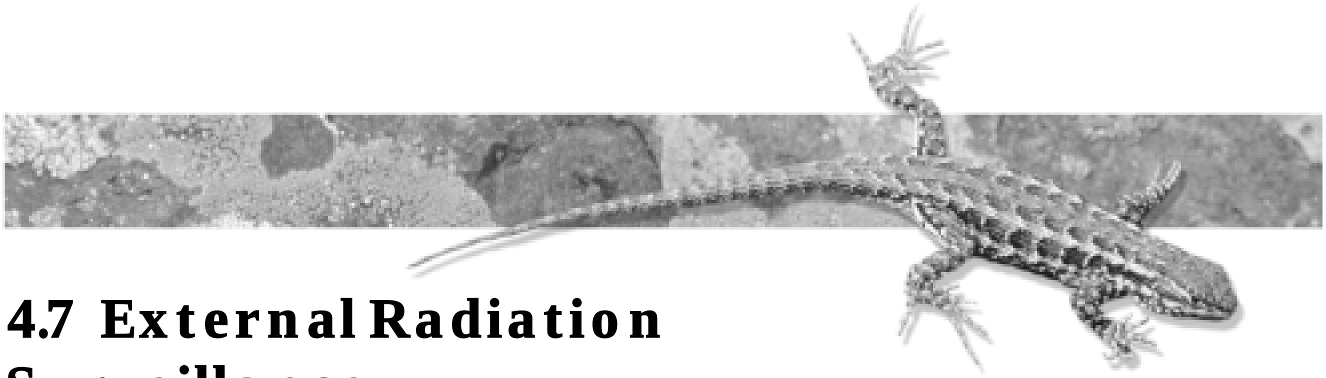

# 4.7 External Radiation Surveillance

*E. J. Antonio*

External radiation is defined as radiation originating from a source external to the body. External radiation fields consist of a natural component and an anthropogenic, or manmade, component. The natural component can be divided into (1) cosmic radiation; (2) primordial radionuclides, primarily potassium-40, thorium-232, and uranium-238; and (3) an airborne component, primarily radon and its progeny. The manmade component consists of radionuclides generated for or from nuclear medicine, power, research, waste management, and consumer products containing nuclear materials. Environmental radiation fields may be influenced by the presence of radionuclides deposited as worldwide fallout from atmospheric testing of nuclear weapons or those produced and released to the environment during the production or use of nuclear fuel. During any year, external radiation levels can vary from 15% to 25% at any location because of changes in soil moisture and snow cover (National Council on Radiation Protection and Measurements 1987).

The interaction of radiation with matter results in energy being deposited in that matter. This is why your hand feels warm when exposed to a light source (e.g., sunlight, flame). Ionizing radiation energy deposited in a mass of material is called radiation absorbed dose. A special unit of measurement, called the rad, was introduced for this concept in the early 1950s. The International System of Units introduced the Gray and is defined as follows: 1 Gray is equivalent to 100 rad (American Society for Testing and Materials 1993).

One device for measuring radiation absorbed dose is the thermoluminescent dosimeter that absorbs and stores energy of ionizing radiation within the dosimeter's crystal lattice. By heating the dosimeter material under controlled laboratory conditions, the stored energy is released in the form of light, which is measured and related to the amount of ionizing radiation energy stored in the material. Thermoluminescence, or light output exhibited by dosimeters, is proportional to the energy absorbed, which by convention is related to the amount of radiation exposure (X), which is measured in units of roentgen (R). The exposure is multiplied by a factor of 0.98 to convert to a dose (D) in rad to soft tissue (Shleien 1992). This conversion factor relating R to rad is, however, assumed to be unity (1) throughout this report for consistency with past reports. This dose is further modified by a quality factor, Q = 1, for beta and gamma radiation and the product of all other modifying factors (N). N is assumed to be unity to obtain dose equivalence (H) measured in rem. The international unit, the sievert (Sv) is equivalent to 100 rem.

$$D \text{ (rad)} = X \text{ (R)} * 1.0$$

$$H \text{ (rem)} = D * N * Q$$

For a point of reference, a radiological dose of 100 rem (1 Sv) beta/gamma to an 8-ounce (227-gram) cup of water will deposit enough energy in the water to increase the temperature of the water by about 1°F (0.55°C).

In 2001, environmental external radiation exposure rates were measured at locations on and off the Hanford Site using thermoluminescent dosimeters and pressurized ionization chambers. External radiation and surface contamination surveys at specified locations were performed with portable radiation survey instruments.

