Vegetation and Foodstuff Monitoring

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Introduction

Lawrence Livermore National Laboratory has a vegetation and foodstuff monitoring program to comply with U.S. Department of Energy (DOE) guidance. This guidance (U.S. DOE 1991) states that periodic sampling and analysis of vegetation should be performed to determine if there is measurable, long-term buildup of radionuclides in the terrestrial environment.

LLNL has historically released tritium to the air during routine operations and, occasionally, by accident. Tritium is the only nuclide of interest in the LLNL vegetation and foodstuff monitoring program because tritium is the only radionuclide released from LLNL activities that occurs in detectable concentrations in vegetation and foodstuff. Tritium moves through the food chain as tritiated water (HTO) and can be rapidly assimilated into plant water and then incorporated into the organic matter of plants through photosynthesis. It can contribute to human radiation dose if it is inhaled, absorbed through the skin, or ingested via vegetables or via milk and meat from animals that have eaten tritiated vegetation.

LLNL has been monitoring tritium in vegetation to some extent since 1966 and has performed vegetation sampling in the vicinity of the Livermore site and Site 300 as part of a continuing monitoring program since 1971. The monitoring program is designed to measure changes in the environmental levels of radioactivity, to evaluate the environmental effect of LLNL operations, and to calculate potential human doses from tritium in the food chain.

In 1977, LLNL added wine to the LLNL monitoring program. Wine is the most important agricultural product in the Livermore Valley, with a retail value estimated conservatively at $140 million. Although the tritium concentrations in all wines are very low, the sampling data indicate that Livermore Valley wines contain statistically more tritium than do wines from other California wine-producing regions.

In the past, other foodstuffs (cow milk, goat milk, and honey) leading to potential dose were also monitored for tritium. At present, however, only tritium concentrations in vegetation and wine are used to assess potential ingestion dose from tritium emitted during LLNL operations.

During 2001, LLNL collected and analyzed samples of herbaceous vegetation and wine. Potential human doses from these foodstuffs were calculated using the monitoring data, and the dose models are presented in Appendix A. In addition, as part of a continuing study, LLNL determined the potential tritium dose to the maximally exposed individual from a pine tree at the Livermore site. This tree serves as a diffuse source of tritium because it loses tritium to the air through evapotranspiration of tritium-contaminated water in the root zone. The dose was calculated using the U.S. Environmental Protection Agency (EPA) model CAP88-PC.

Methods

The methods used for monitoring vegetation and wine are presented in the following sections. All vegetation and wine sampling was conducted according to written and approved standardized procedures in the *Environmental Monitoring Plan* (Tate et al. 1999).

Vegetation

In 2001, LLNL staff collected vegetation samples, usually annual grasses or small herbaceous plants, quarterly from 18 fixed locations in the Livermore Valley, San Joaquin County, and Site 300. LLNL collected approximately 100 to 200 g of vegetation with relatively high water content for each analysis; a sample of equal size from the same location was also collected for archiving. Samples, delivered to LLNL's Chemistry and Materials Science Environmental Services Laboratory, were kept frozen prior to processing. Water from the vegetation was collected using freeze-drying techniques (lyophilization), and the tritium concentration of the extracted water was determined by liquid scintillation counting.

Approximately 10% of the sites were sampled in duplicate to comply with quality assurance protocols. Duplicate samples were preserved, stored, processed, and analyzed with methods identical to those employed for all other samples.

Location maps are provided in **Figure 11-1** and **Figure 11-2**. Sample locations were selected to represent vegetation from locations near LLNL that could be affected by LLNL operations, background locations where vegetation is unlikely to be affected by LLNL operations, and areas of known or suspected LLNL-induced contamination.

Prior to the start of 2001, sampling at locations PARK in the Livermore Valley and CARN, GEO, and GOLF at Site 300 was discontinued as unnecessary, given changes in LLNL operations over the past few years; all other sampling locations were the same as those in 2000.

The routine vegetation sampling locations are designated with permanent location markers. Consistent use of the same general sampling locations allows LLNL to determine trends in data and to monitor areas of concern more closely. Vegetation sampling locations chosen by LLNL are places where ample living vegetation is most likely found. Sampling locations are distant from buildings or other obstructions that can cause unusual patterns of airflow. Irrigated or shaded areas are also avoided. Practical considerations, such as ease of access and personnel safety, also affected selection of sampling locations.

