5 Terrestrial Radioactivity, Ambient Radiation, and Wildlife and Rare Plant Surveys

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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 organic compounds, tritium, and 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 to some extent 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 2002).

LLNL also monitors wildlife and plants at the Livermore site and Site 300, and carries out research relevant to the protection and mitigation of populations of rare plants and animals. Some monitoring 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 included 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 6 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.

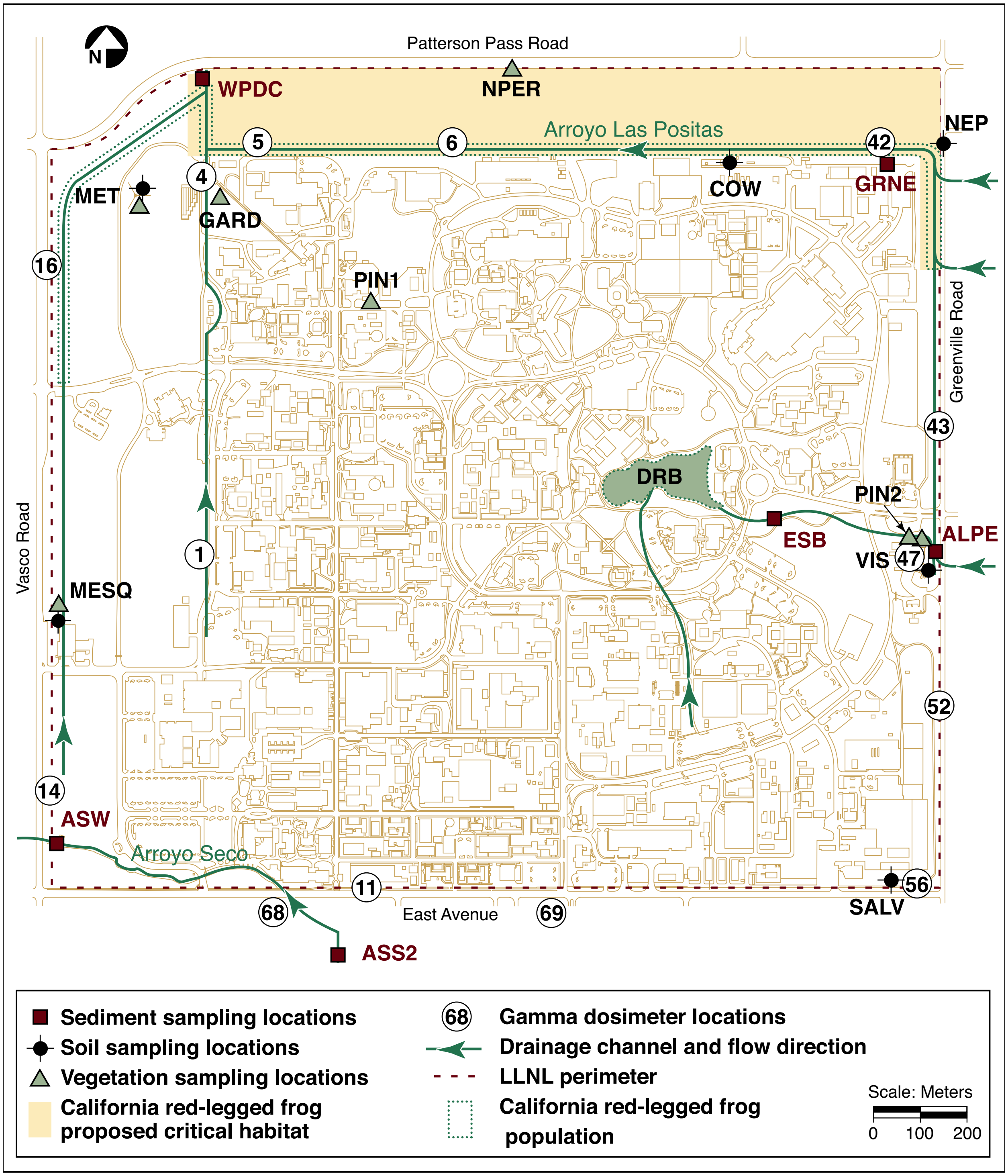


Figure 5-1. Sampling locations, Livermore site, 2003

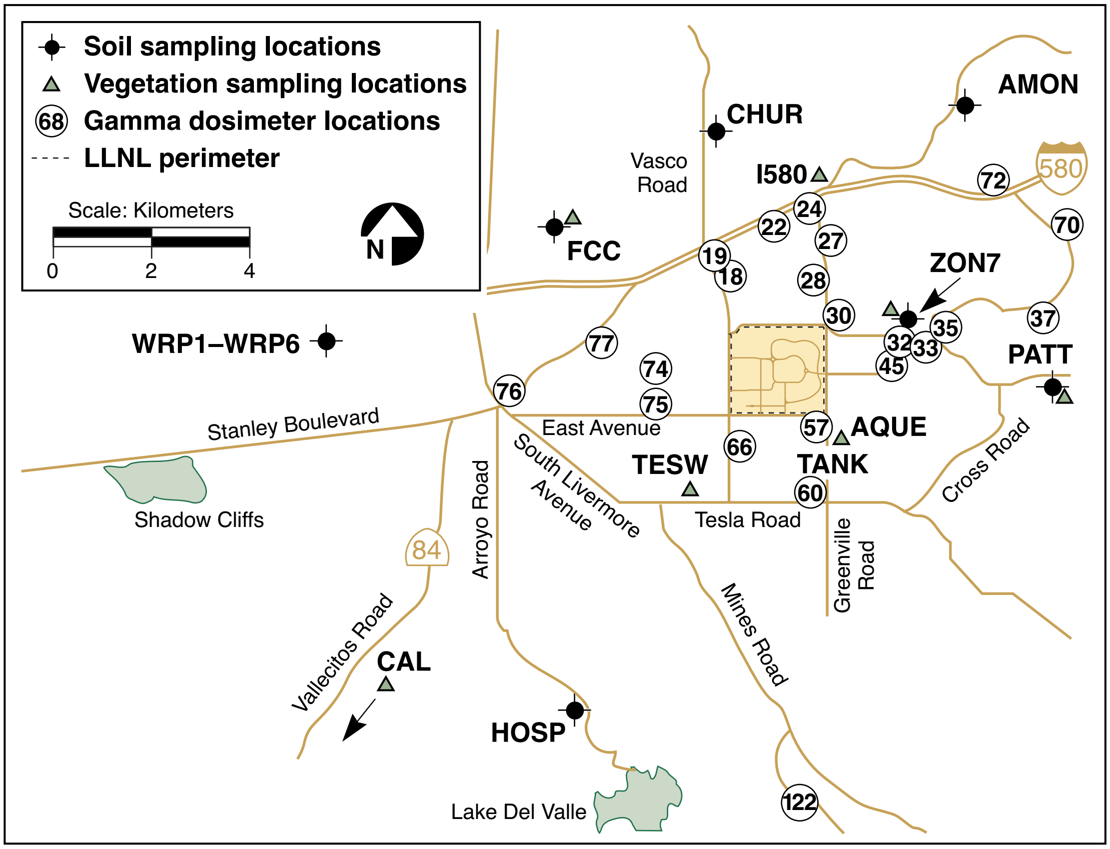


Figure 5-2. Sampling locations, Livermore Valley, 2003

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. All subsamples are collected from the top 5 cm of soil. 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 soluble volatile organic compounds and for polychlorinated biphenyls (PCBs).

