8. Routine Ground Water Monitoring at Site 300

Eric Christofferson

Introduction

The LLNL Experimental Test Site (Site 300) is located in the Altamont Hills, about 12 km southwest of the City of Tracy. Routine ground water monitoring at Site 300 includes both surveillance and compliance monitoring. LLNL routinely monitors 56 ground water wells at Site 300 in addition to Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) monitoring associated with areas of known ground water contamination (see Chapter 2 for a summary of CERCLA activities at Site 300). Ground water monitoring at Site 300 includes the analyses of samples taken from water supply wells and from wells constructed for monitoring purposes only.

Sampling of well waters follows standard operating procedures (SOPs) that minimize the effects of sampling on analytical results (Dibley and Depue 1995). Analytical results are reviewed by a Quality Control (QC) chemist and passed to the responsible water analyst. The analyst compares the results with historical data and predicted trends for each well. If unpredicted increases are observed that violate permitted limits, the analyst alerts LLNL management to the potential problem. Because LLNL requires its analytical laboratories to follow stringent quality control procedures, unpredicted results can often be traced to analytical errors or to typographical errors. Sampling is often repeated to confirm unusual results. In most instances, abrupt increases in the concentration, or the activity, of a constituent in ground water samples are not confirmed by repeated sampling and analysis.

Area-wide surveillance monitoring of ground water at Site 300 utilizes 34 wells and 1 spring. Four of the wells are fitted with a total of 10 Barcad sampling devices that monitor multiple water-bearing zones. Ground water surveillance monitoring is required by U.S. Department of Energy (DOE) Orders 5400.1 and 5400.5. DOE provides additional direction on radiological effluent monitoring in *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (U.S. Department of Energy 1991). For ground water surveillance purposes, LLNL determines the number and locations of sampling wells, the constituents to be monitored, the frequency of sampling, and the analytical methods to be used. This allows LLNL to design a comprehensive, cost-effective monitoring program.

Little flexibility is available to LLNL for compliance monitoring of ground water at Site 300, where requirements are specified in two Waste Discharge Requirement (WDR) Orders, issued by the California Central Valley Regional

Water Quality Control Board (RWQCB), and in post-closure monitoring and reporting plans. The WDRs and post-closure plans specify the wells to be monitored, the constituents to be measured, the frequency of measurements, the analytical methodology to be used, and the frequency and form of required reports. The Site 300 compliance monitoring data that are summarized in this chapter were previously submitted to the DOE, the Central Valley RWQCB , and other interested federal agencies and individuals in four quarterly reports and one annual report for year 1995 (Christofferson and MacQueen 1995a, 1995b, 1995c, 1996a, and 1996b). The extensive compliance monitoring data were not tabled again for this report.

Potential contaminants to ground waters were monitored in the vicinity of two landfills, known as Pit 1 and Pit 7, that were closed under the Resource Conservation and Recovery Act (RCRA), and similar monitoring continued during 1995 in the vicinity of two active surface impoundments, where process water is evaporated. The primary objective of compliance monitoring is the early detection of any release of chemicals to ground water from the closed landfills, or from the active process-water evaporation ponds. Compliance monitoring is accomplished by obtaining ground water samples quarterly from 22 monitoring wells and analyzing the samples for specific constituents of concern (COCs) and general contaminant indicator parameters. Typically, quantitative analyses are conducted for those COCs known to have been buried in a particular landfill or contained in process waters that are evaporated in the surface impoundments.

Networks of ground water monitoring wells that are sampled quarterly are the primary means for detecting the release of chemicals from the closed landfills, whereas wells form a tertiary tier of release detection around the process-water surface impoundments. Primary release detection there consists of weekly visual inspections for leachate flow at the outfalls of perforated pipes installed in a layer of sand confined between each impoundment ' s two liners. Each impoundment has an inner impermeable liner of high density polyethylene (HDPE) and an outer impermeable liner of compacted clay. Secondary release detection there consists of quarterly remote operation of lysimeters installed beneath the outer clay liners. It is unlikely that process water from either impoundment could reach the lysimeters, because it would have to breach both liners. However, if this unlikely event did occur, the network of monitoring wells in the vicinity of the evaporation ponds provides a tertiary release detection system and a means of estimating the environmental impact on the ground water.

Surveillance monitoring of ground water at Site 300 uses samples taken from on-site and off-site wells. Depending on their location and purpose, wells are sampled monthly, quarterly, or annually. Ground water samples from wells

are routinely measured for general contaminant indicators, gross radioactivity, radioisotopes, toxic metals, and a wide range of organic chemicals. Typically, surveillance monitoring involves more COCs than does compliance monitoring.

Compliance Ground Water Monitoring at Site 300

Compliance ground water monitoring at Site 300 is governed specifically by two WDR permits, 85-188 and 93-100, (Central Valley RWQCB 1985; 1993) and a RCRA post-closure monitoring and reporting plan (Rogers / Pacific Corporation 1990). Compliance monitoring involves analyses of water samples drawn from 22 wells associated with two RCRA-closed landfills (17 wells) and two active process water impoundments (5 wells). **Figure 8-1** shows the locations of the closed landfills (Pit 1 and Pit 7), the two process water surface impoundments, and the on-site and off-site wells used for surveillance monitoring purposes. A complete description of the stratigraphy and hydrogeologic conditions at Site 300 can be found in the *Final Site-Wide Remedial Investigation Report, Lawrence Livermore National Laboratory Site 300* (Webster-Scholten 1994), hereafter referred to as the Final SWRI report. A brief description of the monitored areas and their associated wells follows.

Pit 1 Area

Figure 8-2 locates Pit 1, monitoring wells, an adjacent closed landfill identified as Pit 2, and the Advanced Test Accelerator (ATA) Building 865 area. Pit 1 lies in the upper part of the Elk Ravine drainage area at an average elevation of 330 m above sea level. Although the test site is a semiarid locale, intense rainfall does occur. In order to combat erosion, rain runoff from the pit cap and surrounding area is collected in a concrete channel that encircles the pit. The outfall is at the southwest corner of Pit 1 where surface runoff flows to Elk Ravine. Subsurface water flow beneath Pit 1 is east-northeasterly and generally follows the dip of the underlying sedimentary rocks. Of eight designated Pit 1 compliance monitoring wells, Wells K1-01C and K1-07 are hydrologically upgradient from Pit 1, Wells K1-02B, K1-03, K1-04, and K1-05 are downgradient; and Wells K1-08 and K1-09 are cross-gradient to this RCRA-closed landfill. Pit 2 was closed before RCRA became effective. Pit 2 is hydrologically upgradient from Pit 1 with respect to subsurface water flow, but it is downslope from Pit 1 with respect to rain runoff into Elk Ravine. The ATA Building 865 area is hydrologically upgradient from Pit 1 monitoring wells K1-05, K1-08, and K1-09 with respect to ground water flow.

The eight Pit 1 monitoring wells are completed near the contact between the Tertiary Neroly Formation lower blue sandstone member and the underlying mid-Miocene Cierbo Formation consisting of claystones and siltstones. The Tertiary Neroly and Cierbo sedimentary rock formations contain the main water-bearing strata beneath the test site.

