SGW-53024
Revision 0

200-PW-1 Operable Unit (OU) Soil Vapor Extraction (SVE) System Operational Strategy

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

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Terms

CCU	Cold Creek unit
CY	calendar year
GAC	granular activated carbon
OU	operable unit
SVE	soil vapor extraction

1 Introduction

The purpose of this document is to present an operational strategy for the 200-PW-1 Operable Unit (OU) soil vapor extraction (SVE) system for removing carbon tetrachloride from the vadose zone residing above the 200-ZP-1 OU groundwater and for collecting data to evaluate the flux of carbon tetrachloride from the vadose zone to groundwater. Three waste sites (216-Z-9 Trench, 216-Z-1A Tile Field, and 216-Z-18 Crib) were used from 1955 through 1973 for disposal of liquid waste containing carbon tetrachloride (Figure 1). In 1992, SVE was implemented as an interim remedial action ("Action Memorandum: Expedited Response Action Proposal for 200 West Area Carbon Tetrachloride Plume" [Smith and Stanley, 1992]).

The *Record of Decision, Hanford 200 Area Superfund Site: 200-CW-5 and 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units* (EPA et al., 2011) was finalized in September 2011. The Record of Decision selected SVE as the final remedial action for vadose zone carbon tetrachloride contamination at waste sites that received carbon tetrachloride waste liquids. Remediation using SVE mitigates the threat to the environment caused by migration of carbon tetrachloride vapors through the soil column and into the groundwater.

During SVE operations, vapor-phase carbon tetrachloride is extracted through vadose zone wells and adsorbed onto granular activated carbon (GAC) before the treated, clean vapor is released to the atmosphere. The SVE operations from 1992 through 1997 were highly effective, removing 74,851 kg of carbon tetrachloride before the concentrations and mass removal rate substantially decreased (Figure 2) (SGW-51807, *Performance Evaluation Report for Soil Vapor Extraction Operations at the 200-PW-1 Operable Unit Carbon Tetrachloride Site, Calendar Year 2011*). Since 1997, an additional 5,000 kg have been removed by the SVE system (SGW-51807).

From 1998 through 2011, cyclic operation has been applied to allow vapor concentrations to rebound due to diffusive mass transfer from low-permeability source zones (SGW-51807; "Analysis of Soil Vapor Extraction Data to Evaluate Mass-Transfer Constraints and Estimate Source-Zone Mass Flux [Brusseau et al., 2010]). In 2011, two SVE systems, each with a design capacity of 14.2 m^3/min, were used from March through October to remove carbon tetrachloride from the vadose zone. Each SVE system extracts simultaneously from multiple wells. The systems were maintained in standby mode from November 2011 through February 2012 to allow time for carbon tetrachloride vapor concentrations to rebound. Operations were restarted on April 2, 2012.

In 2011, the two systems removed 195 kg of carbon tetrachloride from the vadose zone and treated 3.7 million m^3 of vapor. Since startup of SVE operations in 1992, a total of 79,945 kg of carbon tetrachloride have been removed from the vadose zone in 115 million m^3 of soil vapor. Since 1992, the SVE operations reduced the concentration of carbon tetrachloride measured in SVE wells over the past 20 years (Figure 3).

In 2000, passive SVE was initiated at eight wells near the 216-Z-1A Tile Field and 216-Z-18 Crib (Figure 1). Passive SVE is a naturally occurring process driven by barometric pressure fluctuations and is often referred to as "barometric pumping." Eight passive SVE systems operated throughout 2011 and removed approximately 4 kg of carbon tetrachloride. Since 2000, the passive SVE systems have removed approximately 104 kg of carbon tetrachloride from the vadose zone.