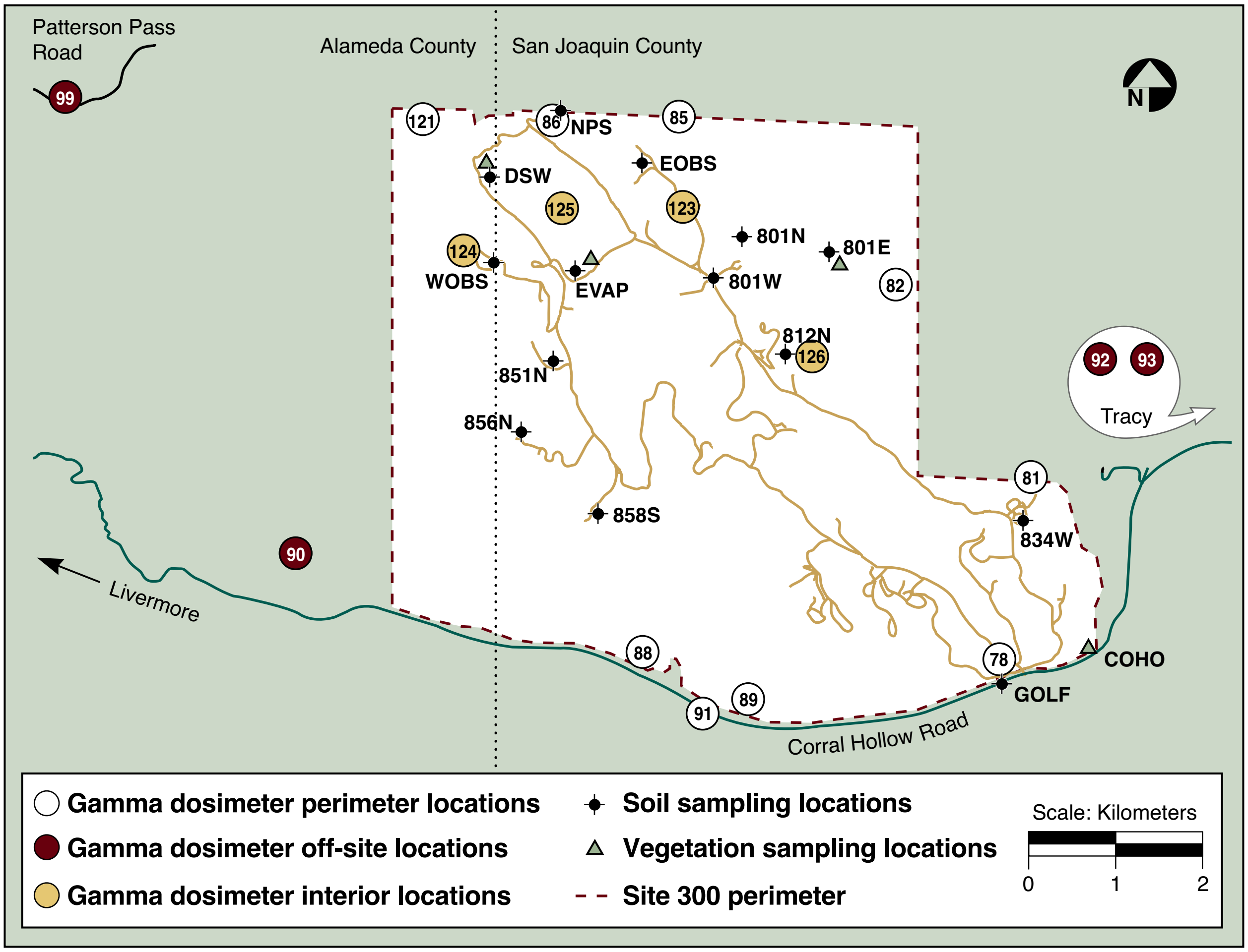


Figure 5-3. Sampling locations at Site 300 and off-site, 2003

In 2003, 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 Livermore site were analyzed for plutonium, gamma-emitting radionuclides, and tritium. Vadose zone samples were analyzed for total and soluble metals, and for soluble volatile organic compounds; one vadose zone location was analyzed for PCBs.

Prior to radiochemical analysis, surface soil and sediment samples are dried, ground, sieved, and homogenized. The plutonium content of a 100-g sample aliquot is determined by alpha spectroscopy. Other sample aliquots (300-g) are analyzed by gamma spectroscopy 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 2003, as in the previous three 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 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.

Table 5-1. Plutonium activity concentrations in Livermore Valley soil, 2003

Location	Plutonium-238 (mBq/dry g)	Plutonium-239+240 (mBq/dry g)
L-AMON-SO	0.0027 ± 0.0019	0.054 ± 0.0089
L-CHUR-SO	0.0057 ± 0.0026	0.14 ± 0.017
L-COW-SO	0.0019 ± 0.0028	0.020 ± 0.0062
L-FCC-SO	0.0028 ± 0.0016	0.089 ± 0.011
L-HOSP-SO	0.0037 ± 0.0026	0.068 ± 0.010
L-MESQ-SO	0.0012 ± 0.0019	0.034 ± 0.0065
L-MET-SO	0.00037 ± 0.0012	0.044 ± 0.0074
L-NEP-SO	0.0033 ± 0.0017	0.052 ± 0.0075
L-PATT-SO	–0.00010 ± 0.0012	0.024 ± 0.0048
L-SALV-SO	0.019 ± 0.0038	0.18 ± 0.019
L-TANK-SO	0.0044 ± 0.0020	0.13 ± 0.014
L-VIS-SO	0.020 ± 0.0041	0.35 ± 0.035
L-ZON7-SO	0.0026 ± 0.0016	0.031 ± 0.0055
Median	**0.0028**	**0.054**
IQR[(a)]	**0.0025**	**0.096**
Maximum	**0.02**	**0.35**

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, 2003

Location	Plutonium-238 (mBq/dry g)	Plutonium-239+240 (mBq/dry g)	Americium-241 (mBq/dry g)
L-WRP1-SO	0.48 ± 0.048	11 ± 1.1	4.9 ± 1.8
L-WRP2-SO	0.26 ± 0.029	4.7 ± 0.44	3.8 ± 3.0
L-WRP3-SO	0.056 ± 0.0087	0.97 ± 0.095	<0.41
L-WRP4-SO	0.023 ± 0.0083	0.36 ± 0.047	<0.4
L-WRP5-SO	0.082 ± 0.014	14 ± 0.14	<0.41
L-WRP6-SO	0.026 ± 0.0058	0.41 ± 0.043	<0.8
Median	**0.069**	**2.8**	**<0.61**
IQR[a]	**0.18**	**8.9**	**Not calculated[b]**
Maximum	**0.48**	**14**	**4.9**

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, 2003

Location	Plutonium-238 (mBq/dry g)	Plutonium-239+240 (mBq/dry g)	Tritium (Bq/L)
L-ALPE-SD	0.00080 ± 0.0016	0.012 ± 0.0033	13 ± 2.4
L-ASS2-SD	–0.00017 ± 0.00059	0.0071 ± 0.0021	12 ± 2.6
L-ASW-SD	0.0024 ± 0.0018	0.038 ± 0.0077	2.9 ± 2.0
L-ESB-SD	0.18 ± 0.019	1.9 ± 0.17	27 ± 2.9
L-GRNE-SD	0.0076 ± 0.0033	0.17 ± 0.021	4.6 ± 2.1
L-WPDC-SD	0.00030 ± 0.00098	0.015 ± 0.0038	2.1 ± 2.0
Median	**0.0016**	**0.027**	**8.3**
IQR[a]	**0.0059**	**0.12**	**9.4**
Maximum	**0.18**	**1.9**	**27**

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

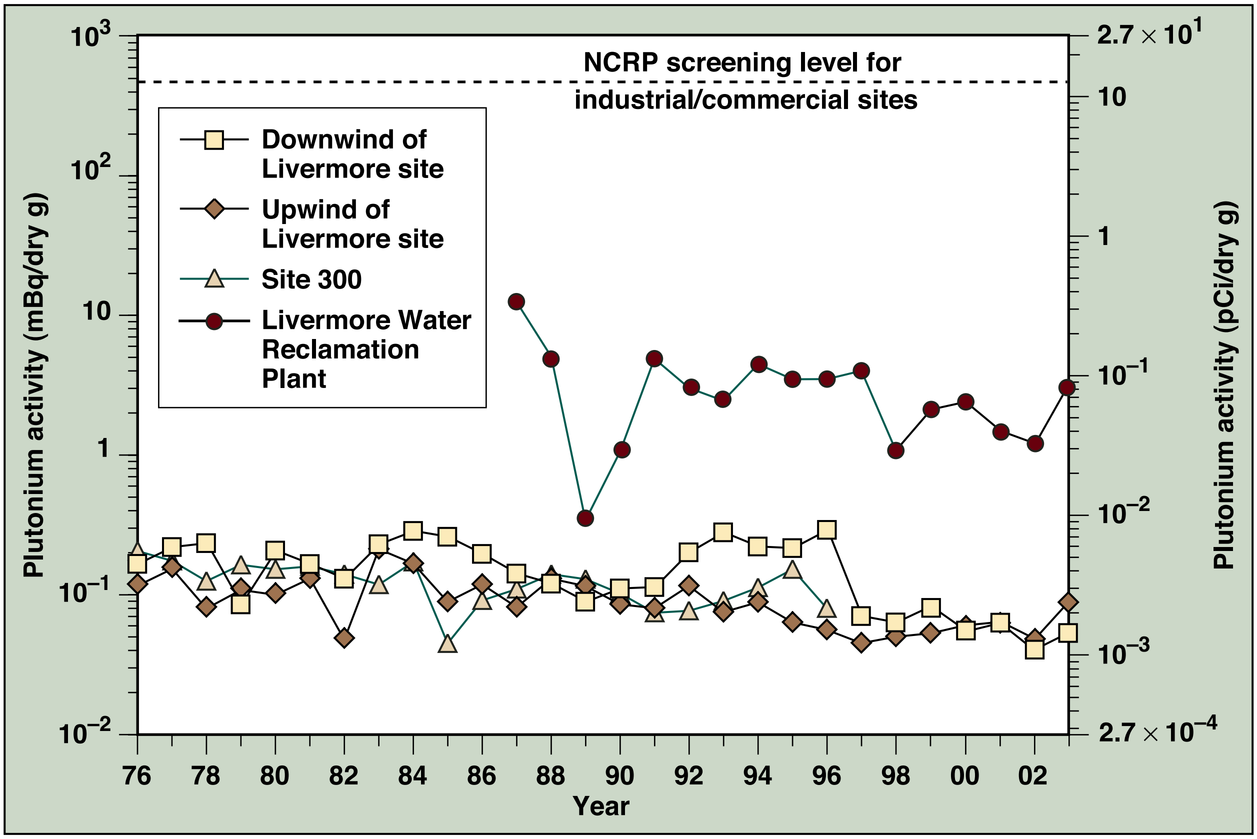
The concentrations and distributions of all observed radionuclides in soil for 2003 are within the ranges reported in previous years and generally reflect worldwide fallout and naturally occurring concentrations. Plutonium has, in the past, been detected at levels above background at VIS, a perimeter sampling location near the east boundary of the Livermore site. In 2003, the measured plutonium-239+240 value for VIS was 0.35 mBq/dry g (9.4×10^{-3} pCi/dry g), a value that is less than 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. Nonetheless, plutonium-239+240, from historic operations, can be carried off site by resuspension of soil by wind.

