9 Ground Water Monitoring

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Introduction

Lawrence Livermore National Laboratory regularly samples and analyzes ground waters in the Livermore Valley and in the Altamont Hills. LLNL maintains multiple ground water monitoring programs to comply fully with environmental regulations, U.S. Department of Energy (DOE) orders, and the requirements of the Ground Water Protection Management Program (GWPMP). The objectives of the ground water monitoring programs described in this chapter are to measure compliance with waste discharge requirements and post-closure plans and to assess the impact, if any, of current LLNL operations on ground water resources.

DOE Order 5400.1 and the to-be-promulgated 10 CFR 834 require all DOE facilities to prepare a GWPMP that describes the site's ground water regime, areas of known contamination, remediation activities, programs to monitor the ground water, and the means to monitor and control potential sources of ground water contamination. Considerable ground water monitoring and remediation, discussed in Chapter 8, are carried out under Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) restoration efforts. Soil and sediment surveillance monitoring under the GWPMP is described in Chapter 10. Additional programs address the sanitary sewer system, building drains, and underground storage tanks.

Surveillance Monitoring

Ground water monitoring at LLNL complies with DOE Order 5400.1, which affirms DOE's commitment to protect the environment. LLNL conducts surveillance monitoring of ground water in the Livermore Valley and in the Altamont Hills through networks of wells and springs that include private wells off site and DOE CERCLA wells on site. The two monitored areas are not connected hydrologically; they are separated by a major drainage divide and numerous faults. The Livermore site in the Livermore Valley drains to San Francisco Bay via Alameda Creek. Most of Site 300 drains to the San Joaquin River Basin via Corral Hollow Creek, with a small undeveloped portion in the north draining to the north and east toward Tracy. In order to maintain a comprehensive, cost-effective monitoring program, LLNL determines the

number and locations of surveillance wells, the analytes to be monitored, the frequency of sampling, and the analytical methods to be used.

A wide range of analytes is monitored to assess the impact, if any, of current LLNL operations on local water resources. Because surveillance monitoring is geared to detecting substances at very low concentrations in ground water, it can detect contamination before it significantly impacts ground water resources. Wells at the Livermore site, in the Livermore Valley, and at Site 300 in the Altamont Hills are included in LLNL's surveillance monitoring plan. Historically, the surveillance and compliance monitoring programs have detected relatively elevated concentrations of various metals, nitrate, perchlorate, and depleted uranium (uranium-238) in ground water at Site 300. Subsequent CERCLA studies have linked several of these contaminants to past operations, while others are the objects of continuing study. Present-day administrative, engineering, and maintenance controls in place at both LLNL sites are specifically tailored to prevent damage to the environment.

Compliance Monitoring

The Compliance Ground Water Monitoring Program complies with numerous federal and state controls (see Chapter 2, **Table 2-4**, for a summary of LLNL permits). Compliance monitoring of ground water is conducted at Site 300 to satisfy state-issued permits associated with closed landfills containing solid wastes and with continuing discharges of liquid waste to surface impoundments, sewage ponds, and percolation pits. Ground water compliance monitoring at Site 300 is specified in Waste Discharge Requirement (WDR) orders issued by the Central Valley Regional Water Quality Control Board (CVRWQCB) and in landfill closure and postclosure monitoring plans. The WDRs and postclosure plans specify wells and effluents to be monitored, constituents of concern (COCs) to be measured, measurement frequency, inspections to be conducted, and the frequency and form of required reports. These monitoring programs include quarterly and semiannual monitoring of ground water, monitoring of various influent waste streams, and visual inspections. LLNL conducts additional operational monitoring of wastewater effluents discharged to surface impoundments and sewage evaporation and percolation ponds to comply with WDRs issued under California's Porter-Cologne Water Quality Control Act. Quarterly and annual written reports of analytical results, inspection findings, and maintenance activities are required for each monitoring network.

Table 9-1 in the Data Supplement shows the analytical methods and reporting limits for inorganic constituents (including specific radioisotopes analyzed by alpha spectroscopy and other sensitive methods), organic constituents, and radioisotopes in ground water.

Livermore Site and Environs

Livermore Valley

LLNL has monitored tritium in water hydrologically downgradient of the Livermore site since 1988. Tritium is potentially the most mobile ground water contaminant emanating from LLNL. Rain and storm water runoff in the Livermore Valley, which recharges local aquifers, contains small amounts of tritium from natural sources, past worldwide atmospheric nuclear weapons tests, and atmospheric emissions from LLNL. (See Chapters 4, 5, and 7 for further discussion of air emissions, rain, and storm water runoff.) Ground water samples were obtained during 1999 from 18 of 21 wells in the Livermore Valley (see **Figure 9-1**) and measured for tritium activity.

Ground water is recharged at the Livermore site from arroyos by rainfall. Recharge enters primarily through the arroyos (see also Chapter 7). Ground water flow at the Livermore site, which is generally westward, is discussed generally in Chapter 1 and

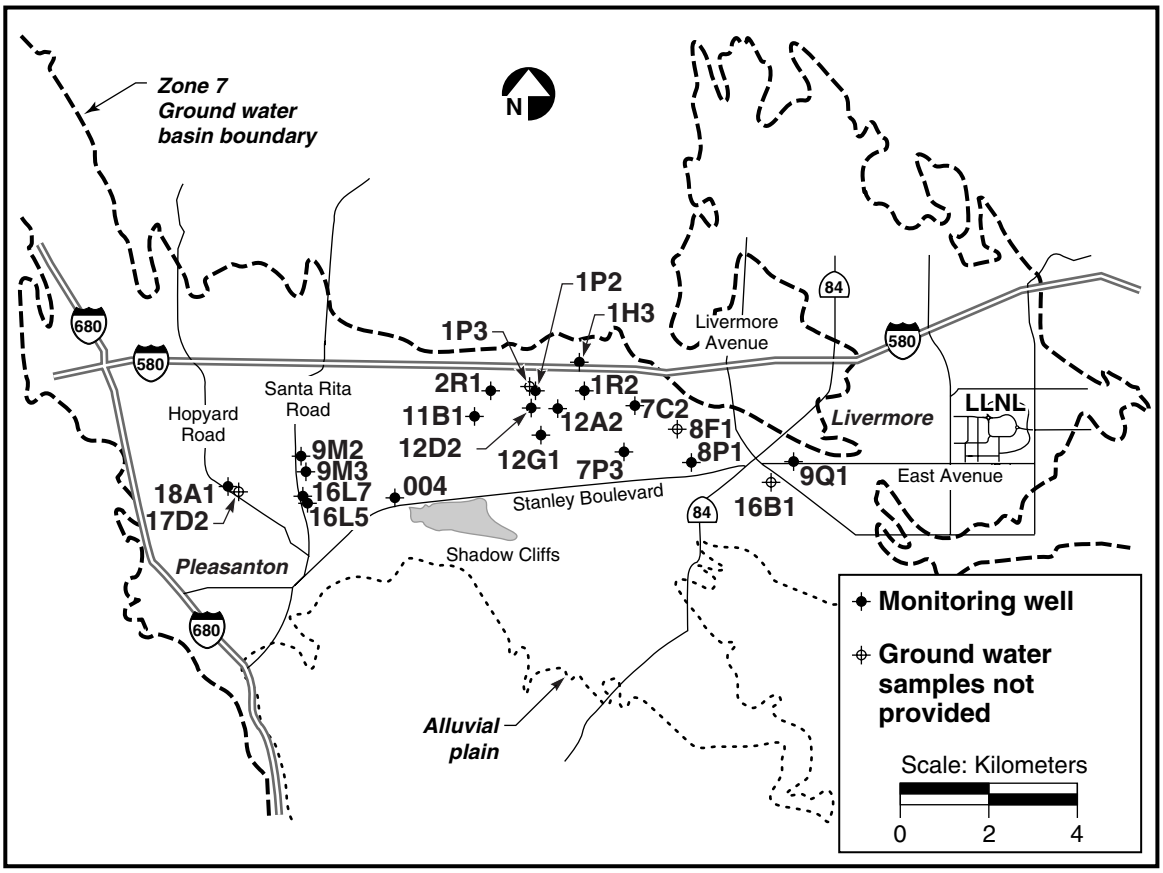

Figure 9-1. Locations of off-site tritium monitoring wells in the Livermore Valley.

in detail in the *CERCLA Remedial Investigation Report for the LLNL Livermore Site* (Thorpe et al. 1990) and the annual *LLNL Ground Water Project* reports (Aarons et al. 2000).

Livermore Site Perimeter

LLNL designed a surveillance monitoring program to complement the Livermore Ground Water Project (discussed in Chapter 8). The intent of this network is to monitor for possible contaminants other than volatile organic compounds (VOCs), which are handled under the Livermore Site Ground Water Project. The perimeter portion of this surveillance ground water monitoring network makes use of three background monitoring wells near the eastern boundary of the site and seven western perimeter monitoring wells, located near the western boundary (see **Figure 9-2**). These seven wells located in the regions of Treatment Facilities A, B, and C (see **Figure 8-1**) meet the requirements of DOE Order 5400.1. These western perimeter wells monitor the uppermost aquifers for COCs that are outside, but very near to, the areas where ground water is being treated.

The screened interval for each surveillance monitoring well is in the uppermost saturated aquifer (or aquifers) at that well location. As discussed in Chapter 8, the alluvial sediments have been divided into seven hydrostratigraphic units (HSUs). HSUs are described in Chapter 8 and shown in **Figure 8-1**.

Two of the background wells, W-008 (screened in HSUs 3A/3B) and W-221 (screened in HSU 3A), were sampled and analyzed once for semivolatile organic compounds (SVOCs), semiannually for minerals, and quarterly for trace metals and most radioactive constituents in order to obtain sufficient data for statistical analyses. Background well W-017 (screened in the deeper HSU 5) was sampled and analyzed once during the third quarter for trace metals and radioactive constituents. The seven western perimeter wells screened in shallower HSUs 1B and 2 were sampled and analyzed annually for nonradioactive constituents and quarterly for many radioactive constituents. Each well was sampled and the water analyzed for metals and minerals, herbicides, gross alpha and beta, tritium, and other radioisotopes. Routine surveillance monitoring data for 1999 are presented in the Data Supplement (Tables 9-2 through 9-11). These monitoring results help establish baseline conditions for future monitoring and detect the presence of any COCs that may adversely affect public health or the environment.

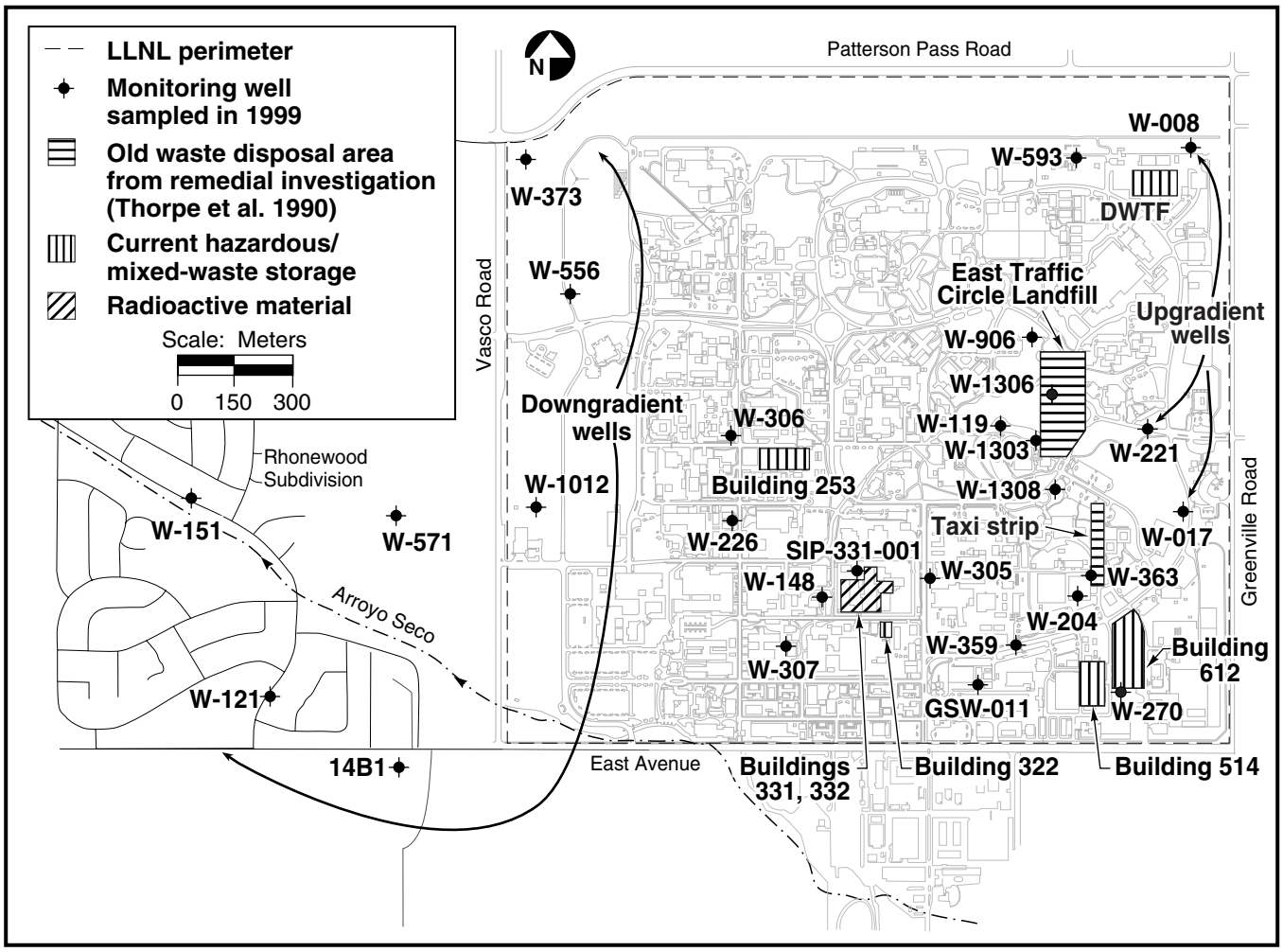

Figure 9-2. Locations of routine surveillance ground water monitoring wells at the Livermore site.