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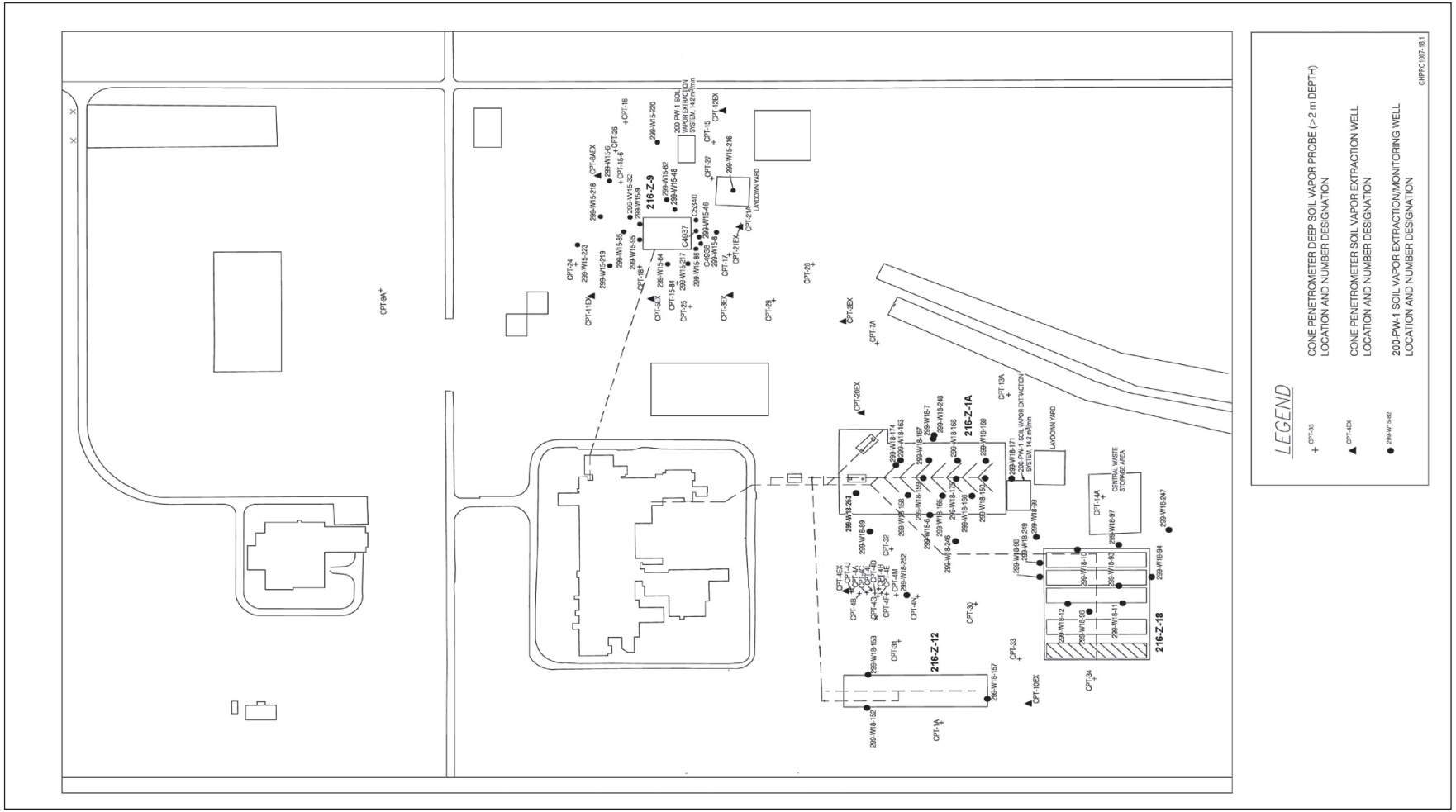

Figure 1. Extraction and Monitoring Wells and Soil Vapor Probes at the Carbon Tetrachloride Soil Vapor Extraction Sites.

