Environmental Functional Area

Water, Air, Monitoring & Analysis

UCRL-AR-132057-11-4

Lawrence Livermore National Laboratory (LLNL) Experimental Test Site (Site 300)

Compliance Monitoring Program for the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)-Closed Pit 6 Landfill

Fourth Quarter/Annual Report for 2011

Authors

Richard G. Blake
John E. Valett

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Summary

This monitoring report is required by the *Post-Closure Plan for the Pit 6 Landfill Operable Unit, Lawrence Livermore National Laboratory, Site 300* (Ferry et al., 1998). It summarizes post-closure compliance activities performed at the closed Pit 6 landfill during the fourth quarter of 2011. Compliance requirements for Pit 6 are also described in *Compliance Monitoring Plan/Contingency Plan for Environmental Restoration at Lawrence Livermore National Laboratory, Site 300* (Dibley et al., 2009) and the *Site-Wide Record of Decision for Lawrence Livermore National Laboratory, Site 300* (U.S. DOE, 2008). Results from quantitative analyses by state-certified analytical laboratories of chemical constituents of concern in ground water samples are summarized in the report and listed in the appendices.

Constituents of concern measurements made during the fourth quarter for 2011 did not differ significantly from past quarters. Tritium exceeded its statistical limits (SLs) in one downgradient detection monitoring program (DMP) well and all other constituents of concern were below the SLs. SLs for tritium were previously exceeded in samples collected from some ground water wells near the Pit 6 landfill. These elevated tritium activities have been previously reported to the Central Valley Regional Water Quality Control Board (CVRWQCB). As stated in previous reports, it is likely that the elevated tritium concentrations detected in ground water samples at Pit 6 are related to past releases from the landfill prior to its closure in 1998.

During 2011, the annual Pit 6 visual inspection was conducted in the second quarter on April 18, and the annual Pit 6 engineering inspection was conducted on April 26. No deficiencies were noted in either the visual or engineering inspection. In addition, the annual pit cap permanent marker elevation survey was conducted in the third quarter by an LLNL licensed surveyor. No notable elevation changes were observed compared to the 2010 survey and the pit cap and drainage structures continue to function properly.

Introduction

Site 300 is the LLNL Experimental Test Facility located in the Altamont Hills approximately 10.5 kilometers (km) (6.5 miles [mi]) southwest of downtown Tracy, California (**Figure 1**). Site 300 is owned by the United States Department of Energy (U.S. DOE) and is an approximately 28.3 km^2 (10.9 mi^2) area site operated by Lawrence Livermore National Security, LLC. The closed Pit 6 landfill is located within Site 300 near its southern boundary (**Figure 2**). A post-closure plan requiring quarterly and annual reports of compliance monitoring activities at the Pit 6 landfill (Ferry et al., 1998) was implemented during the second quarter of 1998.

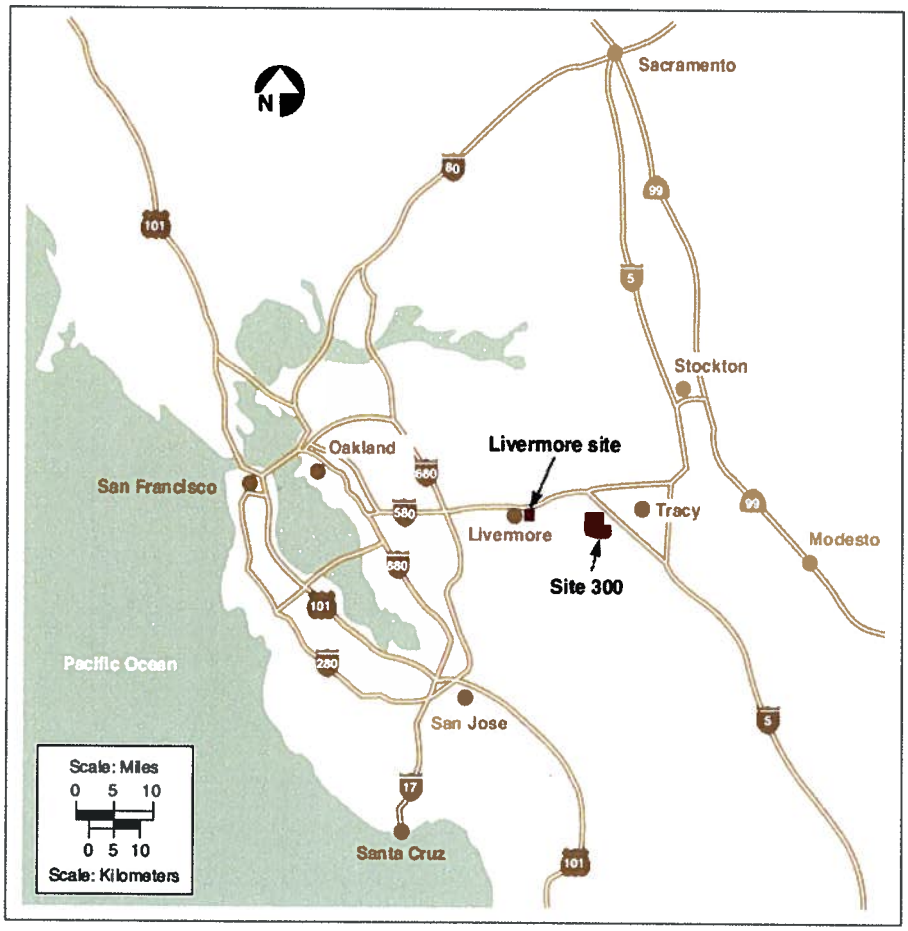

Figure 1. Location of LLNL Site 300.

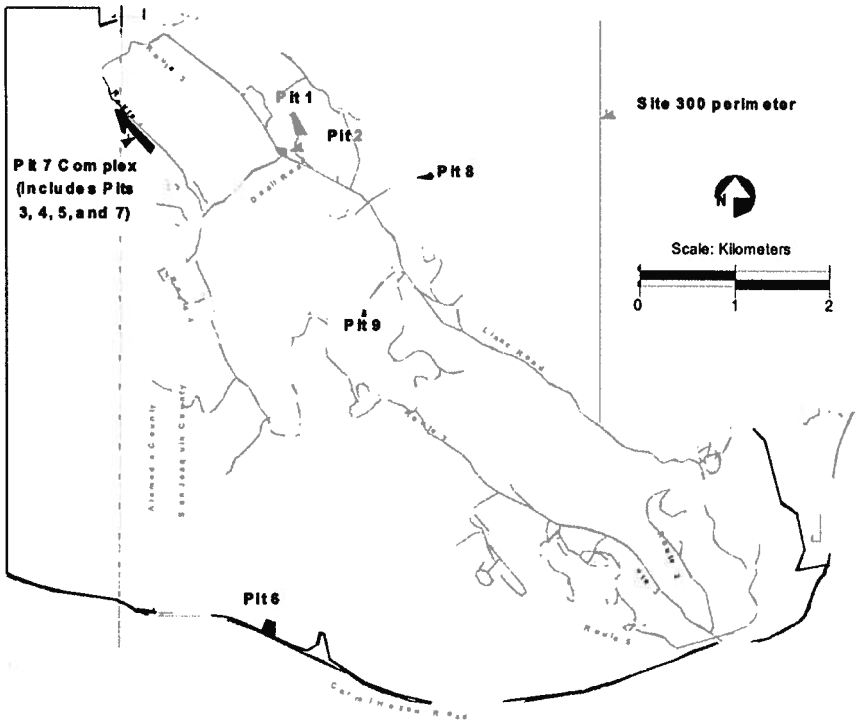

Figure 2. Location of Pit 6 at LLNL Site 300.

Figure 3 shows the locations of the wells that are used to monitor the ground water in the vicinity of the Pit 6 landfill, including upgradient wells, detection monitoring wells, and corrective action monitoring wells (Ferry et al., 1998). The northern limit of the Carnegie-Corral Hollow Fault zone extends beneath Pit 6 as shown in **Figure 3**. Ground water flows southeastward, following the inclination (dip) of the underlying sedimentary rocks. Depth to the water table ranges from 10 to 20 meters (m) or 33 to 66 feet (ft) in terrace deposit gravels within the fault zone beneath Pit 6. Ground water flows within these gravels to the east-southeast, parallel to the Site 300 boundary fence line (Webster-Scholten, 1994).

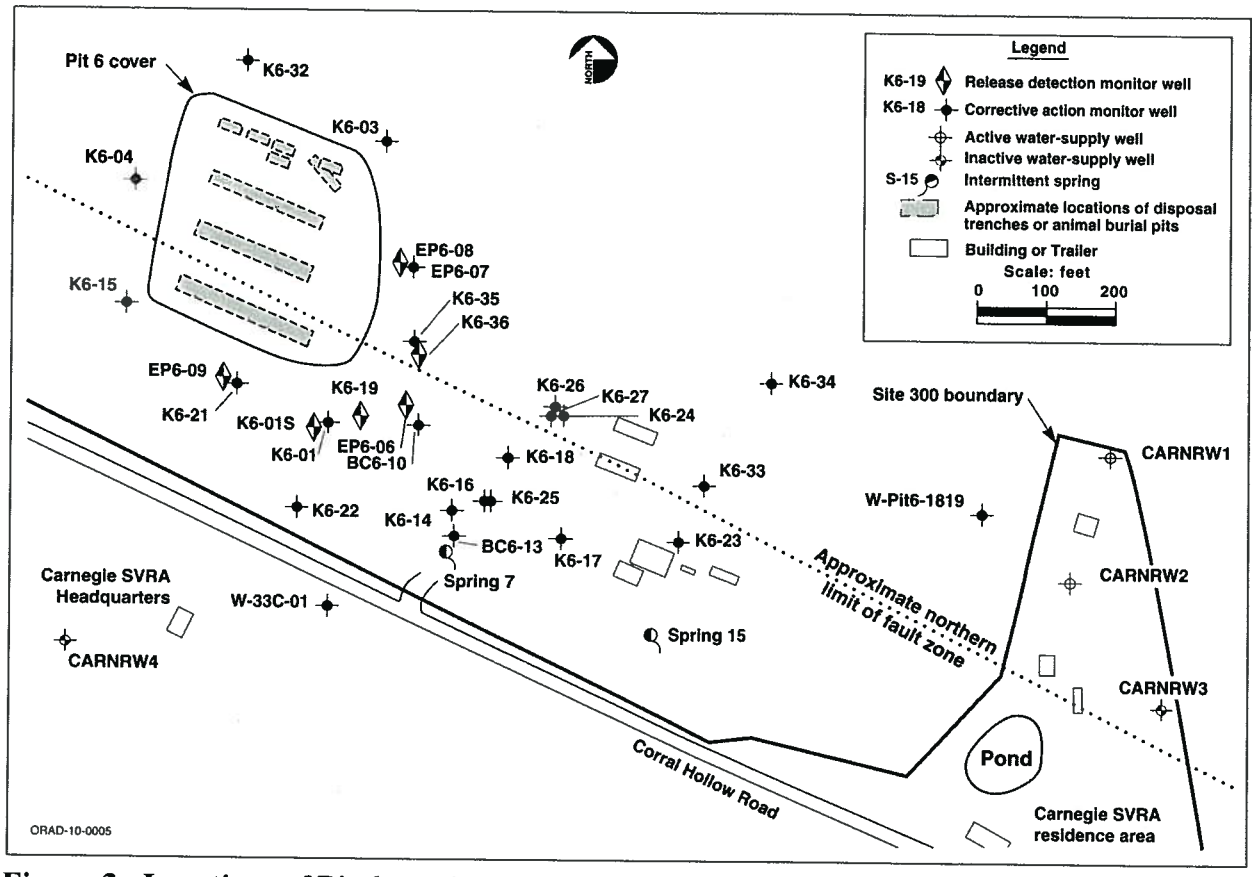

Figure 3. Locations of Pit 6 monitoring wells.