## 4.7.1 External Radiation Measurements

The Harshaw 8800-series environmental dosimeter consists of two TLD-700 chips and two TLD-200 chips and provides both shallow and deep dose measurement capabilities. The two TLD-700 chips were used to determine the average total environmental dose at each location. The average dose rate was computed by dividing the average total environmental dose by the number of days the dosimeter was in the field. Quarterly dose equivalent rates (millirem per day) at each location were converted to annual dose equivalent rates (millirem per year) by averaging the quarterly dose rates and multiplying by 365 days per year. The two TLD-200 chips were included only to determine doses in the event of a radiological emergency and were not needed in 2001.

Thermoluminescent dosimeters were positioned 1 meter (3.28 feet) above the ground at 29 onsite locations (Figure 4.7.1). Figure 4.7.2 shows the locations around the site perimeter, in nearby communities, and distant locations. Figure 4.7.3 gives the locations along the Columbia River shoreline. One onsite thermoluminescent dosimeter surveillance location was added in 2001 and one was moved from a community station to a shoreline location due to vandalism. All thermoluminescent dosimeters were collected and read quarterly.

To determine the maximum dose rate for each distance classification, the annual average dose rates, as calculated above for each location, were compared and the highest value was reported. The uncertainties associated with the maximum dose rates were calculated as two standard deviations of the quarterly dose rates then corrected to annual rates.

All community and most of the onsite and perimeter thermoluminescent dosimeter locations were collocated with air monitoring stations. The onsite and perimeter locations were selected based on determinations of the highest potentials for public exposures (i.e., access areas, downwind population centers) from past and current Hanford Site operations. The two background stations in Yakima and Toppenish were chosen because they are generally upwind and distant from the site.

The shoreline of the Columbia River in the Hanford Reach was monitored by a series of 26 thermoluminescent dosimeters located in the area from upstream of the B Reactor to downstream of Bateman Island at the mouth of the Yakima River. Ground contamination surveys also were conducted quarterly at 13 shoreline locations. These measurements are made to estimate radiation exposure levels attributed to sources on the Hanford Site, to estimate background levels along the shoreline, and to help assess exposures to onsite personnel and offsite populations. Ground contamination surveys were conducted using Geiger-Müeller meters (Geiger counters) and Bicron® Microrem meters. Results are reported in counts per minute and microrem per hour, respectively. Geiger counter measurements were made within 2.54 centimeters (1 inch) of the ground and covered a 1-square meter (10-square feet) area. The Bicron® measurements were taken 1 meter (3.28 feet) above the ground surface and at least 10 meters (33 feet) away from devices or structures which may have contributed to the ambient radiation levels.

Pressurized ionization chambers were situated at four community-operated monitoring stations (see Section 8.4). These instruments provided a way to measure ambient exposure rates near and downwind of the site and at locations distant and upwind of the site. Real-time exposure-rate data are displayed at each station to provide information to the public and to serve as an educational tool for the teachers who manage the stations.

## External Radiation Results

Thermoluminescent dosimeter readings were converted to annual dose equivalent rates by the process described above. Table 4.7.1 shows the maximum and mean dose rates for perimeter and offsite locations measured in 2001 and the previous 5 years. External dose rates reported in Tables 4.7.1 through 4.7.3 include the maximum annual dose rate (±2 standard deviations) for all locations within a given surveillance zone and the mean dose rate (±2 standard error of the mean) for each distance class. Locations were classified (or grouped) based on their location on or near the Hanford Site.

Table 4.7.2 summarizes the results of 2001 onsite measurements, which are grouped by operational area. The average dose rates in all operational areas were higher than average dose rates measured at distant locations. The highest annual average dose rate on the site (96 ± 8 mrem/yr [0.96 ± 0.08 mSv/yr]) was detected around the 200 Areas and was due to former waste disposal activities at B Pond. The 5-year maximum onsite dose rate (138 ± 31 mrem/yr [1.38 ± 0.31 mSv/yr]) was measured in 1996 near the US Ecology low-level waste disposal facility.

The annual dose rates measured offsite in 2001 are given in Table 4.7.1 and Appendix B, Table B.10. The mean perimeter dose rate was 91 ± 4 mrem/yr (0.91 ± 0.04 mSv/yr) in 2001, the maximum was 99 ± 16 mrem/yr (0.99 ± 0.16 mSv/yr), and the 5-year perimeter mean dose rate was 89 ± 2 mrem/yr (0.89 ± 0.02 mSv/yr). The location of the maximum perimeter dosimeter result was across the Columbia River from the 300 Area at Byers Landing (location 4 on Figure 4.7.2). For the past few years, Byer's Landing has had the highest and most variable thermoluminescent dosimeter readings (Figure 4.7.4).