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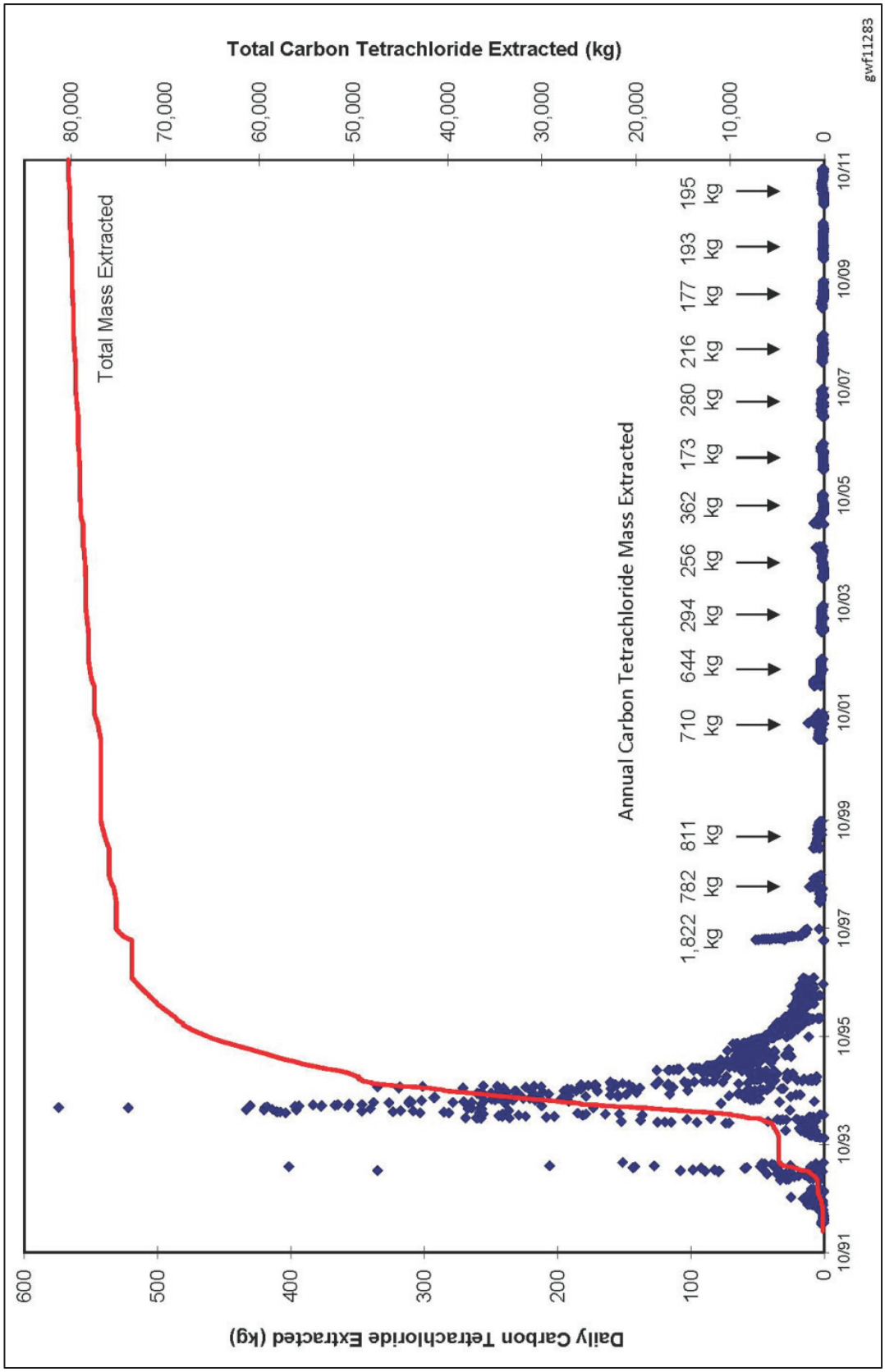


