Endpoint Evaluation for 200-PW-1 Operable Unit Soil Vapor Extraction, Hanford Site, Washington — 16478

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ABSTRACT

On the Central Plateau of the Hanford Site in semi-arid southeast Washington State, the 216-Z-9 Trench, 216-Z-1A Tile Field, and 216-Z-18 Crib were used from 1955 to 1973 for soil column disposal of liquid wastes containing carbon tetrachloride. The geological setting underneath these disposal areas consists of an approximately 70 m thick vadose zone with a nominally 5 m thick low-permeability layer at a depth of 30 m. Infiltration of the liquid waste through the vadose zone to the groundwater was driven by the liquid volume introduced during disposal. Carbon tetrachloride readily volatilizes in the vadose zone, making soil vapor extraction (SVE) the preferred remediation technology. Between 1992 and 2012, SVE recovered 80,107 kg of carbon tetrachloride from the vadose zone below the three waste sites. Of this total recovery, 93 percent was removed during the first 5 years of operations. The last 7 percent was recovered in the last 16 years of operation.

In 2011, a final cleanup level of 100 ppmv for carbon tetrachloride in soil vapor was established in the record of decision for the 200-PW-1 Operable Unit, which includes the three carbon tetrachloride waste sites. The final cleanup decision specified that soil vapor concentrations and the cleanup level would be further refined and assessed in the future to ensure groundwater protection. A subsequent treatability test was conducted and the results were used to further refine the definition of vadose zone source conditions that are protective of groundwater. Based on this treatability test, predictions indicate that current and future vadose zone conditions will meet groundwater protection objectives. SVE operations were not performed in 2013, 2014, and 2015, and soil vapor concentrations in all SVE wells (and all but two monitoring probes installed using direct-push technology) remained below the 100 ppmv cleanup level during this time.

SVE endpoint guidance was prepared in 2013 as a joint effort between Pacific Northwest National Laboratory, U.S. Army Corps of Engineers, and U.S. Environmental Protection Agency. This SVE guidance was used to develop a path forward for the 200-PW-1 Operable Unit SVE remedy. The guidance asks the following questions:

1. Are data collected to date adequate to support a well-defined conceptual site model?
2. Have remediation goals (cleanup levels) been defined?
3. Are environmental pathways and risk understood well enough to support site closeout?
4. Will remaining contamination in the vadose zone cause groundwater cleanup levels to be exceeded?

If the answer to the first three questions is “Yes”, and the answer to the fourth question is “No”, then the site is ready for closure. At this time, the site has compiled appropriate information to answer these questions to support a remedy decision to terminate SVE operations. The U.S. Environmental Protection Agency recently provided concurrence that termination of SVE operations within the 200-PW-1 Operable Unit is appropriate.

INTRODUCTION

Soil vapor extraction (SVE) has been used since 1992 to remove carbon tetrachloride from the vadose zone within the 200-PW-1 Operable Unit (OU), which is located on the Central Plateau of the Hanford Site in Washington State. The primary sources of the carbon tetrachloride are three waste sites (216-Z-9 Trench, 216-Z-1A Tile Field, and 216-Z-18 Crib) that were used from 1955 to 1973 for disposal of waste liquids from historical process operations at the Plutonium Finishing Plant (Fig. 1). Fig. 1 shows the locations for all of the SVE wells and monitoring probes near the three waste sites that are used to support SVE operations. The purpose of SVE operations near these waste sites is to mitigate the threat of carbon tetrachloride vapors migrating through the soil column and contaminating the underlying groundwater.

