7.2 Vadose Zone Monitoring

S. P. Reidel and D. G. Horton

Vadose zone monitoring continued at the Hanford Site in 2002. Leachate and soil-gas were sampled and analyzed as part of monitoring of the Solid Waste Landfill and the Environmental Restoration Disposal Facility. Soil-gas monitoring continued at the carbon tetrachloride expedited-response site and geophysical borehole monitoring continued at single-shell tank farms to detect leaks and subsurface migration of contaminants. Borehole geophysical monitoring (or characterization) of drywells at past-practice liquid disposal sites began during 2002. The first monitoring events at each of these sites were designed to provide results that will serve as a baseline to compare subsequent logging events to detect any subsurface contaminant movement.

7.2.1 Tank Farms Vadose Zone Monitoring Project

P. D. Henwood, A. W. Pearson, and R. G. McCain

A project was established during 2001 to monitor the movement of radioactive contaminants in the vadose zone using boreholes in single-shell tank farms (MAC-HGLP 1.8.1). During 2002, 384 new logs were completed in wells and boreholes. A new geophysical logging detection system, the Radionuclide Assessment System, was used because it was simpler to use, faster than the previous systems, and more cost-effective for routine monitoring than other systems available at the Hanford Site. The previous system, the Spectral Gamma Logging System, was used between 1995 and 2000 to establish a baseline record of existing radionuclide contamination in the vadose zone. Measurements using the new system can easily be compared to the baseline data acquired by the older system. When routine monitoring by the new system identifies anomalies relative to the baseline, a more detailed examination of the anomaly may be required using the older system, which was designed specifically for such detailed work. A significant cost-savings is achieved by using the older systems only when necessary.

Monitoring is performed from quarterly to once during 5 years, depending on the location of a borehole with respect to known or potential contaminant plumes. The intent of the program is to log (i.e., to measure the distribution of gamma-emitting radionuclides) in each borehole at least once during a 5-year period. A list prioritizing the boreholes was developed based on proximity to known or suspected contaminant plumes, proximity to tanks known to be leaking, and proximity to tanks containing relatively large volumes of drainable liquid. All high-priority boreholes in tank farms have been monitored at least once since June 2001.

Comparisons that were made between earlier geophysical logs and subsequent logs suggest there is a possibility of contaminant movement in 25 boreholes from seven tank farms; however, only two boreholes show confirmed contaminant movement. One borehole was in C Tank Farm in the 200-East Area, and the other was in TY Tank Farm in the 200-West Area. Cobalt-60 and processed uranium (uranium-235 and uranium-238) were the main contaminants detected in these boreholes. Borehole geophysical logs are included in the quarterly reports available at http://www.gjo.doe.gov/programs/hanf/HTFVZ.html.

A special investigation of boreholes around tank U-107 in the U Tank Farm, 200-West Area, was started during 2001 to support pending waste retrieval operations. No significant changes in contaminant profiles were observed at that tank during the five monitoring events that were conducted there during 2001 and 2002.

7.2.2 Geophysical Logging at Past-Practice Disposal Facilities

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

Geophysical logging (i.e., the measurement of radioactive contaminants using geophysical methods) of boreholes began at liquid waste disposal sites and solid waste burial grounds at the 200-East and 200-West Areas during 2001. The purpose of this work is to determine concentrations of naturally occurring and manmade radionuclides in the vadose zone; this work is an extension of the baseline characterization work at single-shell tank farms. In addition, geophysical logging also was done to support remedial investigation projects and the RCRA Groundwater Monitoring Project. The newly acquired data establish a baseline for future comparisons to determine contaminant mobility.

During 2002, geophysical logging for vadose zone characterization was completed in 70 boreholes. Nine of these boreholes were new boreholes and were logged to support remedial investigation projects. Five boreholes were new RCRA groundwater monitoring wells and three new wells were drilled for the Integrated Disposal Site in the 200-East Area. Geophysical data from each borehole were analyzed to determine concentrations of naturally occurring radionuclides (potassium-40, thorium-232, uranium-238, and associated decay products) and manmade radionuclides (e.g., cobalt-60, antimony-125, cesium-137, europium-152, europium-154, uranium-235, and uranium-238).

Waste site summary reports were issued for the results from geophysical logging in the following 200-East Area sites: 216-B-8 crib and adjacent areas (GJO-2002-343), 216-B-35 to 216-B-42 trenches (GJO-2002-322), and 216-B-5 injection well and 216-B-9 crib (GJO-2002-358-TAC).