Monitoring Program Overview

The primary post-closure monitoring activity performed by LLNL at the Pit 6 landfill is the collection of ground water samples for chemical and radioisotope analysis. Two ground water monitoring programs have been implemented at the Pit 6 landfill to ensure compliance with regulations. The Detection Monitoring Program (DMP) detects any new releases of constituents of concern to ground water from wastes buried in the landfill. Constituents of concern, as defined by Title 23 of the California Code of Regulations (CCR), Chapter 15, are waste constituents, reaction products, and hazardous constituents that are reasonably expected to be in or derived from waste buried in the Pit 6 landfill. Twenty-four constituents of concern, including volatile organic compounds (VOCs) and radioisotopes, were identified for monitoring under the DMP in the Pit 6 Post-Closure Plan (Ferry et al., 1998). A select set of DMP wells are monitored quarterly for constituents of concern in compliance with the Pit 6 Post-Closure Plan (**Figure 3**). Field measurements of ground water physical parameters are collected at the time of sampling.

The Corrective Action Monitoring Plan (CAMP) monitors movement of historically-released contaminants of concern in ground water. Contaminants of concern are anthropogenic

chemicals, metals, radionuclides, or other substances detected in environmental media that pose a risk to human or ecological receptors or a threat to ground water. VOCs and tritium were identified at the Pit 6 landfill as ground water contaminants of concern for monitoring under the CAMP. CAMP wells are monitored at least annually in compliance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Compliance Monitoring Plan (Dibley et al., 2009).

Perchlorate and nitrate were detected in ground water near Pit 6 during CERCLA site-wide surveys subsequent to the Pit 6 Post-Closure Plan. Perchlorate was added to the list of constituents of concern to be monitored under the DMP. Since January 2003, nitrate and perchlorate were added as contaminants of concern to be monitored in an expanded set of CAMP wells (**Figure 3**). Additional changes to the monitoring program implemented since January 2003 are discussed in **Appendix D**.

As required by Executive Order 12770, our measurements are reported in *Système Internationale* (SI) units. The SI unit for radioactivity is the becquerel (Bq), equal to 1 nuclear disintegration per second. The more commonly used unit, the picocurie (pCi), is equal to 1 nuclear disintegration per 27 seconds. As a convenience, maximum contaminant levels (MCLs) for radioactivity in drinking water are given in both becquerels per liter (Bq/L) and picocuries per liter (pCi/L) in **Table 1**, below. Note that MCLs are provided for reference only.

Table 1. MCLs for radioactivity in drinking water.

Radiological parameter	MCL (Bq/L)	MCL (pCi/L)
Gross alpha	0.555	15
Gross beta	1.85	50
Tritium	740	20,000
Uranium (total)	0.74	20

DMP Objective

The primary DMP objective is to detect any new release of constituents of concern to ground water. Ground water is sampled quarterly from six wells located hydraulically downgradient of Pit 6 along the point of compliance. These wells are identified as EP6-06, EP6-08, EP6-09, K6-01S (K6-01 if K6-01S is dry), K6-19, and K6-36 in **Figure 3**. Water samples are sent to state-certified laboratories where they are analyzed quantitatively for the presence (or absence) of constituents of concern (see **Table C-1** for the list of DMP constituents of concern). Gross alpha and gross beta radioactivity measurements are used as surrogates for seven radionuclide constituents of concern other than uranium and tritium. Additional field measurements of ground water general parameters are obtained quarterly at the time of sample collection.

Potential releases of constituents of concern from Pit 6 are indicated by comparing analytical results for ground water samples with statistically-determined limits of concentration, called statistical limits, or SLs (see **Appendix C**, **Table C-1**, for the list of constituents of concern and

their respective SLs). If a constituent of concern measurement exceeds a SL, the measurement is investigated further to determine its validity. Consistent with state regulations, two independent ground water samples, called retest samples, are obtained from the associated monitoring well at least one week apart and analyzed for the suspect constituents of concern. If the constituent of concern is present in either sample at a concentration that exceeds the SL, then the initial analysis is deemed to be valid and it is reported as statistically significant evidence of a release. If neither retest sample measurement exceeds the SL, then the initial exceedance is not confirmed, and a release report is not made. Any further investigation of a constituent of concern is at the discretion of the Site 300 Remedial Project Managers (RPMs) and is conducted by LLNL under CERCLA.

CAMP Objectives

The primary CAMP objectives are to: (1) evaluate the effectiveness of the corrective action; (2) evaluate natural attenuation of the ground water VOC and tritium plumes; (3) monitor perchlorate and nitrate in ground water; and (4) evaluate the need for implementing contingency actions. To accomplish the CAMP objectives, ground water samples are collected from the monitoring wells shown in **Figure 3** at least annually and analyzed for the CERCLA contaminants of concern (VOCs, tritium, perchlorate, and nitrate) and water levels are measured quarterly as specified in the CERCLA Compliance Monitoring Plan.

The Pit 6 landfill received waste from 1964 through 1973 and the pit was officially closed when an engineered cap was constructed at the site in the summer of 1997, and followed by the Final Post Closure Plan in May 1998 (Ferry, 1998). Several VOCs, tritium, and perchlorate were released to ground water from Pit 6 prior to its capping and closure. Nitrate has also been detected in ground water at concentrations that exceed drinking water standards. Contaminants of concern in Pit 6 ground water have been described and evaluated previously in the *Final Site-Wide Remedial Investigation Report, Lawrence Livermore National Laboratory, Site 300* (Webster-Scholten, 1994), the *Final Feasibility Study for the Pit 6 Operable Unit, Lawrence Livermore National Laboratory, Site 300* (Devany et al., 1994), the *Addendum to the Pit 6 Engineering Evaluation/Cost Analysis, Lawrence Livermore National Laboratory, Site 300* (Berry, 1996), and the *Final Site-Wide Feasibility Study for Lawrence Livermore National Laboratory, Site 300* (Ferry et al., 1999). The selected CERCLA clean-up remedy for the Pit 6 landfill is described in the *Interim Site-Wide Record of Decision for Lawrence Livermore National Laboratory, Site 300* (U.S. DOE, 2001) and the *Site-Wide Record of Decision for Lawrence Livermore National Laboratory, Site 300* (U.S. DOE, 2008).

The engineered cap is in place to prevent further releases from Pit 6. Monitored natural attenuation is the remedial action selected for tritium and VOCs in Pit 6 ground water in the Site-Wide Record of Decision. Due to the limited extent of perchlorate and nitrate in Pit 6 ground water, a monitoring-only remedy was selected in the Site-Wide Record of Decision. Ground water monitoring is conducted to evaluate the effectiveness of the remedial action and to ensure there is no impact to downgradient water-supply wells.

Additional post-closure activities for Pit 6 include: (1) inspection of the landfill cap by LLNL technical staff annually and following major storms; (2) an annual comprehensive inspection of the landfill by an independent state-certified Professional Engineer (PE); (3) an annual pit cap elevation survey; (4) repairs as necessary to maintain the integrity of the landfill cap, its water diversion system, and its network of monitoring wells; and (5) preparation of reports. Reports of post-closure activities are provided quarterly to the participating regulatory agencies for their information and use.

Quality Assurance

To ensure data quality, LLNL works within the established Quality Assurance (QA) program of the LLNL Environmental Restoration Department (ERD). LLNL uses protocols and procedures that cover all aspects of ground water sampling, sample tracking, and data management. These written protocols and procedures are contained in the *LLNL Livermore Site and Site 300 Environmental Restoration Project Standard Operating Procedures (SOPs)* (Goodrich and Lorega, 2009), and the *Environmental Monitoring Plan* (Gallegos, 2012). Data quality is assessed by the following four methods: (1) analytical results for the routine and duplicate samples are compared by the analysts responsible for this report; (2) field blank samples are submitted to the analytical laboratories together with the routine ground water samples for identical analyses; (3) equipment blanks are prepared and analyzed to ensure that sampling equipment is properly cleaned before use; and (4) when samples are collected for VOC analysis, a trip blank (prepared at the analytical laboratory) is carried into the field. A summary of QA results may be found in **Appendix E, Table E-1**.

DMP Summary for the Fourth Quarter 2011

This section summarizes the monitoring results for DMP constituents of concern. Constituents of concern measurements for the DMP wells are listed in **Appendix A, Table A-1**. Field measurements of ground water parameters and analytical laboratory measurements of total dissolved solids (TDS) for the DMP wells are listed in **Appendix A, Table A-2**. Data collected during the fourth quarter of 2011 do not differ significantly from the past quarter (see Blake and Valett, 2011). Wells K6-36 and EP6-08 again were either dry or contained insufficient water to collect samples this quarter.

Tritium and VOCs that were released to ground water from the landfill prior to its closure in 1998 continue to be detected (**Table A-1**). Tritium activities continued to exceed the SL of 3.7 Bq/L (100 pCi/L) in ground water samples from one downgradient DMP well (K6-19) during the fourth quarter of 2011 from a routine sample (7.0 Bq/L [189 pCi/L]). Tritium activity in this well is higher than the level reported last quarter K6-19 (6.2 Bq/L [168 pCi/L]). Historically, tritium activities in well K6-19 have dropped since September 1999 from the maximum of 93 Bq/L (2520 pCi/L). Since then, tritium activities have decreased (Campbell, 2007; Blake et al., 2011) and have always been well below the U.S. Environmental Protection Agency (EPA) drinking water MCL of 740 Bq/L (20,000 pCi/L). Historical tritium activities for these wells are displayed in **Figure 4**.

