6. Terrestrial Monitoring

*Nicholas A. Bertoldo, Gretchen Gallegos, Lisa Paterson,
Anthony M. Wegrecki, Jim Woollett*

Lawrence Livermore National Laboratory monitors several aspects of the terrestrial environment. LLNL measures the radioactivity present in soil, vegetation, and wine, and the absorbed gamma radiation dose at ground-level receptors from terrestrial and atmospheric sources.

The LLNL terrestrial radioactivity monitoring program is designed to measure any changes in environmental levels of radioactivity. All monitoring activities follow U.S. DOE guidance criteria. On-site monitoring activities detect radioactivity released from LLNL that may contribute to radiological 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 radiological 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 7**) is calculated using a screening model that requires knowledge of radionuclide concentrations in soils, sediments, and surface water.

Sampling for all media is conducted according to written, standardized procedures summarized in Woods (2005).

In addition to terrestrial radioactivity monitoring, LLNL monitors the abundance, distribution, and ecological requirements of plant and wildlife species, and conducts research relevant to the protection of rare plants and animals. 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 other applicable regulations as they pertain to endangered, threatened, and other special status species, their habitats, and designated critical habitats that exist at both LLNL sites.

6.1 Soil and Sediment Monitoring

The number of soil and sediment sampling locations are as follows:

Livermore site—6 soil, 4 sediment (see **Figure 6-1**)

Livermore Valley—10 soil, including 3 at the WRD (see **Figure 6-2**)

Site 300—14 soil (see **Figure 6-3**)

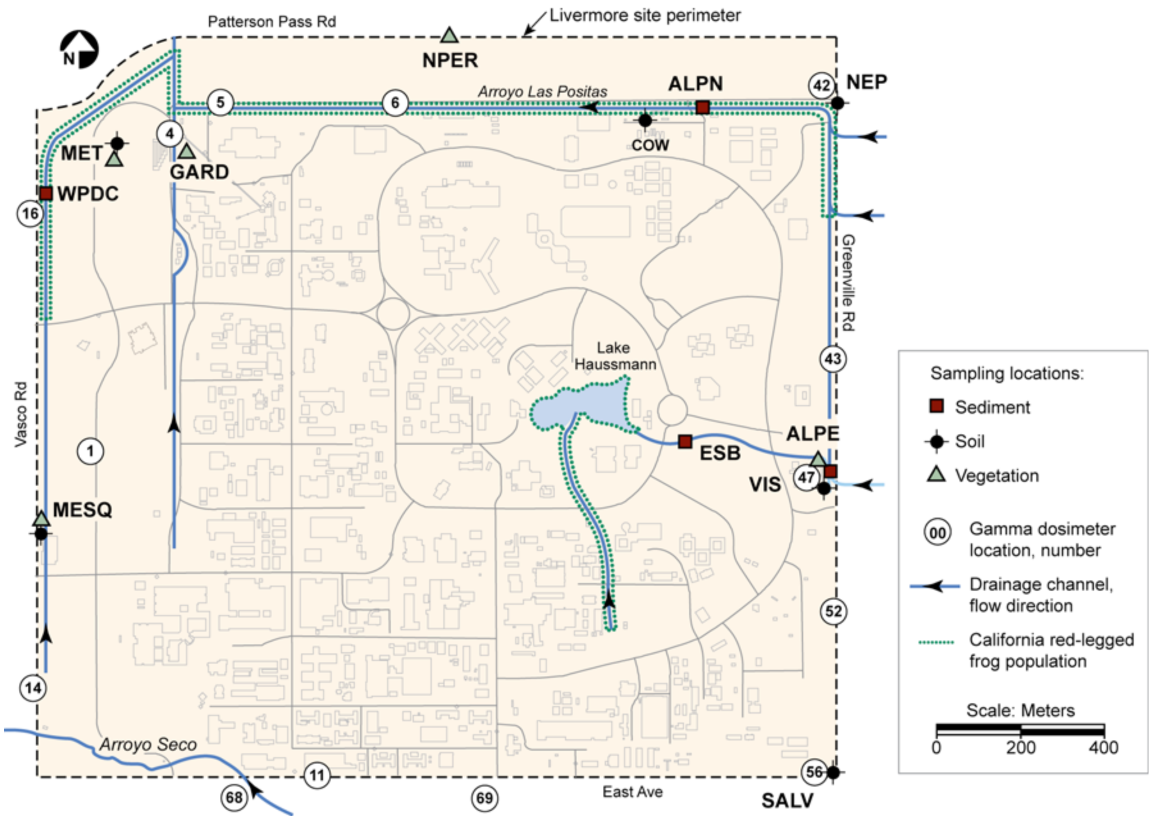

Figure 6-1. Sampling locations and populations of the California red-legged frog, a threatened species, Livermore site, 2007.

These locations were selected to represent background concentrations (distant locations unlikely to be affected by LLNL operations) as well as areas with the potential to be affected by LLNL operations. Sampling locations also include areas with known contaminants, such as the WRD and around explosives testing areas at Site 300.

Surface sediment and vadose zone soil samples are collected from selected arroyos and other drainage areas on and around the Livermore site. These sampling locations, shown in **Figure 6-1,** coincide largely with selected LLNL storm water sampling locations (see **Chapter 5**).

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 at the corners and center of each square by an 8.25-cm-diameter, stainless-steel core sampler.

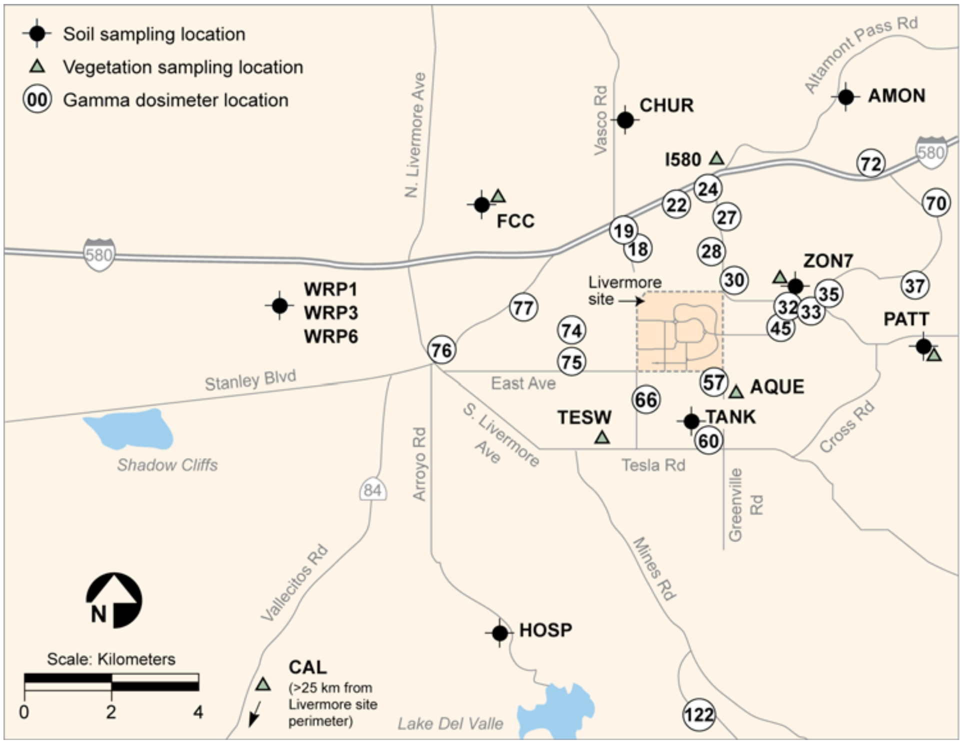

Figure 6-2. Sampling locations and gamma dosimeter locations, Livermore Valley, 2007.

