3.2 Vadose Zone Monitoring

D. G. Horton

Vadose zone monitoring occurred at four major areas on the Hanford Site in fiscal year 2003. Leachate and soil-gas monitoring continued at the Solid Waste Landfill and the Environmental Restoration Disposal Facility. Also, soil-gas monitoring at the carbon tetrachloride expedited-response-action site continued during fiscal year 2003. Finally, geophysical borehole monitoring continued at single-shell tank farms for leak detection and to determine subsurface contaminant migration. This section summarizes these vadose zone monitoring activities.

3.2.1 Leachate and Soil-Gas Monitoring at the Solid Waste Landfill

R. A. Del Mar

The Solid Waste Landfill is a disposal facility in the center of the Hanford Site (part of the Central Landfill illustrated on Figure 2.1-2). The landfill covers an area of ~26.7 hectares and began operating in 1973 to receive non-hazardous, non-radioactive sanitary waste generated from Hanford Site operations. The Solid Waste Landfill stopped receiving waste in 1996 and an "interim cover" consisting of 0.6 to 1.2 meters of soil was placed over all trenches. Current monitoring at the Solid Waste Landfill consists of quarterly sampling of groundwater, soil gas, and leachate. Recent groundwater monitoring results are discussed in Section 2.11.5.2. This section summarizes leachate and soil-gas monitoring results.

Leachate is collected beneath part of the Solid Waste Landfill. The volume of leachate increased in fiscal year 2003 because of increased precipitation.

In all, the Solid Waste Landfill consists of ~70 single trenches and 14 double trenches. Based on trench geometry and the thickness of the waste layer, the capacity of a trench per linear foot is 8.4 cubic meters for the single trenches and ~30.6 cubic meters for the double trenches. Based on this estimate, total design capacity of the Solid Waste Landfill is ~596,400 cubic meters.

One of the double trenches overlies a lined, basin lysimeter designed to collect leachate generated by infiltration through the overlying refuse. This lysimeter covers an area of ~88 square meters. A discharge pipe continuously drains leachate by gravity flow from the basin to a nearby collection pump. However, leachate collected from this lysimeter may not be representative of leachate drainage throughout the entire landfill area because the lysimeter only collects leachate from 1 of 84 trenches, and is installed under one of the newer trenches built after implementation of regulations that restrict land disposal practices. Still, the lysimeter provides some indication of the rate of infiltration and some of the contaminants that may be reaching groundwater.

Leachate is collected from the basin lysimeter every 10 to 14 days. Figure 3.2-1 shows the rate of leachate generated over the past 4 years. Prior to calendar year 2003, the generation rate was consistently between 4 to 8 liters per day. However, during calendar year 2003, the generation rate jumped to >19 liters per day. This increase is mainly attributed to above average rainfall recorded at the Hanford Site during the winter of 2002/2003. The Hanford Meteorological Station recorded 12.6 centimeters of rain during the 3-month period from December 2002 through February 2003. This was more than a 90% increase over the 3-month winter average of 6.5 centimeters recorded at the Hanford Site dating back to 1946. Drainage from the winter rainfall started showing up in the lysimeter collection tank in late April 2003.

The landfill leachate is sampled quarterly for indicator parameters and site-specific contaminants.

During fiscal year 2003, several analytes continued to be found in the landfill leachate in concentrations above WAC 173-200 groundwater quality criteria. These constituents include arsenic, manganese, nickel, iron, 1,4-dioxane, 1,4-dichlorobenzene, and tetrachloroethene. In addition, the indicator parameters chloride and total dissolved solids exceeded groundwater quality criteria in fiscal year 2003.

Soil-gas monitoring at the Solid Waste Landfill uses eight shallow monitoring stations located around the perimeter of the landfill. Each station consists of two soil-gas probes at depths of ~2.75 and 4.6 meters. Soil gas is monitored quarterly to determine concentrations of oxygen, carbon dioxide, methane, and several key volatile organic compounds. No contaminants of concern were discovered above reporting limits during the reporting period.

