leakage from 2011–2014; the simulations assume three different fixed source concentrations (500 ppmv, 300 ppmv, or 200 ppmv) with both the eastern and western source regions leaking with the same concentrations for a particular simulation. When the two source regions are fixed at 500 ppmv, the model generates concentrations that are higher than the data. Similarly, when the source regions are fixed at 200 ppmv, the model generates concentrations that begin to fall below the measured data. Using a least squares regression between model and data, it was determined that a fixed concentration of 300 ppmv in the source regions leads to the best match between the model and data from the set of 100–1000 ppmv, run in discrete leakage steps of 100 ppmv. Also included in Figure 5.2-1 are the +30% data reproducibility bounds on either side of the 1:1 line. Results on a plane 60 ft bgs are shown in Figure 5.2-2 where the two source regions are visible with higher concentrations.

5.3 Predicted Plume Behavior Compared with Measured SVE Response

This section presents model predictions for the first 10 mo of SVE operations. First, predicted effluent concentrations from both SVE-West and SVE-East are compared with the data. Second, predictions of subsurface concentration are presented at locations corresponding to ports sampled during the November 2015 quarterly sampling event. The effluent predictions were calculated in December 2014 before the SVE system was started in January 2015, with pumping assumed to run continuously on both east and west units for a full year. The subsurface monitoring predictions use the same simulation setup; however, the simulation was adjusted to replicate the timing of SVE operations, with the SVE-West unit starting on January 9, 2015, the SVE-East unit starting on January 26, 2015, and both units ceasing to operate on November 18, 2015.

The SVE-West predictions of effluent concentration based on the previously calibrated permeabilities are similar to the effluent data (Figure 5.3-1). However, SVE-East effluent predictions, shown in Figure 5.3-2, are consistently higher than the measured data. To better understand the simulated effluent results, a comparison of concentrations in the subsurface is instructive.

Figures 5.3-3 and 5.3-4 show data versus model correlation for individual ports in wells surrounding both the SVE-West and SVE-East boreholes, respectively. Around the SVE-West borehole, model and data are fairly close to the 1:1 line at higher concentrations, with the majority of the points in Figure 5.3-3 lying within half an order of magnitude of the 1:1 line (thin blue lines). This correlation, combined with the goodness of fit on the SVE-West effluent extraction, gives confidence that the model captures the behavior of the plume under both diffusive and advective regimes. The SVE-East side is not as well correlated and contains regions where the modeled concentrations are more than half an order of magnitude above the data and regions where the data are over half an order of magnitude higher than the model (Figure 5.3-4). All ports in boreholes 54-02089 and 54-24238 show data that are more than half an order of magnitude higher than the model results: four out of five ports in 54-24243 and three out of five ports in 54-02002 have model predictions that are more than half an order of magnitude above the data. Both wells are fairly close to SVE-East, and the mismatch in concentrations in the subsurface is likely impacting the mismatch in effluent concentrations between model and data.

The less accurate model for the SVE-East side of MDA L may be related to two unexplained differences that have been observed. First, ports in boreholes 54-02089 and 54-24243 are impacted by currently unexplained increases in concentration that push the data higher the baseline. Second, the latest SVE-East suction required to pull 100 scfm (25 kPa) is significantly higher than suction required in 2006 to pull the same gas flow rate (19 kPa). In addition to the unexplained issues, the initial state of the SVE pumping calculations may play a role in the data/model mismatch on the SVE-East side of MDA L. The initial state was generated to get a rough match and was not meant to capture the exact pre-SVE plume. Thus, some areas of the pre-SVE plume could be matched more closely and may result in better data/model correlation. For example, both 54-24241 and 54-02002 have higher simulated concentrations than the September 2014 baseline data. All these changes are under investigation, and possible explanations for the causes of these changes will be described in the next progress report.

6.0 DEVIATIONS

This section describes deviations from the IMWP (LANL 2014, 261843). The deviations discussed below include ports that could not be sampled, a reduction from 1 full year of operation, and issues with the dual packer in borehole 54-24399.

6.1 Sampling Ports

Several ports listed in Table 2.2-1 and 2.2-2 were found to be either fully or partially blocked. If ports were partially or fully blocked for two consecutive sampling rounds, these ports are assumed to be suspect and were removed from the sampling plan. Additionally, radiological concerns caused some ports to be temporarily removed from the sampling plan in November 2015. RCT monitoring detected gas concentrations of greater than 20 $\mu g/m^3$ in 18 ports (Table 2.2-2). However, this issue has been resolved, and an RCT-approved method for sampling will allow these 18 ports to be sampled in the future.

6.2 Active Extraction Duration

The SVE system was run from January 2015 to November 2015. This is a deviation from the initial plan to run the system for a full year. The decision to stop the SVE units in November 2015 was based on production of condensate from the SVE units during times when temperatures dropped below freezing. Subsurface vapor, containing both water vapor and VOC gases, condenses in the SVE system and accumulates in the 20-gal. liquid storage container (Figure 2.1-1). This liquid must be characterized because of the dissolved VOC component. Furthermore, the liquid must be removed from the storage container on a regular basis because several gallons per day can accumulate during cold weather. To avoid issues with condensate, the decision was made to shut down the SVE units in November 2015.

6.3 Deep Borehole Dual-Packer Failure

During the April 2015 sampling event, the dual packer sampling system used to isolate a 1-ft interval (568–569 ft bgs) directly beneath the casing of borehole 54-24399 was badly damaged. The lower packer was shredded when it came in contact with very sharp basalt. The sharp nature of the vesicular basalt can be observed in the video log of borehole 54-24399 (Appendix F). The video log shows a limited region of massive basalt directly below the casing (less than 2 ft), followed by a large void area. To avoid further problems with packer destruction, the decision was made to stop using the dual-packer in the open borehole. The single packer will continue to be placed at the bottom of the casing (561.5 to 565.5 ft bgs) to collect pore-gas samples in the open portion of the borehole.

7.0 CONCLUSIONS

During the first year of SVE operation, the two SVE units removed 553 kg (1217 lb) of total organic vapor mass. The mass was primarily removed from within approximately 150-ft radius surrounding each of the extraction wells. Mass removal was higher initially and continued at a removal rate of nearly 17 lb/mo after 10 mo of operation. The long-term ability of the SVE system to remove significant quantities of organic vapor has been demonstrated, and data collected during the IM will be analyzed further as part of ongoing efforts to support the selection and design of a final remedy for MDA L.

8.0 RECOMMENDATIONS

The following recommendations are based on 10 mo of SVE operation at MDA L.

- Continue quarterly and annual vapor sampling from boreholes surrounding the plume though September 2017.
- Evaluate data collected during the SVE IM to refine the assumptions in the MDA L CME.
- Modify the Tier II screening algorithm to include depth-dependent diffusion and update the assumptions for VOC transport to the regional aquifer.
- Reevaluate potential engineered solutions (e.g., passive SVE, active SVE), including pumping scenarios and number/placement of extraction wells, that were presented in the MDA L CME.
- Develop cleanup goals to support the corrective measures implementation phase of site closure.
- Provide data and modeling analyses of the physical and geochemical processes impacting VOC vapor transport beneath MDA L.

In addition, two key areas of additional data collection are proposed for 2016 and are described below.

8.1 Rebound Analysis

To more fully evaluate SVE strategies for MDA L, the Laboratory proposes to collect and analyze data related to plume rebound following shutdown of the SVE units in November 2015. Rebound data will allow the Laboratory to better design a long-term strategy for using SVE as a vapor-plume control measure at MDA L. Rebound sampling will also help determine whether, and to what degree, ongoing VOC releases from the shafts are occurring. Quarterly and annual monitoring data will be a vital part of the rebound analysis and will be collected through July 2017. Additionally, the Laboratory plans to restart both SVE units for short periods (2–4 d) to allow integrated rebound assessment. These brief restarts will begin in April 2016 and will be performed until data are deemed sufficient for rebound analysis, probably through September 2016, with the option of collecting longer-term rebound data in 2017. Because the SVE systems pull vapor from a large volume of the subsurface, the rebound characteristics of the SVE restarts measured on the effluent of the SVE units will provide data to complement point measurements of rebound gathered in the quarterly and annual subsurface vapor sampling.

8.2 Tracer Study

To further characterize subsurface rock properties in the Cerros del Rio basalt, the Laboratory proposes a gas tracer test for the summer of 2016 to determine diffusivity in the fractured basalt that makes up nearly half the thickness of the unsaturated rock column between the MDA L disposal area and the regional water table. Overall, the tracer test will provide fundamental gas flow and transport information under field conditions that would be difficult to obtain otherwise.

Preliminary activities include planning, coordination with U.S. Department of Energy and NMED, permitting, and analysis of data. The tracer test will include one or more injections of gas tracer (e.g., SF_6) into borehole 54-24399 through a packer system and subsequent monitoring of concentration decay as the tracer spreads in the subsurface. Monitoring at basalt ports in boreholes 54-01015 and 54-01016 may also be useful in this test; however, recent analysis using high-resolution numerical modeling suggests that tracer concentrations at these boreholes may be too dilute to detect. Analysis of data will be performed using a combination of both analytical solutions and 3-D numerical simulation.

9.0 REFERENCES

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Copies of the master reference set are maintained at the NMED Hazardous Waste Bureau and the ESH Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

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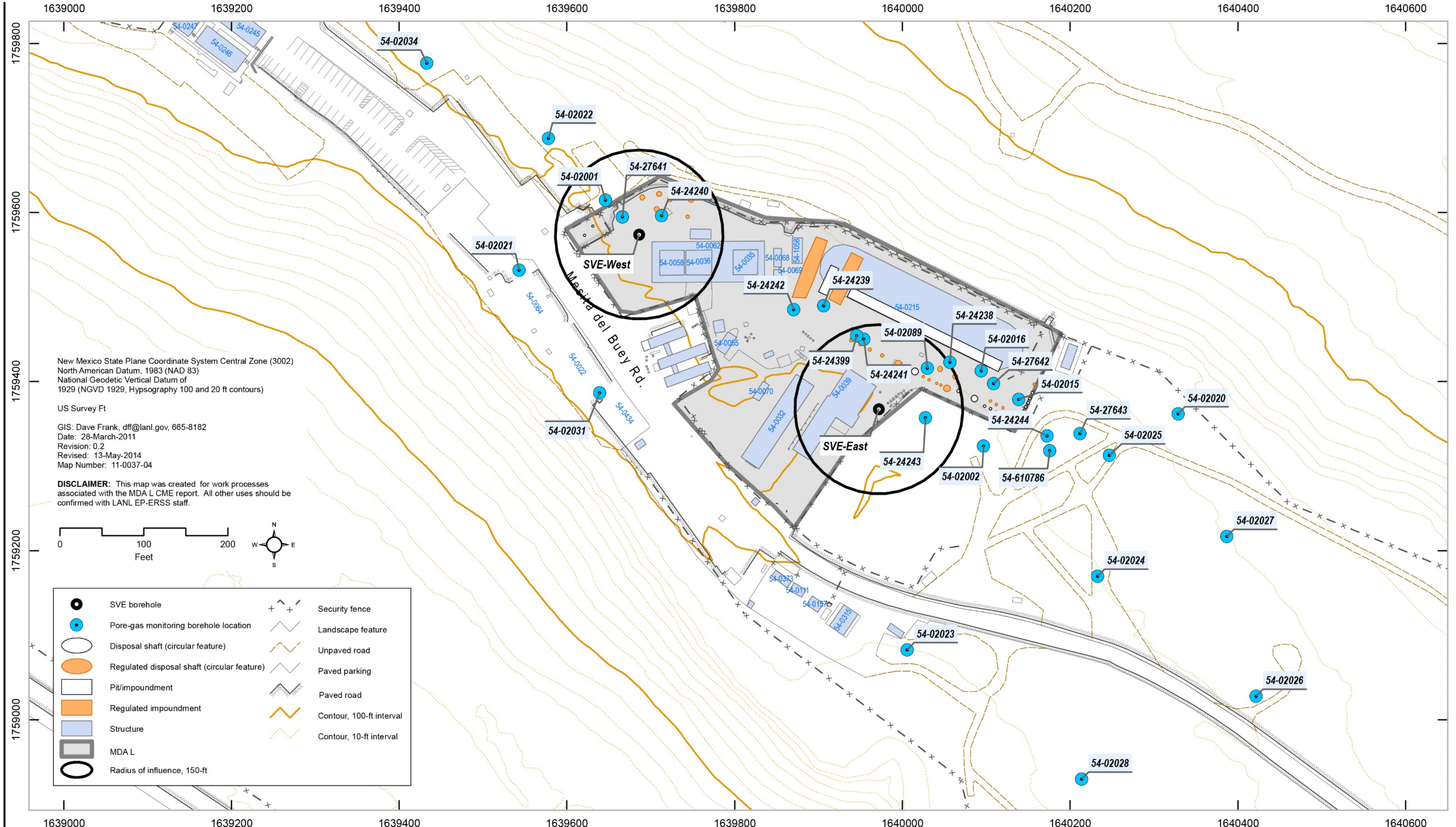


Figure 1.1-1 View of MDA L with disposal units, surface structures, pore-gas monitoring boreholes, SVE boreholes, and 150-ft ROI of extraction wells

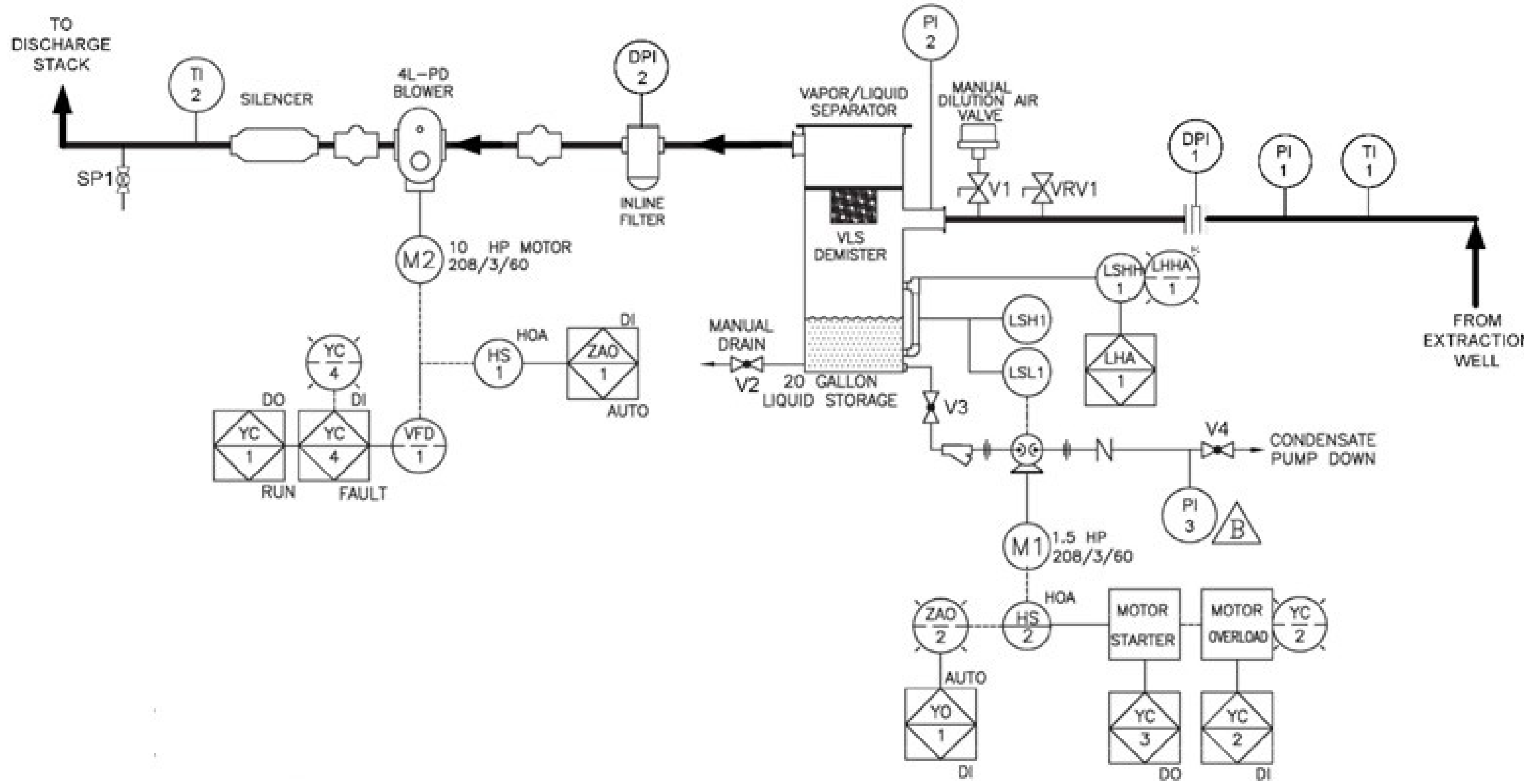


Figure 2.1-1 **Diagram of SVE-East and SVE-West system piping and instrumentation**

Figure 2.1-2 SVE-East unit

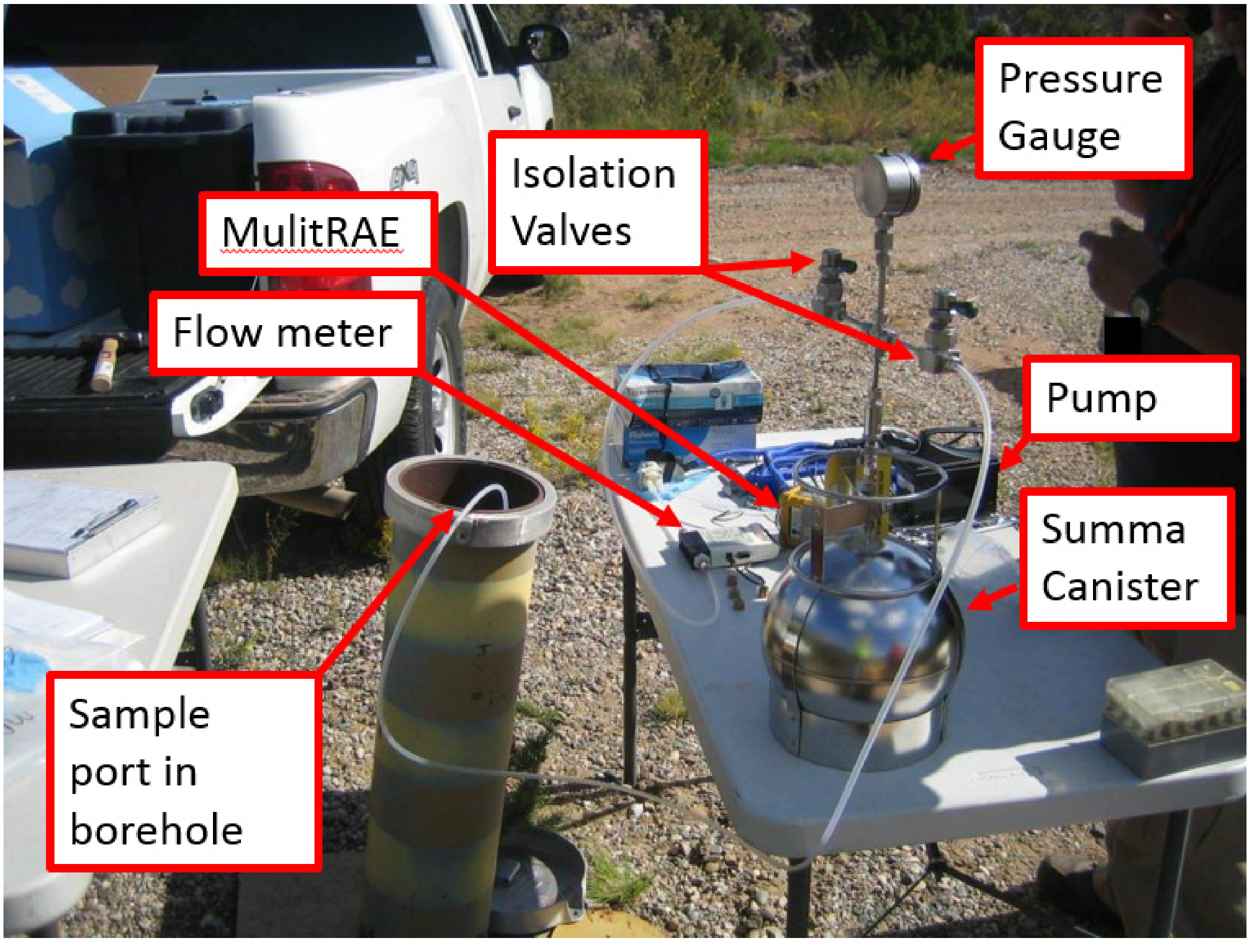


Figure 2.2-1 Subsurface sampling train

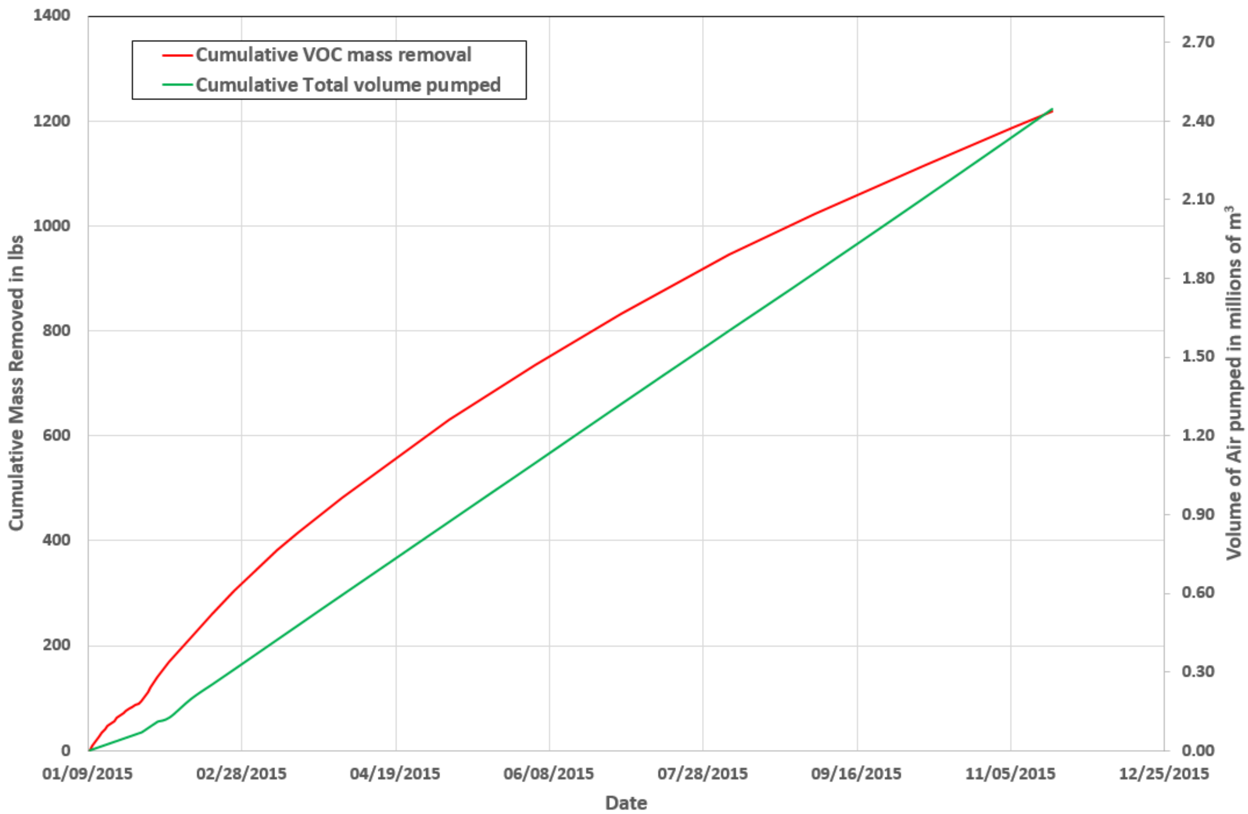


Figure 4.1-1 Cumulative mass removal and cumulative volume of pore-gas pumped from the subsurface from both SVE units as a function of time