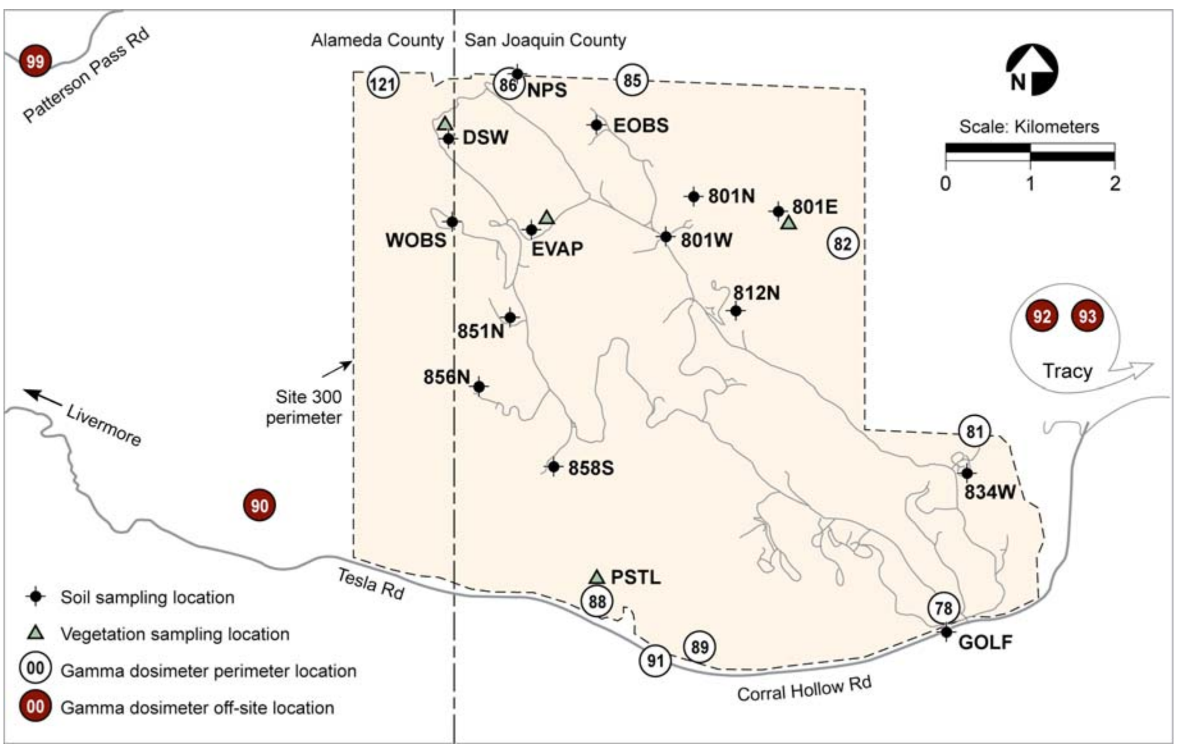

Figure 6-3. Sampling locations at Site 300 and off-site, 2007.

Surface sediment samples are collected in a similar manner. Ten subsamples, 5-cm deep, are collected at 1-m intervals along the transect of an arroyo or drainage channel. At one of the subsample locations, a 15-cm deep sample is taken 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 but at deeper positions; a 30- to 45-cm deep sample is collected for metals analysis, and a 45- to 65-cm deep sample is collected for analysis for PCBs.

In 2007, 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 collected at the four sediment sampling locations and 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. For beryllium, 10-g subsamples are analyzed by atomic emission spectrometry. Vadose zone soil samples are analyzed by standard EPA methods.

6.1.1 Radiological Monitoring Results

The 2007 data on the concentrations of radionuclides in surface soil and sediment from the Livermore Valley sampling locations are provided in **Appendix A**, **Section A.8**.

The concentrations and distributions of all observed radionuclides in soil for 2007 are within the ranges reported in previous years and generally reflect worldwide fallout and naturally occurring concentrations. Slightly higher values at and near the Livermore site have been attributed to historical operations (Silver et al. 1974), including the operation of solar evaporators for plutonium-containing liquid waste in the southeast quadrant of the site. LLNL ceased operating the solar evaporators in 1976 and no longer engages in any other open-air treatment of plutonium-containing waste. Sampling at location ESB, which is in the drainage area for the southeast quadrant of the Livermore site, shows the effects of the historical operation of solar evaporators. The measured value for plutonium-239+240 at this location in 2007 was 1.5 mBq/dry g (4.1×10^{-2} pCi/dry g). 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 WRD sampling locations in 2007. The highest detected plutonium-239+240 value at the WRD was 7.0 mBq/dry g (1.9×10^{-1} pCi/dry g). In addition, americium-241 was detected in one WRD sample at a concentration of 2.9 mBq/dry g (7.8×10^{-2} pCi/dry g) and was most likely caused by the natural radiological decay of the trace concentrations of plutonium-241 that were present in these historical releases to the sewer.

The highest detected value for tritium in 2007 (6.8 Bq/L [180 pCi/L]) was at location ALPN, which is downwind of the Tritium Facility. In 2007, tritium emissions were consistent with the Tritium Facility's associated operations, as described in **Chapter 4**. All tritium concentrations were within the range of previous data.

The soils data for Site 300 for 2007 are provided in **Appendix A**, **Section A.8**. The concentrations and the distributions of all radionuclides observed in Site 300 soil for 2007 lie within the ranges reported in all years since monitoring began. At 13 of the 14 sampling locations, the ratio of uranium-235 to uranium-238 reflects the natural ratio of 0.00725. 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 values for uranium-235 and uranium-238 in a single sample were 0.36µg/g (0.029 Bq/g or 0.78 pCi/g) and 170 µg/g (2.1 Bq/g or 57 pCi/g), respectively. The uranium-235 to uranium-238 ratio in this sample is 0.0021, which at the levels of uncertainty associated with the analysis equals the ratio for depleted uranium of 0.002. Such values at Site 300 result from the use of depleted uranium in explosive experiments.

6.1.2 Nonradiological Monitoring Results

Analytical results for metals are compared with site-specific natural background concentrations for metals. (See **Appendix A**, **Section A.8**, for background concentrations for both the Livermore site and Site 300 and analytical results for metals.)

All metal concentrations at the Livermore site were within site background values with the exception of total and soluble zinc at location ESB. Livermore site groundwater surveillance monitoring (see **Chapter 5**) determines the impact of these metals, if any, on-site groundwater.