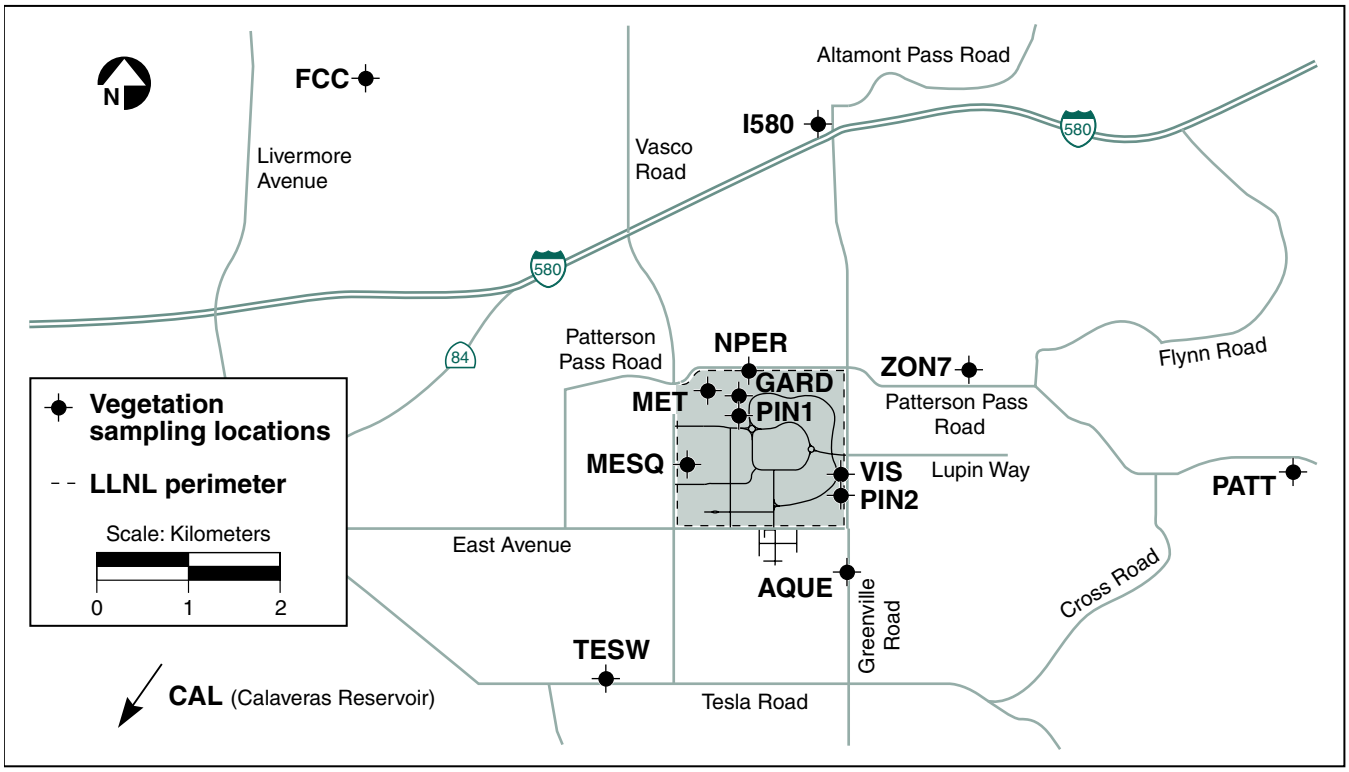

Figure 11-1. Livermore site and Livermore Valley vegetation sampling locations, 2001

Wine

In 2001, twelve bottles of wine from the Livermore Valley, six bottles of wine from different wine-growing regions of California (excluding Livermore), and four wines from different regions of Italy, France, and Germany were collected and analyzed for tritium. An equal mix of red and white wines was selected to represent each area. Any estate-bottled wine from a designated area was considered representative of that area.

Selection of wines from a particular wine-growing region was based primarily on availability in local stores. The wines were purchased from local retailers to represent what the general public could buy and drink during 2001. Approximately 10% of the total complement of wines was sampled in duplicate to comply with quality assurance protocols.

LLNL analyzed wines for tritium using ^{3}He mass spectrometry in the Analytical and Nuclear Chemistry Division's Noble Gas Mass Spectrometry Laboratory, which is in the newly formed Environmental Radiochemistry Group. Using this highly sensitive method (Surano et al. 1992), the minimum detectable tritium concentration is about 0.056 Bq/L (1.5 pCi/L), well below measured concentrations in wine. With great care, a conventional scintillation detection system's sensitivity can reach about 1 Bq/L (27 pCi/L); this detection level, however, is not sensitive enough to detect small differences in wine samples.