Geophysical logging of 19 vadose zone boreholes and 13 groundwater wells northeast of Waste Management Area B-BX-BY, in the 200-East Area, detected cobalt-60, cesium-137, europium-154, uranium-235, and uranium-238. Cobalt-60 and cesium-137 were detected in the vadose zone and in the uppermost part of the aquifer; however, this was only observed in older wells (1950s) and not in newer stainless steel casings. The resulting apparent distribution of contamination is probably related to radioactive metals that were sorbed onto or into iron alteration minerals from the rusted casing. Rust can easily sorb trace metals, whereas the newer stainless steel casings are designed to prevent this. Thus, the contaminant concentrations in the groundwater could be small; however, over time concentrations in the rusting casings increase. Uranium contamination originating from the BX Tank Farm was detected east of its presumed source at tank BX-102 (Figure 7.2.1). This contamination had reached borehole 299-E33-41 (Figure 7.2.2) and well 299-E33-18 between 1991 and 1997 and the logging results suggest that the amount of manmade uranium has increased in well 299-E33-18 since 1997.

Eleven boreholes were logged at trenches located west of Waste Management Area B-BX-BY, in the 200-East Area (GJO-2002-322; Figure 7.1.3 shows the location of the trenches). Cesium-137 was detected in all boreholes. A comparison between data collected during 2002 and data collected during the 1990s shows good agreement indicating contaminants have not migrated during the last 10 years.

7.2.3 Carbon Tetrachloride Monitoring and Remediation

V. J. Rohay

Carbon tetrachloride was disposed of in the 200-West Area. This section summarizes activities related to determining its distribution in the subsurface and its remediation as part of a CERCLA expedited response action.

7.2.3.1 Soil-Vapor Extraction

Soil-vapor extraction technology 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 DOE to initiate this technology during 1992 as a CERCLA expedited response action.