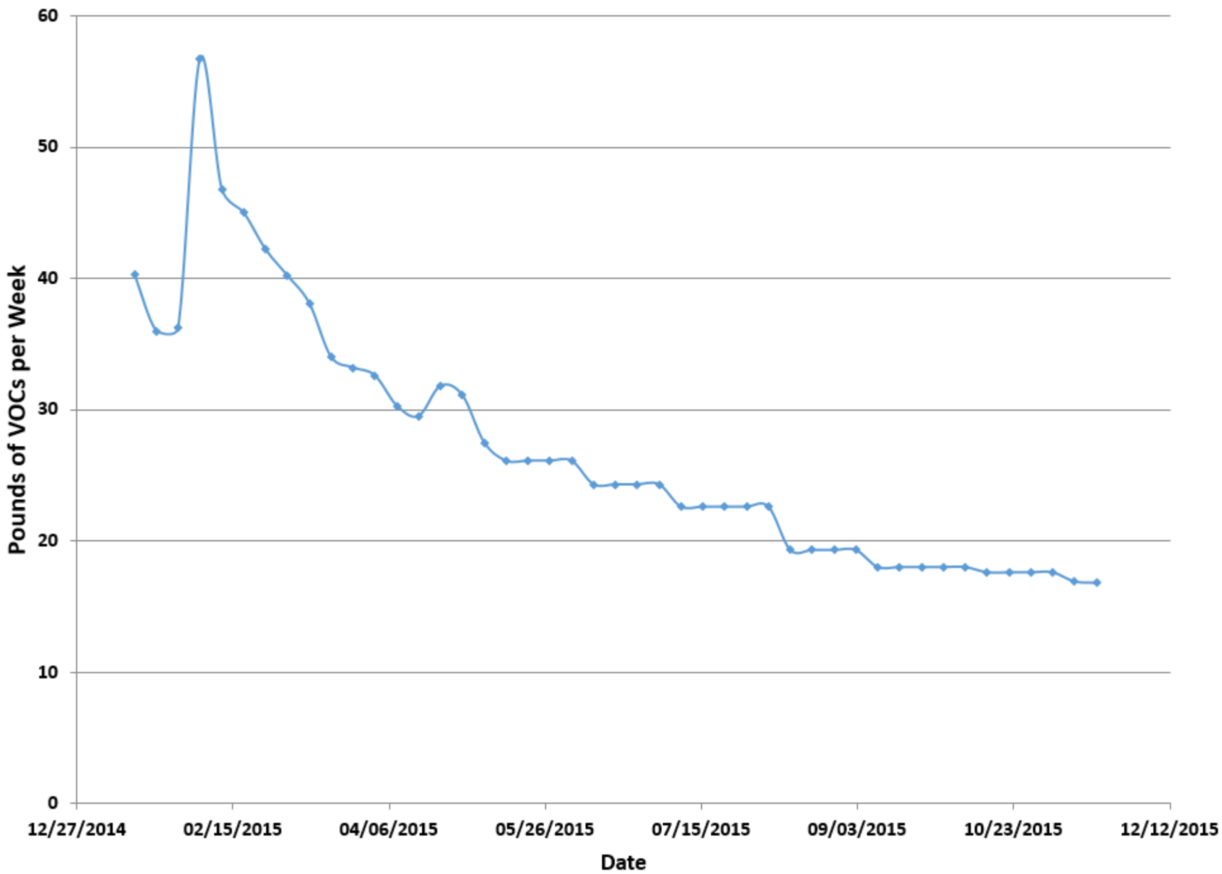


Figure 4.1-2 Weekly mass removal rate from both SVE units as a function of time

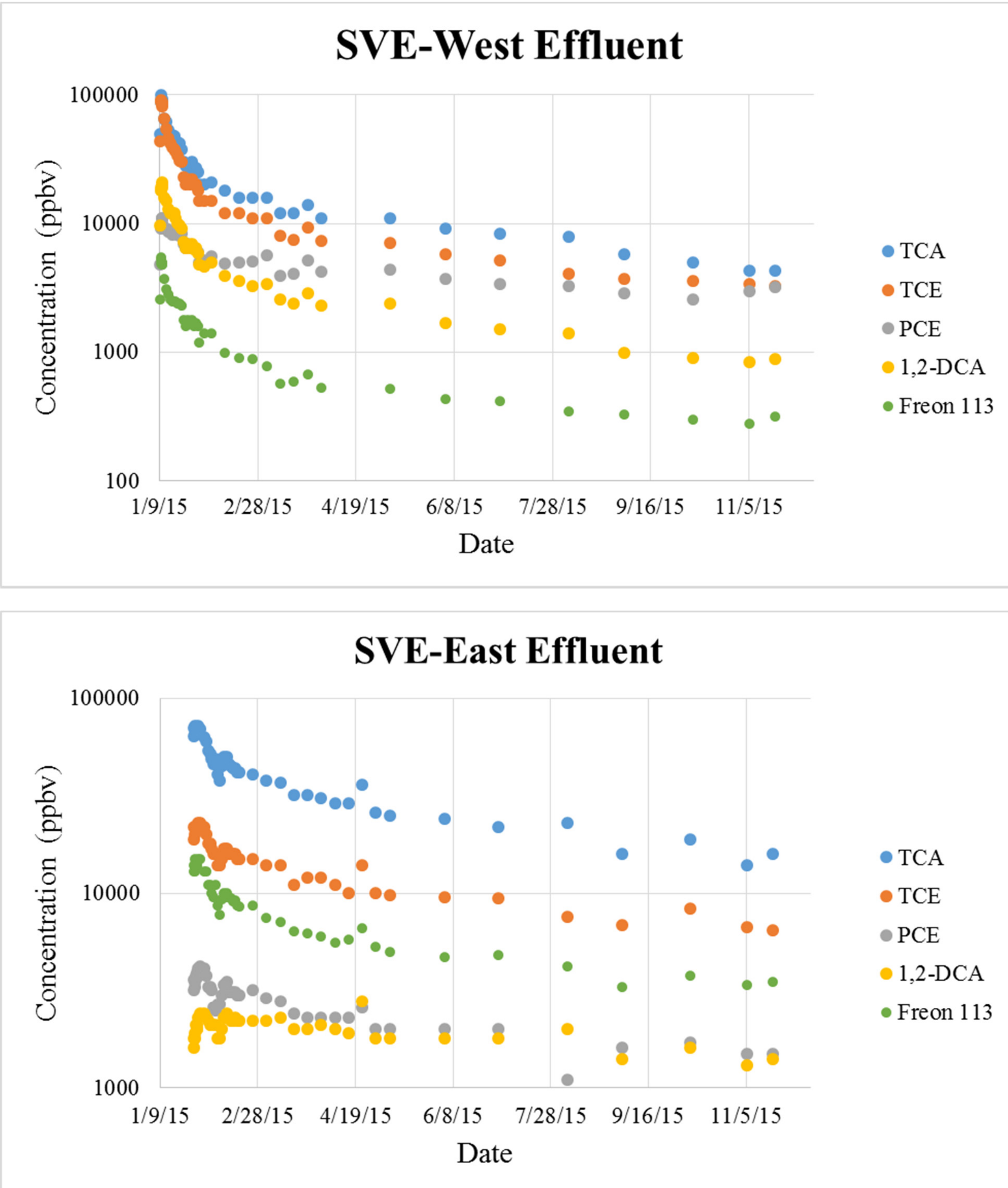
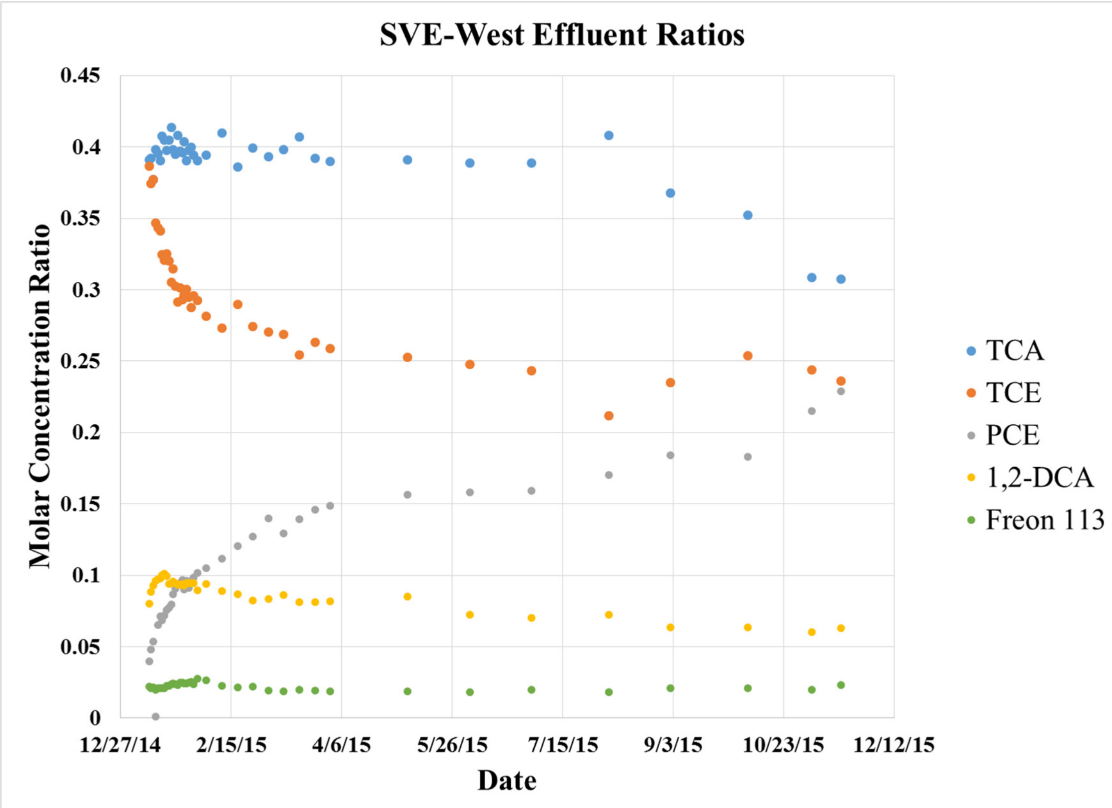


Figure 4.2-1 Effluent concentration versus time for SVE-West and SVE-East



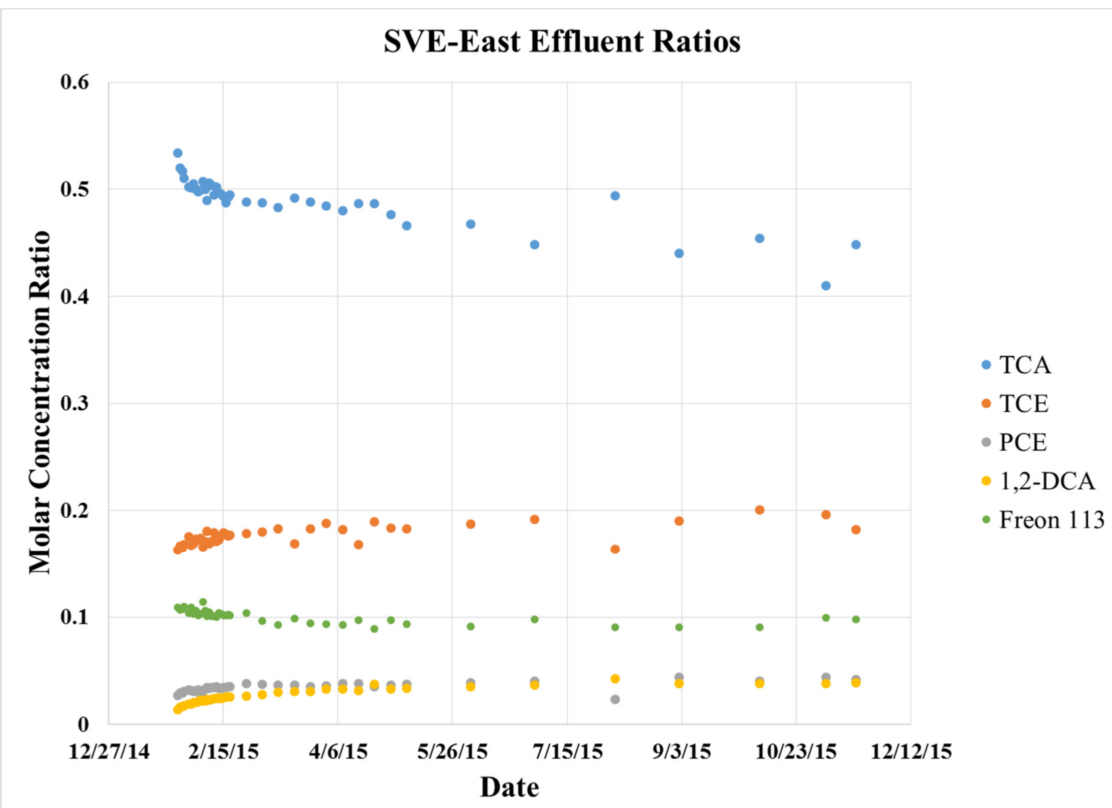


Figure 4.2-2 Effluent concentration ratios versus time for SVE-West and SVE-East

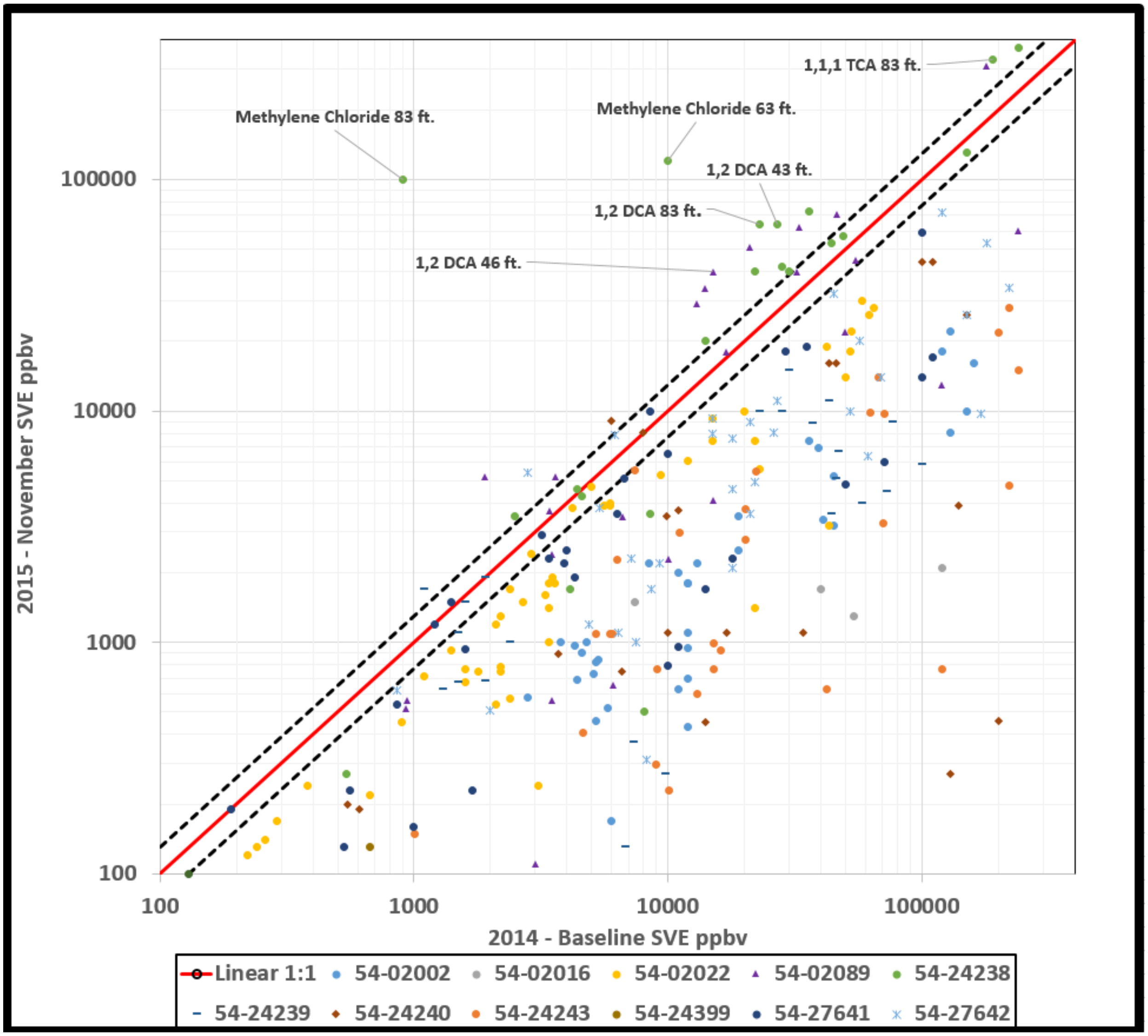


Figure 4.3-1a Comparison of subsurface VOC concentrations before SVE (Baseline 2014) and after 10-plus months of SVE pumping (November 2015)