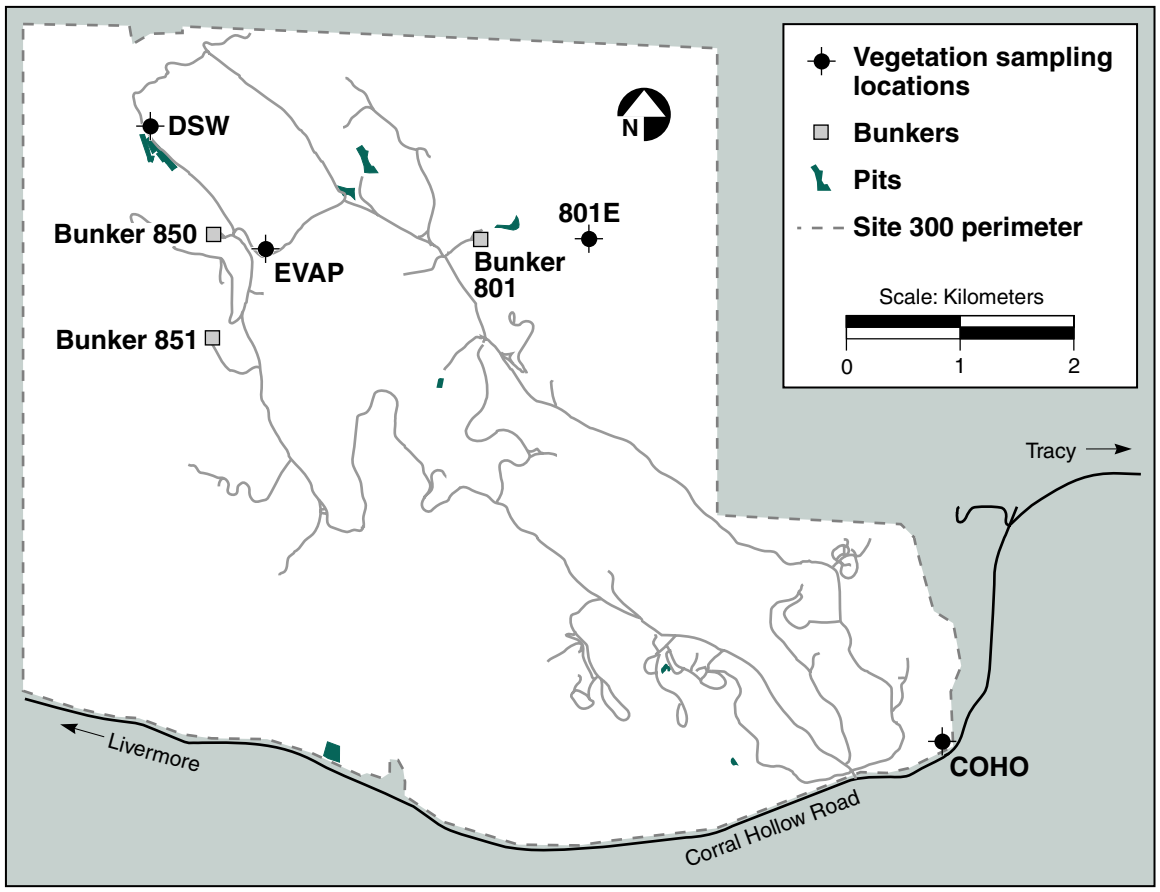

Figure 11-2. Site 300 vegetation sampling locations, 2001

Results

The results of vegetation monitoring for the Livermore site and Site 300 and the results of wine monitoring are presented in the following sections.

Livermore Site

Vegetation

The Livermore site and Livermore Valley vegetation locations are put into four groups for statistical evaluation:

- **Near:** locations within 1 km of the Livermore site perimeter. Near locations are AQUE, GARD, MESQ, NPER, MET, PIN2, and VIS.
- **Intermediate:** locations in the Livermore Valley 1–5 km from the Livermore site perimeter that are often downwind and, thus, potentially under the influence of tritium releases at the site. The Intermediate locations are I580, PATT, TESW, and ZON7.
- **Far:** locations unlikely to be affected by LLNL operations. One background location (CAL) is more than 25 km away. The other (FCC), although in the Livermore Valley, is unlikely to be affected by LLNL operations because it is more than 5 km from the Livermore site and generally upwind.

- **PIN1:** location of a pine tree rooted in an area of known tritium contamination on the Livermore site.

Table 11-2 shows tritium for all vegetation collected for the LLNL vegetation monitoring program in 2001. Figure 11-3 shows the 2001 medians of the tritium concentrations for PIN1, Near, Intermediate, and Far Livermore locations as a continuation of historic median concentrations from 1971 to 2000.

For 1998 through 2000, the medians for the Far locations were negative. In the SAER figures for 1999 and 2000, the lowest positive value reported was used for plotting. This year it was decided that values far below the detection limit that vary considerably are meaningless and therefore will be arbitrarily given values of 1 Bq/L for plotting. This 1 Bq/L value is well below the lower limit of detection for tritium in vegetation.

For 2001, the data for tritium in vegetation were compared using Scheffé's *F* and Games/Howell multiple comparisons (Scheffé 1953; Games and Howell 1976). These tests are the most appropriate tests for these distributions of data. The Near group was found to be significantly different at the 5% level from the Far group, but not from the Intermediate group. The Intermediate group was also statistically different from the Far group.

There was significant overlap in the ranges of values for some of the Near and Intermediate locations. The highest tritium results for individual vegetation sampling locations were found at the Near location AQUE and at the Intermediate location I580. The small upturn in median values for the Near and Intermediate groups (Figure 11-3) is most likely caused by variability due to frequency of sampling.

In 1997, PIN1, a pine tree growing in a known area of tritium contamination at the Livermore site, was monitored on a monthly basis to estimate emissions for compliance with National Emissions Standards for Hazardous Air Pollutants (NESHAPs). In 1998, the tree sampling was coordinated with the quarterly vegetation sampling. NESHAPs dose calculations to the maximally exposed individual (MEI), now based on quarterly observations, assume the tree to be a diffuse source of tritium.

To assess the contribution of soil water tritium to PIN1, LLNL also sampled a second tree (PIN2), which is not growing in tritium-contaminated soil. Concentrations of tritium in PIN2, like in all other vegetation sampled near the Livermore site, are from air and soil water in quasi-equilibrium with air. When samples from PIN1 were compared with samples from each Near location for 2001 using Scheffé's *F* procedure, concentrations of tritium in PIN1 were found to be significantly higher than concentrations at all other locations, including PIN2, at the 5% significance level.

