7.2 Vadose Zone Monitoring

D. G. Horton

Vadose zone monitoring occurred at four major areas on the Hanford Site in fiscal year 2001. Leachate and soil gas monitoring continued at the Environmental Restoration Disposal Facility and the Solid Waste Landfill. Also, soil gas monitoring at the carbon tetrachloride expedited-response-action site continued during fiscal year 2001. During the year, borehole geophysical monitoring of dry wells in single-shell tank farms to detect leaks and the migration of subsurface contaminants continued.

In addition to these monitoring activities, several vadose zone monitoring instruments were installed at one borehole at Waste Management Area B-BX-BY tank farms. These instruments will provide continuous soil column monitoring in that tank farm.

7.2.1 Leachate Monitoring at the Environmental Restoration Disposal Facility

J. M. Faurote

The Environmental Restoration Disposal Facility is used to dispose of radioactive, hazardous, dangerous, and mixed waste generated during waste management and remediation activities at the Hanford Site. In fiscal year 2001, the results of groundwater monitoring and sampling at the Environmental Restoration Disposal Facility for the year 2000 were published (BHI-01489). 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 Figure 6.1.1), the facility is currently operating one trench that is receiving waste. That trench became active during June 2000. Two other trenches received waste until September 2000. Interim covers were placed over the used parts of those cells. A fourth trench was constructed but has not been used to date. The four existing trenches have an area of ~20 hectares (~50 acres).

Each trench is lined to collect leachate resulting from water added to the trench as a dust suppressant and natural precipitation. The liner in the trench slopes to a sump and the leachate is pumped from the sump to the holding tanks. After ~760,000 liters (~200,770 gallons) of leachate are collected, samples are taken and analyzed for 64 semivolatile organics, 41 volatile organics, 23 metals, 9 radionuclides, and gross alpha and gross beta. The number of samples collected during the year depends on the amount of leachate collected.

The leachate monitoring data provide a contents inventory of the Effluent Treatment Facility, where the leachate is disposed, and provide quarterly information for delisting analyses. The purpose of the delisting analyses is to determine if the leachates can be handled as nonhazardous waste. The results also are used to determine whether there are additional analytes in the leachate that should be monitored in the groundwater beneath the facility.

Analyses of leachate collected from the Environmental Restoration Disposal Facility indicate that the liquid collected to date meets established limits (ROD 1999; BHI-01489). The data also show that the leachate contains several common inorganic ions and metals that are usually associated with leachates from landfills receiving primarily soil (BHI-01489). In addition, phthalate esters, plasticizers commonly encountered in landfill leachates that have contacted synthetic liner materials, also were present. Based on the analytical results of leachate samples, no additional analytes are required for monitoring the groundwater beneath the facility.

7.2.2 Leachate and Soil Gas Monitoring at the Solid Waste Landfill

R. A. Del Mar

The Solid Waste Landfill is a land disposal facility located at the Central Landfill in the center of the Hanford Site (see Figure 6.1.1). The Solid Waste Landfill covers an area of ~26.7 hectares (~66 acres) and began operations 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 (2 to 4 feet) 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 6.1. This section summarizes leachate and soil gas monitoring results.

In all, the Solid Waste Landfill consisted of ~70 single-wide trenches, and 14 double-wide trenches. Based on trench geometry and the thickness of the waste layer, the capacity of a trench per linear meter was ~30.6 cubic meters (~40 cubic yards) for the double trenches, and 8.4 cubic meters (11 cubic yards) for the single trenches. Based on this estimation, total design capacity of the Solid Waste Landfill was ~596,400 cubic meters (~780,060 cubic yards).

Leachate Monitoring. One of the double-wide trenches is lined with a plastic material to collect leachate generated by precipitation filtering through the overlying refuse. This liner covers an area of ~88 square meters (~950 square feet). A discharge pipe continuously drains leachate by gravity flow from the trench to a nearby collection pump. However, because the liner only collects leachate from 1 of 84 trenches, and it is installed under one of the newer trenches built after implementation of regulations restricting land disposal practices, leachate collected from this trench may not be representative of leachate drainage throughout the entire landfill area. Still, it provides some indication of the rate of infiltration and some of the contaminants that may be reaching the groundwater.