Figure 2. Carbon Tetrachloride Removed by SVE Since 1992

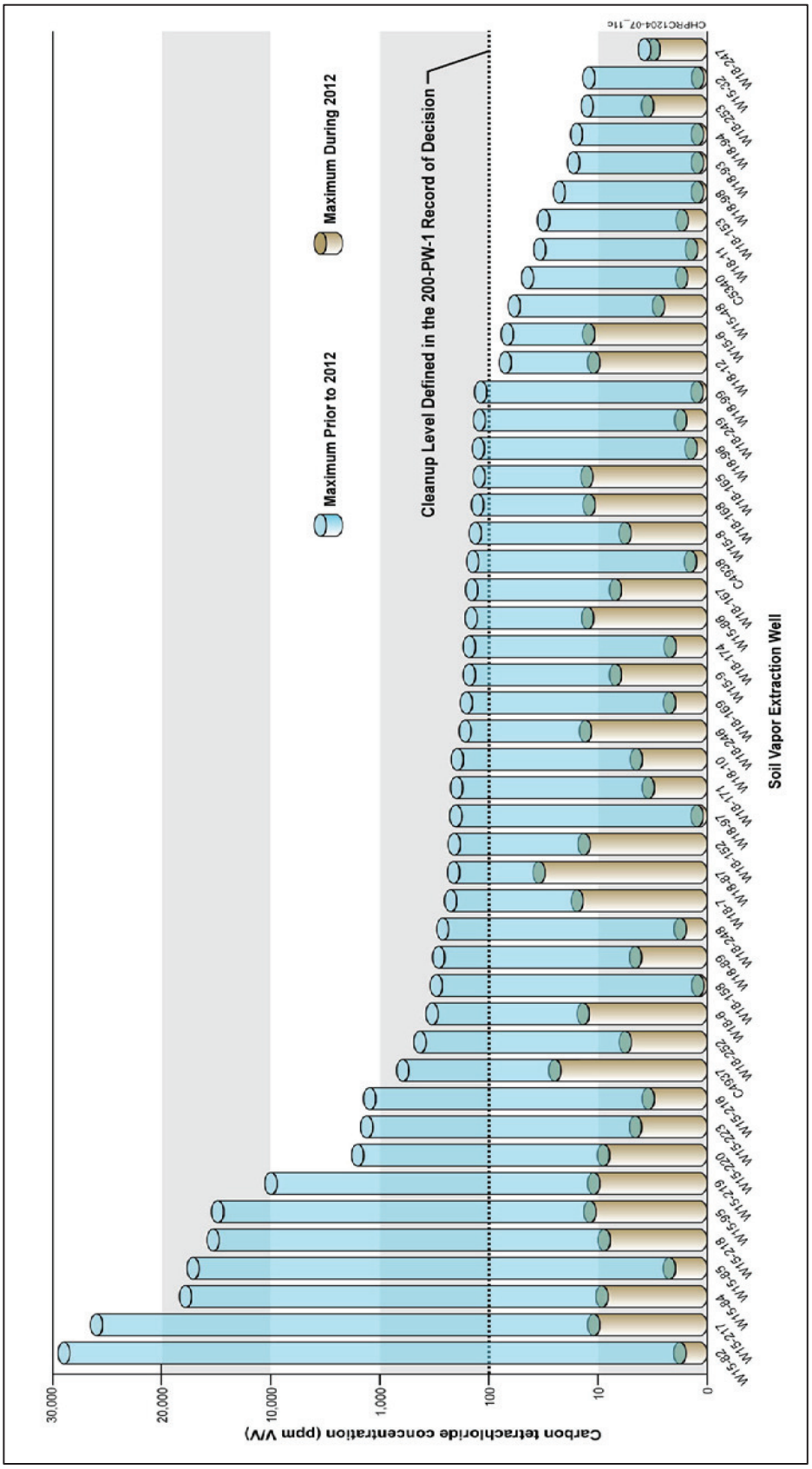


Figure 3. Maximum Carbon Tetrachloride Concentrations in SVE Wells Between 1992 and 2012

Additional details for SVE system operations and vadose zone monitoring for 2011 are provided in the performance evaluation report (SGW-51807). The performance evaluation report also presents a general overview of the entire operating period from February 25, 1992, through December 31, 2011, and provides a list of reports that contain detailed information on previous SVE operating periods.