Wine

Data from the analysis of tritium in wine can be used to estimate the potential tritium dose received by consumers during the year of purchase. However, because wines purchased in 2001 represent vintage years 1997, 1998, 1999, and 2000, the 2001 sampling data cannot be used to indicate how LLNL's operations affected concentrations of tritium in wines produced from grapes grown in 2001. To analyze trends and help determine the impact of LLNL operations on tritium in wine for the year of harvest, LLNL corrects the wine concentrations for radiological decay that has occurred between the approximate date of the grape harvest and the date when the wine was analyzed in the laboratory. Comparisons can then be made of wine concentrations that represent the year when the grapes were exposed to the tritium.

Table 11-1. Concentrations of tritium in plant water (Bq/L) collected quarterly from various sampling locations, 2001

	First Quarter	Second Quarter	Third Quarter	Fourth Quarter	Median	IQR[a]	Dose (nSv/y)[b]	
							Median	Maximum
Sampling locations within 1 km of the Livermore site perimeter								
AQUE	2.3 ± 2.0	–1.6 ± 2.0	9.9 ± 2.4	3.0 ± 2.1	2.7	3.4	13	49
GARD	1.3 ± 1.9	–0.73 ± 2.1	–1.0 ± 2.0	4.1 ± 2.2	0.29	2.8	1.4	20
MESQ	0.60 ± 1.9	–1.7 ± 2.0	–1.5 ± 1.9	3.0 ± 1.5	–0.45	2.8	—[c]	15
MET	3.8 ± 2.0	3.2 ± 2.2	–0.42 ± 2.0	4.9 ± 2.2	3.5	1.8	17	24
NPER	3.3 ± 2.0	1.5 ± 2.2	2.1 ± 2.1	2.9 ± 2.1	2.5	1.1	12	16
PIN2	5.2 ± 2.1	4.9 ± 2.3	6.8 ± 2.3	5.0 ± 2.2	5.1	0.63	—[d]	—[d]
VIS	4.3 ± 2.0	5.7 ± 2.3	0.77 ± 2.0	5.3 ± 2.2	4.8	2.0	24	28
PIN1[e]	61 ± 3.7	13 ± 2.6	170 ± 5.8	70 ± 4.0	66	46	0.0042[f]	0.011[f]
Sampling locations 1–5 km from the Livermore site perimeter								
I580	3.4 ± 2.0	–3.9 ± 1.9	14 ± 2.6	1.9 ± 2.1	2.6	5.6	13	69
PATT	1.4 ± 1.9	–0.64 ± 2.1	1.1 ± 2.1	–0.90 ± 2.0	0.23	1.9	1.1	6.9
TESW	3.2 ± 2.0	0.51 ± 2.1	1.0 ± 2.0	1.3 ± 2.0	1.1	0.89	5.4	16
ZON7	3.7 ± 2.0	0.045 ± 2.1	4.6 ± 2.2	2.4 ± 2.1	3	2.1	15	23
Sampling locations more than 5 km of the Livermore site perimeter								
CAL	1.3 ± 1.9	–0.66 ± 2.1	0.10 ± 2.0	0.0021 ± 2.0	0.051	0.56	0.25	6.4
FCC	1.0 ± 1.9	–1.7 ± 2.0	–0.37 ± 2.0	–0.80 ± 2.0	–0.59	1.0	—[c]	4.9
Sampling locations at Site 300								
COHO	1.5 ± 1.6	–2.1 ± 2.0	–0.076 ± 2.0	–1.2 ± 1.9	–0.64	1.7	—[c]	7.4
801E	0.78 ± 1.5	–2.3 ± 2.0	–1.0 ± 2.0	–0.30 ± 2.0	–0.65	1.3	—[c]	3.8
DSW[e]	120 ± 4.8	2700 ± 22	190 ± 6.1	0.85 ± 2.0	160	730	780	13000
EVAP[e]	3.2 ± 1.7	190 ± 6.2	460 ± 9.3	0.64 ± 2.0	97	250	480	2300

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 14.

a IQR = Interquartile range

b 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 Appendix A.

c Dose is not calculated when the median concentration is negative.

d Doses were not calculated because pine trees are not ingested by human beings. Concentrations from PIN2 are included with NEAR vegetation (**Figure 11-3**) because plant water tritium concentrations are similar among plant types.

e Plant(s) rooted in area of known subsurface contamination

f For this dose calculation, PIN1 is treated as a diffuse source of tritium (since pine needles are not eaten by human beings). Dose, calculated using CAP88-PC (see Chapter 13), is to the maximally exposed individual.