Livermore Site

Livermore site (interior) ground water sampling locations include areas where releases to ground may have occurred in the recent past or where previously detected COCs have low concentrations that do not require CERCLA remedial action. Monitoring wells screened in the uppermost aquifers are situated downgradient from, and as near as possible to, the potential release locations.

The Taxi Strip Area and the East Traffic Circle Landfill are two potential sources of ground water contamination for which surveillance monitoring wells were added to the surveillance monitoring network in 1997 (see **Figure 9-2**). Ground water samples from monitoring wells screened in HSUs 2 and 3A downgradient from the Taxi Strip Area and East Traffic Circle Landfill were analyzed for americium, plutonium, thorium,

uranium, gross alpha and beta radiation, radium-226, radium-228, tritium, metals, polychlorinated biphenyls (PCBs), and general minerals. The locations of these wells—W-204, W-363, W-119, W-906, W-1303, W-1306, and W-1308—are shown in **Figure 9-2**. All surveillance monitoring analytical data for the Taxi Strip Area and the East Traffic Circle Landfill are presented in Data Supplement Tables 9-12 through 9-18.

Another potential source of ground water contamination is the Decontamination and Waste Treatment Facility (DWTF) in the northeastern portion of LLNL. Ground water samples were obtained downgradient from this facility from well W-593 during 1999 and were analyzed for the same suite of analytes as the East Traffic Circle Landfill and Taxi Strip Area (see Data Supplement Table 9-19).

The hazardous waste/mixed waste storage facilities around Buildings 514 and 612 are monitored by wells W-270, W-359, and GSW-011. These wells were sampled and analyzed for trace metals and radioactive constituents in 1999. In addition, ground water samples from well W-359 were also analyzed for minerals and for SVOCs. All surveillance monitoring analytical data from the Hazardous Waste Management Area are presented in Data Supplement Tables 9-20 through 9-22.

Ground water samples were also obtained downgradient from areas where minor releases of metals to ground have occurred. Samples were obtained from monitoring well W-307 (screened in HSU 1B), downgradient from a fume hood vent on the roof of Building 322. Soil samples obtained from the area show elevated concentrations (in comparison with LLNL's site background levels) of chromium, copper, lead, nickel, zinc, and occasionally other metals. LLNL removed contaminated soils near Building 322 in 1999 and replaced them with clean fill. The area was then paved over, making it less likely that metals will migrate from the site. Analytical results for dissolved metals in 1999 ground water samples are presented in Data Supplement Table 9-23.

Ground water samples were also obtained downgradient from a location where sediments containing metals (including cadmium, copper, lead, mercury, and zinc) had accumulated in a storm water catch basin near Building 253 (Jackson 1997). These ground water samples were obtained from monitoring wells W-226 and W-306 screened in HSUs 1B and 2, respectively. Analytical results for dissolved metals in these samples are presented in Data Supplement Tables 9-24 and 9-25.

The additional surveillance ground water sampling locations for 1999 surround the area where the Plutonium Facility (Building 332) and the Tritium Facility (Building 331) are located (see **Figure 9-2**). Possible contaminants include plutonium-239 and americium-241 from the Plutonium Facility and tritium from the Tritium Facility. Both plutonium and

americium are more likely to bind to the soils rather than to migrate into the ground water. Tritium, on the other hand, is likely to migrate into ground water if spilled in sufficient quantities. Upgradient of these facilities, well W-305 is screened in HSU 2; downgradient well W-148 is screened in HSU 1B; and SIP-331-001 is screened in HSU 2. Analytical results are presented in Data Supplement Tables 9-26 through 9-28.

Site 300

For surveillance and compliance ground water monitoring at Site 300, LLNL uses DOE CERCLA wells on site and private wells and springs off site. Representative ground water samples are obtained at least once per year; they are routinely measured for various elements (primarily metals), a wide range of organic compounds, nitrate, general radioactivity (gross alpha and gross beta), uranium activity, and tritium activity. Typically, Environmental Protection Agency- (EPA-) approved analytical methods are used because they are both accurate and sensitive. (See Data Supplement Table 9-1 for a complete list of COCs and for the EPA or other standard analytical methods used to measure them.)

Figure 9-3 shows the ground water sampling locations with wells and springs at Site 300. Although ground water from the uppermost water-bearing zone is the target of most of the sampling, at several locations up to three vertically separated water-bearing zones are sampled by means of multiple-completion installations fitted with Barcad devices. Barcads are identified in **Figure 9-3** by the capital letters A, B, and C at the end of a monitoring installation's identifier code. ("A" is assigned to the Barcad that samples the deepest of three, or deeper of two, water-bearing zones.)

Twelve ground water monitoring locations are off site. Two are springs, identified as MUL2 and VIE1, which are located near the northern boundary of Site 300. Off-site surveillance well VIE2 (not shown in **Figure 9-3**) is located 6 km west of Site 300 in the upper reaches of the Livermore Valley watershed. Nine off-site surveillance locations are wells located near the southern boundary of Site 300 in, or adjacent to, the Corral Hollow Creek floodplain.

On-site wells that were installed for CERCLA characterization studies during the 1980s continue to be used to monitor several former landfills, a former open-air burn pit, two connected surface water impoundments, and two connected sewer ponds. The former landfills—which are identified as Pit 1, Pit 2, Pit 7 Complex, Pit 8, and Pit 9—are located in the Elk Ravine drainage area, while Pit 6, the former burn pit, the two surface

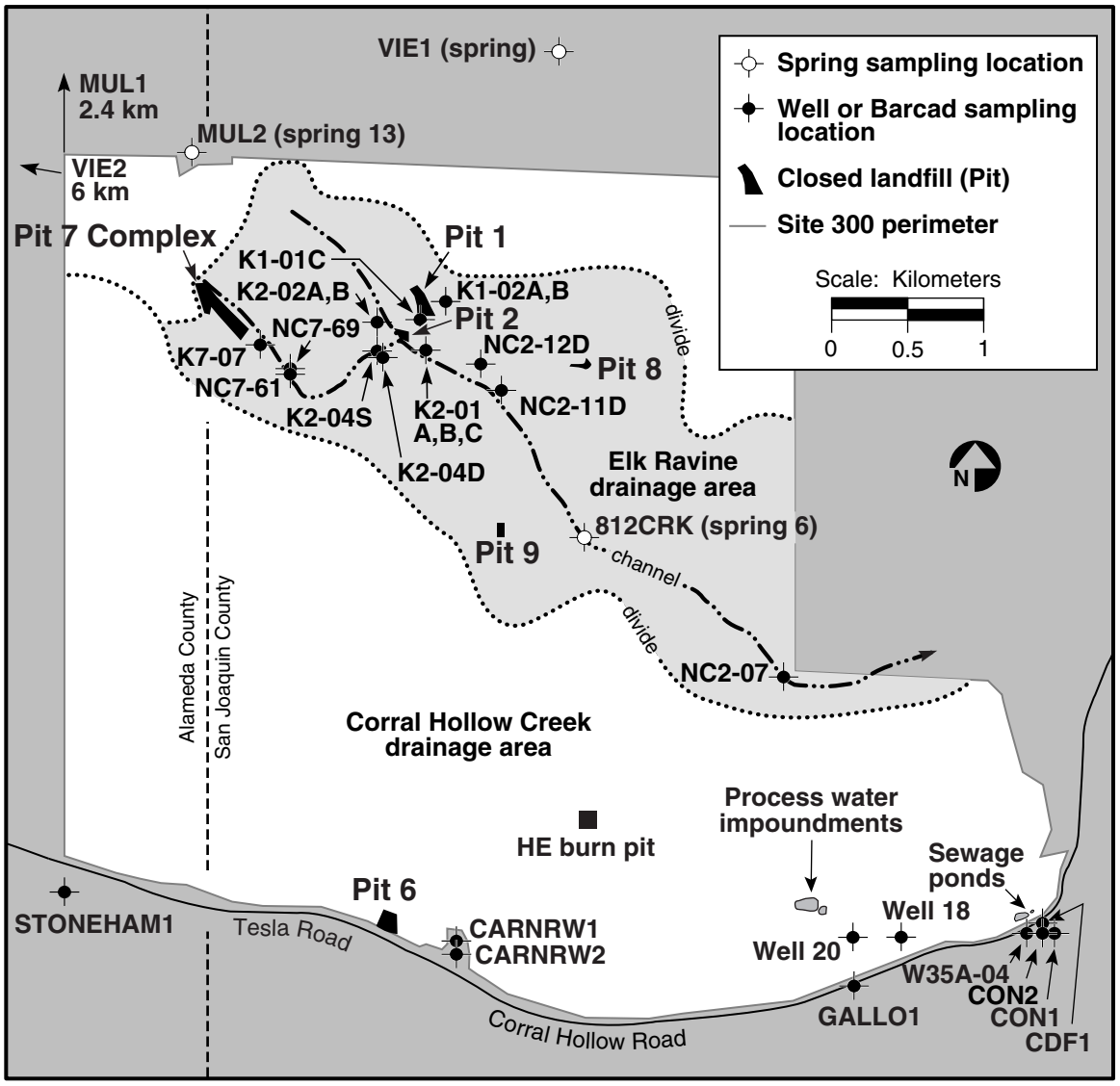

Figure 9-3. Locations of surveillance ground water wells, Barcads, and springs at Site 300.

impoundments, and the sewer ponds are located in the Corral Hollow Creek drainage area. Two on-site water supply wells, well 18 and well 20, are also used for surveillance monitoring purposes. Well 20 provides potable water to the site. Well 18 is maintained as a standby supply well.

Brief descriptions of the Site 300 ground water monitoring networks are given below. Networks within the Elk ravine drainage area are described first, followed by the networks in the Corral Hollow creek drainage area. CERCLA wells within Site 300 have

been selected for compliance and surveillance monitoring use based on their locations and our general understanding of local geologic and hydrogeologic conditions at Site 300 as described in Webster-Scholten 1994 (see also Chapter 8 for a summary of Site 300 stratigraphy and hydrogeology.) Ground water measurements made during 1999 that have not been published elsewhere are listed in tables in the Data Supplement that accompanies this volume. References to the publications that contain the remaining ground water data collected during 1999 are cited herein.

Elk Ravine Drainage Area

The Elk Ravine drainage area, a branch of the Corral Hollow Creek drainage system, includes most of northern Site 300 (see **Figure 9-3**). Storm water runoff from closed landfills within the Elk Ravine drainage area (Pits 1–5 and 7–9) collects in arroyos and quickly infiltrates into the ground. Ground water from wells that lie within the Elk Ravine drainage area are monitored for COCs because of the system of surface and underground flows that connect the entire Elk Ravine drainage area. The area contains eight of the nine closed landfills (Pits 1–5 and 7–9) and a number of firing tables where explosives tests have been conducted. The following descriptions of monitoring networks within Elk Ravine begin with the headwaters area and proceed downstream. (See Chapter 8 for a review of ground water contamination in this drainage area as determined from numerous CERCLA investigations.)

Pit 7 Complex

Monitoring requirements for the closed Pit 7 landfill in the Elk Ravine drainage area are specified in *Waste Discharge Requirements Order 93-100* (WDR 93-100) administered by the CVRWQCB (1993 and 1998) and in *LLNL Site 300 RCRA Closure and Post-Closure Plans— Landfill Pits 1 and 7* (Rogers/Pacific Corporation 1990).

The Pit 7 complex area is located at an elevation of about 400 m in the most elevated portion of the Elk Ravine drainage area. The complex comprises four adjacent landfills identified as Pits 3, 4, 5, and 7 (see **Figure 9-4**). From 1963 to 1988, the landfills received waste gravels and debris from hydrodynamic tests of explosive devices conducted on firing tables at Site 300. The gravels contained concrete, cable, plastic, wood, tritium, depleted uranium (uranium-238), beryllium, lead, and other metals in trace amounts. In 1988, 9440 m^3 of gravel were removed from six firing tables at Site 300 and placed in Pit 7 (Lamarre and Taffet 1989). These were the last solid wastes to be placed in a landfill at Site 300.

