11. Vegetation and Foodstuff Monitoring

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Introduction

Because pollutants originally released to the soil, air, or water can be transported to vegetation, the sampling and analysis of native vegetation can provide information about the presence and movement of radionuclides in the environment. Vegetation can contribute a radiation dose to humans directly through ingestion or indirectly through human ingestion of products from animals that have consumed it. DOE guidance 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 (U.S. Department of Energy 1991).

Since 1972, vegetation and foodstuff sampling in the vicinity of LLNL and Site 300 has been part of a continuing LLNL monitoring program designed to measure any changes in environmental levels of radioactivity, to evaluate any increase in radioactivity that might have resulted from LLNL operations, and to calculate potential human doses resulting from direct and indirect ingestion of these products. During 1995, LLNL collected and analyzed samples of native vegetation and wine. Potential human doses from these foodstuffs are calculated using the monitoring data and dose models presented in Appendix B.

Tritium is the nuclide of major interest in the LLNL vegetation and foodstuff monitoring program because LLNL has historically released tritium to the air both accidentally and in the course of routine operations. Tritium is likely to move into the environment as tritiated water and can be assimilated easily into vegetation and foodstuff. It can contribute to human radiation dose burdens if it is inhaled or ingested directly or indirectly. Although other radionuclides are used at LLNL, our assessments show that only tritium could be present in vegetation in detectable concentrations.

Methods

Our methods for monitoring vegetation and wine are presented in the following sections.

Vegetation

LLNL collects vegetation samples, usually annual grasses, quarterly from fixed locations in the Livermore Valley, San Joaquin Valley, San Ramon Valley, and Site 300, and then analyzes them for tritium. Sampling locations DAN and MOD were eliminated in 1995; lower release levels of tritium reduced the need for numerous background sampling locations. Location maps are provided in **Figures 11-1** and **11-2**. These locations have been selected so samples would represent vegetation from: (1) locations near LLNL that could be affected by LLNL operations, (2) background locations where vegetation was similar to that growing near LLNL but was unlikely to be affected by LLNL operations, and (3) areas of known or suspected LLNL-induced contamination.

All vegetation sampling is conducted according to written and approved standardized procedures (Tate et al. 1995). Approximately 10% of the sites are sampled in duplicate to comply with quality assurance protocols (Garcia and Failor 1993).