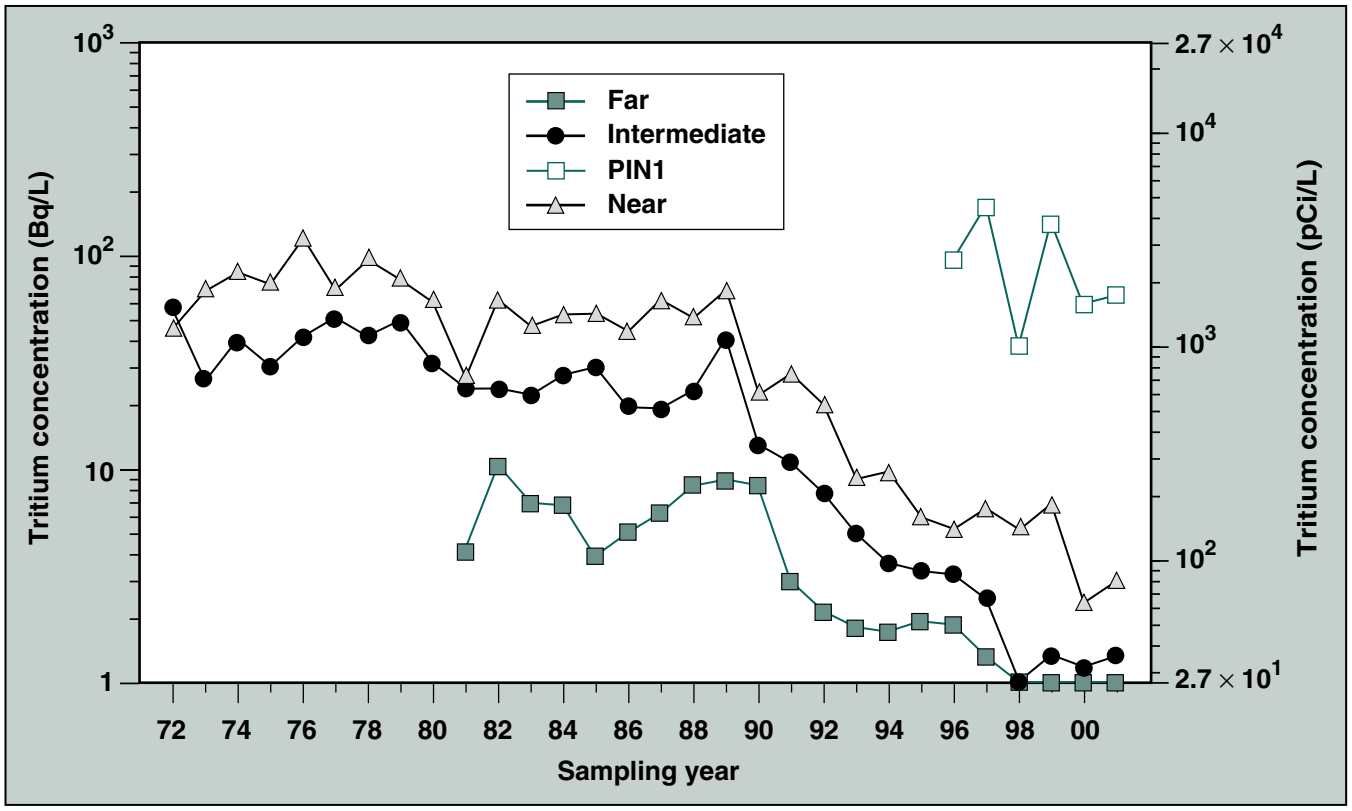

Figure 11-3. Median tritium concentrations in Livermore site and Livermore Valley plant water samples, 1971–2001. When median values are below detection limits, values are plotted arbitrarily as 1 Bq/L.

The results from the 2001 wine tritium analyses are shown in Table 11-2. Tritium concentrations are within the range of those reported in previous years and remain low in wines from all areas. The data for the 2001 sampling year were analyzed using Scheffé's *F* and Games/Howell multiple comparisons. The results of the comparisons are the same as in previous years. Both analyses show that the tritium concentrations of Livermore Valley wines are higher than those of the six California wines at the 5% significance level. The Scheffé's *F* test, which can be used when the number of samples is fewer than six, also demonstrated that the California wines sampled have significantly lower tritium concentrations than the European wines sampled and that tritium concentrations in European wine are statistically indistinguishable from tritium concentrations in Livermore Valley wines.

There is remarkably little variability in Livermore Valley wines collected for 2001, although the vintage years represented are 1997, 1998, 1999 and 2000.

Concentrations of tritium in wine corrected to vintage year are plotted in Figure 11-4. The downward trend for Livermore Valley and California wines continues. Two peaks of concentration stand out in Figure 11-4, one in 1989 and one in 1996.

Table 11-2. Tritium in retail wine (Bq/L), 2001[a]

Sample	Area of production		
	Livermore Valley	California	Europe
1	0.95 ± 0.21	0.35 ± 0.19	0.76 ± 0.2
2	0.99 ± 0.21	0.40 ± 0.19	1.2 ± 0.22
3	1.0 ± 0.21	0.40 ± 0.19	1.2 ± 0.22
4	1.0 ± 0.21	0.42 ± 0.19	3.9 ± 0.44
5	1.4 ± 0.23	0.52 ± 0.19	
6	1.4 ± 0.23	0.53 ± 0.19	
7	1.6 ± 0.25		
8	1.7 ± 0.25		
9	1.9 ± 0.26		
10	2.4 ± 0.31		
11	2.6 ± 0.32		
12	2.6 ± 0.32		
Median	1.5	0.41	1.2
Interquartile range	1.0	0.095	0.79
Dose (nSv/y)[b]			
Median concentration	1.3	0.37	1.1
Maximum concentration	2.3	0.48	3.5

Note: Radioactivities are reported here 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 14.

a Wines from a variety of vintages were purchased and analyzed in 2001. 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 Appendix A).