Aroclor 1260, a PCB, has been detected at location ESB since surveillance for PCBs began at this location in 2000. In 2007, the concentration was 1.1 mg/kg. The presence of PCBs suggests residual low-level contamination from the 1984 excavation of the former East Traffic Circle landfill (see **Chapter 5**). 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 in 1991. The highest value, 9.1 mg/kg, was found in an area that has historically been used for explosives testing. This value is much lower than the 110 mg/kg detected in 2003. The differing results reflect the particulate nature of the contamination.

6.1.3 Environmental Impact on Soil and Sediment

6.1.3.1 Livermore Site

Routine surface soil, sediment, and vadose zone soil sample analyses indicate that the impact of LLNL operations on these media in 2007 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 for plutonium-239+240 in 2007 (7.0 mBq/dry g [0.19 pCi/dry g]), measured at WRD, is 1.5% of the National Council on Radiation Protection (NCRP) recommended screening limit of 470 mBq/g (12.7 pCi/g) for property used for commercial purposes (NCRP 1999).

LLNL has investigated the presence of radionuclides in local soils frequently over the years including possible impacts of the distribution to the public of sludge contaminated by the 1967 plutonium release (see Table 6-5 in the *Environmental Report 2006* [Mathews et al. 2007] for a list of previous studies.) The studies have consistently shown that the concentrations of radionuclides in local soils are below levels of health concern. In fact, the concentrations are of such low levels of health concern that the Agency for Toxic Substances and Disease Registry (ATSDR) (2003) strongly recommended against further study of local soils for the purpose of identifying locations where plutonium-contaminated sludge from the 1967 release may remain.

6.1.3.2 Site 300

The concentrations of radionuclides and beryllium detected in soil samples collected at Site 300 in 2007 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 occurred near the firing tables. They result from the fraction of the firing table operations that disperse depleted uranium. The highest measured uranium-238 concentration was 170 µg/g (2.1 Bq/g or 57 pCi/g) and was well below the NCRP-recommended screening level for commercial sites (313 µg/g [3.9 Bq/g or 105 pCi/g]). These values occurred near Bunker 812 and are a result of historic operations at that location. A CERCLA Remedial Investigation/Feasibility Study report for Bunker 812 will be submitted to the regulatory agencies in 2008. This Investigation/Feasibility Study specifies the nature and extent of contamination, risk assessment, and remedial alternatives for CERCLA cleanup of the site (see **Chapter 8**).

6.2 Vegetation and Foodstuff Monitoring

Vegetation sampling locations at the Livermore site (see **Figure 6-1**) and in the Livermore Valley (see **Figure 6-2**) are divided for comparison into the following three groups:

- Near locations (AQUE, GARD, MESQ, NPER, MET, and VIS) are on-site or less than 1 km from the Livermore site perimeter.
- Intermediate locations (I580, PATT, TESW, and ZON7) are in the Livermore Valley and 1 to 5 km from the Livermore site perimeter.
- Far locations (FCC and CAL) are more than 5 km from the Livermore site perimeter; FCC is about 5 km away and CAL is more than 25 km away. Both locations are generally upwind of the Livermore site.

Tritium in vegetation due to LLNL operations is most likely to be detected at the Near and Intermediate locations and is highly unlikely to be detected at the Far locations.

Site 300 has four monitoring locations for vegetation (PSTL, 801E, DSW, and EVAP) (see **Figure 6-3**). Vegetation at locations DSW and EVAP exhibit variable tritium concentrations due to occasional uptake of contaminated groundwater by the roots. At the other two locations, 801E and PSTL, the only likely potential source of tritium uptake is the atmosphere, although groundwater in the vicinity of PSTL is contaminated with low levels of tritium.

Vegetation is sampled and analyzed quarterly. Water is extracted from vegetation by freeze-drying and analyzed for tritiated water (HTO) using liquid scintillation techniques.

Wines for sampling in 2007 were purchased from supermarkets in Livermore. The wines represent the Livermore Valley, two other regions of California, and the Rhone Valley in France. Wines were prepared for sampling using a method that separates the water fraction from the other components of the wine and were analyzed using an ultra-low-level scintillation counter.

6.2.1 Vegetation Monitoring Results

Median and mean concentrations of tritium in vegetation based on samples collected at the Livermore site, in the Livermore Valley, and Site 300 in 2007 are shown in **Table 6-1**. (See **Appendix A**, **Section A.9**, for quarterly tritium concentrations in plant water). The highest mean tritium concentration for 2007 was 22 Bq/L at the Intermediate location TESW located approximately 2 km southwest of the Livermore site. For Site 300, the highest mean concentration for 2007 was 99 Bq/L at EVAP located in an area where the groundwater is contaminated with tritium.

Median concentrations of tritium in vegetation at sampling locations at the Livermore site and in the Livermore Valley have decreased noticeably since 1989 (see **Figure 6-4**). Median concentrations at the Far locations have been below the detection limit of approximately 2.0 Bq/L since 1993. Median concentrations at the Intermediate locations have been below the detection limit since 1998, except in 2002 when the median concentration was 2.3 Bq/L. Median concentrations at the near locations were below detection limit between 2003 and 2005 and more recently have been slightly above the detection limit.

At Site 300, the median concentrations of tritium in vegetation at locations 801E, DSW and PSTL were below detection limit. The median concentration of tritium in vegetation at EVAP was 82 Bq/L.

6.2.2 Wine Monitoring Results

Analysis of the wines purchased in 2007 demonstrates the same relationship between the Livermore Valley, California (other than the Livermore Valley), and the Rhone Valley (France) wines that has been seen routinely in the past. Concentrations of tritium in California wines are low and reflect residual historical bomb fallout and cosmogenic tritium levels; concentrations in Livermore Valley wines range from the low levels seen in California wines to the higher levels seen in Rhone Valley wines; and the concentrations in both of the Rhone Valley wines is higher than any of the Livermore Valley wines (see **Table 6-2**). The highest concentration in a

Livermore Valley wine sampled in 2007 (2.1 Bq/L [57 pCi/L]) was from a wine made from grapes harvested in 2005.

Table 6.1. Median and mean concentrations of tritium in plant water for the Livermore site, Livermore Valley, and Site 300 sampled in 2007. The table includes mean annual ingestion doses calculated for 2007.

Sampling locations		Concentration of tritium in plant water (Bq/L) Median	Mean	Mean annual ingestion dose[(a)] (nSv/y)
NEAR (on-site or <1 km from Livermore site perimeter)	AQUE	1.3	1.3	<10[(b)]
	GARD	2.2	2.6	13
	MESQ	2.2	7.3	36
	MET	1.5	1.5	<10[(b)]
	NPER	3.2	4.3	21
	VIS	2.5	7.2	35
INTERMEDIATE (1–5 km from Livermore site perimeter)	I580	1.2	1.2	<10[(b)]
	PATT	0.59	0.62	<10[(b)]
	TESW	1.4	22	110
	ZON7	1.1	0.81	<10[(b)]
FAR (>5 km from Livermore site perimeter)	CAL	0.35	0.34	<10[(b)]
	FCC	0.01	-0.048	<10[(b)]
Site 300	801E	1.1	1.2	(c)
	DSW[(d)]	0.18	1.6	(c)
	EVAP[(d)]	82	99	(c)
	PSTL	-0.46	-0.31	(c)

(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 6-3**.

