# Environmental Radiation Monitoring

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## Introduction

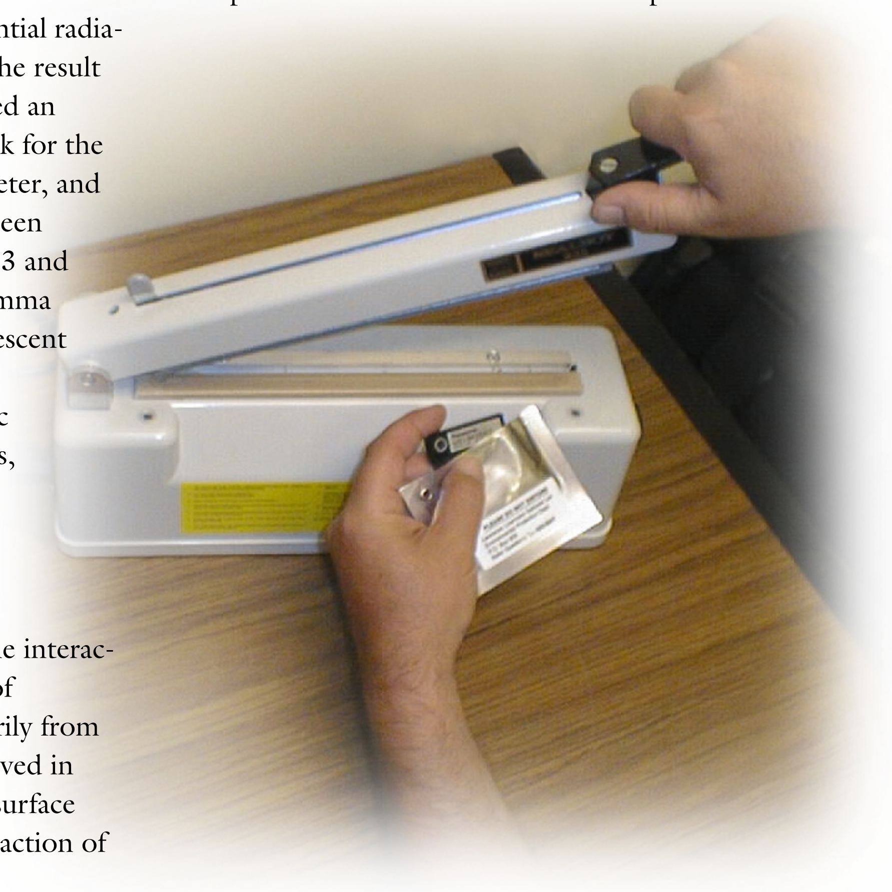
In accordance with federal regulations and applicable portions of Department of Energy (DOE) Orders 5400.1 and 5400.5, Lawrence Livermore National Laboratory monitors the natural background gamma radiation to establish radiation levels in its vicinity and to determine the environmental radiological impact of its operations. Gamma radiation in the environment primarily occurs naturally from terrestrial and cosmic sources. Because environmental radiological monitoring is used as one measure of the potential radiation dose that the public may receive as the result of LLNL operations, LLNL has developed an extensive radiological monitoring network for the Livermore site perimeter, Site 300 perimeter, and off-site locations. Gamma radiation has been measured at the Livermore site since 1973 and at Site 300 since 1988. The absorbed gamma radiation dose imparted to thermoluminescent dosimeters (TLDs) is the result of TLD exposure from both terrestrial and cosmic radiation sources as well as LLNL sources, if any.

### Cosmic Radiation Component

Gamma radiation in air is produced by the interaction of cosmic rays. Cosmic rays consist of high-energy particles and emanate primarily from beyond the solar system. Radiation observed in the lower atmosphere and at the earth's surface are secondary radiations formed in the reaction of these high-energy particles with nuclei in the upper atmosphere. The cosmic radiation component accounts for about half the observed site annual average gamma radiation.

### Terrestrial Radiation Component

Terrestrial gamma radiation is caused by naturally occurring isotopes of the uranium (uranium-238 parent), thorium (thorium-232 parent), and actinium (uranium-235 parent) decay series that are present in soil worldwide and that produce



gamma radiation during radioactive decay. The concentration of naturally occurring radionuclides in soil is variable and is determined by the ratio of thorium-232 to uranium-238 (present in these regions at the time of the earth's formation over four billion years ago), which ranges from 3 to 4 around the world. By characterizing the natural background radiation, LLNL can determine whether or not there is a contribution to gamma exposure from Laboratory operations.