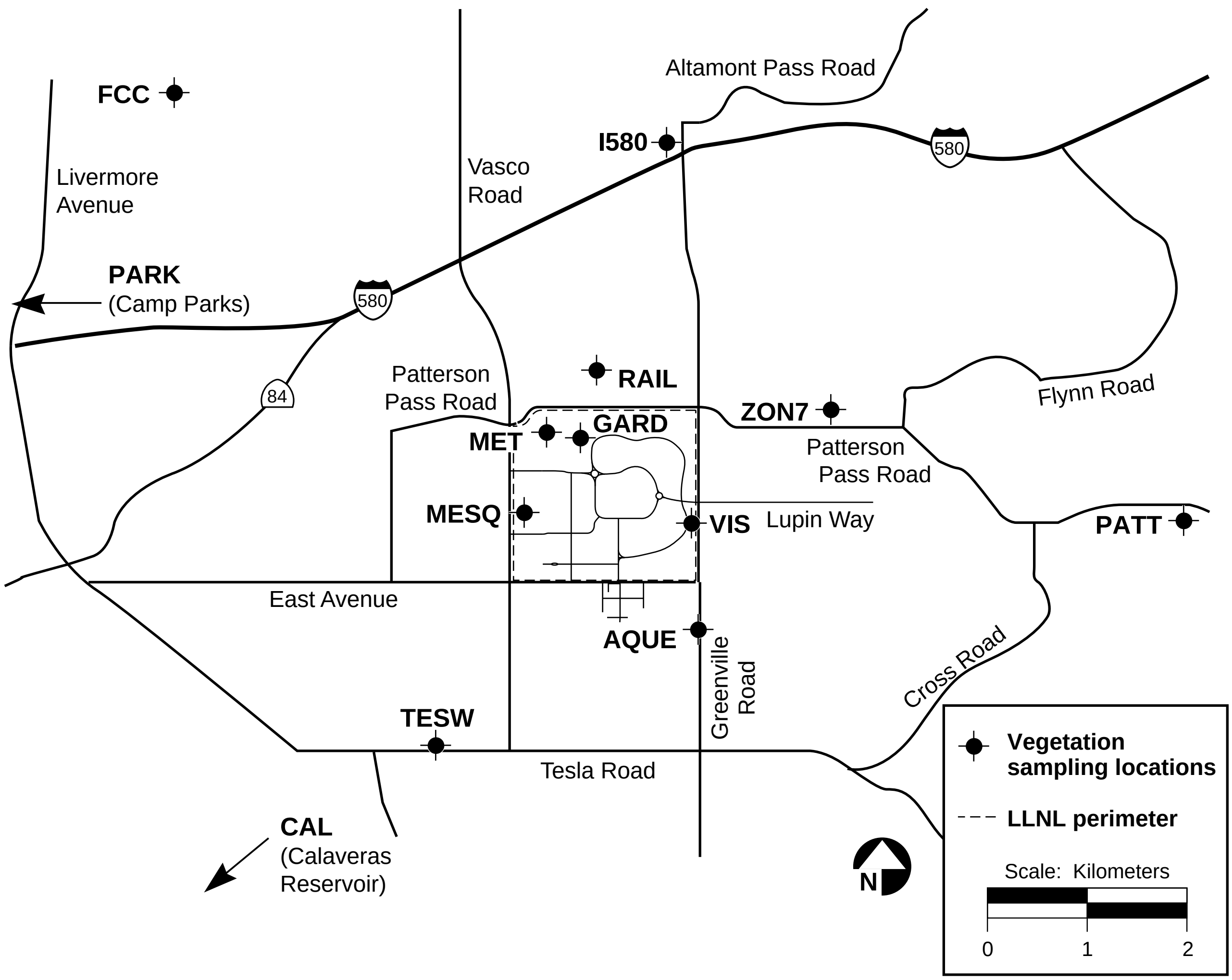

Figure 11-1. Livermore Valley vegetation sampling locations, 1995.

