5

Terrestrial Monitoring

Gretchen M. Gallegos
Nicholas A. Bertoldo
Richard A. Brown
Lisa Paterson
S. Ring Peterson

INTRODUCTION

Lawrence Livermore National Laboratory measures the radioactivity present in soil, sediment, vegetation, and wine. LLNL also measures absorbed gamma radiation dose at ground level receptors from terrestrial and atmospheric sources. The LLNL monitoring program is designed to measure any changes in environmental levels of radioactivity and to evaluate any increase in radioactivity that might have resulted from LLNL operations. All monitoring activity follows U.S. Department of Energy (DOE) guidance. Monitoring on site or in the vicinity of the Livermore site or Site 300 detects radioactivity released from LLNL that may contribute to radiation dose to the public or to biota; monitoring at distant locations not impacted by LLNL operations detects naturally occurring background radiation.

Terrestrial pathways from LLNL operations leading to potential radiation dose to the public include resuspension of soils, infiltration of constituents of runoff water through arroyos to groundwater, ingestion of locally grown foodstuffs, and external exposure to contaminated surfaces and radioactivity in air. Potential ingestion doses are calculated from measured concentrations in vegetation and wine; doses from exposure to ground level external radiation are obtained directly from thermoluminescent dosimeters (TLDs) deployed for environmental radiation monitoring. Potential dose to biota (see Chapter 6) is calculated using a simple screening model that requires knowledge of radionuclide concentrations in soils, sediments, and surface water.

Surface soil samples are analyzed for plutonium and gamma-emitting radionuclides. Gamma-emitting radionuclides in surface soils include uranium isotopes, which are used to provide data about the natural occurrence of uranium as well as data about the effects of explosive tests at Site 300, some of which contain depleted uranium. Other gamma-emitting, naturally occurring nuclides (potassium-40 and thorium-232) provide additional data about local background conditions, and the long-lived fission product cesium-137 provides information on global fallout from historical nuclear weapons testing. In addition, soils at Site 300 are analyzed for beryllium, a potentially toxic metal used there. With the addition of tritium, a similar suite of nuclides is analyzed in the sediments. Vadose zone soil concentrations are compared with de minimis concentrations for tritium and background concentrations for metals. Vegetation and wine samples are measured for tritium alone because tritium is the only nuclide released from LLNL that can be measured in these products. Cosmic radiation accounts for about half the absorbed gamma dose measured by the TLDs; naturally occurring isotopes of the uranium-thorium-actinium decay series provide the dose from natural background radiation found in the earth's crust. By characterizing the background radiation, LLNL can determine what, if any, excess dose can be attributed to laboratory operations.

Surface soils near the Livermore site and Site 300 have been sampled since 1971. Around the Livermore site, sediments (from selected arroyos and other drainage areas) and vadose zone soils have been sampled since 1988 and 1996, respectively; sampling of sediments or vadose zone soils is not warranted at Site 300. LLNL has been monitoring tritium in vegetation since 1966 and has performed routine vegetation sampling on and around the Livermore site and Site 300 since 1971. External radiation has been monitored around the Livermore site since 1973 and around Site 300 since 1988.

Sampling for all media is conducted according to written, standardized procedures summarized in the *Environmental Monitoring Plan* (Woods 2005).

LLNL also monitors wildlife and plants at the Livermore site and Site 300, and carries out research relevant to the protection of rare plants and animals. Some monitoring and research programs are required by existing permits, while additional monitoring programs are designed to track the distribution and abundance of rare species. In addition, baseline surveys are conducted to determine distribution of special status species on LLNL property. Monitoring and research of biota on LLNL property is conducted to ensure compliance with requirements of the U.S. Endangered Species Act, the California Endangered Species Act, the Eagle Protection Act, the Migratory Bird Treaty Act, and the California Native Plant Protection Act as they pertain to endangered or threatened species and other special status species, their habitats, and designated critical habitats that exist at the LLNL sites.

Soil and Sediment Monitoring

There are 6 soil and 4 sediment sampling locations on LLNL's Livermore site (**Figure 5-1**); 13 soil sampling locations in the Livermore Valley, including 6 at the Livermore Water Reclamation Plant (LWRP) (**Figure 5-2**); and 14 soil sampling locations at or near Site 300 (**Figure 5-3**). The locations were selected to represent background concentrations (distant locations unlikely to be affected by LLNL operations) as well as areas where there is the potential to be affected by LLNL operations. Areas with known contaminants, such as the LWRP and areas around explosives tests areas at Site 300, are also sampled.

Surface sediment and vadose zone soil samples are collected from selected arroyos and other drainage areas at and around the Livermore site; these locations (**Figure 5-1**) largely coincide with selected storm water sampling locations (see Chapter 4). Soils in the vadose zone (the region below the land surface where the soil pores are only partially filled with water) are collected in arroyo channels at the Livermore site as part of the Ground Water Protection Management Program. Infiltration of natural runoff through arroyo channels is a significant source of groundwater recharge, accounting for an estimated 42% of resupply for the entire Livermore Valley groundwater basin (Thorpe et al. 1990). The collocation of sampling for these media facilitates comparison of analytical results.

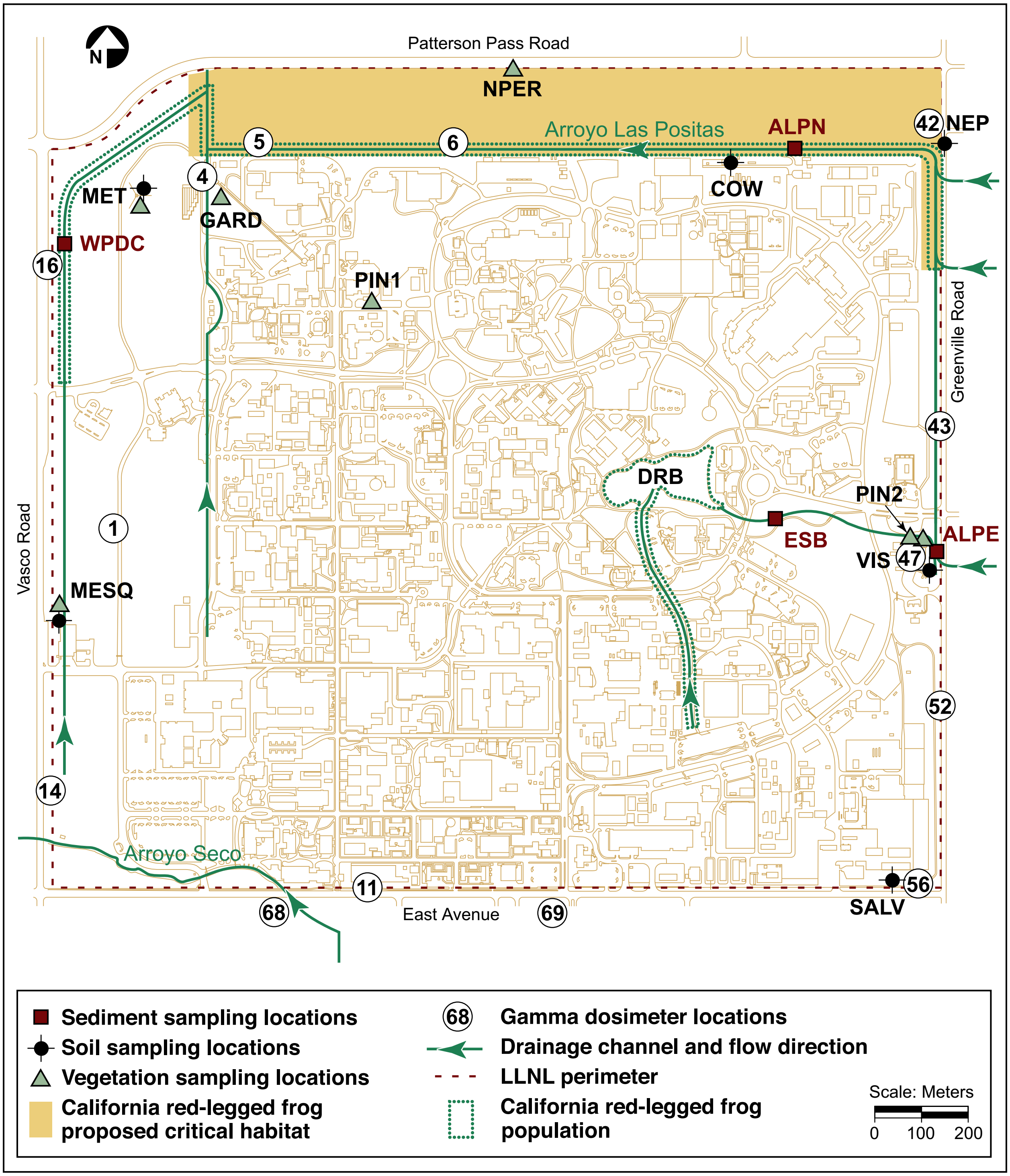


Figure 5-1. Sampling locations, Livermore site, 2004

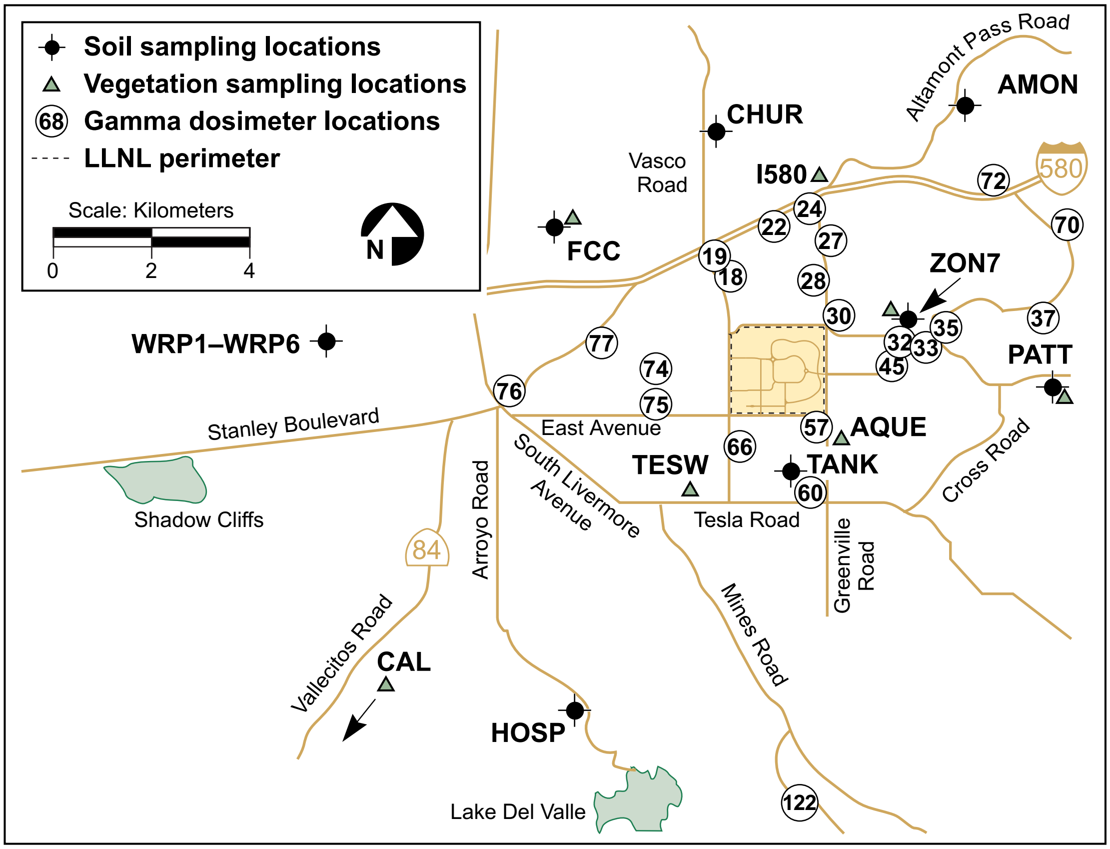


Figure 5-2. Sampling locations, Livermore Valley, 2004

Surface soil samples are collected from the top 5 cm of soil because aerial deposition is the primary pathway for potential contamination, and resuspension of materials from the surface into the air is the primary exposure pathway to nearby human populations. Two 1-m squares are chosen from which to collect the sample. Each sample is a composite consisting of 10 subsamples that are collected with an 8.25 cm diameter stainless steel core sampler at the corners and the center of each square. Surface sediment samples are collected in a similar manner. Ten subsamples, 5-cm deep, are collected at 1-m intervals along a transect of the arroyo or drainage channel. At one of the subsample locations, a 15-cm deep sample is acquired for tritium analysis; this deeper sample is necessary to obtain sufficient water in the sample for tritium analysis. Vadose zone samples are collected at the same location as the tritium subsample. A hand auger is used to collect a 30- to 45-cm deep sample for metals analysis, and an electric drive coring device is used to collect a sample 45- to 65-cm deep for analysis for polychlorinated biphenyls (PCBs).