Leachate is collected from the trench every 10 to 14 days. Figure 7.2.1 shows the rate of leachate generation since routine monitoring was started in 1996. For the past 2 to 3 years, the generation rate has been between 3.8 to 7.6 liters per day (1 to 2 gallons per day), which is consistent with what is expected based on precipitation, soil type, and the vegetative cover.

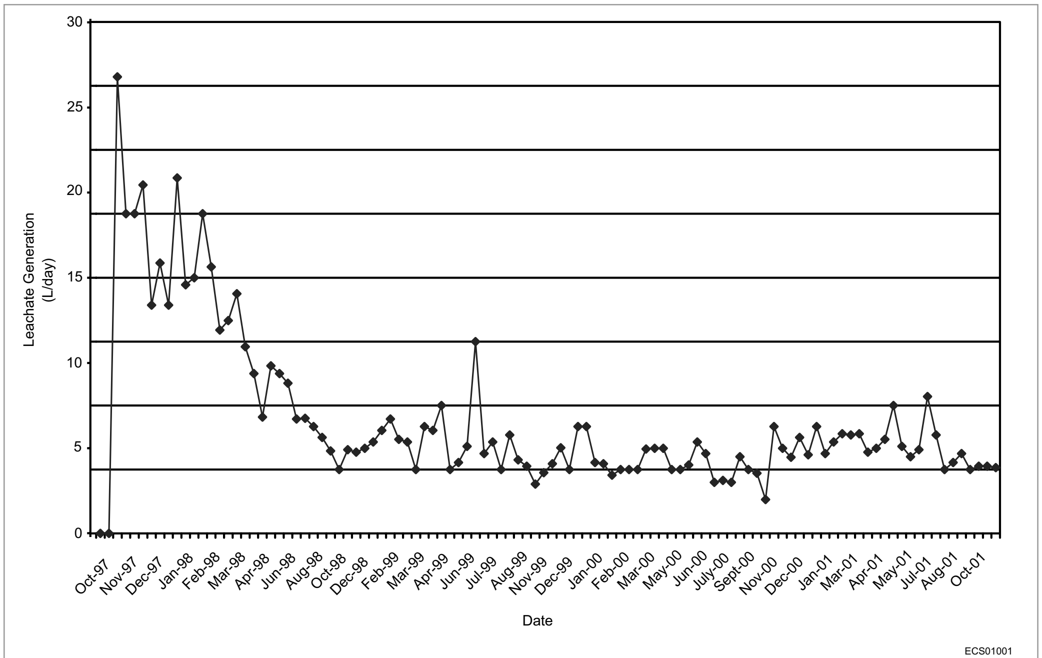

Figure 7.2.1. The Rate of Leachate Generation at the Solid Waste Landfill Since Routine Monitoring Started in 1996

Figures 7.2.2 and 7.2.3 provide historical data on some of the key metal and organic contaminants found in the leachate. Some of these contaminants (most notably 1,4-dioxane, arsenic, manganese, and nickel) continue to be found in concentrations exceeding groundwater quality criteria (WAC 173-200) and/or maximum contaminant levels (WAC 246-290).

The most notable change during the 2000/2001 sampling period was a brief spike in several non-chlorinated organic constituents, including 2-butanone, 2-hexanone, and 2-pentanone, which were found in the 20 to 30 μg/L range. All of these organics were again below detectable limits during the latest sampling period, i.e., third quarter of fiscal year 2001.

Soil Gas Monitoring. 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 (~9 and 15 feet). Soil gas is monitored quarterly to determine concentrations of carbon dioxide, methane, oxygen, and several key volatile organic compounds. No contaminants of concern were discovered above reporting limits during the 2000/2001 sampling period.

7.2.3 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 (EPA) and the Washington State Department of Ecology authorized the U.S. Department of Energy (DOE) to initiate this remediation in 1992 as a *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) expedited response action. The primary focus in the following discussion is on fiscal year 2001 activities associated with the carbon tetrachloride removal. For descriptions of past work, see BHI-00720 and Section 3.2 in PNNL-13404.