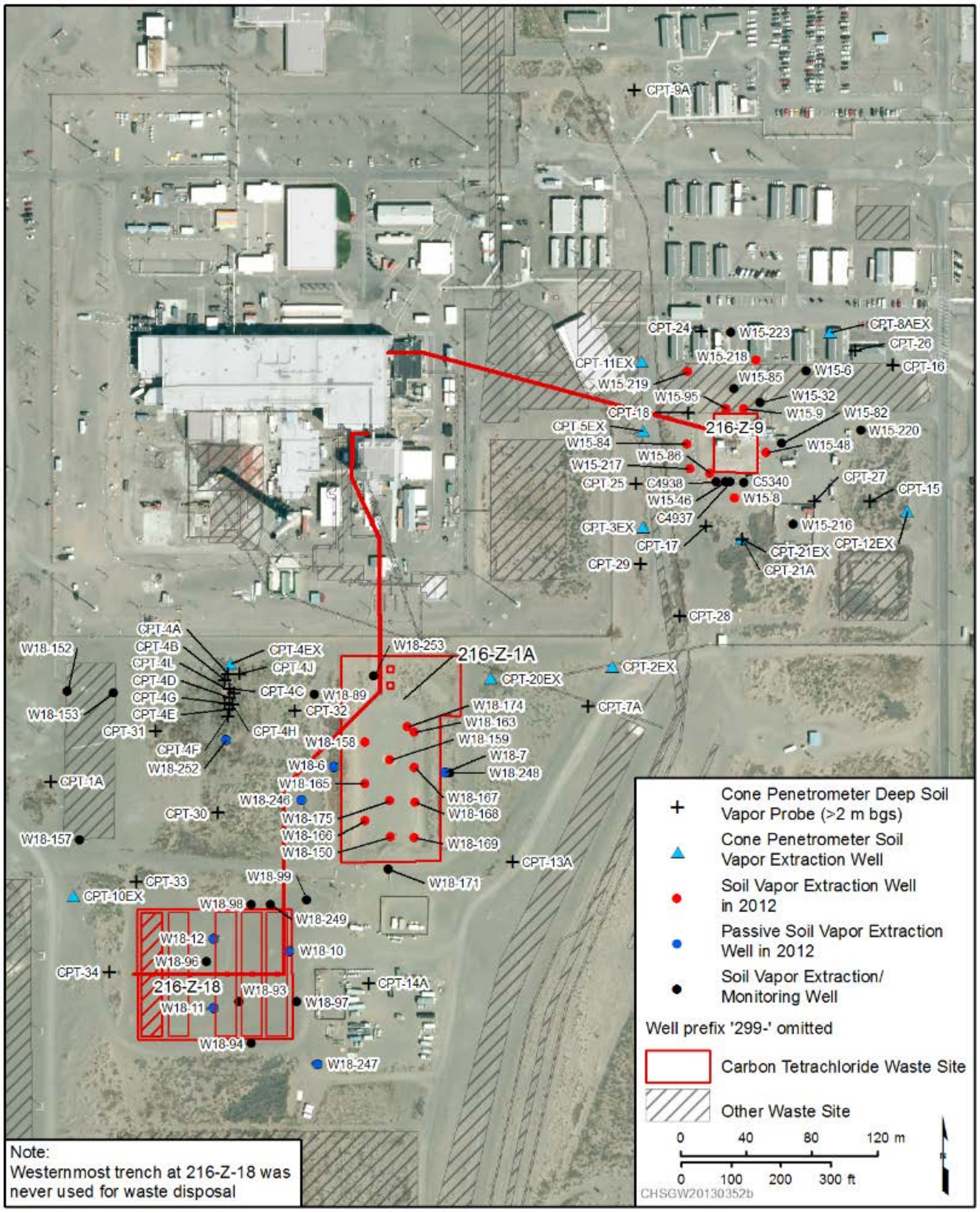


Fig. 1. Map Showing the Three Primary Carbon Tetrachloride Waste Sites in the 200-PW-1 OU.

SVE was first implemented as an interim action in 1992 [1]. More recently, SVE is being implemented to meet the requirements of the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* [2] Record of Decision for the 200-PW-1 OU [3], which was finalized in September 2011. The Record of Decision selected SVE as the final remedial action for carbon tetrachloride contamination in the vadose zone.

BACKGROUND

Between 1992 and 1997, three SVE systems operated continuously at 14.2, 28.3, and 42.5 m^3/min, respectively, to recover carbon tetrachloride from the vadose zone. During these first five years of SVE operations, 74,851 kg of carbon tetrachloride were removed. The SVE systems were not operated in 1997 so that a rebound study could be conducted. Based on the rebound study results and the declining carbon tetrachloride recovery rates, only the 14.2 m^3/min SVE system was operated between 1998 and 2008. Rather than operating year around, this single system was typically only operated from April through September, alternating between the 216-Z-9 Trench and the 216-Z-1A Tile Field/216-Z-18 Crib for approximately three months at each site. The SVE system was maintained in nonoperational mode for the remainder of the year to allow vadose zone vapor concentrations to rebound. More recently, two new 14.2 m^3/min SVE systems were operated simultaneously, one at each of the two sites, for 6 to 8 months each year from 2009 to 2012. By 2012, annual recovery of carbon tetrachloride had dropped to 162 kg. From 1992 through 2012, approximately 80,107 kg of carbon tetrachloride have been removed from the vadose zone during the processing of 118 billion m^3 of soil vapor (Fig. 2).