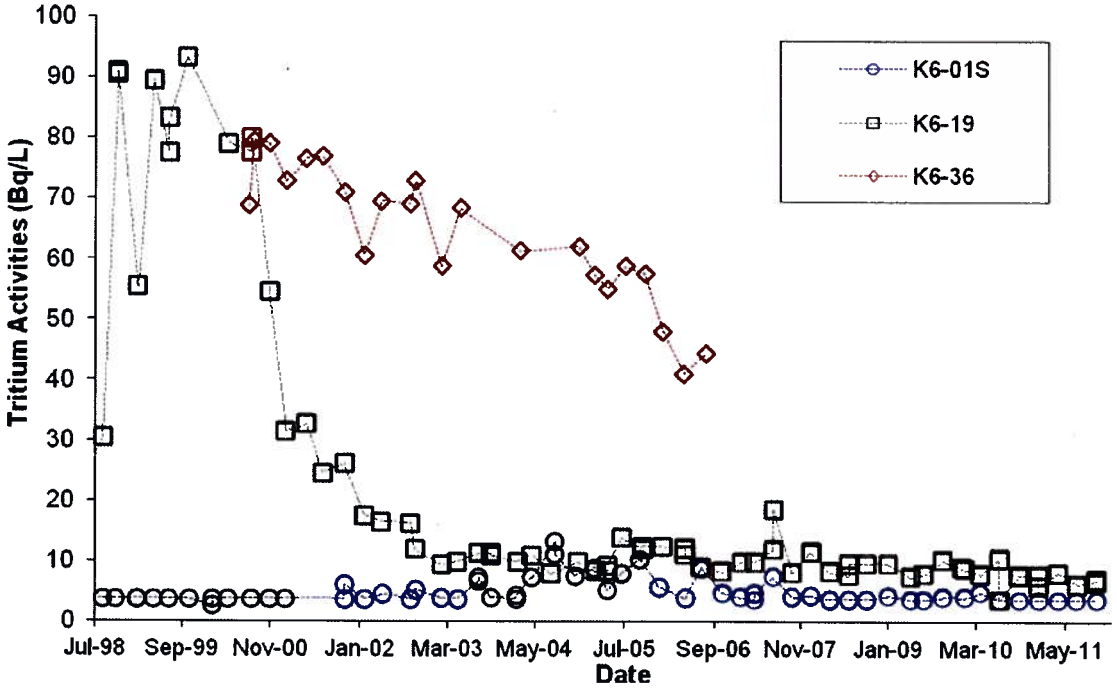

Figure 4. Historical tritium activities at Pit 6 for wells K6-01S, K6-19, and K6-36.

The VOCs detected in Pit 6 DMP wells, including trichloroethene (TCE), were not detected at concentrations greater than the SL in any ground water samples collected during the fourth quarter of 2011 (**Table A-1**). Historical TCE concentrations for EP6-09, K6-01S, K6-19, and EP6-08 are displayed in **Figure 5**.

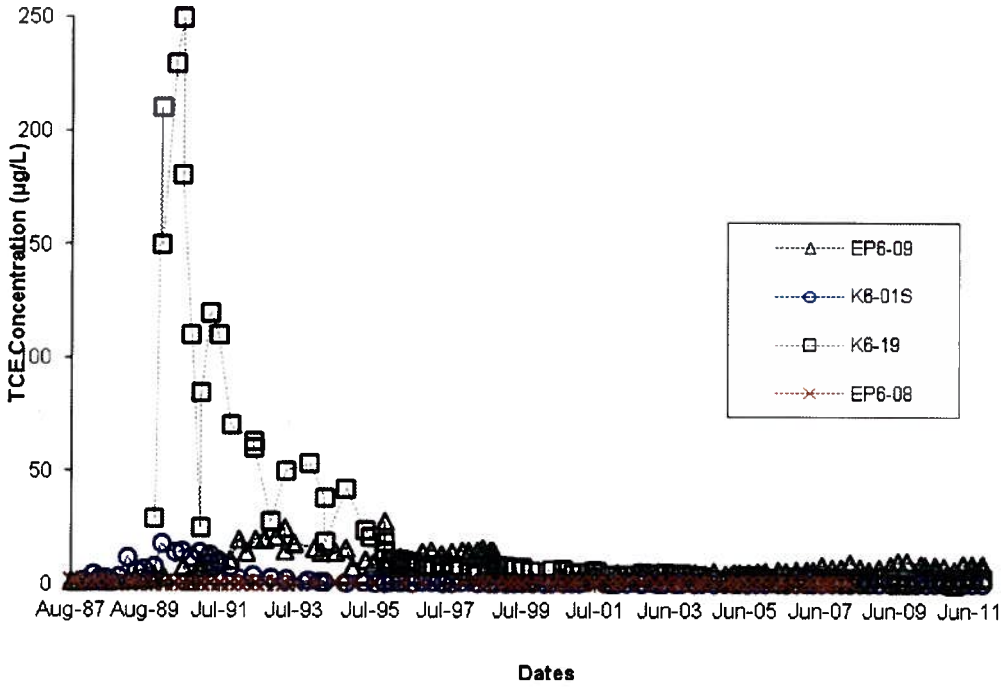

Figure 5. Historical TCE concentrations at Pit 6 for wells EP6-08, EP6-09, K6-01S, and K6-19.

CAMP Summary for the Fourth Quarter 2011

This section summarizes analysis of ground water elevation and contaminant of concern data collected as part of the CAMP monitoring during the fourth quarter of 2011. The primary CERCLA contaminants of concern for the Pit 6 area are several VOCs and tritium (Ferry et al., 1998). Perchlorate and nitrate were subsequently detected at concentrations above the State MCL for drinking water in ground water samples from several Pit 6 monitoring wells during site-wide investigations by LLNL. Perchlorate was designated a secondary contaminant of concern in 2000. Beginning in 2003, nitrate also became a secondary contaminant of concern. Ground water elevations for the fourth quarter of 2011 are listed in **Table B-1**. Detections of VOCs, tritium, perchlorate, and nitrate in ground water samples collected during the fourth quarter are listed in **Tables B-2, B-3,** and **B-4**, respectively. Ground water elevation and TVOC, tritium, perchlorate, and nitrate data are discussed in the following sections.

Ground water elevations (GWE). Figure 6 is a ground water elevation contour map for the first water-bearing zone for fourth quarter of 2011. During this quarter, due to dry conditions or restricted access, ground water levels were measured in only two first water-bearing zone wells north of the fault zone (W-PIT6-1819 and CARNRW1). Therefore, hydrograph curve matching with current water elevation data from deeper paired wells or nearby shallow wells was used to estimate the ground water contours (shown as dashed contour lines) for much of the area north of

the fault zone. Ground water elevations beneath Pit 6 are approximately a minimum of 12 m (40 ft) below the buried waste trenches.

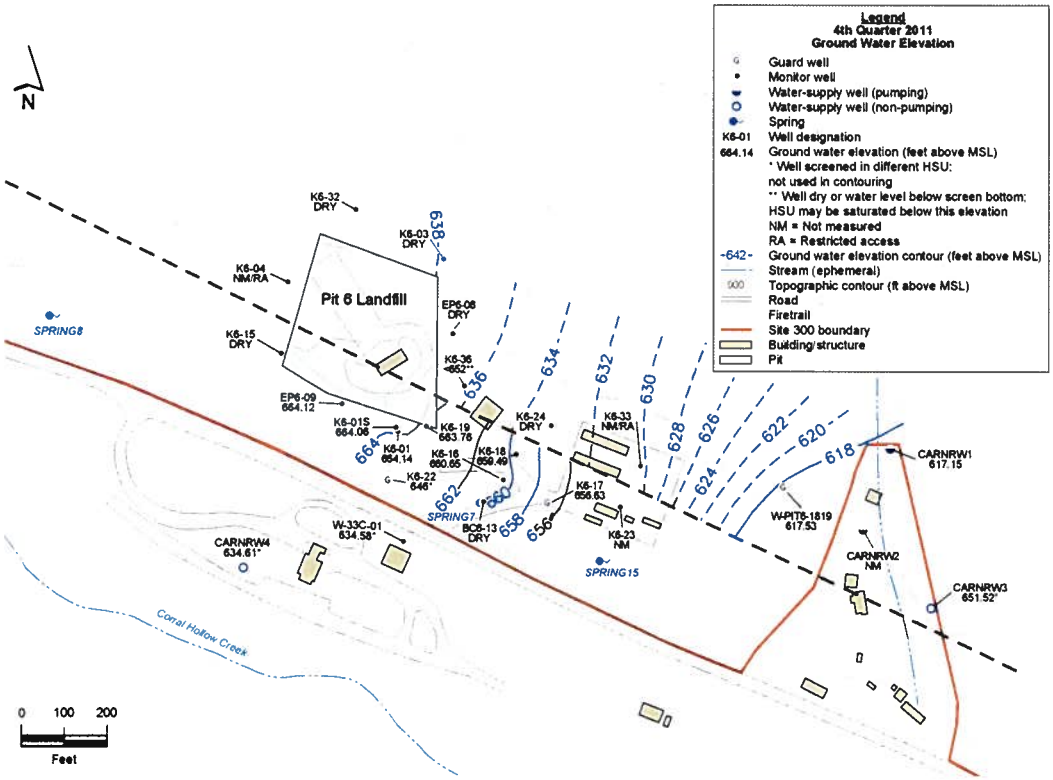

Figure 6. Ground water elevations (ft above MSL) in the first water-bearing zone at Site 300 Pit 6, fourth quarter 2011.

The predominantly southeast flow direction shown on **Figure 6** is consistent with potentiometric surface maps from previous quarters. Within the fault zone, ground water flows to the southeast with a hydraulic gradient of approximately 0.03. North of the fault zone, ground water flows to the southeast with a hydraulic gradient of approximately 0.01–0.02. Fractures in the Neroly formation $Tnbs_1$ stratigraphic unit play a dominant role in conveying ground water flow. A large component of the flow north of the fault is often affected by pumping from offsite water-supply wells CARNRW1 and CARNRW2. During the measurement of the fourth quarter 2011 ground water elevations in December 2011, the water level technician observed that CARNRW1 was not pumping. Ground water elevations to the south, within the fault zone, do not appear to be strongly influenced by pumping.