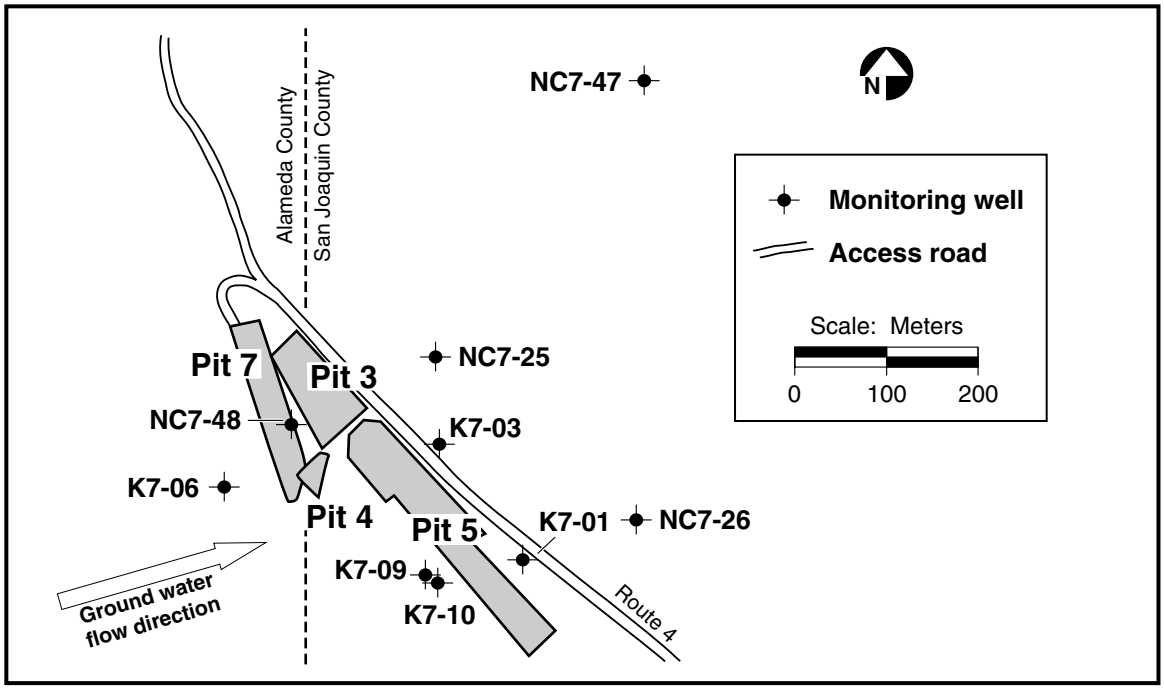

Figure 9-4. Locations of compliance ground water monitoring wells, Pit 7 complex.

The main objective of monitoring is the early detection of any release of COCs from Pit 7 to ground water. All detected COCs are investigated. Most of the COCs detected by the Pit 7 monitoring network have been previously linked to historical releases from other pits near Pit 7. Detected COCs such as arsenic, barium, and uranium are released from the underlying rocks and sediments where they occur naturally. Comparison of new data with historical data helps analysts to identify releases from wastes buried in Pit 7, versus releases from sources other than Pit 7, including natural sources. Most of the COCs detected during 1999 in the ground water near Pit 7 were released historically from Pits 3 and 5 (Webster-Scholten 1994). (See Chapter 8 for a review of the stratigraphy, hydrogeology, and ground water contamination in the Pit 7 area.)

As required by the monitoring and reporting program contained in WDR 93-100, LLNL obtained ground water samples quarterly from Pit 7 monitoring wells during 1999 and analyzed them for inorganic COCs (mostly metallic elements), general radioactivity (gross alpha and beta), activity of certain radioisotopes (tritium, radium, uranium, and thorium), explosive compounds (HMX and RDX), and VOCs (EPA Method 601). Field measurements of ground water depth, temperature, pH, and specific conductance were obtained at each well at the time of sample collection. Three quarterly reports and one annual report covering monitoring activities at Pit 7 during 1999 have been published previously (Christofferson and MacQueen 1999a, 1999b, 1999c, 2000). Tables and graphs of Pit 7 ground water data for 1999 can be found in *LLNL Experimental Test Site 300*

Compliance Monitoring Program for RCRA-Closed Landfill Pits 1 and 7, Annual Report for 1999 (Christofferson and MacQueen 2000).

Elk Ravine

As planned, ground water samples were obtained twice (semiannually) during 1999 from the widespread Elk Ravine surveillance monitoring network. Samples were analyzed for inorganic COCs (mostly metallic elements), general radioactivity (gross alpha and beta), tritium and uranium activity, explosive compounds (HMX and RDX), and VOCs (EPA Method 601).

Pit 2

The closed Pit 2 landfill lies in the upper portion of Elk Ravine, about 320 m above sea level (**Figures 9-3** and **9-5**). The landfill primarily contains gravels and debris from hydrodynamic tests of explosive devices conducted at the Building 801 and 802 firing tables. The buried waste material contains depleted uranium (uranium-238), and trace amounts of beryllium, thorium, and (possibly) tritium.

As planned for surveillance purposes, LLNL obtained ground water samples twice (semiannually) during 1999 from the Pit 2 monitoring network (comprising mostly Barcad installations) and analyzed them for inorganic COCs (mostly metallic elements), general radioactivity (gross alpha and beta), activity of certain radioisotopes (tritium and uranium), and explosive compounds (HMX and RDX).

Pit 1

Monitoring requirements for the closed Pit 1 landfill are specified in *Waste Discharge Requirements Order 93-100* (WDR 93-100) administered by the CVRWQCB (1993 and 1998) and in *LLNL Site 300 RCRA Closure and Post-Closure Plans— Landfill Pits 1 and 7* (Rogers/Pacific Corporation 1990).

Pit 1 lies in the Elk Ravine drainage area about 330 m above sea level. The Resource Conservation and Recovery Act (RCRA)-closed Pit 1 landfill and the positions of the eight ground water wells used to monitor it are shown in **Figure 9-5**.

As required by the monitoring and reporting program contained in WDR 93-100, LLNL obtained ground water samples from Pit 1 monitoring wells every quarter during 1999. Samples were analyzed for inorganic COCs (mostly metallic elements), general radioactivity (gross alpha and beta), activity of certain radioisotopes (tritium, radium, uranium, and thorium), explosive compounds (HMX and RDX), and VOCs (EPA Method 601). Every other quarter, analyses were conducted for an additional seven

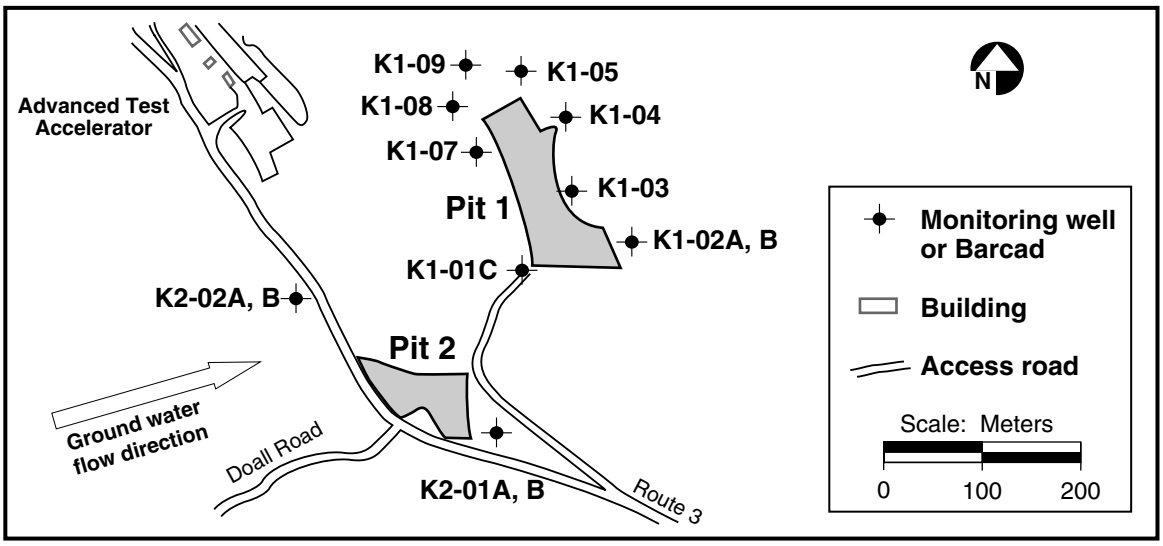

Figure 9-5. Locations of Pit 2 surveillance Barcads (K1-02A, K2-01A, K2-01B, and K2-02A) and surveillance well K2-02B, and Pit 1 compliance ground water monitoring wells (K1-01C, -07, -02B, -03, -04, -05, -08, and -09).

elements. Additional annual analyses were conducted on fourth-quarter samples for extractable organics (EPA Method 625), pesticides and PCBs (EPA Method 608), and herbicides (EPA Method 615). Field measurements of ground water depth, temperature, pH, and specific conductance were obtained at each well at the time of quarterly sample collection. Three quarterly reports and one annual report covering monitoring activities at Pit 1 during 1999 have been published previously (Christofferson and MacQueen 1999a, 1999b, 1999c, 2000). Tables and graphs containing Pit 1 ground water data for 1999 can be found in *LLNL Experimental Test Site 300 Compliance Monitoring Program for RCRA-Closed Landfill Pits 1 and 7, Annual Report for 1999* (Christofferson and MacQueen 2000).

Pit 8

The closed Pit 8 landfill is located in the Elk Ravine drainage area adjacent to the Building 801 firing table, where explosives experiments were conducted from 1958 to 1974. Approximately 40 m^3 of untreated debris from the firing table were placed in the pit during that time. Buried debris may contain trace amounts of tritium, depleted uranium (uranium-238), lead, and beryllium.

Figure 9-6 shows the Building 801 and Pit 8 areas and the locations of the monitoring wells. The pit is located in a narrow ravine within the Elk Ravine drainage area about 350 m above sea level. Chemical analysis of soil and rock samples obtained from this area during CERCLA remedial investigations detected no COCs above background concentrations (Webster-Scholten 1994). However, low concentrations

of trichloroethylene (TCE) have been detected in ground water samples from Pit 8 surveillance monitoring wells, including upgradient well K8-01, since 1987. Previous remedial investigation links the TCE to a dry well near Building 801 that was once used to dispose liquid wastes (Webster-Scholten 1994).

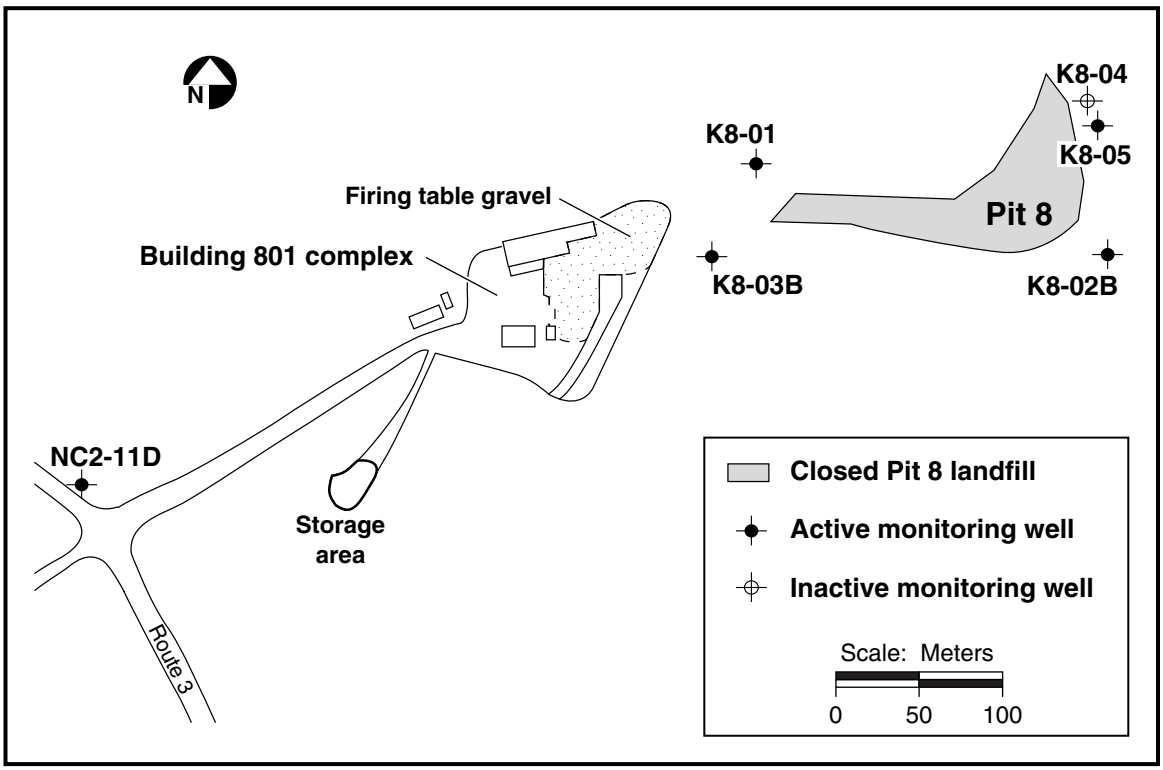

Figure 9-6. Locations of surveillance ground water monitoring wells, Pit 8, 1999.

Because of construction activities in the vicinity of Pit 8, ground water samples could be obtained from only two surveillance monitoring wells during 1999. Ground water samples from wells K8-01 and K8-02B were analyzed for inorganic COCs (mostly metallic elements), general radioactivity (gross alpha and beta), activity of certain radioisotopes (tritium and uranium), explosive compounds (HMX and RDX), and VOCs (EPA Method 601).