(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) Dose is not calculated because there is no pathway to dose to the public.

(d) Plants at these locations are rooted in areas of known subsurface contamination.

The Livermore Valley wines represent vintages from 2001, 2005 and 2006; the California wines represent vintages from 2003 and 2005; and the Rhone Valley wines represent vintages from 2003 and 2004. Tritium concentrations must be decay-corrected to the year of harvest to correlate with tritium concentrations in air and soil to which the grape was exposed. In 2007, decay-corrected concentrations for Livermore Valley wine samples ranged from 0.77 to 2.4 Bq/L; for the two California wine samples, 0.38 and 0.72 Bq/L; and for the two Rhone Valley wine samples, 3.2 and 4.5 Bq/L.

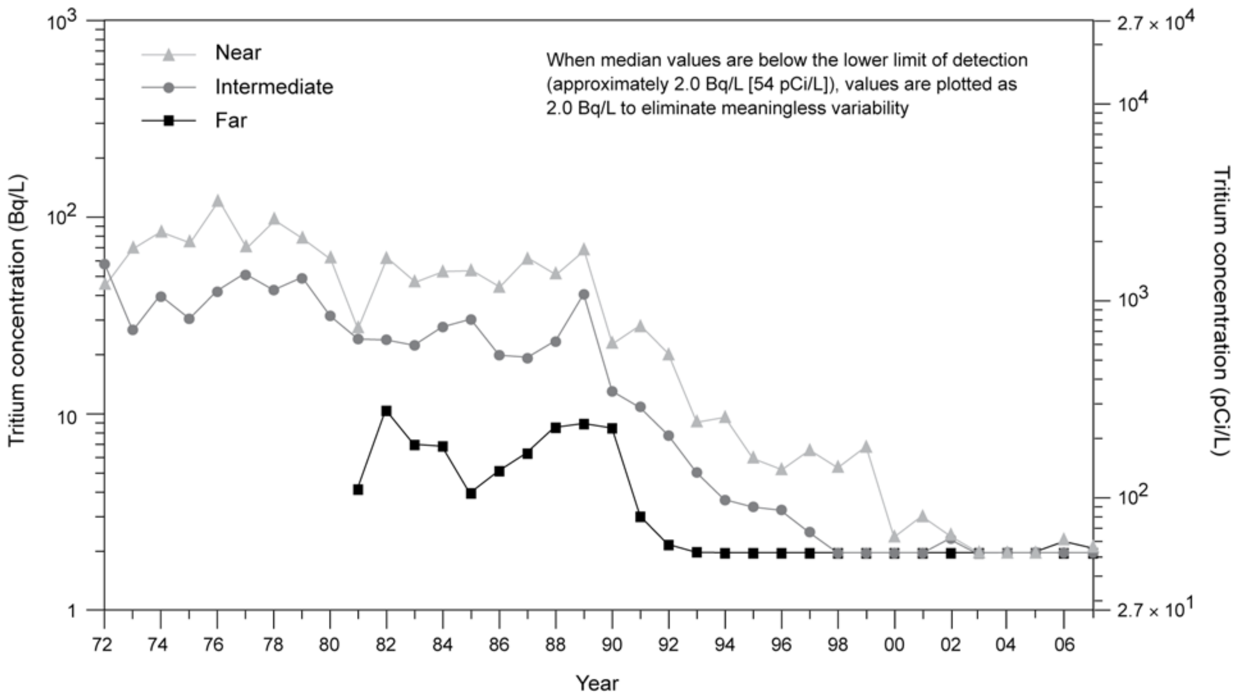

Figure 6-4. Median tritium concentrations in Livermore site and Livermore Valley plant water samples, 1972 to 2007.

Table 6-2. Tritium in retail wine, 2007[(a,b)]

Sample	Concentration by area of production (Bq/L)		
	Livermore Valley	**California**	**Europe**
1	1.9 ± 0.09	0.56 ± 0.08	3.7 ± 0.09
2	0.67 ± 0.08	0.33 ± 0.08	2.5 ± 0.09
3	1.5 ± 0.08		
4	2.0 ± 0.09		
5	1.4 ± 0.08		
6	2.1 ± 0.08		
Dose (nSv/y)[(c)]	2.6	0.68	4.5

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

(b) Wines from a variety of vintages were purchased and analyzed for the 2007 sampling. Concentrations are those measured in March 2008.

(c) Calculated based on consumption of 52 L wine per year at maximum concentration (see **Chapter 7**). Doses account for contribution of OBT as well as of HTO.

6.2.3 Environmental Impact on Vegetation and Wine

6.2.3.1 Vegetation

Hypothetical annual ingestion doses for mean concentrations of tritium in vegetation are shown in **Table 6-1**. These hypothetical doses, from ingestion of HTO in vegetables, milk, and meat, were calculated from annual mean measured concentrations of HTO in vegetation using the transfer factors from **Table 6-3** based on U.S. Nuclear Regulatory Commission Regulatory Guide 1.109 (U.S. NRC 1977). The hypothetical annual ingestion dose, based on the highest observed mean HTO concentration in vegetation for 2007, was 110 nSv (11 µrem).

Table 6-3. Bulk transfer factors used to calculate inhalation and ingestion doses (in µSv) from measured concentrations in air, vegetation, and drinking water

Exposure pathway	Bulk transfer factors[(a)] times observed mean concentrations
Inhalation and skin absorption	0.21 x concentration in air (Bq/m^3); see **Chapter 4**
Drinking water	0.013 x concentration in drinking water (Bq/L); see **Chapter 5**
Food ingestion	0.0049 x concentration in vegetation (Bq/kg); factor obtained by summing contributions of 0.0011 for vegetables, 0.0011 for meat and 0.0027 for milk

(a) See Sanchez et al. (2003), Appendix C, for the derivation of bulk transfer factors.

Doses calculated based on Regulatory Guide 1.109 neglect the contribution from organically bound tritium (OBT). However, according to 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, p. 27). Thus, the maximum estimated ingestion dose from LLNL operations for 2007, including OBT, is 220 nSv/y (22 µrem/y). This maximum dose is about 1/13,000 of the average annual background dose in the United States from all natural sources and about 1/46 the dose from a panoramic dental x-ray.

Ingestion doses of Site 300 vegetation were not calculated because neither people nor livestock ingest vegetation at Site 300.