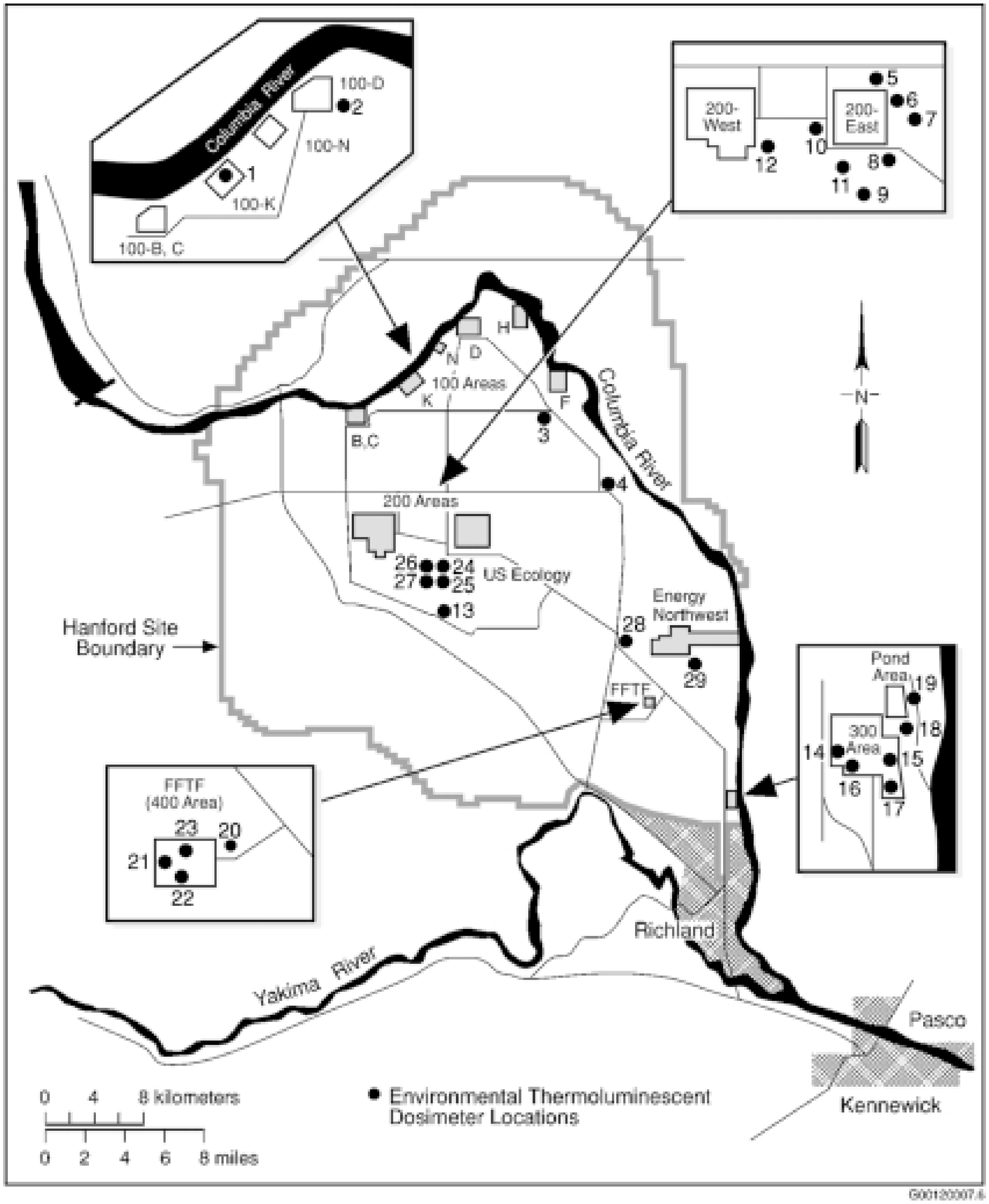


**Figure 4.7.1. Thermoluminescent Dosimeter Locations and Station Numbers on the Hanford Site, 2001 (see Appendix B, Table B.10 for station names)**