3.2.2 Leachate Monitoring at the Environmental Restoration Disposal Facility

D. A. St. John and R. L. Weiss

Concentrations of some constituents have been increasing in leachate from the Environmental Restoration Disposal Facility.

Bechtel Hanford, Inc. operates the Environmental Restoration Disposal Facility to dispose of radioactive, hazardous or dangerous, and mixed waste generated during waste management and remediation activities at the Hanford Site. In fiscal year 2003, Bechtel Hanford, Inc. published the results of groundwater monitoring and sampling at the Environmental Restoration Disposal Facility during the calendar year 2002 (BHI-01684). Part of the published results contains laboratory analyses of leachate collected from beneath the facility. This section discusses those results.

The Environmental Restoration Disposal Facility began operation in July 1996. Located between the 200 East and 200 West Areas (see Appendix C, Figure C.5), the facility is currently operating two disposal cells that became active during June 2000. Through calendar year 2002, ~3.5 million metric tons of remediation waste have been disposed at the facility since operations began in July 1996.

Each disposal cell is lined to collect leachate that is a result of water added as a dust suppressant and natural precipitation. Leachate is pumped from the sumps beneath the cells to tanks. After ~760,000 liters of leachate are collected, samples are taken and analyzed to provide an inventory to the Effluent Treatment Facility, where the leachate is disposed, and to provide semiannually sampling of leachate for delisting analyses. The purpose of the delisting analyses is to enable handling the leachate as non-hazardous waste. The results are also used to determine whether additional constituents should be added to the groundwater monitoring list of contaminants of concern.

Composite leachate samples were collected in duplicate in June and December 2002. Leachate samples contained detectable concentrations of common metals, anions, and mobile radionuclides. Constituents that were generally increasing in concentration since calendar year 2000 include selenium, nitrate, gross alpha, gross beta, carbon-14, and technetium-99 and total uranium:

- Until June 2001, concentrations of selenium were non-detectable. Since June 2001, the concentration of selenium has gradually increased to an average of 9.6 µg/L during 2003.
- Nitrate concentration which averaged ~260 mg/L from 2000 to 2002, increased somewhat to an average of 348 mg/L in 2003.
- Gross alpha averaged 121 pCi/L from 2000 through 2002. June 2003 values for gross alpha were non-detects, and December 2003 values for gross alpha averaged 556 pCi/L.
- Gross beta concentrations remained fairly stable until June 2001. Since that time, gross beta concentrations have been increasing to an average of 1,050 pCi/L in December 2002. The increasing gross beta is consistent with increasing technetium-99.

- The first detectable carbon-14 values were reported in December 2002 at an average value of 30.4 pCi/L.
- Technetium-99 concentrations have been increasing slightly since first reported in June 2001. The average technetium-99 concentration for December 2002 was 1,265 pCi/L.
- Uranium concentration remained stable from December 2000 through December 2001. In calendar year 2002, uranium concentration increased to an average of 824 pCi/L in December 2002.

The analyses for selenium, nitrate, gross alpha, gross beta, carbon-14, technetium-99, and uranium showed possible increasing concentration trends over the past 3 years. Groundwater monitoring data for these constituents were examined to determine whether the Environmental Restoration Disposal Facility has affected groundwater. In all cases, groundwater concentrations for these constituents remained stable or decreased. Based on this comparison, it appears that the Environmental Restoration Disposal Facility leachate has not had an impact on groundwater at this location.

The target constituents for the groundwater monitoring program are consistent with the leachate monitoring program. At this time, no additional constitutes are recommended for addition to the groundwater monitoring program at the Environmental Restoration Disposal Facility landfill based on that evaluation.