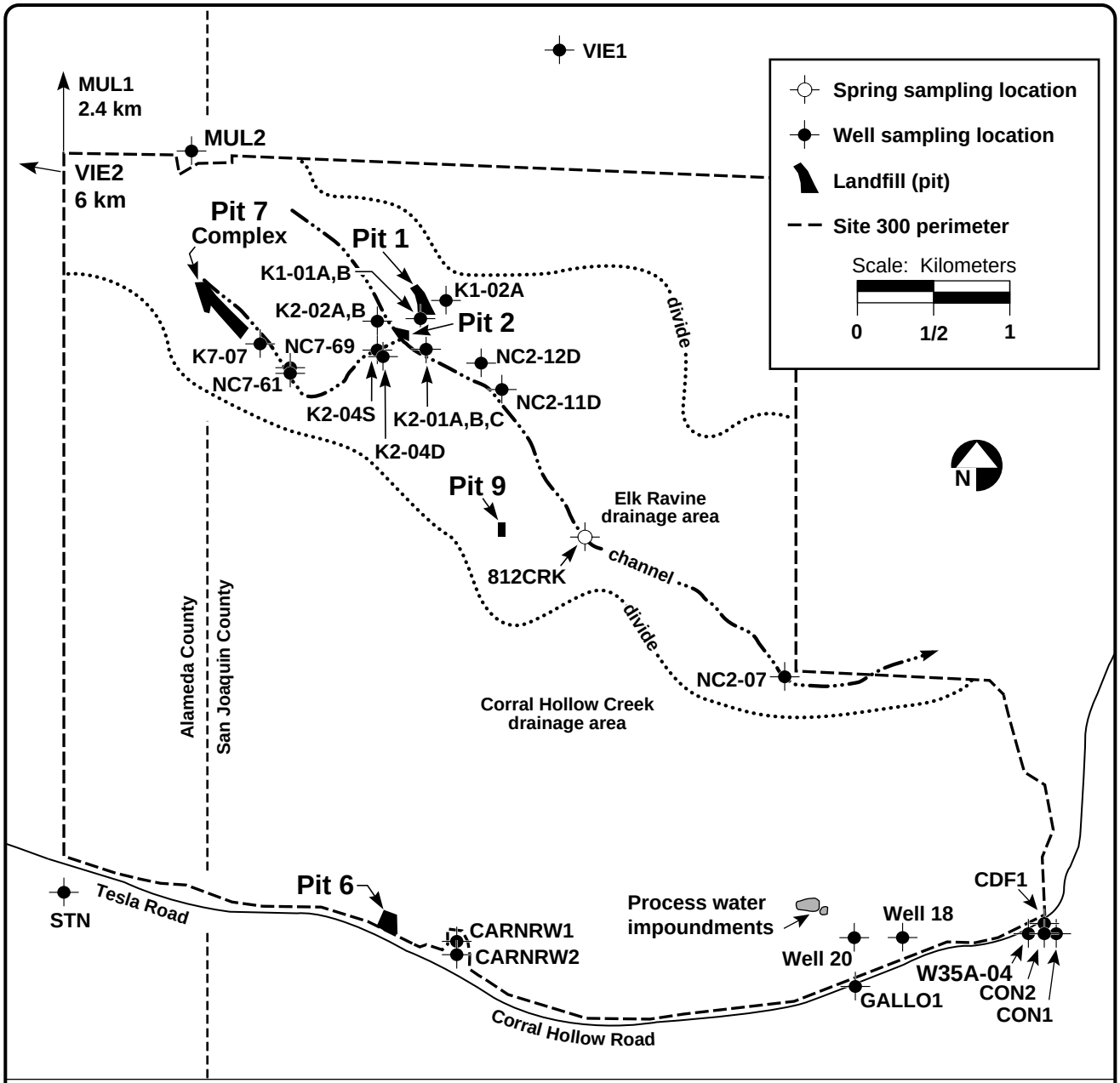

Figure 8-1. Site 300 surveillance wells, spring, impoundments, and closed landfills (pits).

Pit 1 ground water samples were analyzed for constituents fulfilling the requirements of WDR Order No. 93-100 and a post-RCRA-closure monitoring plan (Rogers / Pacific Corporation 1990). Measurements were performed for water table elevation; total dissolved solids (TDS); specific conductance; temperature; pH; metals; high-explosive (HE) compounds (cyclotetramethylenetetramine [HMX], hexahydro-1,3,5-trinitro-1,3,5-triazine [RDX], and

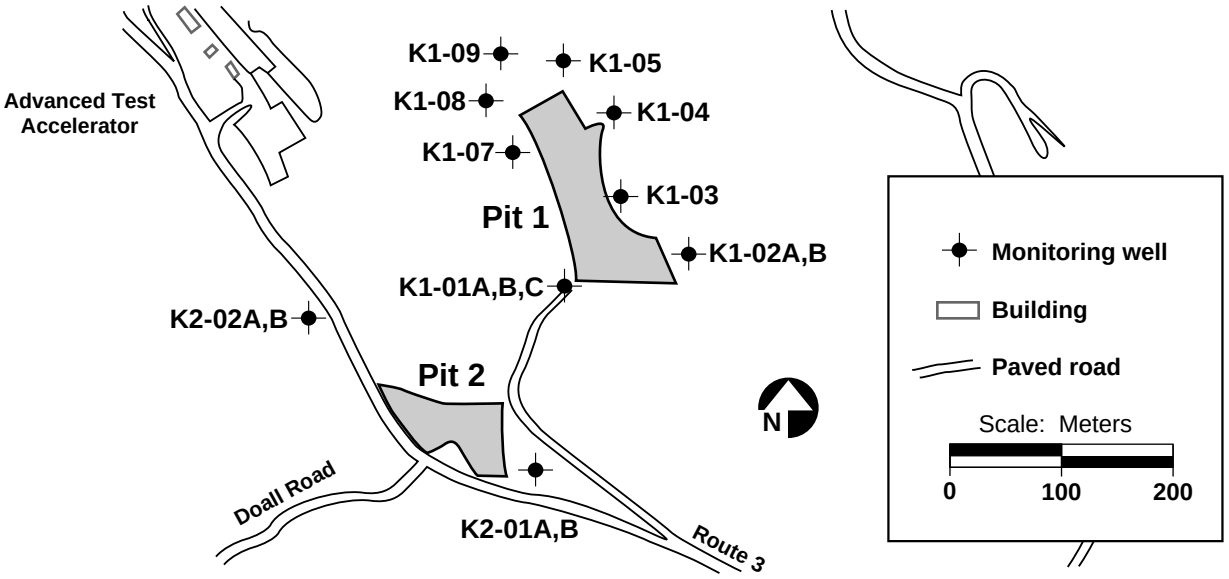

Figure 8-2. Pit 1 compliance wells and Pit 2 surveillance wells.

trinitrotoluene [TNT]); general minerals; total organic carbon (TOC); total organic halides (TOX); radioactivity (gross alpha and gross beta); the radioisotopes tritium (^{3}H), radium (^{226}Ra), uranium (^{234}U, ^{235}U, and ^{238}U), and thorium (^{228}Th and ^{232}Th); herbicides and pesticides (EPA Methods 615 and 608); purgeable organic compounds (EPA Method 624); and extractable organic compounds (EPA Method 625).