In 2004, surface soil samples in the Livermore Valley were analyzed for plutonium and gamma-emitting radionuclides. Samples from Site 300 were analyzed for gamma-emitting radionuclides and beryllium. Annual sediment samples collected at the

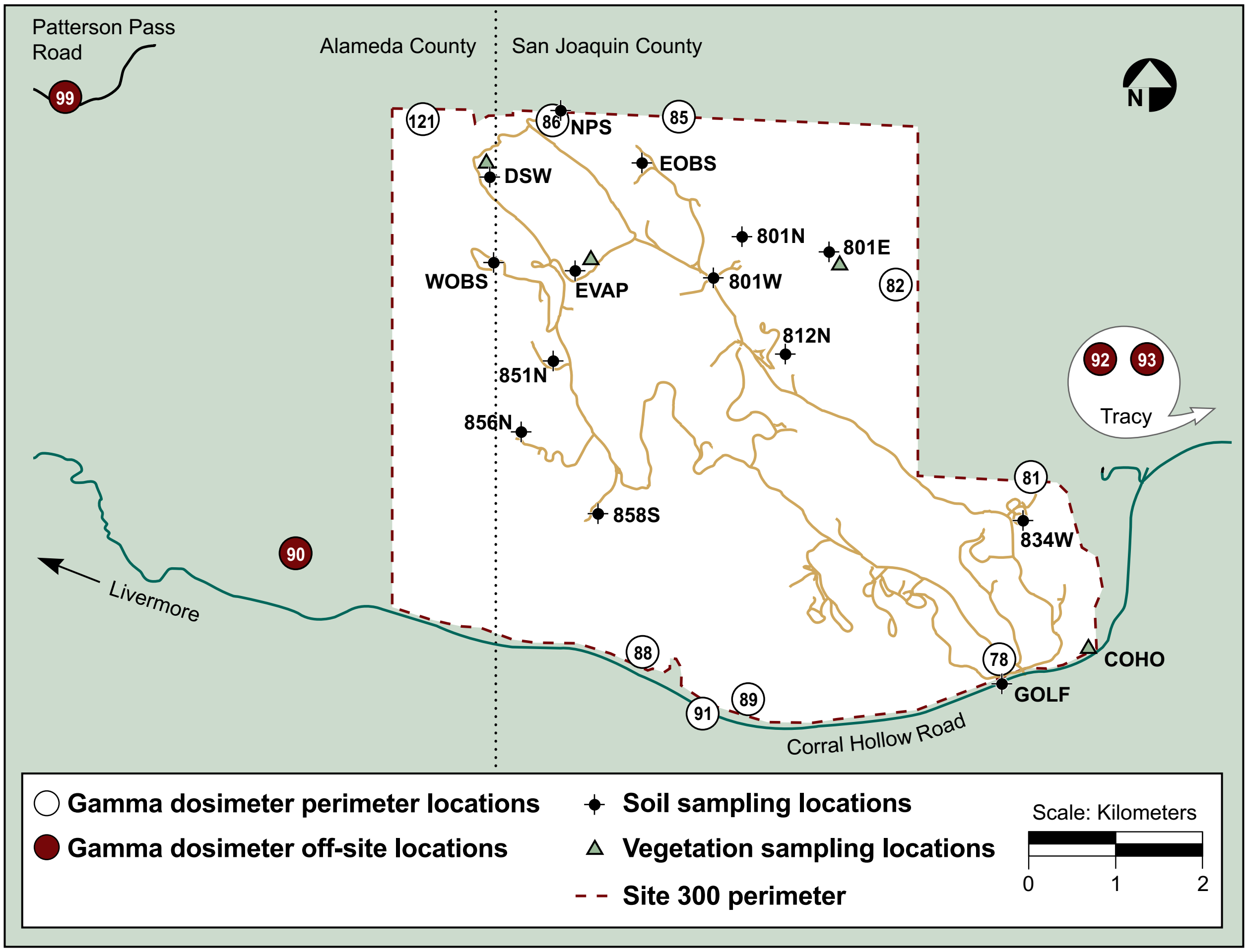


Figure 5-3. Sampling locations at Site 300 and off-site, 2004

Livermore site were analyzed for plutonium, gamma-emitting radionuclides, and tritium. Vadose zone samples were analyzed for total and soluble metals; one vadose zone location was analyzed for PCBs.

Prior to radiochemical analysis, surface soil and sediment samples are dried, sieved, ground, and homogenized. The plutonium content of a 100-g sample aliquot is determined by alpha spectrometry. Other sample aliquots (300-g) are analyzed by gamma spectrometry using a high-purity germanium (HPGe) detector for 47 radionuclides, including fission products, activation products from neutron interactions on steel, actinides, and natural products. The 10-g subsamples for beryllium analyses are analyzed by atomic emission spectrometry.

Vadose zone soil samples are analyzed by standard EPA methods. In 2004, as in the previous four years, a vadose zone soil sample from location ESB (**Figure 5-1**) was also analyzed for PCBs.

Radiological Monitoring Results

Tables 5-1 through **5-3** present data on the concentrations of plutonium-238 and plutonium-239+240 in the Livermore Valley surface soils and sediments; data for americium-241, which is only detected at LWRP; and data for tritium, which is only measured in surface sediments. Data for cesium-137, potassium-40, thorium-232, uranium-235, and uranium-238 in surface soils from the Livermore Valley sampling locations are included in the file "Ch5 Soil" provided on the report CD.

The concentrations and distributions of all observed radionuclides in soil for 2004 are within the ranges reported in previous years and generally reflect worldwide fallout and naturally occurring concentrations. Plutonium has, in the past, been detected at levels above background at VIS, a perimeter sampling location near the east boundary of the Livermore site. In 2004, the measured plutonium-239+240 value for VIS was

Table 5-1. Plutonium activity concentrations in Livermore Valley soil, 2004

Location	Plutonium-238 (mBq/dry g)	Plutonium-239+240 (mBq/dry g)
L-AMON-SO	0.0075 ± 0.0021	0.093 ± 0.0094
L-CHUR-SO	0.0038 ± 0.0037	0.11 ± 0.015
L-COW-SO	0.0058 ± 0.0019	0.025 ± 0.0042
L-FCC-SO	0.0041 ± 0.0016	0.037 ± 0.0053
L-HOSP-SO	0.0051 ± 0.0019	0.038 ± 0.0055
L-MESQ-SO	0.0055 ± 0.0020	0.025 ± 0.0041
L-MET-SO	0.0017 ± 0.0011	0.050 ± 0.0061
L-NEP-SO	0.0078 ± 0.0031	0.046 ± 0.0077
L-PATT-SO	0.0034 ± 0.0042	0.023 ± 0.0072
L-SALV-SO	0.015 ± 0.0031	0.051 ± 0.0064
L-TANK-SO	0.0067 ± 0.0020	0.095 ± 0.0098
L-VIS-SO	0.022 ± 0.0043	0.47 ± 0.037
L-ZON7-SO	0.0050 ± 0.0012	0.056 ± 0.0051
Median	**0.0055**	**0.050**
IQR[(a)]	**0.0034**	**0.056**
Maximum	**0.022**	**0.47**

Note: Radioactivities are reported as the measured concentration and either an uncertainty (±2σ counting error) or as being less than or equal to the detection limit. If the concentration is less than or equal to the uncertainty or the detection limit, the result is considered to be a nondetection. See Chapter 8.

a IQR = Interquartile range

Table 5-2. Plutonium and americium activity concentrations in LWRP soil, 2004

Location	Plutonium-238 (mBq/dry g)	Plutonium-239+240 (mBq/dry g)	Americium-241 (mBq/dry g)
L-WRP1-SO	0.45 ± 0.034	9.6 ± 0.65	4.8 ± 1.4
L-WRP2-SO	0.25 ± 0.020	4.4 ± 0.30	2.8 ± 2.3
L-WRP3-SO	0.057 ± 0.0083	0.96 ± 0.073	<0.77
L-WRP4-SO	0.027 ± 0.0043	0.51 ± 0.038	<0.51
L-WRP5-SO	0.074 ± 0.0086	1.7 ± 0.12	<1.1
L-WRP6-SO	0.069 ± 0.0076	1.2 ± 0.085	<0.51
Median	**0.072**	**1.5**	**<0.94**
IQR[a]	**0.15**	**2.7**	—[b]
Maximum	**0.45**	**9.6**	**4.8**

Note: Radioactivities are reported as the measured concentration and either an uncertainty (±2σ counting error) or as being less than or equal to the detection limit. If the concentration is less than or equal to the uncertainty or the detection limit, the result is considered to be a nondetection. See Chapter 8.

a IQR = Interquartile range

b Interquartile range not calculated because of high incidence of nondetections.

Table 5-3. Plutonium and tritium activity concentrations in surface sediment, 2004

Location	Plutonium-238 (mBq/dry g)	Plutonium-239+240 (mBq/dry g)	Tritium (Bq/L)
L-ALPE-SD	0.0016 ± 0.0010	0.025 ± 0.0041	2.1 ± 3.0
L-ALPN-SD	0.0041 ± 0.0017	0.017 ± 0.0032	0.0096 ± 2.9
L-ESB-SD	0.12 ± 0.011	1.3 ± 0.094	1.9 ± 3.0
L-WPDC-SD	0.00019 ± 0.00060	0.0054 ± 0.0018	0.63 ± 2.9
Median	**0.0029**	**0.021**	**1.3**
IQR[a]	—[b]	—[b]	—[b]
Maximum	**0.12**	**1.3**	**2.1**

Note: Radioactivities are reported as the measured concentration and either an uncertainty (±2σ counting error) or as being less than or equal to the detection limit. If the concentration is less than or equal to the uncertainty or the detection limit, the result is considered to be a nondetection. See Chapter 8.

a IQR = Interquartile range

b Interquartile range not calculated because of high incidence of nondetections

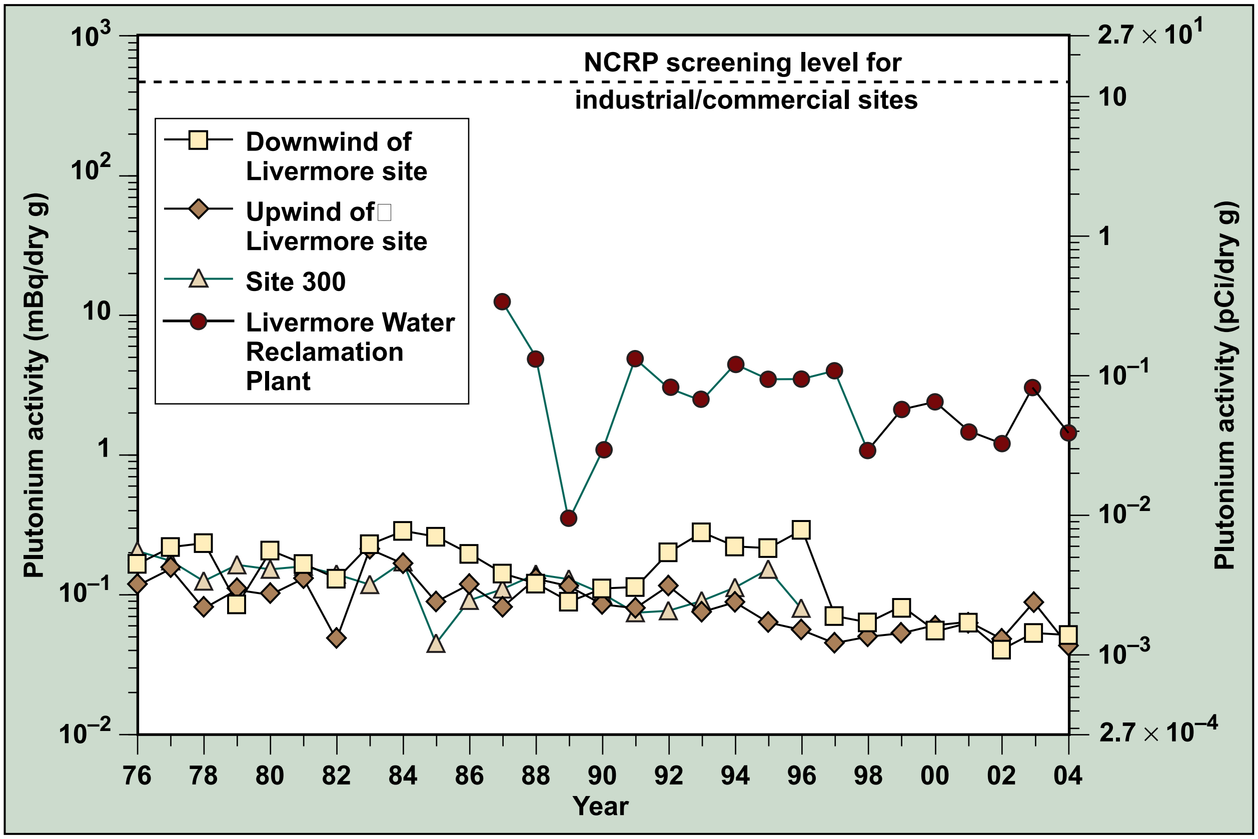
0.47 mBq/dry g (1.28 × 10^{-2} pCi/dry g), a value that is approximately equal to the 95% upper confidence level for the 95th percentile calculated for background data (i.e., 0.48 mBq/dry g [1.3 × 10^{-2} pCi/dry g]) (LLNL 1998, Appendix D). The slightly higher values at and near the Livermore site have been attributed to historic operations, including the operation of solar evaporators for plutonium-containing liquid waste in the southeast quadrant (Silver et al. 1974). LLNL ceased operating the solar evaporators in 1976 and no longer engages in any other open-air treatment of plutonium-containing waste.