Vadose Zone Monitoring Study at the Environmental Restoration Disposal Facility. In 2002, DOE, EPA, and Ecology agreed to fund a study of vadose zone monitoring at the Hanford Site. The first part of that study (DOE/RL-2003-31) was completed in fiscal year 2003 and evaluated the potential for vadose zone monitoring at the Environmental Restoration Disposal Facility. The second part of the study, to be completed in fiscal year 2004, will evaluate the potential use of vadose zone monitoring at other places on the Central Plateau.

The fiscal year 2003 study recommended that a monitoring system be incorporated into the design of the final caps to be placed over the Environmental Restoration Disposal Facility cells when they are closed. Strategically placed lysimeters and topographic methods to evaluate the integrity of landfill covers were recommended.

The study also concluded that the addition of vadose zone monitoring during the operational phase of the double-lined Environmental Restoration Disposal Facility cells is not required or necessary. However, for newly constructed cells, it was recommended that basin lysimeters be installed below the sumps and that perforated access tubes be installed below the secondary liner and admix layer. Such monitoring systems would provide information on the expected performance of vadose zone monitoring systems and their potential use in future disposal facilities at the Hanford Site. Data collected from the systems could be used to evaluate the vadose zone systems and would not be part of the performance monitoring for the Environmental Restoration Disposal Facility cells.

Routine vadose zone monitoring determines if contamination is moving beneath the tanks.

3.2.3 Vadose Zone Monitoring at Single-Shell Tank Farms

R. G. McCain

The S.M. Stoller Corporation is responsible for borehole geophysical logging at the Hanford Site. From 1995 to 2000, spectral gamma logs from 769 existing monitoring boreholes in the single-shell tank farms were used to characterize the subsurface contamination in the vicinity of the farms. Based on the characterization data, a comprehensive monitoring project for existing boreholes in the single-shell tank farms was established in fiscal year 2001. This project uses the radionuclide assessment system to detect subsurface contaminant plumes and/or movement of existing plumes in the immediate vicinity of the single-shell tanks. Gamma activity levels detected by the radionuclide assessment system are compared against previous data and against the baseline contamination conditions established from the characterization project between 1995 and 2000. By comparing gamma activity between subsequent logging runs, it is possible to identify changes that may indicate contaminant migration of new or existing plumes. Log data and reports are accessible via the internet at http://www.gjo.doe.gov/programs/hanf/HTFVZ.html.

The intent of the routine monitoring project is to measure gamma activity in each of the 769 existing boreholes in the 12 single-shell tank farms at least once in a 5-year period. Some boreholes have been selected for more frequent monitoring: yearly, semiannually, or quarterly. Monitoring frequency for each borehole is determined by its proximity to known or suspected subsurface contaminant plumes, proximity to tanks classified as leaking, and proximity to tanks known to contain relatively large volumes of drainable liquid. Monitoring results are corrected for radioactive decay when necessary and compared against previous results and against the baseline to determine if statistically significant changes have occurred. Routine monitoring results are summarized on a quarterly basis. Anomalies are investigated using additional logging tools, and a special report or memorandum may be issued if warranted.

During fiscal year 2003, monitoring operations were performed in a limited number of boreholes within each of the 12 single-shell tank farms. In general, contaminant plumes identified by baseline characterization activities appear to be stable over time.

Also in fiscal year 2003, monitoring of subsurface gamma activity and moisture content was performed in support of retrieval operations at tanks U-107, C-106, and S-112. Monitoring gamma activity and moisture content in existing boreholes in the immediate vicinity of the tank is a way to detect leaks during retrieval operations. Geophysical logs were run immediately prior to retrieval operations to provide a pre-retrieval baseline. During retrieval operations, both spectral gamma logs and neutron moisture logs are collected on a monthly basis. Both types of logs are collected again within a month of completing the retrieval operations and on a quarterly basis thereafter. Additional moisture measurements over limited depth intervals are made by tank farm personnel using hand-held moisture gauges, at a frequency of once per week.

Soil-vapor extraction is being used to remove carbon tetrachloride from the vadose zone in the 200 West Area.