Pit 7 Complex Area

Nine designated compliance wells monitor the Pit 7 Complex that consists of three pre-RCRA-closed landfills (Pits 3, 4, and 5), and one RCRA-closed landfill (Pit 7; **Figure 8-3**). The complex of closed landfills is in the Pit 7 Complex Valley, which occupies the uppermost reach of the Elk Ravine drainage area. The average elevation of the pit complex is 425 m. To combat erosion in this area of high relief and to reduce local ground water recharge, rain runoff from the Pit 7 cap is collected in several diversion channels made of concrete. Pit 7 is nearly encircled by a diversion channel that collects rain runoff from the pit cap and directs it southeasterly into the Elk Ravine drainage system. A second diversion channel was constructed on the west side of Pit 7. Runoff entering this northerly directed channel develops on the hillside immediately to the west of the Pit 7 landfill. Subsurface water can flow in two directions through this area. With sufficient seasonal rainfall, a shallow, unconfined, southeastward flow can develop in the unconsolidated surficial Quaternary valley-fill deposits. The predominant ground water flow, however, follows the east-northeasterly dip of

the underlying Tertiary sedimentary rocks of the Neroly and Cierbo formations. With respect to Pit 7 and the predominant flow direction, Well K7-06 is upgradient, Wells K7-09 and K7-10 are cross-gradient, and Wells K7-01, K7-03, NC7-25, NC7-26, NC7-47, and NC7-48 are downgradient. Wells K7-01, K7-10, and NC7-26 are completed in the lower blue sandstone of the Tertiary Neroly Formation that underlies much of the Pit 7 Complex. The remaining wells are completed within the claystones and sandstones of the mid-Miocene Cierbo Formation.

Pit 7 ground water samples were analyzed for constituents fulfilling the requirements of WDR Order No. 93-100 and the monitoring plan for the post-RCRA closure. Measurements were performed for water table elevation; TDS; specific conductance; temperature; pH; metals; general minerals; the radioisotopes tritium (^{3}H), radium (^{226}Ra), uranium (^{234}U, ^{235}U, and ^{238}U), and thorium (^{228}Th and ^{232}Th); HE compounds (HMX, RDX, and TNT); and a wide range of organic chemicals.

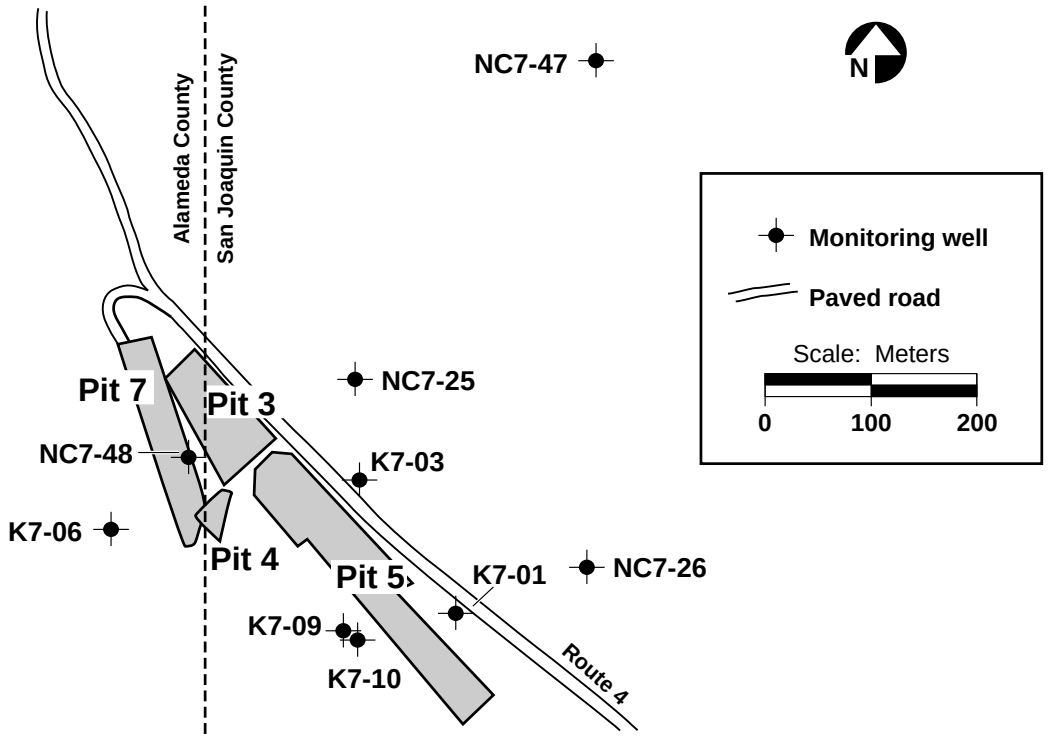

Figure 8-3. Pit 7 Complex compliance wells.

High Explosives Process Area

Figure 8-4 shows the portion of the HE Process Area that includes the two process-water impoundments, their five compliance monitoring wells, and Buildings 815 and 817. Compliance monitoring of the two impoundments is specified in permit WDR Order No. 85-188, issued by the Central Valley RWQCB (1985). Beneath both process water impoundments are systems of perforated pipes whose purpose is leak detection. Seven lysimeters installed at greater depth provide an additional leak detection system. Four of the five compliance monitoring wells are completed in the underlying Neroly upper blue sandstone, a water-bearing formation. The fifth well, W-817-03A, is completed at shallow depth in a nonmarine formation, consisting of unconsolidated sediments and sedimentary rocks, that locally overlies the Neroly Formation. The overlying formation contains a perched water-bearing zone that is very restricted laterally and vertically. The direction of water flow in both formations is approximately southeasterly. Well W-817-01 is hydrologically upgradient with respect to the impoundments, and wells W-817-02, -03, -03A, and -04 are hydrologically downgradient.

Ground water samples were collected quarterly during 1995 from the five compliance monitoring wells in the B-817 HE Process Area. Samples from the four deeper wells completed in the Neroly upper blue sandstone formation were analyzed for metals, general parameters, HE compounds, organic compounds, and tritium. Leachate collection systems were checked weekly for the presence of water, and lysimeters were operated quarterly to extract any water present.

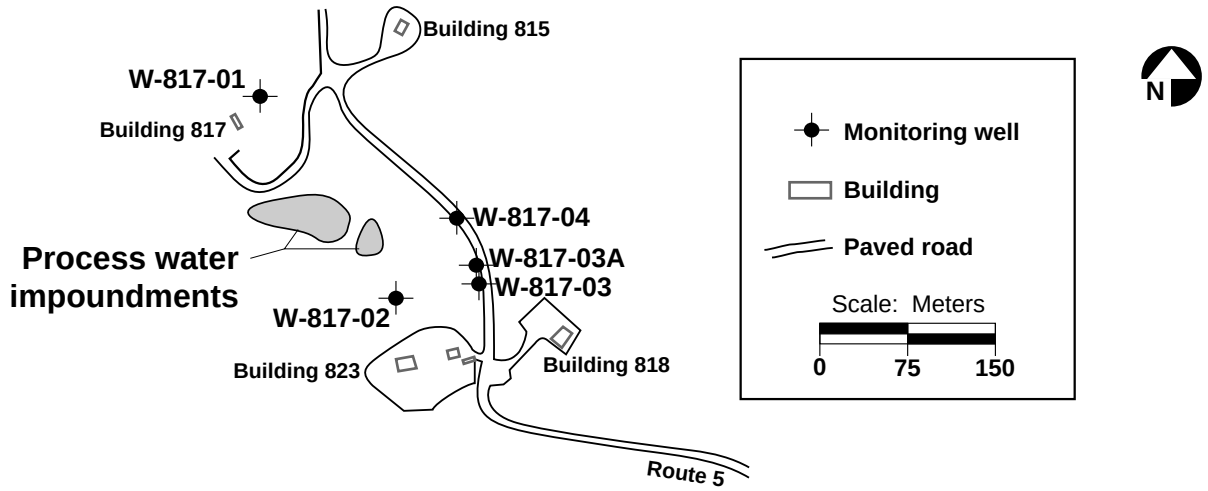

Figure 8-4. HE Process Area compliance wells.