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 at this location for 2003 was 1.9 mBq/dry g (5.0×10^{-2} pCi/dry g). The highest detected value for tritium, 27 Bq/L (740 pCi/L), was at location ESB, which is also downwind of the Tritium Facility. All tritium concentrations were within the range of previous data. Tritium in sediments will continue to be evaluated as long as the measured values remain above the detection limits of the liquid scintillation analytical method.

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 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 2003 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; 2003 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 2003 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,



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, 1976–2003

due to the difficulty of measuring low activities of uranium-238 by gamma spectrometry. The highest measured value for 2003 occurred at 812N, a location where explosives tests have been conducted. 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.

Nonradiological Monitoring Results

Analytical results for organic compounds found in vadose zone soil samples are compared with de minimus concentrations developed by LLNL and approved by the San Francisco Bay Regional Water Quality Control Board (SFBRWQCB) (Folks 1997; Marshack 2003). Analytical results for metals are compared with natural background concentrations for metals developed by LLNL. (See the file "Ch5 Soil" provided on the report CD for de minimus concentration levels of organic compounds and background concentrations of metals.)

Table 5-4. Uranium and beryllium concentrations in Site 300 soil, 2003

Location	Uranium-235[(a)] (µg/dry g)	Uranium-238[(b)] (µg/dry g)	U235/U238 ratio	Beryllium (mg/kg)
3-801E-SO	0.023 ± 0.011	2.1 ± 0.94	0.011 ± 0.0072	1
3-801N-SO	0.035 ± 0.012	9.9 ± 2.8	0.0035 ± 0.0016	0.6
3-801W-SO	0.026 ± 0.014	4.2 ± 1.4	0.0062 ± 0.0039	<0.5
3-812N-SO	0.24 ± 0.018	110 ± 7.4	0.0022 ± 0.00022	110
3-834W-SO	0.019 ± 0.012	2.2 ± 1.7	0.0086 ± 0.0086	0.6
3-851N-SO	0.031 ± 0.012	3.7 ± 1.5	0.0084 ± 0.0047	0.6
3-856N-SO	0.022 ± 0.0095	2.5 ± 1.1	0.0088 ± 0.0054	<0.5
3-858S-SO	0.017 ± 0.0086	2.1 ± 0.94	0.0081 ± 0.0055	<0.5
3-DSW-SO	0.027 ± 0.011	3.1 ± 1.5	0.0087 ± 0.0055	<0.5
3-EOBS-SO	0.020 ± 0.014	1.6 ± 1.3	0.013 ± 0.013	<0.5
3-EVAP-SO	0.030 ± 0.010	5.0 ± 1.6	0.0060 ± 0.0028	<0.5
3-GOLF-SO	0.022 ± 0.014	2.4 ± 1.4	0.0092 ± 0.0079	<0.5
3-NPS-SO	0.022 ± 0.011	2.4 ± 1.2	0.0092 ± 0.0065	<0.5
3-WOBS-SO	0.023 ± 0.011	4.5 ± 1.2	0.0051 ± 0.0028	<0.5
Median	**0.023**	**2.8**	**0.0085**	**<0.5**
IQR[(c)]	**0.0073**	**2.2**	**0.0031**	**—[(d)]**
Maximum	**0.24**	**110**	**0.013**	**110**

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.

All analytical results for soluble VOCs were below detection limits. Unfortunately, detection limits were elevated for all compounds due to matrix interferences. All total metals concentrations were within site background. See the file "Ch5 Soil" provided on the report CD for analytical results for VOCs and metals. Since 2000, Aroclor 1260 (a PCB) has been detected at location ESB. In 2003, it was again detected at location ESB at a concentration of 0.7 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.

Beryllium results for soils at Site 300 were within the ranges reported since sampling began. The highest value, 110 mg/kg, was found at B812, which is an area that has been used for explosives testing. The QA duplicate was collected at this location; the result for beryllium was 6.0 mg/kg. 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 2003 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 11 mBq/dry g (0.31 pCi/dry g) for plutonium-239+240 measured at LWRP is 2.3% 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 **Table 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 active and inactive 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. Depleted uranium has been detected in soil and groundwater in the area. The Site 300 CERCLA activities are discussed in more detail in Chapter 7.

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.

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 should 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 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.

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 the 2003 sampling were purchased from supermarkets and wine merchants in Livermore except for one bottle purchased in southern California. Wines represent the Livermore Valley, six regions of California, and three countries in Europe.

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 2003 are shown in **Table 5-6**. The highest mean and maximum concentrations in vegetation for 2003 were at the Intermediate location ZON7, but concentrations at the Near location VIS were similar. Given normal dispersion, concentrations of tritium are expected to be higher at VIS than at ZON7, because ZON7 is 1.5 km farther away from tritium sources. As well, ZON7 is in the same downwind direction as VIS from the Tritium Facility. However, ZON7 and VIS do not lie in the same wind direction from the diffuse source of tritium at the B612 yard, and samples are not collocated in time. When winds shift, tritium concentrations in plants rapidly approach equilibrium with air moisture. Thus it is not too surprising that concentrations in vegetation at ZON7 can occasionally be greater than at VIS.

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. For the past six years, median concentrations for vegetation collected from the Intermediate and Far locations have been below detection limits, and even the median Near concentration for 2003 is at the detection limit. Only one (Games and Howell 1976) of several statistical tests determined that the Near and Far locations are different at the 5% significance level.

The concentration of HTO extracted from vegetation is basically that of the tritium in air moisture to which the plant was exposed for at most the two hours prior to sampling. Thus, quarterly sampling is not necessarily expected to be representative of the air seen by the vegetation for an entire year. For 2003, the mean or median concentrations of the vegetation samples do not reflect the increase in total tritium released from LLNL compared with 2002, but the samples taken in early May 2003 (second quarter) did detect increased emissions.

As in the past, concentrations in PIN1, because of the contaminated groundwater source, were higher than those in other vegetation. However, because of the higher tritium concentrations in air during the second quarter sampling and somewhat lower concentrations in PIN1 in 2003 compared with 2002, there is no statistical difference between PIN1 and PIN2 at the 5% significance level in 2003.

Table 5-6. Quarterly concentrations of tritium in plant water (Bq/L) and mean annual ingestion doses, 2003

	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	3.7 ± 2.1	0.58 ± 2.0	2.6 ± 1.5	2.1 ± 1.5	2.4	2.2	11
GARD	0.013 ± 1.9	1.9 ± 2.1	0.30 ± 1.4	1.5 ± 1.4	0.9	0.93	< 10[b]
MESQ	0.66 ± 2.0	1.7 ± 2.1	–0.50 ± 1.4	1.5 ± 1.4	1.1	0.84	< 10[b]
MET	–0.061 ± 2.0	1.3 ± 2.1	–0.52 ± 1.4	–0.40 ± 1.3	–0.23	0.08	< 10[b]
NPER	4.2 ± 2.1	2.6 ± 2.1	4.4 ± 1.6	0.42 ± 1.4	3.4	2.9	14
PIN2	3.8 ± 2.1	31 ± 3.1	3.8 ± 1.6	3.4 ± 1.5	3.8	10	—[c]
VIS	4.4 ± 2.1	22 ± 2.8	1.8 ± 1.5	0.77 ± 1.4	3.1	7.2	35
PIN1[d]	31 ± 3.1	45 ± 3.5	94 ± 4.2	15 ± 2.1	38	46	—[e]
Sampling locations from 1 to less than 5 km from the Livermore site perimeter							
I580	1.8 ± 2.0	2.8 ± 2.1	–0.38 ± 1.4	1.4 ± 1.4	1.6	1.4	< 10[b]
PATT	1.1 ± 2.0	–0.93 ± 2.0	–0.65 ± 1.4	–0.62 ± 1.3	–0.64	–0.28	< 10[b]
TESW	2.8 ± 2.1	1.0 ± 2.0	–0.87 ± 1.3	2.0 ± 1.4	1.5	1.2	< 10[b]
ZON7	4.6 ± 2.1	23 ± 2.9	1.2 ± 1.5	1.0 ± 1.4	2.9	7.5	37
Sampling locations more than 5 km from the Livermore site perimeter							
CAL	1.8 ± 2.0	0.00026 ± 2.0	–1.8 ± 1.3	–0.49 ± 1.3	–0.24	–0.12	< 10[b]
FCC	0.16 ± 1.9	–1.1 ± 2.0	–0.37 ± 1.4	1.5 ± 1.4	–0.11	0.047	< 10[b]
Sampling locations at Site 300							
COHO	0.71 ± 2.0	–0.41 ± 2.0	–0.49 ± 1.4	0.20 ± 1.3	–0.1	0.0025	< 10[b]
801E	–0.45 ± 2.0	–0.32 ± 2.0	0.45 ± 1.4	0.36 ± 1.3	0.02	0.01	< 10[b]
DSW[d]	19 ± 2.7	33 ± 3.2	2100 ± 19	24 ± 2.4	29	540	2600
EVAP[d]	74 ± 4.1	0.90 ± 2.1	230 ± 6.5	42 ± 3.0	58	87	430

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.