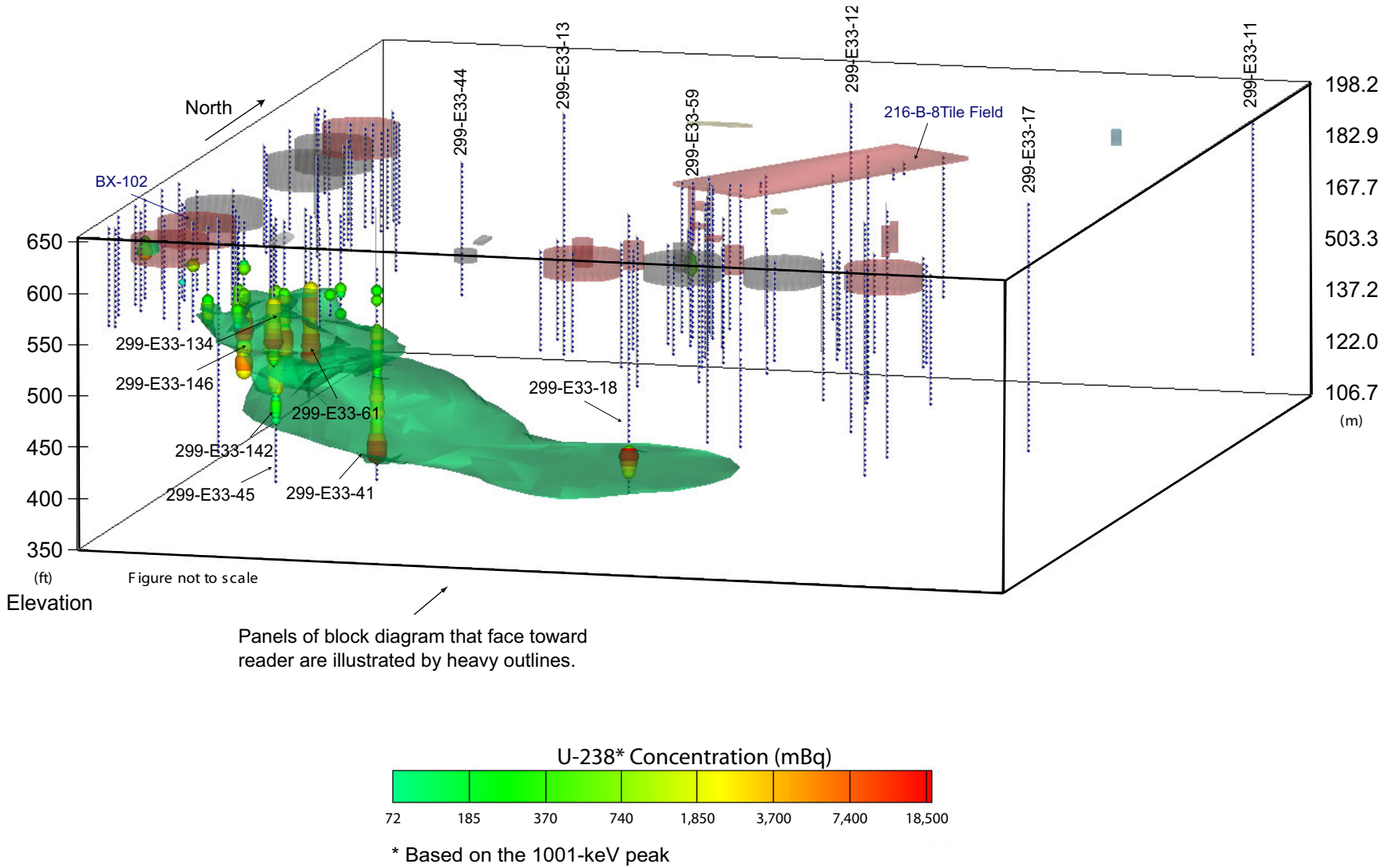

Figure 7.2.1. Uranium-238 Contamination North of the BX Tank Farm in the 200-East Area of the Hanford Site. Wells and boreholes are shown as dashed blue lines. Also shown are projections of tanks (cylinders) and the 216-B-8 tile field.

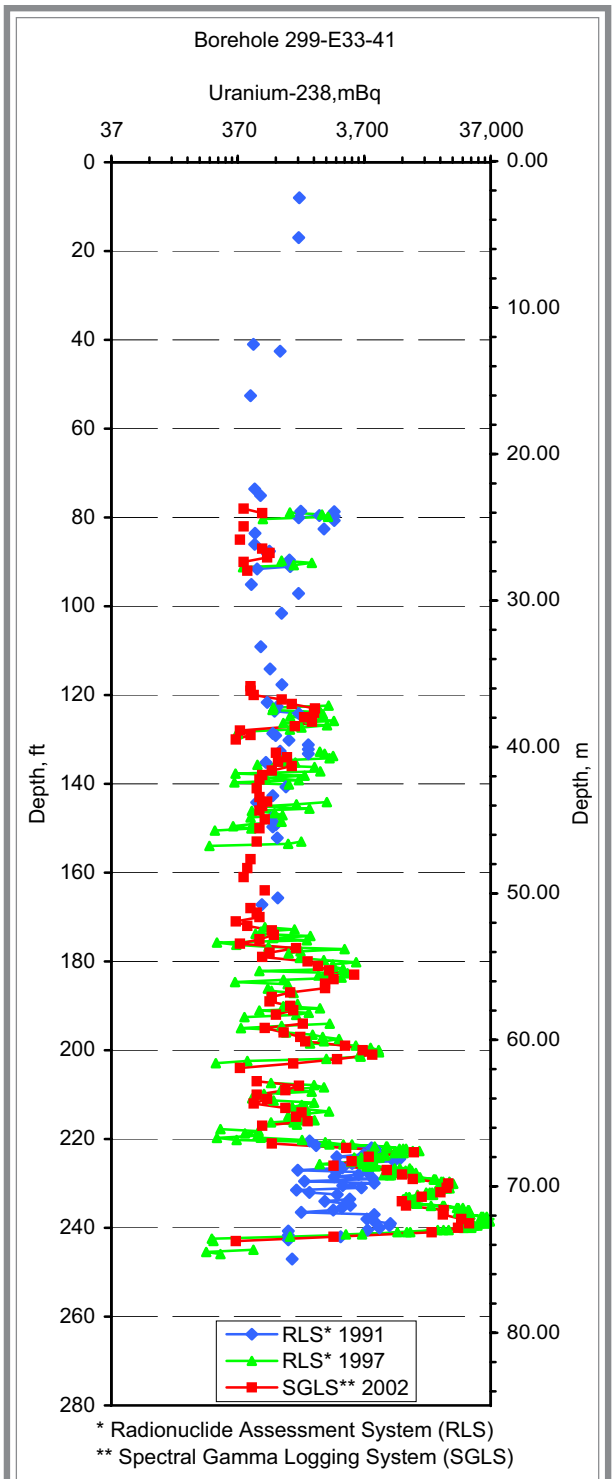

Figure 7.2.2. Comparison of 1991, 1997, and 2002 Spectral Gamma Logs from Borehole 299-E33-41 Located East of the BX Tank Farm in the 200-East Area of the Hanford Site