Pit 9

The Pit 9 landfill is centrally located within Site 300 about 340 m above sea level. Similar to the other closed landfills in Elk Ravine, the closed Pit 9 landfill contains firing table gravels and debris from explosives experiments conducted on the Building 845 firing table nearby.

Figure 9-7 shows the locations of the four surveillance wells used to monitor the ground water in the vicinity of Pit 9. Ground water flows east-northeasterly beneath Pit 9 in the Neroly lower blue sandstone unit ($Tnbs_1$). The water table lies about 40 m below the ground surface at Pit 9. Monitoring well K9-02 is hydrologically upgradient from Pit 9, and wells K9-01, K9-03, and K9-04 are downgradient.

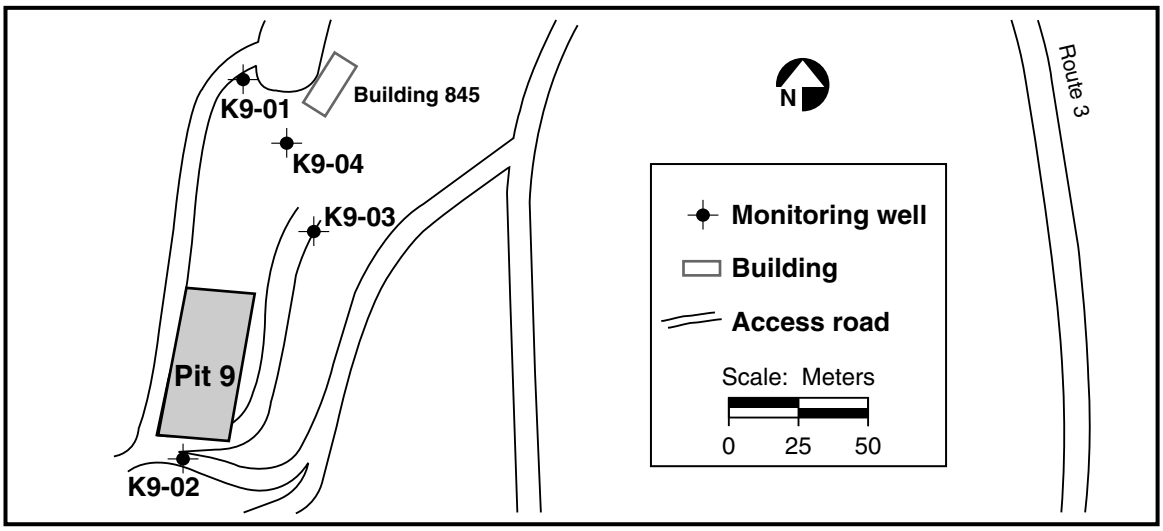

Figure 9-7. Locations of surveillance ground water monitoring wells, Pit 9, 1999.

As planned for surveillance purposes, the four Pit 9 monitoring wells were sampled once (annually) during 1999. Ground water samples from the four wells were analyzed for inorganic COCs (mostly metallic elements), general radioactivity (gross alpha and beta), activity of certain radioisotopes (tritium and uranium), explosive compounds (HMX and RDX), VOCs (EPA Method 601), and extractable organics (EPA Method 625).

Corral Hollow Creek Drainage Area

This section describes the ground water monitoring networks that are located in the southern half of Site 300 where runoff and ground water flow south to Corral Hollow creek. (See Chapter 8 for a review of ground water contamination in this drainage area as determined from numerous CERCLA investigations.)

Pit 6

Compliance monitoring requirements for the closed Pit 6 landfill in the Corral Hollow Creek drainage area are specified in the *Post-Closure Plan for the Pit 6 Landfill Operable Unit Lawrence Livermore National Laboratory Site 300* (Ferry et al. 1998). The closed Pit 6 landfill covers an area of about 1 hectare (2.5 acres). Its elevation is approximately 215 m above

sea level. From 1964 to 1973, approximately 1500 m^3 of solid wastes were buried there in nine separate trenches. The trenches were not lined, consistent with historical disposal practices. Three larger trenches contain 1300 m^3 of solid waste that includes empty drums, glove boxes, lumber, ducting, and capacitors. Six smaller trenches contain 230 m^3 of biomedical waste, including animal carcasses and animal waste. Minor releases of VOCs—primarily the solvent TCE, and tritium—occurred prior to closure. During 1997, a multilayered cap was constructed over all the trenches, and a drainage control system was installed around the cap. The cap and the drainage control system are engineered to keep rainwater from contacting the buried waste (Ferry et al. 1998).

The Pit 6 disposal trenches were constructed in Quaternary terrace deposits (Qt) above and north of the Corral Hollow Creek flood plain. Surface runoff from the pit area flows southward to Corral Hollow Creek. The Carnegie-Corral Hollow Fault zone extends beneath the southern third of Pit 6. The northern limit of the fault zone is shown in **Figure 9-8**. Beneath the northern two-thirds of Pit 6, ground water flows south-southeast, following the inclination (dip) of the underlying sedimentary rocks. Ground water seepage velocities are less than 10 m/y. Depths to the water table range from 10–20 m. Beneath the southern third of Pit 6, a trough containing terrace gravel within the fault zone provides a channel for ground water to flow southeast, parallel to the Site 300 boundary fence (Webster-Scholten 1994). (See Chapter 8 for a review of the stratigraphy, hydrogeology, and ground water contamination in the Pit 6 area.)

Two ground water monitoring programs were implemented at the Pit 6 landfill during 1998 to ensure compliance with all regulations: (1) The Detection Monitoring Program (DMP), designed to detect any new release of COCs to ground water from wastes buried in the Pit 6 landfill, and (2) the Corrective Action Monitoring Program (CAMP), which operates under CERCLA, and monitors the movement of existing releases (see Chapter 8 for a summary of CAMP monitoring results for Pit 6). Twenty-four COCs, including VOCs and radioisotopes, are monitored in ground water near Pit 6 (Ferry et al. 1998). **Figure 9-8** shows the locations of Pit 6 and the wells used to monitor ground water there.

As required by the monitoring program contained in the postclosure plan, ground water at the Pit 6 monitoring wells was sampled quarterly during 1999. Samples were analyzed for inorganic COCs (mostly metals), general radioactivity (gross alpha and beta), tritium activity, uranium activity, VOCs (EPA Method 624), extractable organics (EPA Method 625), pesticides and PCBs (EPA Method 608), and herbicides (EPA Method 615). Field measurements of ground water depth, temperature, pH, and specific conductance were obtained at each well at the time of sample collection. Three quarterly reports and one annual report covering monitoring activities at Pit 6 during 1999 have been published previously (Christofferson and Taffet 1999a, 1999b, 1999c, 2000). Tables listing the 1999 ground water data for Pit 6 can be found in Christofferson and Taffet 2000.

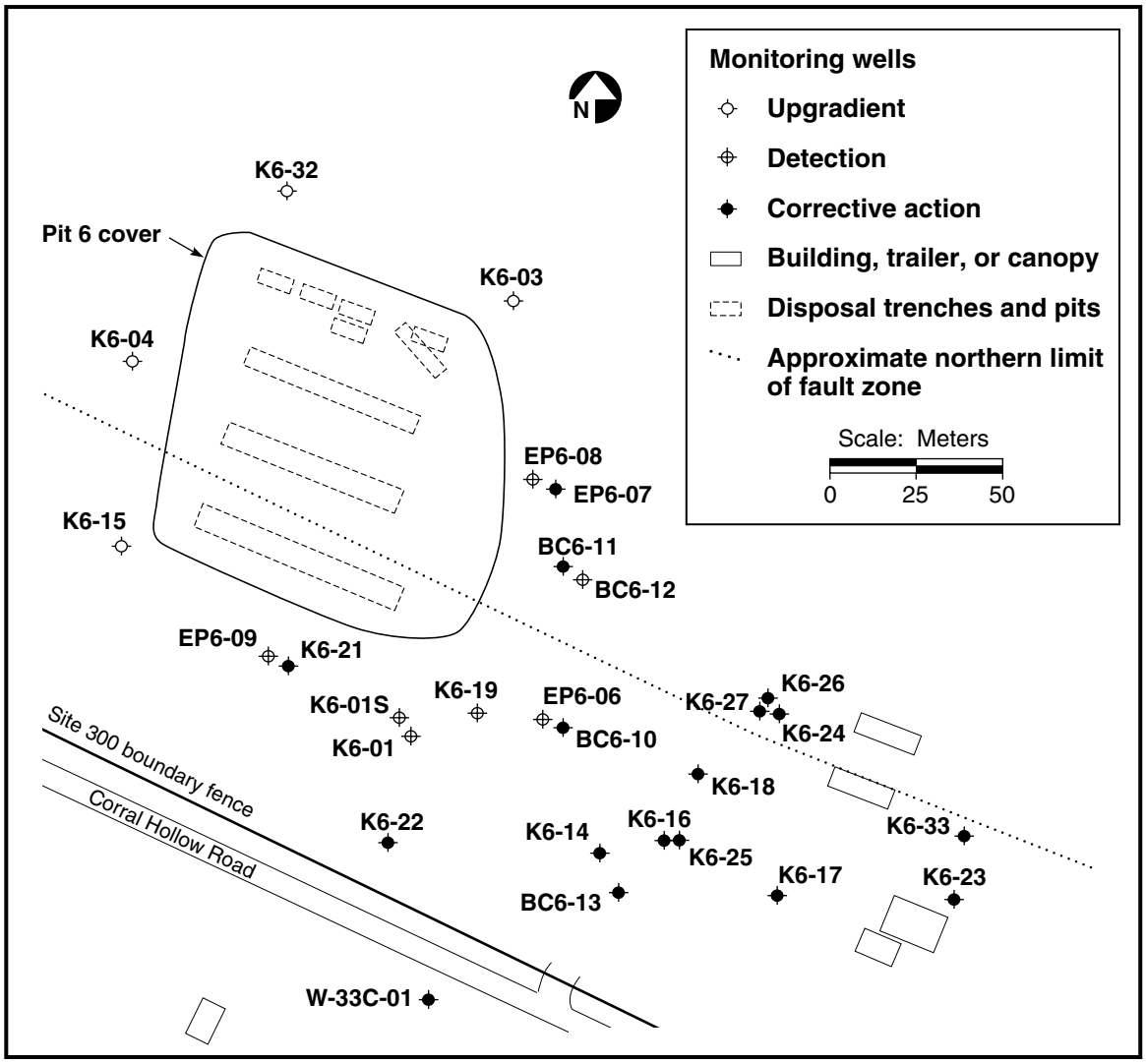

Figure 9-8. Locations of Pit 6 ground water monitoring wells.

HE Process Area Closed Burn Pits

The former High-Explosives (HE) Open Burn Treatment Facility, part of the Building 829 Complex, is located on a ridge within the southeast portion of Site 300 at an elevation of about 320 m (1050 ft) (see **Figure 9-9**). The facility included three shallow unlined pits constructed in unconsolidated sediments that cap the ridge (Tps formation). The former burn facility was covered with an impervious cap during 1998 following RCRA guidance. The facility was used to thermally treat explosives waste generated by research operations at Site 300. Surface water drains southward from the facility toward Corral Hollow Creek. The nearest site boundary lies about 1.6 km (4500 ft) to the south

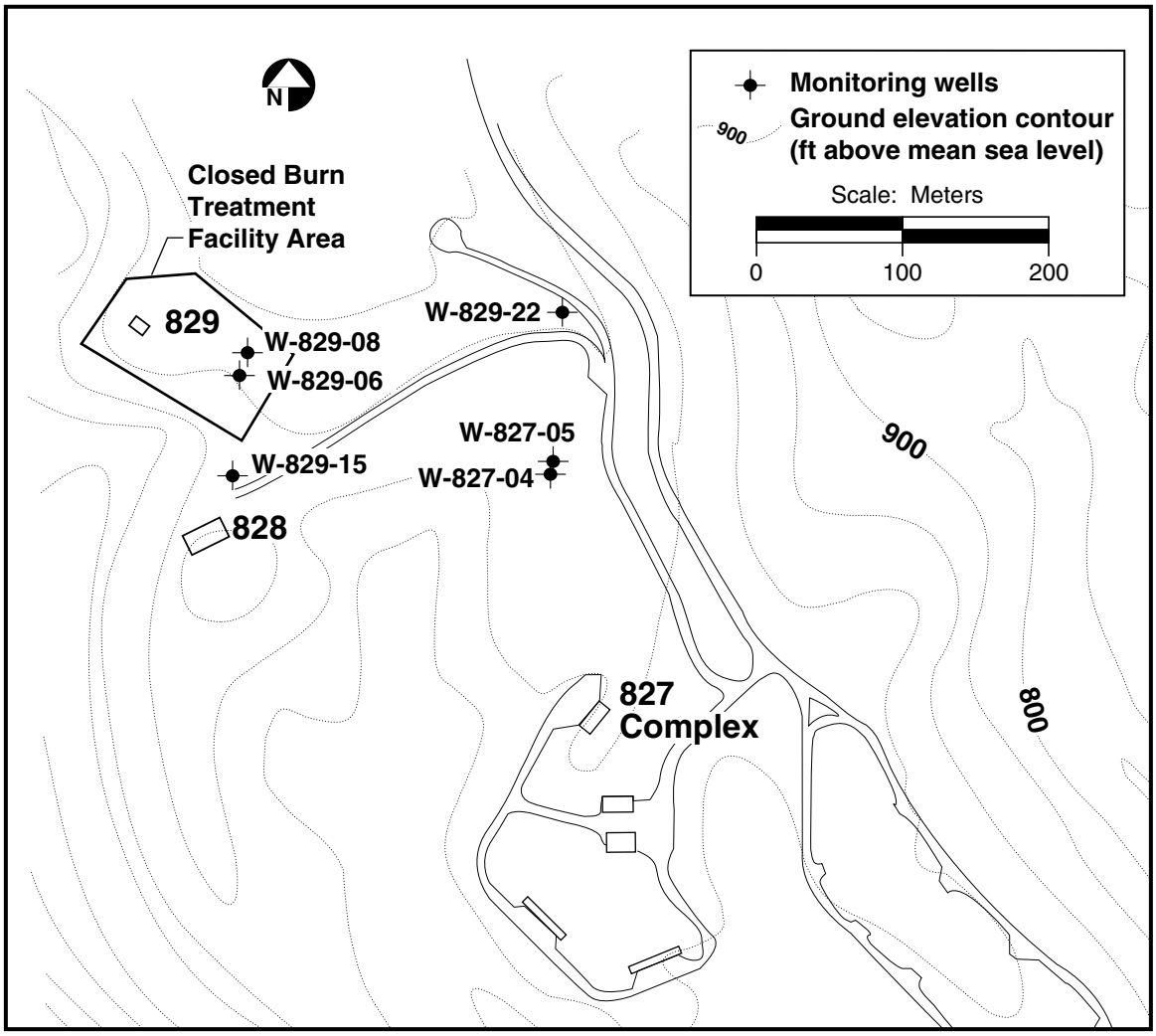

Figure 9-9. Locations of monitoring wells in Building 829 closed burn facility area.