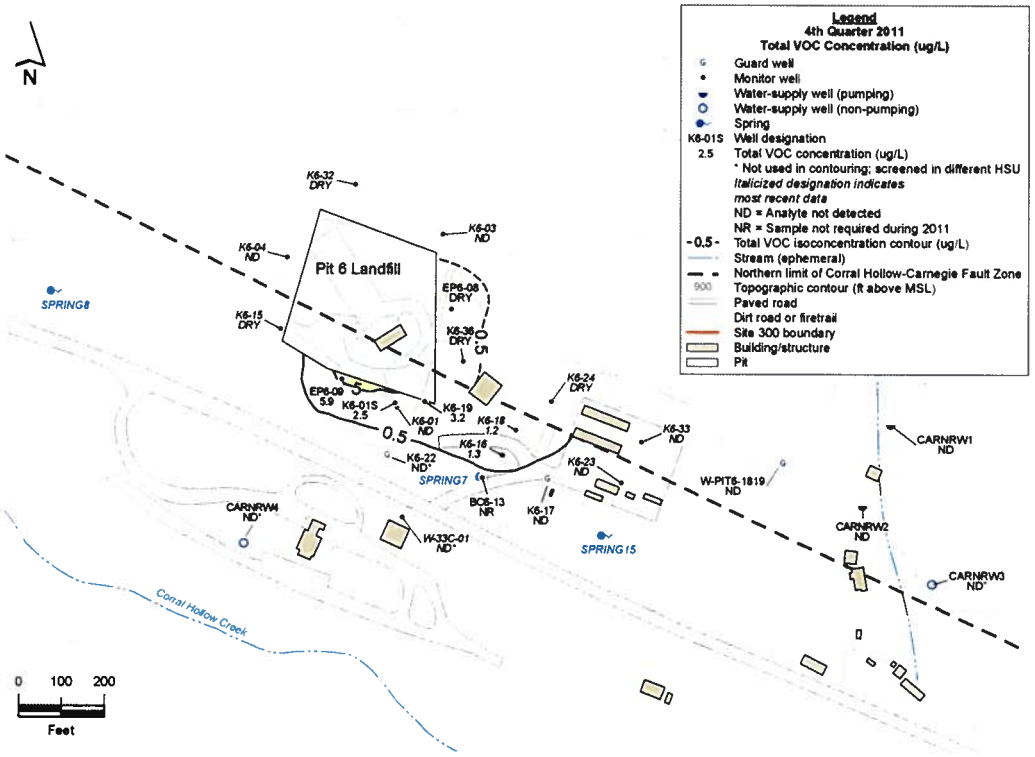

Figure 7. Ground water TVOC concentrations (µg/L) in the first water-bearing zone at Site 300 Pit 6, fourth quarter 2011.

Ground water TVOC concentrations. Figure 7 presents the distribution of total VOC (TVOC) concentrations for the shallow water-bearing zone wells sampled during the fourth quarter of 2011. Fourteen VOCs are summed for the calculation of TVOC. For wells that were dry or were otherwise not sampled fourth quarter, the most recent TVOC concentrations were used for plume contouring. The distribution of TVOCs depicted on **Figure 7** is similar to last quarter's. The maximum TVOC concentration this quarter was 5.9 µg/L, detected in the sample from well EP6-09; the only VOC detected was TCE. Last quarter, this well also yielded the maximum concentration of TVOCs at Pit 6 (7.8 µg/L). VOCs were detected last quarter in ground water samples from monitoring wells EP6-09, K6-01S, K6-16, K6-18, and K6-19. Two of the wells that yielded VOCs last quarter, wells K6-16 and K6-18, were not sampled this quarter and are only sampled twice a year (during the first and third quarters) per CERCLA Comprehensive Monitoring Plan (CMP) requirements. VOCs were also detected in ground water samples from wells K6-01S and K6-19 during the fourth quarter.

Ground water TCE concentrations during the fourth quarter of 2011 were similar to those detected in previous quarters and years. The maximum TCE concentration at Pit 6 this quarter was 5.9 μg/L in the routine ground water sample collected from well EP6-09 (duplicate sample from EP6-09 yielded 5.0 μg/L). These sample results were the only ones that met or exceeded the 5 μg/L MCL. One other well, K6-19, yielded samples containing TCE (3.2 μg/L routine; 3.2 μg/L duplicate) in excess of the 0.5 μg/L detection limit, but below the MCL.

Ground water samples collected from well EP6-09 during the previous three quarters contained 7.8, 9.3, and 8.9 μg/L, respectively, of TCE. The maximum historical TCE concentration for ground water from this well was 28 μg/L in January 1995. By year, the maximum TCE concentrations measured in ground water at Pit 6 were 6.3 μg/L in 2000 (well K6-18), 5.4 μg/L in 2001 (well K6-19), 5.1 μg/L in 2002 (well EP6-09), 5.5 μg/L in 2003 (well EP6-09), 5.4 μg/L in 2004 (well EP6-09), 6.4 μg/L in 2005 (well EP6-09), 8.5 μg/L in 2006 (well EP6-09), 9.8 μg/L in 2007 (well EP6-09), 10 μg/L (well EP6-09) in 2008, 9 μg/L (well EP6-09) in 2009, 9.2 μg/L (well EP6-09) in 2010, and 9.3 μg/L (well EP6-09) in 2011. Monitoring data do not indicate a new release of TCE to ground water from Pit 6 during this quarter or year.

As in the past, cis-1,2-DCE was detected in a ground water sample from Pit 6. During the fourth quarter of 2011, 2.5 μg/L of cis-1,2-DCE were detected in the ground water sample from well K6-01S. Cis-1,2-DCE has never been detected at or above the 70 μg/L Federal MCL, 60 μg/L State MCL, or 100 μg/L State PHG in samples from any well in the Pit 6 area. Last quarter, cis-1,2-DCE was detected in one ground water sample, from well K6-01S, at a concentration of 2.2 μg/L. The most recent previous detections of cis-1,2-DCE (first, second, third, and fourth quarters of 2010 and first and second quarters of 2011) in samples from this well were 2.5, 2.3, 2.3, 2.3, 3, and 2.2 μg/L, respectively. The presence of cis-1,2-DCE, a degradation product of TCE, suggests that natural decomposition may be occurring.

During the first quarter of 2011, acetone, which is not included in the TVOC calculation, was detected in a sample collected from EP6-09 at a concentration of 57 μg/L. Acetone has been detected sporadically in a total of 9 samples (7 routine, 2 duplicates) collected between July 2008 and present from well EP6-09 at concentrations ranging from 18 to 220 μg/L. Acetone has also been reported in seven discrete one-time samples from seven other wells near Pit 6 ranging in concentrations from 5.4 to 78 μg/L. Of these seven samples, four were collected in late October 1990 and may reflect laboratory contamination. One of the remaining three sample results is 28 μg/L reported in a February 17, 2000 sample from well K6-01S. The duplicate sample collected from this well on this date contained no acetone above the 20 μg/L detection limit. Of the other two samples, the most recent result was 8 μg/L of acetone in a sample collected from well EP6-08 in October 2003. As a result of the first quarter 2011, acetone detection in EP6-09 and sporadic acetone detections in some historical samples, LLNL has been collecting two quarterly ground water samples (a routine and a duplicate) from EP6-09 since second quarter 2011, with each sample analyzed for acetone at a different laboratory. As reported last quarter, acetone was not detected in either sample; however, it was noted that the trip blank accompanying the routine sample yielded acetone at a concentration of 26 μg/L.

Similarly, during third quarter 2011, acetone was not detected in either sample, however, it was noted that the trip blank accompanying the routine sample yielded acetone at a concentration of 14 μg/L. During this quarter (fourth quarter 2011), acetone was detected in the duplicate sample at a concentration of 12 μg/L, but not detected in the routine sample. LLNL will continue to take quarterly duplicate samples for acetone from well EP6-09 over the next year to assist with monitoring and evaluating the possible occurrence of acetone in Pit 6 ground water, and will present the results in a subsequent report. There is no State or Federal MCL for acetone, and the concentrations mentioned above are well below the taste and odor threshold of 300,000 μg/L.

Ground water tritium activity. **Figure 8** shows the areal distribution of tritium activities in ground water in the first water-bearing zone for the fourth quarter of 2011. For wells that were not sampled during the fourth quarter, the most recent tritium activities were used for plume contouring. This quarter, tritium activities in excess of the 3.7 Bq/L (100 pCi/L) detection limit in the first water bearing zone north of the fault zone were found in one ground water sample (W-PIT6-1819 at 7.0 Bq/L [189 pCi/L]). This well is a guard well and is used to define the downgradient extent of the tritium plume north of the fault zone in the first water-bearing zone. It is located about 30 m (100 ft) west of the Site 300 boundary with the Carnegie State Vehicle Recreation Area residence area and about 60 m (200 ft) west of the CARNRW1 and CARNRW2 water-supply wells **(Figure 8).** Last quarter, the sample from well W-PIT6-1819 contained 10.0 Bq/L (270 pCi/L) of tritium. This well has historically yielded tritium activities ranging from below detection limits (< 3.7 Bq/L [100 pCi/L]) to 10.9 Bq/L (295 pCi/L). Tritium activities were below the detection level of 3.7 Bq/L (100 pCi/L) in the monthly ground water samples obtained during the fourth quarter of 2011 from the off-site CARNRW wells. Within the fault zone this quarter, tritium was detected in samples from well K6-19 (routine, 7.0 Bq/L [190 pCi/L] and duplicate, 6.7 Bq/L [182 pCi/L]). The tritium plume depicted in **Figure 8** is similar in magnitude and extent to the plume shown during third quarter 2011. Tritium was not detected at or above the 740 Bq/L (20,000 pCi/L) MCL or the 14.8 Bq/L (400 pCi/L) State Public Health Goals (PHG) in samples from any wells in the Pit 6 area.

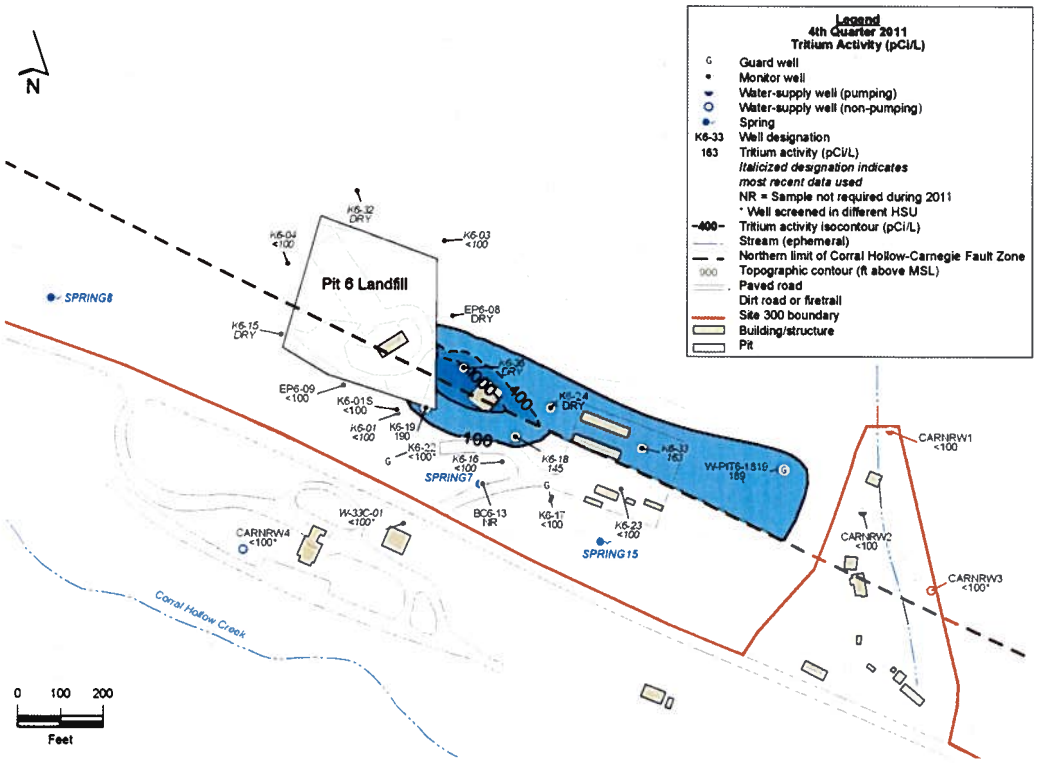

Figure 8. Ground water tritium activities (pCi/L) in the first water-bearing zone at Site 300 Pit 6, fourth quarter 2011.