A sediment sampling location, ESB, also shows the effects of historic operation of the solar evaporators; it is in the drainage area for the southeast quadrant at LLNL. The measured value for plutonium-239+240 at this location for 2004 was 1.3 mBq/dry g (3.6 × 10^{-2} pCi/dry g). All tritium concentrations were less than the range of concentrations for previous years; all results were below the detection limit.

Elevated levels of plutonium-239+240 (resulting from an estimated 1.2 × 10^{9} Bq [32 mCi] plutonium release to the sanitary sewer in 1967 and earlier releases) were again detected at LWRP sampling locations. In addition, americium-241 was detected in two LWRP samples; it is most likely caused by the natural radiological decay of the trace concentrations of plutonium-241 that were present in the releases to the sewer.

Historical median plutonium-239+240 concentrations in soil in the Livermore Valley upwind and downwind of the center of the LLNL Livermore site and at LWRP are shown in **Figure 5-4**. Livermore Valley upwind concentrations have remained relatively constant since monitoring began and generally are indicative of worldwide fallout. Greater variation can be noted in the downwind concentration data, which in 2004 included sampling locations VIS, PATT, NEP, COW, AMON, SALV, and ZON7, compared with the upwind data. Notable variability in plutonium-239+240 is also seen in samples from LWRP. Because the plutonium-239+240 is likely to be present in discrete particles, the random presence or absence of the particles dominates the measured plutonium-239+240 in any given sample.

Table 5-4 presents data on the concentrations of uranium-235, uranium-238, and beryllium in soil from the Site 300 sampling locations; 2004 soils data for Site 300 for cesium-137, potassium-40, and thorium-232 are included in the file "Ch5 Soil" provided on the report CD. The concentrations and the distributions of all observed radionuclides in Site 300 soil for 2004 lie within the ranges reported in all years since monitoring began. The ratio of uranium-235 to uranium-238 generally reflects the natural ratio of 0.7%. There is significant uncertainty in calculating the ratio, however, due to the difficulty of measuring low activities of uranium-238 by gamma spectrometry. The highest measured value for 2004 occurred at 812N. The uranium-235 to uranium-238 ratio in this sample equals that ratio for depleted uranium (i.e., 0.002). Such values at Site 300 result from the use of depleted uranium in explosive experiments.



Note: Upwind and downwind designations are relative to the center of the Livermore site.
NCRP = National Council on Radiation Protection and Measurements

Figure 5-4. Median plutonium-239+240 activities in surface soils, 1976–2004

Nonradiological Monitoring Results

Analytical results for metals are compared with site-specific natural background concentrations for metals. (See the file "Ch5 Soil" provided on the report CD for the background concentrations and analytical results for metals.)

All total metals concentrations at the Livermore site were within site background, with the exception of zinc at location ESB. Livermore site groundwater surveillance monitoring (see Chapter 4) will determine any impacts on site groundwater. Since 2000, Aroclor 1260 (a PCB) has been detected at location ESB. In 2004, it was again detected at location ESB at a concentration of 3.7 mg/kg. The presence of PCBs suggests that this sample represents residual low-level contamination from the 1984 excavation of the former East Traffic Circle landfill (see Chapter 4). The detected concentrations are below the federal and state hazardous waste limits.

Table 5-4. Uranium and beryllium concentrations in Site 300 soil, 2004

Location	Uranium-235[(a)] (µg/dry g)	Uranium-238[(b)] (µg/dry g)	U235/U238 ratio	Beryllium (mg/kg)
3-801E-SO	0.020 ± 0.098	2.3 ± 1.1	0.0087 ± 0.0060	<0.5
3-801N-SO	0.029 ± 0.013	5.7 ± 1.6	0.0051 ± 0.0027	0.64
3-801W-SO	0.029 ± 0.015	4.3 ± 1.6	0.0067 ± 0.0043	<0.5
3-812N-SO	0.36 ± 0.025	180 ± 37	0.0020 ± 0.00043	9.3
3-834W-SO	0.017 ± 0.012	1.9 ± 1.5	0.0089 ± 0.0095	0.61
3-851N-SO	0.030 ± 0.014	4.3 ± 2.0	0.0070 ± 0.0046	0.67
3-856N-SO	0.021 ± 0.0083	2.2 ± 0.77	0.0095 ± 0.0050	<0.5
3-858S-SO	0.023 ± 0.015	2.0 ± 0.79	0.012 ± 0.0088	<0.5
3-DSW-SO	0.035 ± 0.012	5.6 ± 1.6	0.0063 ± 0.0028	<0.5
3-EOBS-SO	0.025 ± 0.012	2.1 ± 1.7	0.012 ± 0.011	<0.5
3-EVAP-SO	0.033 ± 0.010	4.9 ± 1.5	0.0067 ± 0.0029	<0.5
3-GOLF-SO	0.021 ± 0.012	1.8 ± 1.5	0.012 ± 0.012	<0.5
3-NPS-SO	0.022 ± 0.0093	2.0 ± 0.91	0.011 ± 0.0067	<0.5
3-WOBS-SO	0.015 ± 0.0086	1.5 ± 1.0	0.010 ± 0.0088	<0.5
Median	**0.024**	**2.3**	**0.0088**	**<0.5**
IQR[(c)]	**0.0087**	**2.8**	**0.0041**	**—[(d)]**
Maximum	**0.36**	**180**	**0.012**	**9.3**

Note: Radioactivities are reported as the measured concentration and either an uncertainty (±2σ counting error) or as being less than or equal to the detection limit. If the concentration is less than or equal to the uncertainty or the detection limit, the result is considered to be a nondetection. See Chapter 8.

a Uranium-235 activities can be determined by multiplying the mass concentration provided in the table in µg/dry g by specific activity of uranium-235 (i.e., 0.080 Bq/µg or 2.15 pCi/µg).

b Uranium-238 activities can be determined by multiplying the mass concentration provided in the table in µg/dry g by specific activity of uranium-238 (i.e., 0.01245 Bq/µg or 0.3367 pCi/µg).

c IQR = Interquartile range

d Interquartile range not calculated because of high incidence of nondetections.

Beryllium results for soils at Site 300 (**Table 5-4**) were within the ranges reported since sampling began. The highest value, 9.3 mg/kg, was found at B812, which is an area that has been used for explosives testing. This value is much less than the 110 mg/kg detected at B812 in 2003. These differing results reflect the particulate nature of the contamination.

Environmental Impact on Soil and Sediment

Livermore Site

Routine surface soil, sediment, and vadose zone soil sample analyses indicate that the impact of LLNL operations on these media in 2004 has not changed from previous years and remains insignificant. Most analytes of interest or concern were detected at background concentrations or in trace amounts, or could not be measured above detection limits.

The highest value of 9.6 mBq/dry g (0.26 pCi/dry g) for plutonium-239+240 measured at LWRP is 2% of the National Council on Radiation Protection and Measurements (NCRP) recommended screening limit of 470 mBq/g (12.7 pCi/g) for property used for commercial purposes (NCRP 1999). Regression analysis of the annual medians of the upwind and downwind data groups shows a slight decrease in plutonium-239+240 values with time.

Over the years, LLNL has frequently investigated the presence of radionuclides in local soils. Several of the studies are listed in **Tables 2-1** and **5-5**. These studies have consistently shown that the concentrations of radionuclides in local soils are below levels of health concern.

Site 300

The concentrations of radionuclides and beryllium observed in soil samples collected at Site 300 are within the range of previous data and are generally representative of background or naturally occurring levels. The uranium-235/uranium-238 ratios that are indicative of depleted uranium occur near firing tables at Buildings 801 and 812. They result from the fraction of the firing table operations that disperse depleted uranium. The uranium-238 concentrations are below the NCRP recommended screening level for commercial sites of 313 µg/g (3.9 Bq/g or 105 pCi/g). Historically, some measured concentrations of uranium-238 near Building 812 have been greater than the screening level. A CERCLA remedial investigation is underway at the Building 812 firing table area to define the nature and extent of contamination.

Vegetation and Foodstuff Monitoring

Vegetation sampling locations at the Livermore site (**Figure 5-1**) and in the Livermore Valley (**Figure 5-2**) are divided into four groups (Near, Intermediate, Far, and PIN1) for statistical evaluation. Tritium from LLNL operations may be detected at the Near and Intermediate locations depending upon wind direction and the magnitude of the releases. Near locations (AQUE, GARD, MESQ, NPER, MET, PIN2, and VIS) are onsite or within 1 km of the LLNL site perimeter; Intermediate locations in the

Table 5-5. Special soil and sediment studies

Year	Subject[a]	Reference
1971-1972	Radionuclides in Livermore Valley soil	Gudiksen et al. 1972; Gudiksen et al. 1973
1973	Radionuclides in San Joaquin Valley soil	Silver et al. 1974
1974	Soil study of southeast quadrant of Livermore site	Silver et al. 1975
1976	Evaluation of the Use of Sludge Containing Plutonium as a Soil Conditioner for Food Crops	Myers et al. 1976
1977	Sediments from LLNL to the San Francisco Bay	Silver et al. 1978
1980	Plutonium in soils downwind of the Livermore site	Toy et al. 1981
1990	195 samples taken in southeast quadrant for study	Gallegos et al. 1992
1991	Drainage channels and storm drains studied	Gallegos 1991
1993	EPA studies southeast quadrant	Gallegos et al. 1994
1993	Historic data reviewed	Gallegos 1993
1995	LLNL, EPA, and DHS sample soils at Big Trees Park	MacQueen 1995
1999	Summary of results of 1998 sampling at Big Trees Park	Gallegos et al. 1999
2000	Health Consultation, Lawrence Livermore National Laboratory, Big Trees Park 1998 Sampling	ATSDR 2000
2002	Livermore Big Trees Park:1998 Results	MacQueen et al. 2002
2003	ATSDR Public Health Assessment Plutonium 239 in Sewage Sludge Used as a Soil or Soil Amendment in the Livermore Community	ATSDR 2003

a See Acronyms and Abbreviations for list of acronyms.

Livermore Valley (I580, PATT, TESW, and ZON7) are greater than 1 and less than 5 km from the LLNL perimeter. Far locations are unlikely to be affected by LLNL operations; one background location (CAL) is more than 25 km distant, and the other (FCC) is about 5 km from the Livermore site but generally upwind. The PIN1 location is a pine tree rooted in an area of known tritium groundwater contamination on the Livermore site. Sampling of both PIN1 and PIN2 was discontinued at the end of 2004 due to an infestation of red turpentine beetles in PIN1 and because doses from minor sources no longer need to be calculated for compliance with NESHAPs regulations (see Chapter 6).

There are four monitoring locations for vegetation at Site 300 (**Figure 5-3**). Vegetation at locations DSW and EVAP exhibit variable tritium concentrations due to uptake of contaminated groundwater by roots. At the two other locations, 801E and COHO, the only potential source of tritium uptake is the atmosphere.

Wines for sampling in 2004 were purchased from supermarkets and wine merchants in Livermore. Wines represent the Livermore Valley, two regions of California, and the Rhone Valley in France. In 2004, the wine sampling network was cut by more than half; judicious choice of wines can provide as much information as was obtained from the larger network.

Water is extracted from vegetation by freeze-drying and counted for tritiated water (HTO) using liquid scintillation techniques. Both HTO and organically bound tritium (OBT) are detected in wine using helium-3 mass spectrometry, but the relative fractions of each are not determined.

Vegetation Monitoring Results

All concentrations of tritium in Livermore vegetation for 2004 are shown in **Table 5-6**. The highest mean and maximum concentrations in vegetation for 2004 were at the Near location NPER. NPER is not the location at which the highest concentrations are normally expected. The high concentration in vegetation at NPER occurred during the two-week period when concentrations at the DWTF ambient air tritium sampler were more than eight times higher than the biweekly mean for 2004 (see file "Ch3 Ambient Air" provided on the report CD).

Median values for each set of sampling locations are graphed in **Figure 5-5** to show the trend in tritium concentrations in vegetation since 1972. Concentrations at the Far and Intermediate locations have been below the detection limits for several years. In 2003 and 2004, the median concentrations for Near locations were also below detection limits. The lower limit of detection (LLD) has varied over the years, and a comparison of results based on the recent mean value of the LLD of about 2.0 Bq/L (54 pCi/L) eliminates variability arising from uncertain counting statistics at these low levels. The value for the median for Near locations for 2003 was 1.8 Bq/L (49 pCi/L); for 2004, it was 1.5 Bq/L (40 pCi/L). Although the changes in these concentrations may reflect the lower tritium emissions in 2004 compared with 2003, it can only be by chance, because statistically there is no difference between them.