at Corral Hollow Road. Stratified rocks of the Neroly (Tn) formation underlie the facility and dip southeasterly. Two water-bearing zones exist at different depths beneath the facility. The shallower zone, at a depth of about 30 m (100 ft), is perched within the Neroly upper siltstone/claystone aquitard ($Tnsc_2$). The deeper zone, at a depth of about 120 m (400 ft), represents a regional aquifer within the Neroly upper sandstone member ($Tnbs_2$). (See Chapter 8 for a review of the stratigraphy, hydrogeology, and ground water contamination in this area.)

Based on ground water samples recovered from boreholes, previous CERCLA remedial investigations determined that the perched ground water beneath the burn facility was contaminated with VOCs, primarily TCE, but that the deeper regional aquifer was free of any contamination stemming from operation of the facility (Webster-Scholten 1994).

Subsequent assays of soil samples obtained from shallow boreholes prior to closure revealed that low concentrations of HE compounds, VOCs, and metals exist beneath the burn pits (Mathews and Taffet 1997). Conservative transport modeling indicates that the shallow contamination will not adversely impact the regional aquifer, primarily because its downward movement is blocked by a 100-m-thick intervening aquitard. However, beginning in 1999, LLNL implemented the intensive ground water monitoring program for this area described in the post-closure plan (Mathews and Taffet 1997) to track the fate of contaminants in the perched water-bearing zone and to watch the deep regional aquifer for the appearance of any potential contaminants from the closed burn facility.

Figure 9-9 shows the locations of the closed burn treatment facility area and the six wells used to monitor the ground water. Two wells, W-829-06 and W–829-08, are screened in the perched water-bearing zone beneath the former burn facility. The remaining four wells are screened in the deep regional aquifer downgradient of the closed facility. During 1999, quarterly samples were obtained from five of the six monitoring wells. One of the deep wells, W-829-04, was dry during 1999. Ground water samples from the wells screened in the deep regional aquifer were analyzed quarterly for inorganic COCs (mostly metals), general minerals, explosive compounds (HMX, RDX, and TNT), VOCs (EPA Method 624), extractable organics (EPA Method 625), pesticides and PCBs (EPA Method 608), general radioactivity (gross alpha and beta), activity of certain radioisotopes (tritium, radium, and uranium), total organic carbon (TOC), total organic halides (TOX), and coliform bacteria. Ground water samples from the two wells screened in the shallow perched water-bearing zone were analyzed for explosive compounds and VOCs for the first three quarters of 1999. Fourth-quarter samples of the perched ground water were subjected to the same analyses as described above for the deep ground water in the regional aquifer.

Water Supply Wells

Water suppy wells 18 and 20 are located in the southeastern part of Site 300 (**Figure 9-3**). Both are deep, high-production wells. Well 20 supplied potable water at the site during 1999, while well 18 was maintained as a standby water supply well. Both wells are screened in the $Tnbs_1$. The well 18 screen extends upwards into the aquitard unit ($Tnsc_1$) that separates the upper ($Tnbs_2$) and lower blue sandstone units of the Neroly Formation. Each well can produce up to 1500 L/min of potable water. For many years, well 18 ground water samples have shown trace amounts of TCE. CERCLA studies have not yet determined the source of the TCE in well 18 (see Chapter 8 for locations of TCE plumes at Site 300).

As planned for surveillance purposes, ground water samples were obtained quarterly from these two on-site supply wells. Quarterly water samples from well 20 were analyzed for inorganic COCs (mostly metals), VOCs (EPA Method 502.2) explosive compounds (HMX, RDX), general radioactivity, and tritium activity. Quarterly water samples from standby well 18 were analyzed for arsenic, zinc, and VOCs; general radioactivity (gross alpha and gross beta); and tritium.

Explosives Process Area

WDR Order No. 96-248 establishes the basis for compliance monitoring of the two adjacent surface impoundments (see **Figure 9-10**). This includes quarterly monitoring of the ground water, monitoring of various influent waste streams to the surface impoundments, and visual observations of leachate collection and removal systems. Influent wastewater monitoring complements administrative controls that regulate the discharge of chemicals that could degrade the polyethylene liners of the impoundments. A three-tiered monitoring program comprising weekly visual inspections of the leachate collection and removal systems, quarterly inspections of lysimeters, and quarterly sampling of monitoring wells is in place to detect any release of chemicals from the surface impoundments in the Explosives Process Area.

As part of the Monitoring and Reporting Program (MRP) for the surface impoundments, contained in WDR 96-248, LLNL is required to obtain ground water samples quarterly from four monitoring wells (see **Figure 9-10**) and to establish statistical concentration limits for COCs in ground water beneath the surface impoundments.

WDR 96-248 establishes limits for discharges of COCs into the surface impoundments and requires monitoring of the photographic process and chemistry area wastewater retention tanks that discharge to the surface impoundments as well as direct discharges to the surface impoundments from explosives processing. Influent streams are monitored at a prescribed frequency for area-specific COCs.

Retention tanks containing photographic process rinsewater from Buildings 801, 823, 850, and 851 are sampled to confirm that discharges are consistent with effluent discharge limits specified in WDR 96-248. Discharges to the surface impoundments occur after samples are obtained, except for rinsewater from the Building 823 retention tanks, which is discharged automatically to the surface impoundments and sampled quarterly.

Samples of process wastewater from the Chemistry Area (Buildings 825, 826, and 827 complex) are collected when the retention tanks are ready for discharge to the surface impoundments. The wastewater is held in retention tanks until analytical results indicate compliance with WDR 96-248.

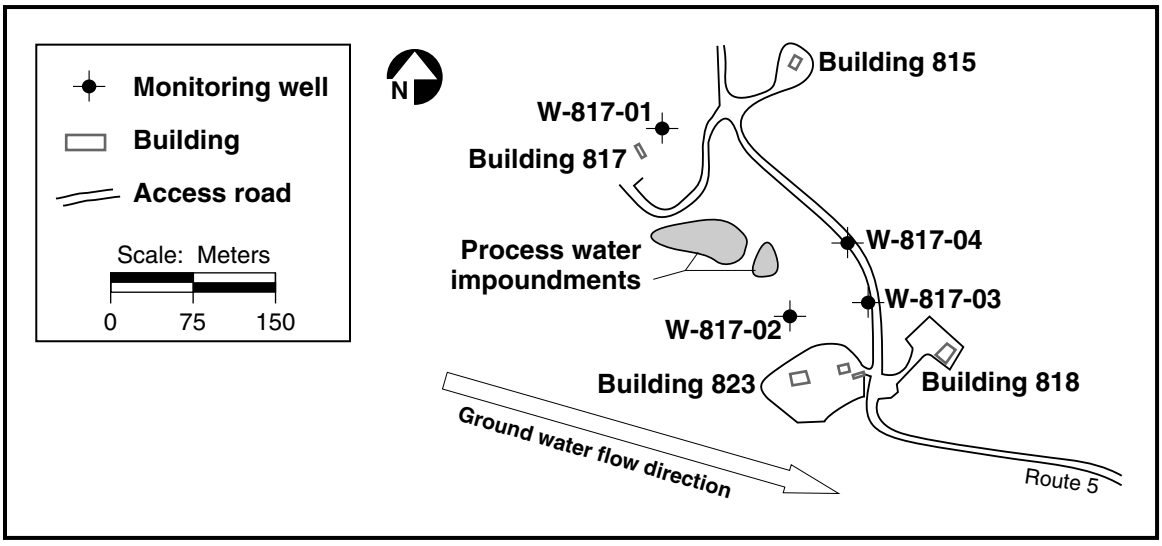

Figure 9-10. Locations of compliance ground water monitoring wells in the Explosives Process Area.

Process water discharges to the surface impoundments are analyzed for COCs that have been found (or are likely to be found) in the process water from each specified building within the Explosives Process Area. This monitoring program includes process area wastewater from Buildings 806/807, 809, and 817. WDR 96-248 requires annual analysis of this waste stream from Buildings 806/807, 809, and 817.

Percolation Pits

Percolation pits that are designed to accept discharges from mechanical equipment are located at Site 300 Buildings 806A, 827A, 827C, 827D, and 827E. In other remote Site 300 facilities, these types of waste streams are discharged to septic systems. This discharge is permitted by WDR 96-248. WDR 96-248 specifies monthly observations and monitoring requirements for overflows. Overflows of the percolation pits, should they occur, are sampled and analyzed to determine if any metals are present.

Sewage Evaporation and Percolation Ponds

Site 300 is not serviced by a publicly owned treatment works (POTW) as is the Livermore site; therefore, alternate methods of treating and disposing of sanitary waste are necessary. Sewage generated at buildings in the General Services Area is discharged into a lined evaporation pond. The wastewater is disposed of through evaporation from the pond. However, during rare periods of high rainfall, treated wastewater may overflow into an unlined percolation pond, where it enters the ground and the shallow ground water.

The environmental monitoring requirements for the sewage evaporation and percolation ponds (hereafter sewage ponds) are specified in MRP 96-248. The monitoring requirements include both wastewater monitoring and monitoring of the ground water to detect potential impacts of the sewage on ground water quality.

Wastewater is sampled quarterly at an influent location (ISWP) and within the pond (ESWP). Overflows are sampled as needed at location DSWP. The sampling locations are shown in **Figure 9-11**.

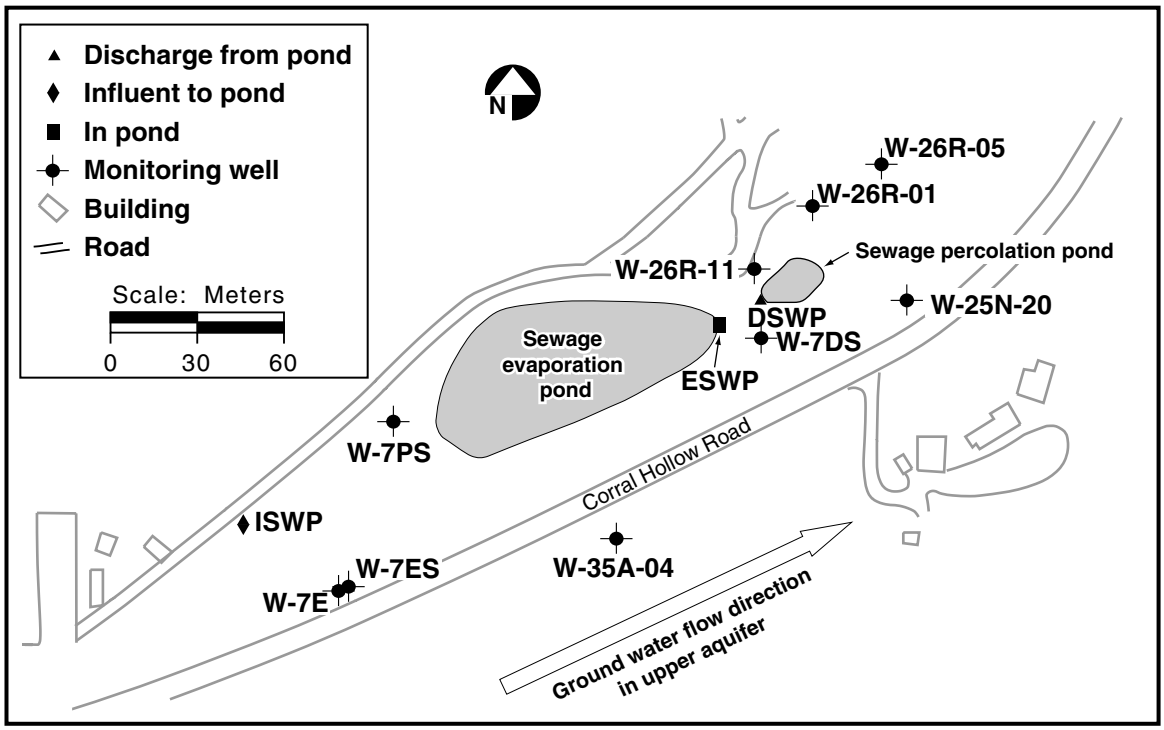

Figure 9-11. Sewage evaporation and percolation ponds, compliance ground water monitoring wells, and wastewater monitoring locations.