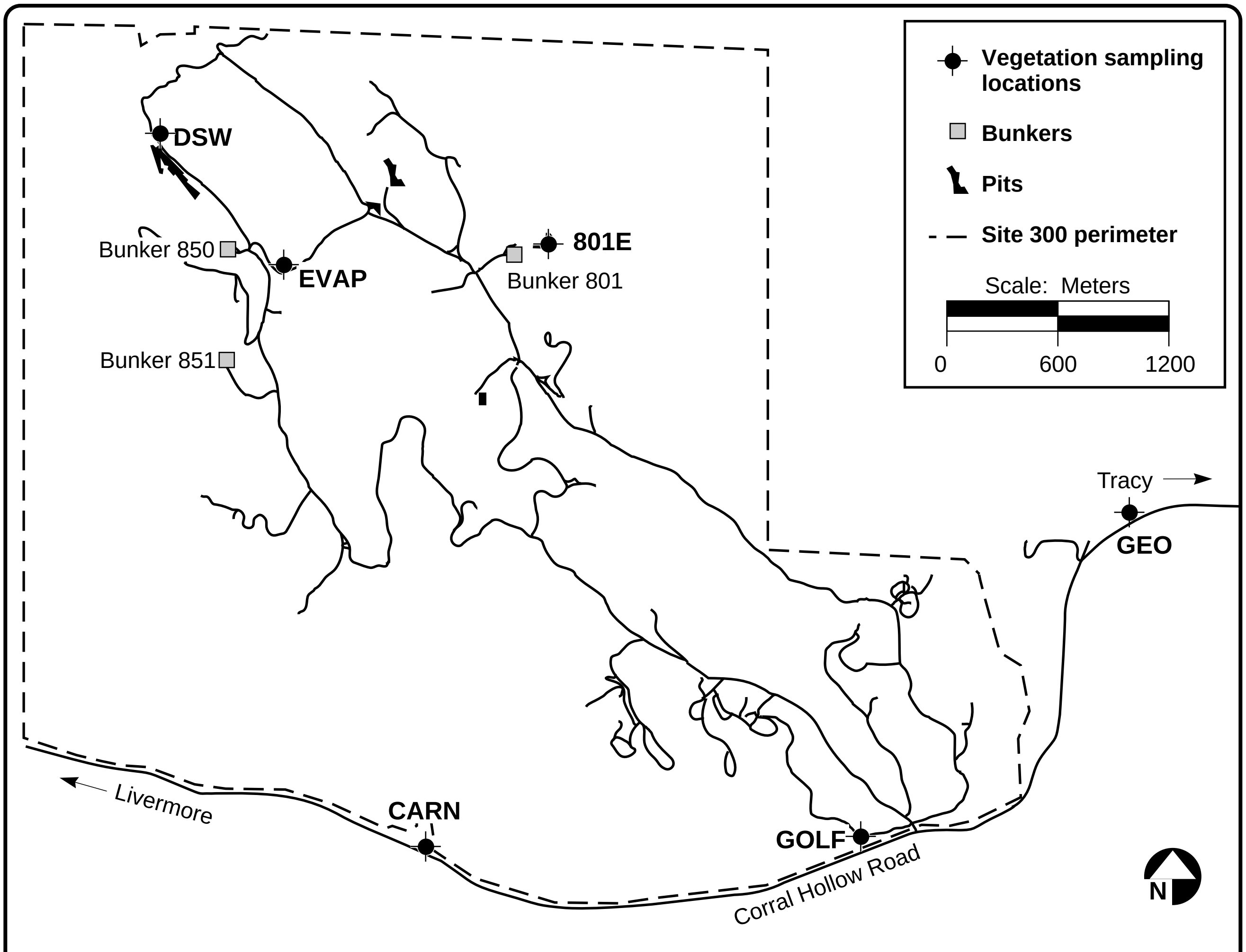

Figure 11-2. Site 300 vegetation sampling locations, 1995.

Wine

Wine is the most important agricultural product in the Livermore Valley, representing an approximately $30-million annual industry. Although the tritium concentrations in all wines are low, the data since monitoring began (in 1977) indicate that Livermore Valley wines contain statistically more tritium than do their California counterparts.

Three types of wine samples were collected and analyzed for tritium concentrations: wine produced from grapes grown in the Livermore Valley, wines produced from grapes grown in California outside the Livermore Valley, and wines produced from grapes grown in Europe (France, Germany, and Italy). The latter two groups were divided into 8 and 13 wine-producing regions, respectively, and were used as comparative samples.

The wine samples were purchased from local retailers in a variety of vintages and reflect the body of wines locally available to the general public during 1995. The resulting analytical data can be used to estimate the potential tritium dose received by consumers during the year of purchase. The 1995 sampling data cannot, however, be used to indicate how LLNL's operations affected wines produced in 1995. Some time—in some cases, several years—will have elapsed between the harvest of the grapes and the release of the vintage. However, wine sample data are decay-corrected to original tritium concentrations (given the number of months that have elapsed between wine production and LLNL analysis) to determine trends and to help determine the impact of LLNL operations during a particular vintage year.

The wine samples were submitted for analysis unopened to avoid airborne tritium contamination. Wines were analyzed for tritium using ^{3}He mass spectrometry in the LLNL Isotope Sciences Noble Gas Mass Spectrometry Laboratory (Surano et al. 1991). This highly sensitive method has a detection limit of less than 0.5 Bq/L (13 pCi/L), and is used to determine the small differences in the tritium content of the samples. Conventional scintillation detection systems typically have detection limits between 5 and 10 Bq/L (150–300 pCi/L); therefore, the differences in the samples would not have been detected had conventional detection methods been used.

Approximately 10% of the total complement of wines was sampled in duplicate, 30% of all the samples were analyzed multiple times, and traceable standards were evaluated to comply with quality assurance protocols.

Results

The results of vegetation and foodstuff monitoring for the Livermore site and Site 300 are presented below.

Livermore

Vegetation

Table 11-1 shows summary tritium data for vegetation collected in the Livermore site vegetation monitoring program in 1995 (the individual sampling values are presented in Volume 2 of this document). In general, the 1995 tritium levels in vegetation were slightly less than levels measured in 1994.