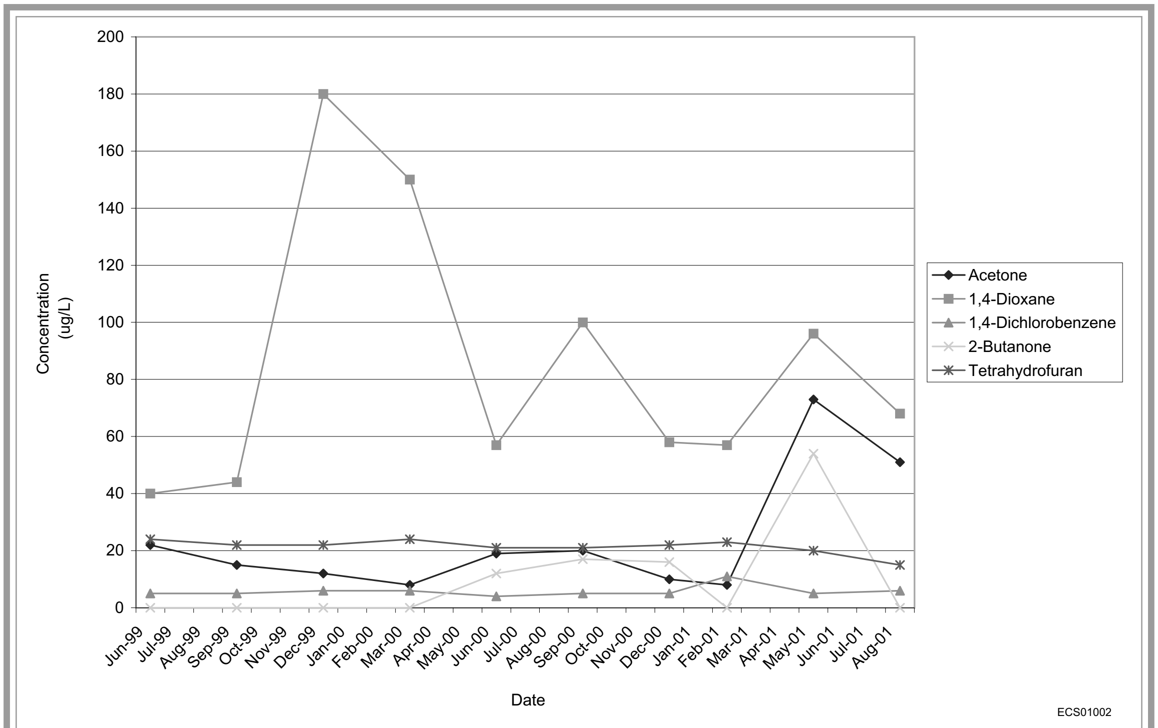

Figure 7.2.2. Key Organic Compounds Found in Leachate from the Solid Waste Landfill