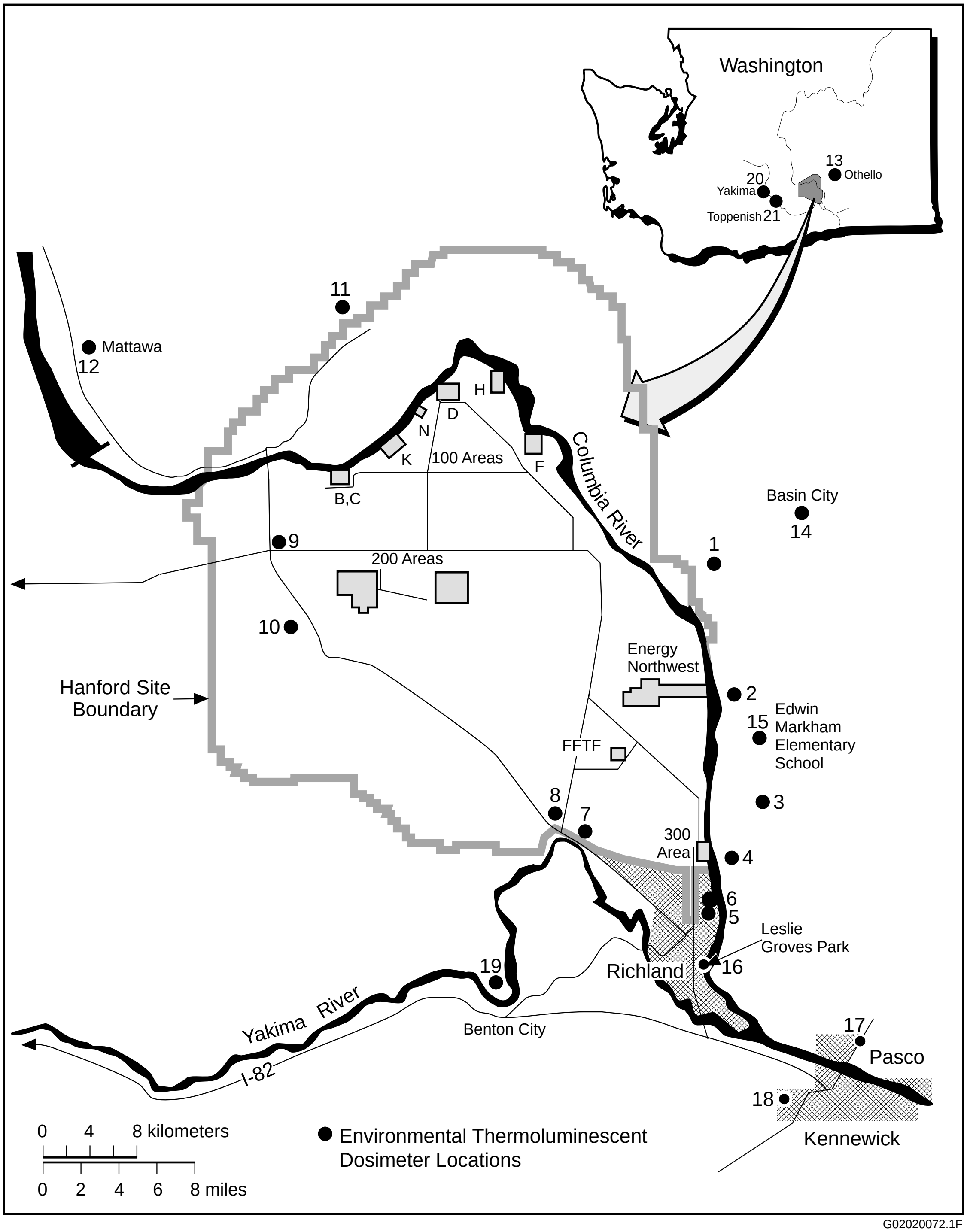


**Figure 4.7.2. Thermoluminescent Dosimeter Locations and Station Numbers for Community, Distant, and Perimeter Sites, 2001 (see Appendix B, Table B.10 for station names)**