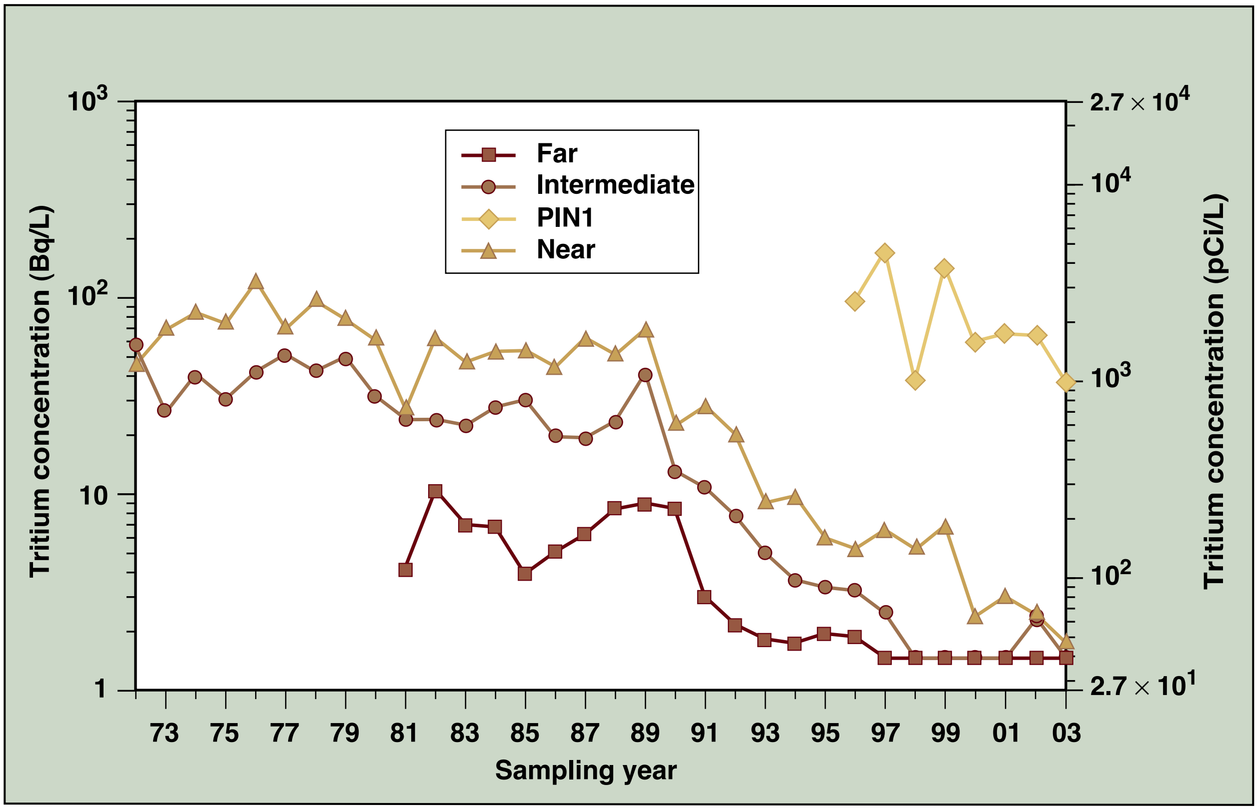
a Ingestion dose is based on conservative assumptions that an adult's diet is exclusively vegetables with this tritium concentration, and that meat and milk are derived from livestock fed on grasses with the same concentration of tritium. See **Table 6-6**.

b When concentrations are less than the detection limit (about 2.1 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 and a dose was calculated. Beginning in 2003, for NESHAPs compliance, ambient air monitoring at LLNL accounts for small diffuse sources, so a dose was not calculated.



Note: When median values are below 1.5 Bq/L (below detection limits), values are plotted as 1.5 Bq/L to eliminate meaningless variability.

Figure 5-5. Median tritium concentrations in Livermore Site and Livermore Valley plant water samples, 1972 to 2003

All samples at Site 300 locations 801E and COHO were below detection limits; median concentrations at these locations have been at or below detection limits since 1992. Tritium in vegetation at DSW and EVAP continues its erratic pattern dating from 1983, with high concentrations at times and non-detections at other times, depending upon whether or not the roots are taking up contaminated groundwater. The median concentrations at DSW and EVAP for 2003 were similar to those in 2002. The highest concentration (2100 Bq/L) was observed at DSW.

Wine Monitoring Results

The mean concentration of Livermore Valley wines sampled in 2003 reached an all-time low since sampling began (0.89 Bq/L); the mean concentration in European wines also reached the same low; California wines continue to reflect residual historical bomb fallout and cosmogenic tritium levels (Table 5-7). The highest concentration in a Livermore Valley wine (1.7 Bq/L) was from a wine made from grapes harvested in

Table 5-7. Tritium in retail wine (Bq/L), 2003[(a)]

Sample	Area of production		
	Livermore Valley	California	Europe
1	0.58 ± 0.19	0.29 ± 0.19	0.51 ± 0.19
2	0.62 ± 0.20	0.39 ± 0.19	0.66 ± 0.20
3	0.73 ± 0.20	0.39 ± 0.19	0.79 ± 0.20
4	0.74 ± 0.20	0.40 ± 0.19	1.6 ± 0.24
5	0.75 ± 0.20	0.43 ± 0.19	
6	0.79 ± 0.20	0.64 ± 0.20	
7	0.85 ± 0.20		
8	0.96 ± 0.21		
9	0.96 ± 0.21		
10	0.98 ± 0.21		
11	1.0 ± 0.21		
12	1.7 ± 0.25		
Mean ± standard deviation	0.89 ± 0.29	0.42 ± 0.12	0.89 ± 0.49
Dose (nSv/y)[(b)]			
Mean concentration	0.88	0.42	0.88
Maximum concentration	1.7	0.63	1.6

Note: Radioactivities are reported here as the measured concentration and an uncertainty ($\pm 2\sigma$ 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 Wines from a variety of vintages were purchased and analyzed in 2003. 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 (see Chapter 6).

1998. A 2002 European wine had a similar concentration (1.6 Bq/L); European wines sampled tend to be very variable, because some wines will come from areas of background tritium while others will come from areas with a local source of tritium.

The wines purchased in 2003 represent vintages from 1998 to 2002. 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 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/WHO 2001) 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).

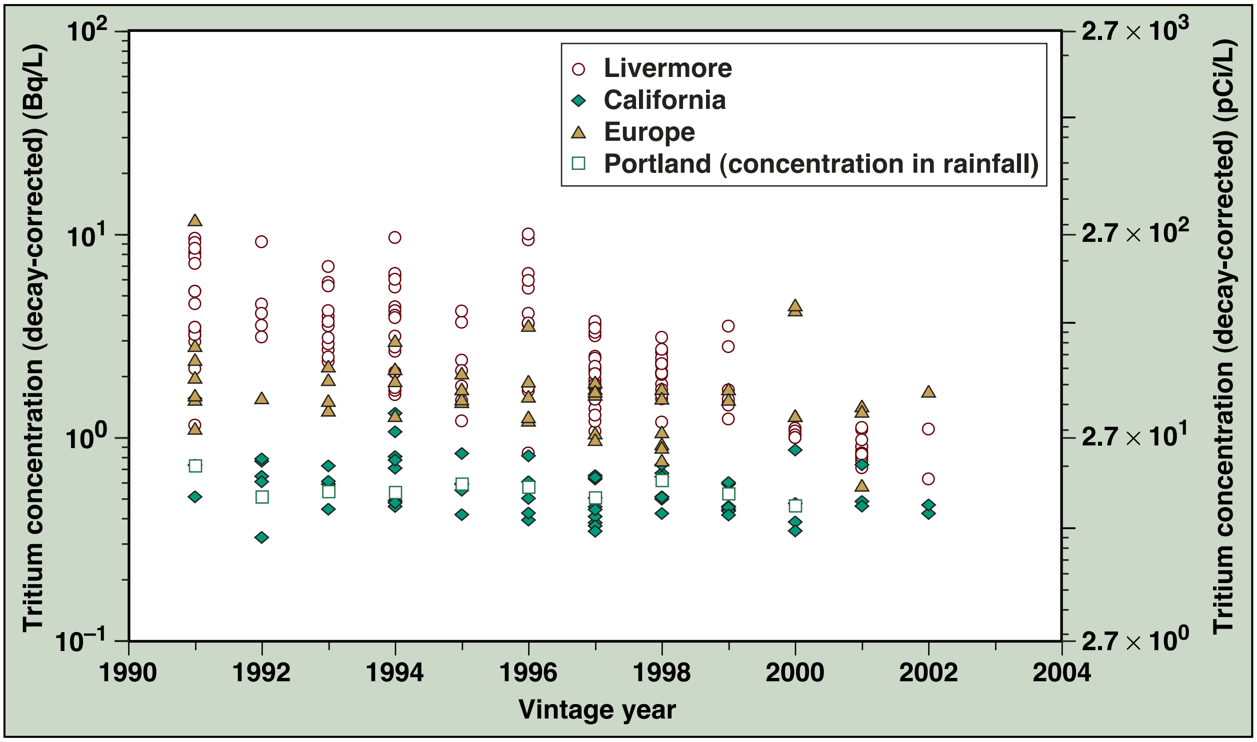


Figure 5-6. Tritium concentrations in all retail wines decay-corrected from the sampling year to the vintage year

Data for the 2003 sampling year were analyzed using Games/Howell multiple comparisons. Tritium concentrations in Livermore Valley wines were higher than California wines at the 5% significance level; using Scheffé's *F* test (Scheffé 1953) European wines were indistinguishable statistically both from Livermore Valley and from California wines. This is due to the large uncertainty on the mean of the European wines.