As in the past, concentrations in PIN1, because of the contaminated groundwater source, were much higher than those in other vegetation. In 2004, PIN2, the pine at location VIS that is only exposed to atmospheric tritium, exhibited concentrations indistinguishable from the herbaceous VIS samples. All Near sample concentrations were statistically different from concentrations in PIN1.

All samples at Site 300 locations 801E and COHO were below detection limits. Median concentrations at locations 801E and COHO have been at or below detection limits since 1991. Tritium in vegetation at DSW and EVAP continues its erratic pattern dating from 1983, with high concentrations at times and nondetections at other times, depending upon whether or not the roots are taking up contaminated groundwater. The median concentrations at DSW and EVAP for 2004 were lower than those in 2003. The highest concentration (360 Bq/L [9700 pCi/L]) was observed at EVAP.

Table 5-6. Quarterly concentrations of tritium in plant water (Bq/L) and mean annual ingestion doses, 2004

	First quarter	Second quarter	Third quarter	Fourth quarter	Median	Mean	Mean dose[a] (nSv/y)
Sampling locations within 1 km of the Livermore site perimeter							
AQUE	1.4 ± 1.4	1.5 ± 1.9	–0.016 ± 2.6	1.5 ± 1.5	1.5	1.1	< 10[b]
GARD	–0.042 ± 1.3	0.39 ± 1.9	–0.070 ± 2.7	4.1 ± 1.7	0.17	1.1	< 10[b]
MESQ	0.27 ± 1.4	1.7 ± 2.0	1.8 ± 2.8	1.1 ± 1.6	1.4	1.2	< 10[b]
MET	–0.60 ± 1.3	5.4 ± 2.1	0.70 ± 2.6	2.3 ± 1.6	1.5	2.0	< 10[b]
NPER	1.2 ± 1.4	5.2 ± 2.1	13 ± 3.0	1.3 ± 1.6	3.3	5.2	25
PIN2	2.4 ± 1.5	6.0 ± 2.1	2.4 ± 3.1	4.5 ± 1.7	3.5	3.8	—[c]
VIS	0.54 ± 1.4	5.4 ± 2.1	0.16 ± 2.6	0.96 ± 1.5	0.75	1.8	< 10[b]
PIN1[d]	22 ± 2.4	44 ± 3.4	210 ± 6.7	84 ± 4.0	64	90	—[e]
Sampling locations from 1 to less than 5 km from the Livermore site perimeter							
I580	–1.7 ± 1.2	1.7 ± 2.0	–0.31 ± 2.7	2.3 ± 1.6	0.70	0.50	< 10[b]
PATT	–0.57 ± 1.3	2.2 ± 2.0	0.38 ± 2.7	1.5 ± 1.6	0.94	0.88	< 10[b]
TESW	1.4 ± 1.4	2.0 ± 2.0	–2.0 ± 2.6	1.7 ± 1.6	1.6	0.77	< 10[b]
ZON7	–0.77 ± 1.3	3.1 ± 2.1	0.86 ± 2.7	1.5 ± 1.5	1.2	1.2	< 10[b]
Sampling locations more than 5 km from the Livermore site perimeter							
CAL	–1.1 ± 1.3	1.9 ± 2.0	0.063 ± 2.6	0.58 ± 1.6	0.32	0.36	< 10[b]
FCC	–2.2 ± 1.2	–2.3 ± 1.5	–1.4 ± 2.6	–0.081 ± 1.5	–1.8	–1.5	< 10[b]
Sampling locations at Site 300							
COHO	–2.1 ± 1.2	1.0 ± 1.9	–1.8 ± 2.9	–0.91 ± 1.4	–1.4	–0.95	< 10[b
801E	–0.38 ± 1.3	2.0 ± 2.0	3.0 ± 3.1	–0.02 ± 1.5	0.99	1.2	< 10[b]
DSW[d]	13 ± 2.0	3.4 ± 2.0	4.5 ± 3.0	3.0 ± 1.7	4.0	6.0	29
EVAP[d]	14 ± 2.0	5.8 ± 2.1	360 ± 9.0	18 ± 2.2	16	99	490

Note: Radioactivities are reported as the measured concentration and an uncertainty (±2σ counting error). If the concentration is less than or equal to the uncertainty, the result is considered to be a nondetection. See Chapter 8.

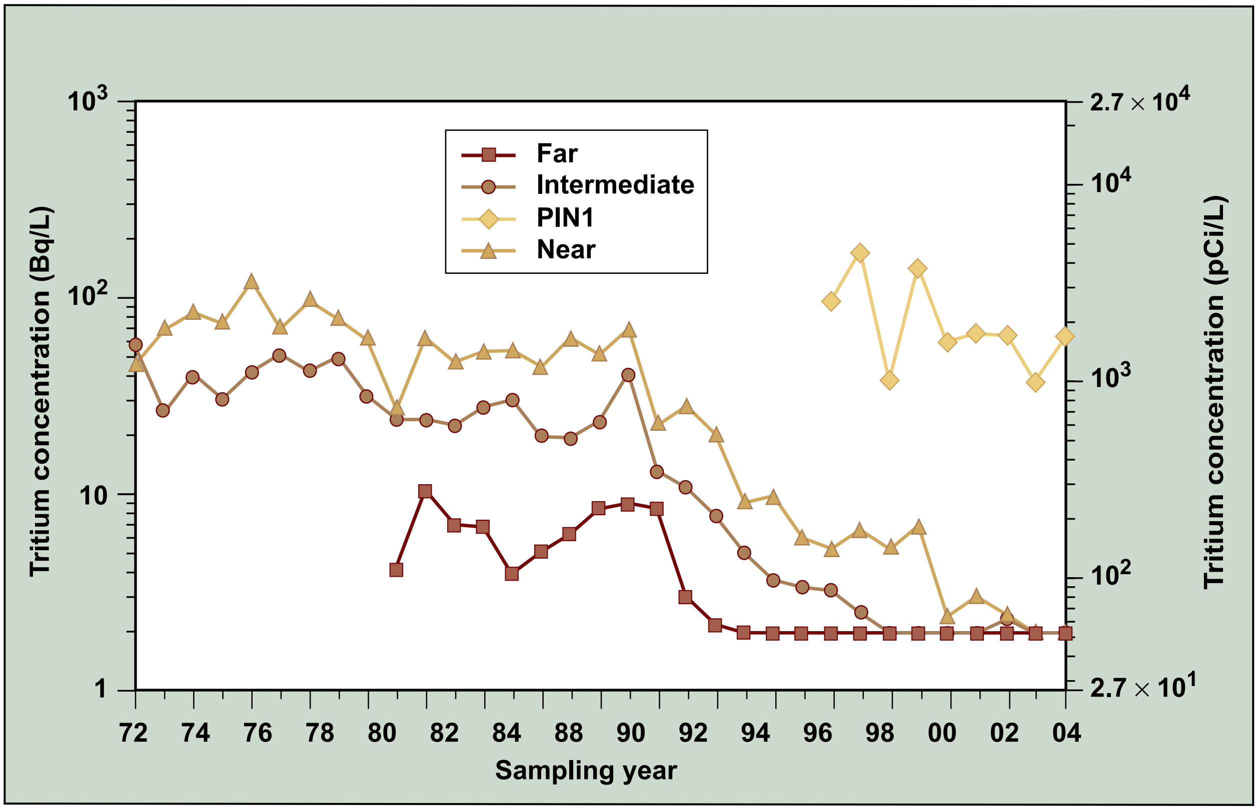
a Ingestion dose is based on conservative assumptions that an adult's diet is exclusively vegetables with this tritium concentration, and that meat and milk are derived from livestock fed on grasses with the same concentration of tritium. See **Table 6-6**.

b When concentrations are less than the detection limit (about 2.0 Bq/L), doses can only be estimated as being less than the dose at that concentration.

c Doses were not calculated because pine trees are not ingested by human beings. Concentrations from PIN2 are included with NEAR vegetation because plant water tritium concentrations are similar among plant types.

d These plants are rooted in areas of known subsurface contamination.

e Between 1997 and 2002, PIN1 was treated as a diffuse source (because pine needles are not eaten by human beings) and a dose was calculated. Beginning in 2003, for NESHAPs compliance, ambient air monitoring at LLNL accounts for minor diffuse sources, so a dose was not calculated.



Note: When median values are below 2.0 Bq/L (54 pCi/L; below the lower limit of detection), values are plotted as 2.0 Bq/L to eliminate meaningless variability.

Figure 5-5. Median tritium concentrations in Livermore Site and Livermore Valley plant water samples, 1972 to 2004

Wine Monitoring Results

The mean concentration (0.88 Bq/L [24 pCi/L]) of Livermore Valley wines sampled in 2004 is essentially the same as the mean (0.89 Bq/L [24 pCi/L]) for 2003; California wines continue to reflect residual historical bomb fallout and cosmogenic tritium levels (**Table 5-7**). The two wines from the Rhone Valley in France are as high or higher than any European wine previously sampled by LLNL and vinted after 1991 (**Figure 5-6**); this is not surprising because the Rhone Valley is home to numerous nuclear reactors used for power production. The highest concentration in a Livermore Valley wine (1.4 Bq/L [38 pCi/L]) was from a wine made from grapes harvested in 2000. Both Rhone Valley wines were vinted in 2001.

The wines purchased in 2004 represent vintages from 2000 to 2003. Thus, to compare the effect of LLNL operations on local wines, concentrations at the time of laboratory analysis must be corrected for the radiological decay that has occurred since the approximate date of harvest. Decay-corrected concentrations of tritium in wine for the

Table 5-7. Tritium in retail wine (Bq/L), 2004[(a)]

Sample	Area of production		
	Livermore Valley	California	Europe
1	0.57 ± 0.19	0.22 ± 0.19	3.5 ± 0.39
2	0.59 ± 0.20	0.52 ± 0.19	5.9 ± 0.62
3	0.86 ± 0.20		
4	0.87 ± 0.20		
5	1.0 ± 0.21		
6	1.4 ± 0.23		
	Dose (nSv/y)[(b)]		
	1.4	0.51	5.8

Note: Radioactivities are reported here as the measured concentration and an uncertainty (±2σ counting error).

a Wines from a variety of vintages were purchased and analyzed in 2004. The concentrations reported are those at the time the bottle was opened.

b This dose is calculated based on consumption of 52 L wine per year at maximum concentration (see Chapter 6).

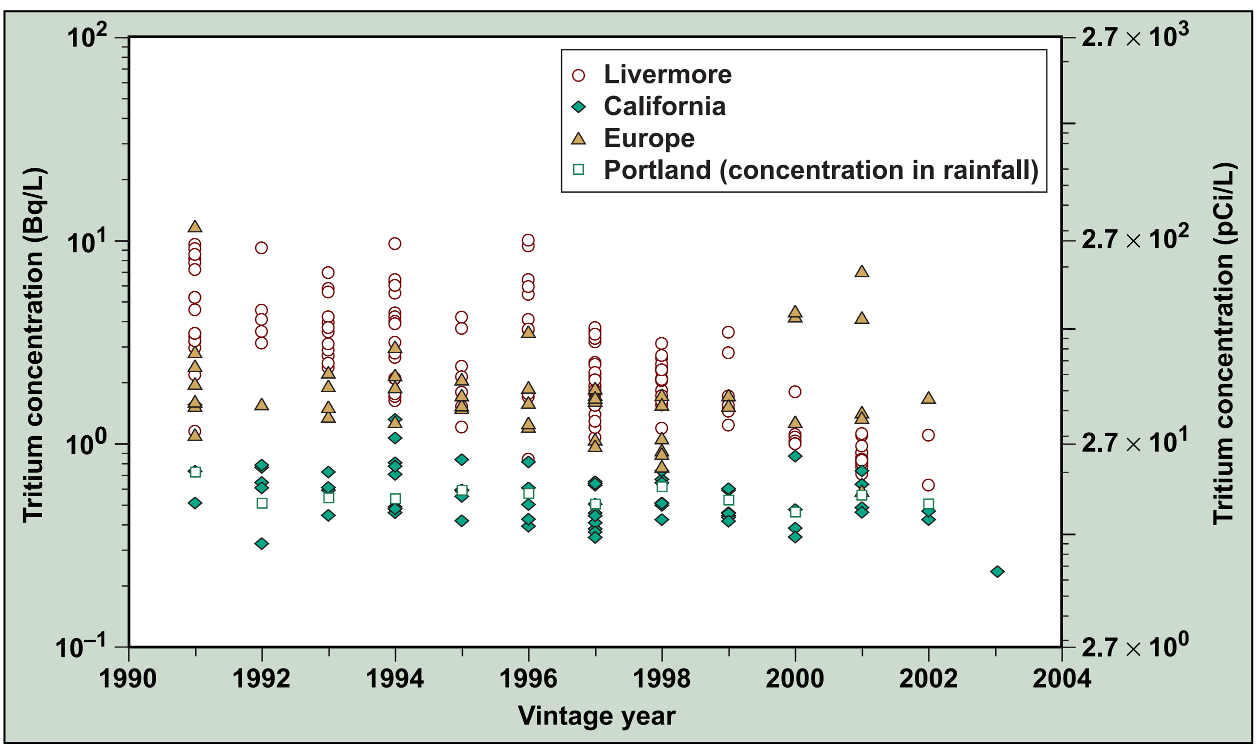


Figure 5-6. Tritium concentrations in all retail wines sampled since 1991 decay-corrected from the sampling year to the vintage year

Livermore Valley, California, and Europe are shown in **Figure 5-6** for the years from 1991 to present. Concentrations in all sampled wines are shown. The concentration of tritium in rainfall at Portland, Oregon (IAEA/WMO 2004) is also shown to demonstrate the similarity between tritium concentrations in California wines and background tritium concentrations on the Pacific coast (no similar data exist for California).