At the end of fiscal year 2003, the saltcake dissolution studies in tank U-107 had been completed and retrieval operations were ongoing in tanks C-106 and S-112. No evidence of leakage associated with retrieval operations was detected.

3.2.4 Carbon Tetrachloride Monitoring and Remediation

V. J. Rohay

Soil-vapor extraction is being used to remove carbon tetrachloride from the vadose zone in the 200 West Area. The U.S. Environmental Protection Agency and the Washington State Department of Ecology authorized the U.S. Department of Energy to initiate this remediation in 1992 as a *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) expedited response action. The following discussion summarizes fiscal year 2003 activities associated with the carbon tetrachloride removal. For descriptions of past work, see BHI-00720, WMP-17869, and Section 3.2.3 in PNNL-14187. See Figure 3.2-2 for locations of vapor extraction wells.

The 14.2-cubic-meter-per-minute soil-vapor extraction system operated at the combined 216-Z-1A/216-Z-12/216-Z-18 well field from April 1 through September 30, 2003. The soil-vapor extraction system was not operated at the 216-Z-9 well field during fiscal year 2003 to avoid interfering with characterization sampling that was conducted during drilling of a well at that site. The system was maintained in standby mode from October 1, 2002 through March 31, 2003. The 28.3- and 42.5-cubic-meter-per-minute soil-vapor extraction systems were not maintained in standby mode during fiscal year 2003. Temporarily suspending soil-vapor extraction operations at each well field allows the carbon tetrachloride concentrations to recharge and be more economically extracted when operations resume.

To track the effectiveness of the remediation effort, soil-vapor concentrations of carbon tetrachloride were monitored at the inlet to the soil-vapor extraction system and at individual online extraction wells during the 6-month operating period. To assess the impact of the soil-vapor extraction system on subsurface concentrations, soil-vapor concentrations of carbon tetrachloride were monitored at off-line wells and probes during the entire fiscal year.

Remediation efforts during fiscal year 2003 also included passive soil-vapor extraction.

Approximately 78,100 kilograms of carbon tetrachloride have been removed from the vadose zone since extraction operations started in 1991.

3.2.4.1 Soil-Vapor Extraction

Soil-vapor extraction to remove carbon tetrachloride from the vadose zone resumed April 1, 2003 at the combined 216-Z-1A/216-Z-12/216-Z-18 well field. Initial online wells were selected within the perimeter of the 216-Z-1A tile field. As extraction continued, wells farther away from the tile field were brought online. Extraction wells open near the less-permeable Cold Creek unit, where the highest carbon tetrachloride concentrations have consistently been detected in the past, were selected to optimize mass removal of contaminant. Initial carbon tetrachloride concentrations measured at the soil-vapor extraction inlet were ~20 parts per million vapor (ppmv) (Figure 3.2-3). After 3 weeks of extraction, additional wells were added to the system and concentrations increased to nearly 30 ppmv. After 26 weeks of extraction, concentrations had decreased to ~15 ppmv.

As of September 2003, ~78,100 kilograms of carbon tetrachloride have been removed from the vadose zone since extraction operations started in 1991 (Table 3.2-1). Since initiation, the extraction systems are estimated to have removed 7% of the residual mass at 216-Z-1A/216-Z-12/216-Z-18 well field and 22% of the mass at 216-Z-9 well field. This estimate assumes that all of the mass that has not been lost to the atmosphere (21% of the original inventory), dissolved in groundwater (2% of the original inventory), or biodegraded (1% of the original inventory) is still available in the vadose zone as residual mass (WMP-17869; WHC-SD-EN-TI-101).

3.2.4.2 Monitoring at Off-Line Wells and Probes

The temporary suspension of soil-vapor extraction in fiscal year 2003 appears to have caused minimal vertical transport of carbon tetrachloride through the soil surface to the atmosphere.