When regressions are calculated based on the time-dependent data in **Figure 5-6**, the correlation coefficients are very low for Europe and California; for the Livermore Valley the correlation coefficient is only 0.5. Nevertheless, for the 2003 sampling year, the half-life of tritium in Livermore Valley wines appears to be about half that of Europe or California. This demonstrates that LLNL tritium releases declined considerably between 1991 and 2002.

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 annual ingestion dose, based on highest observed mean HTO concentration in vegetation for 2003, is 37 nSv (3.7 µrem/y). Since 1991, the hypothetical annual ingestion dose based on the maximum observed mean has decreased by a factor of ten; since 1980, a year after LLNL started calculating ingestion dose in this manner, the hypothetical dose has decreased by a factor of 55. Doses calculated in this manner 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." (U.S. Department of Health and Human Services 2001) Thus the maximum estimated ingestion dose from LLNL operations for 2003 is at most 74 nSv (7.4 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 small 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 2003. Furthermore, sampling of PIN1 and PIN2 will be terminated in 2004 since 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 (74 nSv; 7.4 mrem/y) is just 1/40,000 of the average annual background dose in the United States from all sources and just 1/1400 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 2003 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 2003 would be 2.6 µSv (0.26 mrem), which is very small.

Wine

For Livermore Valley wines purchased in 2003, the highest concentration of tritium (1.7 Bq/L) is just 0.22% of the Environmental Protection Agency's standard for maximal permissible levels of tritium in drinking water (740 Bq/L). A person would have to drink at least 435 liter-bottles of Livermore Valley wine a day to exceed the EPA standard. Dose from drinking 1 L per day of the Livermore Valley wine with the highest concentration purchased in 2003 would be 12 nSv/y (1.2 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 (0.89 Bq/L) is 0.88 nSv/y (0.088 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 1/250,000 of the average annual background dose from naturally occurring sources of radiation.

Ambient Radiation Monitoring

Gamma radiation in the environment can come from two natural sources. The first source is from the terrestrial component of natural elements of the earth's crust (i.e., parents [uranium-238, thorium-232, and potassium-40] and daughter radiation produced in the physical decay of the uranium, thorium, and actinium series). The second source is from cosmic 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 surface (Eisenbud 1987).

Sampling locations for 2003 are the same as for 2002, although, in 2003, several site locations were unavailable in one quarter due to the inadvertent removal of samples during the replacement of perimeter fencing by a construction crew. Sampling locations for TLDs are divided into three groups for analysis:

1. Moderate consumption is higher than the average consumption of wine in the United States (2.01 gal/y or 7.6 L/y) (California Wine Institute 2001).
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).

Livermore site locations—TLDs are positioned at 14 perimeter and near fence line locations (**Figure 5-1**). The labeling system used has been maintained for historical reference purposes.

Livermore Valley locations—The 22 Livermore valley sites (**Figure 5-2**) represent natural background for this geological area.

Site 300 and vicinity locations—9 TLDs are deployed to monitor the perimeter of Site 300, while 4 are deployed within Site 300. Two off-site TLD locations are maintained nearby Site 300, and 2 others in the city of Tracy (**Figure 5-3**).

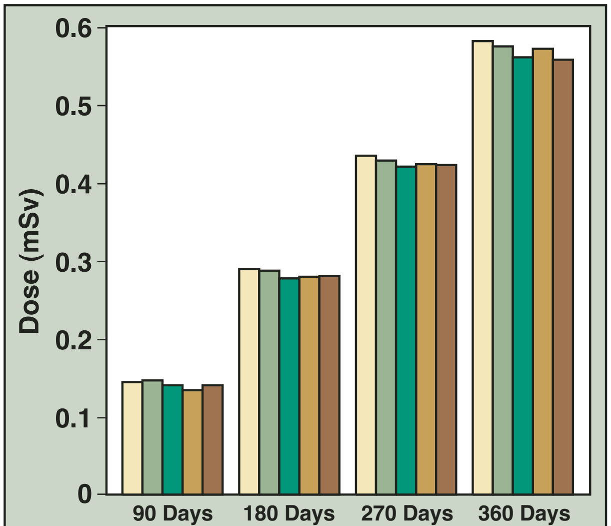
As policy, the State of California Radiological Health Branch maintains several collocated TLD sample sites around the LLNL perimeter and Livermore Valley for the purpose of independent monitoring for comparison.

LLNL uses the Panasonic UD-814AS1 TLD to passively measure gamma radiation in the environment. This TLD type contains four crystal elements. One is a $Li_2B_4O_7$ element and three are thallium-activated $CaSO_4$ elements. The $CaSO_4$ crystals absorb gamma radiation and hold this induced excitation with minimal fading until the TLD has been thermally heated to release it following deployment. This trapped energy is released in the form of emitted light. The output of the light intensity is proportional to the gamma ray that initiated the process. This value is the TLD absorbed dose in units of milliroentgen (mR) and is recorded and then corrected for reader calibration. TLDs are prepared for re-use in a process known as "annealing" (reheating the TLD to erase its memory of "absorbed energy"). Four quarterly deployment cycles are made throughout the year at the beginning of each quarter. When the TLDs are retrieved from the sites, a new quarter's deployment is made. The group retreived is then taken back for analysis. The data turnaround time is normally 2 to 3 days. Data is checked and recorded in the data base. For reporting comparisons, data is normalized to a "standard 90-day quarter." This is the dose reported in millisievert (mSv) for the field period.

Monitoring Results

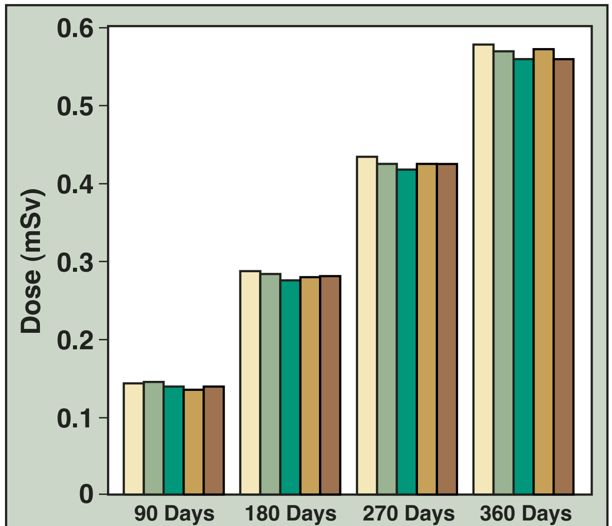
In **Figures 5-7** through **5-10**, the quarterly average cumulative doses in mSv for 2003 are presented for the Livermore site, the Livermore Valley, on-site at Site 300 and off-site at Site 300 along with quarterly doses from 1999 to 2003.

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 downward trend in the site-wide annual dose as 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.



	Dose (mSv)			
	90 Days	180 Days	270 Days	360 Days
1999	0.144	0.289	0.434	0.581
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

Figure 5-7. Livermore site perimeter cumulative dose (mSv), 1999 through 2003



	Dose (mSv)			
	90 Days	180 Days	270 Days	360 Days
1999	0.142	0.286	0.432	0.576
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

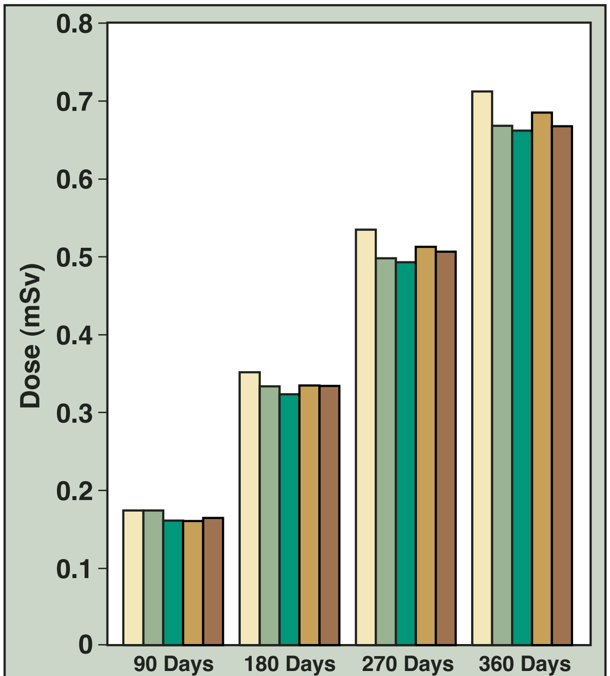
Figure 5-8. Livermore Valley cumulative dose (mSv), 1999 through 2003

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 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**).