Ground water perchlorate concentrations. A map showing fourth quarter 2011 perchlorate concentrations in ground water samples collected from the shallow water bearing zone is presented in **Figure 9**. If a well was not sampled for perchlorate during fourth quarter 2011, the most recent data was posted. This quarter, as well as the last three quarters, there were no wells that yielded perchlorate at or in excess of the reporting limit of 4 µg/L or the 6 mg/L State PHG. Perchlorate concentrations in Pit 6 ground water have decreased significantly from the historical maximum of 65 µg/L in 1998.

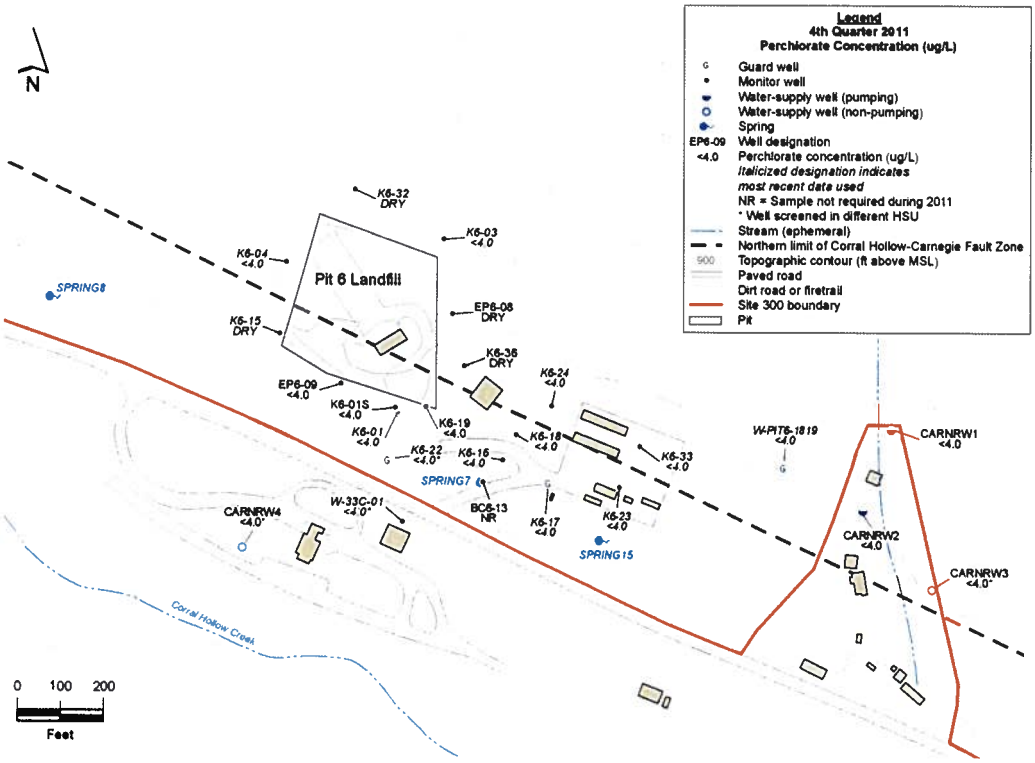

Figure 9. Ground water perchlorate concentrations (µg/L) in the first water-bearing zone at Site 300 Pit 6, fourth quarter 2011.

Ground water nitrate concentrations. A map showing fourth quarter 2011 nitrate concentrations in the shallow water-bearing zone at Pit 6 is presented in **Figure 10**. If a well was not sampled for nitrate during fourth quarter 2011, the most recent data was posted. This quarter, there were no wells that yielded nitrate above the 45 milligram per liter (mg/L) MCL. During the second quarter of 2011, nitrate was detected above the 45 milligram per liter (mg/L) MCL in a ground water sample from one well, K6-24, at a concentration of 63 mg/L. This well (K6-24) was sampled for nitrate during second quarter 2011 due to a first time nitrate detection (62 mg/L) above the MCL in this well during first quarter 2011. K6-24 was dry during third and fourth quarter 2011. The source of nitrate in K6-24 is currently unknown. During the third quarter of 2011, nitrate was detected in a sample from well K6-23 above the MCL at a concentration of 150 mg/L. Ground water nitrate concentrations from this well are consistently the highest at Pit 6. Well K6-23 is located in close proximity to the Building 899 septic system, which is a potential source of the nitrate at this location. The maximum fourth quarter 2011

nitrate concentration in monthly samples from the four CARNRW offsite water-supply wells (CARNRW1, CARNRW2, CARNRW3, and CARNRW4) was 0.9 mg/L in the December 2011 sample from CARNRW2.

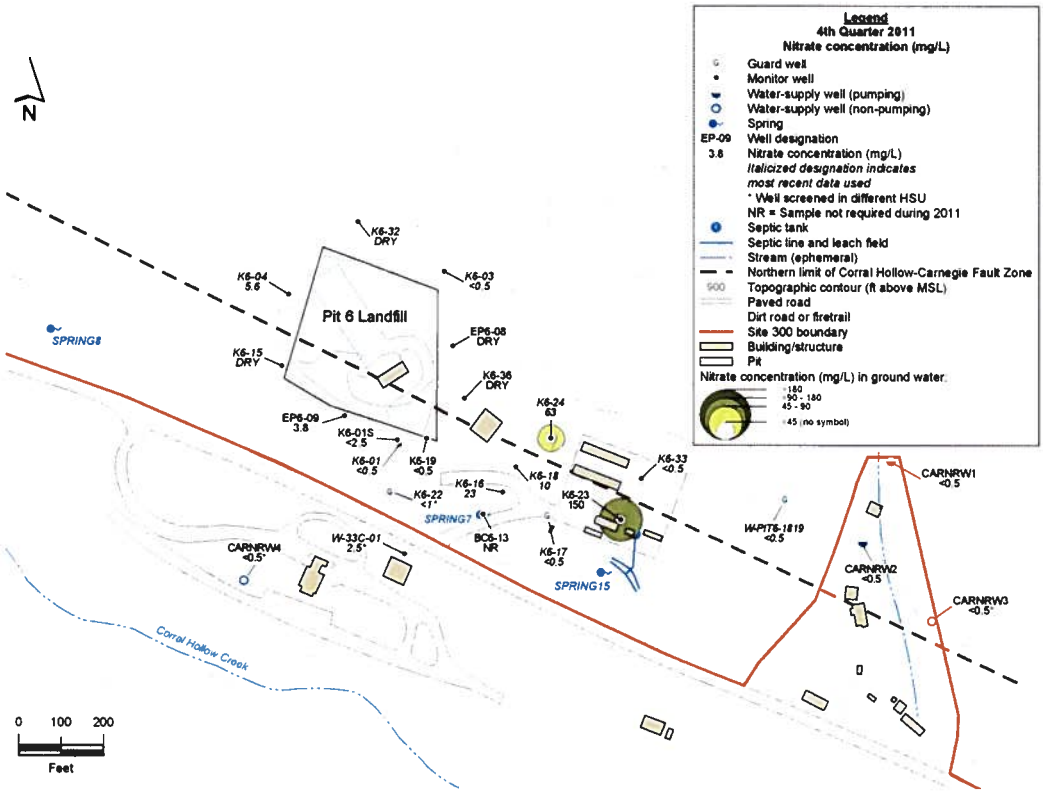

Figure 10. Ground water nitrate concentrations (mg/L) in the first water-bearing zone at Site 300 Pit 6, fourth quarter 2011.

Inspection and Maintenance Summary

As a recap of Pit 6 inspections for 2011, the annual visual inspection was conducted in the second quarter on April 18, and the annual Pit 6 engineering inspection was conducted on April 26. No deficiencies were noted in either the visual or engineering inspection. In addition, the annual pit cap permanent marker elevation survey was conducted in the third quarter by an LLNL licensed surveyor. No notable elevation changes were observed compared to the 2010 survey and the pit cap and drainage structures continue to function properly.

References

Berry, T. (1996), *Addendum to the Pit 6 Engineering Evaluation/Cost Analysis, Lawrence Livermore National Laboratory, Site 300*, Lawrence Livermore National Laboratory, Livermore, CA (UCRL-AR-113861 Add.).

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Abbreviations and Acronyms

Bq	becquerel (international unit of radioactivity equal to 27 pCi)
CAMP	Corrective Action Monitoring Program
CCR	California Code of Regulations
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
Cis-1,2-DCE	Cis-1,2-dichloroethene
CL	concentration limit (background concentration of a chemical)
CVRWQCB	Central Valley Regional Water Quality Control Board
DMP	Detection Monitoring Program
DOE	U.S. Department of Energy
DTSC	California Department of Toxic Substances Control
DUP	duplicate sample
EPA	U.S. Environmental Protection Agency
ERD	LLNL Environmental Restoration Department
ft	foot (used as a measure of elevation above MSL)
GWE	ground water elevation in feet above MSL
km	kilometer
km^2	square kilometer
L	liter
LLNL	Lawrence Livermore National Laboratory
m	meter
m^2	square meter
MCL	maximum contaminant level (for drinking water)
MSL	mean sea level (datum for elevation measurements)
mg	milligram
µg	microgram
pCi	picocurie (unit of radioactivity)
PHG	California State Public Health Goal (PHG)
PE	Professional Engineer
QA	quality assurance
RL	reporting limit (contractual concentration near zero)
RPM	remedial project manager
RTN	routine sample

Site 300	Experimental Test Site, LLNL
SL	Statistically-determined concentration limit
SOP	standard operating procedure
TCE	trichloroethene
TDS	total dissolved solids
$Tnbs_l$	Neroly Formation lower blue sandstone unit
VOC	volatile organic compound
yr	year

Appendix A

Tables of Ground Water Measurements for Detection Monitoring Wells

Table A-1. Pit 6 post-closure monitoring plan constituents of concern, detection monitoring wells, SLs, MCLs, and quarterly analytical results for 2011.