6.2.3.2 Wine

For Livermore Valley wines purchased in 2007, the highest concentration of tritium (2.1 Bq/L [57 pCi/L]) was just 0.28% of the EPA's standard for maximal permissible level of tritium in drinking water (740 Bq/L [20,000 pCi/L]). Drinking one liter per day of the Livermore Valley wine with the highest concentration purchased in 2007 would have resulted in a dose of 18 nSv/y (1.8 µrem/y). A more realistic dose estimate, based on moderate drinking (one liter per week)[(1)] at the mean of the Livermore Valley wine concentrations (1.6 Bq/L [43 pCi/L]) would have been 1.9 nSv/y (0.19 µrem/y). Both doses explicitly account for the added contribution of OBT.[(2)]

(1) Moderate consumption is higher than the average consumption of wine in California (15.7 L/yr) (Avalos 2005).

(2) Dose from wine was calculated based on the measured concentration of HTO multiplied by 1.3 to account for the potential contribution of OBT that was removed so that the tritium in wine could be counted using liquid scintillation counting. Dose coefficients for HTO and OBT are those of the International Commission on Radiological Protection (1996).

The potential dose from drinking Livermore Valley wines in 2007, including the contribution of OBT, even at the high consumption rate of one liter per day, and the highest observed concentration, would be about 1/740 of a single dose from a panoramic dental x-ray.

6.3 Ambient Radiation Monitoring

LLNL's ambient radiation monitoring program is designed to distinguish between naturally occurring gamma radiation and any ambient radiation field as a direct result of LLNL operations. By sampling at enough locations in the surrounding community, the variance in the natural background from season to season and by location is measured and compared to a five-year trend. The long-term trend analysis allows the radiation field affects from operations to be readily recognized.

In addition to the surveillance monitoring effort for normal operations, a network of real-time sensors was deployed in August of 2001 to monitor for off-normal conditions at the laboratory's perimeter that may occur. A complete discussion of the development and operation of the RTRAM network may be found in the peer reviewed journal article in IEEE Special Issue on Sensors for the Prevention of Terrorist Acts titled "Development of a Real-Time Radiological Area Monitoring Network for Emergency Response at Lawrence Livermore National Laboratory" (Bertoldo 2005).

6.3.1 Methods and Reporting

Exposure to external radiation is measured by correlating the interaction of ionizing energy with its effect on matter that absorbs it. LLNL uses the Panasonic UD-814AS1 TLD, which contains three crystal elements of thallium-activated calcium sulfate ($CaSO_4$), to measure environmental gamma dose representative of external exposure to the public at these sample locations. Comparisons are made for LLNL perimeter locations to those of the Livermore Valley (background location) for the purposes of determining an elevated radiation field. This is similarly done for Site 300 and its nearby locations.

As a 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 released in the form of light emission (glow curve) upon heating is proportional to the TLD absorbed dose which is calibrated to a known standard of cesium-137 gamma energy of 662 keV. The calculated result of the TLD exposure is then reported in the SI unit of Sv from the measured dose in mR.

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

- comparison of the average quarterly dose (mSv) for the Livermore site, Livermore Valley, and Site 300 locations for the five-year period from 2002 to 2007
- comparison of the average quarterly dose (mSv) for the Livermore site and Livermore Valley locations in 2007

- comparison of average quarterly dose (mSv) for Site 300, city of Tracy, and Site 300 vicinity in 2007

The results of these comparisons are shown in **Figure 6-5**.

To obtain a true representation of local site exposure and determine any dose contribution from LLNL operations, an annual environmental monitoring compliance assessment is done in accordance with DOE Order 450.1 through a quarterly deployment cycle. TLDs are deployed at a height of 1 m, adhering to regulatory guidance.

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

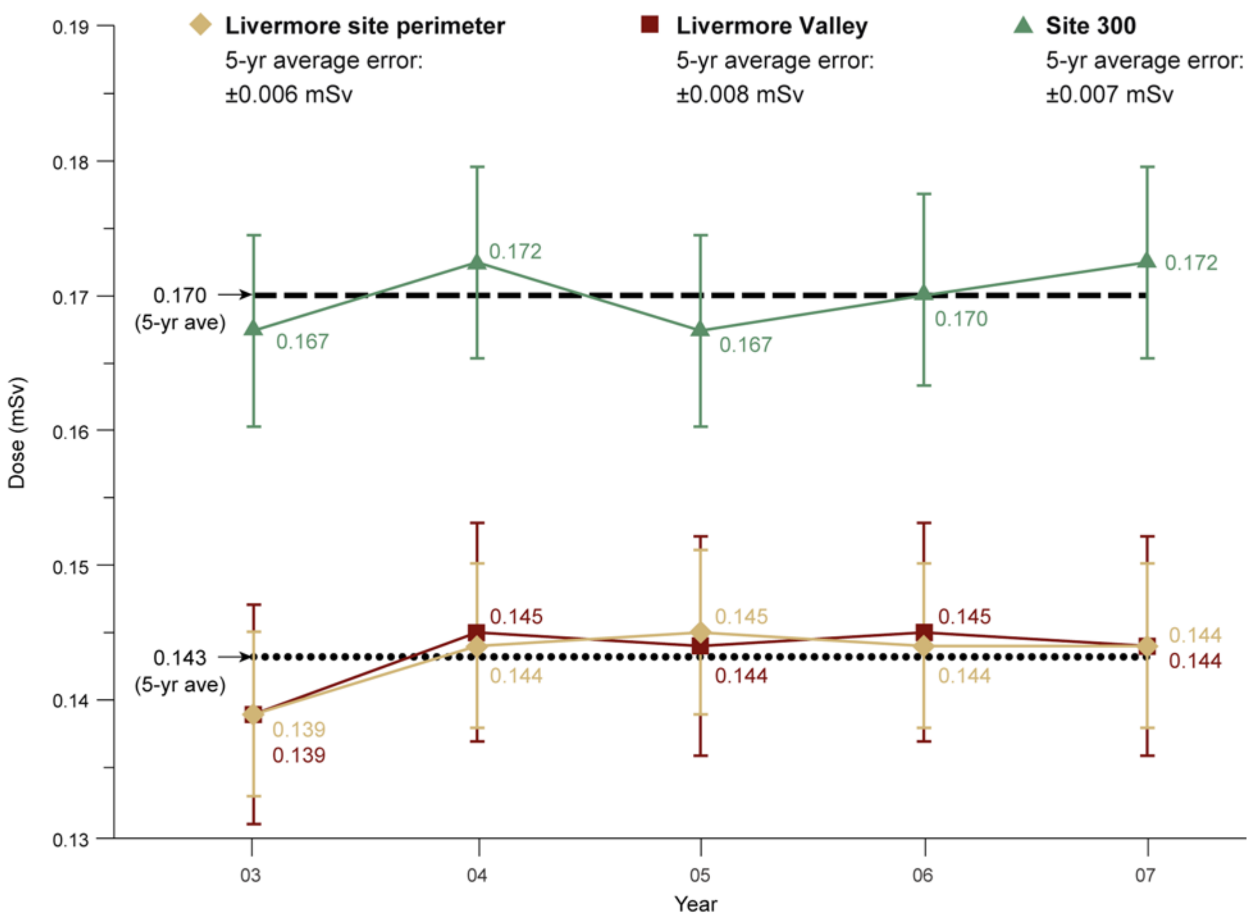

Figure 6-5. Comparison of the average quarterly dose for the Livermore site, Livermore Valley, and Site 300 monitoring locations from 2003 to 2007.