Surveillance Ground Water Monitoring at Site 300

Methods of sampling and analysis are the same for compliance and surveillance monitoring wells, but the COCs and the frequency of sampling may differ. Special consideration is given to monitoring those elements and organic compounds known to be toxic in trace amounts. Analytical methods are selected that have reporting limits at, or lower than the toxic concentrations. Typically, drinking water maximum contaminant levels (MCLs) are referred to when selecting COCs, and EPA-approved analytical methods are used to measure them.

Thirty-four ground water wells and one spring are monitored at Site 300 as part of the ground water surveillance program (**Figure 8-1**). Twenty-two wells are on site and 12 are off site. A surveillance spring, designated 812CRK, is located on site in the Elk Ravine drainage area. Three of the 12 off-site surveillance wells are located north of Site 300, where the Altamont Hills slope down to the San Joaquin Valley. One well, designated VIE2, is located in the Altamont Hills approximately 6 km west of Site 300 in the upper reaches of the Livermore Valley watershed. The remaining eight off-site surveillance wells are located adjacent to Site 300 on the south in the Corral Hollow Creek drainage area. Twelve of the 22 on-site surveillance wells monitor three inactive landfills (closed pits). Six wells monitor Pit 6 (**Figure 8-5**). Four wells monitor Pit 9 (**Figure 8-6**). Three multiple completion wells monitor Pit 2 (**Figure 8-2**). Nine surveillance wells and one spring, designated 812CRK, are located along the system of fault-marked ravines and arroyos that comprise the Elk Ravine drainage area (**Figure 8-1**). Well 20 is a production well that provides potable water to Site 300 (**Figure 8-1**). Well 18 is the backup production well (**Figure 8-1**). The wells are described briefly below. A more complete description of the stratigraphy and the hydrogeologic conditions can be found in the Final SWRI report (Webster-Scholten 1994).

Pit 6

The closed Pit 6 landfill is positioned along the southern boundary of Site 300 at an elevation of 210 m above sea level (**Figure 8-1**). It lies in Quaternary terrace deposits above and north of the Corral Hollow Creek flood plain. The Tertiary Neroly Formation sedimentary rocks underlie the terrace deposits. Surface runoff from the pit area is southward to Corral Hollow Creek. Ground water flow beneath the pit is also southward, following the south-dipping sedimentary rocks of the Neroly Formation. However, the direction of the subsurface flow changes from south to southeast beneath the southern margin of the landfill where the Carnegie Fault has brought vertically dipping strata on the south into contact with gently dipping strata on the north. A deposit of terrace gravel fills a southeasterly trending trough within the vertically dipping strata immediately south of the landfill and acts as a channel for the ground water after it passes beneath Pit 6.

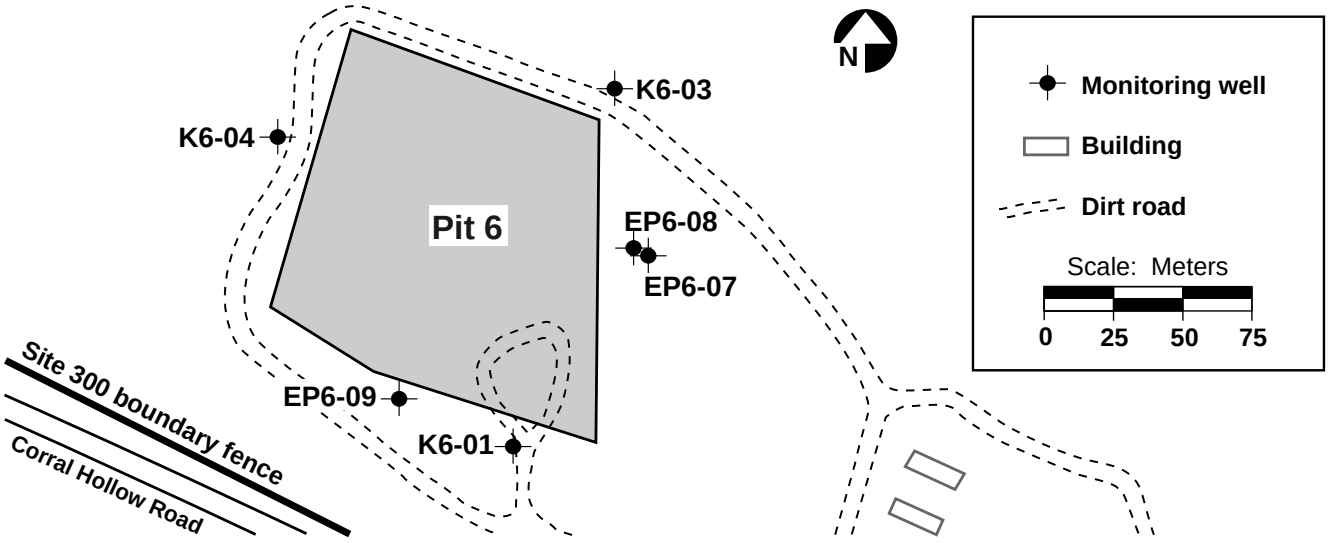

Figure 8-5. Pit 6 surveillance wells.

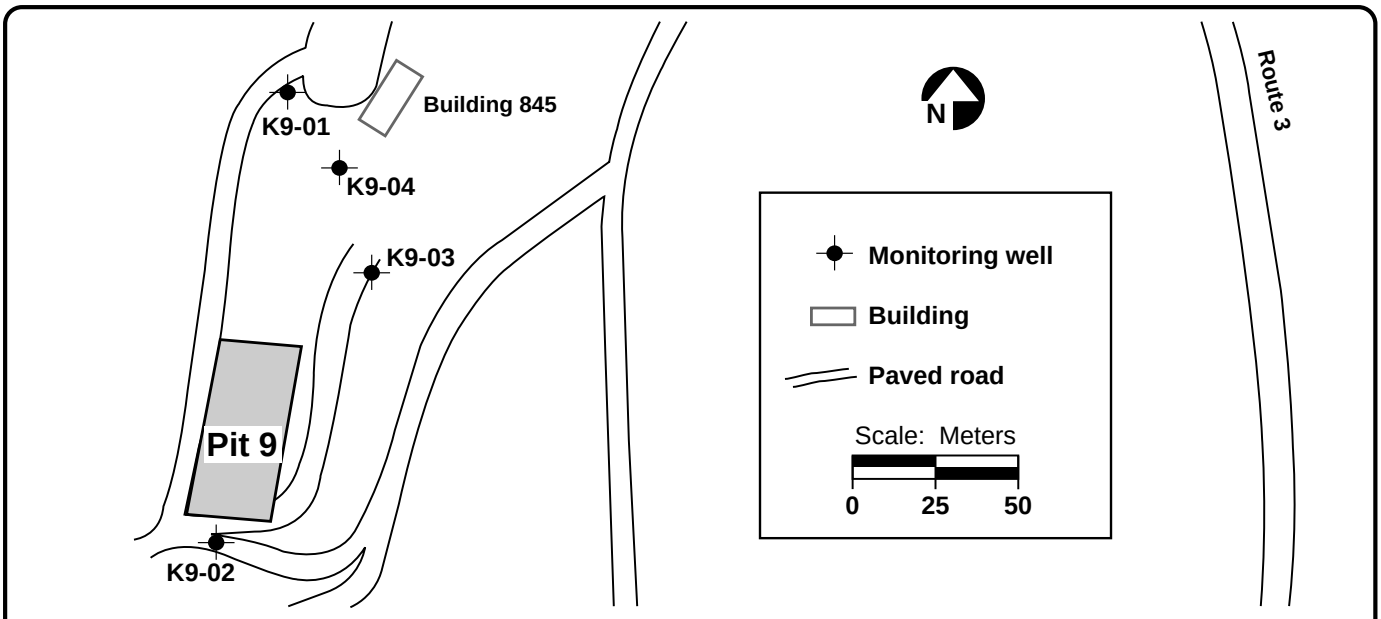

Figure 8-6. Pit 9 surveillance wells.