The vegetation locations were put into three groups for statistical evaluation:

- Near—locations at or within 1 km of the Livermore site perimeter. Near locations include AQUE, RAIL, GARD, MESQ, MET, and VIS.

Table 11-1. Tritium in vegetation (in Bq/L), 1995.

Location[(a)]	Detection frequency	Median	Interquartile range	Maximum	Dose (μSv/y)[(b)]	
					Median	Maximum
Livermore site near locations	21/24	6.0	8.3	78	0.029	0.38
Livermore site intermediate locations	9/16	3.4	—[(c)]	12	0.016	0.059
Livermore site background locations	4/12	<2.0	—[(c)]	3.0	<0.010	0.015
Location DSW at Site 300[(d)]	3/4	22	160	530	0.11	2.5
Location EVAP at Site 300[(d)]	3/4	12	18	64	0.059	0.31
All other locations at LLNL Site 300	4/16	<2.1	—[(c)]	2.9	<0.010	0.014

Note: Detection frequency means the number of samples of all samples taken having measured values above the detection limit.

a See **Figures 11-1** and **11-2** for sampling locations.

b Dose calculated based on conservative assumptions that an adult's diet is exclusively vegetables with this tritium concentration and that meat and milk is derived from livestock fed on grasses with the same concentration of tritium. See Appendix B, Methods of Dose Calculations.

c Insufficient number of detections to calculate IQR.

d Sampling location in known area of contamination.

- Intermediate—locations in the Livermore Valley further from the site (1 to 5 km from the Livermore site perimeter) but close enough and often downwind so that they are still potentially under the influence of tritium releases at the site. The intermediate locations were I580, TESW, ZON7, and PATT.
- Background—locations unlikely to be affected by LLNL operations. One background location (CAL) is more than 25 km away. The other two (FCC and PARK) are in the Livermore Valley but are greater than 5 km from the Livermore site and are generally upwind so they are unlikely to be affected by LLNL operations.

The changes in tritium levels between 1994 and 1995 for the vegetation from within each of the Near, Intermediate, and Far groups were statistically insignificant.

Because the data for tritium in vegetation were lognormally distributed, the means of the logarithms were compared, using the Tukey-Kramer honestly significant difference (HSD) test. This evaluation showed a significant difference among all three groups, that is, the Near values are significantly different from Intermediate, which in turn are significantly different from the Far values. **Figure 11-3** shows the historic averages for the three groups. The highest tritium results for individual vegetation sampling locations were found at AQUE and VIS. These locations are downwind of SNL / California, and the Livermore site and historically have exhibited higher values than other locations.