Statistically, the concentrations in wines from 1989 are indistinguishable from those from 1988 and 1990. Concentrations of tritium in 1996 Livermore Valley wines are significantly higher than those from 1997, 1998, and 2000 but are indistinguishable from those of 1995 and 1999. As mentioned, wines are sampled randomly. Quite by chance, the 1996 wines unequally represent vineyards close to LLNL and therefore exhibited higher values.

Site 300

Vegetation

There are four monitoring locations for vegetation at Site 300 (**Figure 11-2**). Of these, 801E and COHO show changes in atmospheric tritium concentrations. Vegetation from locations DSW and EVAP grows in areas of known groundwater contamination.

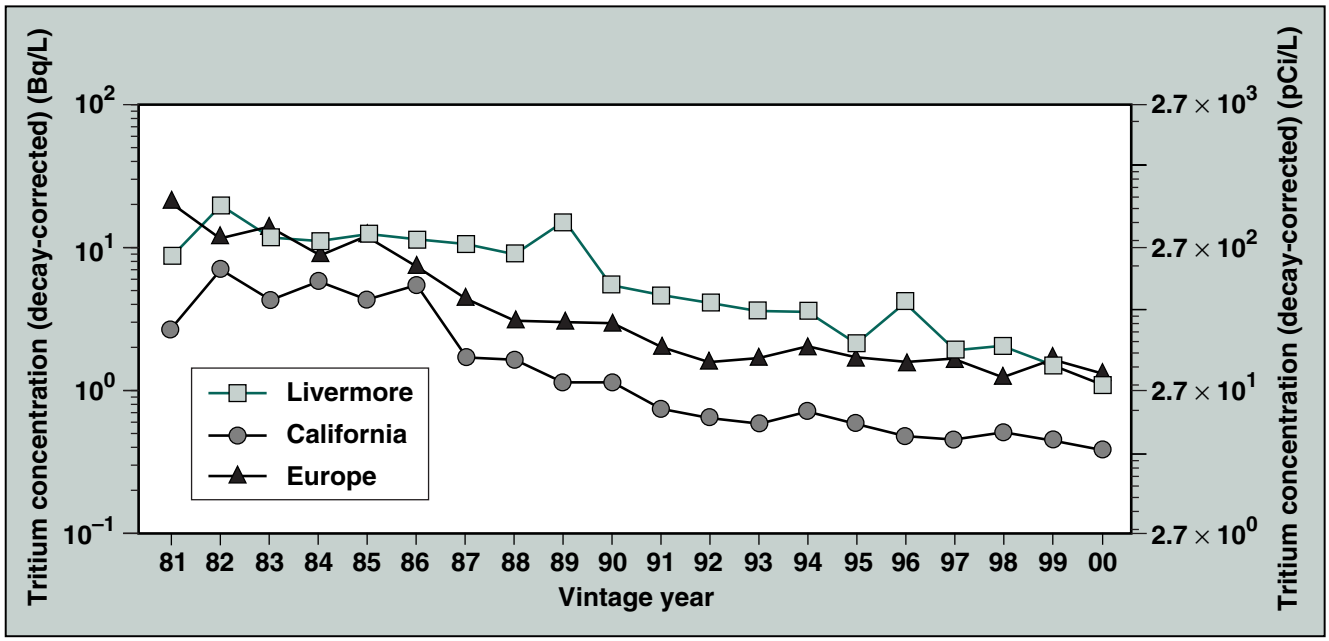

Figure 11-4. Median tritium concentrations in retail wines decay-corrected from the sampling year to the vintage year

Plants can take up tritiated water from two sources: air moisture and soil moisture. When a plant's soil water is contaminated with tritium, and there is little tritium in the air moisture, the tritium concentrations in the plant water will be somewhat lower than those of soil water, but will be much higher than concentrations in air moisture.

Table 11-1 shows all tritium data for vegetation collected at Site 300 during 2001. Historic median values for tritium at Site 300 sampling locations are shown in Figure 11-5. Results from 801E and COHO for 2001 were all below detection limits. Locations EVAP and DSW yielded the most results above detection limits. EVAP's median tritium concentration is somewhat higher than that of 2000. DSW's median value is the highest it has been in 15 years; this result is probably an artifact caused by the small sample size, because tritium concentrations in groundwater at Pit 5 are dropping. As shown in Figure 11-3, median concentrations below 1 Bq/L (well below the limits of detection) are assumed equal to 1 Bq/L to avoid plotting large, meaningless differences.

The highest tritium result (2700 Bq/L, about twice the maximum in 2000) for a single vegetation sample occurred at location DSW (see Table 11-1). This sampling location is adjacent to a landfill area that contains debris contaminated with tritium from past experiments. Tritium concentrations in vegetation are also above background levels at location EVAP, which is near a spring where groundwater flows near the surface and evaporates. Groundwater near EVAP is contaminated with tritium from Pit 3, Pit 5, and the firing table at Building 850. The DSW and EVAP locations are both within the East and West Firing Area (EFA/WFA) and the Study Area of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) environmental restoration study areas (see Chapter 8).