A soil-vapor extraction system operated at the 216-Z-9 well field in the 200-West Area from April 1 through July 22, 2002, and at the combined 216-Z-1A/216-Z-12/216-Z-18 well field in the 200-West Area from July 24 through September 30, 2002. The system had been in standby mode from October 1, 2001, through March 31, 2002.

To track the effectiveness of the remediation effort, soil-gas concentrations of carbon tetrachloride were monitored during the 6-month operating period. Results were reported in 2002 (BHI-00720; WHC-SD-EN-TI-101).

As of September 2002, ~77,800 kilograms (171,549 pounds) of carbon tetrachloride had been removed from the vadose zone since startup in 1991. 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 the 216-Z-9 well field.

7.2.3.2 Monitoring at Off-Line Wells and Probes

During 2002, soil-gas concentrations of carbon tetrachloride also were monitored near the ground surface, near the Cold Creek unit (a sediment layer ~40 meters [131 feet] below ground surface), and near groundwater (~66 meters [216 feet] below ground surface). This monitoring was done to evaluate whether non-operation of the soil-vapor extraction system would adversely affect carbon tetrachloride concentrations in the atmosphere or groundwater near the extraction site.

The suspension of soil-vapor extraction activities appears to have had minimal impact on the movement of carbon tetrachloride through the sediment to the atmosphere. This is supported by data that show carbon tetrachloride concentrations did not increase significantly near the ground surface or in the groundwater.

7.2.3.3 Passive Soil-Vapor Extraction

Passive soil-vapor extraction is a remediation technology that uses changes in atmospheric pressure to move carbon tetrachloride vapor from the subsurface 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 were installed during 1999 at eight wells that are open near the vadose-groundwater interface at the 216-Z-1A/216-Z-12/216-Z-18 well field in the 200-West Area. 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 canisters with granular activated carbon that adsorbs carbon tetrachloride from the vapor before it is vented to the atmosphere. The check valve prohibits flow of atmospheric air into the borehole when barometric pressure increases, which would allow air to dilute and spread carbon tetrachloride vapors in the subsurface. The concentrations measured at four of the wells during 2002 indicate that the passive system has the capability to remove carbon tetrachloride from the sediment.

7.2.4 Leachate Monitoring at the Environmental Restoration Disposal Facility

C. W. Miller, C. S. Wright, and R. S. Edrington

Bechtel Hanford, Inc. operates the Environmental Restoration Disposal Facility landfill to dispose of radioactive, hazardous or dangerous, and mixed waste generated during waste management and remediation activities at the Hanford Site. The facility began operating during July 1996 and is located between the 200-East and 200-West Areas (ERDF on Figure 6.1.1). The facility is currently operating its second set of two disposal cells since June 2000. The initial cells received waste until September 2000. Each of the four cells is lined to collect leachate resulting from natural precipitation and water added as a dust suppressant.

During 2002, Bechtel Hanford, Inc. published the results of groundwater monitoring and sampling at the Environmental Restoration Disposal Facility during 2001 (BHI-01641). The purpose of the data was to provide a contaminant inventory for the Effluent Treatment Facility, where the leachate is disposed.

Composite leachate samples were collected during June and December 2001 and reported in 2002. Leachate samples contained detectable concentrations of common metals, anions, and mobile radionuclides. The constituents detected in leachate samples were compared to the groundwater monitoring constituent list to determine if additional constituents should be added to the groundwater monitoring program. Results indicated that the target constituents for the groundwater monitoring program were consistent with the leachate monitoring program. At this time, no additional constituents will be added to the groundwater monitoring program at the Environmental Restoration Disposal Facility landfill.