Nine ground water monitoring wells are sampled semiannually to provide information on the ground water quality in the vicinity of the sewage ponds (**Figure 9-11**). The wells are screened in three different geological formations (Qal, $Tnbs_1$, and $Tnsc_1$—see Chapter 8). $Tnbs_1$ (Neroly Formation lower blue sandstone unit) is the regional aquifer.

Off-site Surveillance Wells and Springs

As planned for surveillance purposes, ground water samples were obtained from two off-site springs and ten off-site wells during 1999. With the exception of one well, all off-site monitoring locations are near Site 300. The exception, well VIE2, is located at

a private residence 6 km west of the site. It represents a typical Altamont Hills potable water supply well. One stock watering well, MUL1, and two stock watering springs, MUL2 and VIE1, are adjacent to Site 300 on the north. Eight wells, CARNRW1, CARNRW2, CDF1, CON1, CON2, GALLO1, STONEHAM1, and W-35A-04, are adjacent to the site on the south (**Figure 9-3**). Seven of the wells to the south are privately owned and were constructed to supply water for human consumption, stock watering, or fire suppression. The exception is well W-35A-04, which is a DOE CERCLA well that was installed for monitoring purposes only.

Ground water samples were obtained quarterly during 1999 at six off-site surveillance well locations south of Site 300. Of these, CARNRW1 and CON2 samples were analyzed for VOCs only (EPA Method 601). Samples from CARNRW2, CDF1, CON1, and GALLO1 were analyzed quarterly for inorganic COCs (mostly metals), general radioactivity (gross alpha and beta), tritium activity, explosive compounds (HMX and RDX), and VOCs (EPA Method 502.2). Additional analyses were conducted on third-quarter samples for uranium activity, extractable organics (EPA Method 625), pesticides and PCBs (EPA Method 608), and herbicides (EPA Method 615).

Ground water samples were obtained once (annually) during 1999 from four off-site surveillance monitoring locations—MUL1, MUL2, VIE1, and VIE2 (north of Site 300) and STONEHAM1 and W-35A-04 (south of Site 300). Samples were analyzed for inorganic COCs (mostly metals), general radioactivity (gross alpha and beta), tritium and uranium activity, explosive compounds (HMX and RDX), VOCs (EPA Method 502.2), extractable organics (EPA Method 625), pesticides and PCBs (EPA Method 608), and herbicides (EPA Method 615).

Sampling and Analytical Methods

Representative samples of ground water were obtained from monitoring wells in accordance with the *LLNL Livermore Site and Site 300 Environmental Restoration Project Standard Operating Procedures (SOPs)* (Dibley and Depue 1999). These protocols cover sampling techniques and specific information concerning the chemicals in ground water that are routinely searched for. Different sampling techniques were applied to different wells depending on whether they were fitted with submersible pumps, had to be bailed, or contained Barcad devices. See the Data Supplement for sampling details.

At Site 300, wastewater samples from the photographic and explosives process areas, sewage evaporation pond influent, water in the pond, and overflow water from the percolation pits pond were obtained in accordance with the standardized procedures

of the Operations and Regulatory Affairs Division (Tate et al. 1999). Standard sample handling and hygiene procedures were employed to prevent cross-contamination (e.g., wearing disposable gloves, decontaminating equipment between uses, and maintaining samples at 4 ± 2°C). Replicates, field blanks, and trip blanks were obtained for quality assurance/quality control purposes. Analyses were performed by state-certified contract analytical laboratories.

Technologists collected wastewater samples from retention tanks in the Chemistry Area associated with Buildings 825, 826, and 827 using Hazardous Waste Management Procedure 411. Wastewater was held in retention tanks until analytical results were reviewed for compliance with WDR 96-248. Some of the analyses were performed by LLNL, which is state-certified for some analyses. The remainder of the analyses were done by off-site contract laboratories late in the year.

Results

This section presents the monitoring results for the Livermore site and environs as well as Site 300.

Livermore Site and Environs

Livermore Valley

Measurements of water samples obtained during the summer of 1999 from 18 wells (some of the wells were dry in 1999) in the Livermore Valley continue to show very low tritium levels compared with the 740 Bq/L (20,000 pCi/L) maximum contaminant level (MCL) established by the State of California. The highest tritium activity measured off site was 8.5 ± 2.4 Bq/L in a ground water sample from well 11B1 (see **Figure 9-1**), located about 11 km west of LLNL (results are reported in Data Supplement Table 9-29).

Tritium activity has been decreasing in Livermore Valley ground waters downgradient of LLNL. The median activities of tritium in ground water samples from these downgradient wells decreased from 4.59 Bq/L in 1989 to –0.01 Bq/L in 1999 based on the five positive detections of tritium and 13 calculated values.

Livermore Site Perimeter

Tritium activity ranged from –2.8 (calculated) Bq/L to 4.4 Bq/L in ground water samples from on-site background monitoring wells and from –4.4 (calculated) to 10.5 Bq/L in western perimeter monitoring wells.

The semivolatile organic compound di(2-ethylhexyl)adipate was detected in ground water samples collected from wells W-556 and W-373 (see **Figure 9-2**). This compound is a plasticizer. Concentrations analyzed were 3.9 µg/L in the W-556 sample and 5.2 µg/L in the W-373 sample (see Data Supplement Tables 9-10 and 9-11, respectively). The California drinking water MCL for di(2-ethylhexyl)adipate is 400 µg/L. No other organic compounds, excluding VOCs that were not COCs for this surveillance monitoring effort, were detected in the ground water during 1999.

The inorganic compounds detected, including dissolved trace metals and minerals, occur naturally in the ground water at variable concentrations. **Table 9-1** shows the three anions with the highest concentrations in two of the background wells (W-008 and W-221) and the seven western perimeter wells at LLNL. Concentrations of these major anions are higher in the background wells than in the western perimeter wells (see Tables 9-2 through 9-11 in the Data Supplement). Concentrations of chloride in background wells W-008 and W-221 are higher than California's recommended secondary MCL of 250 mg/L, while chloride concentrations in none of the western perimeter wells exceed 250 mg/L. Likewise, sulfate concentrations in background well W-008 exceed California's recommended secondary MCL of 250 mg/L, while sulfate concentrations in none of the western perimeter wells exceed 250 mg/L. Additionally, the boron concentration of 9.4 mg/L in background monitoring well W-008 in February 1999 is an order of magnitude higher than it is in the western perimeter wells. Poor ground water quality in the background portions of the site has been described previously in the remedial investigations (Thorpe et al. 1990).

Table 9-1. Concentration ranges for three major anions in background and western perimeter monitoring wells.

Hydrologic Flow	Concentration range (mg/L)					
	Bicarbonate (HCO_3^-)		Chloride (Cl^-)		Sulfate (SO_4^{2-})	
	Range	Median	Range	Median	Range	Median
Background	220–330	270	280–560	400	77–340	209
Western perimeter	190–270	240	76–130	87	12–65	38

In March 1996, nitrate was first detected at concentrations greater than the MCL of 45 mg/L (68 to 80 mg/L) in ground water samples obtained from western perimeter monitoring well W-1012 (screened in HSU 2) (see **Figure 9-2**). From a ground water sample collected in February 1999, the concentration of nitrate for this well was 79 mg/L (see Data Supplement Table 9-9). This is the highest nitrate concentration measured in any on-site monitoring well during 1999. Because of the hydrologic influence of Treatment Facility B that pumps and treats ground water from HSUs 1B and 2 (see Chapter 8), ground water with high nitrate concentrations is not moving off site to the west. The highest concentration measured in an off-site well was below the MCL at 31 mg/L, in downgradient monitoring wells W-151 and W-571 (see Data Supplement Tables 9-7 and 9-8). Monitoring well W-571 is off site and downgradient from well W-1012, but is screened in HSU 1B. During 1999, concentrations of nitrate in on-site background wells W-008 and W-221 ranged from <0.5 mg/L (not detected) to 31 mg/L. Detected concentrations of nitrate in site western perimeter wells ranged from 12 to 31 mg/L. Fluctuations in nitrate concentrations have occurred since regular surveillance monitoring began in 1996, but nitrate concentrations have not increased overall in ground water from the western perimeter monitoring wells since 1996. The nitrate may originate as an agricultural residue (Thorpe et al. 1990).

Of the 22 metal COCs, nine were detected in western perimeter surveillance wells during 1999. Only chromium and hexavalent chromium exceeded California's MCL of 50 µg/L in western perimeter well W-373 (see Data Supplement Table 9-11). Ground water samples collected from this well are from HSU 1B, and the nearby Treatment Facility C (see **Figure 8-1**) treats ground water from HSU 1B for chromium. Consequently, concentrations of chromium (including hexavalent chromium) have been continually decreasing. Concentrations of iron reach 23% of California's secondary MCL in off-site monitoring well 14B1 (see Data Supplement Table 9-5). No other metal COC concentration exceeded 23% of its MCL or secondary MCL in ground water samples collected from western perimeter monitoring wells during 1999 (see Data Supplement Tables 9-2 through 9-11).

None of the ground water samples obtained from surveillance monitoring wells during 1999 had of any radioactivity that exceeded a drinking water MCL. A ground water sample collected from well W-593 reached 75% of the MCL (0.41 ± 0.12 Bq/L, see Data Supplement Table 9-19) for gross alpha radioactivity, but that radioactivity was not significantly higher than for background well W-008 (0.38 ± 0.10 Bq/L, see Data Supplement Table 9-2). Gross beta radioactivity was highest in background well W-008 (0.20 ± 0.10 Bq/L, see Data Supplement Table 9-2), but was only 11% of California's MCL for gross beta radioactivity. The highest tritium activity measured in a Livermore site perimeter ground water sample was 10.5 Bq/L, equal to 1.4% of the tritium MCL. The sample was from monitoring well W-373 (see Data Supplement Table 9-11).

Activities of total uranium (U-234 + U-235 + U-238) continued to be highest in the background wells W-008, W-017, and W-221 during 1999. Activities of total uranium in those wells range from 0.19 ± 0.02 Bq/L to 0.30 ± 0.03 Bq/L (41% of California's MCL). (See Data Supplement Tables 9-2, 9-3, and 9-4). Activities of total uranium are significantly lower, from 0.024 ± 0.005 Bq/L (in well W-121) to 0.14 ± 0.02 Bq/L (19% of California's MCL in well W-1012), in ground water from each of the western monitoring wells. Uranium and its radioactive daughters, thorium-230, radium-226, and radon-222, occur naturally in the sediments and rock layers beneath and surrounding LLNL. Uranium activities did not exceed drinking water limits.

Livermore Site

Ground water downgradient of potential sources showed possible impact from two releases of metals to ground. Ground water at well W-307 near Building 322 showed a maximum concentration of chromium(VI) at 13 µg/L, just slightly greater than 11 µg/L, measured in background well W-017 (see Data Supplement Tables 9-23 and 9-4, respectively). Chromium (total) and chromium(VI) were detected at elevated concentrations in ground water samples from wells W-226 and W-306, downgradient from the Building 253 catch basin. Chromium (total) concentrations were measured as 71 µg/L and 19 µg/L (at well W-226) and 37 µg/L (at well W-306); chromium(VI) concentrations were 27 and 24 µg/L (at well W-226) and 25, 33, and 13 µg/L (at well W-306) (see Data Supplement Tables 9-24 and 9-25). The accumulated sediment in the catch basin is a potential source of several metals (Jackson 1997). Only the concentration of chromium (total) measured in a ground water sample collected from well W-226 on February 11, 1999, exceeded the MCL of 50 µg/L for chromium drinking water. Chromium concentration was measured again during the fourth quarter and was below the MCL (see Data Supplement Table 9-24).

The initial analytical results from well W-148, downgradient from both the Plutonium and Tritium Facilities, show plutonium-238 detected at 0.006 ± 0.002 Bq/L (0.17 ± 0.06 pCi/L). Meanwhile, the activity for plutonium-239+240 was analyzed at only 0.0002 ± 0.0004 Bq/L (0.006 ± 0.012 pCi/L). This was considered unusual because plutonium-239 might be expected, but not plutonium-238. Plutonium-239 is the isotope that was used in weapons development at LLNL, and all historical waste records at LLNL indicate the presence of plutonium-239 rather than plutonium-238. A second aliquot of this sample was analyzed with a result of 0.01 ± 0.01 Bq/L for plutonium-238. Another ground water sample was collected from this well on March 15, 2000, and was analyzed for americium-241 and expected plutonium radioisotopes; no radioisotopes were detected. A ground water sample was collected downgradient from the Plutonium Facility from SIP-331-001 on October 21, 1999, and analyzed for plutonium-239+240 along with other analytes. The initial analytical result for plutonium-239+240 was 0.004 ± 0.002 Bq/L (0.10 ± 0.06 pCi/L). However, this sample

from SIP-331-001 appeared to contain too much particulate matter. The remaining sample was then filtered and reanalyzed by both the off-site analytical laboratory and the on-site laboratory, and neither result indicated the presence of plutonium. The conclusion is that no dissolved plutonium is present in the ground water downgradient from the Plutonium Facility. Ground water samples will continue to be collected biannually from these wells and analyzed for americium and plutonium radioisotopes. (Analytical results from first quarter 2000 samples from both wells are below detectable limits for americium-241 and plutonium radioisotopes.)