6.3.2 Monitoring Results

Figure 6-5 represents the average quarterly dose (in mSv) for the recent five-year period for the Livermore site perimeter, Livermore Valley and Site 300. Tabular data for each sampling location are provided in **Appendix A**, **Section A.9**.

The difference in the doses at the Livermore site perimeter, Livermore Valley, and Site 300 can be attributed directly to the difference in the geological substrates. The Neroly Formation in the region around Site 300 contains higher levels of naturally occurring thorium that provides the higher external radiation dose.

6.3.3 Environmental Impact from Laboratory Operations

There is no increased ambient radiation field produced as a direct result of LLNL operations for 2007 as measured by this network. Radiation dose trends remain consistent with annual average levels for each sample location and synonymous to natural background levels. As depicted in **Figure 6-5**, the annual average gamma radiation dose for the LLNL site perimeter and the Livermore Valley from 2002 to 2007 are statistically equivalent and show no discernible impact due to operations conducted at LLNL.

6.4 Special Status Wildlife and Plants

Special status wildlife and plant monitoring at LLNL focuses on species considered to be rare, threatened, or endangered (including species listed under the federal or California ESAs; species considered of concern by the California Department of Fish and Game [CDFG] and the USFWS; and species that require inclusion in NEPA and California Environmental Quality Act [CEQA] documents).

Five species that are listed under the federal or California ESAs 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 macrotis mutica*) at Site 300, this species is known to have historically 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 (see **Figure 6-1**).

Known observations of the five listed species and two California species of special concern (Western Burrowing Owl [*Athene cunicularia*] and Tricolored Blackbird [*Agelaius tricolor*]) are shown in **Figures 6-6** and **6-7**. Vertebrate species and rare invertebrate species known to occur at Site 300, including state and federally listed species and other species of special concern are listed in **Appendix C**. A similar list has not been prepared for the Livermore site.

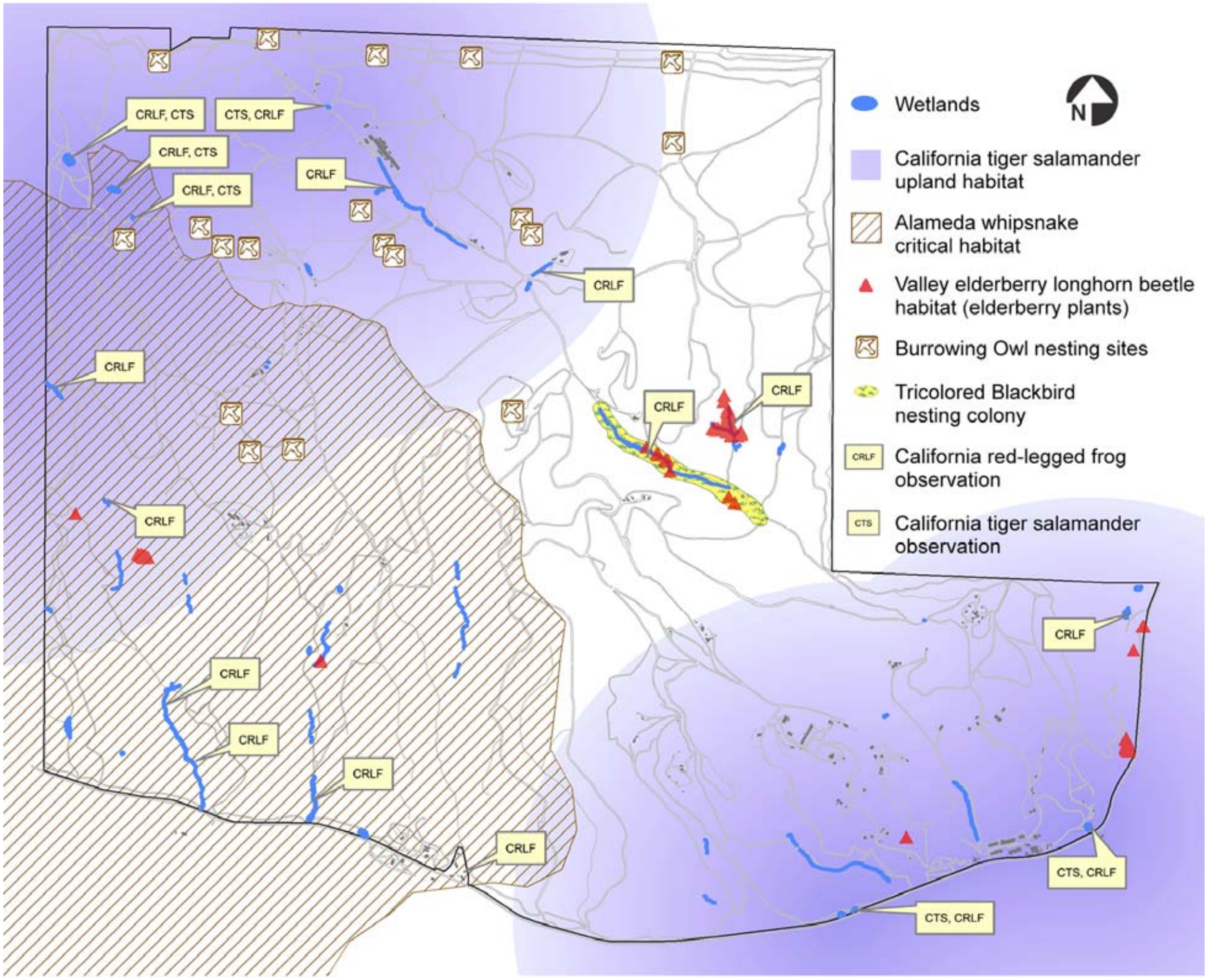

Figure 6-6. Distribution of special status wildlife, Site 300, 2007.

Including the federally endangered large-flowered fiddleneck, four rare plant species and four uncommon plant species are known to occur at Site 300. The four rare species—the large-flowered fiddleneck, the big tarplant (*Blepharizonia plumosa*), the round-leaved filaree *(California macrophylla)*, and the diamond-petaled California poppy (*Eschscholzia rhombipetala*)—are included in the California Native Plant Society (CNPS) List 1B (CNPS 2008). These species are considered rare and endangered throughout their range. The location of these four rare plant species at Site 300 is shown in **Figure 6-7**.

The four uncommon 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 2008). Past surveys have failed to identify any rare plants on the Livermore site (Preston 1997, 2002).