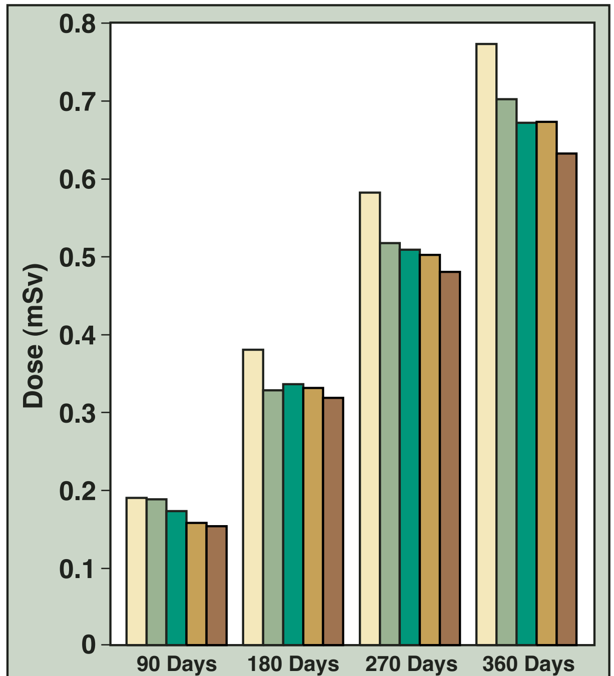
Environmental Impact on Ambient Radiation

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 2003. The radiation dose trends remain consistent with annual location average levels for each sample site. Although some locations have had anomalous annual



	Dose (mSv)			
	90 Days	180 Days	270 Days	360 Days
1999	0.173	0.350	0.533	0.710
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

Figure 5-9. On-site at Site 300 cumulative dose (mSv), 1999 through 2003

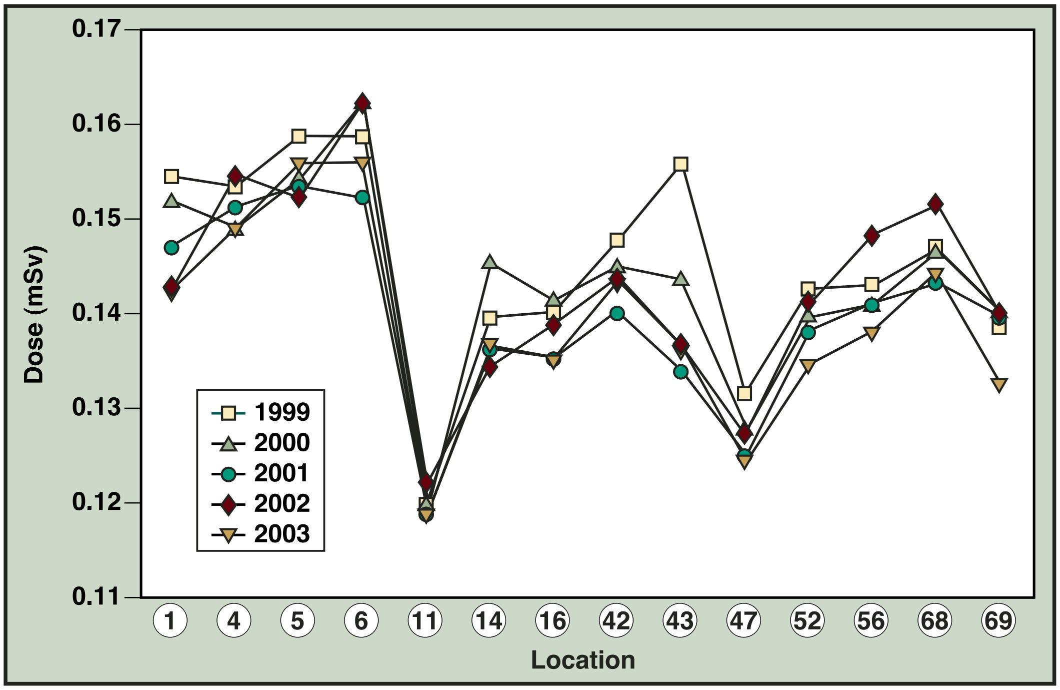


	Dose (mSv)			
	90 Days	180 Days	270 Days	360 Days
1999	0.189	0.379	0.581	0.772
2000	0.187	0.327	0.516	0.701
2001	0.172	0.335	0.508	0.671
2002	0.157	0.330	0.501	0.672
2003	0.153	0.318	0.480	0.632

Figure 5-10. Site 300 environs cumulative dose (mSv), 1999 through 2003

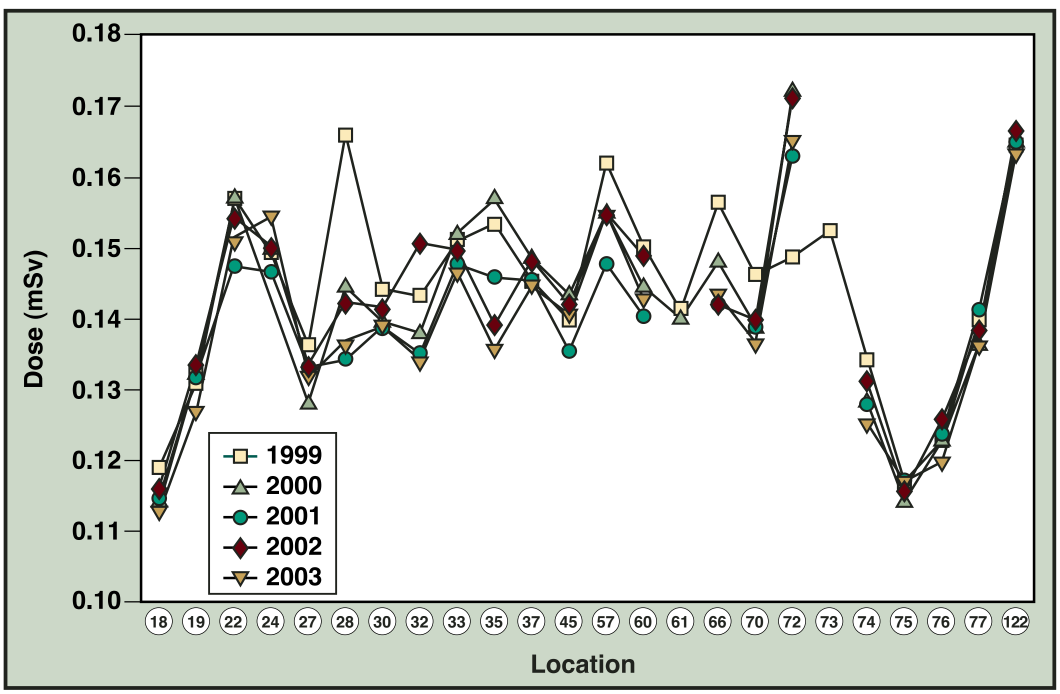
values in comparison to the long term trend for these locations, the trends would have continued at those sample sites had there been any contamination effecting the dose at that site. This is the most important reason for long term trend analysis and why these spurious excursions are not considered alarming.

As depicted in **Figure 5-14**, the annual average gamma radiation dose from 1999 to 2003 is statistically equivalent and shows no discernible impact due to operations conducted at LLNL.



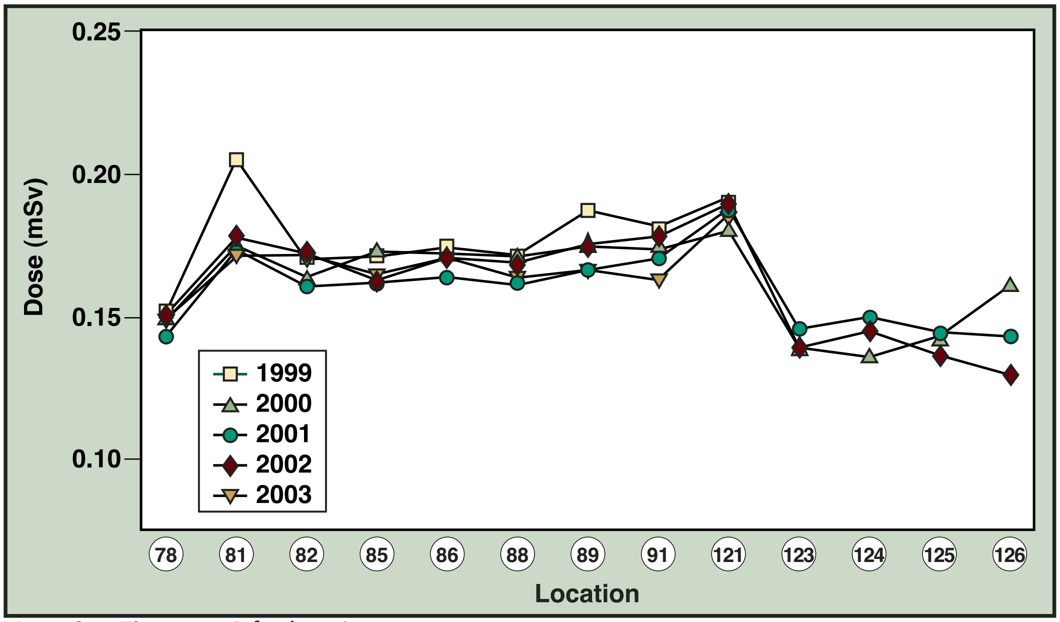
Note: See **Figure 5-1** for locations.