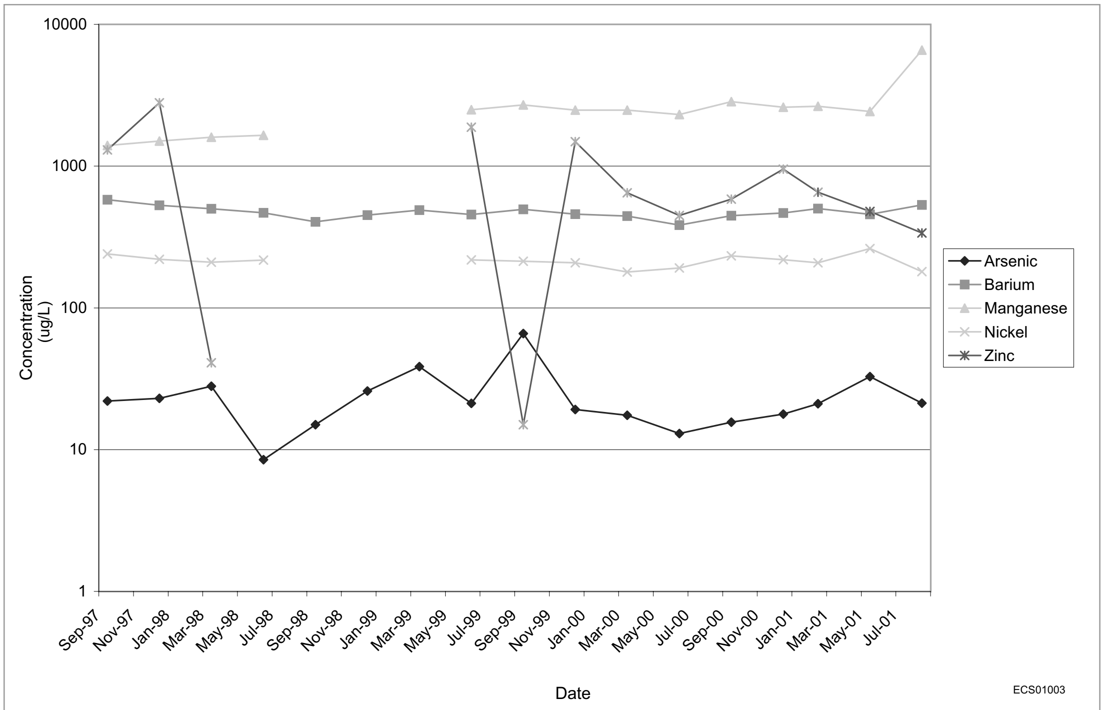

Figure 7.2.3. Key Metals Found in Leachate from the Solid Waste Landfill

There are three soil-vapor extraction systems in use: 14.2, 28.3, and 42.5 cubic meter (18.5, 37, and 56 cubic yard) systems. The 14.2 cubic meters per minute (18.5 cubic yards per minute) soil-vapor extraction system operated from April 4 through July 18, 2001, at the combined 216-Z-1A/-12/-18 well field and from July 20 through September 30, 2001, at the 216-Z-9 well field (see PNNL-13080 for location maps of the well fields). The system was maintained in standby mode throughout fiscal year 2000 and during the winter in fiscal year 2001 (October 1, 1999, through April 3, 2001). The 28.3 and 42.5 cubic meters per minute (37 and 56 cubic yards per minute) soil-vapor extraction systems were maintained in standby mode during fiscal years 2000 and 2001.

To track the effectiveness of the extraction 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 non-operation of the soil-vapor extraction system, soil-vapor concentrations of carbon tetrachloride were monitored at offline wells and probes during the entire fiscal year.

Soil-Vapor Extraction. Soil-vapor extraction to remove carbon tetrachloride from the vadose zone resumed April 4, 2001, at the 216-Z-1A/-12/-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 and wells within the 216-Z-12 and 216-Z-18 cribs were brought online. Extraction wells open near the less-permeable Plio-Pleistocene Unit, where the highest carbon tetrachloride concentrations have consistently been detected, were selected to optimize mass removal of contaminant. (The Plio-Pleistocene Unit is a geologic stratum that may be a confining layer to carbon tetrachloride vapors.) Initial carbon tetrachloride concentrations measured at the soil-vapor extraction system inlet were ~40 ppmv (Figure 7.2.4). After 15 weeks of extraction, concentrations had decreased to ~25 ppmv. The daily mass-removal rate increased significantly at least once during this period as a result of adjustments in the mix of online wells and the flow rate.

Soil-vapor extraction resumed July 20, 2001, at the 216-Z-9 well field. Initial online wells were selected close to the 216-Z-9 trench. As extraction continued, wells farther away from the trench were brought online. Each selection of online wells included wells open near the groundwater and wells open near the Plio-Pleistocene Unit. Initial carbon tetrachloride concentrations measured at the soil-vapor extraction system inlet were ~215 ppmv (see Figure 7.2.4). After 10 weeks of extraction, concentrations had decreased to ~40 ppmv. The daily mass removal rate increased significantly at least once during this period as a result of adjustments in the mix of online wells and the flow rate.