## General Methods

LLNL deploys TLDs in the field to assess the environmental impact of laboratory operations at both the Livermore site and Site 300. This assessment is done by comparing the gamma radiation data acquired from the Livermore perimeter site locations to various locations monitored in the Livermore Valley, and gamma radiation data from Site 300 perimeter locations to locations in the City of Tracy and near Site 300.

As previously mentioned, the variability of the naturally occurring radioisotopes present in the soil caused by geological formations is the largest contributor to variations in measurements. Meteorological conditions contribute to seasonal variability, as does cosmic variation.

LLNL deploys TLDs at the beginning of each quarter of the year and retrieves them from the monitoring locations as near to the end of the quarter as possible in order to have a 90-day exposure period. All data are normalized to a 90-day standard quarter basis in order to make valid comparisons for the measurement period.

Details of the TLD calculations are described in an Operations and Regulatory Affairs Division (ORAD) procedure. Reporting of external gamma radiation dose can be found in Chapter 14 of the Data Supplement.

## Monitoring Locations

In 2001, external doses from gamma radiation were monitored at 14 Livermore site perimeter locations (shown in **Figure 12-1**) and at 22 Livermore Valley locations (**Figure 12-2**), which are used for background comparison to perimeter location data. Similarly, gamma doses are monitored at 9 perimeter monitoring locations at Site 300 (**Figure 12-3**). In addition to the perimeter locations historically measured at Site 300, the 4 interior locations deployed in 2000 are being maintained. These site locations are depicted in **Figure 12-3**. Additionally, 2 off-site locations near Site 300 and 2 locations in nearby Tracy are also monitored for comparison to the Site 300 data. Summary dose calculations for all gamma-monitoring locations are presented in **Table 12-1**.

## Results of Gamma Monitoring

**Figure 12-4** shows gamma doses for the Livermore site perimeter, Livermore Valley, and Site 300 from 1988 through 2001. Beginning in 1995, all quarterly gamma radiation data points were normalized to 90-day standard quarters, as is the practice of the Nuclear Regulatory Commission (NRC) (Struckmeyer 1994). Correcting the data by this method normalizes the data for comparison and reduces the data variability caused by field duration.

### Livermore Site

**Table 12-1** presents a summary of the quarterly and annual TLD gamma radiation dose equivalents for the Livermore site perimeter locations and Livermore Valley off-site locations. The annual 2001 dose equivalent from external radiation exposure at the Livermore site perimeter, 0.560 ± 0.002 mSv, is statistically the same as the background external dose measured in the Livermore Valley, 0.557 ± 0.003 mSv. The