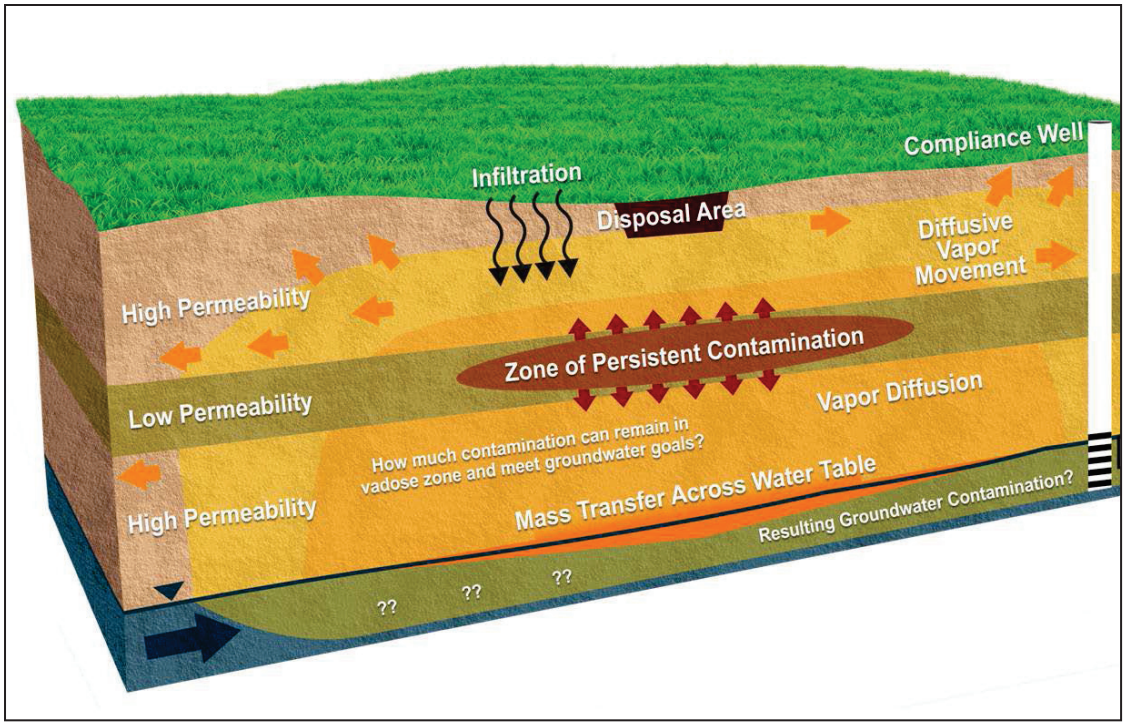
2 Pacific Northwest National Laboratory Treatability Testing

During 2011, a treatability test was conducted by Pacific Northwest National Laboratory at the 216-Z-9 Trench (Figure 1) to apply and evaluate two types of characterization methods targeted at 1) quantifying the overall source mass discharge in the vadose zone, and 2) estimating the size and location of carbon tetrachloride sources. The characterization information also provided input to this operational strategy for continued SVE operation and decisions regarding closure of the SVE system or transition to other remedies. The treatability test was conducted in accordance with the *Treatability Test Plan for Characterization of Vadose Zone Carbon Tetrachloride Source Strength Using Tomographic Methods at the 216-Z-9 Site* (DOE/RL-2010-79). Test methods and recommendations are reported in *Treatability Test Report: Characterization of Vadose Zone Carbon Tetrachloride Source Strength Using Tomographic Methods at the 216-Z-9 Site* (PNNL-21326).

The treatability test involved testing one interval within an extraction well at a time. Many of the extraction wells have two screened (or perforated) intervals within one steel-cased well (one casing string). The intervals are isolated from each other by a packer placed in the well between the screens. The screened intervals are referred to as “U” (upper, above the Cold Creek unit [CCU]) and “L” (lower, below the CCU). For example, the upper screened extraction interval (299-W15-9U) in well 299-W15-9 was tested on one day and the lower screened extraction interval (299-W15-9L) was tested on a different day. During the testing period in August and September, a total of 22 extraction well intervals were added online sequentially for single-well testing.