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

R. A. Del Mar

The Solid Waste Landfill is a land disposal facility in the center of the Hanford Site (Figure 6.1.1). It began operating in 1973 to receive non-hazardous, non-radioactive sanitary waste generated from Hanford Site operations. The Solid Waste Landfill stopped receiving waste during 1996, and an interim cover was placed over all trenches. Current monitoring at the Solid Waste Landfill consists of quarterly sampling of groundwater, soil gas, and leachate.

The Solid Waste Landfill consists of ~70 single disposal trenches and 14 double disposal trenches. One of the double trenches overlies a lined, basin lysimeter designed to collect leachate that infiltrates through the overlying refuse. A discharge pipe continuously drains leachate by gravity flow from the basin to a nearby collection pump. However, because the lysimeter only collects leachate from 1 of 84 trenches, it may not be representative of leachate drainage throughout the entire landfill area but it does provide some indication of the rate of infiltration and contaminants that may be entering the vadose zone from the landfill.

Between 3.8 and 7.6 liters (1 and 2 gallons) of leachate per day are produced at the site, which are then collected from the basin lysimeter every 10 to 14 days. These volumes are consistent with expectations based on precipitation, sediment type, and vegetative cover. Some of the contaminants in the leachate (most notably arsenic, manganese, nickel, and 1,4-dioxane) continue to be found in concentrations exceeding groundwater quality criteria (WAC 173-200) and/or maximum contaminant levels (WAC 246-290). In addition, some of the indicator parameters exceeded groundwater quality criteria and/or maximum contaminant thresholds, including conductivity, chloride, and total dissolved solids. The most notable change that occurred during 2002 was an increase in several non-chlorinated organic constituents, including acetone, 2-butanone, 2-hexanone, and 2-pentanone.

Soil-gas monitoring at the Solid Waste Landfill uses eight shallow monitoring stations located around the perimeter of the landfill. Soil gas is monitored quarterly to determine concentrations of oxygen, carbon dioxide, methane, and several key volatile organic compounds. No contaminants of concern in concentrations above reporting limits were discovered during 2002.

7.2.6 Hydrologic Characterization Using Vadose Zone Monitoring Tools at Hanford

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

Characterization of the vadose zone is needed to assess contaminant migration from buried waste. In addition, data from vadose zone monitoring provide direct measures of sediment-water pressures, temperatures, and water fluxes or rates of infiltration. Vadose zone monitoring can document waste site responses to changes in precipitation (rain and snowmelt), the occurrence of water-line leaks at a site, or help detect tank leaks during waste retrieval operations. Since most flow rates (flux) in the vadose zone are relatively low and changes generally occur slowly, most results will not be instantaneous. Meaningful data sets will require an extended monitoring period (several years or more).

The Pacific Northwest National Laboratory, in collaboration with CH2M HILL Hanford Group, Inc., Idaho National Engineering and Environmental Laboratory, and Duratek Federal Services, deployed a suite of vadose-zone instruments for characterization and monitoring at the Hanford Site. Several new instruments were tested. One instrument, the advanced tensiometer developed at Idaho National Engineering and Environmental Laboratory, measures sediment-water pressures in the vadose zone and was tested successfully at the Hanford Site. Another new instrument, the water fluxmeter (Figure 7.2.3) directly measures rates at which water drains through the sediment. It also was deployed and successfully tested to obtain in situ hydrologic characterization data, to verify drainage potential, and to obtain estimates of current water recharge rates under a range of surface conditions.

A series of tests to confirm performance and longevity of vadose zone monitoring sensors has been ongoing since 1999 (http://vadose.pnl.gov). A nearly continuous record that has been maintained since sensor installation indicates that the instruments have been reliable and have required little or no maintenance for periods up to 3 years or longer. The sensor site contains a set of instruments designed to simulate waste burial ground conditions. The data confirm that drainage persists at the site in spite of the arid climate

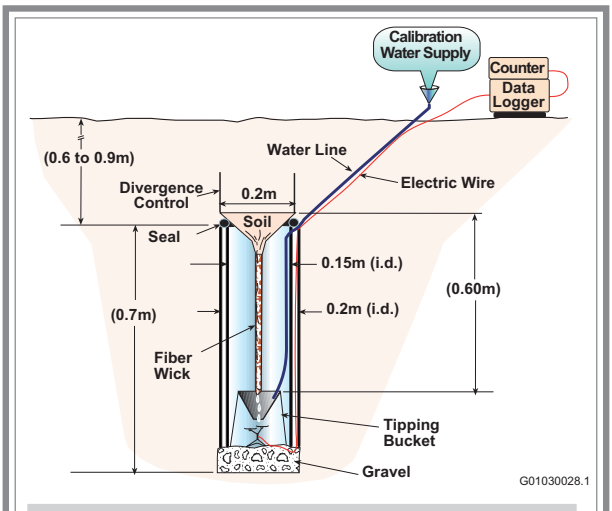

Figure 7.2.3. Schematic View of the Pacific Northwest National Laboratory Water Fluxmeter. The divergence control for all drainage tests was at least 60 centimeters (24 inches) deep. For bare sediment conditions including tank farms, the divergence control was brought to the surface or within a few centimeters of the surface to minimize any lateral flow.