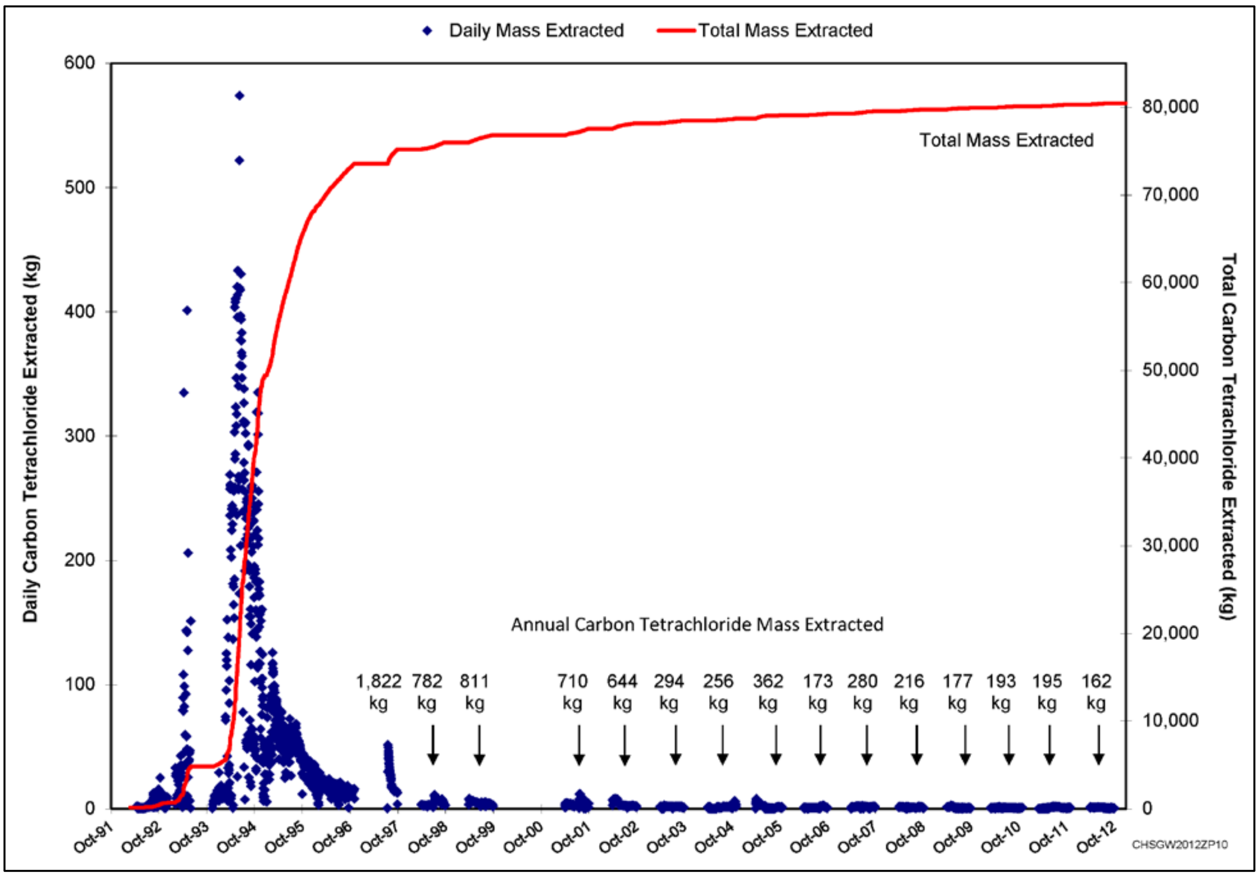
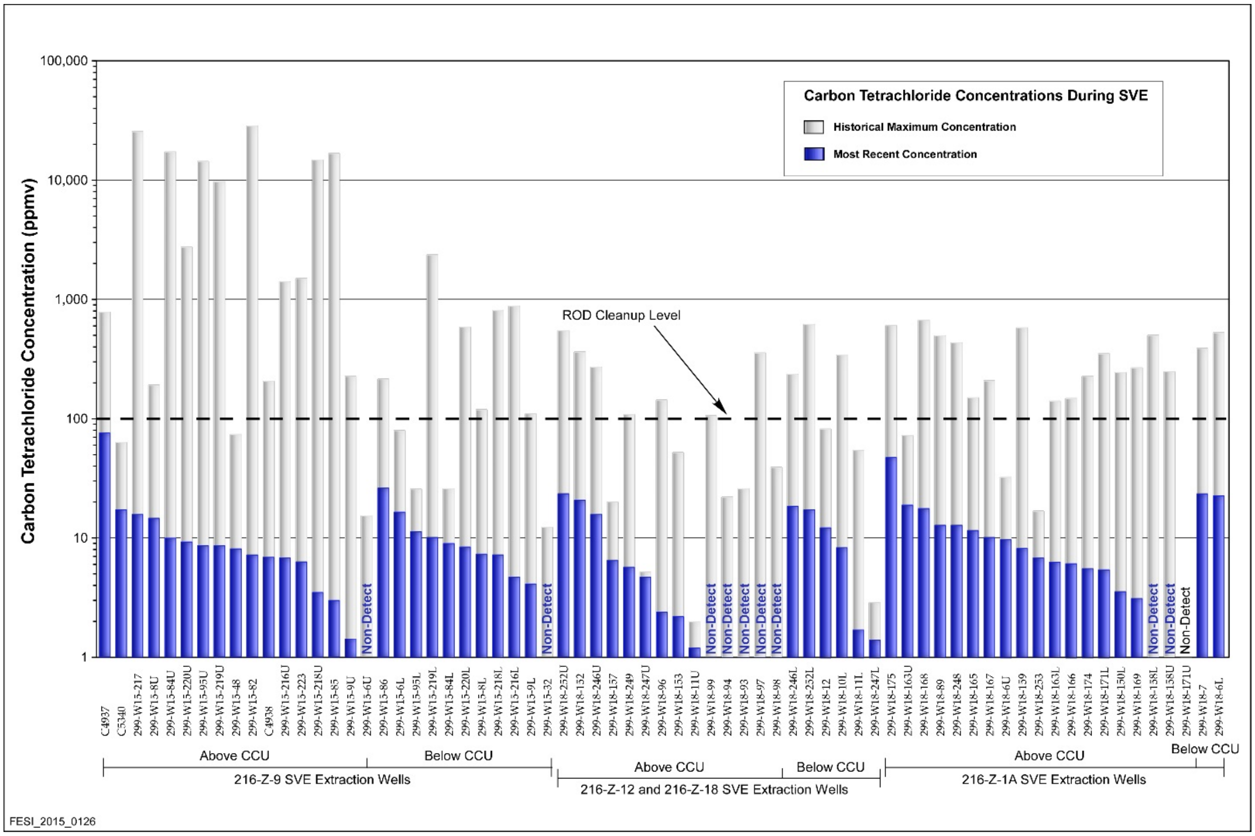