Six wells comprise the surveillance monitoring network at closed landfill Pit 6 (**Figure 8-5**). Well K6-03 is hydrologically upgradient from Pit 6 and is completed and screened in the gently southward dipping Tertiary Neroly sedimentary rocks. Wells K6-04, EP6-07, and EP6-08 are hydrologically cross-gradient from Pit 6 and are also completed and screened in the south-dipping Neroly sedimentary rocks. The completion interval of Well K6-04 extends upwards into the Quaternary terrace deposits. Wells EP6-09 and K6-01 are hydrologically downgradient from Pit 6 and are completed and screened in the vertically dipping Tertiary sedimentary rocks.

Ground water samples from the Pit 6 surveillance wells were analyzed for metals; toxic organic compounds, HE compounds, radioactivity (gross alpha and gross beta); and tritium (^{3}H).

Pit 2

The inactive Pit 2 landfill lies in the upper portion of Elk Ravine at 320 m above sea level (**Figure 8-2**). Surface runoff from the pit area is southerly into Elk Ravine. Subsurface water flow beneath the pit is east-northeasterly following the dip of the underlying Neroly and Cierbo sedimentary rocks. Multiple completion Well K1-01 (**Figure 8-2**) is completed at three separate depth intervals in the claystone and sandstone mid-Miocene Cierbo Formation. It contains three Barcad sampling devices. Each Barcad samples a discrete water-bearing zone within the Cierbo Formation. The deepest of the three zones is sampled by Barcad K1-01A, the intermediate zone by Barcad K1-01B, and the upper zone by Barcad K1-01C, which serves as one of two upgradient water monitoring points for Pit 1. Surveillance monitoring Wells K2-01 and K2-02 are hydrologically cross-gradient from Pit 2. These are also multiple completion wells and are fitted with Barcad sampling devices. Barcads K2-01A, K2-02A, and K2-02B are completed in the Cierbo Formation. Barcad K2-01B is completed in the lower blue sandstone of the Tertiary Neroly Formation that overlies the Cierbo Formation.

Samples from the Barcad-fitted multiple completion wells were taken quarterly during 1995 and were analyzed for metals; radioactivity (gross alpha and gross beta); and tritium (^{3}H).

Pit 9

Inactive landfill Pit 9 is centrally located within Site 300 at an elevation of 340 m above sea level. Surface runoff from Pit 9 flows northeastward into Elk Ravine. Subsurface ground water flow is also east-northeasterly in the lower blue sandstone of the Neroly Formation. **Figure 8-6** shows the locations of the surveillance monitoring wells with respect to Pit 9. Monitoring Well K9-02 is hydrologically upgradient from Pit 9. Wells K9-01, K9-03, and K9-04 are

downgradient. Well K9-02 is completed and screened in the Neroly lower blue sandstone at its contact with the underlying Cierbo Formation. Wells K9-01, K9-03, and K9-04 are completed and screened in the Cierbo Formation, just below its contact with the Neroly Formation.

Pit 9 surveillance monitoring Wells K9-01, K9-02, and K9-03 were sampled and analyzed once during 1995 for metals; radioactivity (gross alpha and gross beta); the radioisotopes tritium (^{3}H), radium (^{226}Ra), uranium (^{234}U, ^{235}U, and ^{238}U; HE compounds; and toxic organic compounds.

Elk Ravine Drainage Area

The Elk Ravine drainage area includes most of northern Site 300, the area between the drainage divides shown on **Figure 8-1**. This semiarid area collects rare surface runoff into arroyos from inactive landfill Pits 1, 2, 3, 4, 5, 7, and 9. The Pit 7 Complex comprises Pits 3, 4, 5, and 7. Surface runoff from the Pit 7 Complex area flows mainly southeastward to Doall Road, where it is deflected northeastward into Doall Ravine by a landslide deposit. At the northeastern end of Doall Ravine, the runoff combines with channeled runoff from the ATA Building 865 area. From this confluence point, the arroyo trends southeasterly within Elk Ravine. Near Well NC2-07, channeled runoff turns easterly away from the trend of the Elk Ravine fault and flows off site for approximately 2 km to its confluence with Corral Hollow Creek. Except for Doall Ravine, the arroyos traverse and follow faults, especially the extensive Elk Ravine Fault that may provide conduits to the underlying water-bearing Neroly strata. For this reason, ground waters from wells that lie within this drainage network are monitored. The monitored wells are (from highest to lowest elevation) K7-07, NC7-61, NC7-69, K2-04D, K2-04S, K2-01C, NC2-12D, NC2-11D, and NC2-07. The 812CRK sampling location is a natural spring that is designated Spring 6 in the Final SWRI report (Webster-Scholten, 1994). This spring is located in the main Elk Ravine arroyo on the Elk Ravine Fault. Individual wells are discussed below.

Well K7-07 is a shallow well, completed and screened in the upper Neroly lower blue sandstone and the overlying Quaternary alluvium. The well was dry during the first quarter of 1995. Wells NC7-61 and NC7-69 are completed and screened in and sample separate water-bearing zones beneath the upper reach of Doall Ravine, downstream from Well K7-07. Well NC7-61 is completed and screened in the shallower Neroly Formation lower blue sandstone, and Well NC7-69 is completed and screened in the deeper Cierbo Formation. Wells K2-04D and K2-04S and Barcad K2-01C are located near the join between Elk Ravine and Doall Ravine. They are all completed and screened in the upper Neroly Formation lower blue sandstone. Wells NC2-12D and NC2-11D are located in Elk Ravine below its join with Doall Ravine. Well NC2-11D is completed at the boundary between the Cierbo and the overlying Neroly formations.

NC2-07 is the furthest downstream surveillance well in the Elk Ravine drainage area. It is completed in the Neroly Formation lower blue sandstone.

Ground water samples from the Elk Ravine surveillance wells and the spring, 812CRK, were analyzed quarterly for metals; radioactivity (gross alpha and gross beta); tritium (^{3}H); HE compounds; and toxic organic compounds.

Wells 18 and 20

Well 20 supplied potable water at Site 300 during 1995, while Well 18 was maintained as a standby water supply well. The wells are located in the south-eastern part of Site 300 (**Figure 8-1**). Both are deep, high-production wells that are completed in the Tertiary Neroly Formation lower blue sandstone. The Well 18 completion zone extends upwards into an aquitard above the lower blue sandstone. The wells can produce up to 1500 L / min of water. Additional geologic and hydrogeologic information regarding these wells is contained in the Final SWRI report (Webster-Scholten 1994).

Ground water samples from the two on-site water supply wells were analyzed quarterly for metals (except Well 18); toxic organic compounds; radioactivity (gross alpha and gross beta); and tritium (^{3}H). Well 18 samples were analyzed once during 1995 for HE compounds.

Off-Site Supply Wells

Ground water samples from 12 off-site water-supply wells were analyzed during 1995 as part of the surveillance monitoring program. Eleven wells are adjacent to Site 300. The most distant well, VIE2, is located 6 km west of the site. Three wells—MUL1, MUL2, and VIE1— are adjacent to the site on the north, and eight wells, CARNRW1, CARNRW2, CDF1, CON1, CON2, GALLO1, STN, and W-35A-04, are adjacent to the site on the south (**Figure 8-1**). Wells CARNRW2, GALLO1, STN, and VIE2 supply water for human consumption.