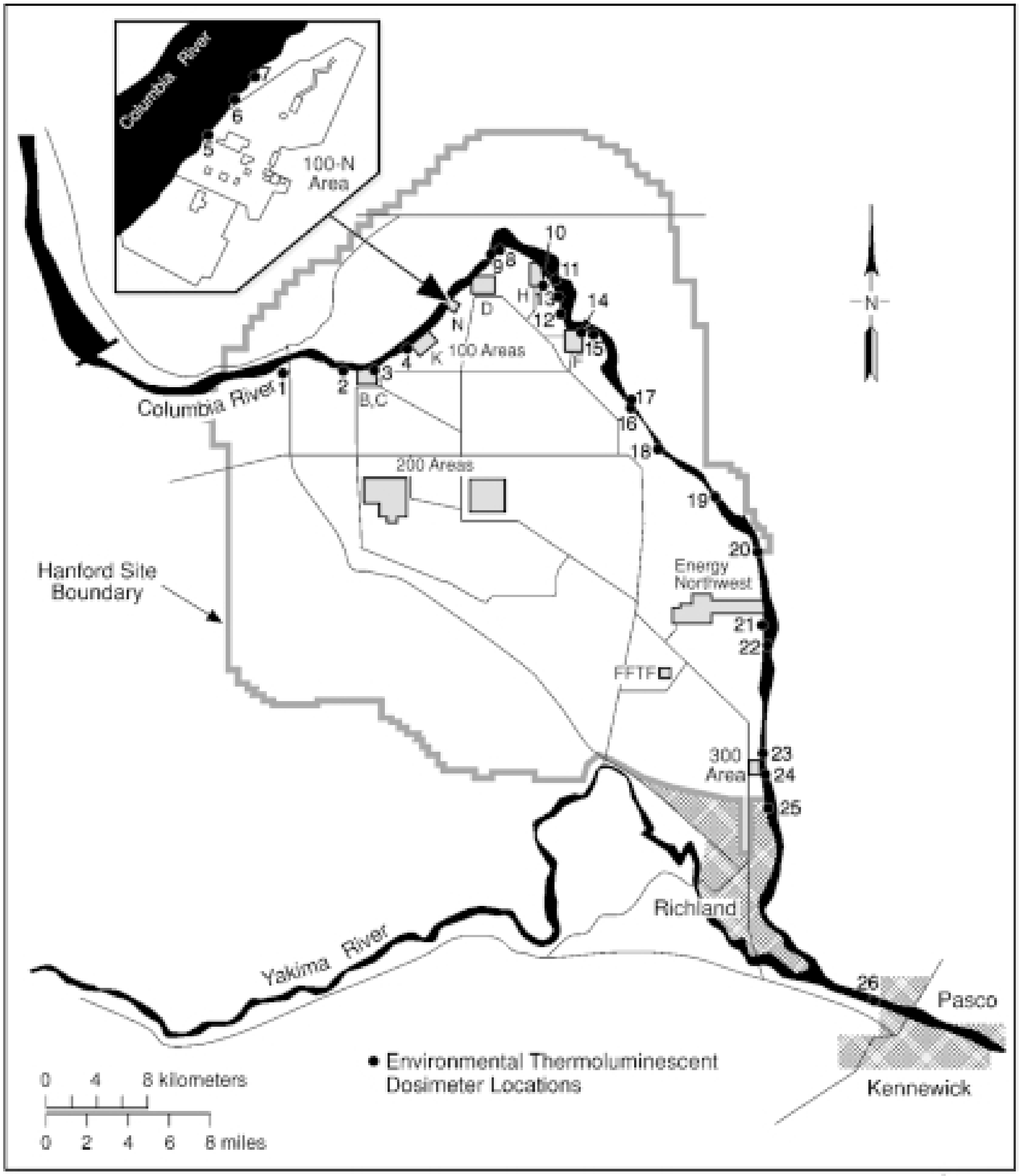


**Figure 4.7.3. Thermoluminescent Dosimeter Locations and Station Numbers along the Columbia River, 2001 (see Appendix B, Table B.10 for station names)**

Table 4.7.1. Dose Rates (mrem/yr[a]) Measured by Thermoluminescent Dosimeters at Perimeter and Offsite Locations, 2001 Compared to Previous 5 Years

| | | 2001 | | 1996-2000 | | |
|---|---|---|---|---|---|---|
| Location | Map Location[b] | Maximum[c] | Mean[d] | No. of Samples | Maximum[c] | Mean[d] |
| Perimeter | 1 - 12 | 99 ± 16 | 91 ± 4 | 75 | 106 ± 8 | 89 ± 2 |
| Community | 13 - 19 | 86 ± 5 | 80 ± 3 | 61 | 90 ± 9 | 79 ± 2 |
| Distant | 20 - 21 | 73 ± 8 | 72 ± 2 | 16 | 75 ± 9 | 71 ± 1 |

(a) Multiply by 10 to convert to µSv/yr.
(b) All station locations are shown on Figure 4.7.2 and are described in Appendix B, Table B.10.
(c) Maximum annual average dose rate for all locations within a given distance classification (±2 standard deviations).
(d) Means computed by averaging annual means for each location within distance class (±2 standard error of the mean).

Table 4.7.2. Dose Rates (mrem/yr[a]) Measured by Thermoluminescent Dosimeters on the Hanford Site, 2001 Compared to Previous 5 Years

| | | 2001 | | 1996-2000 | | |
|---|---|---|---|---|---|---|
| Location | Map Location[b] | Maximum[c] | Mean[d] | No. of Samples | Maximum[c] | Mean[d] |
| 100 Areas | 1 - 3 | 87 ± 10 | 84 ± 5 | 12 | 88 ± 4 | 80 ± 4 |
| 200 Areas | 4 - 12 | 96 ± 8 | 88 ± 2 | 39 | 98 ± 9 | 88 ± 2 |
| 300 Area | 13 - 18 | 87 ± 8 | 83 ± 2 | 30 | 89 ± 7 | 82 ± 1 |
| 400 Area | 19 - 22 | 86 ± 9 | 83 ± 2 | 20 | 89 ± 7 | 83 ± 1 |
| 600 Area | 23 - 29 | 94 ± 7 | 88 ± 2 | 30 | 138 ± 31 | 92 ± 6 |
| Combined onsite | 1 - 29 | 96 ± 8 | 86 ± 2 | 131 | 138 ± 31 | 86 ± 2 |

(a) Multiply by 10 to convert to µSv/yr.
(b) All station locations are shown on Figure 4.7.2 and are described in Appendix B, Table B.10.
(c) Maximum annual average dose rate for all locations within a given distance classification (±2 standard deviations).
(d) Means computed by averaging annual means for each location within distance class (±2 standard error of the mean).