Fig. 2. Daily and Total Carbon Tetrachloride Mass Extracted by SVE in the 200-PW-1 OU. (The annual total mass extracted also is indicated for 1997 through 2012.)

Because carbon tetrachloride concentrations in all of the SVE wells have now decreased to well below the 100 ppmv cleanup level (Fig. 3), as specified in the final Record of Decision [3], the U.S. Environmental Protection Agency (EPA) approved three consecutive one-year rebound studies between 2013 and 2015. Soil vapor concentrations in all SVE wells (and all but two monitoring probes installed using direct-push technology) remained below the 100 ppmv cleanup level during this time.



Note: The logarithmic scale is provided on the Y-axis.

Fig. 3. Historical Maximum and Most Recent Carbon Tetrachloride Concentrations in 200-PW-1 OU SVE Wells (1992 to 2012).

ENDPOINT EVALUATION APPROACH

Carbon tetrachloride mass removal rates for the SVE systems have declined to the point where it is appropriate to evaluate whether a transition from the current cycle of active operations to closure of the SVE systems is warranted. Recently published SVE closure guidance [4] describes an approach and general decision logic for assessing whether termination of SVE operations is justified and appropriate. Fig. 4 summarizes this SVE closure guidance assessment approach, wherein the elements of an updated conceptual site model (CSM), environmental impacts/regulatory context, and estimate of the impact of remaining vadose zone contamination on the groundwater concentrations are combined into a decision logic approach to determine an appropriate SVE endpoint (optimization, transition, or closure) for the site.