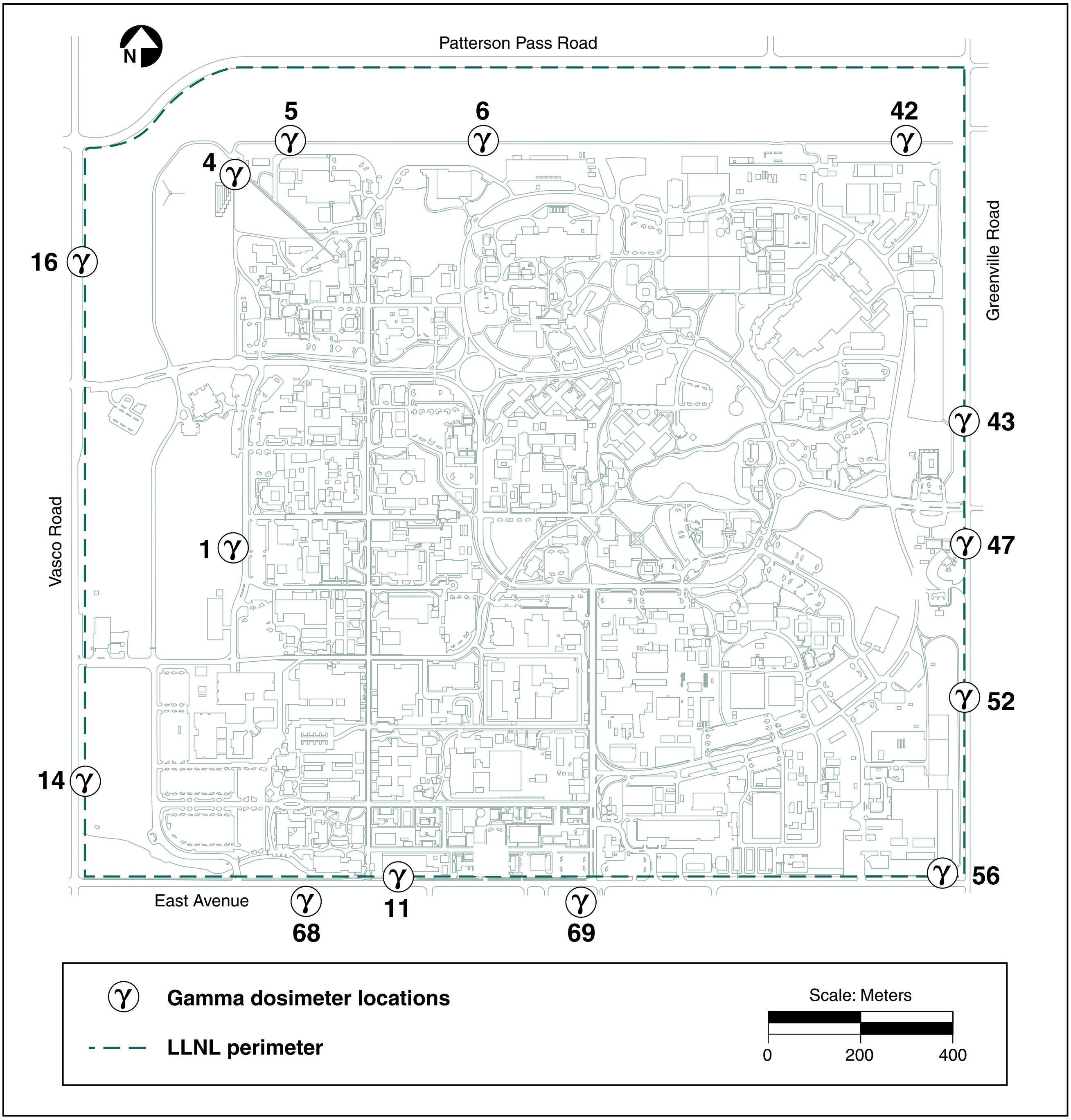



Figure 12-1. Gamma dosimeter locations, Livermore site, 2001

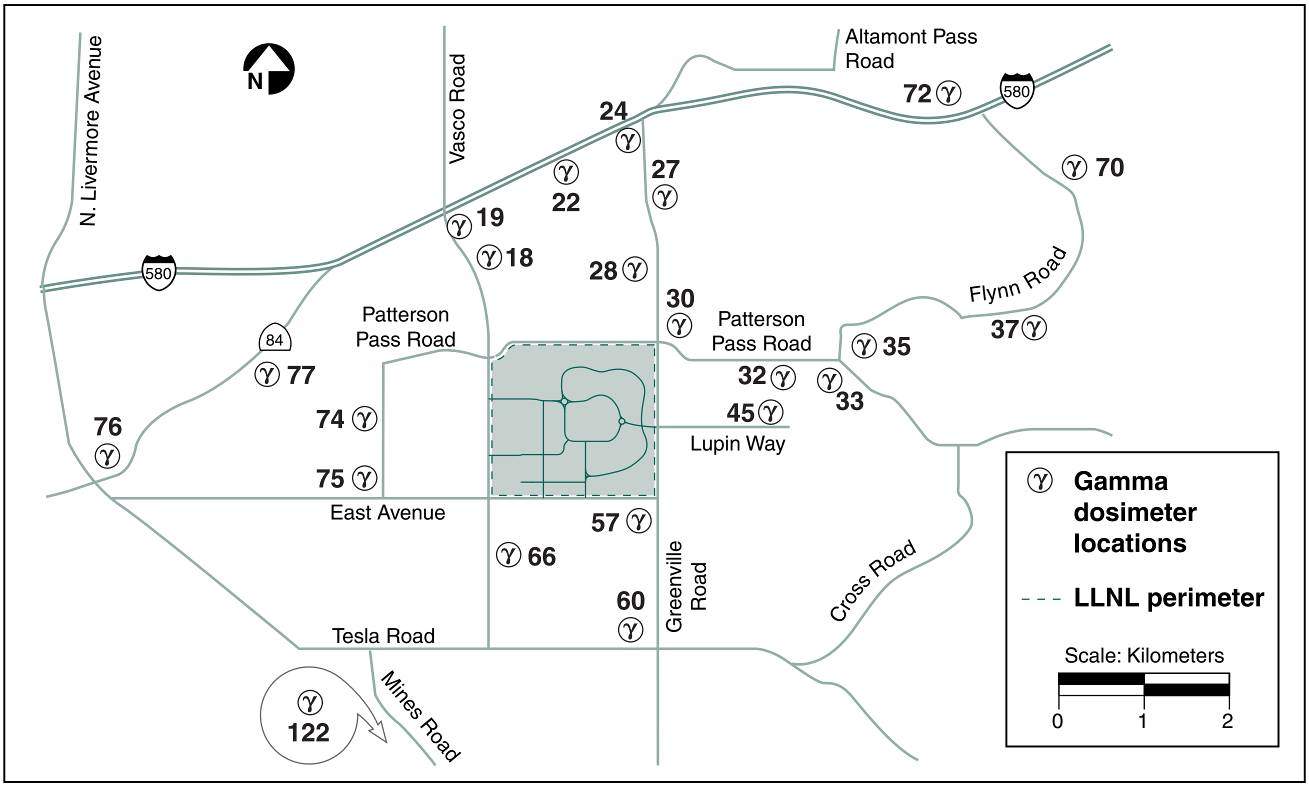



Figure 12-2. Gamma dosimeter locations, Livermore Valley, 2001

independent quarterly means that produce the annual sum for the site perimeter and the Livermore Valley are reported in Table 12-2 of the Data Supplement. All doses fall within the predicted range for background radiation, and no LLNL operational impacts are discernible.

## Site 300

As seen in **Table 12-1**, the measured Site 300 perimeter annual average dose in 2001 was 0.629 ± 0.008 mSv. The measured dose at the off-site locations near Site 300 was 0.663 ± 0.005 mSv. Historically, the off-site dose near Site 300, though slightly higher, is statistically equivalent to the on-site measured dose. The annual off-site dose reported this year is represented by only one complete data set in the first quarter. Locations 94 and 96 were removed in the second quarter because of potential liability issues associated with their location on private property. The annual dose measured for Tracy was 0.581 ± 0.008 mSv and is lower than the annual dose for 2000. All doses are within the predicted range for background radiation, and no LLNL operational impacts are discernible.

The region around Site 300 has higher levels of naturally occurring uranium present in the local geological area called the Neroly Formation. The off-site locations have historically represented the high end of background radiation due to this geological substrate. This area is underlain by a geological substrate composed of alluvial deposits