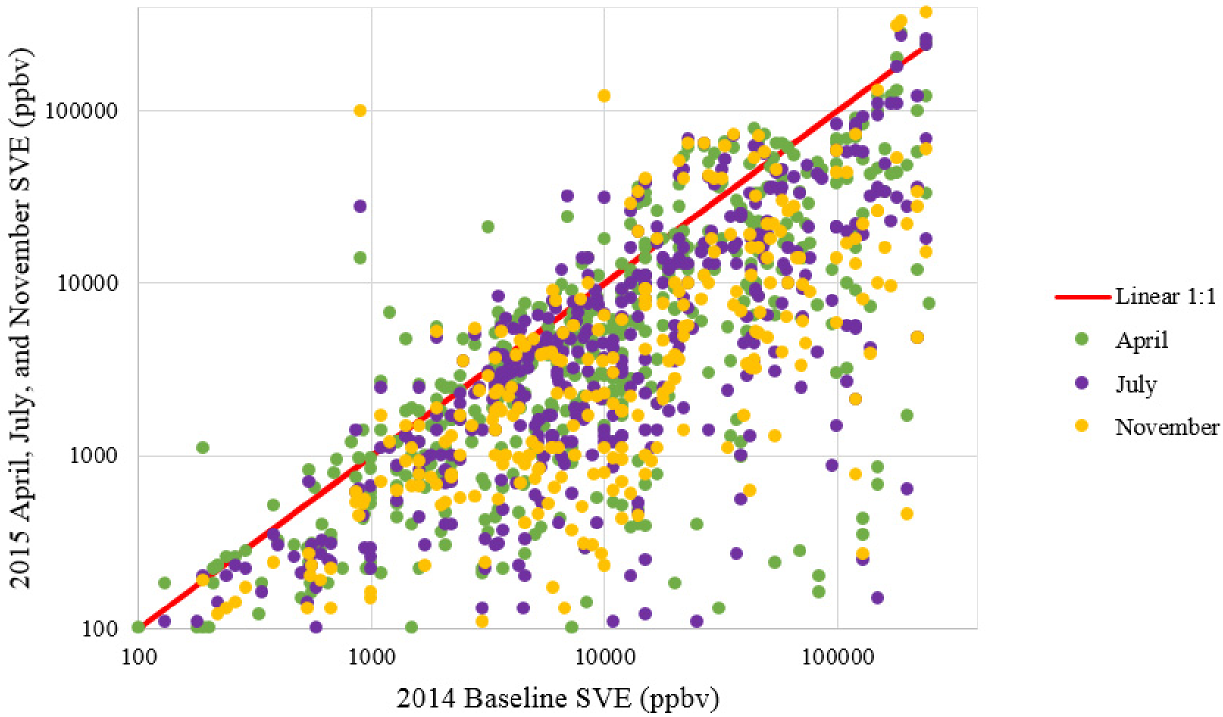


Figure 4.3-1b Comparison of post-SVE and pre-SVE subsurface VOC concentrations

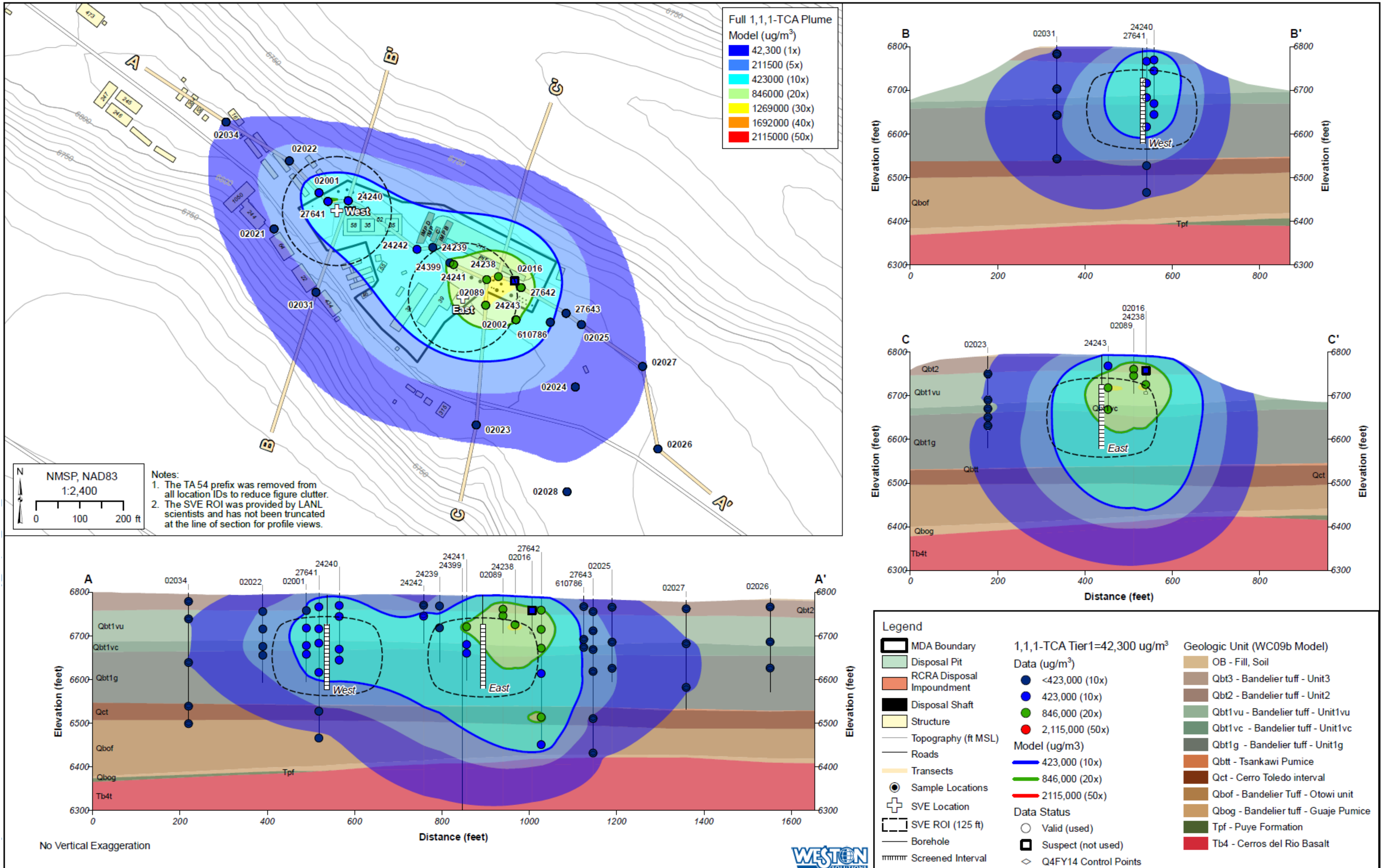


Figure 4.3-2 Baseline 2014 1,1,1-TCA plume data interpolated from borehole data

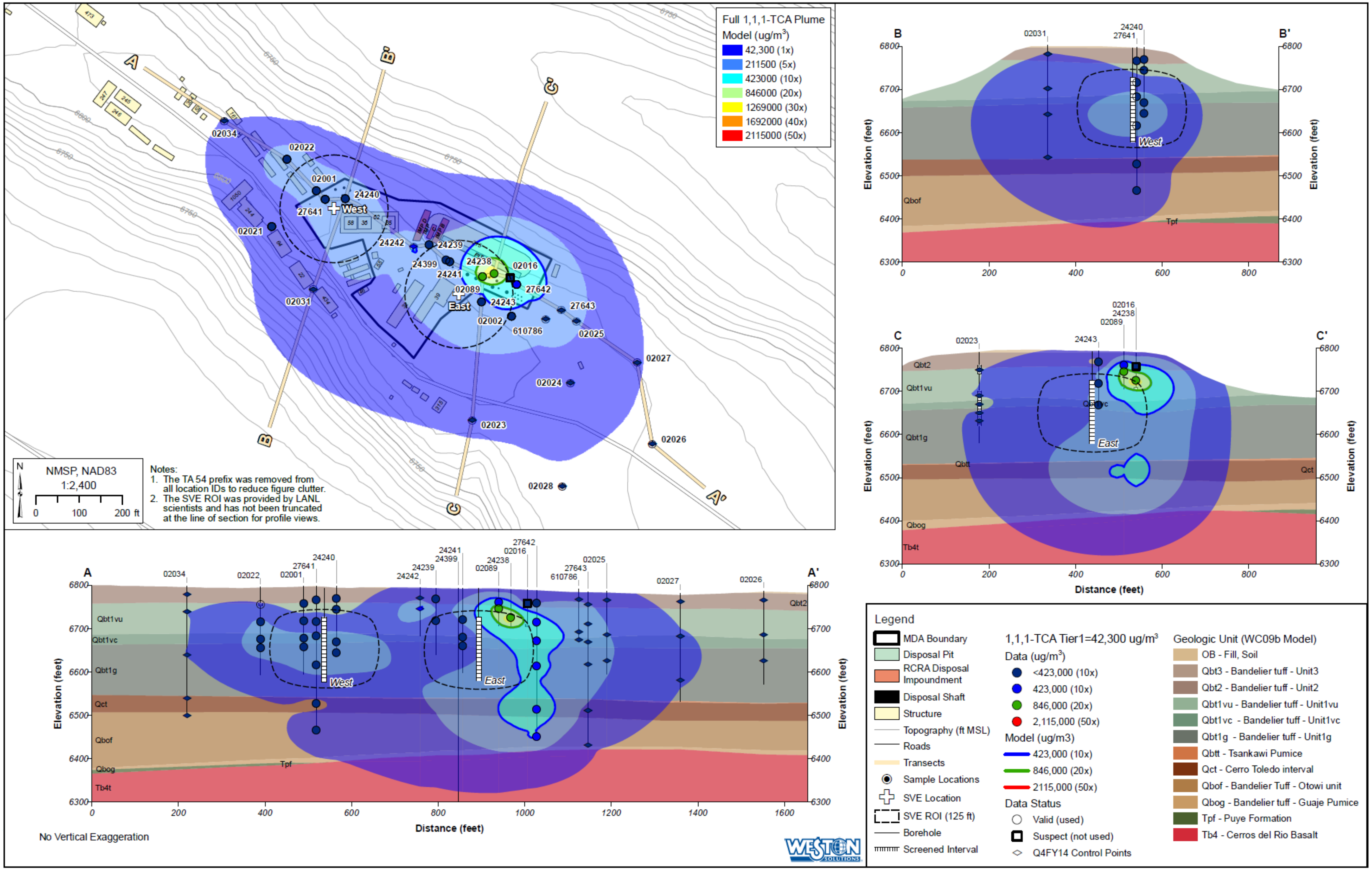


Figure 4.3-3 Third quarter 2015 1,1,1-TCA plume data interpolated from borehole data

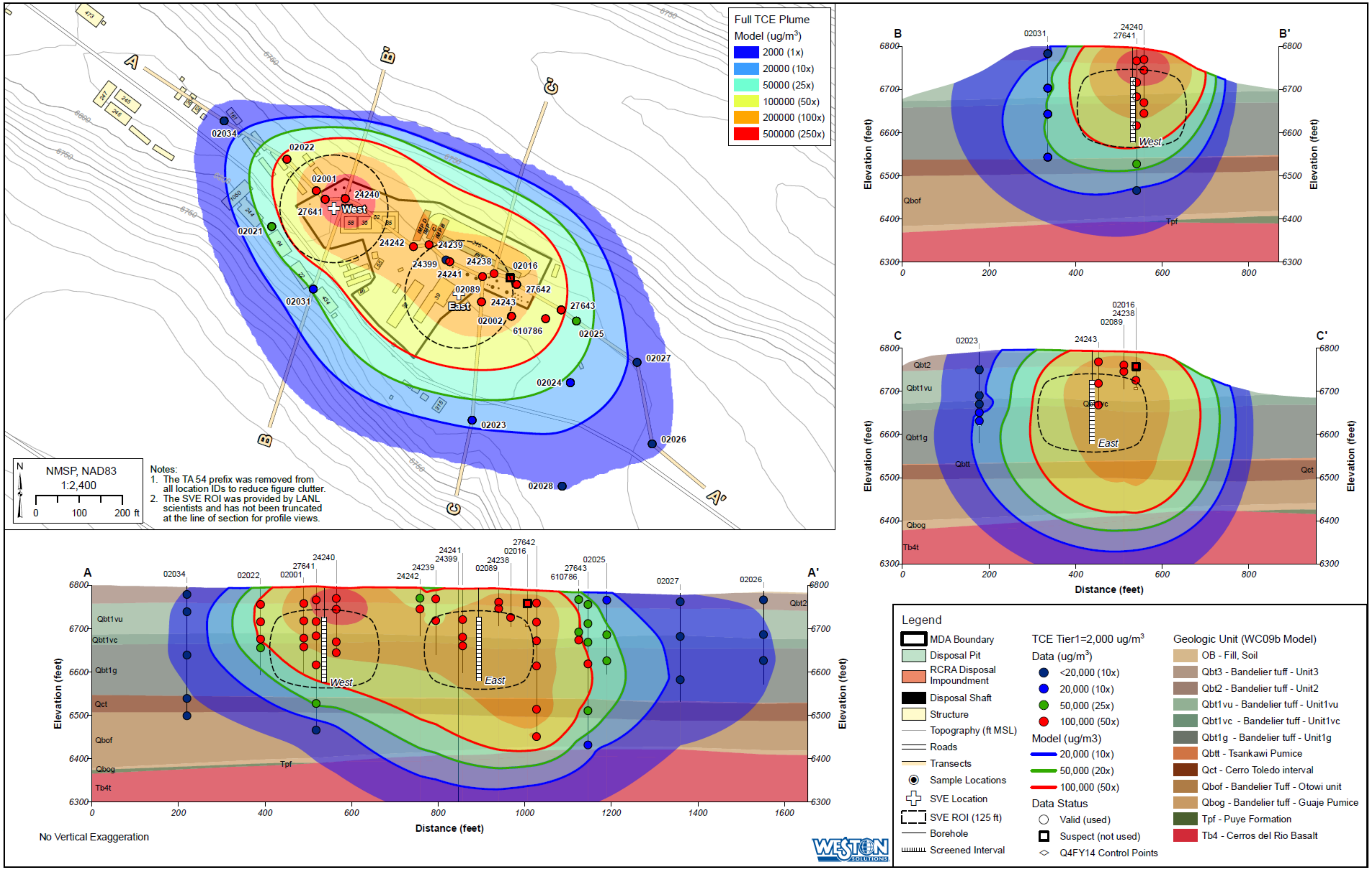


Figure 4.3-4 Baseline 2014 TCE plume data interpolated from borehole data

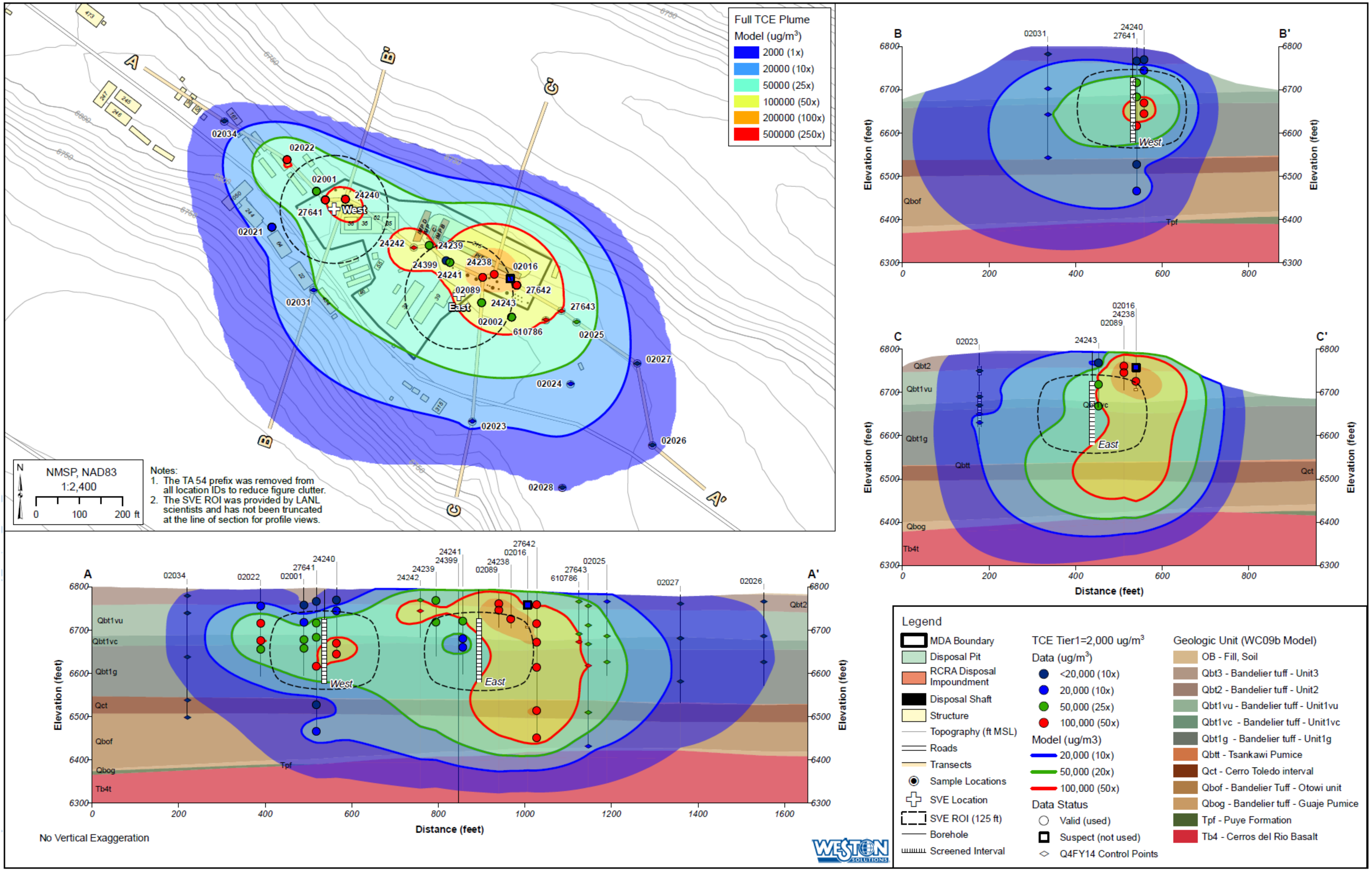


Figure 4.3-5 Third quarter 2015 TCE plume data interpolated from borehole data

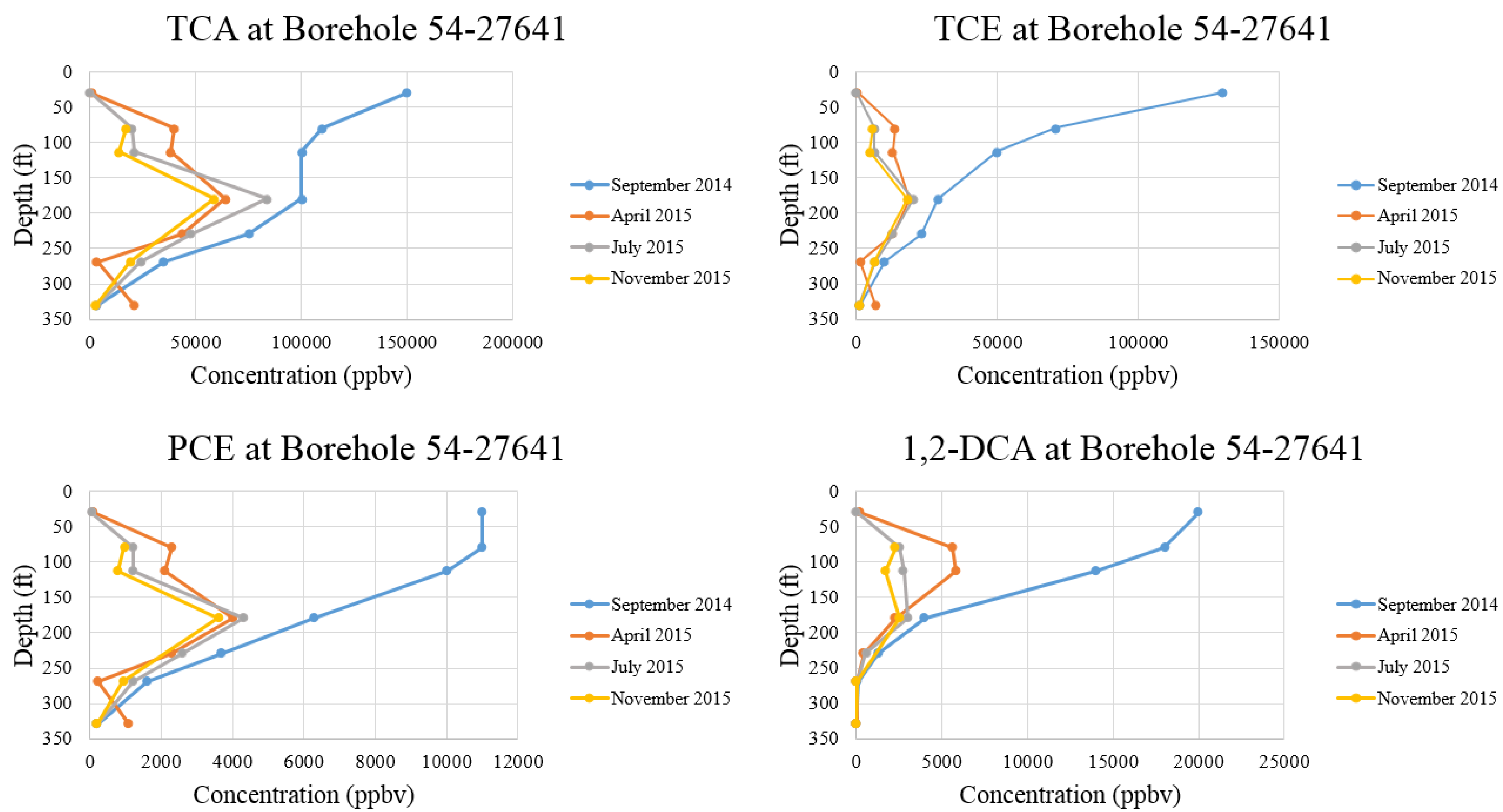


Figure 4.3-6 1,1,1-TCA, TCE, PCE, and 1,2-DCA concentration data for borehole 54-27641

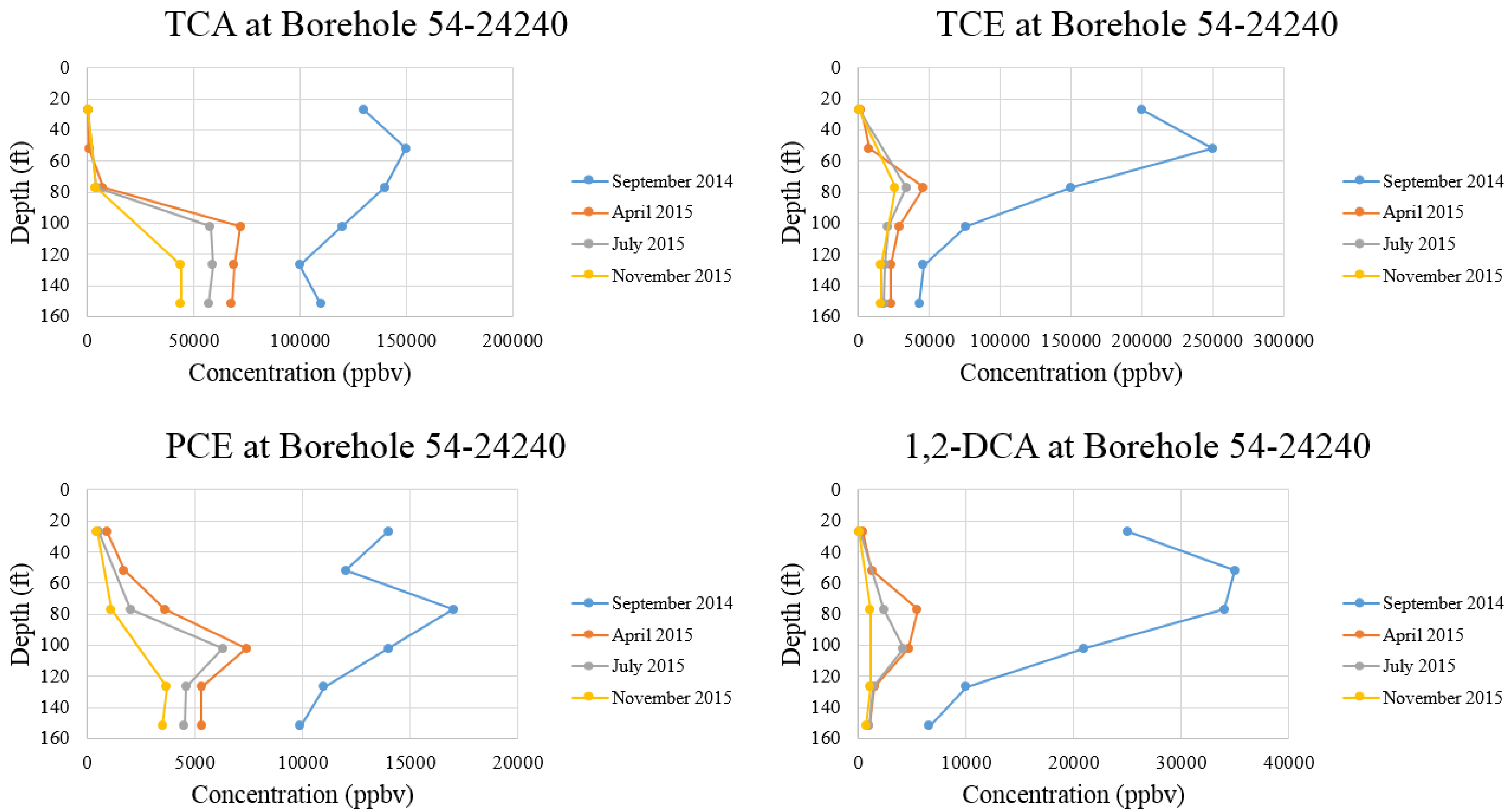


Figure 4.3-7 1,1,1-TCA, TCE, PCE, and 1,2-DCA concentration data for borehole 54-24240