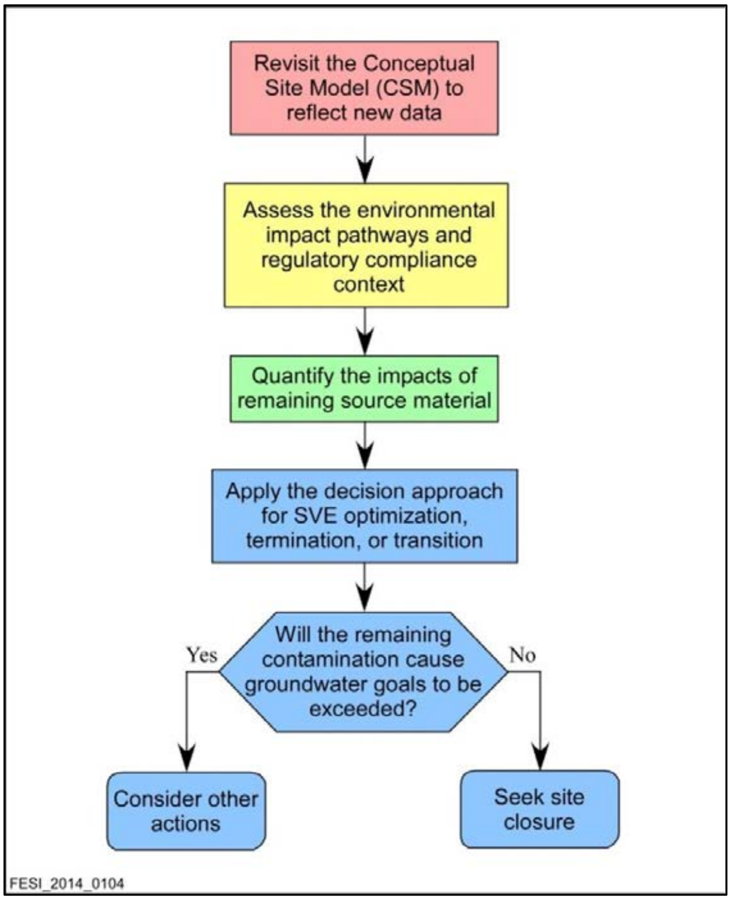


Fig. 4. SVE Closure Guidance Assessment Approach to Support Decisions for SVE System Optimization, Transition, or Closure.

The assessment and decision process shown in Fig. 4 includes four main steps:

1. Revisit the CSM to incorporate new data and assess the adequacy of existing data. This step involves evaluating pertinent information, including carbon tetrachloride monitoring and operational data from 1992 through 2015. The CSM was updated to reflect current knowledge regarding vadose zone contamination, contaminant migration, and subsurface characteristics. An updated CSM provides qualitative and quantitative input to SVE decisions.
2. Assess the environmental impact and regulatory compliance context. This step involves assessing whether the environmental pathways, cumulative risk, and remedial action objectives (RAOs) are adequately defined, given the current (updated) CSM, to support decisions regarding disposition of the SVE systems.
3. Quantify the environmental impact of remaining vadose zone contamination sources. Specifically, estimate the impact of vadose zone contamination on contaminant concentrations in the groundwater.
4. Apply the results of the previous three steps in the decision logic approach to determine appropriate actions for disposition of the SVE systems.

Conceptual Site Model

The CSM (illustrated in Fig. 5) reflects that investigations [8] showed the current residual carbon tetrachloride mass is located primarily within the low-permeability Cold Creek unit, with vapor diffusion of carbon tetrachloride out of the Cold Creek unit currently resulting in relatively low soil vapor concentrations (generally below the 200-PW-1 OU Record of Decision [3] cleanup level of 100 ppmv) in the permeable sediments both above and below the Cold Creek unit. It was concluded that the remaining contamination in the vadose zone (at locations above, within, and below the Cold Creek unit) is well understood, without data gaps. This CSM provides an adequate framework for subsequent assessment of both the environmental/regulatory context and impact to groundwater.