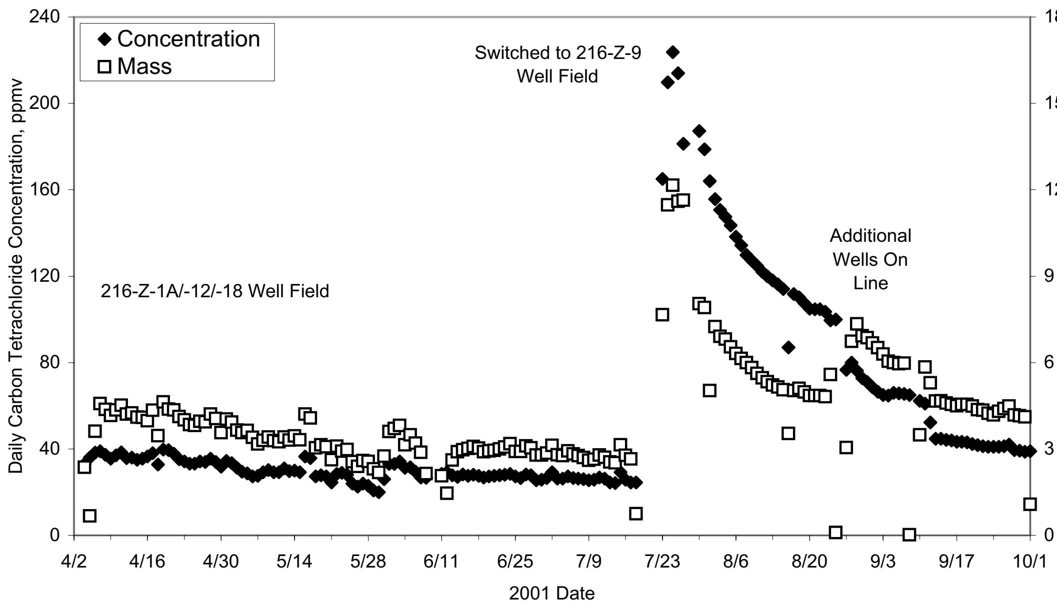

Figure 7.2.4. Time Series Concentrations of Carbon Tetrachloride in Soil Vapor Extracted from the 216-Z-9 Well Field and the 216-Z-1A/-12/-18 Well Field

During 6 months of soil-vapor extraction in fiscal year 2001, 709 kilograms (1,563 pounds) of carbon tetrachloride were removed from the vadose zone. Of this total, 335 kilograms (738 pounds) were removed from the 216-Z-1A/-12/-18 well field during 106 days of operation and 374 kilograms (824 pounds) were removed from the 216-Z-9 well field during 74 days of operation.

As of September 2001, 77,169 kilograms (170,128 pounds) of carbon tetrachloride had been removed from the vadose zone since extraction operations started in 1991 (Table 7.2.1). Since initiation, the extraction systems are estimated to have removed 7% of the residual mass at well field 216-Z-1A/-12/-18 and 22% of the mass at well field 216-Z-9. 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 (BHI-00720; WHC-SD-EN-TI-101).

Table 7.2.1. Carbon Tetrachloride Inventory in Primary Disposal Sites

Well Field	Estimated Mass Discharged 1955 to 1973[(a)] (kg)[(b)]	Estimated Mass Lost to Atmosphere 1955 to 1990[(c)] (kg)	Mass Removed Using Soil-Vapor Extraction 1991 to 2001[(d)] (kg)
216-Z-1A	270,000	56,700	23,846[(e)]
216-Z-9	130,000 to 480,000	27,300 to 100,800	53,323
216-Z-18	170,000	35,700	
Total	570,000 to 920,000	119,700 to 196,800	77,169

(a) Based on DOE/RL-91-32.
(b) To convert kg to lbs, multiply by 2.205.
(c) Based on WHC-SD-EN-TI-101.
(d) Based on BHI-00720.
(e) Includes mass removed from 216-Z-18 site; reported as a combined value because the well fields overlap.

Monitoring at Offline Wells and Probes. During fiscal year 2001, soil-vapor concentrations of carbon tetrachloride were monitored near the ground surface, near the Plio-Pleistocene Unit (~40 meters [~131 feet] below ground surface), and near groundwater (~66 meters [~217 feet] below ground surface). Soil-vapor concentrations were monitored near the ground surface and groundwater to assess whether non-operation of the soil-vapor extraction system is allowing carbon tetrachloride to migrate out of the vadose zone. The maximum concentration detected near the ground surface (between 2 and 10 meters [6 and 30 feet] below ground surface) was 17 ppmv. Near the groundwater, at a depth of 58 meters (190 feet) below ground surface, the maximum concentration was 9 ppmv.

Soil-vapor concentrations also were monitored above and within the Plio-Pleistocene 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 Plio-Pleistocene Unit (between 25 and 41 meters [82 and 134 feet] below ground surface) in 2001 was 360 ppmv at 35 meters (115 feet) below ground surface at the 216-Z-9 site. During monitoring in fiscal years 1997, 1998, 1999, and 2000, the highest carbon tetrachloride concentrations also were detected in the same well.

At the 216-Z-1A/-12/-18 well field, the maximum carbon tetrachloride concentration detected near the Plio-Pleistocene Unit in 2001 was 306 ppmv at 41 meters (134 feet) below ground surface adjacent to the 216-Z-1A tile field. During monitoring in fiscal years 1997, 1998, 1999, and 2000, the highest concentrations were detected at wells within the 216-Z-1A tile field.