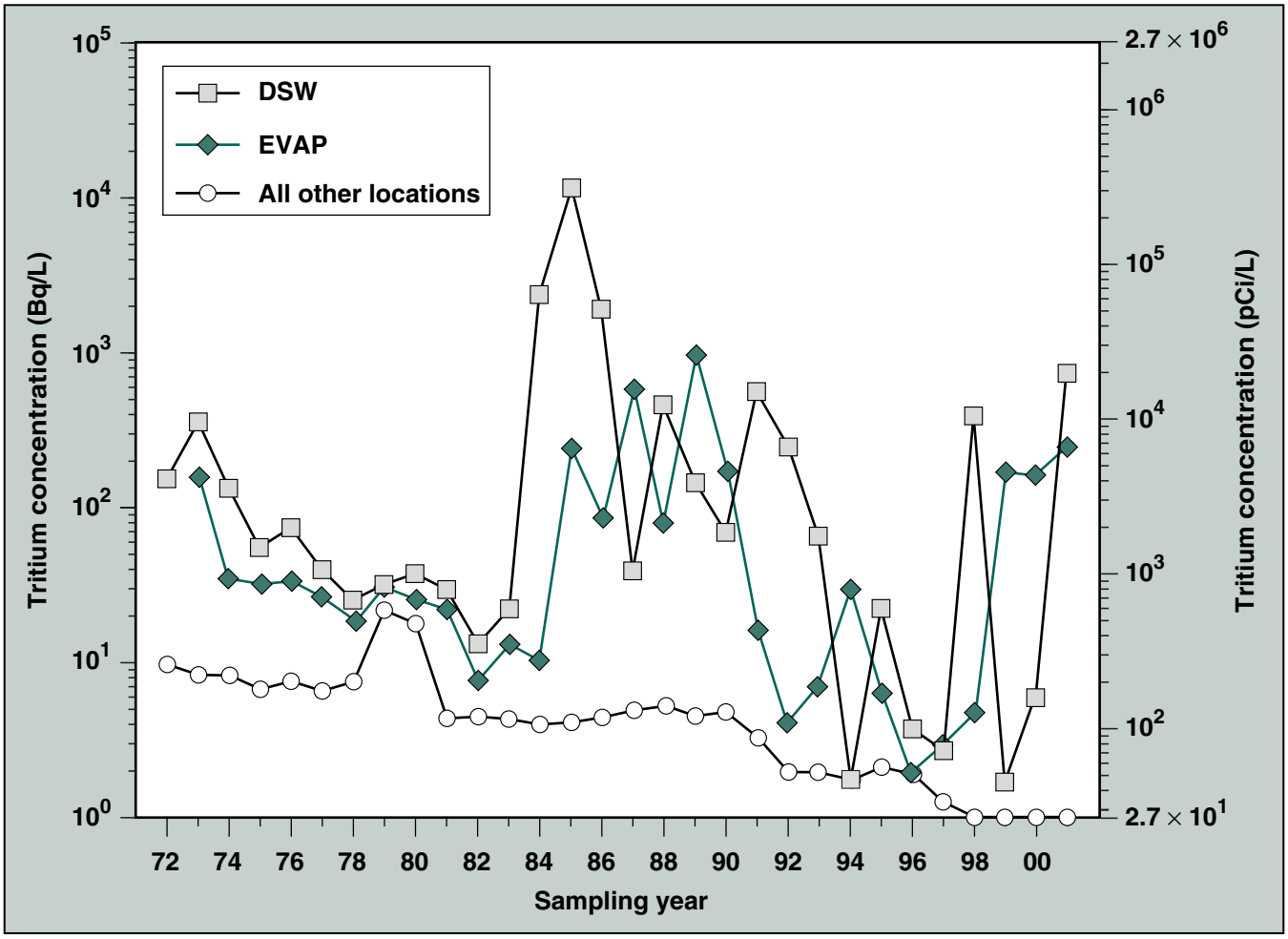

Figure 11-5. Median tritium concentrations in plant water at Site 300 sampling locations, 1971–2001. When the median values are below detection limits, values are plotted arbitrarily as 1 Bq/L.

Relatively high concentrations of tritium in plants at DSW and EVAP are observed only sporadically when the roots of the vegetation come in contact with contaminated groundwater. Evaluation of the 2001 data for Site 300 using Scheffé's *F* procedure yielded no significant difference between 801E, COHO, and EVAP, a result of the high variability of the data and the low number of data points. However, DWS was determined to be different from 801E and COHO at the 5% significance level.

Environmental Impact

In 2001, the environmental impacts of LLNL operations on vegetation and wine, presented below, were small.

Livermore Site Vegetation

LLNL impacts on vegetation in the Livermore Valley remained minimal in 2001. The effective dose equivalents, shown in **Table 11-1**, were

derived using the dose conversion factor (1.73×10^{-11} Sv/Bq) provided by DOE (U.S. DOE 1988) and the dose pathway model from U.S. Nuclear Regulatory Commission (NRC) Regulatory Guide 1.109 (U.S. NRC 1977). Appendix A provides a detailed discussion of dose calculation methods. The dose from ingested tritium is based on the conservative assumptions that an adult's diet (Table A-1, NRC maximum) consists exclusively of leafy vegetables with the measured tritium concentrations, as well as meat and milk from livestock fed on grasses with the same concentrations. In actuality, the vegetables consumed by an adult contain tritium at lower levels than those reported because most vegetables are imported from other areas. Similarly, tritium concentrations in food consumed by local livestock are at or below the concentrations in vegetation measured at the Intermediate and the Far locations. Nevertheless, based on these extremely conservative assumptions, the maximum potential dose from ingestion of vegetables, milk, and meat for 2001 for the Livermore Valley is 69 nSv/y (0.069 μSv or 0.0069 mrem).