Figure 5-11. Livermore site perimeter annual average dose from 1999 to 2003



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

Figure 5-12. Livermore Valley annual average dose from 1999 to 2003



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

Figure 5-13. Site 300 annual average dose from 1999 to 2003

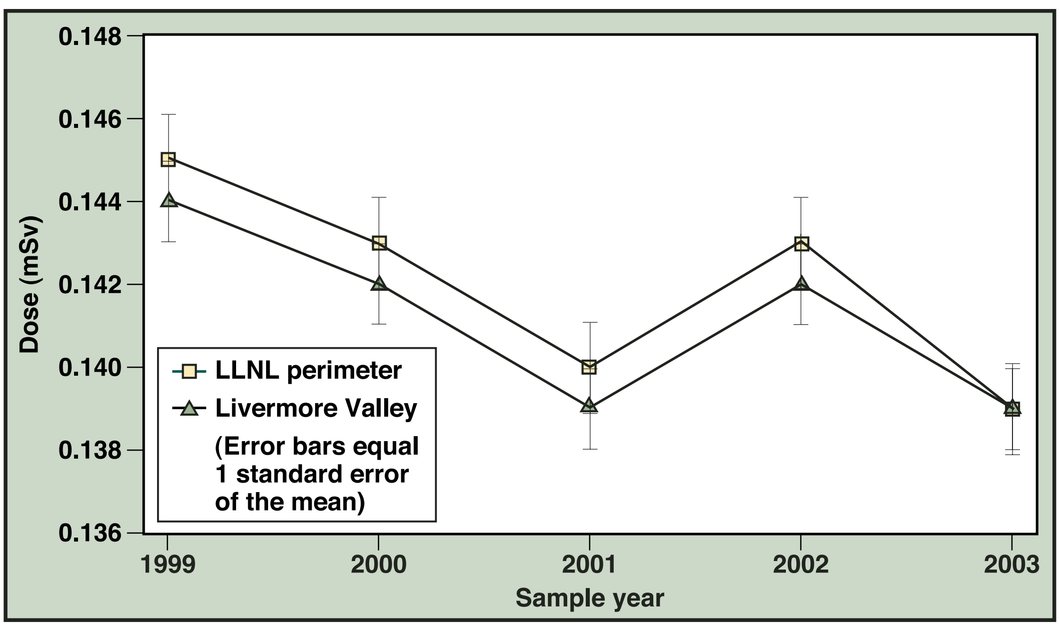


Figure 5-14. Annual average gamma radiation dose comparison for Livermore site and the Livermore Valley

Wildlife and Rare Plants

Wildlife and rare plant monitoring efforts at LLNL are focused on species and their habitats considered by Federal or California agencies and regulations 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.

A list of species known to occur at Site 300, including state and federally listed species, is found in Appendix B. Locations of species of particular interest are shown in **Figure 5-1** for the Livermore site and **Figure 5-15** for Site 300.

Four species that are listed under the federal or California endangered species acts are known to occur at Site 300: the 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 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. State threatened Swainson's Hawks (*Buteo swainsoni*) have been observed at Site 300, but Swainson's Hawk breeding habitat 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 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. 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 with respect to 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

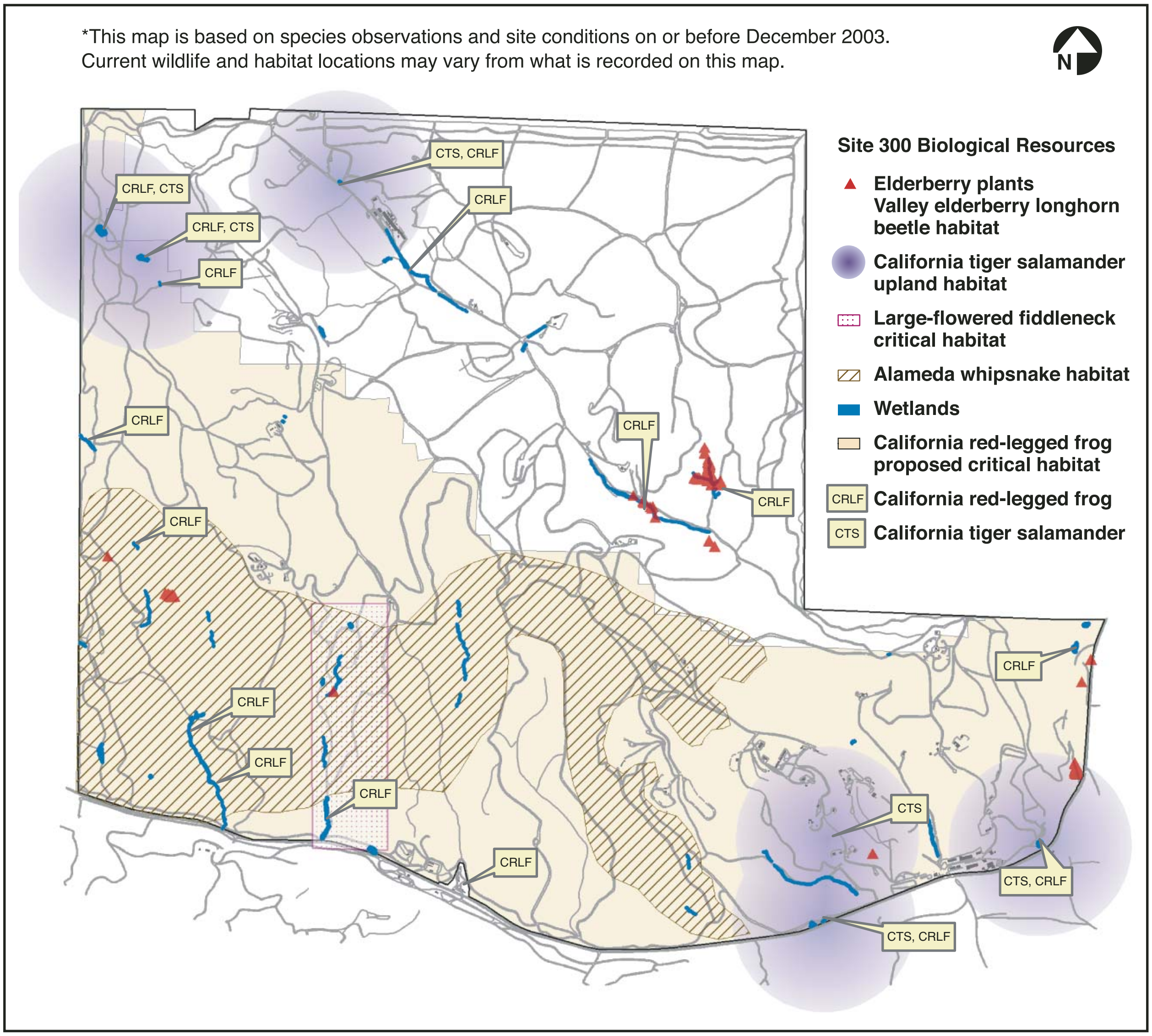


Figure 5-15. Distribution of federal and California threatened and endangered plants and wildlife, Site 300, 2003

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 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. No rare plants are known to occur at the Livermore site despite previous surveys (Preston 1997, 2002a).

The following sections describe results from LLNL wildlife and rare 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. Known locations of California red-legged frogs are shown in **Figures 5-1** and **5-15**. 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 2003.

California red-legged frog monitoring at the Livermore site in 2003 included egg mass surveys. Egg masses were counted, and the location of each egg mass was recorded using handheld GPS. The oviposition site (location and attachment point) was quantified to yield greater insight into microhabitat characteristics that might be important to California red-legged frog breeding ecology in the Arroyo Las Positas. The total number of California red-legged frog egg masses detected in the Arroyo Las Positas was 33 in 2003, similar to the 31 egg masses found in 2002, but the location of these egg masses shifted in 2003. In 2002, several egg masses were found in Arroyo Las Positas where it runs along the eastern edge of the site. Although few egg masses were found in the eastern portion of Arroyo Las Positas in 2003, more were found in the Arroyo near the north buffer zone. Because predation is high, the actual number of frogs produced per egg mass is unknown. Further annual surveys will help to evaluate the long-term viability of this population.