Ground water samples from six wells were analyzed quarterly during 1995. Of these, CARNRW1 and CON2 were analyzed for toxic organic compounds, while CARNRW2, CDF1, CON1, and GALLO1 were analyzed for metals; HE compounds; toxic organic compounds; radioactivity (gross alpha and gross beta); and tritium (^{3}H). The remaining six wells—MUL1, MUL2, STN, VIE1, VIE2, and W-35A-04—were analyzed once during 1995 for metals; HE compounds; toxic organic compounds; radioactivity (gross alpha and gross beta); and tritium (^{3}H).

Results

This section presents the results of ground water measurements at Site 300 in the Pit 1 area, Pit 7 Complex area, HE Process Area, Pit 6 area, Pit 2 area, Pit 9 area, Elk Ravine drainage area, on-site water-supply wells, and off-site water-supply wells.

Pit 1 and Pit 7 Complex Areas

A major compliance monitoring effort was completed during 1995 that improved the statistical methods used to detect chemical releases from landfills Pit 1 and Pit 7. As a result of the work, LLNL petitioned the Central Valley RWQCB to revise the monitoring and reporting requirements of WDR 93-100 (Galles 1995; Hoppes 1995). New statistical concentration limits for COCs in ground water were proposed in order to reduce the number of false positive detections, together with their special reporting requirements. Special reporting is required when a COC exceeds its statistical concentration limit (see Chapter 14, Compliance Self-Monitoring, for COC limits and discussion). LLNL has reported statistically significant evidence for the release of several metallic and radioactive COCs from Pit 1 and Pit 7 since the WDR 93-100 and the RCRA post-closure monitoring plans were implemented in 1993. LLNL reviewed the ground water data for all COCs in 1995 and found additional statistical evidence for releases of arsenic, cadmium, copper, nickel, zinc, and radium-226 from Pit 7, and barium from Pit 1.

Table 8-1 lists the COCs that have shown statistically significant evidence of release, the associated landfill (Pit 1 or Pit 7), the date the statistical evidence was reported by letter to the RWQCB, and the status of their CERCLA investigation. LLNL established a CERCLA evaluation monitoring and assessment program that covers the Building 850/Pit 7 Complex Operable Unit and Pit 1 to determine if the COCs had been released to ground water as suggested from statistical analysis. LLNL completed the assessments of uranium isotopes (Pits 1 and 7), tritium (Pit 7), barium (Pit 7), vanadium (Pit 7), and lead (Pit 7) during 1995. The results of these studies were presented to the CERCLA Remedial Program Managers (RPMs) in February 1996 (Taffet et al. 1996).

The CERCLA uranium characterization was completed in 1995. It included ground water sampling and analysis for uranium isotopes, additional sampling and uranium analysis of soil and rock, fate and transport modeling, and a risk assessment (Taffet et al. 1996). Uranium activities in excess of the 0.74 Bq/L (20 pCi/L) MCL had been measured sporadically in the past in ground water samples from wells NC7-25 and NC7-48. Evidence of a manufactured form of uranium, called “depleted uranium,” or "D-38," from which most of the ^{235}U isotope had been removed, was first reported to the RWQCB in 1993 for a ground water sample from well NC7-48 (Christofferson et al. 1993). Subsequently, mass spectroscopy detected D-38 (99.8% ^{238}U) in ground water samples from other monitoring wells in the vicinity of the Pit 7 Complex and in the vicinity of the Building 850 firing table. The CERCLA study identified Pit 5, Pit 7, and the Building 850 firing table as the likely sources of the depleted uranium in the ground water (Taffet et al. 1996). The D-38 release is confined to two relatively small volumes of ground water, one spreading from the Pit 7 Complex and the other spreading from the Building 850 firing table. (Mass spectroscopic analyses showed no D-38 in ground water samples from the Pit 1 area.)

Table 8-1. Pit 1 and Pit 7 Constituents of concern showing “statistical evidence of release."

Constituent of concern	Pit	Reported to RWQCB	Status of CERCLA investigation
Metals			
Arsenic	1	6/3/94	In progress
Arsenic	7	10/17/95	In progress
Barium	1	10/17/95	In progress
Barium	7	11/9/93	Completed
Cadmium	7	10/17/95	In progress
Copper	7	10/17/95	In progress
Lead	7	2/17/94	Completed
Nickel	7	10/17/95	In progress
Vanadium	7	6/3/94	Completed
Zinc	7	10/17/95	In progress
Radioisotopes			
Radium-226	7	10/17/95	In progress
Tritium	7	11/9/93	Completed
Uranium	1	2/17/94	Completed
Uranium	7	9/10/93	Completed

Tritium activities during 1995 continued above the 740 Bq/L drinking water MCL in ground water samples from downgradient monitoring Wells K7-01, K7-03, and NC7-25. The highest tritium measured in 1995 was 10,175 Bq/L in a second-quarter sample from monitoring Well NC7-25. This activity is 14 times the MCL. However, none of the wells in this area supplies water for purposes other than monitoring.

The CERCLA tritium characterization, which extended from January 1993 to June 1995, included the collection of 1288 ground water samples and their analysis for tritium activity by scintillation counting. Three overlapping plumes of tritium-bearing ground water were found in the Pit 7 Complex Area and their sources were identified to be Pit 3 and Pit 5 in the Pit 7 Complex Area and Building 850 (Taffet et al. 1996). As a result of the CERCLA investigation, the tritium activity measured since 1989 in water samples from the Pit 1 down-gradient monitoring well K1–02B is now clearly associated with the plume

from Building 850. No evidence was found for a tritium release from either Pit 7 or Pit 1.

The CERCLA characterization of barium, vanadium, and lead, included the collection of 1288 ground water samples and their analysis for the concentrations of these metals. The CERCLA investigation concluded that barium and lead may have been released from the Pit 7 Complex landfills, but the occurrence of vanadium in the ground water is most likely natural (Taffet et al. 1996). All three of these metals show concentrations well within the ranges encountered in natural waters in the Coast Range and Great Valley Physiographic provinces, and none exceeded California MCLs for drinking water. Although statistical evidence for the release of lead from Pit 7 was reported (**Table 8-1**), retesting did not confirm a continuous presence. Lead detections occurred infrequently and inconsistently in ground water samples taken from the monitoring wells at Site 300. Lead (primarily from leaded gasoline combustion) has been deposited everywhere and extraordinary measures must be taken to prevent its introduction into water samples at the time of sampling and at the analytical laboratory. The infrequent and inconsistent detections of lead in Site 300 ground water samples most likely comes from this source. To overcome these troublesome lead detections, a validation procedure involving additional sampling and analysis has been implemented.

Of the wide range of analyses that are called for annually in the RCRA post-closure monitoring plan, only phenol, Freon 113, and di-n-butylphthalate were detected in several Pit 1 ground water samples, while quarterly monitoring of the Pit 7 Complex Area detected trichloroethene and 1,1-dichloroethene in samples from several monitoring wells. None of these compounds is associated with a release from either landfill and, except for phenol and di-n-butylphthalate, their sources have been identified (Webster-Scholten 1994; Taffet et al. 1996). The compound 1,1,2-trichloro-1,2,2-trifluoroethane, known as Freon-113, was detected far below the California State Action Level of 1200 μg/L in ground water samples from Wells K1-05, K1-08, and K1-09. However, Pit 1 has no record of Freon disposal. The Pit 1 wells that yield ground water samples containing this Freon compound are also downgradient from the ATA Building 865 area (**Figure 8-3**) where a Freon spill to ground is known to have occurred. The detections of low concentrations of phenol and di-n-butylphthalate near their detection limits are believed to result from unclean sample bottles, or analytical methodology, or both (Christofferson and MacQueen 1996b). To overcome troublesome phenol detections in Site 300 ground water samples, we have discontinued the use of EPA Method 420.1 for total recoverable phenols and will rely on EPA Method 625 that measures individual phenol concentrations.