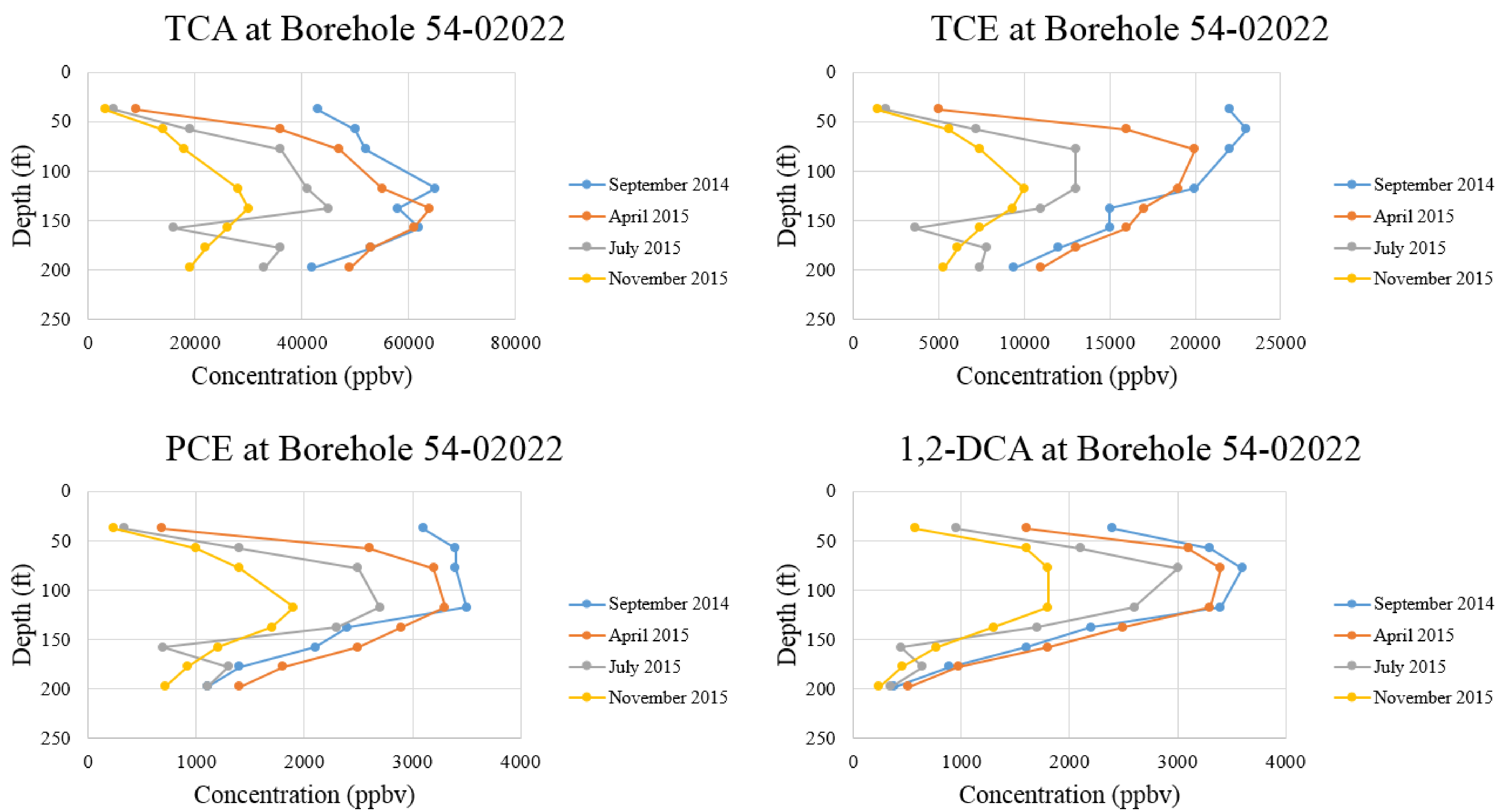


Figure 4.3-8 1,1,1-TCA, TCE, PCE, and 1,2-DCA concentration data for borehole 54-02022

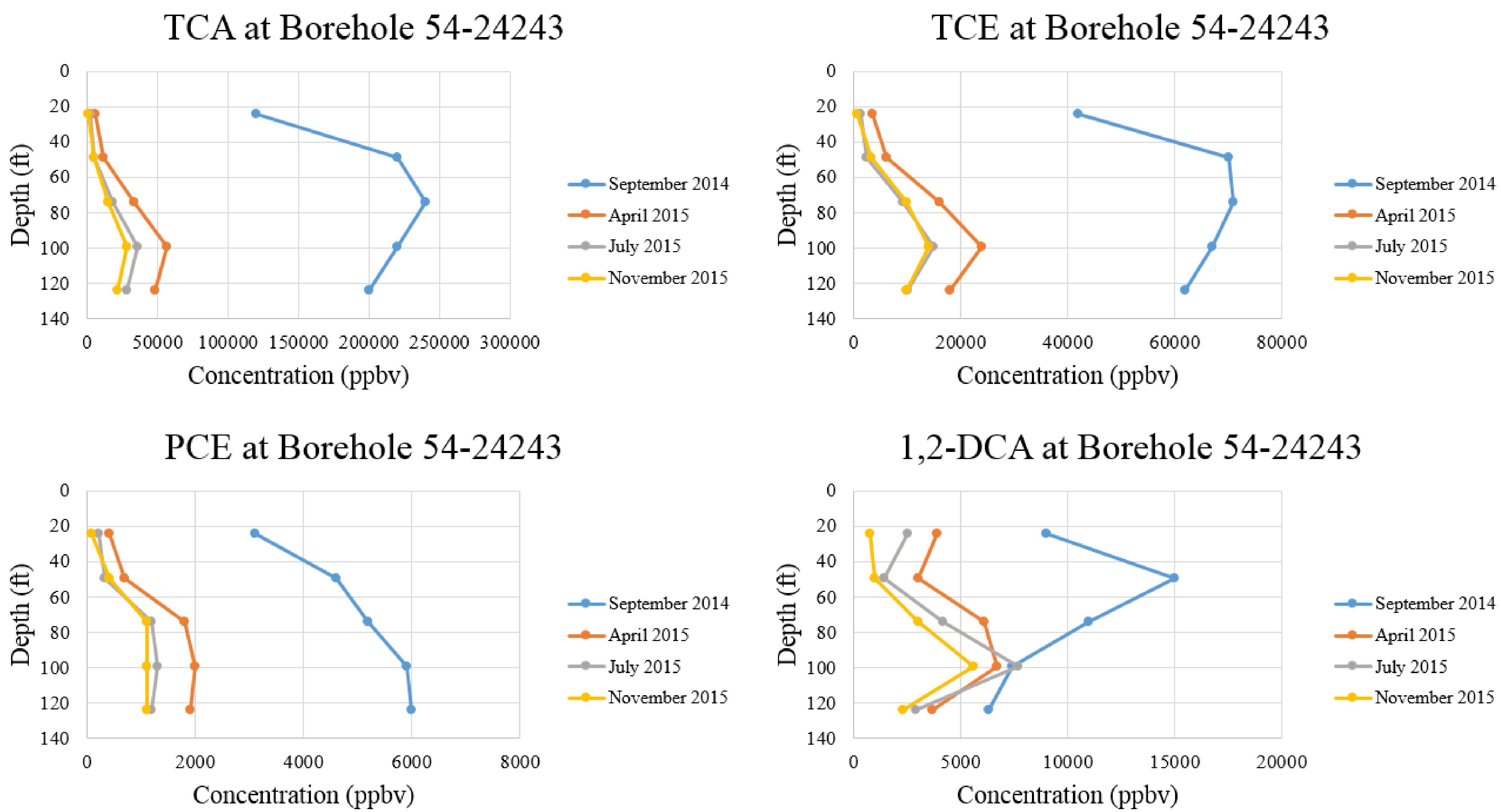


Figure 4.3-9 1,1,1-TCA, TCE, PCE, and 1,2-DCA concentration data for borehole 54-24243

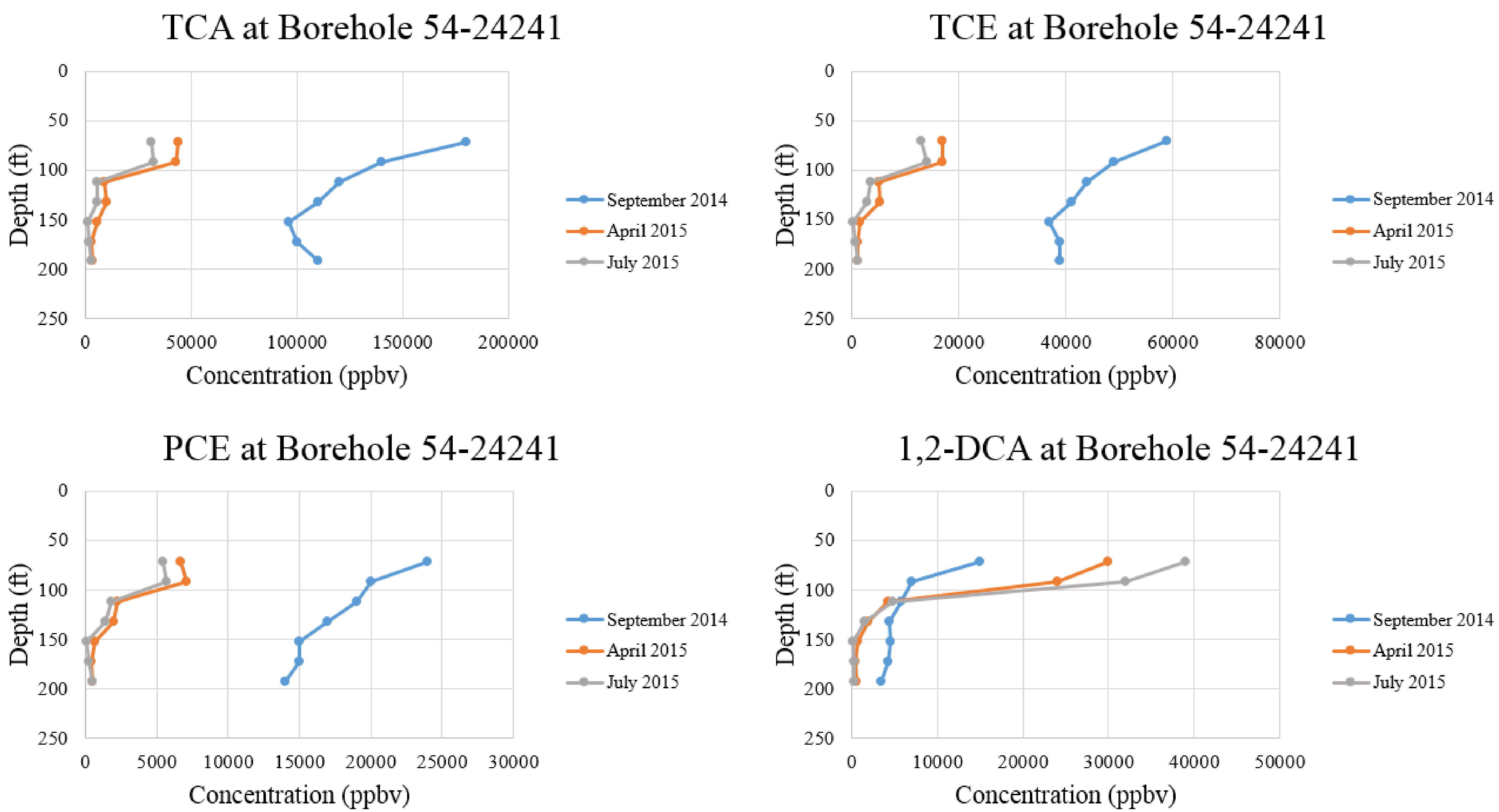


Figure 4.3-10 1,1,1-TCA, TCE, PCE, and 1,2-DCA concentration data for borehole 54-24241

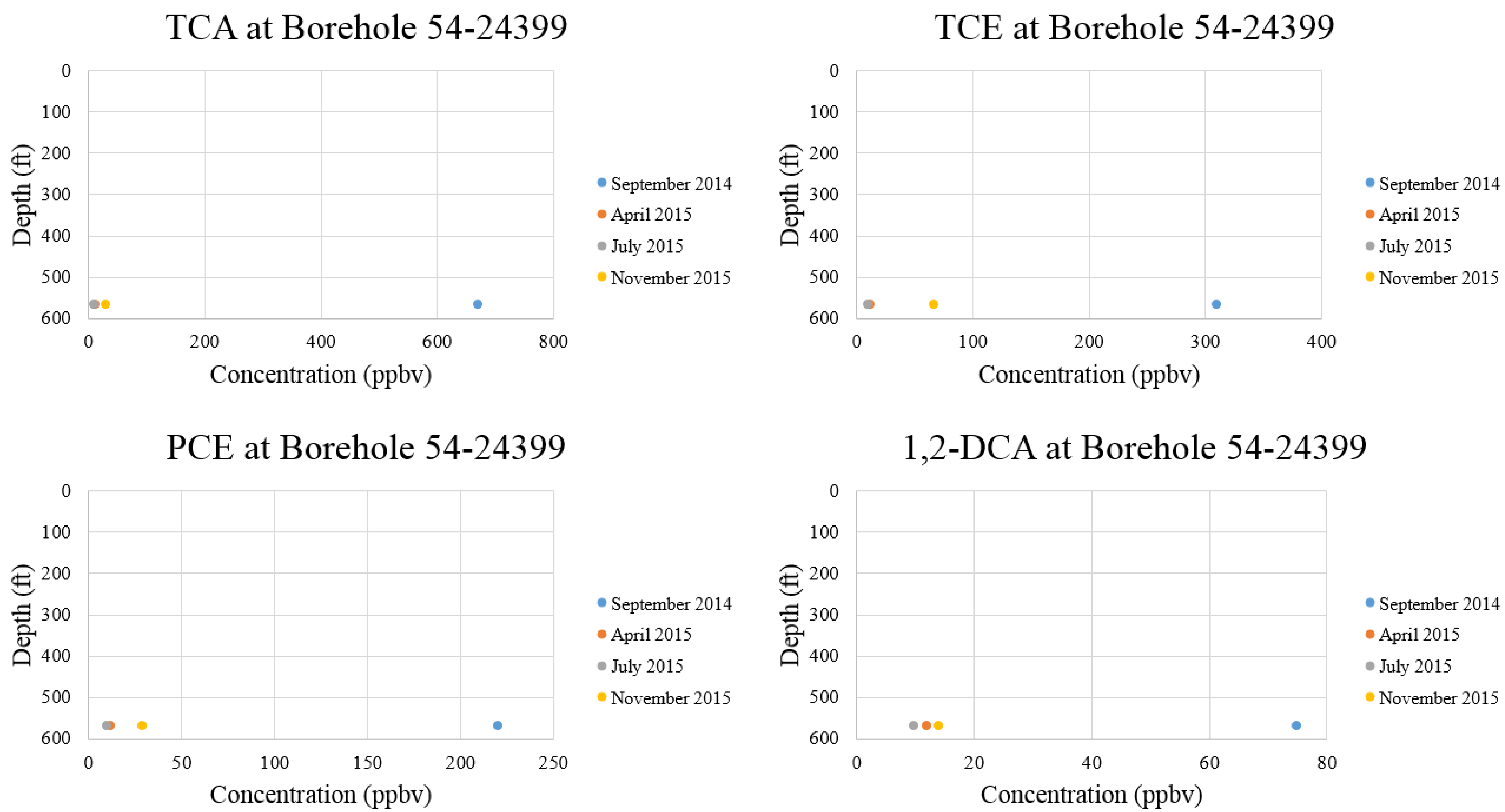


Figure 4.3-11 1,1,1-TCA, TCE, PCE, and 1,2-DCA concentration data for borehole 54-24399

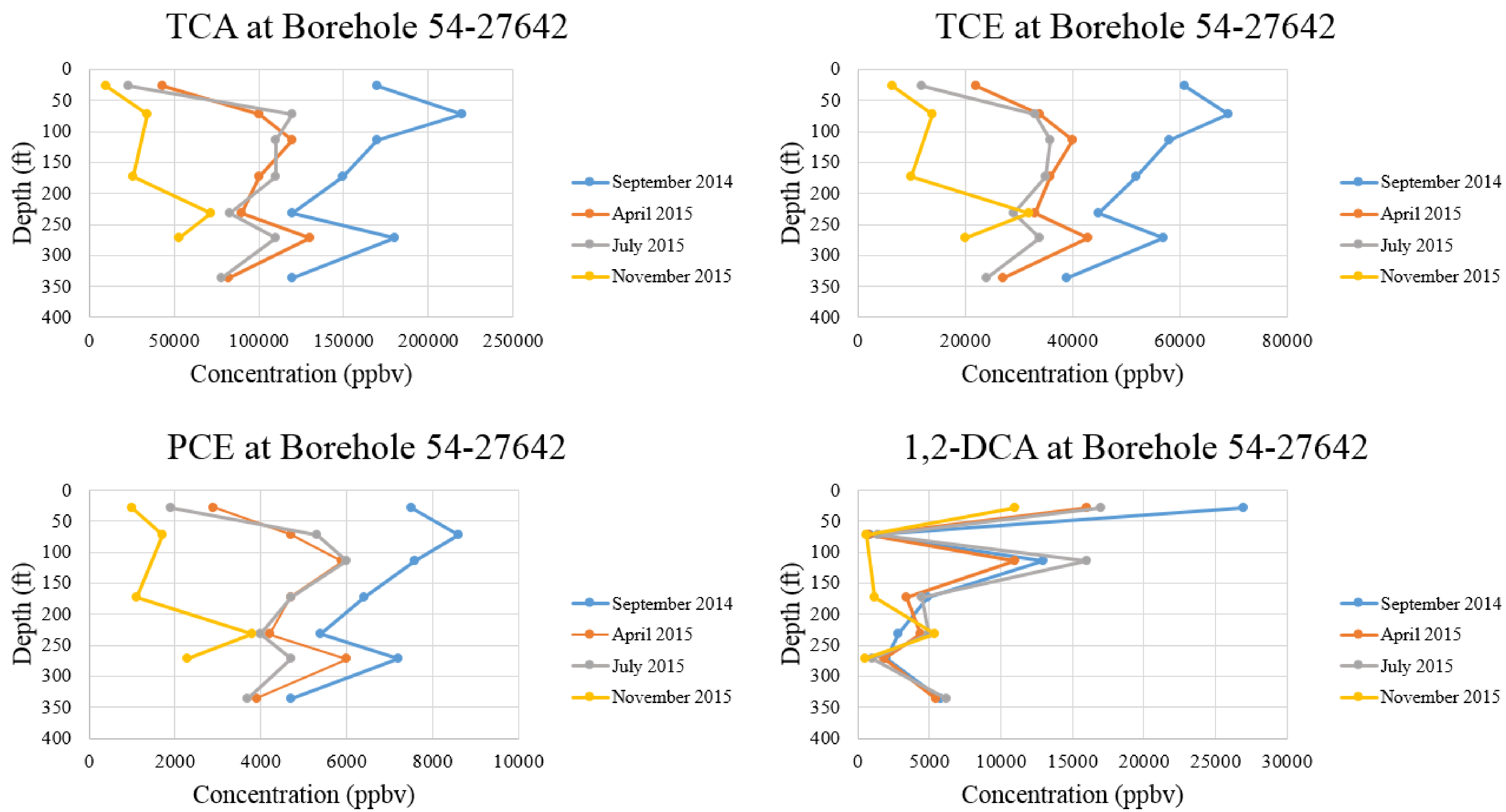


Figure 4.3-12 1,1,1-TCA, TCE, PCE, and 1,2-DCA concentration data for borehole 54-27642

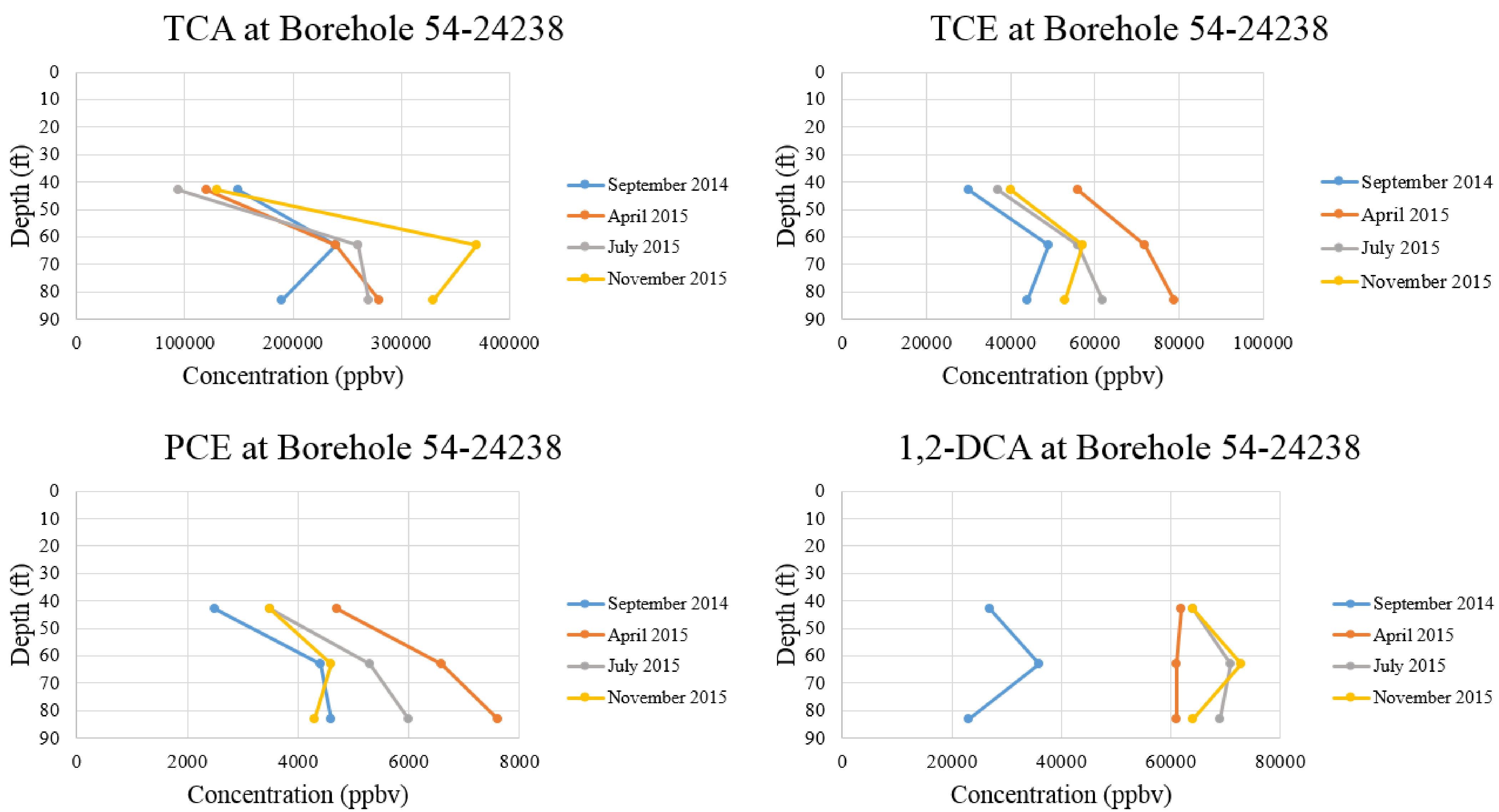


Figure 4.3-13 1,1,1-TCA, TCE, PCE, and 1,2-DCA concentration data for borehole 54-24238