The mean background dose rate (measured at distant communities) in 2001 was 72 ± 2 mrem/yr (0.71 ± 0.02 mSv/yr) compared to the previous year's mean of 69 ± 1 mrem/yr (0.69 ± 0.01 mSv/yr) (PNNL-13487) and the 5-year average of 71 ± 1 mrem/yr (0.71 ± 0.01 mSv/yr). The variation in dose rates may be partially attributed to changes in natural background radiation that can occur as a result of changes in annual cosmic radiation (up to 10%) and terrestrial radiation (15% to 25%) (National Council on Radiation Protection and Measurements 1987). Other factors possibly affecting the annual dose rates reported here have been described in PNL-7124. Figure 4.7.5 displays a comparison of dose rates between onsite, perimeter, and distant thermoluminescent dosimeter locations from 1996 through 2001.

Dose rates were highest along the shoreline near the 100-N Area and were ~1.3 times the typical shoreline dose rates (see Table 4.7.3). The higher dose rates measured along the 100-N Area shoreline have been attributed to past waste management practices in that area (PNL-3127). The 2001 maximum annual shoreline dose rate was 129 ± 6 mrem/yr (1.29 ± 0.06 mSv/yr), which is not significantly different from the maximum

**Table 4.7.3. Dose Rates (mrem/yr[a]) Measured by Thermoluminescent Dosimeters along the Hanford Reach of the Columbia River, 2001 Compared to Previous 5 Years**

| | | 2001 | | 1996-2000 | | |
|---|---|---|---|---|---|---|
| Location | Map Location[b] | Maximum[c] | Mean[d] | No. of Samples | Maximum[c] | Mean[d] |
| Typical shoreline | 1 - 22 | 101 ± 22 | 88 ± 3 | 110 | 102 ± 15 | 85 ± 1 |
| 100-N shoreline | 23 - 26 | 129 ± 6 | 111 ± 21 | 17 | 173 ± 11 | 122 ± 11 |
| All shoreline | 1 - 26 | 129 ± 6 | 91 ± 4 | 127 | 173 ± 11 | 90 ± 3 |

(a) Multiply by 10 to convert to µSv/yr.
(b) All station locations are shown on Figure 4.7.2 and are described in Appendix B, Table B.10.
(c) Maximum annual average dose rate for all locations within a given distance classification (±2 standard deviations).
(d) Means computed by averaging annual means for each location within distance class (±2 standard error of the mean).