HE Process Area

Two Class II surface impoundments are located at Site 300 in the HE Process Area. During 1995, they received process water that evaporated to the atmosphere. The adjacent impoundments were constructed at slightly different elevations and are connected by an overflow pipe. Normally, process water flows into the upper impoundment. When the process water reaches a fixed height, it flows into the lower impoundment. Leak detection systems, consisting of perforated pipes, are installed in a layer of permeable sand that is sandwiched and confined between an inner liner made of high density polyethylene (HDPE) and an outer liner made of impermeable clay. The pipes were installed on top of the clay liner. The clay liners were graded to provide optimum capture and transport of process water should a leak occur in the inner HDPE liners.

As required by WDR 85-188, the pipe outfalls were checked weekly during 1995 for the presence of leachate. In June, during a routine visual inspection, water was detected dripping into the lower impoundment from a leachate collection pipe installed beneath the upper impoundment. Analysis of the water confirmed that it was process water. It contained 55 ppb of HMX, an HE compound. The process water flow continued through 1995 at a variable rate of 2 to 30 L / day, averaging 15 L / day. Upon detection of the flow, LLNL took immediate action and diverted process water inflow to the lower impoundment. An electrical survey method was used to locate three leak points in the HDPE liner. The upper impoundment was emptied and the HDPE liner was repaired in December. The impoundment was then returned to normal operation.

No water was recovered during 1995 from lysimeters installed in the vadose zone directly beneath the outer clay liners of the impoundments. The absence of any water in the lysimeters indicates that the leaked process water remained confined to the space between the inner HDPE liner and the outer impermeable clay liner of the upper impoundment. The water flow from the leachate collection system is expected to continue until the process water stored in the confined sand layer is exhausted. LLNL makes weekly measurements of the flow rate to detect increases that would signify renewed leaking of the upper impoundment 's HDPE liner.

Ground water monitoring results confirm the lysimeter results. Monitoring data do not indicate that any of the process water was released to the ground water in the vicinity of the impoundments. The leaked process water was characterized by the presence of HMX and the absence of RDX, another HE compound, whereas the downgradient monitoring well samples contained RDX, but not HMX. The upgradient monitoring well samples showed both HMX and RDX. These results appear confusing, but the situation is explained fully in the Final SWRI report (Webster-Scholten 1994). The HE compounds presently found in the ground water were introduced by process water infiltration before 1985 when the two

surface impoundments with impermeable liners were placed in operation. Prior to 1985, unlined impoundments were used to dispose of process water.

During 1995, several COCs in ground water samples from the impoundment monitoring wells exceeded California drinking water MCLs. These were arsenic, selenium, nitrate, and trichloroethene (TCE). The maximum values measured during 1995 were: 65 ppb for arsenic (MCL = 50 ppb); 89 ppb for selenium (MCL = 50 ppb); 110 ppm for nitrate (MCL = 45 ppm); and 56 ppb for TCE (MCL = 5 ppb). Drinking water MCLs are used only for reference. The wells in this area are used only for monitoring purposes. Arsenic and selenium in the ground water are believed to result from dissolution of arsenopyrite and mafic minerals found naturally in the volcaniclastic Neroly upper sandstone (Webster-Scholten 1994, Raber and Carpenter 1983). The elevated nitrates in the ground water samples are likely due to natural sources and, possibly, to anthropogenic sources. The TCE source has been identified to be hydrologically upgradient from the process-water impoundments in the vicinity of Building B-815 (Webster-Scholten 1994; **Figure 8-4**).

Pit 6

COC data for the six Pit 6 monitoring wells are presented in Volume 2, Tables 8-3 through 8-8. Metals analyses of Pit 6 monitoring well samples showed mostly non-detections and none was above its MCL. Arsenic, barium, manganese, and selenium were detected at concentrations consistent with natural concentrations in the area ground water (Webster-Scholten 1994).

Of the organic compounds analyzed for, only the solvent TCE was detected above its 5 ppb MCL at 28 ppb in one monitoring well, EP6-09 (Volume 2, Table 8-8). Well EP6-09 lies within a shallow plume of TCE-bearing water that extends 100 m to the east of Pit 6. Computer modeling of TCE movement eastward in the ground water conservatively predicts that a maximum TCE concentration of 1 ppb will be reached in 60 years in the CARNRW2 water supply well (**Figure 8-1**). The extent of TCE in the Pit 6 area and its eastward movement are fully described in the Final SWRI report (Webster-Scholten 1994).

The radioactivity and radioisotope measurements of ground water samples from the Pit 6 area wells were low and were indistinguishable from natural background activities. No activity measurement was above EPA drinking water MCLs. Although glove boxes are known to have been buried in the landfill, no evidence for the release of radioisotopes to ground water has been uncovered.

Pit 2

COC data for the seven Pit 2 monitoring well Barcads are presented in Volume 2, Tables 8-9 through 8-15. Of the metals, arsenic, barium, cadmium, chromium and selenium were measured at least once above detection limits. Two arsenic measurements in ground water samples from Barcad K2-02A exceeded the 0.050 mg/L MCL for arsenic in drinking water. The metal concentrations are all within the range of natural background concentrations found in the ground water at Site 300 (Webster-Scholten 1994). Analysis indicated that none of the metals measured were released from the closed landfill.

The radioactivity and radioisotope measurements show only low background activities for gross alpha, gross beta, and tritium. However, although tritium activities in samples from Barcad K2-01B are barely detectable, they are elevated relative to the activities measured in samples taken from the other six Barcads in this area. This relatively elevated activity defines the boundary of a plume of tritium-bearing water flowing into the Pit 2 area from an identified source 1 km to the west near Building 850 in the West Firing Area (Webster-Scholten 1994; Taffet et al. 1996). The incursion of this tritium-bearing water into the Pit 2 area is also recorded in Barcad K1-02B ground water samples. That Barcad is a downgradient monitoring point for RCRA-closed landfill Pit 1 (**Figure 8-2**). The plume appears to be confined to the lower blue sandstone within the Neroly Formation in the vicinity of Pit 2 and Pit 1.

Pit 9

COC data for the four Pit 9 monitoring wells are presented in Volume 2, Table 8-16. All of the toxic organic compounds measured were below reporting limits. All metals, general minerals, and radioisotope measurements were indistinguishable from normal background concentrations. Tritium activity of 5.1 Bq/L in the farthest downgradient monitoring well K9-01 sample was relatively elevated. It may represent the elevated background activity that marked the period of atmospheric testing of nuclear weapons. A source of tritium in the area of Building 845 is also suggested (**Figure 8-6**). A maximum tritium activity there of 11,470 Bq/L was measured in subsurface soil and rock moisture (Webster-Scholten 1994). There is no indication that Pit 9 has released any chemicals or radioisotopes to the ground water.

Elk Ravine Drainage Area

Surveillance ground water monitoring in the Elk Ravine drainage area included analyses of samples from the wells listed below. Detailed analyses on ground water samples from the Elk Ravine drainage area surveillance monitoring wells during 1995 are given in Volume 2, Tables 8-17 through 8-26.