Doses are calculated based on measured tritium in plant water without considering the contribution of organically bound tritium (OBT). Dose conversion factors of 1.8×10^{-11} Sv/Bq for tritium in the plant or animal water (HTO) and 4.2×10^{-11} Sv/Bq for OBT have been established by the International Commission on Radiological Protection (ICRP 1996). These conversion factors show the relative importance of ingested HTO and OBT to dose.

When vegetables are ingested, the dose from the HTO contribution is greater than the dose from the OBT contribution because the fraction of the vegetable that is organic matter is quite small (10–25%). For example, about 10% of the ingestion dose from leafy vegetables (about 10% dry matter) is contributed by OBT. OBT becomes increasingly important to dose when the fraction of dry matter increases. Pork, for example, has a dry-matter content of about 30–50% (Ciba-Geigy Ltd. 1981), and the resulting ingestion dose from pork is about half from OBT and half from HTO. The OBT in grain, which is 88% dry matter, contributes nearly 90% of the dose from ingested grain.

Given the different fractions of OBT in different foods, the importance of OBT to ingestion dose depends on what quantities of what kinds of foods are consumed. Accounting for a diet extremely high in OBT and for the relative biological effectiveness of the tritium beta possibly being greater than 1.0 would, at most, give an OBT contribution to dose twice that of HTO (U.S. Department of Health and Human Services 2001). Thus, conservatively, the maximum total tritium dose from ingestion of vegetables, milk, and meat from the Livermore Valley for 2001 cannot exceed 210 nSv (0.21 μSv or 0.021 mrem), which is well below any level of concern.

The dose values for PIN1 (shown in **Table 11-1**) were calculated in a different manner from those for edible vegetation because it is unreasonable to assume that any person is directly ingesting pine needles. The pine tree is treated as a diffuse source of tritium to the atmosphere via the contaminated transpirational stream. LLNL used an estimated tritium transpiration rate from the tree to estimate the Ci/y used as the source input to the EPA regulatory model CAP88-PC. LLNL modeled air dispersion of the transpired tritium and calculated a resulting dose from inhalation, skin absorption, and potential ingestion from air concentrations at the location of the maximally exposed individual. This total dose is based on the conservative assumptions that 100% of the individual's time is spent at this location and that his/her diet consists exclusively of foods having the same tritium to hydrogen ratio as occurred in air moisture. The

resulting maximum dose for PIN1 of 0.011 nSv/y (1.1×10^{-5} µSv or 1.1×10^{-6} mrem) is considerably lower than ingestion doses calculated directly from measured concentrations in vegetation because the tree is only an indirect source of air/vegetation contamination.

Livermore Site Wine

No health standards exist for radionuclides in wine. However, all the wine tritium levels were far below drinking water standards. In fact, even the highest detected Livermore Valley value (2.6 Bq/L or 70 pCi/L) represents only 0.35% of the California drinking water standard (740 Bq/L or 20,000 pCi/L). Doses from wine consumption can be calculated according to methods for water ingestion, as described in Appendix A.

Based on the conservative assumption that wine is consumed at the same rate as the average consumption of water (370 L/year or about 1 L/day), the annual dose that corresponds to the highest detected 2001 Livermore Valley tritium value in wine is 17 nSv (1.7 µrem). Assuming a more realistic, yet high,[1] average wine consumption (52 L/year or 1 L/week), and the median tritium values from the three sampling areas, the annual doses from Livermore, European, and California wines would be 1.3 nSv (0.13 µrem), 1.1 nSv (0.11 µrem), and 0.37 nSv (0.037 µrem), respectively.

Summary

Very low concentrations of tritium may be found in foodstuffs grown near the Livermore site as a result of LLNL operations. A potential ingestion dose for 2001 that accounts for contributions from HTO and OBT in vegetables, milk, meat, and wine will realistically be less than 210 nSv (0.21 µSv or 0.021 mrem). This estimate is as high or higher than dose estimates calculated using other assumptions (see Appendix A). This estimate is a factor of 15,000 lower than an annual background dose (~3000 µSv or 300 mrem) and a factor of 500 lower than the dose from a typical chest x-ray (100 µSv or 10 mrem) (Shleien and Terpilak 1984). Therefore, although tritium levels are slightly elevated near the Livermore site, doses from tritium ingestion are negligible.

Site 300

In general, LLNL impacts on tritium concentrations in vegetation at Site 300 for 2001 were insignificant. With the exception of vegetation from previously identified sites of contamination, the tritium levels at Site 300 were below the limits of detection and comparable to those observed in previous years. The areas where tritium is known to be present in the subsurface soil are well delineated and localized.

The calculated maximum potential annual ingestion dose from vegetation at sampling location DWS, based on the maximum value of 2700 Bq/L (73,000 pCi/L), is 13 µSv (1.3 mrem). This dose, based on the conservative modeling assumptions described above, is theoretical—but nevertheless small— because vegetation at Site 300 is not ingested either by people or by livestock.

1. The California Wine Institute, December 2001, states that the average consumption of wine in the United States is 2.01 gal/y (7.6 L/y).