and water pulses from infiltration of winter rain and snow do not appear to penetrate much below 2 meters (6.5 feet) depth. The top 1 meter (3.3 feet) of sediment appears to capture most of the transient water. Measured drainage for the past 3 years has averaged about 55 millimeters (2.16 inches) per year, similar to predictions using measurements from past experiments.

Two instrument packages were deployed within the Hanford Site tank farms during the past 2 years. During 2001, a sensor package containing eight instruments was placed in the vadose zone inside an uncased borehole (C3360) located adjacent to tank B-110 in the 200-East Area. The instruments are part of the Vadose Zone Monitoring System for the Hanford Site tank farms and include advanced tensiometers, heat dissipation units, water content reflectometers, thermal probes, and vadose zone solution samplers. A water fluxmeter was deployed within the top meter (3.3 feet) of the surface to directly measure net infiltration of meteoric water (rain and snowmelt). In addition, a rain gage was located within the tank farm to document onsite precipitation.

Tensiometer data from 2002 show that steady-state conditions have persisted at the B Tank Farm since installation of the instruments more than a year ago (Figure 7.2.4) and indicate continued drainage at this site. The coarse gravel at the surface and the lack of vegetation at the tank farm promote drainage conditions. The data show that drainage is occurring, but do not provide a direct measure of drainage rates. The water fluxmeter provides data on net infiltration of meteoric water but does not indicate how much lateral spreading of water is occurring in the subsurface. Thermal profiles from the instrument packages appear normal and show heating due to radioactivity has had little effect in the subsurface (Figure 7.2.5).

During 2002, four instrument sets were placed in an uncased borehole (C3830) located between tank TX 101 and tank TX 105 in the TX Tank Farm, 200-West Area. Data collected from the TX Tank Farm are similar to those at the B Tank Farm in the 200-East Area and indicate that the vadose zone beneath the tank farm is draining. Water-fluxmeter data collected over the course of the next 3 years will be used to estimate vadose zone drainage rates within the TX Tank Farm.

Based on current observations, however, data from the tensiometers indicate that drainage is occurring at the TX and B Tank Farms. Similar drainage conditions are