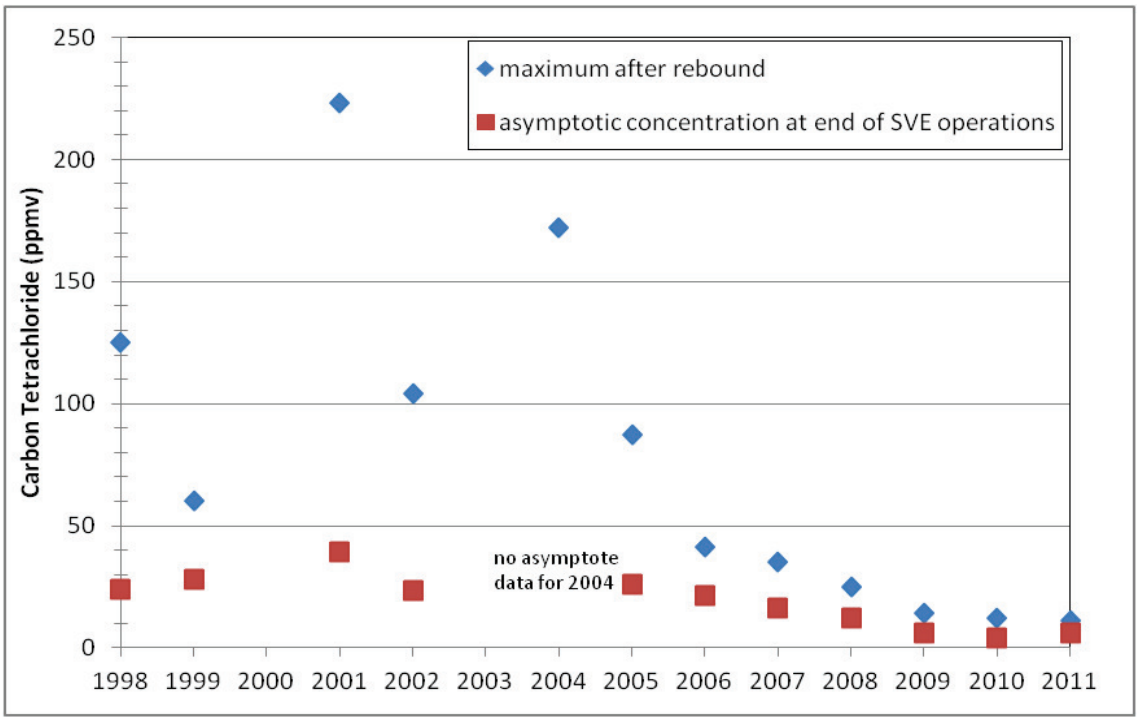
The stratigraphy in the vadose zone beneath the waste disposal sites consists of a fine-textured, low-permeability material (CCU) between an upper (Hanford formation) and lower (Ringold Formation Unit E) coarse-textured, higher permeability material (Figure 4). Vapor extraction focuses on withdrawals from wells screened in the high-permeability material above and below the lower permeability unit. Results from the treatability test suggest that most of the remaining mass resides in the low-permeability material from which the carbon tetrachloride is slowly diffusing (Figure 4). The past strategy for SVE system operations was to extract from the upper and lower high-permeability units from spring to early fall and then turn off the system, allowing time for the carbon tetrachloride concentrations to rebound through diffusion into the coarse material. By repeating this cycle, carbon tetrachloride is systematically removed from the less permeable (tighter) sediments by depletion within the more accessible (open) permeable units.

The nature of the carbon tetrachloride contamination at the 216-Z-9 Trench has changed over time because of mass removal through SVE operation. Between 1997 and 2005, the carbon tetrachloride vapor concentration upon restart of SVE after a shutdown period was higher than the carbon tetrachloride concentration at the end of the previous operational period. This response indicates that vapor concentrations increased (rebounded) during shutdown periods. After 2005, only small differences in initial and final vapor concentrations during SVE operations were detected, indicating a much smaller rebound during the shutdown period (Figure 5). The temporal profile of the vapor concentrations extracted by the SVE system has become less dynamic over time, and in 2009 and 2011 did not show the characteristic progression from high initial concentrations to lower asymptotic concentrations during an operational cycle (PNNL-21326).



Source: PNNL-21326.

Figure 4. Pathway of Carbon Tetrachloride Contamination Through the 200-PW-1 Vadose Zone



Source: PNNL-21326.

Figure 5. Initial (Maximum after Rebound) and Final Vapor Concentrations During SVE Operations at the 216-Z-9 Trench

The testing indicated a distinct pattern in the carbon tetrachloride concentration and mass discharge data that shows higher values near the CCU within a limited lateral extent. These patterns and historical SVE operational data were used to conclude that the CCU is the primary remaining source of carbon tetrachloride in the vadose zone and that the areal extent of the source zone within the CCU is approximately 90 m by 90 m (295 ft by 295 ft) (PNNL-21326). The treatability test applied characterization methods to the 2010 SVE operational period and produced an estimated source mass discharge of 70 grams/day from the 90 m by 90 m (295 ft by 295 ft) source in the CCU. This discharge is estimated to be impacting the groundwater immediately below the 216-Z-9 Trench at a concentration of 24 µg/L (if the vadose zone source is assumed to be the only source of contamination and the groundwater is otherwise uncontaminated). Results from the test also indicated that the rebound is small, and it was recommended that the rebound period be lengthened and operations tailored to enhance the measurement of source strength.