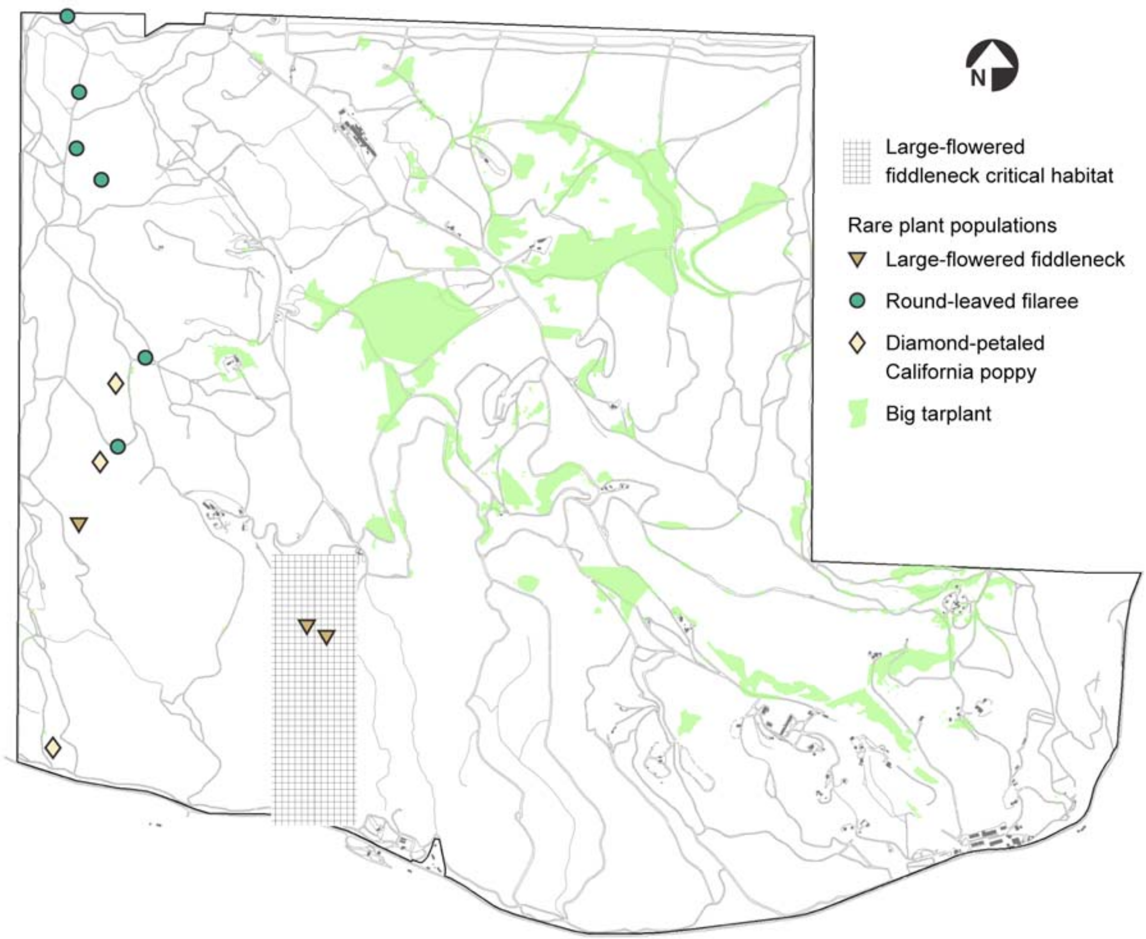

Figure 6-7. Distribution of special status plants, Site 300, 2007.

6.4.1 Compliance Activities

6.4.1.1 Arroyo Seco Restoration

LLNL conducted the second year of the five-year monitoring plan required by USFWS and ACOE for the restoration of the Arroyo Seco Management Plan project site. Monitoring at this site includes annual measurements of the survivorship of plants that were installed as part of the restoration and estimates of the percent cover of grasses and forbs, shrubs, and trees at the project site. Results of this monitoring are documented in Paterson (2008b). In 2007, the percent cover of grasses and forbs was above the expected success criteria for year two in all portions of the project site, although the observed percent cover for shrubs and trees was slightly lower than the success criteria in some portions of the project site. To help correct deviations from the success criteria described above, approximately 135 plants were installed at the site in the winter of 2007/2008 to replace plants that did not survive the previous year, and measures were taken to control weeds at the site.

6.4.1.2 Habitat Enhancement Projects

In late August 2005, LLNL implemented a habitat enhancement project for California red-legged frogs at Site 300 in accordance with a 2002 USFWS BO and ACOE and RWQCB permits. California red-legged frogs were translocated to the new habitat enhancement pools in February and March of 2006. Monitoring demonstrated that California red-legged frogs successfully reproduced in these pools in 2006 and 2007. In 2007, twelve California red-legged frog egg masses were observed in the Upper Mid-Elk Ravine pool and ten egg masses were seen in the lower pool. All egg masses successfully reared larvae. Hundreds of recently metamorphed frogs were counted during fall daytime surveys.

In fall 2005, a depression in the northwest corner of Site 300 below Harrier pool was deepened and expanded to serve as mitigation for California tiger salamander habitat lost as a result of closing two man-made, high explosives rinse water ponds in the Process Area. In 2006, California tiger salamanders successfully bred and metamorphosed from the pool. In 2007, the pool received inadequate inundation and evaporated before the salamander larvae could reach maturity and leave the pond.

6.4.1.3 Oasis and Round Valley Culvert Replacement Projects

In 2006, LLNL completed culvert replacement projects at two Site 300 locations (the Oasis and Round Valley) where unpaved fire trails crossed intermittent drainages. The Round Valley project included the creation of a pool upstream of the project area in part as mitigation for the impacts at the Oasis site and to serve as enhanced habitat for amphibian species. These projects were completed under the USFWS BO for maintenance and operations of Site 300 and ACOE and RWQCB permits. Although the Oasis site no longer contains habitat for breeding California red-legged frogs, one egg mass was found between rip-rap boulders. It did not successfully hatch to produce larvae. The 2006/2007 rainy season was drier than average, and the Round Valley pool did not receive enough water during the 2006/2007 winter to pool and afford potential breeding habitat for amphibians.

6.4.1.4 Pit 7 Remediation

In accordance with the requirements of the NEPA and CEQA documents for the Environmental Remediation of the Site 300 Pit 7 Complex, and the USFWS BO for maintenance and operations of Site 300, pre-construction rare plant surveys and wildlife surveys were conducted at the Pit 7 Remediation site in 2007.

Several small populations of the California androsace were found in rock outcroppings near the project site. Two Western Burrowing Owl nests were also discovered near the construction site, but these were not impacted, as construction did not start until October 2007 after Burrowing Owls had fledged. Buffer zones were established around these rare plants during construction to avoid impacting this species. Ongoing biological surveys conducted during construction ensured that any species discovered in the area received adequate protection. During construction, two California tiger salamanders were relocated from within the project site.

6.4.1.5 Arroyo Mocho Boulder Removal Project

A pumping plant, which draws water from the Hetch Hetchy aqueduct, is the primary source of water for LLNL's Livermore site. Several large boulders fell into the channel of Arroyo Mocho below the pumping plant, potentially forcing the flow of the arroyo toward the hillside that the pumping plant is located on and resulting in an erosion hazard to this hillside and the pumping plant.