The temporary suspension of soil-vapor extraction in fiscal year 2001 appears to have caused minimal transport of carbon tetrachloride through the soil surface to the atmosphere. This view is supported by the fact that carbon tetrachloride concentrations did not increase significantly at the near-surface probes monitored in fiscal year 2001. In addition, suspending operations of the soil-vapor extraction system appears to have had no negative impact on groundwater quality, because carbon tetrachloride concentrations have not increased significantly near the water table since that time.

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, while 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/-12/-18 well field. The passive systems are outfitted with check valves that only allow soil vapor to flow out of the borehole (i.e., one way movement), and a canister holding granular activated carbon that adsorbs carbon tetrachloride 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 would dilute and spread carbon tetrachloride vapors in the subsurface.

Three of eight boreholes have instruments to measure hourly air pressure differentials between the ground surface and the bottom of the borehole, carbon tetrachloride concentrations, temperature, and flow rates. These data can be used to calculate an hourly estimate of the amount of mass removed from the well. Analysis of the granular activated carbon in the cartridge provides a time-integrated estimate of the mass removed while the granular activated carbon was inline.

At the two boreholes with instruments near the 216-Z-1A tile field, the peak carbon tetrachloride concentrations were 40 and 46 ppmv. One well located at the southeastern corner of the 216-Z-18 crib had a peak concentration of 14 ppmv. Flow rates measured at the wells ranged from 0 to as high as 0.4 cubic meters per minute (0.5 cubic yards per minute). Approximately 200 grams of carbon tetrachloride were removed by the passive extraction system in 2001.

7.2.4 Hanford Tank Farms Vadose Zone Monitoring Project

S. M. Sobczyk, P. D. Henwood, A. W. Pearson, R. G. McCain, and S. E. Kos

A comprehensive monitoring project was established in fiscal year 2001 for selected borehole intervals in the single-shell tank farms. The logging system used for monitoring was the Radionuclide Assessment System. The logging results were compared to an established baseline of existing contamination in the vadose zone beneath the single-shell tank farms. The objective was to detect changes occurring since the baseline data were collected.

The general approach of the monitoring project is to prioritize boreholes according to the potential for detectable changes in vadose zone gamma activity and to provide data that will assist in identifying or verifying future tank leaks. Accordingly, boreholes are ranked according to (1) boreholes with measurements that indicate contaminant movement in the past, (2) boreholes located near a tank containing a significant volume of drainable liquid, or (3) boreholes located near a tank that has leaked a significant volume of liquid. The methods used to prioritize boreholes are described in MAC-HGLP 1.8.1. Geophysical monitoring also supports waste retrieval operations and other tank farm activities. When routine monitoring with the Radionuclide Assessment System identifies anomalies, the Spectral Gamma Logging System, the High Resolution Logging System, and the neutron moisture tool may be used for special investigations.

Radionuclide Assessment System spectral gamma logging began in June 2001 and has continued since that time. The Radionuclide Assessment System was used in 113 drywells monitoring the vadose zone at the single-shell tank farm during fiscal year 2001. Routine monitoring reports for the Hanford Tank Farms Vadose Zone Monitoring Project were issued quarterly to summarize the logging results, to provide the status of any ongoing special investigations, and to provide an updated listing of borehole intervals where logging is planned in the coming months. Logging results can be found on the worldwide web at http://www.gjo.doe.gov/programs/hanf/HTFVZ.html.

Radionuclide Assessment System logging was started in tank farms A, BX, SX, T, and U in June 2001. No contaminant movement was detected in tank farms A, BX, and SX. Possible contaminant movement was identified in four boreholes in the U tank farm and in five boreholes in the T tank farm. A special report is being prepared to document contaminant migration at U tank farm to support waste retrieval operations.

Identification of contaminant movement in the U tank farm was based on comparison of current spectral gamma logs with baseline data. The comparison indicated downward migration of uranium-238 and -235 from 1995 through 2001. Comparison of data collected in 1995 and 2001 showed zones with contamination in 2001 that did not have contamination in 1995. This was interpreted as downward movement of uranium. The four boreholes showing subsurface movement of contamination are between tanks U-107 and U-104 in the U tank farm. Radionuclide Assessment System monitoring of these boreholes will be implemented on a quarterly basis beginning in 2002.