				Quarter			
COC (units)	**Well**	**SL**	**MCL**	**First**	**Second**	**Third**	**Fourth**
Metals (µg/L)							
Beryllium	EP6-06	0.2	4	<0.2	<0.2	<0.2	<0.2
	EP6-09	0.2		<0.2	<0.2	<0.2	<0.2
	K6-01S	0.2		<0.8[(b)]	<0.2	<0.2	<0.4
	K6-19	0.2		<0.2	<0.2	<0.2	<0.2
Mercury	EP6-06	0.2	2	<0.2	<0.2	<0.2	<0.2
	EP6-09	0.2		<0.2	<0.2	<0.2	<0.2
	K6-01S	0.2		<0.2	<0.2	<0.2	<0.2
	K6-19	0.2		<0.2	<0.2	<0.2	<0.2
Radioactivity (Bq/L)							
Tritium	EP6-06	3.7	740	-0.81	-0.58	-0.64	1.5
	EP6-09	3.7		0.057	0.47	1.6	0.59
	K6-01S	3.7		0.85	0.71	1.5	2.9
	K6-19	3.7		7.6	8.2	6.2	7
Uranium (total)	EP6-06	0.13	0.74	0.01	0.02	0.02	0.02
	EP6-09	0.14		0.07	0.1	0.1	0.11
	K6-01S	1.00		0.16	0.14	0.16	0.18
	K6-19	0.27		0.13	0.11	0.09	0.09
Gross alpha	EP6-06	0.28	0.55	0.05	0.03	0.07	0.03
	EP6-09	0.18		0.05	0.11	0.09	0.13
	K6-01S	0.96		0.11	0.09	0.14	0.2
	K6-19	0.34		0.09	0.09	0.07	0.12
Gross beta	EP6-06	0.79	1.85	0.22	0.34	0.17	0.3
	EP6-09	0.79		0.32	0.56	0.38	0.24
	K6-01S	2.13		0.53	0.48	0.38	0.67
	K6-19	0.79		0.35	0.37	0.19	0.26
Volatile organic compounds (µg/L, EPA method 8260)							
Benzene	EP6-06	0.5	1	<0.5	<0.5	<0.5	<0.5
	EP6-09	0.5		<0.5	<0.5	<0.5	<0.5
	K6-01S	0.5		<0.5	<0.5	<0.5	<0.5
	K6-19	0.5		<0.5	<0.5	<0.5	<0.5
Carbon disulfide	EP6-06	5	none	<5	<5	<5	<5
	EP6-09	5		<5	<5	<5	<5
	K6-01S	5		<5	<5	<5	<5
	K6-19	5		<5	<5	<5	<5
Chloroform	EP6-06	0.5	80	<0.5	<0.5	<0.5	<0.5
	EP6-09	0.5		<0.5	<0.5	<0.5	<0.5
	K6-01S	0.5		<0.5	<0.5	<0.5	<0.5
	K6-19	1.5		<0.5	<0.5	<0.5	<0.5
1,2-dichloroethane	EP6-06	0.5	0.5	<0.5	<0.5	<0.5	<0.5
	EP6-09	0.5		<0.5	<0.5	<0.5	<0.5
	K6-01S	0.5		<0.5	<0.5	<0.5	<0.5
	K6-19	0.5		<0.5	<0.5	<0.5	<0.5
Cis-1,2-dichloroethene	EP6-06	0.5	6	<0.5	<0.5	<0.5	<0.5
	EP6-09	0.5		<0.5	<0.5	<0.5	<0.5
	K6-01S	7.0		3	2.2	2.2	2.5
	K6-19	0.5		<0.5	<0.5	<0.5	<0.5

Table A-1. Pit 6 post-closure monitoring plan constituents of concern, detection monitoring wells, SLs, MCLs, and quarterly analytical results for 2011.

				Quarter			
COC (units)	**Well**	**SL**	**MCL**	**First**	**Second**	**Third**	**Fourth**
Volatile organic compounds (µg/L, EPA method 8260) (Cont.)							
Ethyl benzene	EP6-06	0.5	700	<0.5	<0.5	<0.5	<0.5
	EP6-09	0.5		<0.5	<0.5	<0.5	<0.5
	K6-01S	0.5		<0.5	<0.5	<0.5	<0.5
	K6-19	0.5		<0.5	<0.5	<0.5	<0.5
Methylene chloride	EP6-06	1	5	<1	<1	<1	<1
	EP6-09	1		<1	<1	<1	<1
	K6-01S	1		<1	<1	<1	<1
	K6-19	1		<1	<1	<1	<1
Tetrachloroethene	EP6-06	0.5	5	<0.5	<0.5	<0.5	<0.5
	EP6-09	0.5		<0.5	<0.5	<0.5	<0.5
	K6-01S	0.5		<0.5	<0.5	<0.5	<0.5
	K6-19	0.5		<0.5	<0.5	<0.5	<0.5
Toluene	EP6-06	0.5	150	<0.5	<0.5	<0.5	<0.5
	EP6-09	0.5		<0.5	<0.5	<0.5	<0.5
	K6-01S	0.5		<0.5	<0.5	<0.5	<0.5
	K6-19	0.5		<0.5	<0.5	<0.5	<0.5
1,1,1-trichloroethane	EP6-06	0.5	200	<0.5	<0.5	<0.5	<0.5
	EP6-09	0.5		<0.5	<0.5	<0.5	<0.5
	K6-01S	0.5		<0.5	<0.5	<0.5	<0.5
	K6-19	0.5		<0.5	<0.5	<0.5	<0.5
Trichloroethene (TCE)	EP6-06	0.5	5	<0.5	<0.5	<0.5	<0.5
	EP6-09	17		8.9	9.3	7.8	5.9
	K6-01S	1.5		<0.5	<0.5	<0.5	<0.5
	K6-19	13		2.9	2.7	2.7	3.2
Xylenes (total)	EP6-06	1	1,750	<1	<1	<1	<1
	EP6-09	1		<1	<1	<1	<1
	K6-01S	1		<1	<1	<1	<1
	K6-19	1		<1	<1	<1	<1
Perchlorate (µg/L)	EP6-06	4.7	6[(a)]	<4	<4	<4	<4
	EP6-09	4		<4	<4	<4	<4
	K6-01S	4		<4	<4	<4	<4
	K6-19	27.5		<4	<4	<4	<4

[(a)] California State Maximum Contaminant Level (MCL).

[(b)] Suspect result. Lab raised detection limit due to matrix interference. Lab did not meet their performance evaluation and corrective action was insufficient.

Table A-2. Pit 6 detection monitoring quarterly ground water physical parameters for 2011.

Detection well	Quarter 2011	Date sampled	GWE[a] (ft)	Temp. (°C)	pH (pH units)	Specific conductivity (µmho/cm)	TDS[b] (mg/L)
EP6-06	Q1	7-Feb	660.80	19.9	7.13	1300	860
EP6-06	Q2	12-Apr	661.00	19.6	7.54	1279	860
EP6-06	Q3	12-Jul	659.78	18.9	7.70	1307	840
EP6-06	Q4	12-Oct	662.51	21.9	7.88	1301	880
EP6-09	Q1	4-Jan	664.04	20.2	7.30	1880	1100
EP6-09	Q2	12-Apr	664.10	21.1	7.62	1816	1300
EP6-09	Q3	7-Jul	664.28	25.9	7.30	1815	1100
EP6-09	Q4	10-Oct	663.10	20.9	7.48	1827	1300
K6-01S	Q1	5-Jan	663.86	21.7	6.94	3694	2900
K6-01S	Q2	12-Apr	664.01	21.6	7.01	3582	2900
K6-01S	Q3	7-Jul	664.19	22.9	6.63	3773	3100
K6-01S	Q4	12-Oct	664.22	21.8	7.30	3839	3300
K6-19	Q1	4-Jan	663.59	21.7	7.39	1222	770
K6-19	Q2	12-Apr	664.00	21.4	7.46	1199	780
K6-19	Q3	12-Jul	663.84	21.3	7.47	1188	760
K6-19	Q4	10-Oct	663.75	21.9	6.64	1202	790

[a] Ground water elevation (water table elevation in feet above mean sea level).

[b] Total dissolved solids.

Appendix B

Tables of Ground Water Measurements for Corrective Action Monitoring Wells

Table B-1. Water elevation (GWE) measurements in Pit 6 ground water monitoring wells, fourth quarter of 2011.

Well	Date sampled	GWE (ft above MSL)
BC6-10	22-Dec	658.00
BC6-13	22-Dec	DRY
CARNRW1	4-Oct	620.1
CARNRW1	22-Dec	617.1
CARNRW3	22-Dec	651.5
CARNRW4	22-Dec	634.6
EP6-06	12-Oct	662.5
EP6-06	22-Dec	662.3
EP6-07	22-Dec	632.9
EP6-08	22-Dec	DRY
EP6-09	10-Oct	663.1
EP6-09	22-Dec	664.1
K6-01	22-Dec	664.1
K6-01S	12-Oct	664.2
K6-01S	22-Dec	664.1
K6-03	22-Dec	DRY
K6-04	22-Dec	NM/RA
K6-14	22-Dec	658.7
K6-15	22-Dec	DRY
K6-16	22-Dec	660.7
K6-17	22-Dec	656.6
K6-18	22-Dec	659.5
K6-19	10-Oct	663.8
K6-19	22-Dec	663.8
K6-21	22-Dec	DRY
K6-22	22-Dec	646.00
K6-24	22-Dec	DRY
K6-25	22-Dec	660.8
K6-26	22-Dec	632.7
K6-27	22-Dec	630.00
K6-32	22-Dec	DRY
K6-33	22-Dec	NM/RA
K6-34	22-Dec	618.5
K6-35	22-Dec	632.4
K6-36	22-Dec	651.7
W-33C-01	22-Dec	634.6
W-34-01	22-Dec	NM/RA
W-34-02	22-Dec	NM/RA
W-PIT6-1819	22-Dec	617.5

NM/RA = No measurement. Restricted access.

Table B-2. Volatile organic compounds detected in Pit 6 ground water samples, fourth quarter of 2011.

Analytical method	VOCs detected	Well	Date sampled	Type	Result (µg/L)
E8260	Acetone	EP6-09	10-Oct	DUP	12.0
E8260	cis-1,2-Dichloroethene	K6-01S	12-Oct	RTN	2.5
E8260	1,2-Dichloroethene (total)	K6-01S	12-Oct	RTN	2.5
E8260	Trichloroethene	EP6-09	10-Oct	RTN	5.9
E8260	Trichloroethene	EP6-09	10-Oct	DUP	5.0
E8260	Trichloroethene	K6-19	10-Oct	RTN	3.2
E8260	Trichloroethene	K6-19	10-Oct	DUP	3.2

Table B-3. Tritium activity measurements in Pit 6 ground water samples, fourth quarter of 2011.