Tritium activity in ground water samples collected from well W-148, downgradient from the Tritium Facility, reached 59 ± 7 Bq/L (1600 ± 180 pCi/L). This activity is less than 10% of the MCL of 740 Bq/L for tritium. The maximum tritium activity in ground water samples from SIP-331-001, downgradient from the Plutonium Facility but upgradient from the Tritium Facility, was 18 ± 3 Bq/L (480 ± 80 pCi/L), and the maximum tritium activity in well W-305, upgradient of both Superblock buildings, was 4.8 ± 2.5 Bq/L (128 ± 69 pCi/L) (see Data Supplement Tables 9-26 through 9-28).

Site 300

The following are summaries of Site 300 ground water surveillance and compliance monitoring results for 1999. Site 300 compliance monitoring results for 1999 have been published previously (Brown et al. 1999a, b, c, and 2000; Christofferson and MacQueen 1999a, b, c, and 2000; Christofferson and Taffet 1999a, b, c, and 2000). Compliance monitoring results for Site 300 that exceeded permitted concentration limits, i.e., statistical limits (SLs), or otherwise suggested a release of a COC to ground water, are discussed again in the following summaries. Surveillance monitoring results for 1999 have not been published elsewhere.

Elk Ravine Drainage Area

Pit 7

Compliance monitoring results for 1999 suggest that zinc was released to ground water from the RCRA-closed Pit 7 landfill. However, it is more likely that it came from waste buried in one of the other closed landfills nearby. Zinc has been detected historically at low, but increasing, concentration in ground water at monitoring well K7-03 since compliance monitoring began there in 1993 (see **Figure 9-4**). During 1999, zinc exceeded the SL of 72 µg/L set in 1998 for well K7-03. It peaked at 160 µg/L during the third quarter. Its fourth-quarter concentration was 70 µg/L, slightly below the SL. The abrupt rise and fall of zinc concentration observed during 1999 was likely caused by a

slug release from a nearby source. Well K7-03 is located hydraulically downgradient of all four closed landfills constituting the Pit 7 Complex. Although LLNL is directed by WDR 93-100 to report any concentration of zinc in excess of its SL as an indication of a release from Pit 7, if such a release occurred, it must have predated pit closure in 1993. Since postclosure monitoring began in 1993, zinc has been detected only sporadically at monitoring well locations other than K7-03. It is improbable that there has been a postclosure release of zinc from Pit 7 because zinc was not detected at well NC7–48, which is located immediately downgradient of Pit 7 (**Figure 9-4**). Although a pre-1993 release of zinc from Pit 7 is not excluded by the historical data, it was likely released more recently from waste buried in the closed Pit 5 landfill, which is close to well K7–03. Pit 5 was inundated from below by rising ground water levels during several past winter rainy seasons (Taffet et al. 1996; Ziagos and Reber-Cox 1998b), which could have released metals to ground water.

A second-quarter total uranium activity of 0.7 Bq/L in ground water at monitoring well K7-01 slightly exceeded the statistical limit of 0.6 Bq/L set for that well. LLNL reported similar statistical evidence of a uranium release during 1998 (Galles 1998). Pits 3 and 5 are located near well K7-01 (**Figure 9-4**). Both Pits 3 and 5 are known to have been partially inundated by rising ground water during the El Niño winter of 1997–1998, when the site received more than double the average seasonal rainfall (Ziagos and Reber-Cox 1998b). Earlier CERCLA uranium investigations have characterized two small ground water plumes containing depleted uranium (uranium-238) that was released in the past from Pit 5, Pit 7, and possibly Pit 3 (Taffet et al. 1996; see Chapter 8 for a map of depleted uranium plumes existing at Site 300).

Tritium activity in the ground water at the Pit 7 monitoring well continued to increase above the MCL of 740 Bq/L (20,000 pCi/L) during 1999, reaching 28,500 Bq/L (770,000 pCi/L) during the fourth quarter. Previous CERCLA tritium investigations have characterized three coalescing plumes of tritium-bearing ground water that originate at Pits 3 and 5 and the Building 850 firing table on the west. The Building 850 plume extends eastward to Pit 1 (Webster-Scholten 1994, Taffet et al. 1996, Ziagos and Reber-Cox 1998b; see Chapter 8 for a map of tritium plumes existing at Site 300). Tritium activity above background occurs in ground water at several Pit 7 monitoring wells, but not at well NC7-48, which excludes Pit 7 as a significant tritium source. Modeling indicates that, given tritium's short half-life of 12.3 years and the relatively slow rate of ground water movement across the site, the activity of the released tritium in ground water will decrease to below the MCL before it reaches a site boundary (Taffet et al. 1996).

As in the past, traces of VOCs including TCE, 1,1-DCE, and trichlorofluoromethane (Freon 11) were detected by the monitoring network during 1999 at concentrations below their respective MCLs. Pit 7 is the likely source of the Freon 11. Previous CERCLA remedial investigations have characterized a small plume containing VOCs that were released in the past from waste buried in Pit 5 (Webster-Scholten 1994; see Chapter 8 for a map of VOC plumes existing at Site 300).

Elk Ravine

Analytical results for the Elk Ravine drainage area surveillance monitoring network for 1999 are listed in Data Supplement Table 9-30 (see **Figure 9-3**). As in past years, arsenic, barium, chromium, selenium, vanadium, and zinc were detected at low concentrations typical of ground water elsewhere in the Altamont Hills. Nitrate appears primarily in the uppermost water-bearing zone. Maximum concentrations were measured in ground water at monitoring wells NC7-61 (62 mg/L and 72 mg/L) and K2-04S (49 mg/L and 61 mg/L). Well NC7-69, which monitors a deeper water-bearing zone, shows very low nitrate concentration (2.7 mg/L). A CERCLA investigation of nitrate in Site 300 ground water is in progress (see Chapter 8 for a map of nitrate plumes existing at Site 300).

The explosive compounds HMX and RDX were detected at low concentrations up to 7 µg/L in shallow ground water at one location, well NC7-61. Although these were the only explosives detected in ground water by surveillance monitoring outside the HE Process Area, it is not surprising at this location. This surveillance well is proximal to the Building 850 firing table, where explosives have been detonated for decades. The firing table is a known source of depleted uranium (uranium-238) and tritium in the ground water (see Chapter 8 for the CERCLA map of contaminant plumes).

Tritium activity was above background in many of the shallow ground water surveillance samples obtained during 1999 from Elk Ravine. Tritium, as tritiated water (HTO), has been released in the past from beneath the firing table at Building 850 (Taffet et al. 1996). HTO was transported to ground water beneath the Building 850 firing table gravels by percolating rainwater. HTO has also been released from closed landfill Pits 3 and 5 over the past decade during wetter-than-normal winters when ground water rose and contacted buried firing table wastes (Ziagos and Reber-Cox 1998b). The most recent release occurred during the wet El Niño winter of 1997–1998. The plumes are mostly shallow in the Neroly lower blue sandstone unit and overlying alluvium (see Chapter 8 for the CERCLA map of tritium plumes). Tritium activity was not discernible in ground water samples from the deeper water-bearing zone monitored at surveillance well NC7-69.

The majority of the Elk Ravine surveillance network tritium measurements made during 1999 support earlier CERCLA studies, which show that, despite additional releases, the tritium contents and extents of the plumes are generally diminishing over time because of natural decay and dispersion (Ziagos and Reber-Cox 1998b). LLNL observe small increases in tritium activity at the distal end of the plume (wells K2-01C, NC2-11D, and NC2-12D), while those wells monitoring the bulk of the plume (NC7-61, K2-04D, and K2-04S) show relatively large decreases in tritium activity over the past several years. For example, tritium activity in ground water at well NC7-61 decreased from 6500 Bq/L in 1996 to 3500 Bq/L in 1999.

Surveillance measurements in Elk Ravine of gross alpha, gross beta, and uranium radioactivity were all low and indistinguishable from background. (Note that gross beta measurements do not detect the low-energy beta emission from tritium decay.)

Pit 2

No release of a COC from Pit 2 to ground water is indicated by the surveillance monitoring data obtained during 1999 (see **Figure 9-5**). Analytical results for the Pit 2 surveillance monitoring network are presented in Data Supplement Table 9-31. Several metals were detected at low concentrations. Most were below analytical reporting limits, which are in the parts per billion (ppb) range. None exceeded an MCL. Arsenic and barium concentrations were within the range of natural (background) concentrations in ground waters at Site 300 (Webster-Scholten 1994). The radioactivity measurements show only low background activities for gross alpha, gross beta, and tritium.

Pit 1

Compliance monitoring results for 1999 suggest that lead was released to ground water from the RCRA-closed Pit 1 landfill (see **Figure 9-5**). However, it more likely came from another source. Over the years, lead has been detected sporadically at low concentrations in ground water samples from monitoring wells located both upgradient and downgradient from Pit 1. Lead was detected more frequently in ground water samples obtained prior to the capping and RCRA-closure of Pit 1 in 1993, implying that the cap is effectively limiting the release of lead. The monitoring data do not point to Pit 1 as being a source of any other COC to ground water. More likely, the lead detected in ground water sampled at downgradient well K1–04 during 1999 is the same lead detected years before at upgradient well K1-01C.

Throughout 1999, tritium activity measured above background in the ground water at Pit 1 monitoring wells K1-01C, K1-02B, and K1-03, where it exceeded the SL. However, no release of tritium from Pit 1 is indicated by these measurements. Rather, the tritium

activity represents a distal lobe of the Building 850 tritium plume, which extends eastward to Pit 1 (see Chapter 8 for a CERCLA map of the Building 850 tritium plume extending to Pit 1).

Measurements of radium, thorium, and uranium made during 1999 in ground water samples from Pit 1 compliance monitoring wells all showed low activities indistinguishable from background.

The VOC 1,1,2-trichloro-1,2,2-trifluoroethane (Freon 113) was detected during 1999 at a maximum concentration of 140 µg/L in ground water at Pit 1 monitoring wells K1-05, K1-08, and K1-09 (**Figure 9-5**). The drinking water MCL for this VOC is 1200 µg/L. Previous CERCLA investigations have linked the appearance of Freon 113 in Pit 1 monitoring wells to past spills in the Advanced Test Accelerator area, about 200 m west and cross-gradient from the affected wells (Webster-Scholten 1994; Taffet et al. 1996).

Pit 8

No release of a COC to ground water from Pit 8 is indicated by the surveillance monitoring data obtained during 1999. Analytical results for the Pit 8 surveillance monitoring network are presented in Data Supplement Table 9-32. Two VOCs, TCE and 1,2-DCA, were detected below their 5 µg/L MCLs. A relatively small VOC plume exists beneath this area (see Chapter 8), which originated prior to 1981 from waste discharged to a dry well upgradient of Pit 8, near Building 801 (Webster-Scholten 1994).

Arsenic, chromium, selenium, and vanadium were detected in concentrations similar to their natural levels in ground water elsewhere in the Altamont Hills.

Pit 9

No evidence for a release from Pit 9 is indicated by the surveillance monitoring data obtained during 1999. Analytical results for the Pit 9 surveillance monitoring network are presented in Data Supplement Table 9-33. COCs either were not detected or were indistinguishable from natural background concentrations. Since annual surveillance monitoring of ground water began there more than a decade ago, no evidence of a release of any COCs from Pit 9 has been recorded.

Corral Hollow Creek Drainage Area

Pit 6

No new release of designated COCs from Pit 6 is indicated by the compliance monitoring results for 1999. However, a release of benzoic acid, which is not a designated COC,

is suggested by the data. Designated COCs known to have been released to ground water prior to pit closure continued to be detected, but their concentrations either remained steady during 1999, or followed historically decreasing trends.

Quarterly COC measurements were mostly below SLs. The few COC measurements that exceeded SLs were not confirmed by retests. At the time of the fourth-quarter sampling in October 1999, designated COCs were all below their respective MCLs.

During 1998, the VOC, 1,2-dichloroethane (1,2-DCA), exceeded its SL in ground water at well EP6-09 (see **Figure 9-8**). Subsequently, during the fall of 1998, a volume of about 270,000 L of VOC-contaminated water was pumped from well EP6-09. VOCs, including 1,2-DCA and TCE, were removed from the pumped water by air-sparging. Evidence of the success of this action was the subsequent decrease in TCE concentration to below the MCL, and the disappearance of detectable concentrations of 1,2-DCA in the ground water sampled at well EP6-09 during 1999.