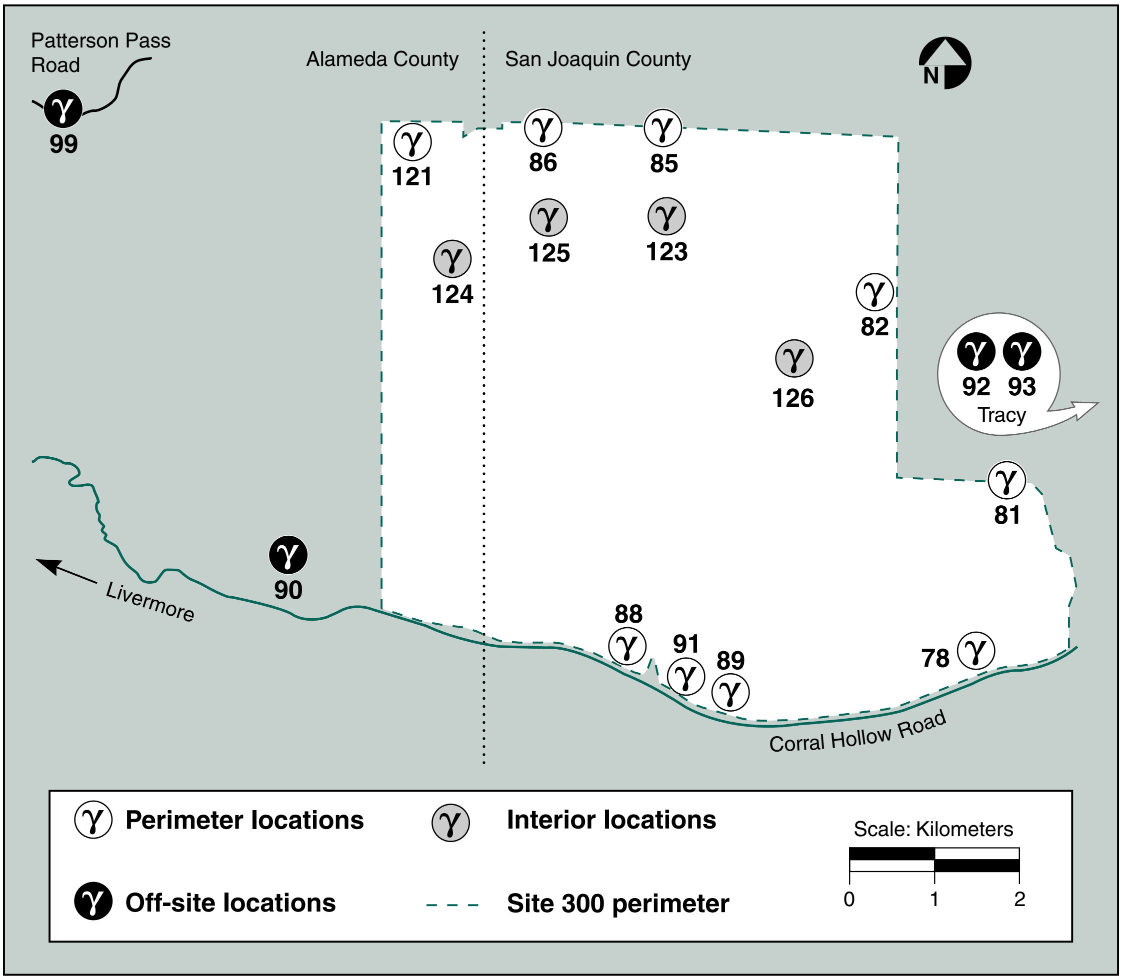



**Figure 12-3. Gamma dosimeter locations, Site 300 and vicinity, 2001**

of clays, sands, and silts overlying bedrock. The difference in the doses can be directly attributed to the difference in geologic substrates.

Fourteen years of annual average doses at the Livermore site perimeter are listed in Table 12-2 from 1988 to 2001. However, while Site 300 doses are comparable to the Livermore site perimeter and Livermore Valley doses, TLD data collected at Site 300 continue to indicate slightly higher gamma doses, as expected, given the differences in geology among these site substrates.

## Environmental Impact

Although the sun cycle may cause the contribution of cosmic radiation to vary, the sum of the measured terrestrial and cosmic radiation dose has been observed to range from 0.55 to 0.60 mSv/y as reported in Table 12-2. In addition, variability due to the local geology and meteorology will also affect this range slightly. Direct radiation doses measured at the Livermore site perimeter in 2001 are near these predicted values and are statistically equivalent to the Livermore Valley doses, which are considered to be natural background levels.