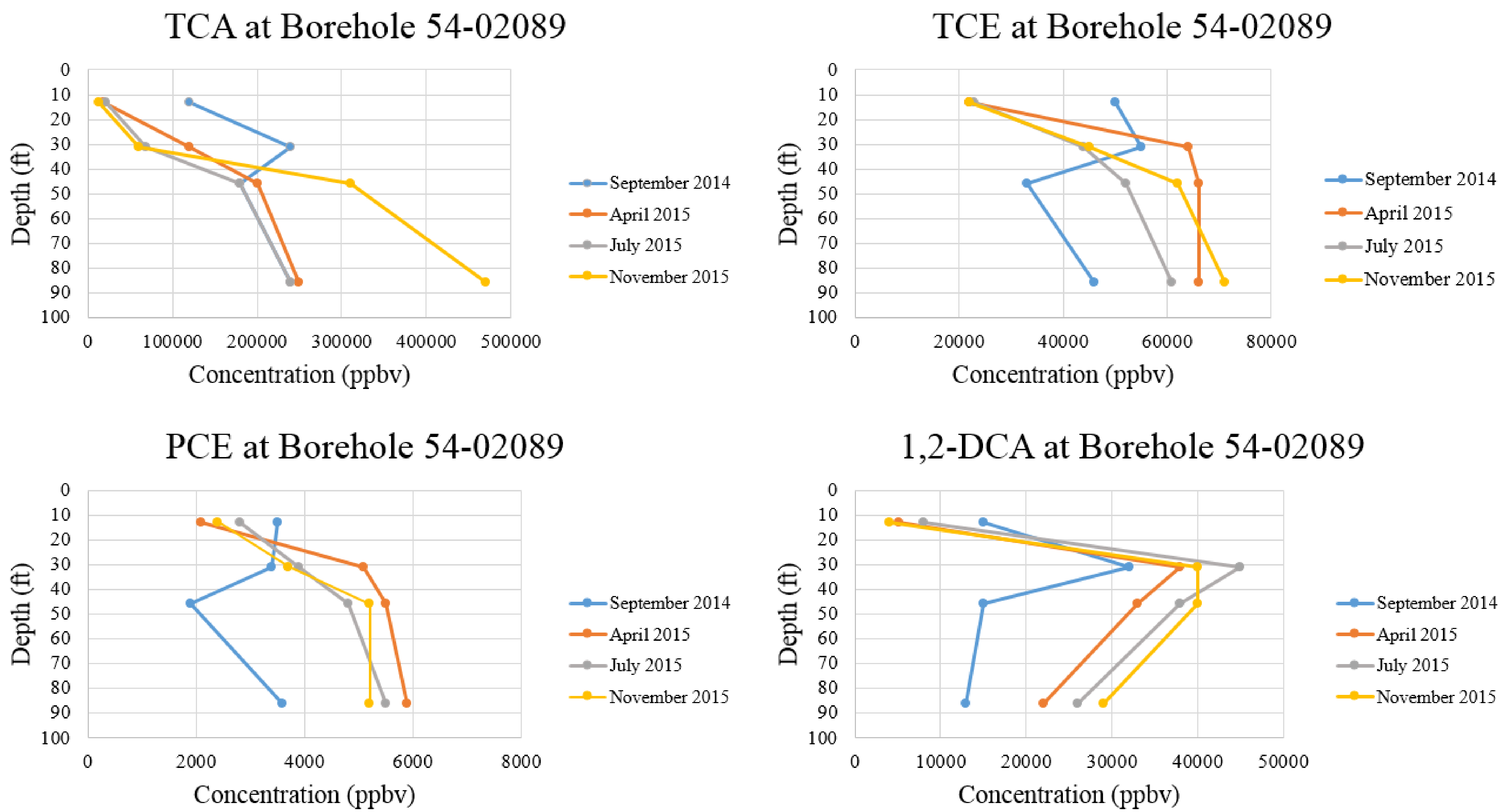
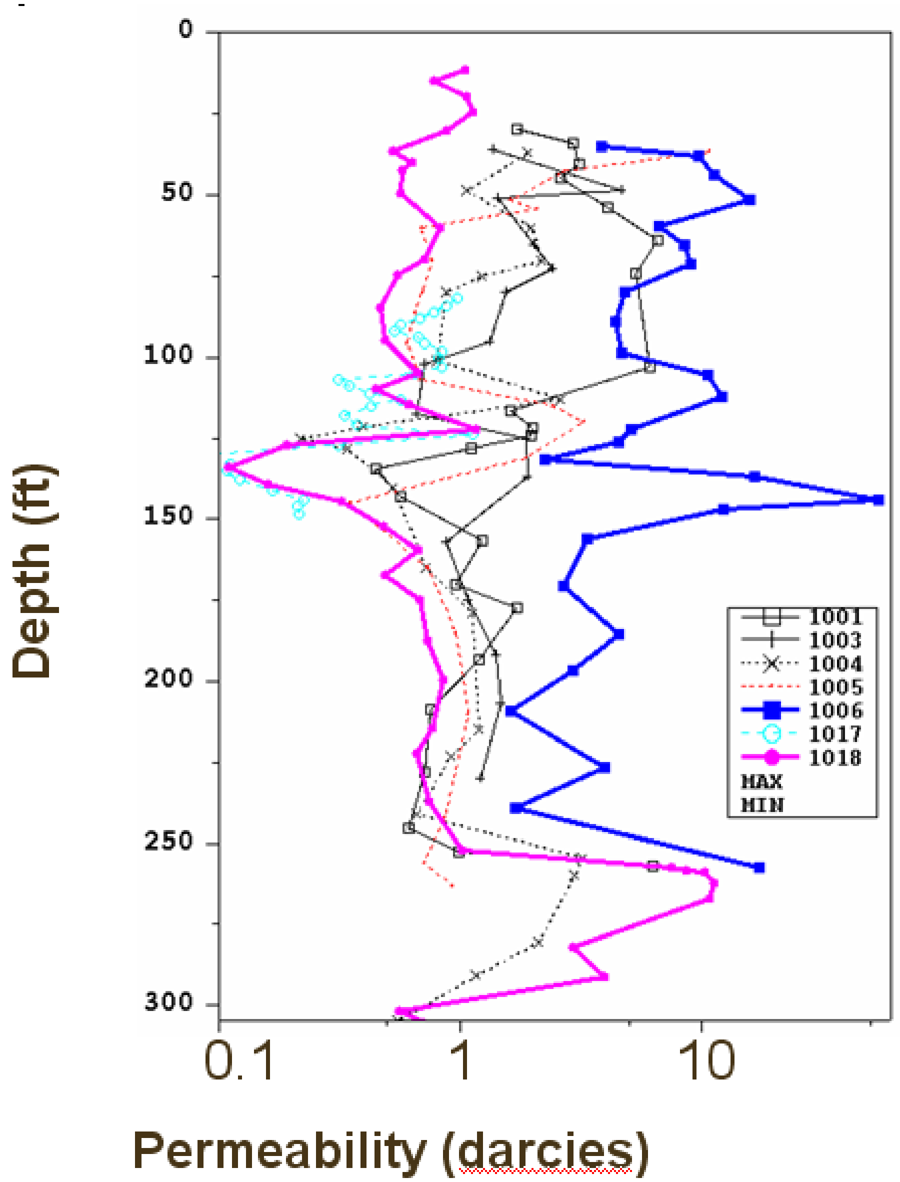


Figure 4.3-14 1,1,1-TCA, TCE, PCE, and 1,2-DCA concentration data for borehole 54-02089



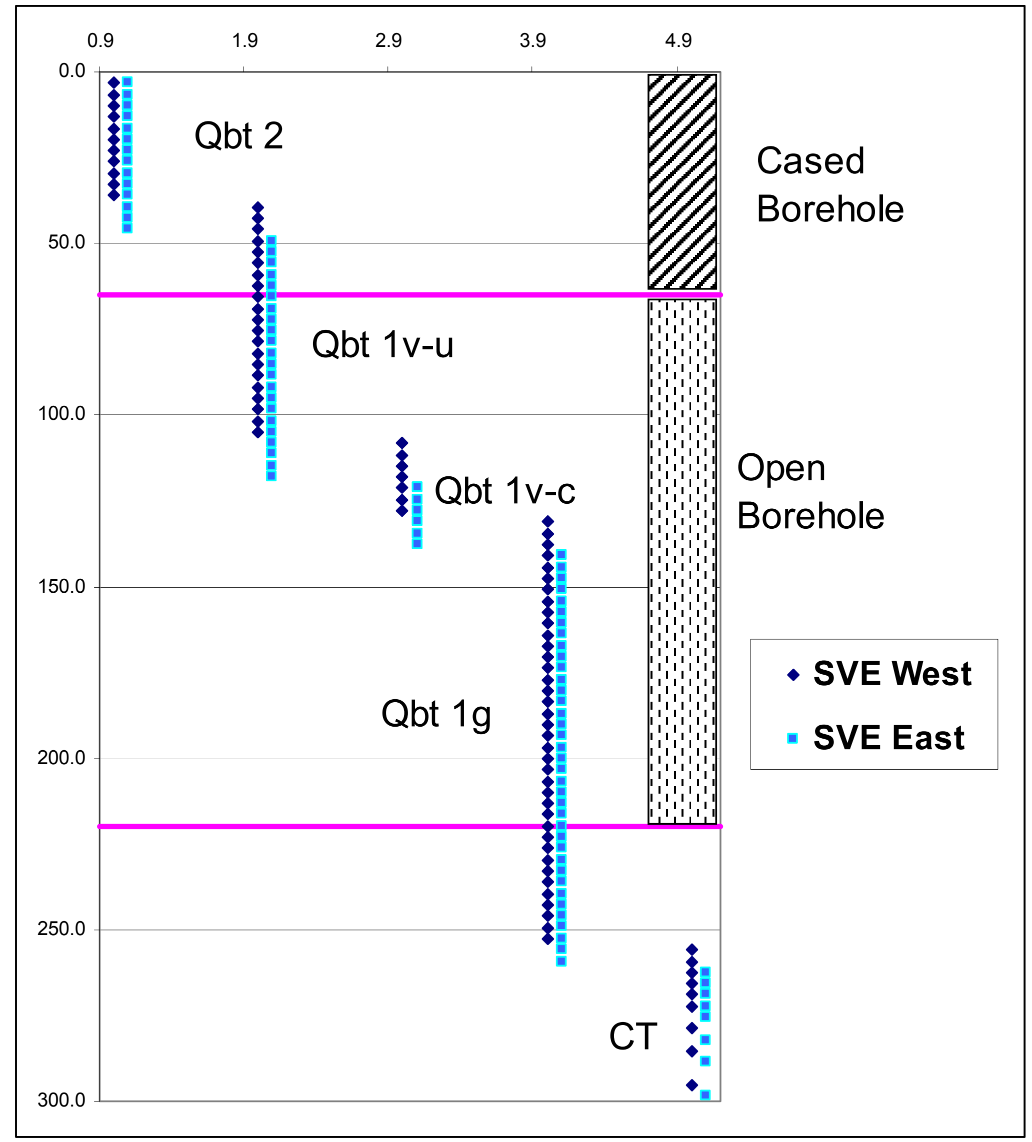


Figure 4.3-15 Straddle-packer permeability data related to geologic units and the SVE borehole design

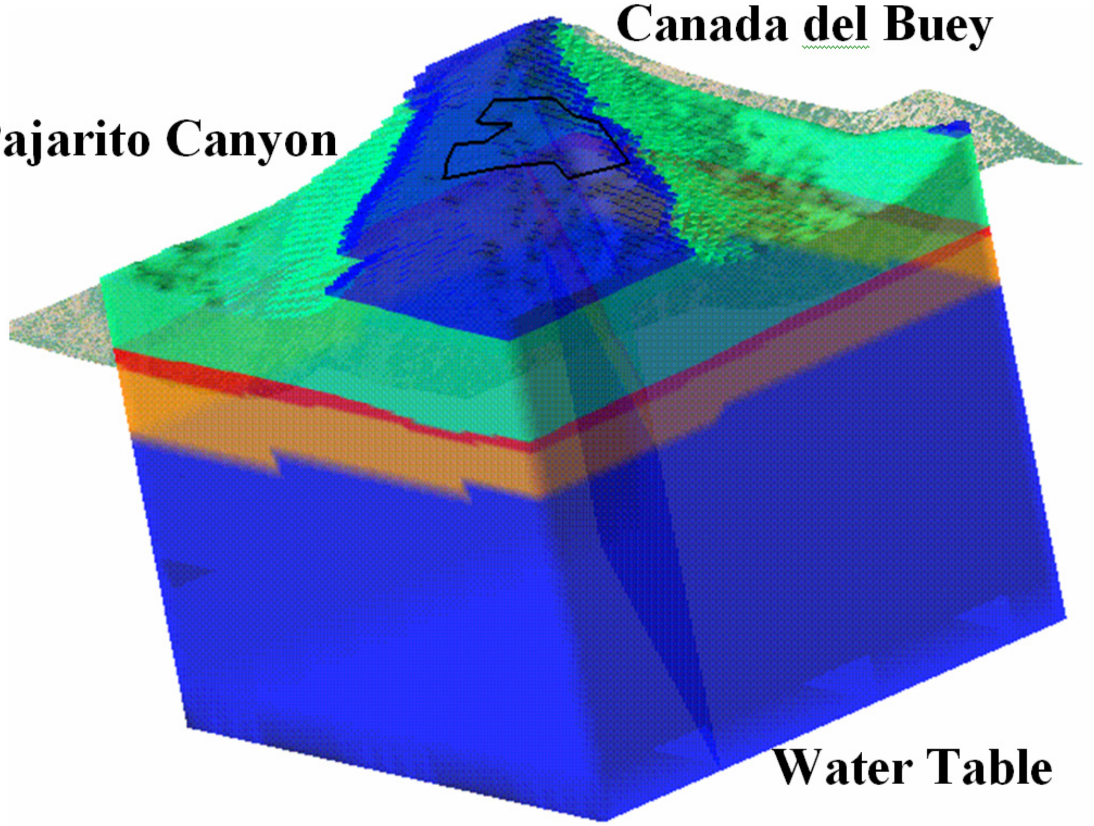


Figure 5.1-1 3-D model domain

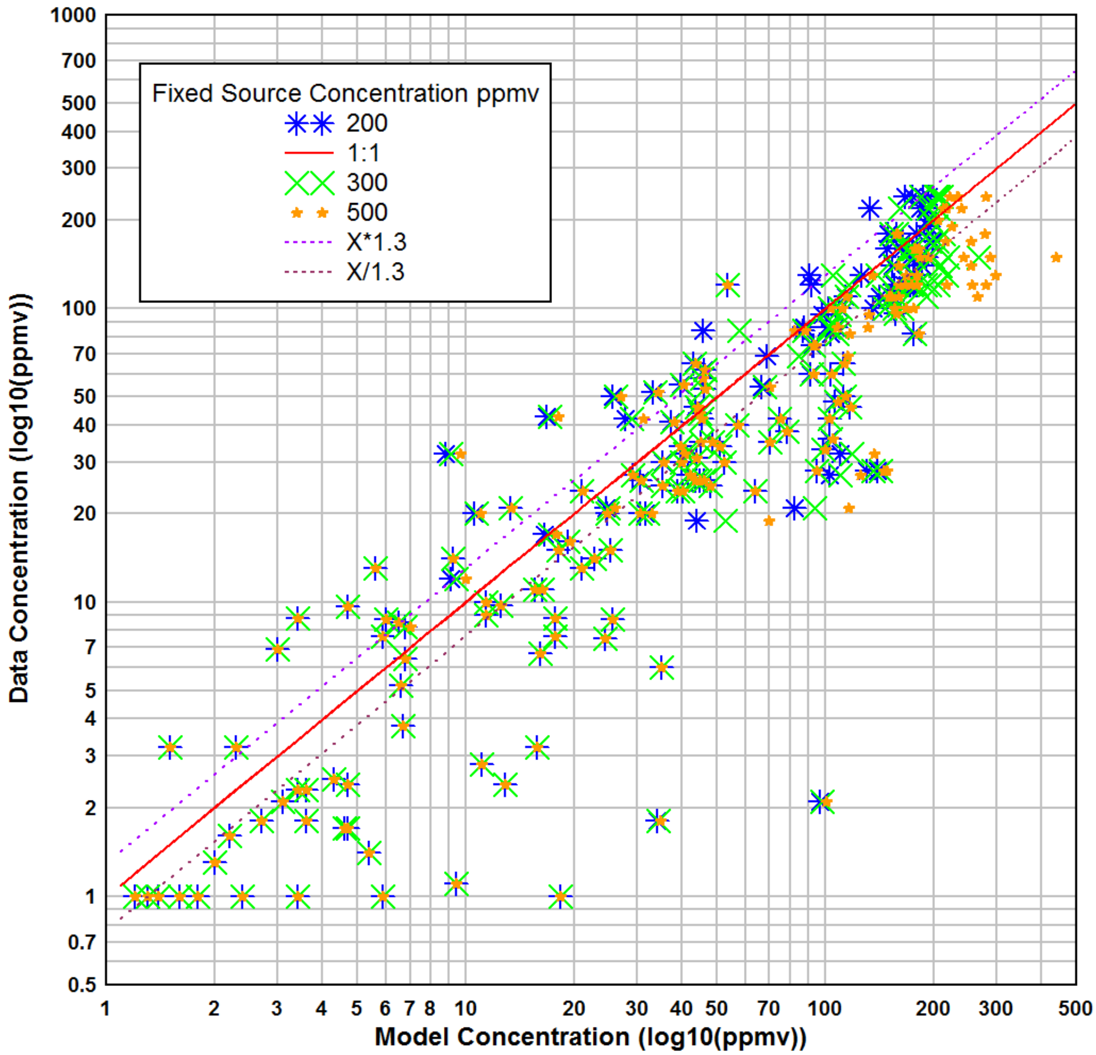
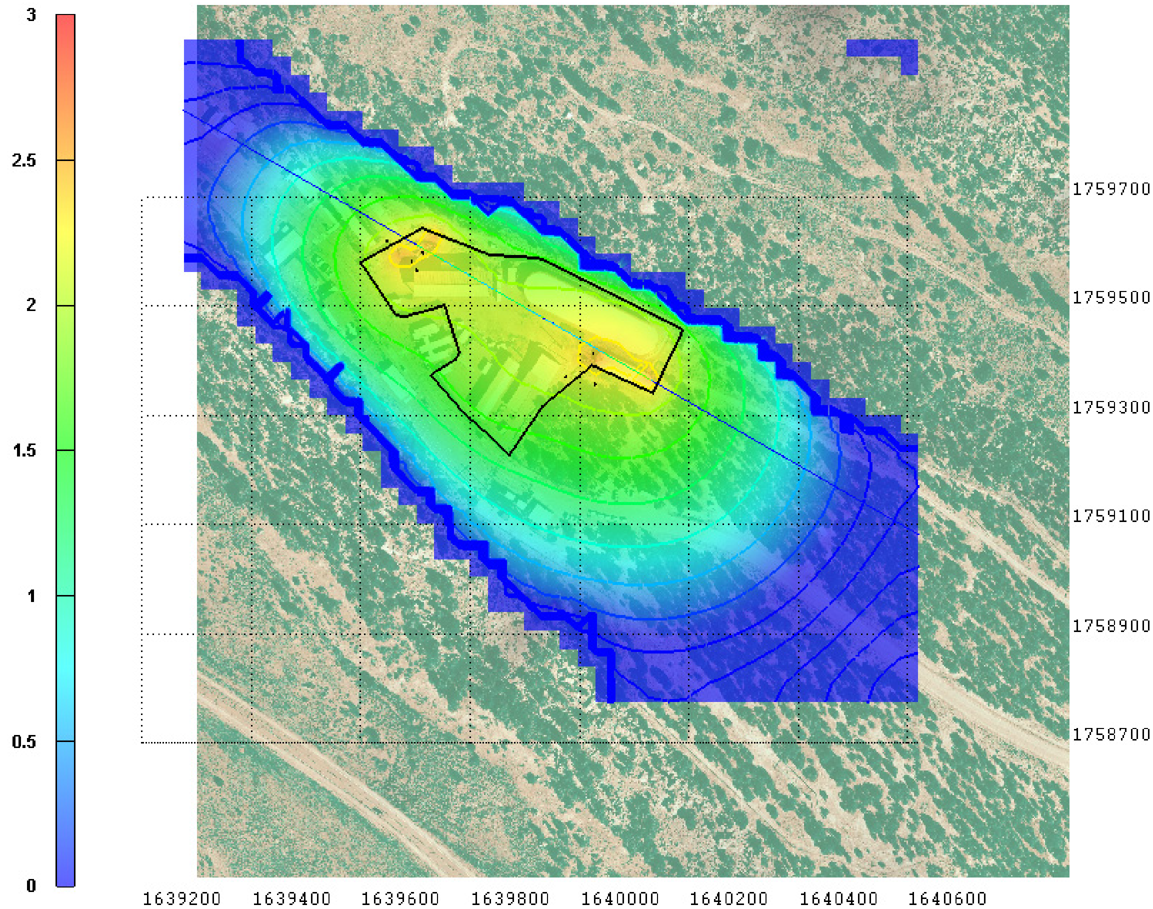


Figure 5.2-1 Simulated concentration compared with data for the 2014 Baseline pre-SVE initial state



Note: X-Y units are State Plan feet while the legend shows log10 (ppmv).