Identification of possible contaminant migration in the T tank farm was based on comparison of Radionuclide Assessment System data with baseline data collected with the Spectral Gamma Logging System. Because this involves comparing the responses from two different detectors, each with different response characteristics, the degree of confidence in the identification is somewhat less, relative to the U tank farm. The boreholes in T tank farm do not define as discrete an area as at U tank farm. These boreholes also have been placed on a quarterly monitoring schedule and future comparisons between successive Radionuclide Assessment System logs are expected to provide more definitive information.

7.2.5 An Instrumented Vadose Zone Monitoring Borehole at Waste Management Area B-BX-BY

G. W. Gee, A. L. Ward, J. C. Ritter, J. B. Sisson, J. M. Hubbell, H. A. Sydnor, and D. A. Myers

The Office of River Protection's Vadose Zone Project drilled borehole 299-E33-46 to 80.5 meters (264 feet) below ground surface in the B tank farm in fiscal year 2001 (see Section 7.1.1). Upon reaching final depth, groundwater samples were collected and analyzed for technetium-99. The analyses showed that technetium-99 was <2,000 pCi/L (74 Bq/L), well below the predetermined criterion of 4,000 pCi/L (148 Bq/L) for completing the borehole as a groundwater monitoring well. However, researchers at Pacific Northwest National Laboratory and Idaho National Engineering and Environmental Laboratory presented a proposal to complete the borehole as the first-ever instrumented vadose zone monitoring structure to be constructed in a Hanford Site tank farm. A complete description of the monitoring structure can be found in PNNL-13712. A summary description is given below.

The conventional technology for subsurface characterization is drilling a series of boreholes and collecting sediment samples during drilling, then analyzing the samples in a laboratory. The resulting network of drywells installed around each tank is then used for continuous monitoring for leak detection. The maximum detection depth is limited by the drywell depth.

During July and August 2001, instruments and sensors for vadose zone monitoring were installed in the B tank farm in a borehole located adjacent to tank B-110. Duratek Federal Services, Northwest Operations drilled the 0.2-meter- (6-inch-) diameter borehole under the direction of CH2M HILL Hanford Group, Inc. The borehole, 299-E22-46, had a steel case with bentonite and sand at the bottom. A vadose zone monitoring system was lowered to the bottom of the hole. The system included an advanced tensiometer and heat-dissipation probes to measure soil water pressure and monitor for perched water or water-table elevations. Temperature and water-content sensors were installed to measure soil temperature and moisture content. The water-content sensor was set against the borehole wall using its attached lever arm. Table 7.2.2 indicates the types of sensors and their depths in the borehole.

Once the vadose zone monitoring system was placed satisfactorily, it was grouted in place with a silica flour slurry. The grout was allowed to settle a few minutes, and a sand plug was added on top of the grout. The addition of grout and sand was repeated up to a depth of 6.2 meters (20 feet) below ground surface, where the backfill materials were switched to sand and native materials. A water fluxmeter was installed at 6 meters (20 feet) below ground surface and extends to within 20 centimeters (8 inches) of the ground surface. A water fluxmeter measures infiltration or drainage. A data logger was installed on the surface to collect and store the field data.

The B tank farm installation is the first installation of a vadose zone monitoring system in the sand and gravel at the Hanford Site. Information gained from this installation will provide guidance to modify the system's electrode geometry to better track changes in vadose zone water content. A preliminary examination of the data collected at borehole 299-E33-46 indicates abnormally high water-content readings at depths of 66.4 and 68.9 meters (218 and 226 feet). A similar high water-content reading was observed in the laboratory when saline solutions >200 mS/m (2 mmho/cm) were used to calibrate the sensors. Thus, adding a salinity sensor to the vadose zone monitoring system sensor is recommended for future arrays of vadose zone monitoring sensors.

Table 7.2.2. Sensor Placement in Borehole 299-E33-46

Sensor Array Number	Depth, m (ft)	Type of Sensor
1	0.6 and 0.91 (2 and 3)	AT, HDS, WCS, WFM
2	1.8 (6)	AT, HDS, WCS
3	2.7 (9)	AT, HDS, WCS
4	4.6 (15)	AT, HDS, WCS
5	16.1 (53)	AT, HDS, WCS
6	25 (82)	AT, HDS, WCS
7	66.4 (218)	AT, SS, HDS, WCS
8	69 (226)	AT, SS, HDS, WCS

AT = Advanced tensiometer.
HDS = Heat dissipation sensor.
SS = Solution sampler.
WCS = Water content sensor.
WFM = Water flux meter.