Because only a small number of bottles of Livermore Valley, California, and European (Rhone Valley) wine were sampled in 2004, a statistical comparison cannot be made. However, it is clear that Livermore Valley wines range in concentration from essentially no different than other California wines to about a factor of three higher. The tritium concentrations in the Rhone Valley wines sampled are distinctly higher than those of the Livermore Valley wines.

Environmental Impact on Vegetation and Wine

Vegetation

Hypothetical annual ingestion doses for mean concentrations of tritium in vegetation are shown in **Table 5-6**. These doses were calculated using the transfer factors from **Table 6-6** based on U.S. Nuclear Regulatory Commission Regulatory Guide 1.109 (U.S. NRC 1977). All doses are estimated based on measured concentrations of HTO in vegetation and consequent dose from HTO ingestion.

The hypothetical annual ingestion dose, based on highest observed mean HTO concentration in vegetation for 2004, is 25 nSv (2.5 µrem/y). This is lower than the 37 nSv in 2003 due to decreased tritium emissions. Since 1989, after which concentrations in vegetation have decreased noticeably (**Figure 5-5**), the hypothetical annual ingestion dose based on the maximum observed mean has decreased by a factor of 25; the decrease for any one location is much greater than this because vegetation sampling locations in 1989 were either off-site or upwind from tritium sources (i.e., NPER or another potentially high perimeter location was not sampled in 1989).

Doses calculated based on Regulatory Guide 1.109 neglect the increased contribution from OBT. However, according to a conclusion by a panel of tritium experts, "the dose from OBT that is ingested in food may increase the dose attributed to tritium by not more than a factor of two, and in most cases by a factor much less than this." (ATSDR 2002). Thus the maximum estimated ingestion dose from LLNL operations for 2004 is at most 50 nSv (5.0 µrem/y).

To demonstrate compliance with NESHAPs, between 1997 and 2002, location PIN1 was treated as a diffuse source of tritium, and a hypothetical dose to the maximally exposed individual at the nearest perimeter location was calculated using the dispersion and dose model CAP88-PC. Mean annual doses from PIN1 have always been less than 9.0 pSv (0.9 nrem). In 2003, LLNL obtained permission from the U.S. Environmental Protection Agency (EPA) to demonstrate compliance by using monitoring data in place of modeling dose from releases from minor sources. Any tritium released by PIN1 is sampled by the air tritium monitoring network. There is thus no reason to calculate a dose from PIN1 in 2004. Furthermore, sampling of PIN1 and PIN2 was terminated at the end of 2004 because it is no longer necessary.

LLNL operations at the Livermore site release small quantities of HTO to the immediate environs that can be measured by conventional methods in vegetation. The ingestion dose calculated based on HTO concentrations in vegetation but that also accounts for OBT (50 nSv; 5.0 µrem/y) is just 1/60,000 of the average annual background dose in the United States from all sources and just 1/2000 the dose from a typical chest x-ray (Schleien and Terpilak 1984). This dose is calculated on the assumption that all the vegetables, milk, and meat ingested have concentrations that represent the location of the sampled vegetation. This is an improbable scenario because the average person lives farther from the Livermore site than the location of the highest vegetation concentrations and grows just a small fraction of total food ingested. Thus the likely potential dose received will be considerably smaller than this already tiny dose (see **Table 6-8**). During 2004 at Site 300, no tritium was released to the atmosphere from LLNL operations. Consequently, vegetation concentrations are below detection limits except at locations of contaminated groundwater (see Chapter 7, “Remediation Activities and Monitoring Results” section). The contaminated groundwater resulting from past activities does affect concentrations in vegetation at locations DSW and EVAP. The dose calculated from these elevated concentrations is entirely hypothetical, because vegetation at Site 300 is not ingested by either livestock or people. The mean dose for 2004 for location EVAP, which exhibited the higher concentrations of the two locations, would be 490 nSv (49 µrem), which is very small.

Wine

For Livermore Valley wines purchased in 2004, the highest concentration of tritium (1.4 Bq/L [38 pCi/L]) is just 0.19% of the Environmental Protection Agency’s standard for maximal permissible levels of tritium in drinking water (740 Bq/L [20,000 pCi/L]). Dose from drinking 1 L per day of the Livermore Valley wine with the highest concentration purchased in 2004 would be 9.7 nSv/y (0.97 µrem/y). A more realistic dose estimate, based on moderate drinking (1 L per week)[1] at the mean of the Livermore Valley wine concentrations (0.88 Bq/L [24 pCi/L]) is 0.87 nSv/y (0.087 µrem/y). Both doses explicitly account for the added contribution of OBT[2].

Local wineries are sufficiently distant from the Livermore site that tritium in wines can only be detected reliably using an ultra-sensitive method. The potential dose from drinking Livermore Valley wines, including the contribution of OBT, even at the high consumption rate of 1 L per day, is about 1/300,000 of the average annual background dose from naturally occurring sources of radiation.

1. Moderate consumption is higher than the average consumption of wine in California (15.7 L/y) (Avalos 2005).
2. Dose from wine is calculated by summing the dose from HTO in the water fraction of wine and the dose from OBT in the organic fraction of wine. Dose coefficients for HTO and OBT are those of the International Commission on Radiation Protection (1996). The organic component of wine (estimated from grape juice) increases the dose by 6% over what it would be had wine no organic fraction.

Ambient Radiation Monitoring

Gamma radiation in the environment comes from two natural sources. The first source is the *terrestrial component*, which is caused by the radioactive decay of parent elements formed in the earth's crust 4.5 billion years ago (e.g., uranium-238, thorium-232, and potassium-40) and their respective daughter radiations.The second source is from the *cosmic component* of external radiation, which induces secondary radiations from interactions with atmospheric nuclei in the upper atmosphere. These cosmic interactions result in the production of meson, neutron, gamma, and electron radiations at the earth's surface (Eisenbud 1987).

LLNL's ambient radiation monitoring program is designed to distinguish any LLNL operational contribution from these natural sources by sampling a significant number of locations to validate the large natural background.

Methods and Reporting

Exposure to external radiation is measured by correlating the interaction of ionizing energy with its effect on matter which absorbs it. The roentgen (R) was adopted as the special unit of exposure dose by the International Commission on Radiological Units in 1956 and is defined as the charge required to ionize a given volume of air (2.58×10^{-4} coulombs per kilogram of air) (Roesch and Attix 1968).

It is this equivalency that is used to determine the quantity of ambient radiation measured by portable thermoluminescent dosimeters (TLDs) placed in the surrounding community. LLNL uses the Panasonic UD-814AS1 TLD, which contains three crystal elements of thallium-activated calcium sulfate ($CaSO_4$).

As the TLD absorbs ionizing energy, electron–hole pairs are created in the crystal lattice, trapping this absorbed energy in the crystal's excited state. The absorbed energy in the TLD crystal is released in the form of light emission upon heating the TLD to extreme temperature. This light emission, which is proportional to the TLD absorbed dose, is then collected by a photomultiplier tube and compared to its glow curve, as it is termed, which is calibrated to a known standard of cesium-137 gamma energy of 662 keV. The result of the TLD exposure is then reported in the International System (SI) unit of sievert (Sv) from the calculated dose in mR (1×10^{-3} R).

In order to compare LLNL dose contributions with the natural background, the analysis is divided into three groups:

- Livermore site locations—shown in **Figure 5-1**
- Livermore Valley locations—shown in **Figure 5-2**
- Site 300 and the local offsite vicinity, and sites in the city of Tracy—shown in **Figure 5-3**

As policy, the State of California Radiological Health Branch maintains several collocated TLD sample sites around the LLNL perimeter and Livermore Valley for independent monitoring comparison.

In order to obtain a true representation of the local site exposure and determine any dose contribution from LLNL operations, an annual environmental monitoring compliance assessment is done in accordance with DOE 450.1 through a quarterly deployment cycle. TLDs are deployed at a 1 meter height, adhering to the guidance of *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (U.S. DOE 1991).

For the purposes of reporting comparisons, data is reported as a "standard 90-day quarter," with the dose reported in millisievert (mSv; 1 mSv = 100 mrem).

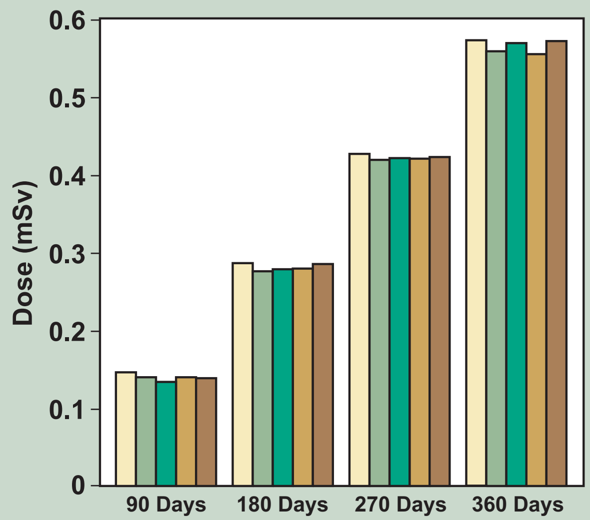
Monitoring Results

In **Figures 5-7** through **5-10**, the quarterly average cumulative doses in mSv for 2004 are presented for the Livermore site, the Livermore Valley, on-site at Site 300 and off-site at Site 300 along with five years of quarterly doses from 2000 to 2004.

Figure 5-7 illustrates the average cumulative dose for the Livermore site perimeter for successive 90 day periods for the entire year. The graph indicates a stable trend in the site-wide annual dose when compared to previous years. Similarly, comparing the data of **Figure 5-8**, which represents the Livermore Valley, the same trend is readily observable. Likewise, when doses for Site 300 (**Figure 5-9**) are compared to the doses for the off-site locations (**Figure 5-10**), the same trends are evident.

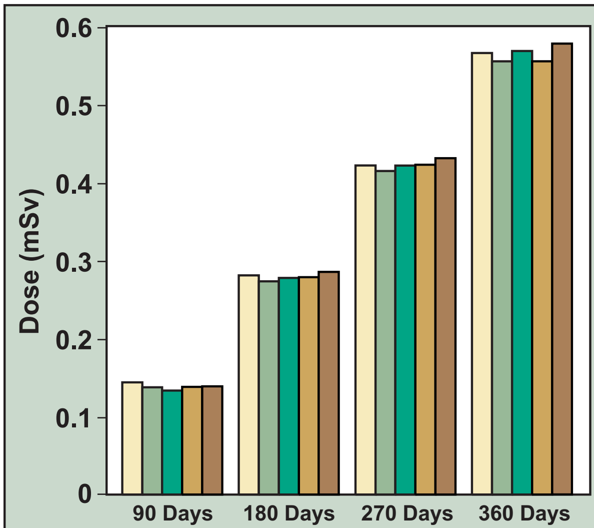
Tabular data for each individual sampling location illustrate the quarterly variation (see file "Ch5 Ambient Radiation" provided on the report CD). Missing data are due to lost or damaged samples. When actual site location data are compared for the same time period of 5 years, similarities are noted. This is indicative of the local and seasonal variations that are smoothed in the site-wide averages.