During fiscal year 2003, soil-vapor concentrations of carbon tetrachloride were monitored near the ground surface, near the Cold Creek unit (~40 meters below ground surface), and near groundwater (~66 meters below ground surface). Soil-vapor concentrations were monitored near the ground surface and groundwater to evaluate whether non-operation of the soil-vapor extraction system negatively affects the atmosphere or groundwater. The maximum concentration detected near the ground surface (between 2 and 10 meters below ground surface) was 22 ppmv. Near the groundwater, at a depth of 55 meters below ground surface, the maximum concentration was 26 ppmv.

Soil-vapor concentrations also were monitored above and within the Cold Creek unit to provide an indication of concentrations that could be expected during restart of the soil-vapor extraction system. The maximum concentration detected near the Cold Creek unit (between 25 and 44 meters below ground surface) was 444 ppmv in well 299-W15-217 (35 meters below ground surface) adjacent to the 216-Z-9 trench. During monitoring in fiscal years 1997, 1998, 1999, 2000, and 2001, the highest carbon tetrachloride concentrations also were detected in this well. Approximately 90 meters south of the 216-Z-9 trench, the maximum carbon tetrachloride concentration detected was 235 ppmv at soil-vapor probe CPT-28 (27 meters below ground surface). Approximately 200 meters north of the 216-Z-9 trench, the maximum carbon tetrachloride

Passive soil-vapor extraction uses naturally-induced pressure gradients to drive soil vapor to the surface.

concentration detected was 36 ppmv at soil vapor probe CPT-9A (18 meters below ground surface). The maximum carbon tetrachloride concentration detected in the vadose zone overlying the Cold Creek unit (between 11 and 23 meters below ground surface) was 90 ppmv at soil vapor probe CPT-21A (14 meters below ground surface) near the 216-Z-9 trench.

At the 216-Z-1A/216-Z-12/216-Z-18 well field, the maximum carbon tetrachloride concentration detected near the Cold Creek unit was 328 ppmv in well 299-W18-165 (33 meters below ground surface) within the 216-Z-1A tile field. During monitoring in fiscal years 1997 through 2002, the highest carbon tetrachloride concentrations in the 216-Z-1A/216-Z-12/216-Z-18 well field also were detected at wells within the 216-Z-1A tile field.

The temporary suspension of soil-vapor extraction in fiscal year 2003 appears to have caused minimal detectable vertical transport of carbon tetrachloride through the soil surface to the atmosphere. This interpretation is supported by data that show carbon tetrachloride concentrations did not increase significantly at the near-surface monitoring probes. In addition, suspending operations of the soil-vapor extraction system appears to have had no negative impact on groundwater quality, because carbon tetrachloride concentrations did not increase significantly near the water table during that time.

3.2.4.3 Passive Soil-Vapor Extraction

Passive soil-vapor extraction is a remediation technology that uses naturally-induced pressure gradients between the subsurface and the surface to drive soil vapor to the surface. In general, falling atmospheric pressure causes subsurface vapor to move to the atmosphere through wells, whereas rising atmospheric pressure causes atmospheric air to move into the subsurface. Passive soil-vapor extraction systems are designed to use this phenomenon to remove carbon tetrachloride from the vadose zone.

Passive soil-vapor extraction systems were installed at the end of fiscal year 1999 at eight boreholes that are open near the vadose-groundwater interface at the 216-Z-1A/216-Z-12/216-Z-18 well field. The passive systems are outfitted with check valves that only allow soil-vapor flow out of the borehole (i.e., one way movement), and canisters holding granular activated carbon that adsorbs carbon tetrachloride upstream of the check valves before the soil vapor is vented to the atmosphere. The check valve prohibits flow of atmospheric air into the borehole during a reverse barometric pressure gradient, which tends to dilute and spread carbon tetrachloride vapors in the subsurface.