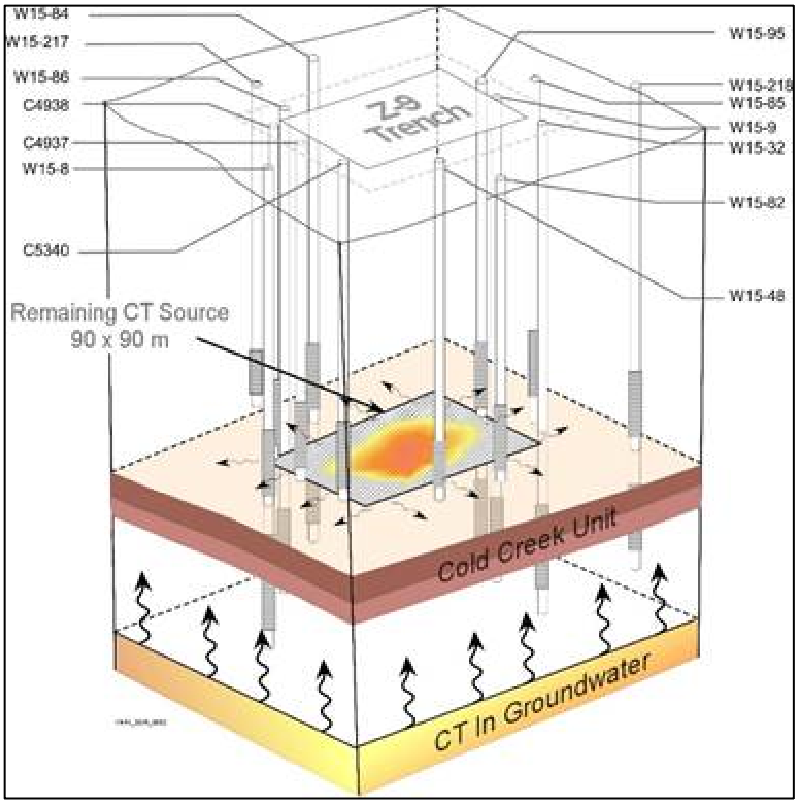


Fig. 5. Conceptual Site Model Summary for Carbon Tetrachloride in the 200-PW-1 OU.

Environmental Impact, Risk, and Remedial Action Objectives

Ground surface exposure pathways for carbon tetrachloride contamination in the vadose zone were eliminated by a comprehensive risk assessment that was performed for the 216-Z-9 and 216-Z-1A waste sites [5]. This risk assessment thoroughly evaluated potential environmental pathways. The baseline risk assessment stated that, under the anticipated industrial scenario and land-use controls, industrial worker exposure to carbon tetrachloride would not occur via direct contact with contaminated soils. The baseline risk assessment also determined that the vapor inhalation pathway was insignificant. The remaining potential environmental pathway is exposure via groundwater (e.g., exposure through drinking, irrigation, and discharge to surface water).

Diffusive transport of carbon tetrachloride in the soil gas below the Cold Creek unit is currently a potential pathway to the groundwater, where interphase mass transfer could result in an impact to the groundwater receptor. This pathway from the vadose zone source (Cold Creek unit sediments) to contamination of groundwater needs to be considered in the subsequent steps of the assessment and decision logic approach to support decisions regarding disposition of the SVE systems at the 200-PW-1 OU. The 3.4 µg/L groundwater cleanup level for carbon tetrachloride, specified in the 200-ZP-1 OU Record of Decision [6] for the underlying groundwater, is relevant input for assessing decisions regarding the disposition of the SVE systems. Thus, the cumulative risk context is well defined and consists of risk assessment as part of the groundwater remedy and a groundwater carbon tetrachloride concentration cleanup goal of 3.4 µg/L.

RAOs were established in the 200-PW-1 OU Record of Decision [3] based on anticipated future industrial land use. Only one RAO applies to the carbon tetrachloride contamination in the vadose zone with the identified environmental impact pathway leading to groundwater exposure. This RAO states, “Control the sources of potential groundwater contamination to support the Central Plateau groundwater goal of protecting the beneficial uses of groundwater, including protecting the Columbia River from adverse impacts.”

The 200-PW-1 OU Record of Decision [3] established a final cleanup level of 100 ppmv for carbon tetrachloride in soil vapor to meet the intent of the RAO stated in the previous paragraph.The Record of Decision also specified that “…soil vapor concentration cleanup levels will be further refined and assessed to ensure they are protective of groundwater…”, and cleanup is subject to the requirements of WAC 173-340 [7]. The data and analyses presented in the treatability test report [8] provide the refined consideration of vadose zone conditions that are protective of groundwater. The 200-PW-1 OU Record of Decision [3] also noted that, “As long as residual contamination remains above levels that allow for unrestricted use, institutional controls will be required.”