From year to year, the exposure of the TLD at one sampling site changes very little. Local variation is largely due to changes in the local distribution of the radon flux as a product of decay from the uranium and thorium series on some small level and from changes in the cosmic radiation flux. For example, when the data for the Livermore site



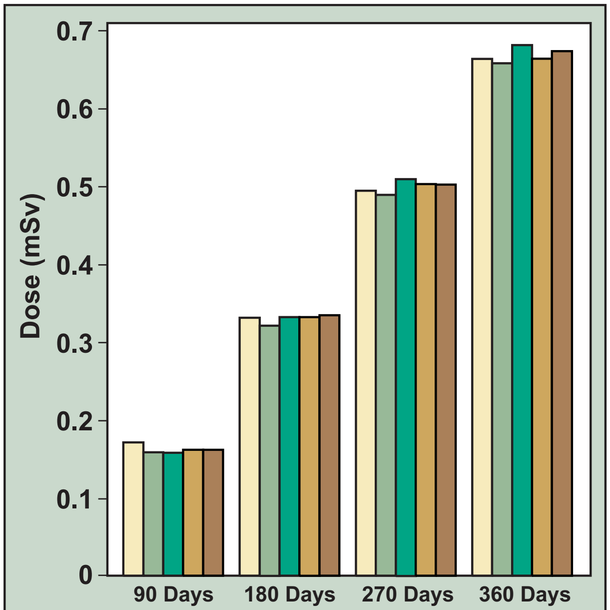
	Dose (mSv)			
2000	0.146	0.287	0.428	0.574
2001	0.140	0.277	0.420	0.560
2002	0.134	0.279	0.423	0.571
2003	0.140	0.280	0.422	0.557
2004	0.139	0.286	0.425	0.573

Figure 5-7. Livermore site perimeter cumulative dose (mSv), 2000 through 2004



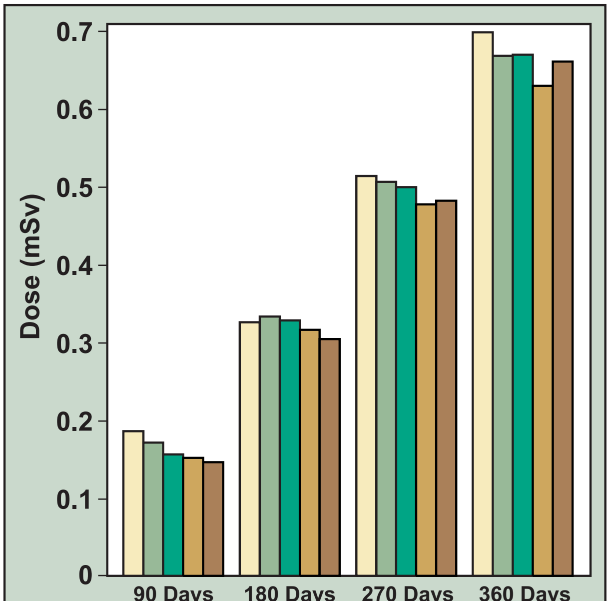
	Dose (mSv)			
2000	0.144	0.282	0.423	0.567
2001	0.138	0.274	0.416	0.557
2002	0.134	0.278	0.423	0.570
2003	0.138	0.279	0.423	0.557
2004	0.139	0.286	0.432	0.580

Figure 5-8. Livermore Valley cumulative dose (mSv), 2000 through 2004



	Dose (mSv)			
2000	0.173	0.332	0.496	0.666
2001	0.160	0.322	0.491	0.660
2002	0.159	0.333	0.511	0.683
2003	0.163	0.333	0.505	0.666
2004	0.163	0.335	0.504	0.676

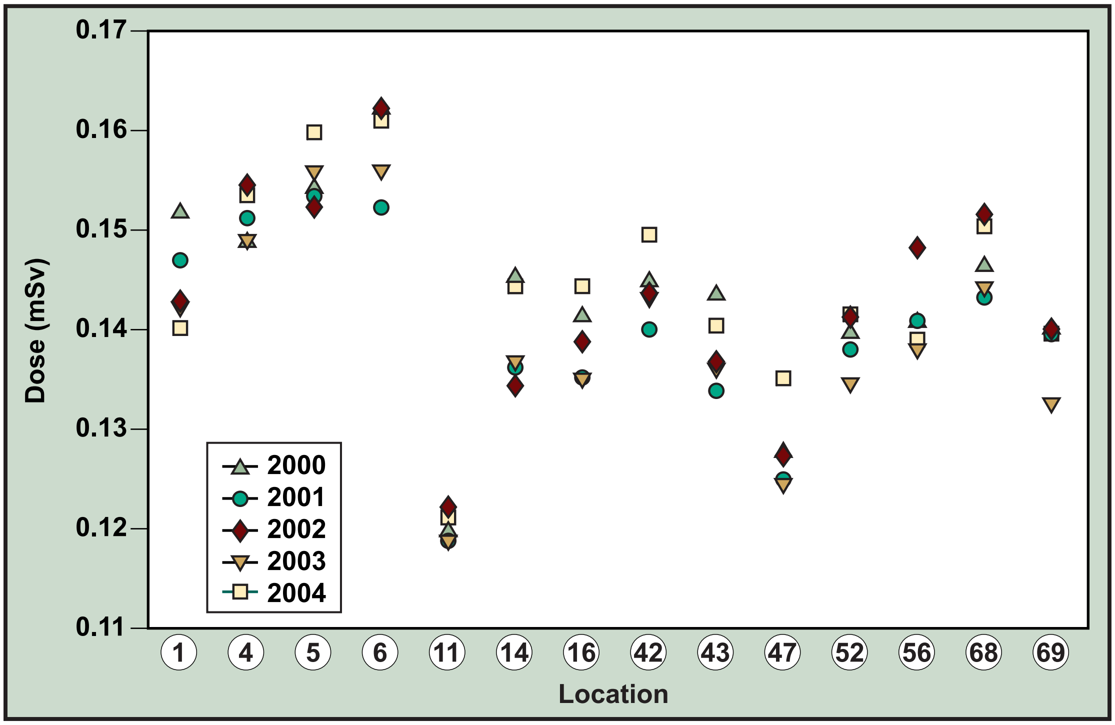
Figure 5-9. Site 300 on-site cumulative dose (mSv), 2000 through 2004



	Dose (mSv)			
2000	0.187	0.327	0.516	0.701
2001	0.172	0.335	0.508	0.671
2002	0.157	0.330	0.501	0.672
2003	0.153	0.318	0.480	0.632
2004	0.147	0.305	0.484	0.663

Figure 5-10. Site 300 environs cumulative dose (mSv), 2000 through 2004

perimeter are examined for the 5 year period by location (**Figure 5-11**), the local variation is readily observed. This is due primarily to the natural soil variability. Similar variability is seen within the other location groups (**Figures 5-12** and **5-13**).



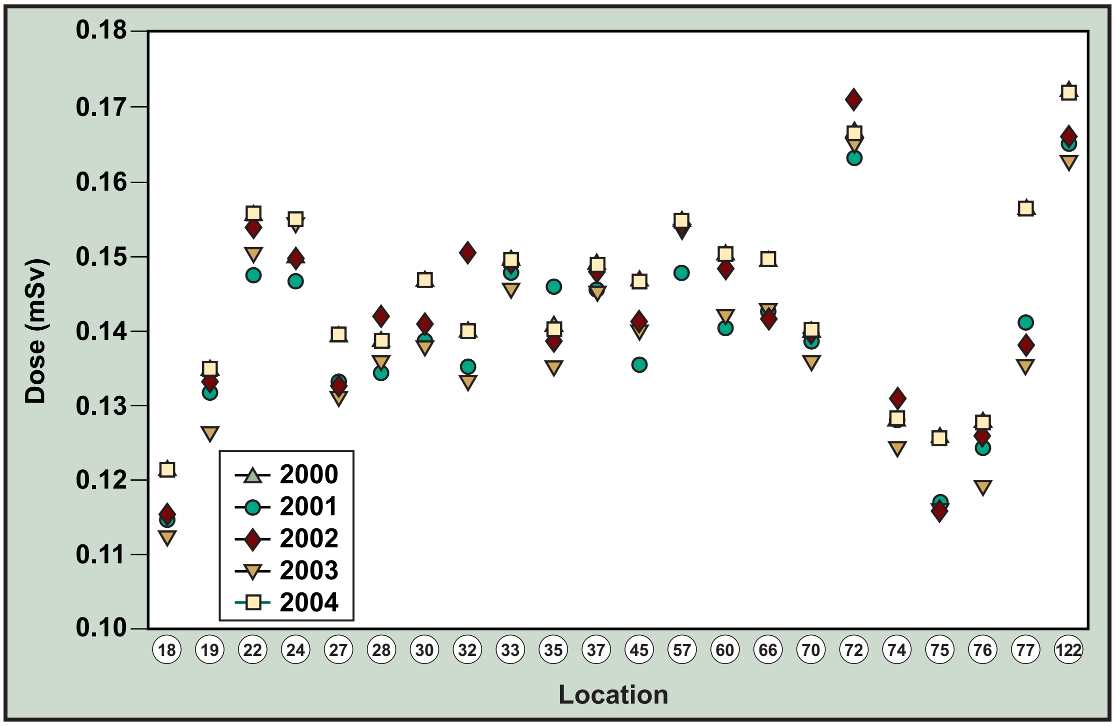
Note: See **Figure 5-1** for locations.

Figure 5-11. Livermore site perimeter annual average dose from 2000 to 2004

Environmental Impact from Laboratory Operations

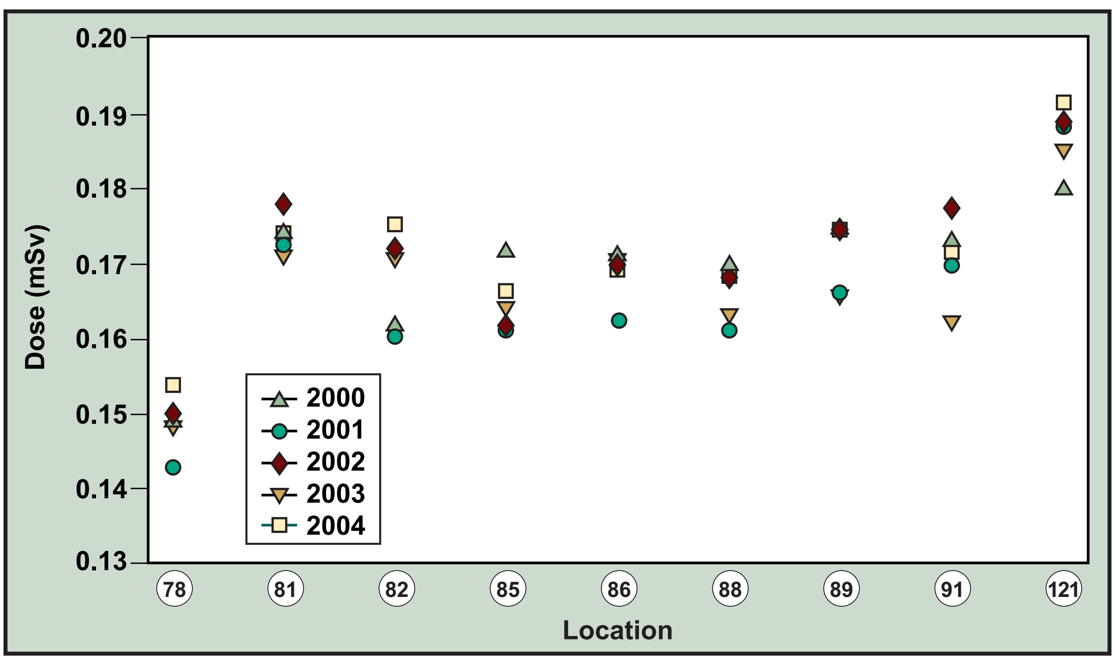
There is no evidence to conclude that there is any environmental impact or increase in direct gamma radiation as a result of LLNL operations as measured by the TLD network for the year 2004. The radiation dose trends remain consistent with annual location average levels for each sample site. Although some locations have had anomalous annual values in comparison to the long term trend for these locations, the trends would have continued at those sample sites had there been any contamination effecting the dose at that site. This is the most important reason for long term trend analysis and why these spurious excursions are not considered alarming.

As depicted in **Figure 5-14**, the annual average gamma radiation dose from 2000 to 2004 is statistically equivalent and shows no discernible impact due to operations conducted at LLNL.



Note: See **Figure 5-2** for locations.

Figure 5-12. Livermore Valley annual average dose from 2000 to 2004



Note: See **Figure 5-3** for locations.