Well	Date sampled	Routine or duplicate	Activity (pCi/L)	Activity (Bq/L)
CARNRW1	4-Oct	RTN	<100	<3.7
CARNRW1	4-Oct	DUP	<100	<3.7
CARNRW1	1-Nov	RTN	<100	<3.7
CARNRW1	1-Nov	DUP	<100	<3.7
CARNRW1	1-Dec	RTN	<100	<3.7
CARNRW1	1-Dec	DUP	<100	<3.7
CARNRW2	4-Oct	RTN	<100	<3.7
CARNRW2	4-Oct	DUP	<100	<3.7
CARNRW2	1-Nov	RTN	<100	<3.7
CARNRW2	1-Nov	DUP	<100	<3.7
CARNRW2	1-Dec	RTN	<100	<3.7
CARNRW2	1-Dec	DUP	<100	<3.7
CARNRW3	4-Oct	RTN	<100	<3.7
CARNRW3	4-Oct	DUP	<100	<3.7
CARNRW3	1-Nov	RTN	<100	<3.7
CARNRW3	1-Nov	DUP	<100	<3.7
CARNRW3	1-Dec	RTN	<100	<3.7
CARNRW3	1-Dec	DUP	<100	<3.7
CARNRW4	4-Oct	RTN	<100	<3.7
CARNRW4	4-Oct	DUP	<100	<3.7
CARNRW4	1-Nov	RTN	<100	<3.7
CARNRW4	1-Nov	DUP	<100	<3.7
CARNRW4	1-Dec	RTN	<100	<3.7
CARNRW4	1-Dec	DUP	<100	<3.7
EP6-06	12-Oct	RTN	<100	<3.7
EP6-09	10-Oct	RTN	<100	<3.7
K6-01S	12-Oct	RTN	<100	<3.7
K6-17	3-Oct	RTN	<100	<3.7
K6-17	3-Oct	DUP	<100	<3.7
K6-19	10-Oct	RTN	190	7
K6-19	10-Oct	DUP	182	6.7
K6-22	3-Oct	RTN	<100	<3.7
K6-34	3-Oct	RTN	<100	<3.7
W-PIT6-1819	3-Oct	RTN	189	7

Table B-4. Perchlorate and nitrate concentrations in Pit 6 ground water samples, fourth quarter of 2011.

Well	Date sampled	Routine or duplicate	Perchlorate (µg/L)	Nitrate (as NO3) (mg/L)
CARNRW1	5-Oct	RTN	<4	<0.5
CARNRW1	5-Oct	DUP	<4	<0.5
CARNRW1	2-Nov	RTN	<4	<0.5
CARNRW1	2-Nov	DUP	<4	<0.5
CARNRW1	2-Dec	RTN	<4	<0.5
CARNRW1	2-Dec	DUP	<4	<0.5
CARNRW2	5-Oct	RTN	<4	<0.5
CARNRW2	5-Oct	DUP	<4	<0.5
CARNRW2	2-Nov	RTN	<4	<0.5
CARNRW2	2-Nov	DUP	<4	<0.5
CARNRW2	2-Dec	RTN	<4	0.9
CARNRW2	2-Dec	DUP	<4	0.5
CARNRW3	5-Oct	RTN	<4	<0.5
CARNRW3	5-Oct	DUP	<4	<0.5
CARNRW3	2-Nov	RTN	<4	<0.5
CARNRW3	2-Nov	DUP	<4	<0.5
CARNRW3	2-Dec	RTN	<4	<0.5
CARNRW3	2-Dec	DUP	<4	<0.5
CARNRW4	5-Oct	RTN	<4	<0.5
CARNRW4	5-Oct	DUP	<4	<0.5
CARNRW4	2-Nov	RTN	<4	<0.5
CARNRW4	2-Nov	DUP	<4	<0.5
CARNRW4	2-Dec	RTN	<4	<0.5
CARNRW4	2-Dec	DUP	<4	<0.5
EP6-06	13-Oct	RTN	<4	<0.5
EP6-09	11-Oct	RTN	<4	3.8
K6-01S	13-Oct	RTN	<4	<2.5
K6-19	11-Oct	RTN	<4	<0.5
K6-19	11-Oct	DUP	<4	<0.5

Table B-5. Pit 6 monitoring locations, monitoring functions, associated monitoring programs, COCs, monitoring frequencies, and fourth quarter 2011 sampling summary.

Monitoring location	Monitoring function	Monitoring program	COCs[a] (sampling frequency)	COCs analyzed	Reason(s), if not completed
K6-17	guard well	CAMP	P (Q), S (SA)	P	
K6-22	guard well	CAMP	P (Q), S (SA)	P	
K6-34	guard well	CAMP	P (Q), S (SA)	P	
W-PIT6-1819	guard well	CAMP	P (Q), S (SA)	P	
SPRING15	plume tracking spring	CAMP	P (A), S (A)	none	Not scheduled
BC6-10	plume tracking well	CAMP	P (SA), S (A)	none	Not scheduled
BC6-13	plume tracking well	CAMP	P (B), S (B)	none	Not scheduled
EP6-07	plume tracking well	CAMP	P (SA), S (A)	none	Not scheduled
K6-01	plume tracking well	CAMP	P (SA), S (A)	none	Not scheduled
K6-03	plume tracking well	CAMP	P (SA), S (A)	none	Not scheduled
K6-04	plume tracking well	CAMP	P (SA), S (A)	none	Not scheduled
K6-14	plume tracking well	CAMP	P (SA), S (A)	none	Not scheduled
K6-15	plume tracking well	CAMP	P (SA), S (A)	none	Not scheduled
K6-16	plume tracking well	CAMP	P (SA), S (A)	none	Not scheduled
K6-18	plume tracking well	CAMP	P (SA), S (A)	none	Not scheduled
K6-21	plume tracking well	CAMP	P (A), S (A)	none	Not scheduled
K6-23	plume tracking well	CAMP	P (SA), S (A)	none	Not scheduled
K6-24	plume tracking well	CAMP	P (SA), S (A)	none	Not scheduled
K6-25	plume tracking well	CAMP	P (SA), S (A)	none	Not scheduled
K6-26	plume tracking well	CAMP	P (SA), S (A)	none	Not scheduled
K6-27	plume tracking well	CAMP	P (SA), S (A)	none	Not scheduled
K6-32	plume tracking well	CAMP	P (SA), S (A)	none	Not scheduled
K6-33	plume tracking well	CAMP	P (SA), S (A)	none	Not scheduled
K6-35	plume tracking well	CAMP	P (SA), S (A)	none	Not scheduled
W-33C-01	plume tracking well	CAMP	P (SA), S (A)	none	Not scheduled
EP6-06	release detection well	DMP	All (Q)	All	
EP6-08	release detection well	DMP	All (Q)	none	DRY
EP6-09	release detection well	DMP	All (Q)	All	
K6-01S	release detection well	DMP	All (Q)	All	
K6-19	release detection well	DMP	All (Q)	All	
K6-36	release detection well	DMP	All (Q)	none	DRY
CARNRW1	water supply well	CAMP	P (M), S (M)	P,S	
CARNRW2	water supply well	CAMP	P (M), S (M)	P,S	
CARNRW3	water supply well	CAMP	P (M), S (M)	P,S	
CARNRW4	water supply well	CAMP	P (M), S (M)	P,S	

[a] "P" = primary contaminants of concern-tritium and VOCs. "S" = secondary contaminants of concern-perchlorate and nitrate. "All" = all DMP constituents of concern (see **Table C-1** for a list). "(M)" = sampled monthly. "(Q)" = sampled quarterly. "(SA)" = sampled semiannually (done first and third quarters of year). "(A)" = sampled annually (done first quarter of year). "(B)"= sampled biennially (done first quarter of year).

Appendix C

Statistical Methods for Detection Monitoring

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Statistical Methods for Detection Monitoring

Monitoring and reporting provisions of the CERCLA closure and post-closure plan for the Pit 6 landfill require the use of statistical methods from the *California Code of Regulations* (CCR) Title 23, Division 3, Chapter 15, Section 2550.7 (Ferry *et al.*, 1998).

We use statistically determined limits of concentration (SLs) to detect potential releases of constituents of concern to ground water from solid wastes contained in the Pit 6 landfill. We employ two statistical methods, prediction intervals (PIs) and control charts (CCs), to generate SLs. Both methods are sensitive to constituents of concern concentration increases. Both methods are cost-effective, requiring only one measurement of a constituent of concern per quarter per monitoring well.

We prefer the PI method when constituents of concern concentrations in ground water are similar up-gradient and down-gradient from the monitored unit. We use parametric PI methods when the up-gradient constituent of concern concentration data are all above the detection limit and the data are approximately normally distributed. We may use parametric methods on log-transformed data, if the transformed data follow a normal distribution. Nonparametric PI methods are more effective when the data cannot be transformed to a normal distribution, or when they contain nondetections.

When the concentration of a constituent of concern is spatially variable in the vicinity of a monitored unit, we develop a control chart for each down-gradient monitoring well. The control chart compares each new quarterly constituent of concern measurement with its concentration history for that well.

Wherever sufficient historical detections exist, we calculate an SL such that any future measurement has approximately a 1-in-100 chance of exceeding the SL, when no change in concentration has actually occurred. This yields a statistical test with a significance level of approximately 0.01. Where historical detections exist, but non-detections constitute part of the data, we set the SL equal to the highest concentration measured. If historical analyses of a constituent of concern show all non-detections, then we set the SL equal to the analytical reporting limit (RL). When a routine constituent of concern measurement exceeds an SL, we perform two discrete retests. This method of data verification is in accordance with CCR Title 23, Chapter 15, Section 2550.7.

Constituents of Concern

Constituents of concern were identified for monitoring in the ground water at the Pit 6 landfill prior to its closure (Ferry *et al.,* 1998). Constituents of concern, as defined by CCR Title 22, Chapter 15, are waste constituents, their reaction products, or hazardous constituents that are

reasonably expected to be in or derived from waste buried in Pit 6. The current constituents of concern for Pit 6 are listed in **Table C-1** below.

Table C-1. Pit 6 constituents of concern, typical analytical reporting limit (RL), concentration limit (CL)[a], and statistical limit (SL) for each of the six detection monitoring wells.

Constituent of concern	Typical analytical RL (units)	Well EP6-06 CL; SL	Well EP6-08 CL; SL	Well EP6-09 CL; SL	Well K6-01S CL; SL	Well K6-19 CL; SL	Well K6-36 CL; SL
1,1,1-TCA	0.5 µg/L	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL
1,2-DCA	0.5 µg/L	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL
Cis-1,2-DCE	0.5 µg/L	<RL; RL	<RL; RL	<RL; RL	5.4; 7.0	<RL; RL	<RL; RL
Chloroform	0.5 µg/L	<RL; RL	0.1; 1.0	<RL; RL	<RL; RL	0.2; 1.5	<RL; RL
Methylene chloride	0.5 µg/L	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL
PCE	0.5 µg/L	<RL; RL	0.4; 1.6	<RL; RL	<RL; RL	<RL; RL	0.5; 1.0
TCE	0.5 µg/L	<RL; RL	<RL; RL	14; 17	1.1; 1.5	8.2; 13	0.8; 2.1
Benzene	0.5 µg/L	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL
Ethylbenzene	0.5 µg/L	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL
Toluene	0.5 µg/L	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL
Total xylenes	1.0 µg/L	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL
Beryllium	0.5 µg/L	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL
Mercury	0.2 µg/L	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL
Carbon disulfide	5.0 µg/L	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL
Perchlorate	4.0 µg/L	<RL; RL	<RL; RL	<RL; RL	<RL; RL	10.2; 27.5	5.3; 14.4
Tritium	100 pCi/L	RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL	2060; 2390
Uranium (total)	0.5 pCi/L	1.9; 3.6	1.2; 1.5	2.1; 3.7	6.6; 27	3.2; 7.2	0.5; 1.4
Gross alpha [b]	2 pCi/L	2.7; 7.7	0.9; 4.0	1.0; 4.9	7.0; 26	2.0; 9.2	<RL; RL
Gross beta [b]	2 pCi/L	8.6; 21	8.6; 21	8.6; 21	14; 58	8.6; 21	9.8; 26

[a] CL (concentration limit) is equivalent to the background concentration of a COC.