Arroyo Mocho and the surrounding area are habitat to California red-legged frog, California tiger salamander, and Alameda whipsnake. In 2007, two of these boulders were removed from Arroyo Mocho to mitigate erosion hazards. This work was conducted under an amendment to the 2004 BO for the Arroyo Mocho Road Improvement and Anadromous Fish Passage project. LLNL wildlife biologists monitored all in-channel work. No listed species were observed at the project site during boulder removal, and no impacts to special status species resulted from this project.

6.4.1.6 Arroyo Mocho Restoration

In 2007, LLNL implemented the third year of a five-year mitigation and monitoring plan for the restoration of the 2004 Arroyo Mocho Road Improvement and Anadromous Fish Passage project. This mitigation and monitoring plan is a requirement by the ACOE permit for this project. Success criteria for this restoration are based on the number of native species present and the percent cover of these species within three monitoring communities (low flood plain, sloping terrace and upland) at the project site. In 2006 and 2007, the number of native species and the percent cover of these species were above the success criteria with one exception. In 2007, the average percent cover of native plants was 44% in the sloping terrace community compared to the success criterion of 45%.

In an attempt to control exotic plants, as specified in the mitigation and monitoring plan, and increase the cover of native plants at the site, hand weeding of exotic species including yellow star thistle and bull thistle was conducted in 2007.

The mitigation and monitoring plan for this project also requires the replacement of container plants that do not survive the first two years following construction. To meet this requirement, container plants were installed in January of 2007 and acorns were planted in December of 2007. The results of the monitoring are documented in Paterson (2008a).

6.4.2 Invasive Species Control Activities

Invasive species control is an important part of LLNL's effort to protect special status species at both sites. Prevention of the downstream dissemination of invasive species is also important to protect native species throughout our region. The bullfrog *(Rana catesbeiana)* and the largemouth bass *(Micropterus salmoides)* are significant threats to California red-legged frogs at the Livermore site, and the feral pig (*Sus scrofa*) threatens California red-legged frog habitat at Site 300.

In 2007, to mitigate threats to California red-legged frogs, six feral pigs were dispatched at Site 300. At the Livermore site, bullfrog control measures were implemented between May and September of 2007. Bullfrog control measures included dispatching adults and removing egg masses in Lake Haussmann and Arroyo Las Positas. To remove bullfrog tadpoles and invasive fish, the LLNL reach of Arroyo Las Positas was allowed to dry out in October of 2007 by temporarily halting groundwater discharges to the arroyo.

6.4.3 Surveillance Monitoring

6.4.3.1 Wildlife Monitoring and Research

Alameda Whipsnake. Since 2002, LLNL has participated in a study, in cooperation with the USFWS and four other agencies, to determine the effects of prescribed burns on the Alameda whipsnake. The USFWS issued a BO for this study that outlined the general conditions for conducting prescribed burns and gathering information about potential impacts to Alameda whipsnakes. Participation in this study allowed LLNL to obtain USFWS approval to conduct prescribed burns necessary for Site 300 operations in areas that support Alameda whipsnakes. Previous LLNL Environmental Reports document the study area and baseline conditions, and early results.

A prescribed burn was conducted at the burn site in the summer of 2003, and the post-burn monitoring has been conducted from the fall of 2003 through 2007. Both the burn and control sites were impacted by a wildfire in 2005. Although no whipsnake fatalities were documented during post-burn surveys, both trapping areas were burned severely and little remnant vegetation was left in the shrubland.

No whipsnakes were captured during the spring 2007 trapping period. Although the effects of the prescribed burn and subsequent impacts of the wildfire on the whipsnake are not yet determined, both the whipsnake and its habitat are adapted to periodic fire events and both the snake and vegetation are expected to recover from the fire in subsequent years.

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 annually nest in the trees along the north, east, and south perimeter of the Livermore site. LLNL staff surveyed potential White-tailed Kite nesting sites during the spring of 2007; two pairs of White-tailed Kites successfully fledged 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 2007 because kites do not typically nest in areas where they may be affected by programmatic activities.

Avian Monitoring Program. In 2007, LLNL continued its avian monitoring program, which was initiated in 2001. A constant effort mist netting station was 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). Captured birds 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**. Data from this program is contributed to the national Monitoring Avian Productivity and Survivorship (MAPS) program, which is operated by the Institute for Bird Population.

California Red-Legged Frog Egg Mass Surveys. LLNL continued diurnal visual surveys for California red-legged frog egg mass at the Livermore site in Arroyo Las Positas and in the habitat enhancement portion of Lake Haussmann. A total of two egg masses were observed in Arroyo Las Positas in 2007. This is down from a maximum of 37 egg masses observed in 2001. Three egg masses were observed in the Habitat Enhancement portion of Lake Haussmann in 2007.

6.4.3.2 Rare Plant Research and Monitoring

Large-Flowered Fiddleneck. This species is known to exist naturally in only two locations—at the Site 300 Drop Tower and on a nearby ranch. The Drop Tower native population contained only one large-flowered fiddleneck plant in 2007, and fewer than 20 plants each year for the past five years.

LLNL established an experimental population of the large-flowered fiddleneck at Site 300 beginning in the early 1990s. The size of the experimental population fluctuates as a result of seed bank enhancement efforts conducted in this population. The two experimental subpopulations combined contained 109 large-flowered fiddleneck plants in 2007.

Big Tarplant. The distribution of big tarplant was mapped at Site 300 using a handheld global positioning system (GPS) in September and October of 2007. This species is abundant at Site 300, especially in or near areas where prescribed burned are routinely conducted, although it is rare outside of Site 300. It is estimated that between 55,000 and 145,000 individual big tarplants occurred at Site 300 in 2007.

Diamond-Petaled California Poppy. Currently three populations of this species are known to occur at Site 300; the population locations are referred to as Site 1, Site 2, and Site 3. Although the species is not listed under the federal or California ESAs, it is extremely rare and is currently known to occur only at Site 300 and in one location in San Luis Obispo County. A census of the three Site 300 populations was conducted in March and April 2007. In 2007, a total of 99 plants were found at Site 300. The most recently discovered population, Site 3, contained by far the largest number (86 plants). Numbers of plants at Sites 1 and 2 have been very small in recent years. In 2007, Site 1 had 7 plants, and Site 2 had 6 plants.

Round-Leaved Filaree. Six populations of round-leaved filaree are known to occur at Site 300. All populations occur in the northwest portion of the site. This species thrives in the disturbed soils of the annually graded fire trails at Site 300. Of the six populations, four occur on fire trails. During the spring of 2007, the extent of the six populations was mapped using a handheld GPS, and the size of each population was estimated. The six populations combined were estimated to contain over 1150 plants.

6.4.4 Environmental Impacts on Special Status Wildlife and Plants

Through monitoring and compliance activities in 2007, LLNL has been able to avoid impacts to special status wildlife and plants. In addition, LLNL continues to monitor and maintain several restoration sites and habitat enhancements that are beneficial to native plants and animals at the Livermore site and Site 300. Invasive species continue to be one of the largest threats to California red-legged frogs at the Livermore site and Site 300, and LLNL continued its program to remove invasive exotic species of amphibians and fish from the Livermore site, and feral pigs from Site 300 in 2007.