The wells are sampled periodically upstream of the granular activated carbon canisters when atmospheric pressure is falling and the wells are venting. The maximum carbon tetrachloride concentrations measured at the four wells (299-W18-6, 299-W18-7, 299-W18-246, and 299-W18-252) in the vicinity of the 216-Z-1A tile field ranged from 24 to 37 ppmv. The maximum carbon tetrachloride concentrations measured at the four wells (299-W18-10, 299-W18-11, 299-W18-12, and 299-W18-247) in the vicinity of the 216-Z-18 crib ranged from 8 to 15 ppmv.

Table 3.2-1. Carbon Tetrachloride Inventory in Primary Disposal Sites

Well Field	Estimated Mass Discharged 1955 to 1973[a] (kg)	Estimated Mass Lost to Atmosphere 1955 to 1990[b] (kg)	Mass Removed Using Soil-Vapor Extraction 1991 to 2003 (kg)
216-Z-1A	270,000	56,700	24,294[c]
216-Z-9	130,000 to 480,000	27,300 to 100,800	53,798
216-Z-18	170,000	35,700	
Total	570,000 to 920,000	119,700 to 196,800	78,092

(a) Based on DOE/RL-91-32.
(b) Based on WHC-SD-EN-TI-101.
(c) Includes mass removed from 216-Z-18 site; reported as a combined value because the well fields overlap.