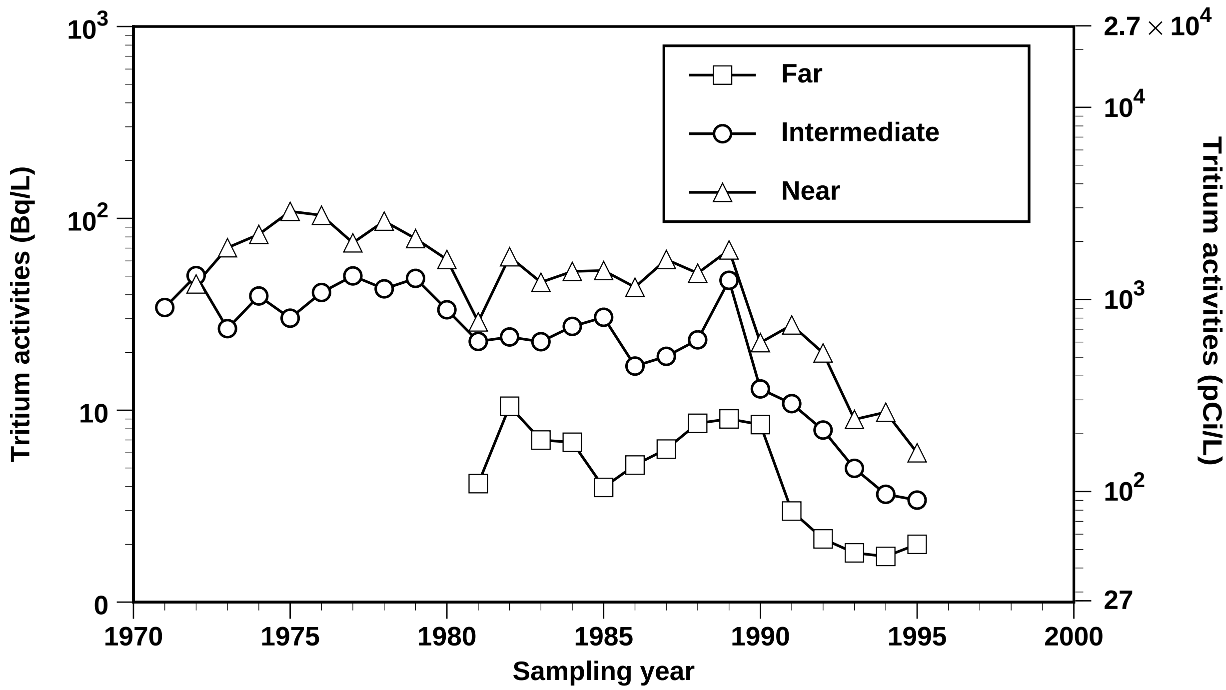

Figure 11-3. Median tritium activities in Livermore Valley vegetation samples, 1971 to 1995.

Wine

The results from the 1995 wine tritium analyses are shown in **Table 11-2**. Tritium concentrations were within the range of those reported in previous years, and they remained low in wines from all areas.

The data for the 1995 sampling year were analyzed using analysis of variance (ANOVA). The statistical analyses showed that the mean tritium concentration of the Livermore wines sampled was statistically greater than that of both the California (other than Livermore) wines and European wines sampled. The statistical analyses also indicated that there was no significant difference between the mean tritium values of the European and California wines sampled. Multiple comparison tests indicated that the mean levels of the 1995 sampling year data from all areas were not statistically different from those reported for the 1993 and 1994 sampling years. **Figure 11-4**, which shows the results of the wine analyses by sampling year since monitoring began, also shows that 1995 tritium concentrations are among the lowest for all Livermore wines since monitoring began.

During the review of historical data, it was discovered that the data for 1977 and 1979 sampling years were averages across multiple sampling years. These data have been corrected in **Figure 11-4**, and are the reason for differences observed when comparing this figure to those published in previous reports.

Table 11-2. Tritium (Bq/L) in retail wine, 1995.[(a)]

Region	Detection frequency	Median	Interquartile range	Mean	Maximum	Dose[(b)] µSv/y (mrem/y)
Livermore Valley	12/12	2.60	2.14	3.20	6.02	0.0028 (0.00028)
California	6/6	0.45	0.22	0.62	1.21	0.0005 (0.00005)
Europe	4/4	1.87	0.58	1.92	2.76	0.0017 (0.00017)

[a] Wines from a variety of vintages were purchased and analyzed during 1995. The concentrations shown are not decay-corrected to vintage year.

[b] This dose is calculated from conservative assumption of drinking 52 L wine/year and using the mean concentration of sampled wines.