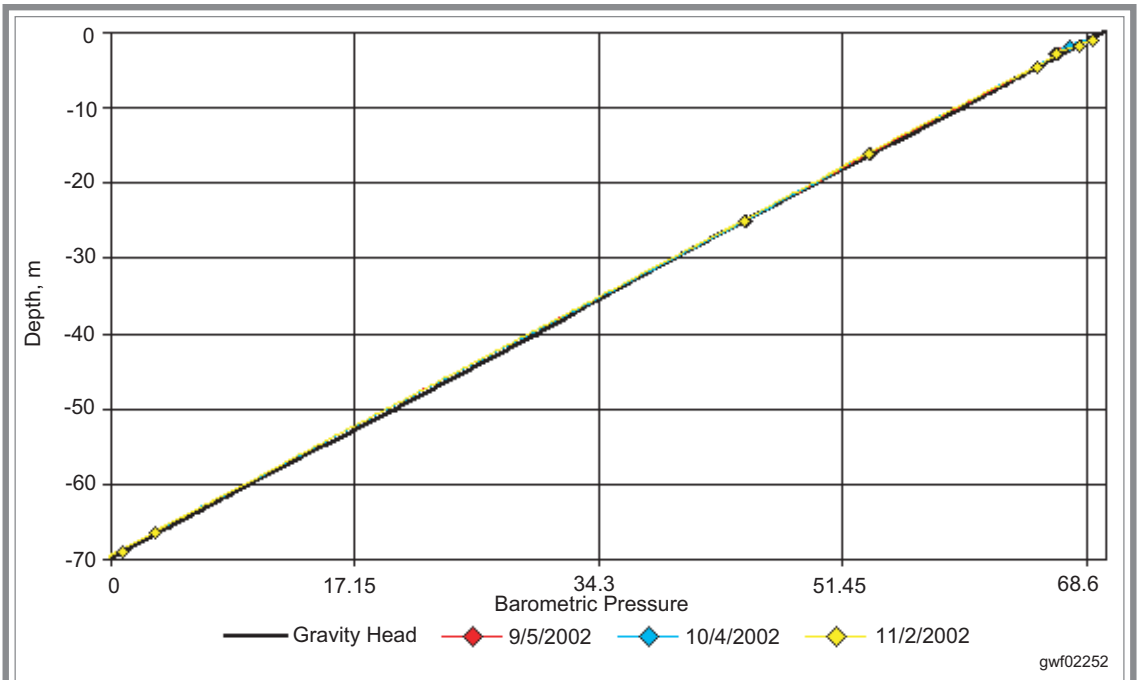

Figure 7.2.4. Total Head Profile Near Tank B-110 in the Hanford Site's B Tank Farm Showing Unit Gradient Conditions

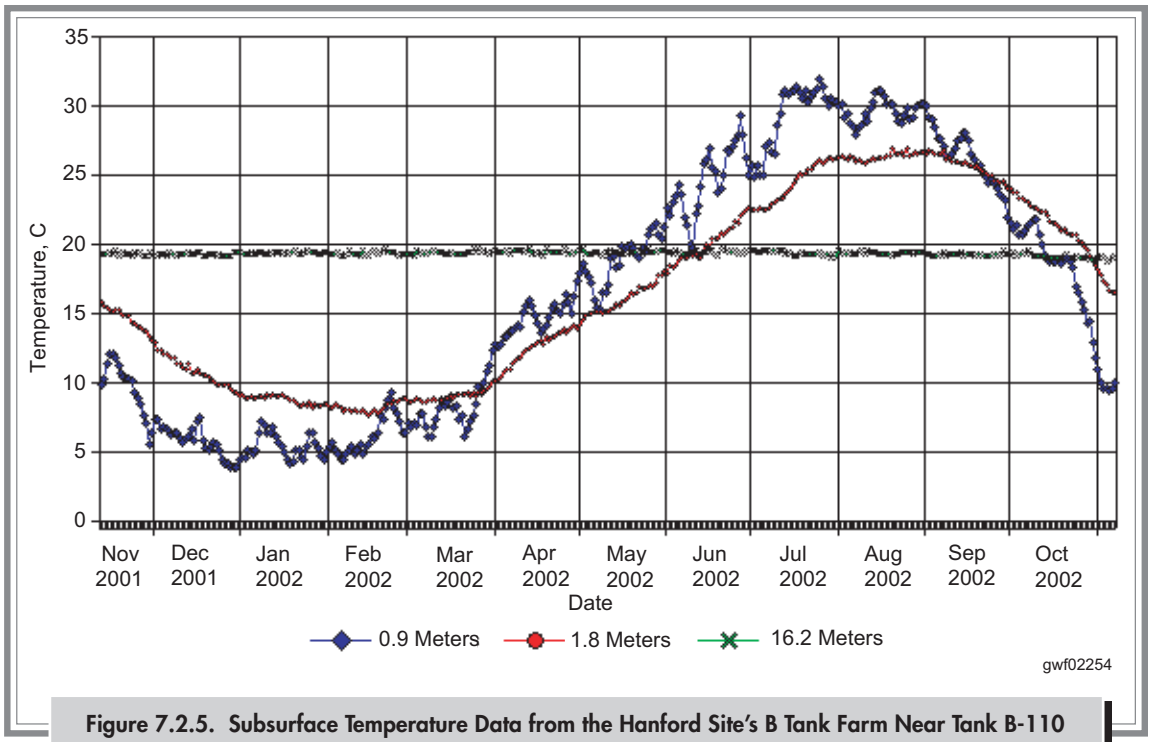

Figure 7.2.5. Subsurface Temperature Data from the Hanford Site's B Tank Farm Near Tank B-110

expected at other tank farms at Hanford, where surfaces are similar. As multiple years of data are collected, vadose zone field monitoring systems with water fluxmeters will be able to provide a direct measure of annual recharge within tank farms and other waste sites, thus providing an early warning to potential future groundwater contamination.