Figure 5.2-2 Simulated concentration on a slice plane 60 ft below the surface of MDA L

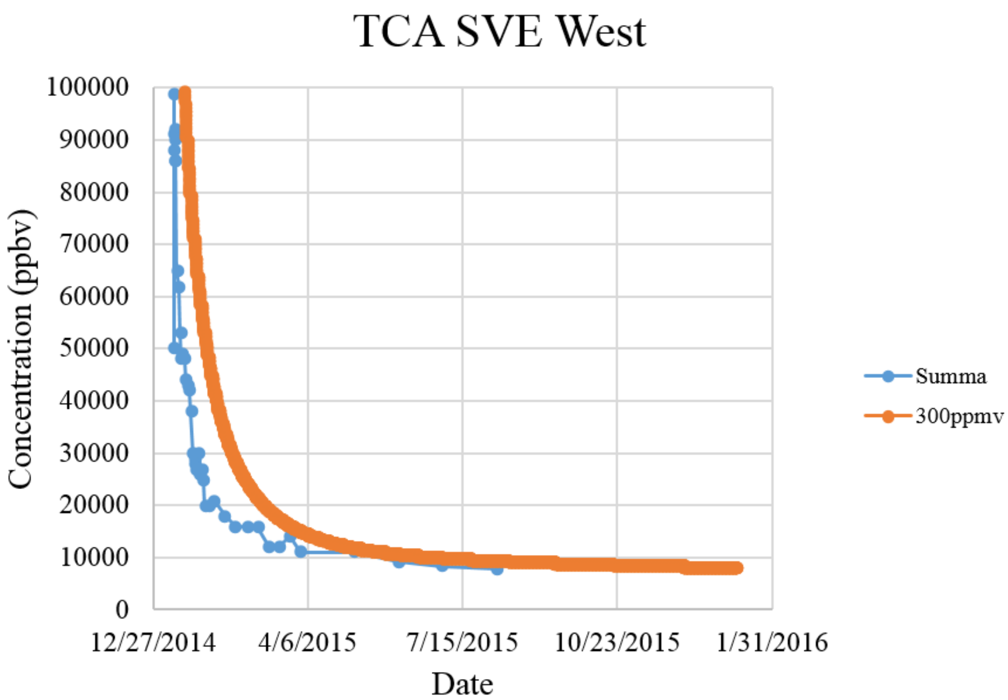


Figure 5.3-1 Predicted versus measured concentrations at SVE-West

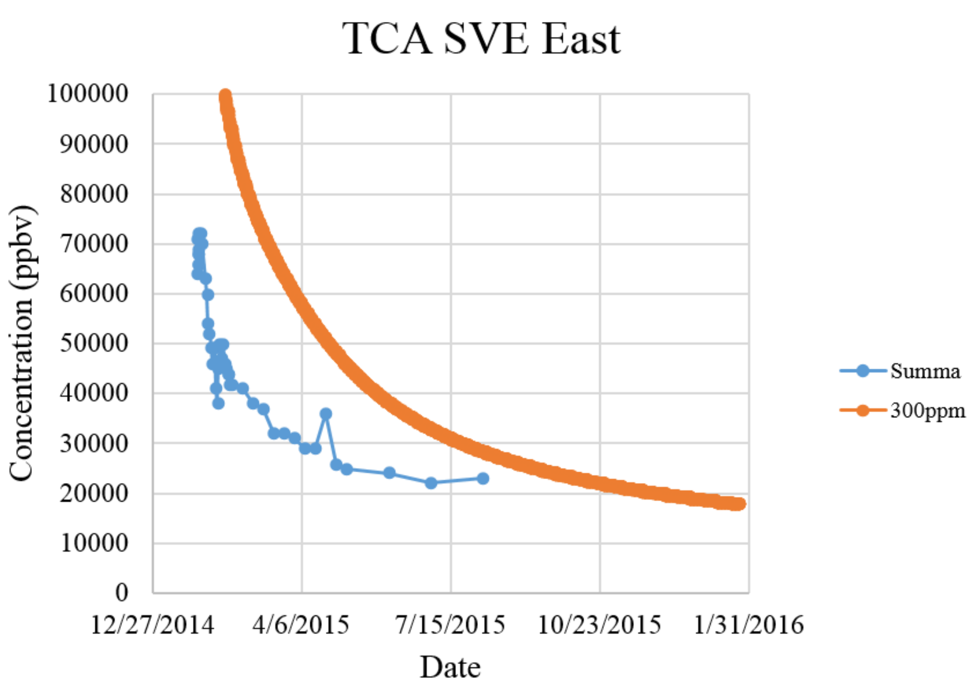


Figure 5.3-2 Predicted versus measured concentrations at SVE-East

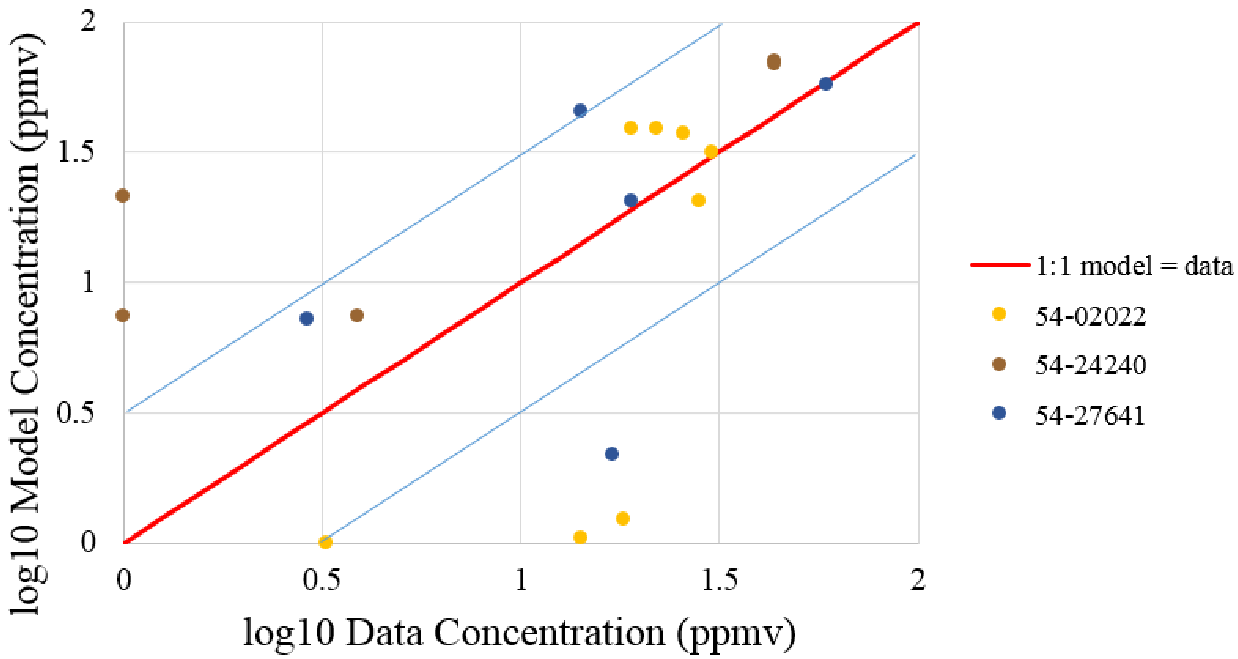


Figure 5.3-3 Predicted versus measured concentrations boreholes near SVE-West (November 2015)

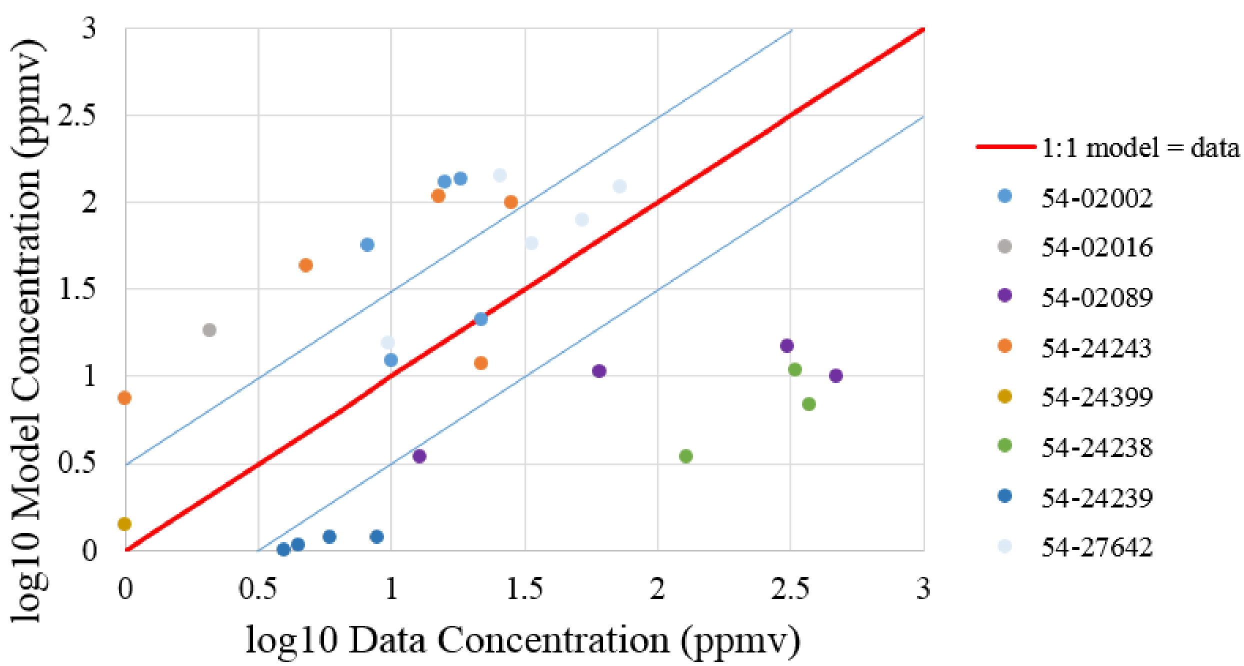


Figure 5.3-4 Predicted versus measured concentrations boreholes near SVE-East (November 2015)

Table 2.2-1
List of 62 Organic Compounds Analyzed
by EPA Method TO-15 during SVE Operations

Acetone	Dioxane[1,4-]
Benzene	Ethanol
Benzyl Chloride	Ethylbenzene
Bromodichloromethane	Ethyltoluene[4-]
Bromoform	Hexachlorobutadiene
Bromomethane	Hexane
Butadiene[1,3-]	Hexanone[2-]
Butanone[2-]	Isooctane
Carbon Disulfide	Isopropylbenzene
Carbon Tetrachloride	Methyl tert-Butyl Ether
Chloro-1-propene[3-]	Methyl-2-pentanone[4-]
Chlorobenzene	Methylene Chloride
Chlorodibromomethane	n-Heptane
Chloroethane	Propanol[2-]
Chloroform	Propylbenzene[1-]
Chloromethane	Styrene
Cyclohexane	Tetrachloroethane[1,1,2,2-]
Dibromoethane[1,2-]	Tetrachloroethene
Dichloro-1,1,2,2-tetrafluoroethane[1,2-]	Tetrahydrofuran
Dichlorobenzene[1,2-]	Toluene
Dichlorobenzene[1,3-]	Trichloro-1,2,2-trifluoroethane[1,1,2-]
Dichlorobenzene[1,4-]	Trichlorobenzene[1,2,4-]
Dichlorodifluoromethane	Trichloroethane[1,1,1-]
Dichloroethane[1,1-]	Trichloroethane[1,1,2-]
Dichloroethane[1,2-]	Trichloroethene
Dichloroethene[1,1-]	Trichlorofluoromethane
Dichloroethene[cis-1,2-]	Trimethylbenzene[1,2,4-]
Dichloroethene[trans-1,2-]	Trimethylbenzene[1,3,5-]
Dichloropropane[1,2-]	Vinyl Chloride
Dichloropropene[cis-1,3-]	Xylene[1,2-]
Dichloropropene[trans-1,3-]	Xylene[1,3-]+Xylene[1,4-]

Table 2.2-2
Subsurface Vapor-Monitoring Locations, Port Depths, and Corresponding Sampling Intervals Used for Baseline and Annual Monitoring

MDA L Well	Port Depth (ft bgs)	Sampling Interval (ft length along borehole)	Status
54-01015[a]	37.6	36–46	S
54-01015[a]	165.4	182–192	S
54-01015[a]	308.3	340–352	S
54-01015[a]	333.3	375–385	S
54-01015[a]	377.7	425–435	S
54-01015[a]	426.5	480–490	S
54-01015[a]	462.1	520–530	S
54-01016[a]	30.8	30–40	S
54-01016[a]	162.2	178–190	S
54-01016[a]	274.7	318–324	S
54-01016[a]	336.3	386–396	S
54-01016[a]	414.3	473–483	S-PB
54-01016[a]	459.5	530–540	S-PB
54-01016[a]	517.6	592–602	S
54-02001	20	17.5–22.5	S
54-02001	40	37.5–42.5	S
54-02001	60	57.5–62.5	S-PB
54-02001	80	77.5–82.5	S
54-02001	100	97.5–102.5	S
54-02001	120	117.5–122.5	S
54-02001	140	137.5–142.5	S
54-02001	160	157.5–162.5	S
54-02001	180	177.5–182.5	S
54-02001	200	197.5–202.5	S-PB
54-02002	20	17.5–22.5	NS-B
54-02002	40	37.5–42.5	S
54-02002	60	57.5–62.5	S
54-02002	80	77.5–82.5	S-PB
54-02002	100	97.5–102.5	NS-B
54-02002	120	117.5–122.5	S
54-02002	140	137.5–142.5	S-PB
54-02002	157/160	154.5–159.5	S
54-02002	180	177.5–182.5	S
54-02002	200	197.5–202.5	S
54-02016	18	15.5–20.5	NS-B

Table 2.2-2 (continued)

MDA L Borehole	Port Depth (ft bgs)	Sampling Interval (ft length along borehole)	Status
54-02016	31	28.5–33.5	S
54-02016	82	79.5–84.5	NS-B
54-02020	20	10–30	S
54-02020	40	30–50	S
54-02020	60	50–70	S
54-02020	80	70–90	S
54-02020	95	90–110	S
54-02020	120	110–130	S
54-02020	140	130–150	S
54-02020	160	150–170	S
54-02020	180	170–190	S
54-02020	200	190–210	S
54-02021	20	10–30	S
54-02021	40	30–50	S
54-02021	60	50–70	S
54-02021	80	70–90	S
54-02021	100	90–110	S
54-02021	120	110–130	S
54-02021	140	130–150	S
54-02021	160	150–170	S
54-02021	180	170–190	S
54-02021	198	190–210	S
54-02022	20	17.5–22.5	S
54-02022	40	37.5–42.5	S
54-02022	60	57.5–62.5	S
54-02022	80	77.5–82.5	S
54-02022	100	97.5–102.5	S
54-02022	120	117.5–122.5	S
54-02022	140	137.5–142.5	S
54-02022	160	157.5–162.5	S
54-02022	180	177.5–182.5	S
54-02022	200	197.5–202.5	S
54-02023	20	10–30	S
54-02023	40	30–50	S
54-02023	60	50–70	S
54-02023	80	70–90	S
54-02023	100	90–110	S
54-02023	120	110–130	S-PB

Table 2.2-2 (continued)

MDA L Borehole	Port Depth (ft bgs)	Sampling Interval (ft length along borehole)	Status
54-02023	140	130–149	S-PB
54-02023	159	149–169	S
54-02023	180	170–190	S-PB
54-02023	200	190–210	S
54-02024	20	10–30	S
54-02024	40	30–50	S
54-02024	60	50–70	S
54-02024	80	70–90	S
54-02024	100	90–110	S
54-02024	120	110–130	S-PB
54-02024	140	130–150	S
54-02024	160	150–170	S
54-02024	180	170–190	S
54-02024	200	190–210	S
54-02025	20	20	S
54-02025	60	60	S
54-02025	100	100	S
54-02025	160	160	S
54-02025	190	190	S
54-02026	20	20	S
54-02026	60	60	S
54-02026	100	100	S
54-02026	160	160	S
54-02026	200	200	S
54-02026	215	215	S
54-02027	20	20	S
54-02027	60	60	S
54-02027	100	100	S
54-02027	160	160	S
54-02027	200	200	S
54-02027	220	220	S
54-02027	250	250	S
54-02028	20	20	S
54-02028	60	60	S
54-02028	100	100	S
54-02028	160	160	S
54-02028	200	200	S
54-02028	220	220	S

Table 2.2-2 (continued)

MDA L Borehole	Port Depth (ft bgs)	Sampling Interval (ft length along borehole)	Status
54-02028	250	250	S
54-02031	20	20	S
54-02031	60	60	S
54-02031	100	100	S
54-02031	160	160	S
54-02031	200	200	S
54-02031	220	220	S
54-02031	260	260	S
54-02034	20	20	S
54-02034	60	60	S
54-02034	100	100	S
54-02034	160	160	S
54-02034	200	200	S
54-02034	220	220	S
54-02034	260	260	S
54-02034	300	300	S
54-02089	13	13	S
54-02089	31	31	S
54-02089	46	46	S
54-02089	86	86	S
54-24238	44	43–45	S
54-24238	64	63–65	S
54-24238	84	83–85	S
54-24239	25	24–26	S
54-24239	50	49–51	S
54-24239	75	74–76	S
54-24239	99.5	98.5–100.5	S
54-24240	28	27–29	S
54-24240	53	52–54	S
54-24240	78	77–79	S
54-24240	103	102–104	S
54-24240	128	127–129	S
54-24240	153	152–154	S
54-24241	73	71–74	S
54-24241	93	92–94	S
54-24241	113	112–114	S
54-24241	133	132–134	S
54-24241	153	152–154	S

Table 2.2-2 (continued)

MDA L Borehole	Port Depth (ft bgs)	Sampling Interval (ft length along borehole)	Status
54-24241	173	172–174	S
54-24241	193	192–194	S
54-24242	25	24–26	S
54-24242	50	49–51	S
54-24242	75	74–76	S
54-24242	100	99–101	S
54-24242	110.5	109.5–111.5	S
54-24243	25	24–26	S
54-24243	50	49–51	S
54-24243	75	74–76	S
54-24243	100	99–101	S
54-24243	125	124–126	S
54-24399[b]	568–608	568–608	S
54-24399[b]	568–569	568–569	S
54-27641	32	29.5–34.5	S
54-27641	82	79.5–84.5	S
54-27641	115	112.5–117.5	S
54-27641	182	179.5–184.5	S
54-27641	232	229.5–234.5	S
54-27641	271	268.5–273.5	S
54-27641	332.5	330–335	S
54-27642	30	27.5–32.5	S
54-27642	75	71.5–76.5	S
54-27642	116	114.5–119.5	S
54-27642	175	172.5–177.5	S
54-27642	235	232.5–237.5	S
54-27642	275	272.5–277.5	S
54-27642	338	335.5–340.5	S
54-27643	30	27.5–32.5	S
54-27643	74	71.5–76.5	S
54-27643	117	114.5–119.5	S
54-27643	167	164.5–169.5	S
54-27643	235	232.5–237.5	S
54-27643	275	272.5–277.5	S
54-27643	354	351.5–356.5	S
54-610786[c]	25	22.5–27.5	S
54-610786[c]	50	47.5–52.5	S
54-610786[c]	75	72.5–77.5	S

Table 2.2-2 (continued)

MDA L Borehole	Port Depth (ft bgs)	Sampling Interval (ft length along borehole)	Status
54-610786[c]	100	97.5–102.5	S
54-610786[c]	118.5	116–121	S

Notes: S = Sampled; S-PB = sample partially blocked; NS-B not sampled because port blocked.

[a] Vapor-monitoring borehole angled. Port depth is depth below ground surface. Port-depth interval is length along borehole.

[b] Open borehole below 565.5 ft bgs.

[c] Drilled in December 2009.