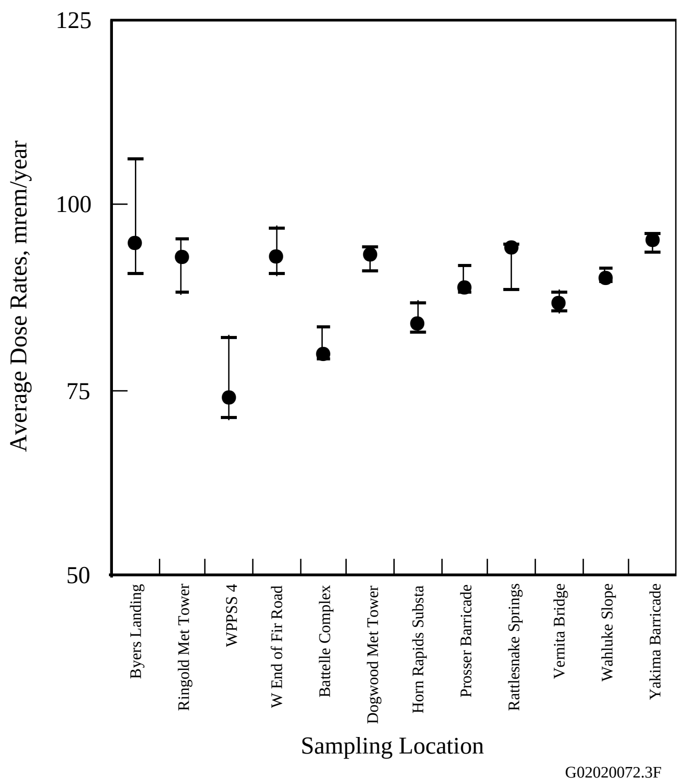


**Figure 4.7.4. Median, Maximum, and Minimum Average Dose Rates at Selected Perimeter Locations, 1996 through 2001**

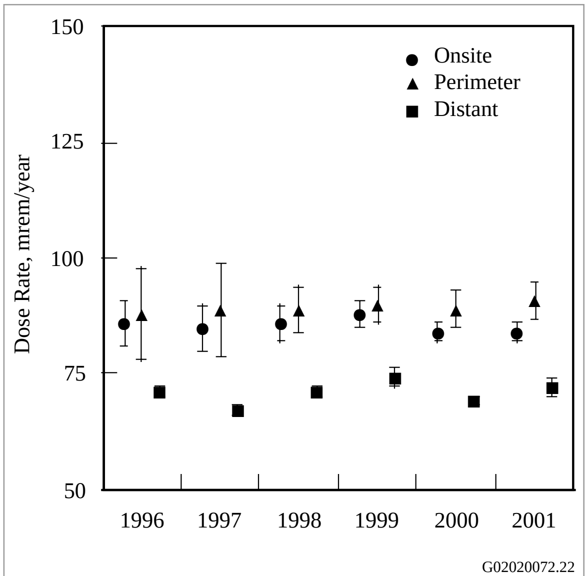


**Figure 4.7.5. Annual Average Dose Rates (±2 standard error of the mean), 1996 through 2001**

of 131 ± 7 mrem/yr (1.31 ± 0.07 mSv/yr) measured in 2000 (PNNL-13487), but is significantly different than the 5-year maximum of 173 ± 11 mrem/yr (1.73 ± 0.11 mSv/yr) measured in 1996. The 5-year maximum also was measured along the 100-N shoreline. The general public does not have legal access to the 100-N Area shoreline above the high-water line but does have access to the adjacent Columbia River and to the shoreline below the high-water line. The dose implications associated with this access are discussed in Section 5.0.

## 4.7.2 Radiological Survey Results

In 2001, Geiger counters and Bicron® Microrem meters were used to perform radiological surveys at selected Columbia River shoreline locations. These surveys provide a coarse screening for elevated radiation fields. The surveys showed that radiation levels at the selected locations were comparable to levels observed at the same locations in previous years. The highest dose rate measured with the Bicron® Microrem meter (20 µrem/h [0.2 (Sv/h]) was measured in winter along the 100-N Area shoreline; the lowest dose rate measured was 4 µrem/h (0.04 µSv/h) and was recorded at several other locations in the spring and autumn. The highest reported count rate measured with the Geiger counter in ground level surveys was 100 counts per minute. The lowest ground level count rate (>50 counts per minute) was recorded at the same location and on the same day that the lowest Bicron® reading was recorded.

Survey data are not included in the 2001 surveillance data report (PNNL-13910, APP. 1) but are maintained in project files at Pacific Northwest National Laboratory and can be obtained on written request from the Surface Environmental Surveillance Project manager.

Gamma radiation levels in air were monitored in 2001 at four community-operated air monitoring stations (see Section 8.4). These stations were located in Leslie Groves Park in Richland, at Edwin Markham Elementary School in north Franklin County, at Basin City Elementary School in Basin City, and at Heritage College in Toppenish (see Figure 4.1.1). Measurements were collected to determine ambient gamma radiation levels near and downwind of the site and upwind and distant from the site, to display real-time exposure rate information to the public living near the station, and for educational aids for the teachers who manage the stations.

Readings at the Leslie Groves Park and Heritage College stations were collected every 10 seconds with a Reuter-Stokes Model RSS-121 pressurized ionization chamber, and an average reading was recorded every hour by a flat panel computer system located at the station. Data were obtained monthly from the computer via modem. Similar data collection systems were installed at Basin City and at Edwin Markham School during 2001. At these locations, data were collected every second and averaged every minute. The 1-minute averages were used to generate either a 30- or 60-minute average, depending on location. Data were not collected at Basin City and Edwin Markham Schools every month because of the transition to the new systems. The data collected at all four stations each month in 2001 are summarized in Table 4.7.4.

Average monthly exposure rates ranged from a maximum of 11.9 µR/h (24.9 pW/kg/s) in Richland