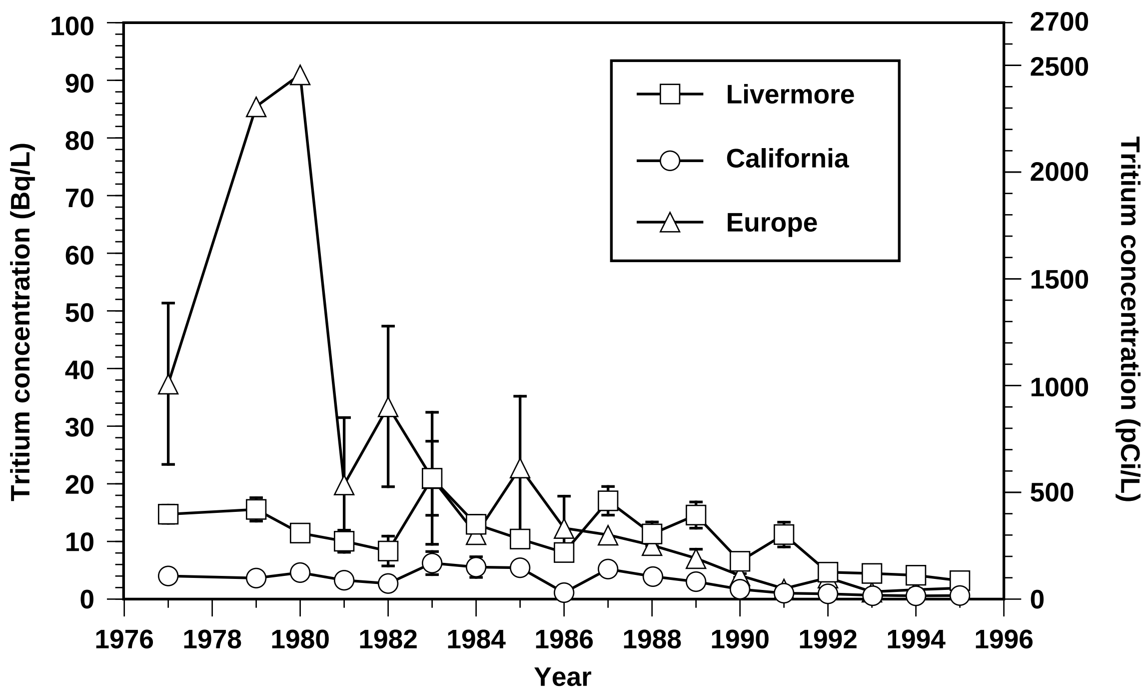

Figure 11-4. Mean tritium in retail wines, 1977 to 1995, plotted by sampling year (error bars are ±1 standard error).

Regression analyses and ANOVA of the wine data when decay-corrected (see **Figure 11-5**) and grouped by vintage year (1994 is last sampled vintage) showed tritium concentrations have statistically decreased for all regions since 1984. Livermore wines, examined by vintage year, have had statistically greater tritium concentrations since 1986 than both European and California wines. However, since 1989 when tritium operations at LLNL were scaled down and the total amount of tritium released was reduced, the concentration of tritium in the Livermore Valley wines has followed a downward trend when decay-corrected and grouped by vintage year.