Well K7-07

Well K7-07 was dry during the first quarter of 1995. Analyses conducted on ground water samples for the remaining three quarters show a few detections of metals, but they are far below MCLs. No HE compounds or toxic organic compounds were detected. Fourth quarter gross alpha was 0.94 Bq/L, above the 0.56 Bq/L MCL for drinking water. This relatively elevated alpha measurement may be related to a small plume of uranium-bearing water located immediately to the north and northwest of well K7-07 in the direction of the Pit 7 Complex (Taffet et al. 1996).

Wells NC7-61 and NC7-69

Analyses detected a few metals far below MCLs. No HE compounds or toxic organic compounds were detected in either well above reporting limits.

Of the radioactivity and radioisotope measurements, Well NC7-61 samples showed elevated tritium. The mean of the four quarterly tritium measurements is 6975 Bq/L. The mean activity is about 9 times the 740 Bq/L drinking water MCL for tritium. The mean is down 7.7% from the 1994 mean of 7560 Bq/L. The decay of tritium (which has a half-life of 12.3 years) accounts for 5.5% of this decrease. The remaining 2.2% decrease is most likely due to the diffusion of tritiated water (HTO) molecules as the tritium-bearing water moves downgradient. The HTO in the Neroly lower blue sandstone at the location of Well NC7-61 comes from three sources; Pit 3, Pit 5, and the firing table at Building 850 (Webster-Scholten 1994; Taffet et al. 1996). As in previous years, HTO in the underlying Cierbo Formation was very low, less than 0.1 Bq/L, as measured in Well NC7-69 ground water samples. The marked difference in tritium activity between ground water samples from these two wells shows that the tritium-bearing water plume remains confined to the Neroly lower blue sandstone in this area.

Wells K2-04D, K2-04S, and K2-01C

Analyses detected a few metals far below MCLs. No HE compounds or toxic organic compounds were detected in these wells above reporting limits.

One gross alpha measurement of 0.85 Bq/L in a ground water sample obtained May 16 from Barcad K2-01C exceeded the 0.56 Bq/L drinking water MCL. Uranium isotope measurements were made by alpha and mass spectroscopy on duplicate ground water samples obtained from this well on March 28. The alpha spectroscopy result for total uranium activity was 0.94 Bq/L. The mass spectroscopy result was 0.69 Bq/L for total uranium activity. Although the alpha

activity in ground water samples from this well can thus be attributed to dissolved uranium, alpha and mass spectroscopy gave different results with regard to the mix of uranium isotopes present. Alpha spectroscopy indicated natural uranium, based on an activity ratio of ^{234}U to ^{238}U of 1.22. Mass spectroscopy suggested that a small amount of D-38 (3%) could be mixed with 97% natural uranium, based on a mass ratio of ^{235}U to ^{238}U of 0.00685.

Elevated tritium activity relative to background was measured in all three wells. The average tritium activity in Well K2-04D was 540 Bq/L; in Well K2-04S, 1227 Bq/L; and Well K2-01C, 227 Bq/L. These wells are located within a plume of tritium-bearing ground water in the Neroly lower blue sandstone that extends beneath Doall Ravine to Elk Ravine and Pit 1. The source of the plume is the firing table at Building 850 in the West Firing Area (Webster-Scholten 1994; Taffet et al. 1996).

Wells NC2-11D and NC2-12D

Arsenic, selenium, and vanadium were detected in samples taken from these two wells. These elements occur naturally in the sediments and sedimentary rocks at Site 300. Both gross alpha and gross beta activity measurements were below drinking water MCLs. Tritium was elevated relative to background in the samples from these wells. These wells are located near the leading edge of the plume of tritium-bearing ground water that is moving slowly northeast in the Neroly Formation beneath Elk Ravine (Webster-Scholten 1994; Taffet et al. 1996).

812CRK

Arsenic, barium, selenium, and vanadium were detected below MCLs in samples from this spring in the Elk Ravine arroyo. No HE compounds were detected above reporting limit. One sample produced the first ever detections of PCE and TCE for this spring. However, additional sampling and analysis did not confirm the presence of these two solvents. Measurements for gross alpha, gross beta, and tritium were all low and were indistinguishable from background activities at Site 300. The spring lies beyond the influence of the tritium plume that has affected the ground water in Elk Ravine upgradient of the spring.

Well NC2-07

No organic constituents of concern were detected in the samples taken in 1995. Gross alpha and gross beta measurements were low and cannot be distinguished from background activities in the Neroly Formation. Tritium measurements

were also very low. This well is downgradient from the slowly moving plume of tritium-bearing ground water, discussed above.

Water-Supply Wells 18 and 20

COC data for the two on-site potable water supply wells are presented in Volume 2, Tables 8-27 and 8-28. No metals of concern were detected in Well 20 during 1995, except zinc at 53 ppb in the first quarter water sample. As in past years, the organic solvent TCE was detected in Well 18 near the reporting limit. TCE concentrations of 0.2 ppb, 0.4 ppb, and 0.5 ppb were measured during 1995. The highest concentration, 0.5 ppb, is 10% of the 5 ppb MCL for TCE in drinking water. (First quarter 1996 measurements have been received, and TCE in the Well 18 ground water sample was below the reporting limit of 0.2 ppb using EPA Method 502.2.) The source of the TCE in Well 18 has not been determined. The radioactivity and tritium activity in water samples from both wells were very low and indistinguishable from natural background activities.

Off-Site Supply Wells

COC data for the 12 water supply wells are presented in Volume 2, Tables 8-29 to 8-35. Some metallic and organic COCs were detected in these wells, but they were far below drinking water MCLs. Well CON1 water samples exceeded the secondary (aesthetic) drinking water MCL of 50 µg/L for manganese.

As in the past, low concentrations of trihalomethanes (THMs) were detected in water samples from the CARNRW2 well. The THMs were far below drinking water MCLs for these compounds. The THMs resulted from chlorination of the well water.

TCE was reported near the reporting limit of 0.2 µg/L in the ground water samples taken from the GALLO1 surveillance well during 1995. Four similarly low detections were measured in ground water samples from this well during 1994. The GALLO1 well is hydrologically upgradient from identified areas of TCE contamination at Site 300 . A study of the GALLO1 well is included in the Final SWRI Report (Webster-Scholten 1994). It was determined that the low concentration of TCE in the well is most likely due to a localized surface spill on the property, possibly from solvents used on a pump truck or another vehicle used to service the private well.

All radioactivity and tritium activities in ground water samples from the off-site surveillance wells were low and indistinguishable from natural background activities in the Site 300 area.

Environmental Impacts

Site 300

Compliance and surveillance monitoring at Site 300 and adjacent properties in the Altamont Hills leave little doubt that the impacts of LLNL activities are minimal on ground water beyond the site boundaries.

During 1995, tritium activities in three Pit 7 downgradient monitoring wells continued to exceed the U.S. and California drinking water MCL of 740 Bq/L. Fate and transport modeling of the tritium-bearing ground water plumes at Site 300 indicates that the tritium will rapidly disappear by radioactive decay to an activity below the MCL before it reaches a site boundary (Webster-Scholten 1994). None of the tritium-bearing ground water is used for agriculture or for consumption by animals and people; therefore, it presents no health risk.

Minor and localized on-site releases of depleted uranium to ground water have occurred in the past from the closed landfills Pit 5 and Pit 7 and from the Building 850 firing table in the West Firing Area (Taffet et al. 1996). Maximum estimated ground water uranium activities that could reach potential exposure points (hypothetical ground water supply wells) are 0.08 Bq/L at the northern boundary of Site 300 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 activities are 10% or less of 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 ground water supply wells on the Site 300 boundary (Taffet et al. 1996).

Ground water data from Pit 1 indicate that the RCRA-closed landfill did not release any potential contaminants to the ground water during 1995.