**Table 4.7.4. Average Exposure Rates Measured by Pressurized Ionization Chambers at Four Offsite Locations[a], 2001**

| Month | | Leslie Groves Park[d] | | Basin City[e] | | Edwin Markham[f] | | Toppenish[d] | |
|---|---|---|---|---|---|---|---|---|---|
| | | Exposure Rate, μR/h[b] (number of readings)[c] | | | | | | | |
| January | Mean | 8.9 | (744) | ND[g] | | ND | | 8.0 | (744) |
| | Maximum | 10.0 | | ND | | ND | | 10.4 | |
| | Minimum | 6.4 | | ND | | ND | | 7.5 | |
| February | Mean | 8.7 | (276) | ND | | ND | | 8.0 | (671) |
| | Maximum | 9.7 | | ND | | ND | | 8.7 | |
| | Minimum | 5.6 | | ND | | ND | | 7.5 | |
| March | Mean | 8.5 | (648) | ND | | ND | | 8.1 | (745) |
| | Maximum | 9.6 | | ND | | ND | | 9.7 | |
| | Minimum | 4.7 | | ND | | ND | | 7.6 | |
| April | Mean | 8.4 | (720) | ND | | ND | | 8.2 | (720) |
| | Maximum | 9.0 | | ND | | ND | | 9.5 | |
| | Minimum | 4.9 | | ND | | ND | | 7.6 | |
| May | Mean | 8.5 | (744) | ND | | ND | | 8.0 | (743) |
| | Maximum | 9.1 | | ND | | ND | | 9.1 | |
| | Minimum | 6.9 | | ND | | ND | | 7.6 | |
| June | Mean | 8.5 | (687) | ND | | ND | | 8.0 | (711) |
| | Maximum | 9.4 | | ND | | ND | | 9.2 | |
| | Minimum | 8.3 | | ND | | ND | | 7.5 | |
| July | Mean | 8.5 | (548) | ND | | ND | | 7.9 | (744) |
| | Maximum | 9.4 | | ND | | ND | | 10.0 | |
| | Minimum | 7.2 | | ND | | ND | | 7.5 | |
| August | Mean | 8.4 | (744) | ND | | 7.4 | (872) | 8.0 | (744) |
| | Maximum | 9.0 | | ND | | 8.4 | | 9.6 | |
| | Minimum | 5.6 | | ND | | 6.8 | | 7.6 | |
| September | Mean | 8.6 | (681) | ND | | 7.5 | (970) | 8.5 | (719) |
| | Maximum | 9.3 | | ND | | 8.4 | | 10.4 | |
| | Minimum | 7.4 | | ND | | 4.7 | | 7.7 | |
| October | Mean | 8.5 | (654) | ND | | 7.4 | (1,477) | 8.7 | (744) |
| | Maximum | 9.3 | | ND | | 8.3 | | 9.8 | |
| | Minimum | 4.6 | | ND | | 6.0 | | 7.8 | |
| November | Mean | 8.1 | (720) | 7.9 | (568) | 7.6 | (1,420) | 8.5 | (693) |
| | Maximum | 9.6 | | 9.6 | | 10.1 | | 11.5 | |
| | Minimum | 4.4 | | 7.4 | | 4.5 | | 7.5 | |
| December | Mean | 8.8 | (744) | 7.8 | (720) | 7.5 | (888) | 8.0 | (636) |
| | Maximum | 11.9 | | 11.0 | | 10.9 | | 10.6 | |
| | Minimum | 5.2 | | 7.3 | | 4.4 | | 7.5 | |

(a) Sampling locations are illustrated in Figure 4.1.1.
(b) To convert to international metric system units (picowatts per kilogram), multiply exposure rates by 2.109.
(c) Number of 30- or 60-minute averages used to compute monthly average.
(d) Readings are stored every 60 minutes. Each 60-minute reading is an average of 360 individual measurements.
(e) Readings were collected every second and averaged each minute. Minute averages were used to compute 60 minute maximum, minimum, and average values.
(f) Readings were collected every second and averaged each minute. Minute averages were used to compute 30 minute maximum, minimum, and average values.
(g) ND = No data collected; instrument problems.

(Leslie Groves Park) in December to a minimum of 4.4 μR/h (9.3 pW/kg/s) at Richland in November and at Edwin Markham School in December (see Table 4.7.4). Mean readings at the stations near Hanford were consistently between 7.4 and 8.9 μR/h, (15.6 and 18.8 pW/kg/s) and readings at the distant station (Heritage College) ranged between 7.9 and 8.7 μR/h (16.7 and 18.3 pW/kg/s). These average exposure rates were similar to exposure rates measured by thermoluminescent dosimeters at these locations (Table 4.7.5).

**Table 4.7.5. Quarterly Average Exposure Rates (μR/h[a,b]) Measured by Thermoluminescent Dosimeters at Four Offsite Locations,[c] 2001**

| Quarter Ending | Leslie Groves Park | Basin City | Edwin Markham | Toppenish |
|---|---|---|---|---|
| March | NS | 8.9 ± 0.08 | 8.5 ± 0.04 | 7.8 ± 0.21 |
| June | NS | 8.4 ± 0.25 | 8.5 ± 0.13 | 8.0 ± 0.54 |
| September | NS | NS | 8.8 ± 0.33 | 7.7 |
| December | 10.4 | 9.5 ± 0.42 | 9.1 ± 0.46 | 9.0 ± 0.54 |

(a) ±2 standard deviations.
(b) To convert to international metric system units (picowatts per kilogram), multiply exposure rates by 2.109.
(c) Sampling locations shown on Figure 4.1.1.
NS = No sample.