The method of Carroll et al. (2012) estimated the relative source mass discharge under conditions representative of periodic SVE operation and demonstrated that the source mass discharge declines over time under post-SVE conditions. Using the information in Carroll et al. (2012), the rate of decline in source mass discharge after SVE is terminated is estimated to be a factor of about 5 slower than the rate of decline in source mass discharge during SVE operations. From this estimate, a source mass discharge starting at a value of 70 g/d would be expected to drop below 10 g/d in about 40 years after SVE shut down. A source mass discharge of 10 g/d results in groundwater concentrations at or less than 3.4 µg/L. In 125 years (representing 25 years of pump-and-treat operations and 100 years of monitored natural attenuation in the groundwater) the source mass discharge is expected to be negligible (PNNL-21326).

Based on the recommendations in PNNL-21326, three operational conditions can be adjusted to improve the source mass discharge estimate. First, SVE operations can be continued for a longer period of time to minimize the carbon tetrachloride vapor concentrations when the system is shut off. Second, the period of shut down can be lengthened to provide additional time for rebound in the vapor concentrations. Third, when SVE operations are restarted after the long rebound period, extraction wells can be selected that initially target the zone of diffusive mass discharge based on the CCU source distribution identified in the treatability test evaluation.

3 Recommendations

Performance improvement and evaluation for SVE at the 200-PW-1 OU could be achieved by the following:

- Increase the rebound period (from September 30 through June 1). Based on past evaluations of soil vapor concentrations measured near the vadose zone/groundwater interface, temporarily suspending operation of the SVE system (rebound period) during the cooler months of the year had no negative impact on groundwater quality (SGW-44694, *Performance Evaluation Report for Soil Vapor Extraction Operations at the 200-PW-1 Operable Unit Carbon Tetrachloride Site, Fiscal Year 2009*). Increasing the rebound period to 8 months per year (from the current 4 or 5 months per year) will result in increased SVE efficiency and will improve the estimate of the source mass discharge. As noted in PNNL-21326, the estimate of 70 g/d was based on data from 2010 when the rebound response used in the estimate was relatively low.
- Operate the SVE systems during the warmer months (June through September) when vapor pressures are at maximum and would increase volatilization of the carbon tetrachloride.

- Reduce GAC usage by operating the system in the warmer months. Typically, one-third the amount of GAC is used in warmer months as is used in cooler months such as March and April. Water condensation accumulates on the GAC in cooler months, which reduces the GAC available for adsorption of carbon tetrachloride. As a result, the GAC has to be replaced more frequently in the cooler months (about every 2 weeks), thus increasing labor and GAC costs. Changing of GAC in warmer months occurs about every 5 to 6 weeks. Water condensation also accumulates in the SVE hose system during the cooler months and has to be drained by operations personnel.
- Operate a select set of wells within the higher concentration areas from June through September.
- Operate wells located along the periphery of higher concentration areas in August and September only. This would increase the rebound period in the peripheral area to 10 months with a corresponding increase in the amount of carbon tetrachloride vapors diffusing into the vadose zone from the CCU.
- Install a manifold that will allow GAC canisters at breakthrough to be valved in and out without shutting down the unit. This will reduce overall operating and project costs and will allow for continuous operations.
- Evaluate the potential for biennial operations should rebound continue to decline.
- Collect operations data to evaluate the performance of individual wells.
- Collect operations data to evaluate the updated source mass discharge using the method of Carroll et al. (2012) and SVE remediation endpoint.
- Collect monitoring data to support evaluation of rebound.

An evaluation of the cost reduction, if the system were operated for 4 months versus 6 months per year in combination with more efficient operational methods, suggests an overall cost savings of approximately $300,000 per year.