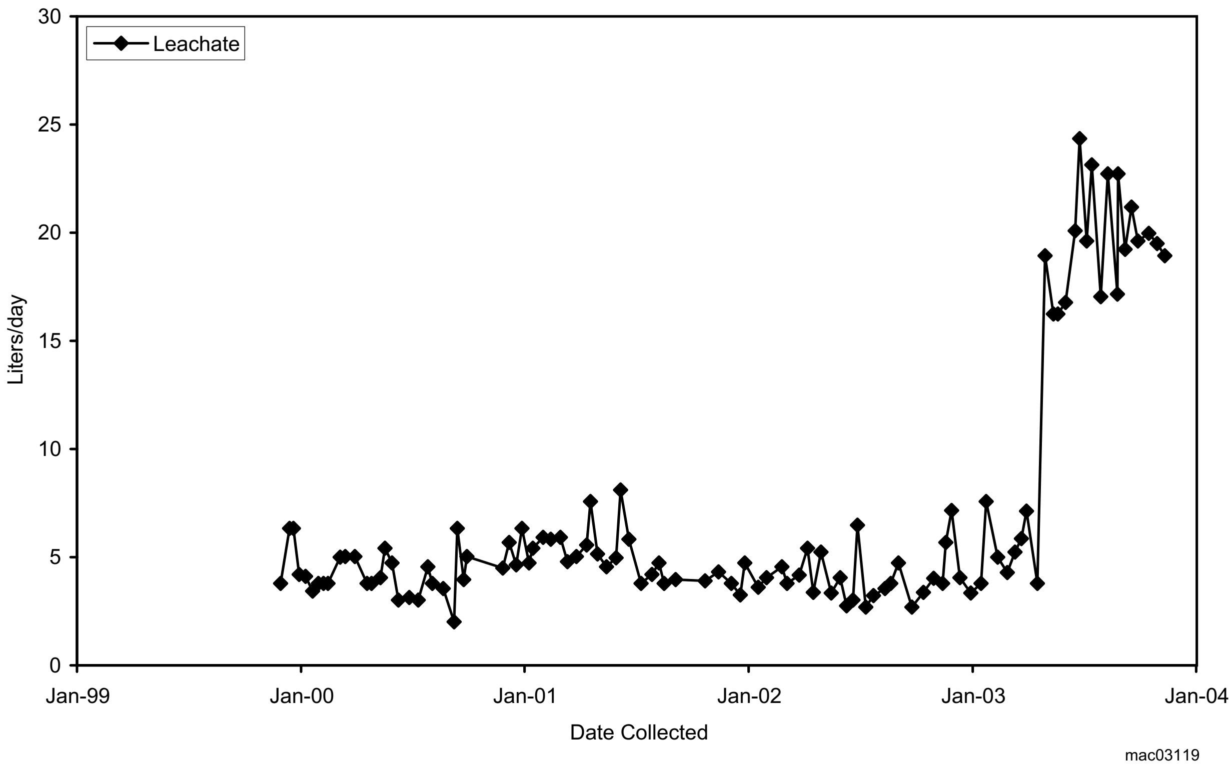

Figure 3.2-1. Leachate Collection Volumes at the Solid Waste Landfill

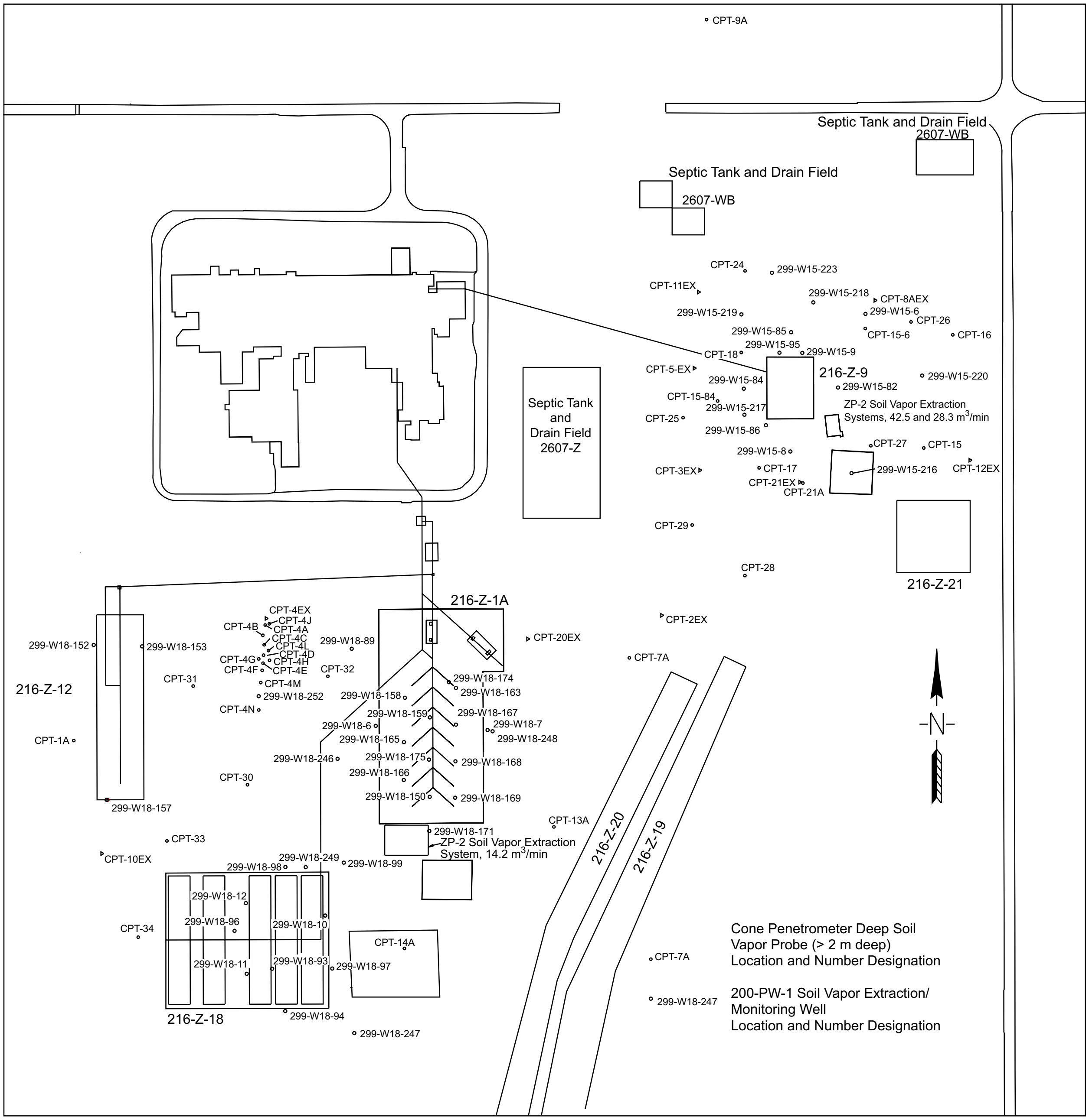

Figure 3.2-2. Locations of Carbon Tetrachloride Vapor-Extraction Wells at the 