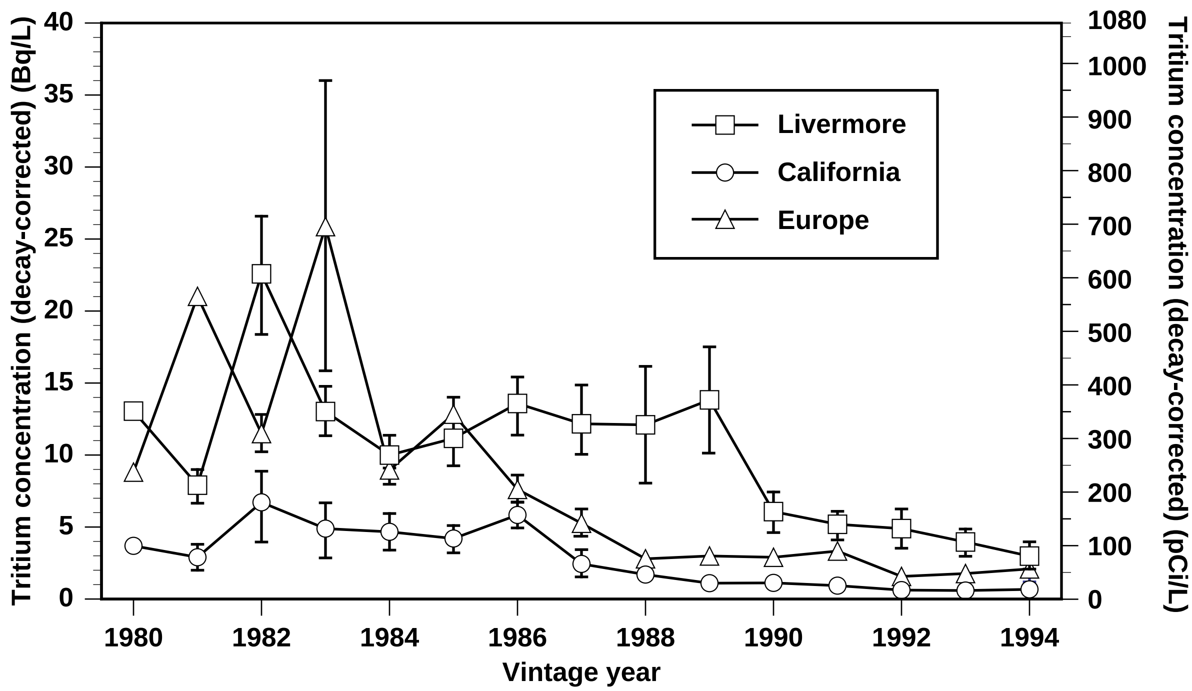

Figure 11-5. Mean tritium in retail wines, vintages 1980 to 1994, values are decay-corrected and plotted by vintage year (error bars are ±1 standard error).

Site 300

Vegetation

Table 11-1 shows summary tritium data for vegetation collected at Site 300 during 1995. Historic values for tritium at Site 300 sampling locations are shown in **Figure 11-6**. Of the six sampling locations at Site 300, four yield results at or near the detection limits. Two locations, EVAP and DSW, yield results above background.

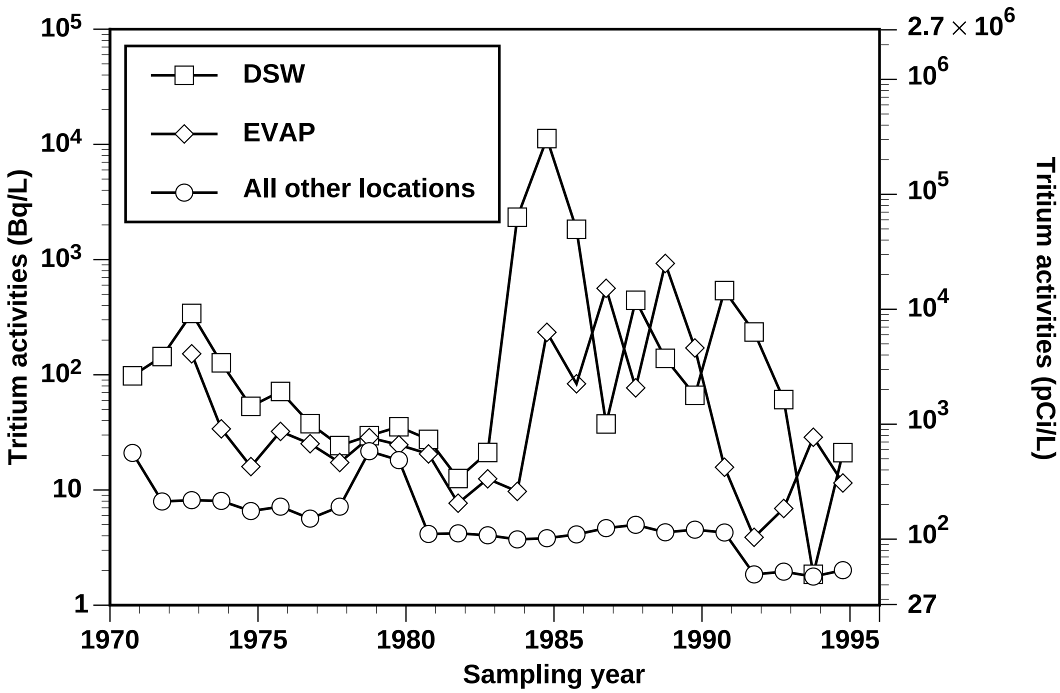

Figure 11-6. Median tritium activities in vegetation at Site 300 sampling locations, 1971 to 1995.