Figure 5-13. Site 300 annual average dose from 2000 to 2004

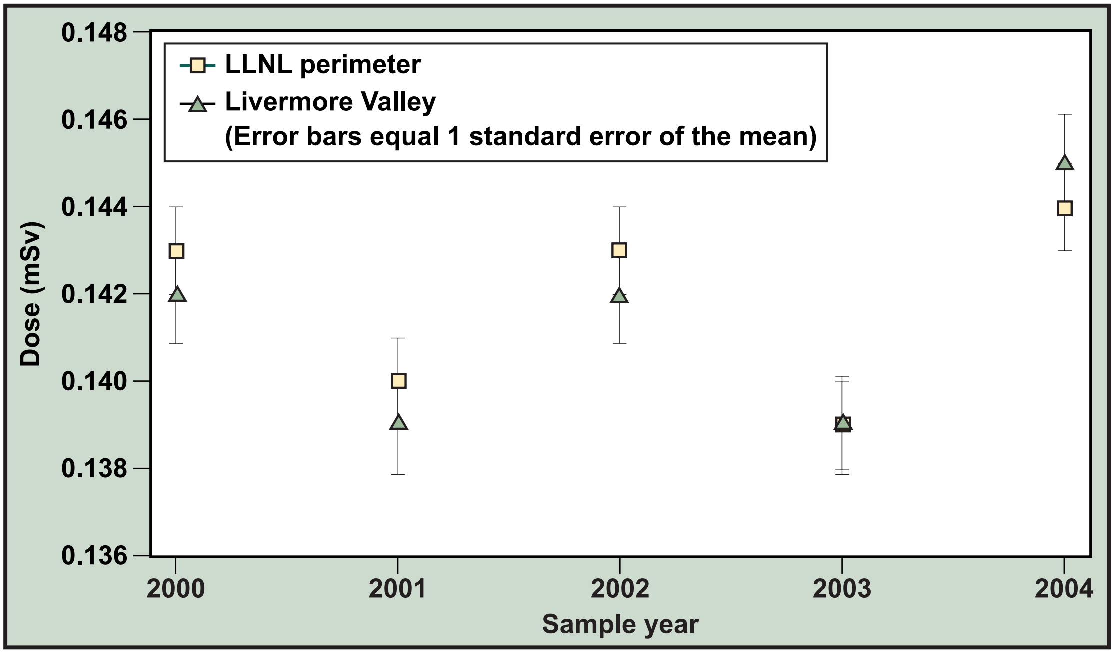


Figure 5-14. Annual average gamma radiation dose comparison for Livermore site and the Livermore Valley

SPECIAL STATUS WILDLIFE AND PLANTS

Special status wildlife and plant monitoring efforts at LLNL are focused on species and associated habitats considered to be rare, threatened, or endangered. This includes species listed under the California or Federal Endangered Species Acts; species considered of concern by the California Department of Fish and Game, and the U.S. Fish and Wildlife Services (USFWS); and species that require inclusion in NEPA and CEQA documents.

Locations of species of particular interest are shown in **Figure 5-1** for the Livermore site and **Figure 5-15** for Site 300. A list of species known to occur at Site 300, including state and federally listed species, is found in Appendix C. (A similar list has not been prepared for the Livermore site.)

Five species that are listed under the federal or California endangered species acts are known to occur at Site 300: the California tiger salamander (*Ambystoma californiense*), California red-legged frog (*Rana aurora draytonii*), Alameda whipsnake (*Masticophus lateralis euryxanthus)*, valley elderberry longhorn beetle (*Desmocerus californicus dimorphus)*, and the large-flowered fiddleneck (*Amsinckia grandiflor*a). Although there are no recorded observations of the federally endangered San Joaquin kit fox (*Vulpes*

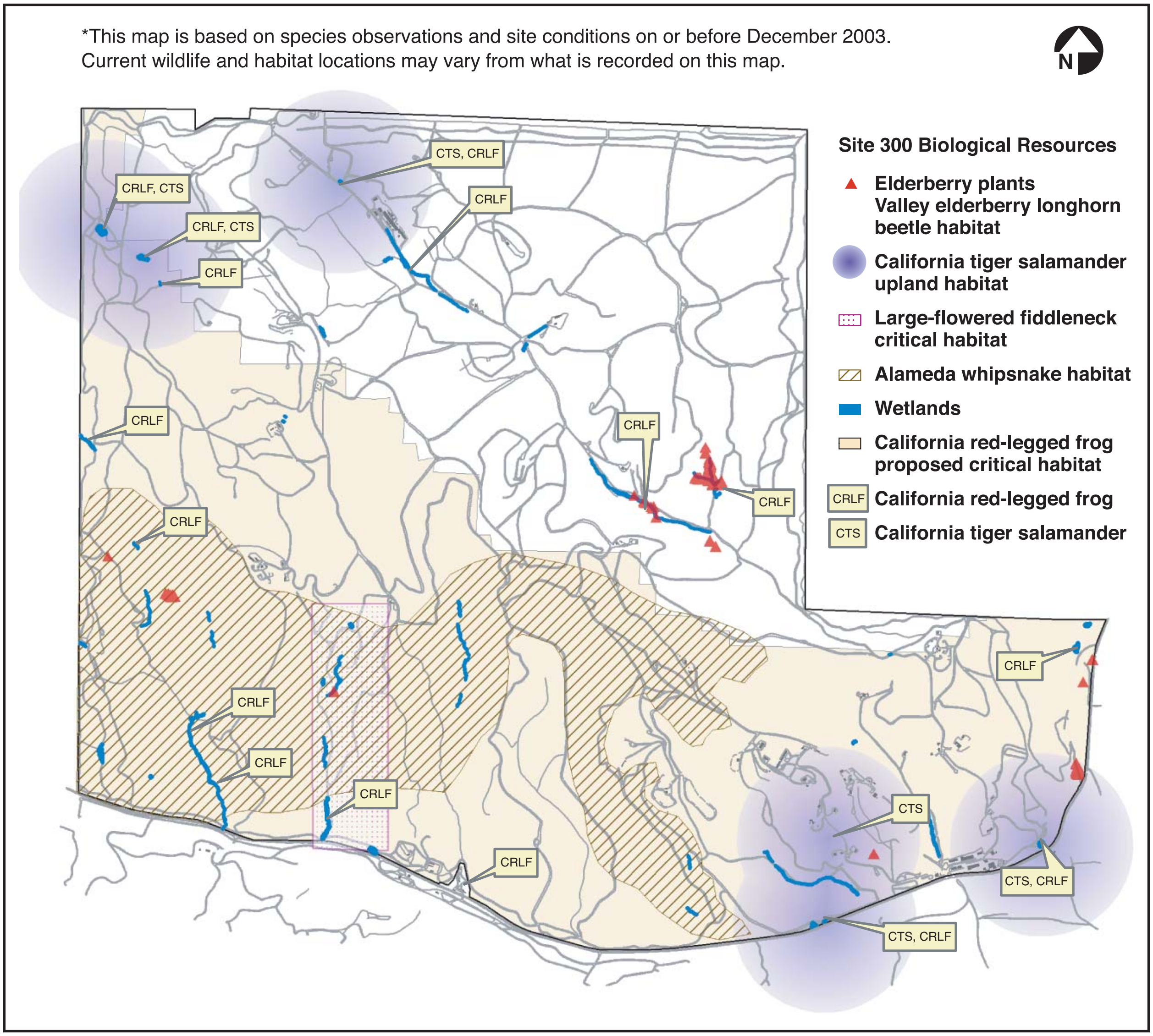


Figure 5-15. Distribution of federal and California threatened and endangered plants and wildlife, Site 300, 2004

macrotis mutica) at Site 300, this species is known to have occurred in the adjacent Carnegie and Tracy Hills areas (USFWS 1998). Because of the proximity of known observations of San Joaquin kit fox to Site 300, it is necessary to consider potential impacts to San Joaquin kit fox during activities at Site 300. California threatened Swainson's Hawks (*Buteo swainsoni*) and California endangered Willow Flycatchers (*Empidonax traillii*) have been observed at Site 300, but breeding habitat for these species does not occur at Site 300. The California red-legged frog is also known to occur at the Livermore site.

In 2001, the USFWS designated critical habitat for the California red-legged frog (USFWS 2001). The North Buffer Zone and eastern edge of the Livermore site in addition to approximately half of Site 300 were included in this 2001 critical habitat designation. Most of this critical habitat designation, including all LLNL areas, was rescinded in 2002 due to a court decision. Critical habitat for the California red-legged frog was proposed again in April of 2004 (USFWS 2004a). This new proposal includes the same LLNL areas as the 2001 designation. Critical habitat for the Alameda whipsnake was designated in 2000 and includes the southwest quarter of Site 300 (USFWS 2000). Similar to the California red-legged frog critical habitat designation, the Alameda whipsnake critical habitat designation was rescinded in 2003 by a court decision. Critical habitat was also proposed for the California tiger salamander in 2004. Proposed critical habitat for the California tiger salamander is not found at Site 300 or the Livermore site (USFWS 2004b). A portion of Site 300 has also been designated as a critical habitat area for the large-flowered fiddleneck and as the *Amsinckia grandiflora* Reserve through a declaration by Secretary of the U.S. DOE. Activities within the reserve are conducted under a memorandum of agreement between the DOE and the USFWS.

Several other species that are considered rare or otherwise of special interest by the federal and state governments also occur at Site 300 and the Livermore site. These species include California Species of Special Concern, California Fully Protected Species, federal Species of Concern, species that are the subject of the federal Migratory Bird Treaty Act, and those species included in the California Native Plant Society's (CNPS's) *Inventory of Rare and Endangered Plants* (CNPS 2001). In particular, monitoring programs have been developed for the Tricolored Blackbird (*Agelaius tricolor*), a California species of special concern, and the White-tailed Kite (*Elanus leucurus*), a California fully protected species.

Including the federally endangered large-flowered fiddleneck, eight species of rare plants are known to occur at Site 300. Three of these species, the large-flowered fiddleneck, the big tarplant (*Blepharizonia plumosa*, also known as *Blepharizonia plumosa* subsp *plumosa*), and the diamond-petaled poppy (*Eschscholzia rhombipetala*), are included in the CNPS List 1B (CNPS 2001). These species are considered rare and endangered throughout their range. An additional species, the round-leaved filaree (*Erodium macrophyllum*) is currently included on CNPS List 2 (CNPS 2001). This list includes species that are rare or endangered in California and elsewhere. The four remaining rare plant species, the gypsum-loving larkspur (*Delphinium gypsophilum* subsp. *gypsophilum*), California androsace (*Androsace elongata* subsp. *acuta*), stinkbells (*Fritillaria agrestis*), and hogwallow starfish (*Hesperevax caulescens*), are all included on the CNPS List 4 (CNPS 2001). List 4 plants are uncommon enough to warrant monitoring, but are not considered rare. Past surveys have failed to identify any rare plants on the Livermore site (Preston 1997, 2002).

The following sections describe results from LLNL special status wildlife and plant studies and surveys. For an estimate of LLNL's dose to biota, see the "Special Topics on Dose Assessment" section in Chapter 6.

Compliance Activities

California Red-Legged Frog

California red-legged frogs occur at the Livermore site and Site 300. Livermore site populations of the California red-legged frog were monitored in accordance with the 1997 and 1998 amended USFWS Biological Opinion for the Arroyo Las Positas Maintenance Project. The 1998 Biological Opinion allows for a checkerboard pattern of Arroyo sections ranging in length from one hundred feet to three hundred feet to be managed annually for excess in-stream vegetation. No stream maintenance was conducted in Arroyo Las Positas in 2004.

Thirty-seven egg masses were observed and quantified in 2001, 32 in 2002, 31 in 2003, and 9 in 2004. Oviposition sites tended to be shallow, and all egg masses were located in water less than 50 cm deep. Most egg masses were within one meter of the shore and near the surface. Egg masses were usually deposited on vegetation that provided structure and to a lesser extent rigidity, such as attached inflorescences, but unattached debris including downed branches and decomposing vegetation was also used for oviposition.

Most 1 m^2 quadrats centered on egg masses included a portion of the stream bank and a portion of the hydrated stream channel; as a result, cover estimates include emergent wetland species that occur in the stream channel and upland and facultative wetland species that occur on the banks of the stream just above the water level. Egg masses were located in areas with approximately 64% cover of open water.

Grasses and emergent wetland species covered a similar percentage of the quadrats. The most common species were the exotic grass barnyard grass (*Echinochloa crus-galli)* and two emergent wetland species, tall flatsedge (*Cyperus eragrostis*) and watercress (*Rorippa nasturtium-aquaticum)*. One tree species, *Salix exigua*, was found in the vegetation quadrats. *S. exigua* was only found near 3 of the 40 egg masses located in Arroyo Las Positas in 2003 and 2004.

Surveys for adult frogs were conducted in locations at Site 300 (intermittent drainages, springs, and ponds) and the Livermore Site (Arroyo Las Positas, Arroyo Seco, and portions of artificial drainage channels). These surveys consisted of walking the perimeter of the stream or pond at night between May 1 and November 1 and surveying in and around the wetland areas using a flashlight. The location of California red-legged frog populations in 2004 are shown in **Figures 5-1** and **5-15**.

Alameda Whipsnake

In 2002, LLNL began participation in a study, in cooperation with the USFWS and four other agencies, to determine the effects of prescribed burns on federally threatened Alameda whipsnakes. In April 2002, the USFWS issued a Biological Opinion for this study that outlined the general conditions for conducting prescribed burns and gathering information about potential impacts to Alameda whipsnakes. Through participation in this study, LLNL obtained USFWS approval to conduct prescribed burns necessary for Site 300 operation in areas that support Alameda whipsnakes. The study area consists of a control site and a burn site that are vegetated by a mosaic of coastal scrub and annual grasslands. Baseline studies were conducted in spring and fall of 2002 and spring of 2003 at Site 300 and consisted of live trapping Alameda whipsnakes, recording the location of individuals, and marking the snakes for future identification.

There was a total of 22 Alameda whipsnakes captures (9 at the control site and 13 in the burn site) during baseline monitoring in the spring and fall of 2002, and 12 captures (7 in the control site and 5 in the burn site) in the spring of 2003. A prescribed burn was conducted at the burn site in the summer of 2003, and the first season of post-burn monitoring was conducted in the fall of 2003. One Alameda whipsnake was captured in the control site in the fall of 2003, and no Alameda whipsnakes were captured in the burn site. Post-burn trapping of Alameda whipsnakes continued in the spring and fall of 2004. In 2004, there was a total of 14 Alameda whipsnake captures during spring trapping (8 in the control area and 6 in the burn area), and no Alameda whipsnakes were captured during the fall trapping period. To date, no conclusions have been made about the effect of the Site 300 prescribed burns on Alameda whipsnakes.