Table 2.2-3
Subsurface Vapor-Monitoring Locations, Port Depths, and Corresponding Sampling Intervals Used for Quarterly Sampling within 150-ft Radius of the SVE Units

MDA L Well	Port Depth (ft bgs)	Sampling Interval (ft length along borehole)	Apr-15	Jul-15	Nov-15	Status
54-02001	20	17.5–22.5	S	S	NS-RC	
54-02001	40	37.5–42.5	S	S	NS-RC	
54-02001	60	57.5–62.5	NS-B	NS-B	NS	RfP
54-02001	80	77.5–82.5	S	S	NS-RC	
54-02001	100	97.5–102.5	S	S	NS-RC	
54-02001	120	117.5–122.5	S	S	NS-RC	
54-02001	140	137.5–142.5	S	S	NS-RC	
54-02001	160	157.5–162.5	NS-B	NS-B	NS	RfP
54-02001	180	177.5–182.5	S	S	NS-RC	
54-02001	200	197.5–202.5	NS-B	S-PB	NS	RfP
54-02002	20	17.5–22.5	NS-B	NS-B	NS	RfP
54-02002	40	37.5–42.5	S	S	S	
54-02002	60	57.5–62.5	S	S	S	
54-02002	80	77.5–82.5	S-PB	S-PB	NS	RfP
54-02002	100	97.5–102.5	NS-B	NS-B	NS	RfP
54-02002	120	117.5–122.5	S	S	S	
54-02002	140	137.5–142.5	S-PB	S-PB	NS	RfP
54-02002	157/160	154.5–159.5	S-PB	S	NS	RfP
54-02002	180	177.5–182.5	S	S	S	
54-02002	200	197.5–202.5	S	S	S	
54-02016	18	15.5–20.5	NS-B	NS-B	NS	RfP
54-02016	31	28.5–33.5	S	S	S	
54-02016	82	79.5–84.5	NS-B	NS-B	NS	RfP
54-02021	20	10–30	S	S	S	
54-02021	40	30–50	S-PB	S-PB	NS	RfP
54-02021	60	50–70	S	S-PB	NS	RfP
54-02021	80	70–90	S-PB	S-PB	NS	RfP
54-02021	100	90–110	S-PB	S-PB	NS	RfP
54-02021	120	110–130	S-PB	S-PB	NS	RfP
54-02021	140	130–150	S	S	S	
54-02021	160	150–170	S	S	S	
54-02021	180	170–190	S	S	S	
54-02021	198	190–210	S	S	S	
54-02022	20	17.5–22.5	NS-B	S-PB	NS	RfP

Table 2.2-3 (continued)

MDA L Well	Port Depth (ft bgs)	Sampling Interval (ft length along borehole)	Apr-15	Jul-15	Nov-15	Status
54-02022	40	37.5–42.5	S	S	S	
54-02022	60	57.5–62.5	S	S	S	
54-02022	80	77.5–82.5	S	S	S	
54-02022	100	97.5–102.5	NS-B	S-PB	NS	RfP
54-02022	120	117.5–122.5	S	S	S	
54-02022	140	137.5–142.5	S	S	S	
54-02022	160	157.5–162.5	S	S	S	
54-02022	180	177.5–182.5	S	S	S	
54-02022	200	197.5–202.5	S	S	S	
54-02089	13	13	S	S	S	
54-02089	31	31	S	S	S	
54-02089	46	46	S	S	S	
54-02089	86	86	S	S	S	
54-24238	44	43–45	S	S	S	
54-24238	64	63–65	S	S	S	
54-24238	84	83–85	S	S	S	
54-24239	25	24–26	S	S	S	
54-24239	50	49–51	S	S	S	
54-24239	75	74–76	S	S	S	
54-24239	99.5	98.5–100.5	S	S	S	
54-24240	28	27–29	S	S	S	
54-24240	53	52–54	S	S	S	
54-24240	78	77–79	S	S	S	
54-24240	103	102–104	S	S	NS-FV	
54-24240	128	127–129	S	S	S	
54-24240	153	152–154	S	S	S	
54-24241	73	71–74	S	S	NS-RC	
54-24241	93	92–94	S	S	NS-RC	
54-24241	113	112–114	S	S	NS-RC	
54-24241	133	132–134	S	S	NS-RC	
54-24241	153	152–154	S	S	NS-RC	
54-24241	173	172–174	S	S	NS-RC	
54-24241	193	192–194	S	S	NS-RC	
54-24243	25	24–26	S	S	S	
54-24243	50	49–51	S	S	S	
54-24243	75	74–76	S	S	S	
54-24243	100	99–101	S	S	S	

Table 2.2-3 (continued)

MDA L Well	Port Depth (ft bgs)	Sampling Interval (ft length along borehole)	Apr-15	Jul-15	Nov-15	Status
54-24243	125	124–126	S	S	S	
54-24399*	568–608	568–608 (565.5–608 Nov-15)	S	S	S	
54-24399*	568–569	568–569	S	S	NS	RfP
54-27641	32	29.5–34.5	S	S	NS-RC	
54-27641	82	79.5–84.5	S	S	S	
54-27641	115	112.5–117.5	S	S	S	
54-27641	182	179.5–184.5	S	S	S	
54-27641	232	229.5–234.5	S	S	NS-RC	
54-27641	271	268.5–273.5	S	S	S	
54-27641	332.5	330–335	S	S	S	
54-27642	30	27.5–32.5	S	S	S	
54-27642	75	71.5–76.5	S	S	S	
54-27642	116	114.5–119.5	S	S	NS-RC	
54-27642	175	172.5–177.5	S	S	S	
54-27642	235	232.5–237.5	S	S	S	
54-27642	275	272.5–277.5	S	S	S	
54-27642	338	335.5–340.5	S	S	NS-RC	

Notes: S = Sampled; S-PB = sample partially blocked; NS-B not sampled because port blocked; NS-RC = not sampled because of radiological concerns; NS = not sampled; NS-FV = not sampled because valve faulty; RfP = removed from plan.

*Borehole open below 565.5 ft bgs.

Table 4.1-1
Mass Removed for Detected Organic Compounds during SVE Operation

Parameter_Name	Cumulative Total Pounds through 2/18/2015 10:53:00 AM	Cumulative Total Pounds through 3/18/2015 10:53:00 AM	Cumulative Total Pounds through 4/18/2015 10:53:00 AM	Cumulative Total Pounds through 5/18/2015 10:53:00 AM	Cumulative Total Pounds through 6/18/2015 10:53:00 AM
Acetone	0.01	0.01	0.01	0.01	0.01
Benzene	0.12	0.22	0.31	0.39	0.48
Carbon Tetrachloride	0.58	0.92	1.22	1.49	1.72
Chlorobenzene	0.00	0.00	0.00	0.01	0.02
Chloroform	5.39	8.51	11.19	13.53	15.65
Dichlorodifluoromethane	0.48	0.74	0.96	1.15	1.33
Dichloroethane[1,1-]	4.16	6.36	8.29	9.97	11.47
Dichloroethane[1,2-]	12.16	17.48	22.52	27.03	31.06
Dichloroethene[1,1-]	5.84	9.73	13.30	16.50	19.82
Dichloropropane[1,2-]	4.13	8.08	11.50	14.62	17.50
Dioxane[1,4-]	0.22	0.60	1.15	1.73	2.39
Ethanol	0.01	0.01	0.03	0.05	0.05
Hexane	0.05	0.05	0.05	0.05	0.05
Isooctane	0.02	0.13	0.13	0.14	0.17
Methylene Chloride	2.52	4.63	6.64	8.51	10.27
n-Heptane	0.02	0.02	0.02	0.02	0.02
Tetrachloroethene	20.10	33.02	45.67	57.13	67.95
Tetrahydrofuran	0.11	0.24	0.35	0.47	0.61
Toluene	0.20	0.43	0.66	0.88	1.11
Trichloro-1,2,2-trifluoroethane[1,1,2-]	21.40	37.13	50.75	62.63	73.57
Trichloroethane[1,1,1-]	116.25	187.31	250.50	305.43	354.80
Trichloroethene	65.87	97.69	125.95	150.78	173.69
Trichlorofluoromethane	1.24	2.13	2.94	3.65	4.27
Xylene[1,3-]+Xylene[1,4-]	0.02	0.03	0.05	0.06	0.07
Total VOCs	260.88	415.49	554.20	676.23	788.08

Table 4.1-1 (continued)

Parameter_Name	Cumulative Total Pounds through 7/18/2015	Cumulative Total Pounds through 8/18/2015	Cumulative Total Pounds through 9/18/2015	Cumulative Total Pounds through 10/18/2015	Cumulative Total Pounds through 11/18/2015
Acetone	0.01	0.01	0.01	0.01	0.01
Benzene	0.56	0.64	0.71	0.78	0.85
Carbon Tetrachloride	1.92	2.10	2.27	2.42	2.56
Chlorobenzene	0.03	0.05	0.06	0.06	0.07
Chloroform	17.59	19.47	21.12	22.62	24.12
Dichlorodifluoromethane	1.50	1.67	1.82	1.95	2.06
Dichloroethane[1,1-]	12.75	13.94	15.00	16.00	16.98
Dichloroethane[1,2-]	34.66	38.12	41.05	43.63	46.19
Dichloroethene[1,1-]	23.11	26.27	28.85	31.15	34.00
Dichloropropane[1,2-]	20.00	22.35	24.51	26.61	28.70
Dioxane[1,4-]	3.04	3.67	4.24	4.79	5.38
Ethanol	0.05	0.05	0.11	0.23	0.31
Hexane	0.06	0.08	0.09	0.09	0.09
Isooctane	0.19	0.19	0.19	0.19	0.19
Methylene Chloride	11.83	13.33	14.72	16.05	17.41
n-Heptane	0.04	0.07	0.09	0.09	0.09
Tetrachloroethene	77.26	85.97	94.19	102.16	110.63
Tetrahydrofuran	0.74	0.86	1.00	1.13	1.25
Toluene	1.29	1.44	1.61	1.79	1.97
Trichloro-1,2,2-trifluoroethane[1,1,2-]	83.64	93.00	101.17	109.01	117.16
Trichloroethane[1,1,1-]	399.42	441.79	477.93	510.09	540.98
Trichloroethene	193.45	211.32	227.65	243.63	259.45
Trichlorofluoromethane	4.86	5.43	5.93	6.38	6.82
Xylene[1,3-]+Xylene[1,4-]	0.11	0.16	0.20	0.21	0.21
Total VOCs	888.08	981.99	1064.50	1141.05	1217.49

Table 4.1-2
Flow Rate Data for SVE-West

Date	Time	Flow Rate (cfm*)
1/9/2015	12:55	0.0
1/9/2015	12:56	99.9
1/9/2015	12:59	99.9
1/9/2015	13:01	99.9
1/9/2015	13:02	99.9
1/9/2015	13:05	99.9
1/9/2015	13:07	99.9
1/9/2015	13:09	99.9
1/9/2015	13:11	99.9
1/9/2015	13:32	99.9
1/9/2015	13:36	99.9
1/9/2015	13:37	99.9
1/9/2015	13:38	99.9
1/9/2015	13:45	99.9
1/9/2015	13:52	99.9
1/9/2015	14:01	99.9
1/9/2015	14:22	99.9
1/9/2015	14:42	99.9
1/9/2015	14:53	99.9
1/9/2015	15:05	99.9
1/9/2015	15:15	99.9
1/9/2015	15:16	99.9
1/9/2015	15:24	99.9
1/9/2015	15:34	99.9
1/9/2015	15:44	99.9
1/9/2015	15:54	99.9
1/9/2015	16:03	99.9
1/9/2015	16:05	99.9
1/9/2015	16:07	99.9
1/10/2015	9:08	99.9
1/10/2015	9:09	99.9
1/10/2015	9:10	99.9
1/10/2015	9:53	99.9
1/10/2015	9:55	99.9
1/10/2015	9:57	99.9
1/10/2015	10:41	99.9
1/10/2015	10:43	99.9

Table 4.1-2 (continued)

Date	Time	Flow Rate (cfm*)
1/10/2015	10:48	99.9
1/10/2015	10:48	99.9
1/10/2015	11:35	99.9
1/10/2015	11:48	99.9
1/10/2015	11:51	99.9
1/10/2015	11:52	99.9
1/11/2015	9:02	99.9
1/11/2015	9:05	99.9
1/11/2015	9:07	99.9
1/12/2015	12:03	99.9
1/12/2015	12:05	99.9
1/12/2015	12:07	99.9
1/13/2015	8:57	99.9
1/13/2015	8:59	99.9
1/13/2015	9:00	99.9
1/14/2015	9:37	99.9
1/14/2015	9:40	99.9
1/14/2015	9:42	99.9
1/15/2015	11:36	99.9
1/15/2015	11:38	99.9
1/15/2015	11:40	99.9
1/16/2015	8:58	99.9
1/16/2015	8:59	99.9
1/16/2015	9:00	99.9
1/17/2015	9:05	99.9
1/17/2015	9:07	99.9
1/17/2015	9:09	99.9
1/18/2015	8:57	99.9
1/18/2015	8:58	99.9
1/18/2015	9:00	99.9
1/18/2015	9:02	99.9
1/19/2015	9:03	99.9
1/19/2015	9:05	99.9
1/19/2015	9:07	99.9
1/19/2015	9:09	99.9
1/20/2015	9:54	99.9
1/20/2015	9:55	99.9
1/20/2015	9:57	99.9
1/21/2015	9:54	99.9

Table 4.1-2 (continued)

Date	Time	Flow Rate (cfm*)
1/21/2015	9:56	99.9
1/21/2015	9:58	99.9
1/22/2015	14:43	99.9
1/22/2015	14:44	99.9
1/22/2015	14:47	99.9
1/23/2015	9:20	100.7
1/23/2015	9:25	100.7
1/23/2015	9:28	100.7
1/24/2015	10:46	99.9
1/24/2015	10:49	99.9
1/24/2015	10:53	99.9
1/25/2015	9:40	100.3
1/25/2015	9:42	100.3
1/25/2015	9:45	100.3
1/26/2015	9:08	99.9
1/26/2015	9:11	99.9
1/26/2015	9:15	99.9
1/27/2015	10:50	99.5
1/27/2015	10:51	99.5
1/27/2015	10:52	99.5
1/28/2015	9:45	99.5
1/28/2015	9:47	99.5
1/28/2015	9:49	99.5
1/29/2015	9:02	99.6
1/29/2015	9:05	99.6
1/29/2015	9:06	99.6
1/31/2015	13:54	99.5
1/31/2015	13:55	99.5
1/31/2015	13:59	99.5
2/4/2015	10:07	99.1
2/11/2015	10:29	99.6
2/18/2015	9:58	97.8
2/25/2015	12:42	99.1
3/4/2015	9:53	100.6
3/11/2015	9:16	99.2
3/18/2015	9:05	100.1
3/25/2015	8:58	100.1
4/1/2015	10:19	99.6
4/8/2015	9:20	99.6

Table 4.1-2 (continued)

Date	Time	Flow Rate (cfm*)
4/9/2015	11:43	99.2
4/14/2015	9:27	99.2
4/15/2015	9:09	99.6
4/21/2015	9:31	99.6
4/22/2015	10:33	99.6
4/28/2015	9:42	98.7
4/29/2015	9:52	99.2
5/6/2015	9:36	99.2
5/13/2015	9:58	99.7
5/20/2015	11:41	98.7
5/27/2015	9:14	98.7
6/3/2015	10:56	98.7
6/10/2015	9:23	100.0
6/17/2015	9:30	100.0
6/24/2015	11:16	100.0
7/1/2015	8:56	97.8
7/9/2015	9:48	99.5
7/15/2015	9:42	98.6
7/22/2015	9:51	97.3
7/29/2015	9:42	99.5
8/5/2015	9:45	97.3
8/12/2015	9:25	99.1
8/19/2015	15:10	98.6
8/26/2015	8:34	99.6
9/2/2015	9:17	100.0
9/9/2015	9:19	99.9
9/16/2015	11:39	99.1
9/23/2015	9:27	99.6
9/30/2015	8:56	100.1
10/7/2015	9:18	100.1
10/14/2015	8:19	100.1
10/22/2015	9:46	100.5
10/28/2015	10:55	99.7
11/5/2015	10:58	99.7
11/12/2015	9:23	101.1
11/17/2015	12:37 PM	99.7
11/18/2015	10:54	99.7

*cfm = Cubic feet per minute.

Table 4.1-3
Flow Rate Data for SVE-East

Date	Time	Flow Rate (cfm*)
1/26/2015	10:20	0.0
1/26/2015	10:21	95.6
1/26/2015	10:25	95.6
1/26/2015	10:30	95.6
1/26/2015	10:34	95.6
1/26/2015	10:57	95.6
1/26/2015	11:01	95.6
1/26/2015	11:03	95.6
1/26/2015	11:18	95.6
1/26/2015	11:21	95.6
1/26/2015	11:27	95.6
1/26/2015	11:31	95.6
1/26/2015	11:41	95.6
1/26/2015	11:47	95.6
1/26/2015	11:55	95.6
1/26/2015	12:01	95.6
1/26/2015	12:05	95.6
1/26/2015	13:59	95.6
1/26/2015	14:06	95.6
1/26/2015	14:10	95.6
1/26/2015	14:15	95.6
1/26/2015	14:20	95.6
1/26/2015	14:24	95.6
1/26/2015	14:29	95.6
1/26/2015	14:31	95.6
1/26/2015	14:44	95.6
1/26/2015	14:47	95.6
1/26/2015	14:53	95.6
1/26/2015	15:02	95.6
1/26/2015	15:10	95.6
1/26/2015	15:17	95.6
1/26/2015	15:19	95.6
1/26/2015	15:21	95.6
1/27/2015	11:17	94.6
1/27/2015	11:19	94.6
1/27/2015	11:21	94.6
1/27/2015	12:18	94.6

Table 4.1-3 (continued)

Date	Time	Flow Rate (cfm*)
1/27/2015	12:20	94.6
1/27/2015	12:22	94.6
1/27/2015	13:57	94.6
1/27/2015	13:59	94.6
1/27/2015	14:00	94.6
1/27/2015	14:55	94.6
1/27/2015	14:57	94.6
1/27/2015	14:59	94.6
1/27/2015	15:45	94.6
1/27/2015	15:50	94.6
1/27/2015	15:52	94.6
1/27/2015	15:54	94.6
1/28/2015	10:20	94.4
1/28/2015	10:21	94.4
1/28/2015	10:23	94.4
1/29/2015	10:12	94.4
1/29/2015	10:13	94.4
1/29/2015	10:15	94.4
1/31/2015	14:37	93.6
1/31/2015	14:40	93.6
1/31/2015	14:41	93.6
2/1/2015	8:51	94.1
2/1/2015	8:54	94.1
2/1/2015	8:57	94.1
2/2/2015	9:40	93.6
2/2/2015	9:42	93.6
2/2/2015	9:46	93.6
2/4/2015	10:07	93.4
2/5/2015	8:51	96.0
2/6/2015	10:23	100.6
2/7/2015	9:34	98.9
2/8/2015	9:21	98.9
2/9/2015	9:58	96.3
2/10/2015	9:34	98.0
2/11/2015	9:47	97.4
2/12/2015	9:00	97.4
2/13/2015	9:03	97.4
2/14/2015	8:58	98.0
2/15/2015	8:58	98.0

Table 4.1-3 (continued)

Date	Time	Flow Rate (cfm*)
2/17/2015	9:39	98.4
2/18/2015	9:25	98.0
2/25/2015	13:18	98.2
3/4/2015	10:41	98.5
3/11/2015	9:47	98.5
3/18/2015	9:39	98.5
3/25/2015	9:21	98.5
4/1/2015	9:21	96.2
4/8/2015	9:45	97.7
4/9/2015	12:13	97.3
4/14/2015	9:55	96.6
4/15/2015	9:34	97.7
4/21/2015	9:58	96.6
4/22/2015	10:49	98.6
4/28/2015	10:05	97.3
4/29/2015	10:19	97.3
5/6/2015	10:10	97.3
5/13/2015	10:30	97.7
5/20/2015	11:59	96.8
5/27/2015	9:40	97.3
6/3/2015	11:48	98.0
6/10/2015	9:45	98.0
6/17/2015	9:45	97.3
6/24/2015	11:37	97.3
7/1/2015	9:15	97.1
7/9/2015	10:28	97.0
7/15/2015	10:02	96.6
7/22/2015	10:14	95.5
7/29/2015	10:08	98.0
8/5/2015	10:06	97.1
8/12/2015	9:47	93.4
8/19/2015	15:25	93.4
8/26/2015	8:49	96.1
9/2/2015	9:37	96.8
9/9/2015	9:36	96.4
9/16/2015	11:56	96.8
9/23/2015	9:45	97.3
9/30/2015	9:13	97.3
10/7/2015	9:49	98.4

Table 4.1-3 (continued)

Date	Time	Flow Rate (cfm*)
10/14/2015	8:39	98.4
10/22/2015	10:09	98.2
10/28/2015	11:15	100.1
11/5/2015	11:30	100.3
11/12/2015	9:42	100.1
11/17/2015	13:18	102.4
11/18/2015	11:30	99.4

* cfm = Cubic feet per minute. Standard conditions for the orifice flow meter are 60°F and 14.7 psi (21.1°C and 101.3 kPa).

Table 4.3-1
Differential Pressure Data at
Sampling Ports Monitored during SVE Operations

Well	Port Depth (ft bgs)	Sampling Interval (ft length along borehole)	Static Pressure (kPa)			
			Baseline 2014	Apr-15	Jul-15	Nov-15
54-01015[a]	37.6	36–46	-0.106	—	—	—
54-01015[a]	165.4	182–192	-0.180	—	—	—
54-01015[a]	308.3	340–352	0.011	—	—	—
54-01015[a]	333.3	375–385	-0.119	—	—	—
54-01015[a]	377.7	425–435	-0.126	—	—	—
54-01015[a]	426.5	480–490	-0.122	—	—	—
54-01015[a]	462.1	520–530	0.000	—	—	—
54-01016[a]	30.8	30–40	-0.056	—	—	—
54-01016[a]	162.2	178–190	0.021	—	—	—
54-01016[a]	274.7	318–324	0.020	—	—	—
54-01016[a]	336.3	386–396	0.016	—	—	—
54-01016[a]	414.3	473–483	0.010	—	—	—
54-01016[a]	459.5	530–540	0.000	—	—	—
54-01016[a]	517.6	592–602	0.010	—	—	—
54-02001	20	17.5–22.5	-0.063	-0.314	-0.206	NS-RC
54-02001	40	37.5–42.5	-0.035	-0.545	-0.253	NS-RC
54-02001	60	57.5–62.5	0.000	NS-B	NS-B	NS
54-02001	80	77.5–82.5	-0.113	-0.855	-0.694	NS-RC
54-02001	100	97.5–102.5	-0.038	-0.349	-0.267	NS-RC
54-02001	120	117.5–122.5	-0.167	-0.989	-0.639	NS-RC
54-02001	140	137.5–142.5	-0.380	-1.034	-0.622	NS-RC
54-02001	160	157.5–162.5	0.000	NS-B	NS-B	NS
54-02001	180	177.5–182.5	-0.022	0.317	-0.210	NS-RC

Table 4.3-1 (continued)

Well	Port Depth (ft bgs)	Sampling Interval (ft length along borehole)	Static Pressure (kPa)			
			Annual	Apr-15	Jul-15	Nov-15
54-02001	200	197.5–202.5	-0.037	NS-B	-0.214	NS
54-02002	20	17.5–22.5	NS-B	NS-B	NS	NS
54-02002	40	37.5–42.5	-0.025	-0.828	0.527	0.565
54-02002	60	57.5–62.5	-0.014	-0.174	0.153	0.187
54-02002	80	77.5–82.5	-0.020	-0.379	NS	NS
54-02002	100	97.5–102.5	NS-B	NS-B	NS	NS
54-02002	120	117.5–122.5	-0.021	-0.746	0.525	0.583
54-02002	140	137.5–142.5	0.000	NS-B	NS-B	NS
54-02002	157/160	154.5–159.5	0.000	NS	0.495	NS
54-02002	180	177.5–182.5	0.100	0.016	0.000	0.00
54-02002	200	197.5–202.5	0.000	-1.092	0.440	0.439
54-02016	18	15.5–20.5	NS-B	NS-B	NS-B	NS
54-02016	31	28.5–33.5	0.041	-0.057	-0.061	0.102
54-02016	82	79.5–84.5	NS-B	NS-B	NS-B	NS
54-02020	20	10–30	-0.041	—	—	—
54-02020	40	30–50	-0.068	—	—	—
54-02020	60	50–70	-0.100	—	—	—
54-02020	80	70–90	-0.129	—	—	—
54-02020	95	90–110	-0.146	—	—	—
54-02020	120	110–130	-0.147	—	—	—
54-02020	140	130–150	-0.154	—	—	—
54-02020	160	150–170	-0.157	—	—	—
54-02020	180	170–190	-0.159	—	—	—
54-02020	200	190–210	0.012	—	—	—
54-02021	20	10–30	-0.044	-0.070	-0.098	-0.028
54-02021	40	30–50	-0.053	-0.075	-0.112	NS
54-02021	60	50–70	-0.250	-0.082	-0.306	NS
54-02021	80	70–90	-0.128	-0.075	-0.155	NS
54-02021	100	90–110	-0.216	-0.093	-0.253	NS
54-02021	120	110–130	0.000	-0.056	-0.227	NS
54-02021	140	130–150	-0.239	-0.120	-0.303	-0.616
54-02021	160	150–170	-0.103	-0.079	-0.110	-0.173
54-02021	180	170–190	-0.269	-0.127	-0.282	-0.697
54-02021	198	190–210	-0.271	0.042	-0.173	-1.129
54-02022	20	17.5–22.5	-0.041	NS-B	NS-B	NS
54-02022	40	37.5–42.5	-0.055	-0.177	-0.173	0.025
54-02022	60	57.5–62.5	-0.070	-0.200	-0.192	0.00