The wells in use for SVE operations during calendar year (CY) 2012 are shown in Table 1 (for the PW1-1 SVE system at the 216-Z-9 site) and Table 2 (for the PW1-2 SVE system at the 216-Z-1A site). The wells in the higher concentration areas were selected for connection to the SVE systems in April and May. The wells on the periphery of the higher concentration areas were selected for connection to the SVE systems in July. This strategy is consistent with the recommendations above and is proposed to be implemented again in CY 2013 (Tables 1 and 2). Adjustments may be made to the set of wells to be connected to each system in CY 2013 based on SVE measurements and operations experience in CY 2012.

Table 1. Status of Soil Vapor Extraction Wells Associated with PW1-1

PW1-1 at Z-9	CY 2012 Connected	CY 2013 Proposed Connected
299-W15-216U	July-October[1]	August-September
299-W15-216L	July-October [1]	August-September
299-W15-217	May-October	June-September
299-W15-218U	July-October [1]	August-September
299-W15-218L	May-October	June-September

Table 1. Status of Soil Vapor Extraction Wells Associated with PW1-1

PW1-1 at Z-9	CY 2012 Connected	CY 2013 Proposed Connected
299-W15-219U	July-October [1]	August-September
299-W15-219L	May-October	June-September
299-W15-220U	July-October [1]	August-September
299-W15-220L	July-October [1]	August-September
299-W15-223	July-October [1]	August-September
299-W15-32	July-October [1]	August-September
299-W15-48	April-October	June-September
299-W15-6U	(a)	(a)
299-W15-6L	(a)	(a)
299-W15-82	(a)	(a)
299-W15-84U	April-October	June-September
299-W15-84L	April-October	June-September
299-W15-85	July-October [1]	August-September
299-W15-86	April-October	June-September
299-W15-8U	April-October	June-September
299-W15-8L	May-October	June-September
299-W15-95U	May-October	June-September
299-W15-95L	May-October	June-September
299-W15-9U	May-October	June-September
299-W15-9L	May-October	June-September
C4937	July-October [1]	August-September
C4938	July-October [1]	August-September
C5340	July-October [1]	August-September

(a) Previously used for SVE; requires evaluation and potential configuration/maintenance for future use as SVE well

[1] Connection prevented due to asbestos hazard and/or inoperable chromatograph.

Table 2. Status of Soil Vapor Extraction Wells Associated with PW1-2

PW1-2 at Z-1A	CY 2012 Connected	CY 2013 Proposed Connected
299-W18-10L	Passive	Passive
299-W18-11L	Passive	Passive
299-W18-12	Passive	Passive
299-W18-150U	July-October [2]	August-September
299-W18-150L	April-October	June-September
299-W18-152	(a)	(a)
299-W18-153	(a)	(a)
299-W18-158U	July-October [2]	August-September
299-W18-158L	May-October	June-September
299-W18-159	May-October	June-September
299-W18-163U	July-October [2]	August-September
299-W18-163L	April-October	June-September
299-W18-165	May-October	June-September
299-W18-166	April-October	June-September
299-W18-167	May-October	June-September
299-W18-168	April-October	June-September
299-W18-169	May-October	June-September
299-W18-171	(a)	(a)
299-W18-174	April-October	June-September
299-W18-175	May-October	June-September
299-W18-246U	July-October [2]	August-September
299-W18-246L	Passive	Passive
299-W18-247U	(a)	(a)
299-W18-247L	Passive	Passive
299-W18-248	July-October [2]	August-September
299-W18-249	July-October [2]	August-September
299-W18-252U	July-October [2]	August-September
299-W18-252L	Passive	Passive
299-W18-253	July-October [1]	August-September
299-W18-6U	July-October [2]	August-September

Table 2. Status of Soil Vapor Extraction Wells Associated with PW1-2

PW1-2 at Z-1A	CY 2012 Connected	CY 2013 Proposed Connected
299-W18-6L	Passive	Passive
299-W18-7	Passive	Passive
299-W18-87	(a)	(a)
299-W18-89	July-October [1]	August-September
299-W18-93	(a)	(a)
299-W18-94	(a)	(a)
299-W18-96	July-October [2]	August-September
299-W18-97	(a)	(a)
299-W18-98	(a)	(a)
299-W18-99	(a)	(a)

(a) Previously used for SVE; requires evaluation and potential configuration/maintenance for future use as SVE well

[1] Connection prevented due to asbestos hazard and/or inoperable chromatograph.

[2] Craft unavailable to connect wells to system.

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