216-Z-1A/216-Z-12/216-Z-18 and the 216-Z-9 Well Fields

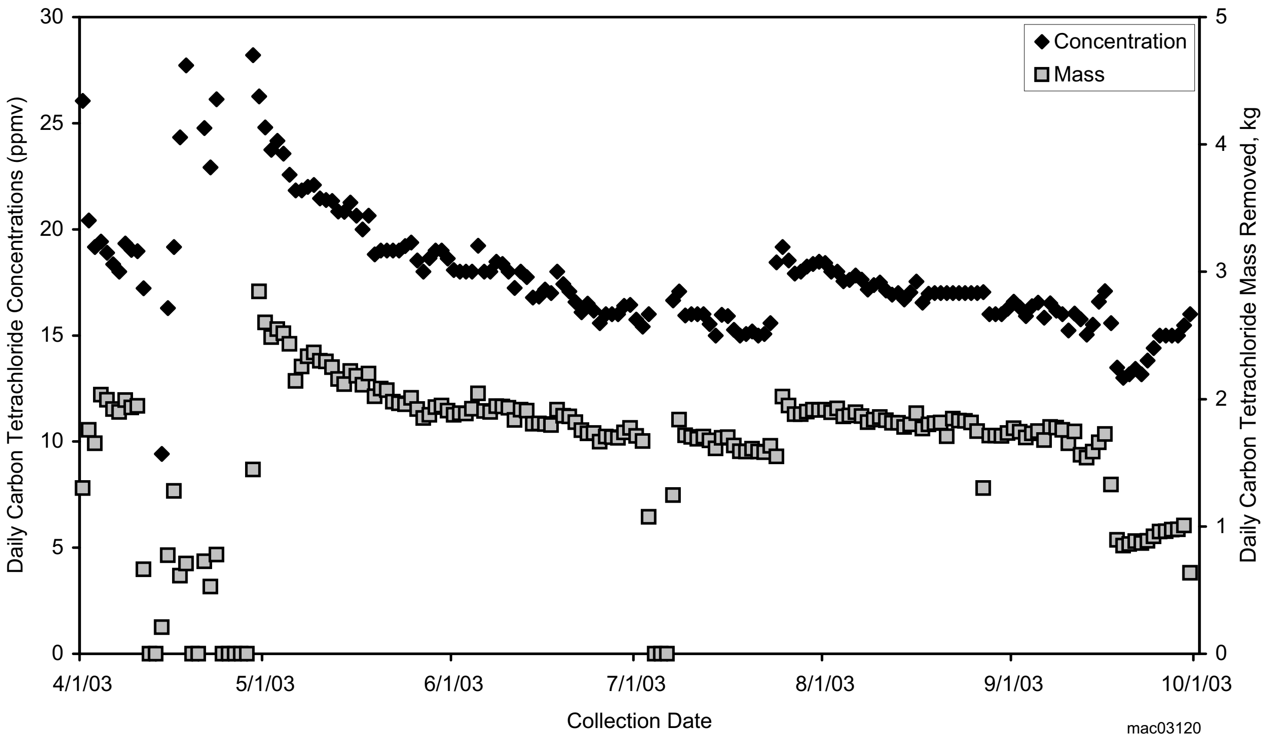

Figure 3.2-3. Time Series Concentrations and Mass of Carbon Tetrachloride in Soil Vapor Extracted from the 216-Z-1A/216-Z-12/216-Z-18 Well Field