Table 4.3-1 (continued)

Well	Port Depth (ft bgs)	Sampling Interval (ft length along borehole)	Static Pressure (kPa)			
			Annual	Apr-15	Jul-15	Nov-15
54-02022	80	77.5–82.5	-0.101	-0.207	-0.243	-0.023
54-02022	100	97.5–102.5	-0.142	NS-B	NS-B	NS
54-02022	120	117.5–122.5	-0.126	-0.247	-0.259	-0.097
54-02022	140	137.5–142.5	-0.085	-0.239	-0.200	-0.219
54-02022	160	157.5–162.5	-0.041	-0.229	-0.185	-0.289
54-02022	180	177.5–182.5	0.000	-0.212	-0.146	-0.336
54-02022	200	197.5–202.5	0.020	-0.200	-0.127	-0.354
54-02023	20	10–30	0.011	—	—	—
54-02023	40	30–50	0.017	—	—	—
54-02023	60	50–70	0.178	—	—	—
54-02023	80	70–90	0.051	—	—	—
54-02023	100	90–110	0.072	—	—	—
54-02023	120	110–130	0.018	—	—	—
54-02023	140	130–149	0.079	—	—	—
54-02023	159	149–169	0.151	—	—	—
54-02023	180	170–190	0.033	—	—	—
54-02023	200	190–210	0.204	—	—	—
54-02024	20	10–30	-0.035	—	—	—
54-02024	40	30–50	-0.034	—	—	—
54-02024	60	50–70	-0.047	—	—	—
54-02024	80	70–90	-0.092	—	—	—
54-02024	100	90–110	-0.132	—	—	—
54-02024	120	110–130	-0.146	—	—	—
54-02024	140	130–150	-0.164	—	—	—
54-02024	160	150–170	-0.182	—	—	—
54-02024	180	170–190	-0.193	—	—	—
54-02024	200	190–210	-0.203	—	—	—
54-02025	20	20	-23.000	—	—	—
54-02025	60	60	0.110	—	—	—
54-02025	100	100	-0.151	—	—	—
54-02025	160	160	-0.174	—	—	—
54-02025	190	190	-0.185	—	—	—
54-02026	20	20	0.000	—	—	—
54-02026	60	60	-0.017	—	—	—
54-02026	100	100	-0.100	—	—	—
54-02026	160	160	-0.217	—	—	—
54-02026	200	200	-0.258	—	—	—

Table 4.3-1 (continued)

Well	Port Depth (ft bgs)	Sampling Interval (ft length along borehole)	Static Pressure (kPa)			
			Annual	Apr-15	Jul-15	Nov-15
54-02026	215	215	-0.277	—	—	—
54-02027	20	20	0.010	—	—	—
54-02027	60	60	-0.017	—	—	—
54-02027	100	100	-0.112	—	—	—
54-02027	160	160	-0.162	—	—	—
54-02027	200	200	-0.170	—	—	—
54-02027	220	220	-0.173	—	—	—
54-02027	250	250	-0.166	—	—	—
54-02028	20	20	0.000	—	—	—
54-02028	60	60	0.000	—	—	—
54-02028	100	100	0.010	—	—	—
54-02028	160	160	0.068	—	—	—
54-02028	200	200	0.086	—	—	—
54-02028	220	220	0.085	—	—	—
54-02028	250	250	0.076	—	—	—
54-02031	20	20	0.000	—	—	—
54-02031	60	60	0.041	—	—	—
54-02031	100	100	0.101	—	—	—
54-02031	160	160	0.106	—	—	—
54-02031	200	200	0.207	—	—	—
54-02031	220	220	0.145	—	—	—
54-02031	260	260	0.235	—	—	—
54-02034	20	20	-0.029	—	—	—
54-02034	60	60	-0.063	—	—	—
54-02034	100	100	-0.041	—	—	—
54-02034	160	160	0.210	—	—	—
54-02034	200	200	0.243	—	—	—
54-02034	220	220	0.247	—	—	—
54-02034	260	260	0.272	—	—	—
54-02034	300	300	0.318	—	—	—
54-02089	13	13	-0.017	-0.049	-0.107	0.106
54-02089	31	31	-0.015	-0.047	-0.107	0.102
54-02089	46	46	-0.024	-0.047	-0.121	0.117
54-02089	86	86	-0.044	-0.192	-0.291	0.314
54-24238	44	43–45	-0.020	-1.728	-0.150	0.017
54-24238	64	63–65	-0.024	-0.258	-0.278	0.293
54-24238	84	83–85	0.011	0.105	0.000	0.324

Table 4.3-1 (continued)

Well	Port Depth (ft bgs)	Sampling Interval (ft length along borehole)	Static Pressure (kPa)			
			Annual	Apr-15	Jul-15	Nov-15
54-24239	25	24–26	-0.024	0.033	-1.509	0.023
54-24239	50	49–51	-0.029	0.047	0.010	0.146
54-24239	75	74–76	0.064	0.028	-0.029	0.015
54-24239	99.5	98.5–100.5	0.103	-0.233	-0.022	0.095
54-24240	28	27–29	0.000	-0.244	-0.227	-0.208
54-24240	53	52–54	-0.013	-0.897	-0.838	-0.846
54-24240	78	77–79	-0.060	-2.053	-1.983	-1.946
54-24240	103	102–104	-0.116	-1.652	-1.488	-1.405
54-24240	128	127–129	-0.143	-1.187	-0.988	-0.883
54-24240	153	152–154	-0.167	-0.654	-0.435	-0.300
54-24241	73	71–74	-0.127	-0.802	-0.394	NS-RC
54-24241	93	92–94	-0.150	-1.035	-0.565	NS-RC
54-24241	113	112–114	-0.180	-1.283	-0.695	NS-RC
54-24241	133	132–134	-0.233	-1.320	-0.659	NS-RC
54-24241	153	152–154	-0.278	-1.409	-0.124	NS-RC
54-24241	173	172–174	-0.282	-1.398	-0.566	NS-RC
54-24241	193	192–194	-0.288	-1.292	-0.585	NS-RC
54-24242	25	24–26	-0.048	—	—	—
54-24242	50	49–51	-0.203	—	—	—
54-24242	75	74–76	-0.112	—	—	—
54-24242	100	99–101	-0.053	—	—	—
54-24242	110.5	109.5–111.5	-0.213	—	—	—
54-24243	25	24–26	0.073	-0.115	-0.129	0.146
54-24243	50	49–51	0.075	-0.145	-0.180	0.139
54-24243	75	74–76	0.109	-0.330	-0.395	0.240
54-24243	100	99–101	0.176	-0.888	-0.961	-0.020
54-24243	125	124–126	0.179	-1.064	-1.253	1.017
54-24399 [b]	561.5–565.5	561.5–565.5	n/a	n/a	n/a	n/a
54-24399 [b]	568–608	568–608	n/a	n/a	n/a	n/a
54-24399 [b]	568–569	568–569	n/a	n/a	n/a	n/a
54-27641	32	29.5–34.5	-0.035	-0.283	-0.300	NS-RC
54-27641	82	79.5–84.5	-0.059	-3.844	-3.919	-3.805
54-27641	115	112.5–117.5	-0.169	-1.169	-1.319	-0.966
54-27641	182	179.5–184.5	-0.178	-0.067	-0.420	-0.053
54-27641	232	229.5–234.5	-0.164	0.053	-0.320	NS-RC
54-27641	271	268.5–273.5	-0.164	0.141	-0.227	-0.257
54-27641	332.5	330–335	-0.175	0.151	-0.195	-0.277

Table 4.3-1 (continued)

Well	Port Depth (ft bgs)	Sampling Interval (ft length along borehole)	Static Pressure (kPa)			
			Annual	Apr-15	Jul-15	Nov-15
54-27642	30	27.5–32.5	-0.028	-0.094	-0.050	0.066
54-27642	75	71.5–76.5	-0.035	-0.667	-0.264	0.300
54-27642	116	114.5–119.5	0.000	-0.761	-0.480	NS-RC
54-27642	175	172.5–177.5	0.049	-0.985	-0.285	0.191
54-27642	235	232.5–237.5	0.038	-0.793	-0.154	0.701
54-27642	275	272.5–277.5	0.000	-0.722	-0.236	0.485
54-27642	338	335.5–340.5	-0.028	-0.526	-0.088	NS-RC
54-27643	30	27.5–32.5	0.018	—	—	—
54-27643	74	71.5–76.5	0.050	—	—	—
54-27643	117	114.5–119.5	0.129	—	—	—
54-27643	167	164.5–169.5	0.251	—	—	—
54-27643	235	232.5–237.5	0.279	—	—	—
54-27643	275	272.5–277.5	0.276	—	—	—
54-27643	354	351.5–356.5	0.133	—	—	—
54-610786 [c]	25	22.5–27.5	0.000	—	—	—
54-610786 [c]	50	47.5–52.5	0.000	—	—	—
54-610786 [c]	75	72.5–77.5	-0.020	—	—	—
54-610786 [c]	100	97.5–102.5	-0.044	—	—	—
54-610786 [c]	118.5	116–121	-0.053	—	—	—

Notes: — = Not measured as part of quarterly sampling; NS = Not sampled because previous rounds port blocked or partially blocked; NS-B = Not sampled because port blocked; NS-RC = Not sampled because of radiological concerns; n/a = Not applicable for packer system.

[a] Vapor-monitoring borehole angled. Port depth is depth below ground surface. Port-depth interval is length along borehole.

[b] Open borehole below 565.5 ft bgs.

[c] Drilled in December 2009.

Appendix A

Spreadsheet Containing Dwyer Orifice Plate Calculations
(on CD included with this document)

Appendix B

Analytical Suites and Results
(on CD included with this document)

Appendix C

Example Calculations for Effluent Mass Removal

This appendix explains calculations of the total mass of volatile organic compounds (VOCs) being removed in the SVE effluent. The numbers presented below are not exact measurements, but they are representative of the data collected during soil-vapor extraction (SVE) operation at Material Disposal Area L, Technical Area 54, at Los Alamos National Laboratory. The example calculations are a simplified description of several Excel macros that combine both flow and concentration data to create graphs of mass removal versus time.

C-1.0 INITIALIZATION OF THE CALCULATION

For both SVE-East and SVE-West, one data point was added and set 1 min before start time and with flow "0." The concentration at the 1 min before start time is assumed to be equal to the first measured concentration.

C-2.0 GENERATING FLOW RATE VERSUS TIME

Air-flow data, in standard cubic feet per minute (scfm), from both SVE-East and SVE-West are loaded into a spreadsheet. Next, data on flow are numerically integrated over discrete time intervals using the trapezoid method to create volumes associated with each time interval (in m^3). Example air-flow data for SVE-West is included in Table C-2.0-1.

Table C-2.0-1
SVE-West Example Air-Flow Data

Time	1/9/2015 12:55	1/9/2015 12:56	1/16/2015 8:58	1/26/2015 9:08	2/25/2015 12:42	2/28/2015 12:42
Flow (scfm)	0	99.9	98.3	101	99.8	99.9

The partial volume pumped for each time interval is calculated using the following formula:

partial volume = (flow1 + flow2)/2 * time difference * 0.0283168 m^3/ft^3,

where 0.0283168 is a recalculation factor from standard cubic feet (scf) to m^3.

For the first data point, this leads to the expression,

Partial volume = (0+99.9)/2*(1/9/2015 12:56:00 PM - 1/9/2015 12:55:00 PM)* 0.0283168

Partial volume = 45.95 cfm *1 min = 1.41 m^3 (for time 1/9/2015 12:56:00 PM).

This calculation is repeated for all five pairs of data in Table C-2.0-1 and leads to the values in Table C-2.0-2 (values are rounded to whole numbers).

Table C-2.0-2
SVE-West, Volumes Pumped for Discrete Time Intervals

Time	1/9/2015 12:55	1/9/2015 12:56	1/16/2015 8:58	1/26/2015 9:08	2/25/2015 12:42	2/28/2015 12:42
Flow	0	99.9	98.3	101	99.8	99.9
(Flow1+flow2)/2 (scfm)		50	99	100	100	100
Time difference		1	9842	14410	43414	4320
Partial volume m^3		**1**	**27619**	**40662**	**123426**	**12215**

Total volume pumped is calculated by adding partial volumes:

- For 1/9/2015 12:56:00 PM: total volume = 1
- For 1/16/2015 8:58:00 AM: total volume = 1 + 27619 = 27620
- For 1/26/2015 9:08 AM: total volume = 1 + 27619 + 40662 = 27620 + 40662 = 68282 and so on.

The results of the calculated total volume pumped at discrete times is included in Table C-2.0-3.

Table C-2.0-3
SVE-West, Integrated Total Volume Pumped at Discrete Times

Time	1/9/2015 12:55	1/9/2015 12:56	1/16/2015 8:58	1/26/2015 9:08	2/25/2015 12:42	2/28/2015 12:42
Flow	0	99.9	98.3	101	99.8	99.9
(Flow1+flow2)/2 (scfm)		50	99	100	100	100
Time difference		1	9842	14410	43414	4320
Partial volume m^3		1	27619	40662	123426	12215
Total volume m^3		**1**	**27620**	**68282**	**191708**	**203923**

C-3.0 INTERPOLATING CONCENTRATION VERSUS TIME TO THE FLOW DATA

To obtain total mass on the compound trichloroethane[1,1,1-] (1,1,1-TCA) in this example, the concentration data versus time have to be interpolated to the total volume scale because concentration data were not collected at every flow rate measurement. Concentrations at discrete times for SVE-West are included in Table C-3.0-1.

Table C-3.0-1
SVE-West, Effluent Concentration at Discrete Times

Time	1/9/2015 12:55	1/9/2015 14:24	1/16/2015 9:04	1/26/2015 9:19	2/25/2015 12:46
Concentration $\mu g/m^3$	479833	479833	261727	141769	87242.3

The volume pumped at the start−1min is equal to 0. For the next data point (at 1/9/2015 14:24), linear interpolation is used:

To use linear interpolation, two points were selected from Table C-2.0-3, one immediately before and one immediately after the interpolation point. For the interpolated point at 1/9/2015 14:24, these points are

1/9/2015 12:56 and 1/16/2015 8:58. Initially, the equation of the line passing through these points is calculated: y = ax + b. At the end of interpolation step, the equation of this line and the time value for interpolated point to find the interpolated total volume are used.

If time is marked as "x" and total volume as "y," the equations are

a = (y2-y1)/(x2-x1),

b = y1-a*x1,

and finally

$y_c = a*x_c+b$.

For the example listed above,

a = (27620-1)/(1/16/2015 8:58:00 AM–1/9/2015 12:56:00 PM) = 4040.98

b = 1-4040.98*(1/9/2015 12:56:00 PM) = −169776018.10

y_c = 4040.98*(1/9/2015 2:24:00 PM)−169776018.10 = 248

Note: In the explanation above, dates as values of x are used. Within Excel, "date values" are used to remove any problems with incorporating dates into equations. Calculations explained above are repeated for three more points from Table C-3.0-1, and the results are included in Table C-3.0-2.

Table C-3.0-2
SVE-West, Effluent Concentration at Discrete Times

Time	1/9/2015 12:55	1/9/2015 14:24	1/16/2015 9:04	1/26/2015 9:19	2/25/2015 12:46
Concentration µg/m^3	479833	479833	261727	141769	87242.3
Total volume pumped m^3	0	248	27637	68313	191719

Table C-3.0-3 presents values of the linear coefficients used in the interpolation for each point in Table C-3.0-2:

Table C-3.0-3
SVE-West Flow Volume Integration

Time	1/9/2015 12:55	1/9/2015 12:56	1/16/2015 8:58	1/26/2015 9:08	2/25/2015 12:42	2/28/2015 12:42
Flow (scfm)	0	99.9	98.3	101	99.8	99.9
(Flow1+flow2)/2 (scfm)		50	99	100	100	100
Time difference		1	9842	14410	43414	4320
Partial volume m^3		1	27619	40662	123426	12215
Total volume m^3		1	27620	68282	191708	203923
		a	4040.98354	4063.37821	4093.919934	4071.666667
		b	-169776018.10	-170717050.49	-172000730.78	-171064746.59

C-4.0 CALCULATION OF MASS REMOVAL SVE-WEST

Data from Table C-3.0-2 may be numerically integrated leading to the total mass of 1,1,1-TCA contained in the effluent stream removed from SVE-West as a function of time mapped to discrete points in time.

Partial mass removed = (concentration1+concentration2)/2*(volume2−volume1)*1e-9 * 2.20462, where 1e-9 is recalculation factor from µg to kg, and '2.20462" is recalculation factor from kg to lb.

Total mass removed is integrated numerically as the sum of the partial masses.

For time "1/9/2015 2:24:00 PM," the partial mass removed = (479833 + 479833)/2*(248-0)*1e-9*2.20462 = 0.3 lb.

Results of the volume-concentration time alignment and mass removal integration for SVE-West are presented in Table C-4.0-1.

Table C-4.0-1
SVE-West, Volume-Concentration Integration of 1,1,1-TCA Mass Removal

Time	1/9/2015 12:55	1/9/2015 14:24	1/16/2015 9:04	1/26/2015 9:19	2/25/2015 12:46
Concentration µg/m^3	479833	479833	261727	141769	87242.3
Total volume pumped m^3	0	248	27637	68313	191719
Partial mass removed lb	0	0.3	22.4	18.1	31.2
Total mass removed lb	0	0.3	22.7	40.8	72

C-5.0 CALCULATION OF MASS REMOVAL SVE-EAST

The same calculation pattern is used to calculate mass numbers for the SVE-East unit. The results are presented in Tables C-5.0-1 and C-5.0-2:

Table C-5.0-1
SVE-East Flow Interpolation Coefficients

Time	1/26/2015 10:20	1/26/2015 10:21	1/27/2015 11:17	2/25/2015 13:18	2/28/2015 13:42
Flow	0	99.5	98.6	98.5	99.1
(Flow1+flow2)/2		50	99	99	99
Time difference		1	1496	41881	4344
Partial volume m^3		1	4196	116874	12153
Total volume m^3		1	4197	121071	133224
		a	4038.930481	4018.494305	4028.618785
		b	-169757988.92	-168899026.40	-169324867.60

Table C-5.0-2
SVE-East Volume-Concentration Integration of 1,1,1-TCA Mass Removal

Time	1/26/2015 10:20	1/26/2015 11:12	1/27/2015 12:27	2/25/2015 13:20
Concentration μg/m^3	348969	348969	370780	223558
Total volume pumped m^3	0	144	4392	121077
Partial mass removed lb	0	0.1	3.4	76.4
Total mass removed lb	0	0.1	3.5	79.9

C-6.0 CALCULATION OF COMBINED SVE-WEST PLUS SVE-EAST MASS REMOVAL

To calculate the total amount of 1,1,1-TCA removed, SVE-West and SVE-East numbers have to be added. Again, interpolation and data alignment are necessary because there are no total mass removed data at the same times for SVE-West and SVE-East.

The SVE-West unit was always sampled and recorded first, so the dates from the SVE-West unit are used as interpolation dates. For each interpolation date, two time points from SVE-East are used, one immediately before (1/27/2015 12:27) and one immediately after (2/25/2015 13:20). Using the interpolation formulas from section 3.0, the following is derived:

a = (79.9-3.5)/(2/25/2015 13:20-1/27/2015 12:27) = 2.6311

b = 3.5-2.6311*(1/27/2015 12:27:00 PM) = -110587.45

Results for interpolation coefficients are listed in Table C-6.0-1.

Table C-6.0-1
Interpolation Coefficients for the Combined Mass Removal

Time	1/26/2015 10:20	1/26/2015 11:12	1/27/2015 12:27	2/25/2015 13:20
Concentration μg/m^3	348969	348969	370780	223558
Total volume pumped m^3	0	144	4392	121077
Partial mass removed lb	0	0.1	3.4	76.4
Total mass removed lb	0	0.1	3.5	79.9
	a	2.769230769	3.231683168	2.631143424
	b	-116391.96	-135829.05	-110587.45

When Tables C-4.0-1 and C-6.0-1 are compared, the only date from Table C-4.0-1 when both units, West and East, were operational is 2/25/2015 12:46:00 PM. Using this date and “a” and “b” coefficients from Table C-6.0-1, the amount of 1,1,1-TCA SVE-East removed at 2/25/2015 12:46:00 PM can be calculated:

yc = a*(2/25/2015 12:46:00 PM)+b = 2.631143424*(2/25/2015 12:46:00 PM)-110587.45 = 79.8 lb

By adding SVE-West and SVE-East (East after interpolation), the total amount of the 1,1,1-TCA removed by both units is (72 +79.8 = 151.8). Table C-6.0-2 presents the combined total mass of 1,1,1-TCA removed by both units.

Table C-6.0-2
Integration of Combined Mass Removal

Time	1/9/2015 12:55	1/9/2015 14:24	1/16/2015 9:04	1/26/2015 9:19	2/25/2015 12:46
Concentration µg/m^3	479833	479833	261727	141769	87242.3
Total volume pumped m^3	0	248	27637	68313	191719
Partial mass removed lb	0	0.3	22.4	18.1	31.2
Total mass removed West lb	0	0.3	22.7	40.8	72
Total mass removed East lb	0	0	0	0.0	79.8
East + West lb	0	0.3	22.7	40.8	151.8

Note: The first four columns for the East unit list “0” because East SVE was not operational on 1/9/2015.

The flow data were integrated each time new SUMMA data were obtained. The calculation pattern for concentrations, as described above, is repeated for each detected analyte. (The analyte does not have to be detected in all SUMMA samples; single detection will trigger the calculations described above.) The total “East+West lb” values were added together to obtain total value of VOC removed.

Appendix D

Field Log Book Entries, Purge Forms, and
Chain of Custody Forms for Borehole 54-24399
(on CD included with this document)

Appendix E

Flow Rate Data for SVE-West and SVE-East
(on CD included with this document)

Appendix F

Video Log of Borehole 54-24399
(on DVD included with this document)