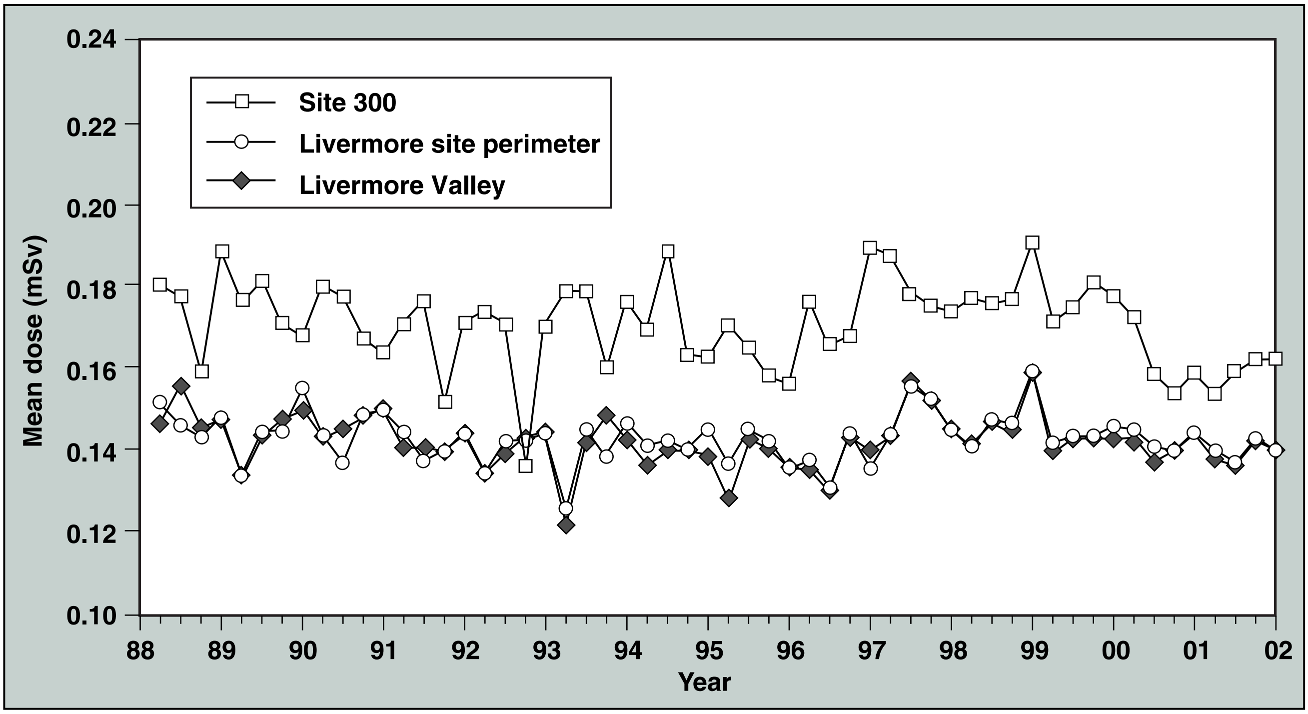



**Figure 12-4. Quarterly mean gamma dose measurements at the Livermore site perimeter, Livermore Valley, and Site 300, 1988–2001**

**Table 12-1. Summary of dose calculations for gamma-monitoring locations (mSv)[a] at all LLNL sites, 2001**

| Quarter | Location | | | | |
|---|---|---|---|---|---|
| | Livermore site | Livermore Valley | Site 300 | Tracy | Near Site 300 |
| | Mean 2 SE[b] | Mean 2 SE[b] | Mean 2 SE[b] | Mean 2 SE[b] | Mean 2 SE[b] |
| First | 0.140 ± 0.012 | 0.138 ± 0.010 | 0.154 ± 0.014 | 0.155 ± 0.048 | 0.172 ± 0.052 |
| Second | 0.137 ± 0.012 | 0.136 ± 0.016 | 0.159 ± 0.020 | 0.134 ± 0.036 | 0.163 ± 0.066 |
| Third | 0.143 ± 0.012 | 0.142 ± 0.014 | 0.162 ± 0.016 | 0.154 ± 0.024 | 0.173 ± 0.076 |
| Fourth | 0.140 ± 0.012 | 0.141 ± 0.012 | 0.162 ± 0.020 | 0.145 ± 0.024 | 0.163 ± 0.046 |
| Annual dose | 0.560 ± 0.002 | 0.557 ± 0.002 | 0.637 ± 0.003 | 0.588 ± 0.009 | 0.671 ± 0.005 |

a 1 mSv = 100 mrem

b SE = Standard Error (standard deviation of the mean)

**Table 12-2. Annual dose by year at the Livermore site perimeter caused by direct gamma radiation.** [a]

| Year | mSv | mrem |
|---|---|---|
| 1988 | 0.59 | 59 |
| 1989 | 0.58 | 58 |
| 1990 | 0.58 | 58 |
| 1991 | 0.56 | 56 |
| 1992 | 0.56 | 56 |
| 1993 | 0.57 | 57 |
| 1994 | 0.56 | 56 |
| 1995 | 0.56 | 56 |
| 1996 | 0.55 | 55 |
| 1997 | 0.59 | 59 |
| 1998 | 0.60 | 60 |
| 1999 | 0.58 | 58 |
| 2000 | 0.57 | 57 |
| 2001 | 0.56 | 56 |

a Data normalized to standard 90 days per quarter (360 days per year).

Although measured gamma exposure at Site 300 and the local vicinity are slightly higher than reported for the Livermore site and Livermore Valley, their range is attributed primarily to the variation of the geological substrate containing radionuclides of natural origin. The measured annual gamma radiation at LLNL monitoring sites does not exceed average natural backgroound exposure levels.