It was concluded that the environmental impact pathway, cumulative risk, and regulatory compliance context have been adequately determined and defined to support evaluation of the impact of vadose zone contamination on the groundwater concentrations and subsequent decisions regarding disposition of the 200-PW-1 OU SVE systems.

Impact of Vadose Zone Contamination on Groundwater

The approach for assessing the impact of carbon tetrachloride in the vadose zone on groundwater concentrations consisted of four steps. This approach, based on the SVE closure guidance [4] and the site-specific treatability test [8], is a refined consideration of vadose zone conditions that are protective of groundwater, as specified in the 200-PW-1 OU Record of Decision [3] and consists of the following four steps:

1. For the three waste sites (216-Z-9 Trench, 216-Z-1A Tile Field, and 216-Z-18 Crib), calculate the impacts of vadose zone releases on groundwater concentrations using the calculation approach described in the SVE closure guidance [4].
2. Assess the current groundwater impact from the 216-Z-9 site based on the treatability test [8]. This assessment involved more detailed, site-specific contaminant transport analyses. (Note: The 216-Z-9 site was selected because it is the most contaminated of the three sites.)
3. Compare the results from step 1 for the 216-Z-9 site to the results from the treatability test (step 2) in terms of impact to groundwater.
4. Assess the future groundwater impact from the 216-Z-9 site (based on the treatability test [8]), with consideration of the ongoing remedy for the 200-ZP-1 OU and upward vapor diffusion from groundwater.

Step 1: Calculate Impacts to Groundwater Using SVE Closure Guidance

The Soil Vapor Extraction Endstate Tool (SVEET), documented in the SVE closure guidance [4], was used to estimate groundwater concentrations resulting from vadose zone sources at the 216-Z-9 Trench, 216-Z-1A Tile Field, and 216-Z-18 Crib. Results from the calculations are presented in Table 1. These results suggest that if the underlying aquifer was clean, the impact to groundwater from current soil gas concentrations near the 216-Z-9 Trench, 216-Z-1A Tile Field, and 216-Z-18 Crib would be 27 µg/L, 17 µg/L, and 12 µg/L, respectively.

TABLE 1. Summary of SVEET Evaluation for the Three Waste Sites

Waste Site	216-Z-9	216-Z-1A	216-Z18
Source gas concentration (ppmv)	24.7	13.9	9.65
Estimated groundwater concentration (μg/L)	27	17	12

Step 2: Assess Impact to Groundwater Based on Treatability Test

A treatability test was performed that applied the methods outlined in Brusseau et al., 2010 [9]. From this test, vadose source discharge was estimated to be 70 g/d. The treatability test also determined that the Cold Creek unit is the primary remaining source of carbon tetrachloride in the vadose zone, with an areal extent of approximately 90 m by 90 m (Fig. 5). The modeling technique provided in Carroll et al., 2012 [10] was used to predict the groundwater impact from a 90 m by 90 m vadose zone source with varying mass release rates. For the measured source mass release rate of 70 g/d, the maximum groundwater concentration for carbon tetrachloride would be approximately 24 μg/L. The source mass release rate and resulting groundwater carbon tetrachloride concentration will continue to decline over time, eventually reaching a condition that meets the groundwater remediation goal.

Step 3: Comparison of Results from SVEET (Step 1) and Treatability Test (Step 2)

SVEET estimates that the groundwater carbon tetrachloride concentration would be approximately 27 μg/L (based on soil vapor concentration of 24.7 ppmv at the source). This estimate is consistent with the 24 μg/L groundwater concentration calculated in the treatability test [8] and corroborates the SVEET calculations. The SVEET results demonstrate that the 216-Z-9 waste site has the highest potential impact to groundwater. Because the treatability test used a more detailed, site-specific analysis than SVEET, it provides a more accurate estimate of the groundwater carbon tetrachloride concentrations resulting from the 216-Z-9 vadose zone contaminant source.

Step 4: Assess Future Groundwater Impact Based On Treatability Test

As described in the treatability test report [8], the source mass release rate will continue to decline over time due to diffusive mass transfer. Fig. 6 shows how the maximum groundwater carbon tetrachloride concentrations (contributed by soil vapor) decline over time, based on the post-SVE decline in the source mass release rate described in the treatability test. With termination of the SVE remedy, the groundwater carbon tetrachloride concentration resulting from the vadose zone source at the 216-Z-9 site will be below the groundwater target concentration of 3.4 μg/L within 40 years.