As was the case for 1992 to 1994, vegetation samples from location DSW contained the highest maximum tritium values detected (see **Table 11-1**). Tritium has been observed in the vegetation of the DSW sampling location since 1971; it is in an area presently being investigated under CERCLA for tritium contamination of ground water. This sampling location is adjacent to a landfill that contains debris contaminated with tritium from past experiments. The landfill area is under continued investigation for tritium in soil and ground water, as described in reports published as part of LLNL's Environmental Restoration Program (Lamarre 1989a, 1989b, and 1989c; Taffet et al. 1989a and 1989b; Taffet et al. 1991; Carlsen 1991a and 1991b; and Webster-Scholten 1994). In the past, purge water from samples of ground water monitoring wells was released to the ground at this location. This practice has been discontinued, and LLNL will continue to monitor vegetation in this area to determine whether the change in purge water deposition affects tritium activities in vegetation samples. The location EVAP is near a spring where ground water flows near the surface and evaporates. Some of the ground water near this location arises near the Building 850 firing table where tritium is released to soil (Surano et al. 1995). Consequently, higher-than-background levels of tritium are measured in vegetation in this area. Evaluation of the 1995 data using the Tukey-Kramer HSD test on the logarithms of the data yielded a significant difference between the set of locations comprising GEO, CARN, GOLF, and 801E, and locations DSW and

EVAP. This is to be expected because DSW and EVAP are areas of known tritium contamination.

Environmental Impact

The environmental impacts of LLNL operations on vegetation and foodstuff monitoring are small and are presented below for the Livermore site and Site 300.

Livermore Site

LLNL impacts on vegetation in the Livermore Valley remained minimal in 1995. The effective dose equivalents shown in **Table 11-1** were derived using the dose conversion factors provided by DOE (U.S. Department of Energy 1988) and the dose pathway model from NRC Regulatory Guide 1.109 (U.S. Nuclear Regulatory Commission 1977). Appendix B provides a detailed discussion of dose calculation methods. The dose from tritium in vegetation is based on the conservative assumptions that an adult's diet consists exclusively of vegetables with the measured tritium concentration, and meat and milk derived from livestock fed on grasses with the same concentration. These assumptions are conservative because neither will most vegetables consumed directly by an adult contain tritium at the levels reported (the tritium levels will actually be much lower), nor will the livestock actually consume vegetation with the reported levels of tritium. Based on these conservative assumptions, the maximum potential dose (from ingestion of affected vegetation) for 1995 for the Livermore site is 0.38 μSv (0.038 mrem).

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 (6.0 Bq/L or 160 pCi/L) represents only 0.8% 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, which are detailed in Appendix B.

The annual dose that corresponds to the highest detected 1995 Livermore Valley tritium value in wine (6.0 Bq/L (160 pCi/L)) is 0.075 μSv (0.0075 mrem), based on the extremely conservative assumption that wine is consumed in the same quantities as water (730 L/year or 2 L/day). Using a more realistic wine consumption factor (52 L/year or 1 L/week of wine from a single area) and the mean tritium values detected in wines from the three sampling areas, the annual dose from Livermore wine would be 0.0028 μSv (0.00028 mrem), from European wine would be 0.0017 μSv (0.00017 mrem), and from California wine would be 0.0005 μSv (0.00005 mrem). Compared with an annual background dose of approximately 3000 μSv (300 mrem), which includes radon, and a 100-μSv (10-mrem) dose from a typical chest x-ray (Shleien and Terpilak 1984), the potential dose from consuming wine from any area is minute. Therefore, although Livermore wines contained statistically more tritium than wines produced in other areas of California, the effects of the tritium are negligible.

Site 300

In general, LLNL impacts on vegetation at Site 300 for 1995 were insignificant. Tritium levels found in the Site 300 vegetation were comparable to those observed in previous years. With the exception of vegetation from previously identified sites of contamination, the levels were low, near the limits of detection. The areas where tritium is known to be present in the subsurface soil are well delineated and localized.

The calculated maximum potential annual dose from vegetation at sampling location DSW, based on the maximum value of 530 Bq/L (14000 pCi/L), is 2.5 µSv (0.25 mrem). This dose, which would never actually be received by anyone, is about 40 times less than a chest x-ray (Shleien and Terpilak 1984). This calculation uses the same conservative pathway modeling assumptions, as described above. In actuality, this dose never would be received because vegetation at Site 300 is not consumed by people or by grazing livestock. In comparison, the calculated potential annual dose from vegetation at all other locations at Site 300 had a median value of <0.010 µSv (<0.0010 mrem; the value is a “less than” value because all measured tritium levels were less than the detection limit). Tritium levels in vegetation at Site 300 will continue to be monitored.