Invasive Species Control Activities

Bullfrog (*Rana catesbeiana*) control activities continued in 2004 in compliance with the 1998 amended USFWS Biological Opinion for the Arroyo Las Positas Maintenance Project. Bullfrog egg masses were removed from the Drainage Retention Basin weekly during spring and summer of 2004. Four nighttime surveys for adult bullfrogs were conducted in the summer of 2004. During these surveys, bullfrogs were identified by a qualified biologist and removed. The control program appears to be stabilizing or reducing the overall numbers of bullfrogs after the original introduction in 1999 and subsequent population explosion.

Arroyo Mocho Road Improvement and Anadromous Fish Passage Project

In 2004, the Environmental Protection Department (EPD) and the UTel Department collaborated on an ambitious project to remove a low flow crossing at Arroyo Mocho, a major tributary to Alameda Creek. The crossing had served as the primary access to the LLNL's Arroyo Mocho Pump Station. The crossing had eroded over the years and was in danger of failure due to undermining by the stream. Furthermore, the crossing and subsequent eroded conditions were impassable to steelhead trout (*Oncorhynchus mykiss*), a federally threatened anadromous fish.

Since Arroyo Mocho is relatively pristine, extreme care was taken by LLNL to replace the crossing with a freestanding bridge while preserving biota habitat and restoring the natural flow characteristics of the stream to facilitate passage by steelhead. The EPD/UTel team worked closely with a construction contractor during the summer to complete the project. EPD Wildlife Biologists were on hand throughout the project and successfully translocated hundreds of amphibians, reptiles, and fish out of harms way. Once the bridge was in place, native plants previously collected and raised elsewhere were planted in the project area to complete restoration activities.

Surveillance Monitoring

Wildlife

Nesting Bird Surveys

LLNL conducts nesting bird surveys to ensure LLNL activities comply with the Migratory Bird Treaty Act and do not result in impacts to nesting birds. White-tailed Kites, a California fully protected species, annually nest in the trees located along the north, east, and south perimeters of the Livermore site. LLNL surveyed potential White-tailed Kite nesting sites using binoculars or a spotting scope during the spring of 2004; three pairs of White-tailed Kites successfully fledged a total of nine young. Although White-tailed Kites are also known to occasionally nest at Site 300, site-wide kite surveys were not conducted at Site 300 in 2004 because they do not typically nest in areas where they may be affected by programmatic activities.

Avian Monitoring Program

An avian monitoring program was initiated in 2001 to obtain background information for the draft *Site-wide Environmental Impact Statement for the Continued Operation of Lawrence Livermore National Laboratory and Supplemental Stockpile Stewardship and Management Programmatic Environmental Impact Statement* (see Chapter 2 for more information on the draft environmental impact statement). A constant effort mist netting station was also established spanning Elk Ravine and Gooseberry Canyon at Site 300. Birds were captured using ten standard passerine mist nets once every ten days throughout the breeding season (May through August 2004). Birds captured in the mist nets were identified to species, banded, aged, sexed, measured, and weighed before being released. All of the species identified in these surveys are listed in Appendix C.

Rare Plants

LLNL conducted restoration and/or monitoring activities in 2004 for four of the eight rare plant species known to occur at Site 300: the large-flowered fiddleneck, the big tarplant, the diamond-petaled poppy, and the round-leaved filaree. The results of this work are described in more detail in a biannual progress report (Paterson et al. 2005).

Large-Flowered Fiddleneck

LLNL established an experimental population of large-flowered fiddleneck at Site 300 in the early 1990s within the *Amsinckia grandiflora* Reserve and is working with the USFWS and the U.S. Bureau of Reclamation on continued monitoring of native and experimental large-flowered fiddleneck populations, and further developing habitat restoration and maintenance techniques for this species. This experimental population is divided into two smaller subpopulations: the flashing subpopulation (the original experimental population) and the fire frequency subpopulation. One extant native population of large-flowered fiddleneck is also found at Site 300. The experimental and native populations were censused during March 2004. During the 2004 spring census, the location and size of each large-flowered fiddleneck plant was recorded in addition to information about the vegetation community in which large-flowered fiddleneck occurred.

The native population continued to be very small in 2004. The native population had only three plants in 2004, which is the smallest population size recorded since 1980. The number of *A. grandiflora* in the flashing and fire frequency experiment subpopulations has also been low recently. Because of the low population numbers in native and experimental populations, LLNL obtained funding from the U.S. Bureau of Land Management to enhance the seed bank of the flashing subpopulation at Site 300 and a second experimental population at Lougher Ridge in Black Diamond Mines Regional Park. A total of 2400 large-flowered fiddleneck seeds from the LLNL-maintained seed bank were planted at the Site 300 experimental population in the fall of 2002.

In 2003, even after the seed bank enhancement of the previous winter, only 69 *A. grandiflora* were found in the flashing subpopulation. Site 300 seedlings suffered from a great deal of herbivory in the winter of 2003, which may have caused many of the plant deaths. There was also an unusual rain pattern during the 2002/2003 rainy season. After a wet December (3.55 inches rainfall) in 2002, there was only a total of 2.0 inches of rain in January through March of 2003. This lack of rainfall early in 2003 may have decreased the survivorship of plants, from the 2002 seed sowing, that germinated after the December rains.

Because of the poor success in 2002, the seed bank enhancement was repeated in the Site 300 and Lougher Ridge subpopulations during the fall of 2003. In the spring of 2004, there were 753 *A. grandiflora* in the flashing experimental population. Unfortunately, these plants were very small and weren't expected to produce much seed. As a result of the 2002 and 2003 seed bank enhancement projects, several conclusions could be made about the methods used to enhance the germination and survival of *A. grandiflora* grown from seed in the experimental populations. Germination in the common garden was high, which indicates that the seed from most seed sources was quite viable. It is likely that seeds had lower germination rates at the two field locations due to two factors: granivory and unsuitable microconditions. Seeds that were not eaten but were unable to germinate due to nonoptimal conditions in 2004 may germinate in future years when conditions are better.

A. grandiflora seed stored in the seed bank at LLNL does appear to lose some viability with age, as demonstrated in the 2002 and 2003 seed bank enhancement projects. Germination studies have also shown that greenhouse and common garden-grown *A. grandiflora* seeds have increased germination rates compared to field grown seeds (unpublished data). This increased germination rate may be due to decreased seed dormancy because of an extremely favorable environment when the seeds were produced rather than due to increased seed viability. Seedlings also grew larger and showed less signs of herbivory when plots were covered in plastic netting designed to exclude birds.

LLNL is also beginning to see results in the long-term fire frequency experiment begun in 2001. The native perennial grass *Poa secunda* is most abundant in plots that are burned annually. Previous research shows that *A. grandiflora* is more successful in plots dominated by *P. secunda* compared to plots dominated by exotic annual grasses (Carlsen et al. 2000), but early results from the fire frequency experiment show that *A. grandiflora* is more abundant in the unburned control plots dominated by dense annual grasses than in the burned plots. Data from plots burned at an intermediate density are not yet available. Clearly there are a variety of factors affecting the success of *A. grandiflora* populations.

While prescribed burns help to produce a plant community dominated by *P. secunda*, predation is also higher in plots that have been burned. Because of the extremely high rates that have been observed in some years, seed predation is very likely a significant factor in determining *A. grandiflora* population sizes.

While LLNL has uncovered some clues to the successful restoration of *A. grandiflora* populations and continues to work to sustain the existing experimental and native populations, the reasons for the sharp declines in this population in recent years are still unclear. Seed bank enhancement efforts are more successful when plots are netted and seeds from greenhouse or common garden experiments are used, but the resulting plants can be small and produce little seed. LLNL can promote the establishment of a native perennial grassland with prescribed burns, but seed predation is quite high in these burned areas.

Big Tarplant

The distribution of big tarplant was mapped using a handheld GPS in October and November 2004. This distribution was compared, using a GIS (Geographic Information System), to the distribution of prescribed burns conducted at Site 300 in 2004 and in previous years. The big tarplant distribution decreased throughout Site 300 in 2004.

Research conducted by LLNL indicates that the annual prescribed burns conducted at Site 300, particularly the edges (or ecotones) between burned and unburned areas, play a role in the abundance of this rare species at Site 300 (Carlsen and Espeland submitted). At Site 300, big tarplant occurs in large numbers in areas that are routinely burned. This is interesting, because at the time of the annual spring burns at Site 300, the plant is a small green seedling, and thus very susceptible to fire damage. It is possible that the larger Site 300 big tarplant population is acting as a group of semi-isolated subpopulations known as a metapopulation. Smaller subpopulations may establish or disappear, depending on fire uniformity and intensity. Although fire is fatal to individual big tarplants directly in its path, it may provide the amount of disturbance necessary to reduce competition with other plant species (such as exotic annual grasses) and allow for subpopulation establishment, thus maintaining the metapopulation.

Diamond-Petaled California Poppy

There are currently three populations of diamond-petaled California poppy (*Eschscholzia rhombipetala)* known to occur at Site 300. Although this species is not listed under the federal or California endangered species acts, it is extremely rare and is only currently known to occur at Site 300 and one additional location in San Luis Obispo County. A census of the three Site 300 populations was conducted in March 2004, during which LLNL recorded the size and location of each diamond-petaled poppy plant and the vegetation community in which this species occurs.

In 2004, a new population (site 3) of *E. rhombipetala* was discovered at Site 300. Containing 389 *E. rhombipetala*, site 3 had the largest population of this species observed at Site 300 since monitoring began in 1998. In 2000 through 2002, site 1 contained over 180 *E. rhombipetala* each year, but in 2003 and 2004 this site contained fewer than 20 plants. 2004 was the third spring LLNL censused site 2. Site 2's population size has followed a similar pattern as site 1. Site 2 contained 76 *E. rhombipetala* in 2002 when this population was first discovered, and in 2003 and 2004 *E. rhombipetala* numbers were extremely small at site 2 (1 plant in 2003 and 2 plants in 2004).

The new population differs from the old population in several ways. Site 3 is found at the bottom of a small stable bowl shaped valley, while site 1 and site 2 are located on steep northwest facing hillsides in areas that are disturbed by slumping soil. *E. rhombipetala* at site 1 and site 2 is also often found in association with the native perennial grass, *P. secunda*, which was not found at site 3. In addition, *E. rhombipetala* at site 3 are larger and have more floral units then plants at sites 1 and 2.

Using vegetation data from site 1 and site 2 collected in 1999 through 2002, there was a positive association of *E. rhombipetala* presence with bare ground. This, in addition to the better performance of plants in the active slump, seemed to indicate that some level of disturbance is necessary for plants of this species to do well. Vegetation data collected at site 3 seems to contradict this. While the disturbance of slumping soils at site 1 and site 2 clearly benefits *E. rhombipetala* at site 1 and site 2, some other factors appear to be in place to promote *E. rhombipetala* at site 3.

Round-Leaved Filaree

One population of round-leaved filaree was located at Site 300 during a site-wide botanical survey conducted in 2002 (Preston 2002), and a second population was located in 2003 during surveys of the fire trail system. In 2004, an additional four populations were found in the northwestern corner of the site during wildlife surveys. 2003 was the first year of monitoring round-leaved filaree at Site 300. During the spring of 2004, the extent of the six Site 300 populations was mapped using a handheld GPS and the size of each population was estimated. These six populations were estimated to contain almost 6000 round-leaved filaree plants.

Environmental Impacts on Special Status Wildlife and Plants

Through monitoring and compliance activities in 2004, LLNL has been able to avoid most impact to special status wildlife and plants.

Large-flowered fiddleneck and diamond petaled California poppy populations are located in remote areas of Site 300 away from programmatic impacts. Four of the six Site 300 round-leaved filaree populations are located in annually graded fire trails. In these fire trail populations, round-leaved filaree is restricted to the areas that are disturbed by grading. This disturbance appears to benefit the species and is not considered a negative impact. Although rare elsewhere, big tarplant is widely distributed throughout Site 300. Although individual big tarplants were disturbed by LLNL activities, including fire trail grading and well drilling, these impacts affected only a very small fraction of the Site 300 tarplant population and are not considered to be significant to this species.

LLNL activities did not result in impacts to California red-legged frogs at the Livermore site. In the Livermore site population of California red-legged frogs, breeding decreased in 2004 compared to 2003, 2002, and 2001 although this decrease is not a result of any impacts from LLNL activities. At Site 300, 2004 surveys of adult California red-legged frogs indicate that the existing small populations of California red-legged frogs continue to persist.

The bullfrog control program continued at the Livermore site in an effort to reduce competitive pressures from this invasive species on the California red-legged frogs. The control program appears to be stabilizing or reducing the overall numbers of bullfrogs after the original introduction and subsequent population explosion.