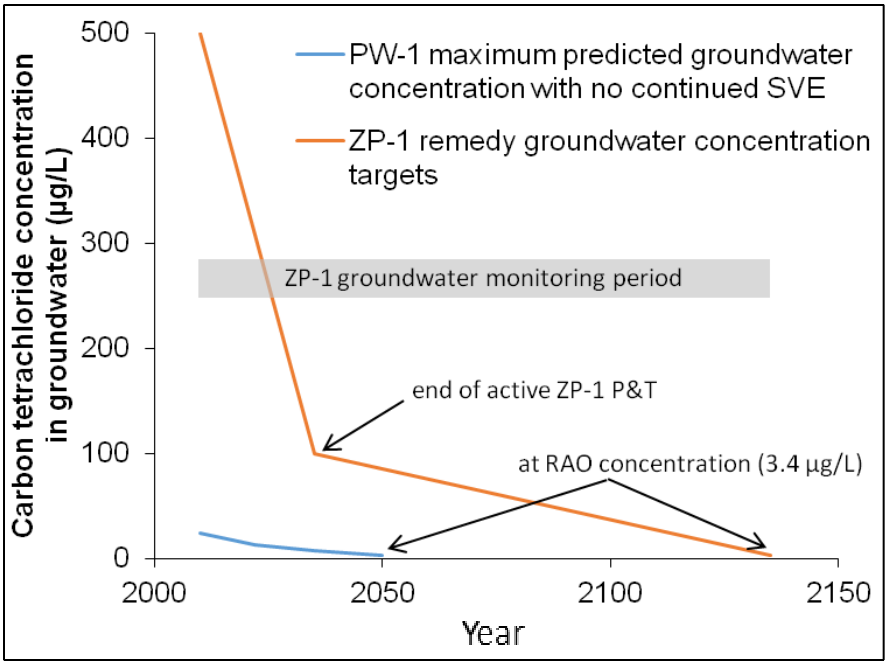


Fig. 6. Predicted Maximum Groundwater Carbon Tetrachloride Concentrations Over Time, Where PW-1 Represents the 200-PW-1 (Vadose Zone) Operable Unit Impact, ZP-1 Represents the 200-ZP-1 Groundwater Operable Unit Conditions, and RAO is the Remedial Action Objective.

The 200-ZP-1 OU groundwater pump-and-treat system is scheduled to operate for 25 years (through 2037) to extract carbon tetrachloride-contaminated groundwater and reduce concentrations to approximately 100 μg/L. The 100 years following pump-and-treat operations will be a monitored natural attenuation phase, during which residual carbon tetrachloride in the groundwater is expected to decline to meet the final cleanup level of 3.4 μg/L.

Current carbon tetrachloride concentrations in groundwater below the 216-Z-9 waste site are approximately 500 μg/L. Based on Henry's Law equilibrium calculations, these elevated groundwater concentrations preclude the migration of carbon tetrachloride vapor from the vadose zone into the groundwater.

While groundwater concentrations remain relatively high, residual carbon tetrachloride concentration in the vadose zone will not migrate downward and, thus, does not pose additional risk to 200-ZP-1 OU groundwater. Within approximately 40 years, vadose zone contamination will have dissipated to approximately 10 g/d mass discharge, which will not pose a threat to clean groundwater. This time frame is well within the groundwater remedy span of 125 years.

CONCLUSIONS

Prior elements of the site-specific assessment approach have presented a CSM that is representative of current conditions and knowledge (without data gaps), determined that the environmental impact pathway/regulatory context is appropriately defined, and evaluated the impact of remaining vadose zone sources on groundwater concentrations. These evaluations have determined that, if SVE is terminated, there is no current or future impact of carbon tetrachloride from the vadose zone to the groundwater that would result in concentrations in the groundwater above the cleanup level (3.4 μg/L) for carbon tetrachloride [6] by the time that this goal is required to be achieved. This suggests that all requirements specified in the SVE closure guidance [4] have been met and also demonstrates that groundwater cleanup levels will not be exceeded. Thus, closure of the SVE remedy (i.e., permanently discontinuing operation of the SVE systems) within the 200-PW-1 OU was recommended. EPA recently provided concurrence to terminate all future 200-PW-1 OU SVE operations and direction to begin preparing a site closeout remedial action report.

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