Surveys for adult frogs were conducted in various 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.

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 whipsnake. 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.

Thirteen Alameda whipsnakes were captured at the control and burn sites in the spring and fall of 2003. (Six of these 13 snakes were previously captured as part of this project). A total of eighteen Alameda whipsnakes were captured during baseline monitoring in 2002. 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. 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 2003 in compliance with the 1998 ammended 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 2003. Four nighttime surveys for adult bullfrogs were conducted in the summer of 2003. 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.

Environmental Impact Statement/Environmental Impact Report Monitoring

In implementing the mitigation monitoring requirements of the *1992 Final Environmental Impact Statement and Environmental Impact Report for Continued Operation of Lawrence Livermore National Laboratory and Sandia National Laboratories, Livermore* (U.S. DOE and UC 1992a,b) biological surveys were performed in 2003 for specific special-status species at Site 300 project construction (ground-disturbing) areas. Presence data for the San Joaquin kit fox, American badger (*Taxidea taxus*), and Western Burrowing Owl (*Speotyto cunicularia hypugaea*) were collected at each project location, and other applicable mitigation measures were implemented where appropriate.

A branchiopod survey was conducted in the 2001/ 2002 and 2002/2003 rainy seasons to determine the distribution of federally listed branchiopods at Site 300 (Weber 2002). 2003 was the final year of branchiopod surveys that were initiated to obtain baseline information for the new *Site-wide Environmental Impact Statement for the Continued Operation of Lawrence Livermore National Laboratory and Supplemental Stockpile Stewardship and Management Programmatic Environmental Imact Statement*. These surveys were conducted according to the USFWS interim survey guidelines for listed vernal pool branchiopods (USFWS 1996). These guidelines require that the survey protocol be conducted during two consecutive wet seasons. At Site 300, potential habitat for branchiopods currently on the federal endangered species list exists in the two vernal pools located in the northwest corner of the site, nine relatively large pools in roadbeds, and three ephemeral pools in intermittent drainages. Surveys consisted of sampling these pools at the water surface, throughout the water column, along the pool margins and at the bottom using a fine-meshed aquarium net. Specimens were identified using a 10x hand lens.

Two branchiopod species that are not federal or California endangered species, California fairy shrimp (*Linderiella occidentalis*) and California clam shrimp (*Cyzicus californicus*), were found during the 2002 and 2003 surveys. Although not listed as threatened or endangered, the California fairy shrimp is a Federal Species of Concern. No listed branchiopods were observed at Site 300.

Surveillance Monitoring

Wildlife

Nesting Bird Surveys

NLLNL conducts nesting bird surveys, which complies with the Migratory Bird Treaty Act. A nest searching technique was used in 2003 to determine the distribution and productivity of the Elk Ravine (Site 300) Tricolored Blackbird colony. The Tricolored Blackbird is not known to nest at the Livermore site. The nests were located in late summer after Tricolored Blackbirds had fledged, and the location of each nest was recorded using a handheld global positioning system (GPS). 577 nests were located and productivity was estimated for the colony at 1731 to 2308 fledglings (clutch size 3 to 4) or more conservatively estimated at 577 to 1731 fledglings (clutch size 1 to 3), representing the largest overall concentration of vertebrate special status species at Site 300. The number of nests found in 2003 is less than the number of nests found during 2002 surveys, which was over 800. Information gathered from the Tricolored Blackbird colony will be used for planning and management in addition to improving regional understanding of the distribution and abundance of this declining species.

White-tailed Kites 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 2003; two pairs of White-tailed Kites successfully fledged a total of five 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 2003.

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). This avian monitoring program continued in 2003 with variable circular plot point count stations systematically distributed through Site 300. Each point was surveyed in the morning on calm dry days between sunrise and 9 a.m. during March, April, and May of 2003. Each site was surveyed once during this time period. Surveys included recording all bird species identified visually using binoculars or by their vocalization in 10 minutes. 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 2003). 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 B. Willow Flycatchers (*Empidonax traillii*) were captured during mist netting in Elk Ravine in 2003. This is of particular interest because the Willow Flycatcher is endangered under the California Endangered Species Act and was not previously known to occur at Site 300.

Rare Plants

LLNL conducted restoration and/or monitoring activities in 2003 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 (*Erodium macrophyllum*). The results of this work are described in more detail in an annual progress report (Carlsen et al. 2003b).

Large-Flowered Fiddleneck

LLNL established an experimental population of large-flowered fiddleneck at Site 300 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. 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 2003. During the 2003 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 occurs.

The number of large-flowered fiddleneck plants in all experimental and native populations has remained extremely low for the past five years. Fewer than 50 large-flowered fiddleneck plants were observed in the native population between 1999 and 2003, and only four plants were observed in 2003. The experimental large-flowered fiddleneck population has also had low numbers in recent years. There have been fewer than 70 large-flowered fiddlenecks in the flashing portion of the experimental population each year since 1998, and this subpopulation dropped to a low of 10 plants in 2001. The fire frequency subpopulation contained 148 large-flowered fiddleneck plants in 2000, 257 in 2001, 57 in 2002, and 50 in 2003.

The experimental population was expanded in 2000 to investigate more fully the use of fire as a management tool. This portion of the experimental population is referred to as the fire frequency subpopulation. Vegetation monitoring after the 2001 and 2002 prescribed burns show that these burns are beneficial in the restoration of native bunch grasses.

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. The 2002 seeding did not result in a large increase in population numbers (69 large-flowered fiddleneck were observed in the flashing subpopulation in 2003) probably due to unusual rainfall during the winter of 2002/2003. Seeding was repeated in the fall/winter 2003.

Seed predation is a factor potentially attributing to the low population number of large-flowered fiddleneck. The amount of seed predation by small mammal populations in the Site 300 experimental population was studied in 2003. Detailed monitoring of populations located in areas undergoing controlled burning is also being conducted to determine the impacts of fire on the population dynamics of this species. Seed predation in 2003 was slightly lower than in 2002 and 2001 and much lower than the extremely high predation rate observed in 1998 and 1999.

Big Tarplant

The distribution of big tarplant was mapped using a handheld GPS in October and November 2003. This distribution was compared, using a GIS (Geographic Information System), to the distribution of prescribed burns conducted at Site 300 in 2003 and in previous years.

The big tarplant remained widespread throughout Site 300 in 2003. Data show the plants do not survive direct contact with the burn but do benefit from reduced competition resulting from a burn. This suggests an intermittent burn frequency in some areas may further increase populations of this species.

Diamond-Petaled California Poppy

In 2003, two populations of diamond-petaled California poppy were known to occur near the western boundary of 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. A census of the two Site 300 populations was conducted in March 2003, during which LLNL recorded the size and location for each diamond-petaled poppy plant, and the vegetation community in which this species occurs.

A total of 10 diamond-petaled poppy plants were observed in the original site (identified in 2001) in 2003; this is down considerably from 285 in 2002 and 189 plants observed in 2001. The majority of these plants produced seed-bearing pods. The second population identified during the 2002 special status plant surveys (Preston 2002a) contained a total of 76 plants in 2002 and only two plants in 2003.

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. 2003 was the first year of monitoring round-leaved filaree at Site 300. During the spring of 2003, the extent of these two populations was mapped using a handheld GPS and the survivorship of round-leaved filaree was measured and compared to the survivorship of the related exotic species red-stem filaree (*Erodium cicutarium*). Survivorship to flowering for round-leaved filaree was high, 93%, compared to red-stem filaree, which had a 66% survivorship to flowering.

Environmental Impacts on Wildlife and Rare Plants

The Livermore site population of California red-legged frogs in 2003 appeared to be stable compared to 2002. The location of reproduction in Arroyo Las Positas shifted in 2003. This shift is probably the result of dredging conducted in 2002 that changed the water depth and vegetation of the dredged reaches of Arroyo Las Positas. In spite of the location shift, reproduction rates appear to be similar in 2003 compared to 2002. At Site 300, 2003 surveys 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 of this invasive species of 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.

LLNL was also able to avoid impacting the nesting of tricolored blackbird and white-tailed kites by monitoring the timing and location of their nesting. LLNL's avian monitoring program also detected one California Endangered Species, the Willow Flycatcher, previously not known to occur at Site 300.

The decline in populations of large-flowered fiddleneck observed over the past several years at Site 300 has been observed in other existing natural and experimental populations of the large-flowered fiddleneck throughout its existing range. These low numbers are probably the result of environmental factors and not related to Site 300 activities. Potential factors contributing to the decline of the large-flowered fiddleneck include encroachment of bush lupine (*Lupinus albifrons*), seed predation, and increase in annual grass density in large-flowered fiddleneck populations. Research continues to help determine what factors are contributing to the decline of this species and what management strategies will be beneficial to this species.

Site 300 as a whole is a place where rare plants flourish. Big tarplant is abundant throughout a large portion of Site 300 despite being very rare throughout California. The diamond-petaled poppy and large-flowered fiddleneck both occur in remote areas of Site 300 and are limited to only one or two other known locations.