[b] Gross alpha and gross beta are surrogates for ^{125}Sb, ^{137}Cs, ^{60}Co, ^{22}Na, ^{90}Sr, ^{204}Tl, and ^{232}Th.

Chlorinated VOCs (including TCE, PCE, 1,2-DCA, 1,1,1-TCA, methylene chloride, chloroform, benzene, toluene, ethylbenzene, and total xylenes) were detected historically in ground water and/or in soil adjacent to Pit 6. These VOCs are constituents of concern.

Beryllium and mercury are constituents of concern because they are listed in the waste disposal records for Pit 6.

Nine radionuclide constituents of concern are associated with waste buried in Pit 6. They are ^{125}Sb, ^{137}Cs, ^{60}Co, ^{22}Na, ^{90}Sr, ^{204}Tl, ^{232}Th, ^{238}U, and tritium. Gross alpha and gross beta radioactivity are used as surrogates for seven of these nuclides, but not for uranium and tritium, which are measured separately (**Table C-1**).

A minor tritium release occurred prior to closure of Pit 6 and is the object of a continuing LLNL CERCLA investigation. The detection monitoring well BC6-12 was destroyed during year 2000 because it was screened across two water-bearing zones and could have provided a conduit for tritium in the shallower zone to contaminate ground water in the deeper zone. Well BC6-12 was replaced by well K6-36, which was constructed adjacent to it. Well K6-36 is screened only in the shallow water-bearing zone. Our calculated constituent of concern SLs for replacement well K6-36 are shown in **Table C-1**.

A post-closure LLNL CERCLA study detected perchlorate in ground water down-gradient of Pit 6. Consequently, perchlorate was added to the constituent of concern list and SLs for this chemical have been calculated (**Table C-1**).

Pesticides were not detected over an 18-month period (6 quarterly sampling events) following pit closure and were removed from the constituents of concern list.

Phthalates were not designated as constituents of concern because they were rarely detected prior to pit closure. However, since post-closure monitoring began in 1998, we have detected bis(2-ethylhexyl)phthalate (also known as di[2-ethylhexyl]phthalate, or DEHP) in ground water both up-gradient and down-gradient from Pit 6.

Table C-2 lists constituents of concern that have indicated statistically significant evidence of release to ground water since post-closure monitoring began in 1998. **Table C-2** also lists the date of our 7-day letter notification to the CVRWQCB and the status of any additional investigation of the constituent of concern. Note that 1,2-DCA has not been detected since 1998.

Table C-2. Pit 6 constituents of concern showing statistical evidence of post-closure release.

Constituent of Concern	Date of 7-day letter report	Status of release investigation
1,2-DCA	10/13/98[a]	Transferred to ERD[b]
TCE	09/11/07[c]	Transferred to ERD[b]
Uranium	02/21/08[d]	Transferred to ERD[b]

[a] Galles, H. L., to S. Timm (1998), Letter: *Statistically Significant Evidence for a Release of 1,2-Dichloroethane from Pit 6* (WGMG98:282, October 13, 1998).

[b] LLNL Environmental Restoration Department.

[c] Goodwin,S., to S. Timm (2007), Letter: *Statistically Significant Evidence for a Release of Trichloroethene (TCE) from Lawrence Livermore National Laboratory Experimental Test Site (Site 300) Pit 6* (WGMG07-109, September 11, 2007).

[d] Jackson, C.S., to S. Timm (2007), Letter: *Statistically Significant Evidence for a Release of Total Uranium from Lawrence Livermore National Laboratory Experimental Test Site (Site 300) Pit 6* (WGMG08-022, February 21, 2008).

Appendix D

Changes in Monitoring Programs or Methods

Appendix D

Changes in Monitoring Programs or Methods

LLNL implemented a compliance monitoring program during the second quarter of 1998 for the CERCLA-closed Pit 6 landfill at Site 300. The program is described in detail in Ferry *et al.*, 1998.

During 2000, two new monitoring –wells, designated K6-35 and K6-36, replaced monitoring wells BC6-11 and BC6-12, which were destroyed by grouting. Well K6-36, which is screened in the first (shallower) of two water-bearing zones, replaced well BC6-12 for re–lease detection. Well K6-35, screened in the next deeper water-bearing zone, is used for corrective-action assessment.

By request of the CVRWQCB, perchlorate was added to the list of Pit 6 constituents of concern during the third quarter of 2000.

By request of the CVRWQCB, since the third quarter of 2000, a table of information (**Table B-5)** has been provided that lists the Pit 6 CERCLA monitoring wells, their monitoring program assignments, their sampling frequencies, the constituents of concern they monitor, and a reason if they were not sampled during the reported quarter.

During 2001, quarterly tritium monitoring was expanded to include CERCLA well K6-33 and the private, off-site water-supply wells designated CARNRW1 and CARNRW2. During 2002, a new CERCLA guard well was completed downgradient from Pit 6 adjacent to the Site 300 boundary. This well is identified as W-PIT6-1819.

Beginning January 1, 2003, the CAMP sampling schedule and constituents of concern have changed as described in the *Compliance Monitoring Plan/Contingency Plan for Interim Remedies at Lawrence Livermore National Laboratory, Site 300* (Ferry, *et al.*, 2002). An expanded set of CAMP wells and springs will be sampled semiannually for tritium and VOCs, and annually for nitrate and perchlorate, while DMP well monitoring remains essentially unchanged. However, upgradient wells K6-03, K6-04, K6-15, and K6-32, which were formerly sampled quarterly for all the DMP constituents of concern listed in **Table C-1**, are now designated to be CAMP plume-tracking wells and are sampled semiannually for tritium and VOCs and annually for nitrate and perchlorate only. As of the fourth quarter of 2004, VOCs have been reported as Total VOCs (TVOCs) to be consistent with other reports.

During 2006, reporting limits provided by the analytical laboratory for U.S. Environmental Protection Agency (EPA) Methods 200.8:Be, 601, and 624 changed due to a transition of the contract laboratory's data management system. Essentially, the analytical laboratory had agreed to provide detection limits for EPA Methods 601 and 624, which were the same as EPA Method 8260. However, after the data management system change, the labs began reporting

only what was specified in our contracts. As a result of this change in practice, the revisions have affected the reported non-detect concentrations for the following constituents of concern: beryllium, benzene, chloroform, 1,2-dichloroethane (cis-1,2-DCE), cis-1,2-dichloroethene, ethylbenzene, PCE, toluene, 1,1,1-trichloroethane, and total xylenes. In all these cases, the different reporting limits represent practical quantitation limits (PQLs) selected by the analytical laboratory, not a change in measured concentrations. LLNL examined if contract modifications, changes in analytical suites, or a change of method would best solve the problem. Starting in the second quarter of 2007, we began reporting VOCs measured with EPA method 8260 and metals with the WGMGMET3 metal contract suite, which provides detection limits consistent with, or lower than, past reports. No changes to this monitoring plan were made during this reporting period.

Appendix E

Quality Assurance Sample Results

Table E-1. Quality assurance samples from Pit 6 during the fourth quarter of 2011.

Constituent*	Units	EP6-09 Routine (Oct 10)	EP6-09 Duplicate (Oct 10)	K6-19 Routine (Oct 10)	K6-19 Duplicate (Oct 10)	PIT6FB Field blank (Oct 10)
Total dissolved solids (TDS)	mg/L	1,300	–	790	680	<5
Beryllium	µg/L	<0.2	–	<0.2	<0.2	<0.2
Mercury	µg/L	<0.2	–	<0.2	<0.2	<0.2
Nitrate (as NO3)	mg/L	3.8	–	<0.5	<0.5	<0.5
Perchlorate	µg/L	<4	–	<4	<4	<4
1,1,1-Trichloroethane	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
1,1,2,2-Tetrachloroethane	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
1,1,2-Trichloroethane	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
1,1-Dichloroethane	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
1,1-Dichloroethene	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
1,2-Dichloroethane	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
1,2-Dichloroethene (total)	µg/L	<1	-	<1	<1	<1
1,2-Dichloropropane	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
cis-1,2-Dichloroethene	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
cis-1,3-Dichloropropene	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
2-Butanone	µg/L	<10	<0.5	<10	<10	<10
2-Chloroethylvinylether	µg/L	<10	<0.5	<10	<10	<10
2-Hexanone	µg/L	<10	<1	<10	<10	<10
4-Methyl-2-pentanone	µg/L	<10	<1	<10	<10	<10
Acetone	µg/L	<10	12	<10	<10	<10
Acrolein	µg/L	<50	<2	<50	<50	<50
Acrylonitrile	µg/L	<50	<2	<50	<50	<50
Benzene	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Bromodichloromethane	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Bromoform	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Bromomethane	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Carbon disulfide	µg/L	<5	<1	<5	<5	<5
Carbon tetrachloride	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Chlorobenzene	µg/L	<0.5	<1	<0.5	<0.5	<0.5
Chloroethane	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Chloroform	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Chloromethane	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Dibromochloromethane	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Dichlorodifluoromethane	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Ethanol	µg/L	<1000	-	<1000	<1000	<1000
Ethylbenzene	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Freon 113	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Methylene chloride	µg/L	<1	<0.5	<1	<1	<1
Styrene	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Tetrachloroethene	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Toluene	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Total xylene isomers	µg/L	<1	<0.5	<1	<1	<1
trans-1,2-Dichloroethene	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
trans-1,3-Dichloropropene	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Trichloroethene	µg/L	5.9	5	3.2	3.2	<0.5
Trichlorofluoromethane	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Vinyl acetate	µg/L	<20	<1	<20	<20	<20
Vinyl chloride	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Tritium	Bq/L	0.59 ± 2.5	–	7.0 ± 3.6	6.7 ± 3.5	6.1 ± 3.5
Gross alpha	Bq/L	0.13 ± 0.071	–	0.12 ± 0.061	0.064 ± 0.051	0.020 ± 0.031
Gross beta	Bq/L	0.24 ± 0.063	–	0.26 ± 0.063	0.25 ± 0.057	0.0045 ± 0.034
Uranium (calculated total)	Bq/L	0.11 ± 0.016	–	0.094 ± 0.014	0.11 ± 0.013	0.00058 ± 0.00079

(–) = Not analyzed.

Environmental Functional Area, Lawrence Livermore National Laboratory
P.O. Box 808, L-627, Livermore, California 94551