The extractable organic compound bis(2-ethylhexyl)phthalate, which is not a designated COC, was detected during 1999 in one upgradient ground water sample at a concentration of 4 µg/L and in two downgradient samples at concentrations of 15 and 24 µg/L. This compound, with an MCL of 4 µg/L, was previously detected in 1998 in four ground water samples at concentrations up to 41 µg/L. The source of this compound is unknown. There is no record of it being placed in Pit 6, but the chemical has been used at Site 300.

The extractable organic compound benzoic acid, which has no MCL, was detected quarterly during 1999 at concentrations up to 75 µg/L in ground water samples from downgradient well K6-19. Of 104 total analyses made since November 1997 in ground water samples obtained throughout Site 300, benzoic acid has been detected in only five ground water samples, all obtained from well K6-19 during 1999. Although the first-quarter detection was not confirmed by two additional retest analyses, the chemical reappeared in increasing concentration during the second, third, and fourth quarters of 1999.

During 1999, tritium activity remained above background and relatively constant in ground water samples from two downgradient wells. The maximum activity recorded was 93.2 Bq/L, which is less than 13% of the 740 Bq/L MCL for tritium in drinking water. Relatively elevated tritium activity is contained within a small volume of ground water adjacent to Pit 6. Continued monitoring of tritium there is being conducted under CERCLA auspices (see Chapter 8 for a CERCLA map of the small tritium plume).

Building 929 Closed HE Burn Facility

Analyses of ground water samples obtained quarterly from the regional aquifer downgradient of the closed HE burn facility show no evidence of contamination from past operation of the facility. Except for the presence of coliform bacteria detected in ground water samples from a new well, W-829-22, the analytical results represent background concentrations of substances dissolved from natural sources in the underlying rocks (see **Figure 9-9**). Monitoring well W-829-22 was newly constructed in 1998. Bacteria may have been introduced during construction. Continued monitoring is necessary to determine their source. Analytical results for 1999 for three of the four wells that are used to monitor the deep regional aquifer are listed in Data Supplement Table 9-34. (A fourth deep well, W-827-04, was dry during 1999.)

As in the past, analyses of ground water samples obtained from the shallower perched ground water beneath the closed facility do show evidence of contamination. Analytical results for 1999 for the two wells that are used to monitor the perched ground water are listed in Data Supplement Tables 9-35. The primary contaminant in the perched ground water is TCE. TCE concentrations up to 310 µg/L were measured during 1999. The perched water has a high total concentration of dissolved substances. Many of the inorganic analytes measured have natural sources in the surrounding rocks. The perched ground water does not contain clearly anthropomorphic chemicals such as pesticides, PCBs, herbicides, or the explosives compounds that were burned at the facility and that are known to exist at shallow depth in the soil above the perched ground water. However, perchlorate was detected in the perched ground water at concentrations up to 21 µg/L, and it may be linked to past operations at the closed burn facility. Similarly, nitrate was measured in the perched ground water at concentrations up to 230 mg/L, and it may be a contaminant from the closed facility above it. CERCLA investigations of perchlorate and nitrate in ground water at Site 300 are in progress.

Water Supply Wells

Analytical results for Site 300 water supply wells 18 and 20 are presented in Data Supplement Tables 9-36 and 9-37. As in past years, TCE was detected below the MCL of 5 µg/L in surveillance ground water samples from well 18 (0.63, and 0.54 µg/L) (see **Figure 9-3**). The source of the TCE has not yet been identified. Methylene chloride was detected at low concentration in two quarterly water samples from well 20. However, both detections were accompanied by similar detections in field blanks or method blanks, which invalidate the results. Gross alpha, gross beta, and tritium activities in water samples from both production wells are very low and are indistinguishable from natural background activities. Barium (62 µg/L) and copper (11 µg/L) were detected once in well 20 water samples during 1999 at concentrations far below their MCLs of 1000 µg/L.

Surface Impoundments

The two leachate collection and removal systems were monitored weekly for the presence of liquids. In 1999, no water was recovered from the leachate collection and removal system. The visual inspections indicate that the impoundment liners did not leak wastewater during 1999. No water has been observed in the leachate collection and removal system since liner repairs were made in 1997. No water was found in five lysimeters, which also indicates that the impoundment liners did not leak wastewater during 1999. Analytical results for all monitored constituents in Site 300 ground water beneath the surface impoundments are contained in the *LLNL Experimental Test Site 300 Compliance Monitoring Report for Waste Discharge Requirements 96-248, Annual/Fourth Quarter Report 1999* (Brown et al. 2000).

The explosive compounds (HMX, RDX, and TNT) and perchlorate are the compounds most indicative of discharges to ground water from the Explosives Process Area surface impoundments. However, prior to 1985, explosives wastewater was discharged into unlined ponds in the vicinity of the surface impoundments, where it infiltrated the soil and some reached ground water. Because of this past practice, it is necessary to discriminate between new releases from the surface impoundments and past releases from the unlined ponds. Analyses of ground water from upgradient monitoring well W-817-01 during 1999 showed HMX concentrations between 8.5 and 17.6 µg/L (see **Figure 9-10**). HMX was not detected above the analytical reporting limit of 1.0 µg/L in any of the ground water samples from the downgradient monitoring wells. Ground water samples from three wells contained detectable concentrations of the explosive compound RDX above the analytical reporting limit of 0.85 µg/L. The ground water samples containing RDX were from upgradient well W-817-01 (from 24 to 54 µg/L) and lower concentrations in downgradient wells W-817-03 and W-817-04. The RDX and HMX originated at closed disposal sites upgradient of the present surface impoundments (Raber and Carpenter 1983, Webster-Scholten 1994). Other explosive compounds or components of explosive compounds, 4-amino-2,6-dinitrotoluene and perchlorate, were detected in upgradient well W-817-01 and in several downgradient wells in this monitoring network. The concentrations observed in the downgradient wells do not exceed their permitted limits, but concentrations of perchlorate exceed the California Department of Health Services' recommended limit of 18 µg/L in drinking water. The remediation of these compounds is discussed in Chapter 8 of this document.

As in the past, ground water concentrations of arsenic and nitrate continued to exceed drinking water MCLs in ground water samples from all the surface impoundment monitoring wells during 1999. Concentrations of both arsenic and nitrate in ground water have historically exceeded their respective MCLs (0.050 mg/L for arsenic and 45 mg/L for nitrate) in this area. Background concentrations of arsenic in ground water monitoring wells upgradient from the surface impoundments have been measured at

concentrations above the drinking water MCL (Webster-Scholten 1994). Although the distribution of arsenic over time and throughout the area suggests a natural source, the occurrence and concentration of arsenic at Site 300 is the subject of a continuing CERCLA study. The remediation of all of these compounds (except for the element arsenic) is discussed in Chapter 8 of this document.

During 1999, all discharges into the surface impoundments were in compliance with discharge concentration limits. See the *LLNL Experimental Test Site 300 Compliance Monitoring Report for Waste Discharge Requirements 96-248, Annual/Fourth Quarter Report 1999* (Brown et al. 2000).

Percolation Pits

During 1999, the percolation pits at Buildings 806A, 827D, and 827E operated normally with no overflows. Standing water was regularly noted in the Building 827C percolation pit inspections, and the pit overflowed during the third quarter. A sample for metals analysis was collected from the overflow water. Ten metals were detected above the analytical reporting limit: aluminum, boron, total chromium, copper, iron, lead, manganese, molybdenum, nickel, and zinc. Water from the overflow infiltrated and saturated the soil surrounding the percolation pit but did not reach a surface water drainage course. Metals data for this overflow event are contained in the *LLNL Experimental Test Site 300 Compliance Monitoring Report for Waste Discharge Requirements 96-248, Annual/Fourth Quarter Report 1999* (Brown et al. 2000).

Sewage Evaporation and Percolation Ponds

All wastewater parameters for the sewage evaporation and percolation ponds complied with permits provisions and specifications throughout 1999, and there were no overflows to the percolation pond.

In June 1999 LLNL performed corrective actions to mitigate odors from the evaporation pond and modified operations to prevent a recurrence (see **Figure 9-11**). The modified operations included raising and maintaining a higher water level in the evaporation pond. LLNL requested permission from the CVRWQCB to operate the pond with reduced freeboard because of the change in operations. All other observations—levee condition, color, and odor—indicated normal operations.

All of the ground water monitored constituents were also in compliance with permitted limits. Nitrate concentrations in downgradient monitoring wells W-26R-01 and W-26R-05 decreased to 33 and 38 mg/L, respectively, during the third quarter. LLNL has not been able to determine the origin of this nitrate, but a sitewide study of nitrate at

Site 300 is continuing, and LLNL continues to monitor these wells and nearby off-site wells for nitrate concentrations (see also Chapter 8).

Off-Site Water Supply Wells

Analytical results for the off-site water supply wells for 1999 are presented in Data Supplement Tables 9-40 to 9-44. Generally, no COC attributable to LLNL activities was detected in the off-site ground water samples. Arsenic and barium were widely detected at these locations, but their concentrations were below MCLs and consistent with natural sources in the rocks. Scattered detections of metals were all below MCLs and were probably related to metals used in pumps and supply piping.

As in past years, TCE was detected at concentrations up to 0.74 µg/L in the ground water samples obtained from well GALLO1 (see **Figure 9-3**). Previous CERCLA remedial investigations concluded that the TCE in the GALLO1 well water was likely caused by a localized surface spill on the property, possibly solvents used to service the private well (Webster-Scholten 1994). (Surveillance monitoring of a similarly sited well, GALLO2, was terminated in 1991 because of contamination from chemicals leaking from the pumping apparatus.) Radioactivity measurements of off-site ground water are all indistinguishable from natural background activities.

Environmental Impacts

The overall impact of LLNL Livermore site and Site 300 operations on off-site ground waters is minimal. With the exception of VOCs being remediated under CERCLA at both sites, current LLNL operations have no measurable impact on ground waters beyond the site boundaries.

Livermore Site and Environs

Ground water monitoring at the LLNL Livermore site and in the Livermore Valley indicates that LLNL operations have minimal impact on ground water beyond the site boundary. (See Chapter 8 for CERCLA remediation activities with VOCs.) During 1999, neither radioactivity nor concentrations of elements or compounds detected in ground water from any off-site monitoring well exceeded primary drinking water MCLs. The maximum tritium activity of 10.5 Bq/L (283 pCi/L), only 1.4% of the MCL, was detected in the ground water sample collected from on-site well W-373 in June (see **Figure 9-2**).

The maximum tritium activity measured off site in the Livermore Valley was even lower, 8.5 Bq/L, in well 11B1 (see **Figure 9-1**).

Of the Livermore on-site monitoring wells, no inorganic data exceeded primary MCLs, with the exceptions of chromium in monitoring well W-373 and nitrate in monitoring well W-1012 (see **Figure 9-2**). Chromium(VI) in ground water in the vicinity of monitoring well W-373 is being removed at Treatment Facilities B and C. The LLNL Ground Water Project reports on the treatment of ground water in the vicinity of the treatment facilities (see Chapter 8). Concentrations of nitrate in ground water samples collected from well W-1012 in June 1999 exceeded California's MCL of 45 mg/L. Nitrate above the MCL has not migrated off site. LLNL continues to monitor this well and monitoring well W-571, which is off site and about 350 meters downgradient from well W-1012, to determine if nitrate at concentrations above the MCL migrates off site.

The arroyo sediment data included in Chapter 10 indicate no potential adverse impact on ground water through the arroyos that cross the Livermore site.

Site 300

Ground water monitoring at Site 300 and adjacent properties in the Altamont Hills shows minimal impact of LLNL operations on ground water beyond the site boundaries.

Within Site 300, the chemicals detected in ground water beneath the High Explosives Process Area will not migrate off site. Plans to remediate TCE, explosive compounds such as RDX, perchlorates, and nitrate are currently being implemented under CERCLA auspices (see Chapter 8). Additionally, LLNL is investigating the distribution and origins of arsenic and zinc in this area.

VOCs, primarily the solvent TCE, have been released historically to shallow ground water at numerous locations at Site 300 (see Chapter 8 and references cited therein). With the exceptions of a small plume in the General Services Area area that extends minimally off site along Corral Hollow Road, all of the TCE-bearing ground water is on site. The plume extending off site from the Eastern GSA area is being drawn back to the site by pumping, and the TCE is being removed from the ground water.

Tritiated water and depleted uranium have been released to ground water from landfills and several firing tables in the northern part of Site 300. The boundaries of the slowly moving ground water plumes lie entirely within the site boundaries. Fate and transport models predict that the tritium will decay naturally to an activity below the drinking

water MCL before the tritium-bearing ground water reaches a site boundary (Webster-Scholten 1994, Taffet et al. 1996).

Maximum uranium activities that could reach potential exposure points (hypothetical ground water supply wells) at the northern boundary of Site 300 are estimated to be 0.08 Bq/L from plumes originating at Pits 5 and 7, and 0.05 Bq/L at the eastern boundary of Site 300 from the plume originating at Building 850. These conservatively estimated maximum activities are small when compared with the 0.74 Bq/L California MCL for uranium in drinking water. The predicted incremental lifetime cancer risks from the released uranium are less than one-in-a-million at the hypothetical exposure points on the Site 300 boundary (Taffet et al. 1996). The VOCs, tritium, nitrate, Freon, perchlorate, and depleted uranium in the shallow ground water beneath Site 300 present no current health risks because the contaminated water is not used for potable domestic, livestock, or industrial water supplies.