4.6 External Radiation Surveillance

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External radiation is defined as radiation originating from a source external to the body. External radiation fields consist of a natural component and a 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 during the early 1950s. The rad is equal to 100 ergs of ionizing energy deposited in one gram of material. The International System of Units introduced the Gray and is defined as follows: 1 Gray = 1 Joule per kilogram and is numerically equivalent to 100 rad (American Society for Testing and Materials 1993).

One device for measuring radiation absorbed dose is the thermoluminescent dosimeter (i.e., "dose meter") 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, measured and related to the amount of ionizing radiation energy stored in the material. Thermoluminescence, or light output exhibited by dosimeters when heated, 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 (0.227 L) cup of water will deposit enough energy in the water to increase the temperature of the water by about 1°F (0.55°C).

During 2002, environmental external radiation exposure was measured at 33 locations on the Hanford Site, 11 locations around the perimeter of the site, 9 locations in surrounding communities including 2 at distant locations, and 27 locations along the Columbia River shoreline using thermoluminescent dosimeters and pressurized ionization chambers. The dosimeter exposure was converted to dose rates by the process described above, then the dose rates were divided by the length of time the dosimeter was in the field. Annual results for 2002 were compared to results obtained during the previous 5 years. External radiation and surface contamination surveys at specified locations were performed with portable radiation survey instruments.

4.6.1 External Radiation Measurements

The Harshaw 8800-series environmental dosimeter consists of two TLD-700 (LiF) chips and two TLD-200 (CaF_2:Dy) 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 during 2002.

Thermoluminescent dosimeters were positioned ~1 meter (~3.3 feet) above the ground at 33 onsite locations (Figure 4.6.1). This is an increase of four onsite locations compared to 2001. Figure 4.6.2 shows the 11 locations around the site perimeter, 7 locations in nearby communities, and 2 distant locations. One community location (Leslie Groves Park) was moved due to continued vandalism and was re-classified as a shoreline location (N. Richland, location number 26 on Figure 4.6.3). Figure 4.6.3 shows the 27 locations along the Columbia River shoreline. 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 exposure (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 27 thermoluminescent dosimeters located in the area from Vernita Bridge 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-foot) area. The Bicron® measurements were taken 1 meter (3.3 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 (Section 4.6.3). 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. External dose rates reported in Tables 4.6.1 through 4.6.3 include the maximum annual dose rate (±2 standard deviations) for all locations within a given surveillance zone and the average 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.

Onsite Results. Table 4.6.1 summarizes the results of 2002 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 measured

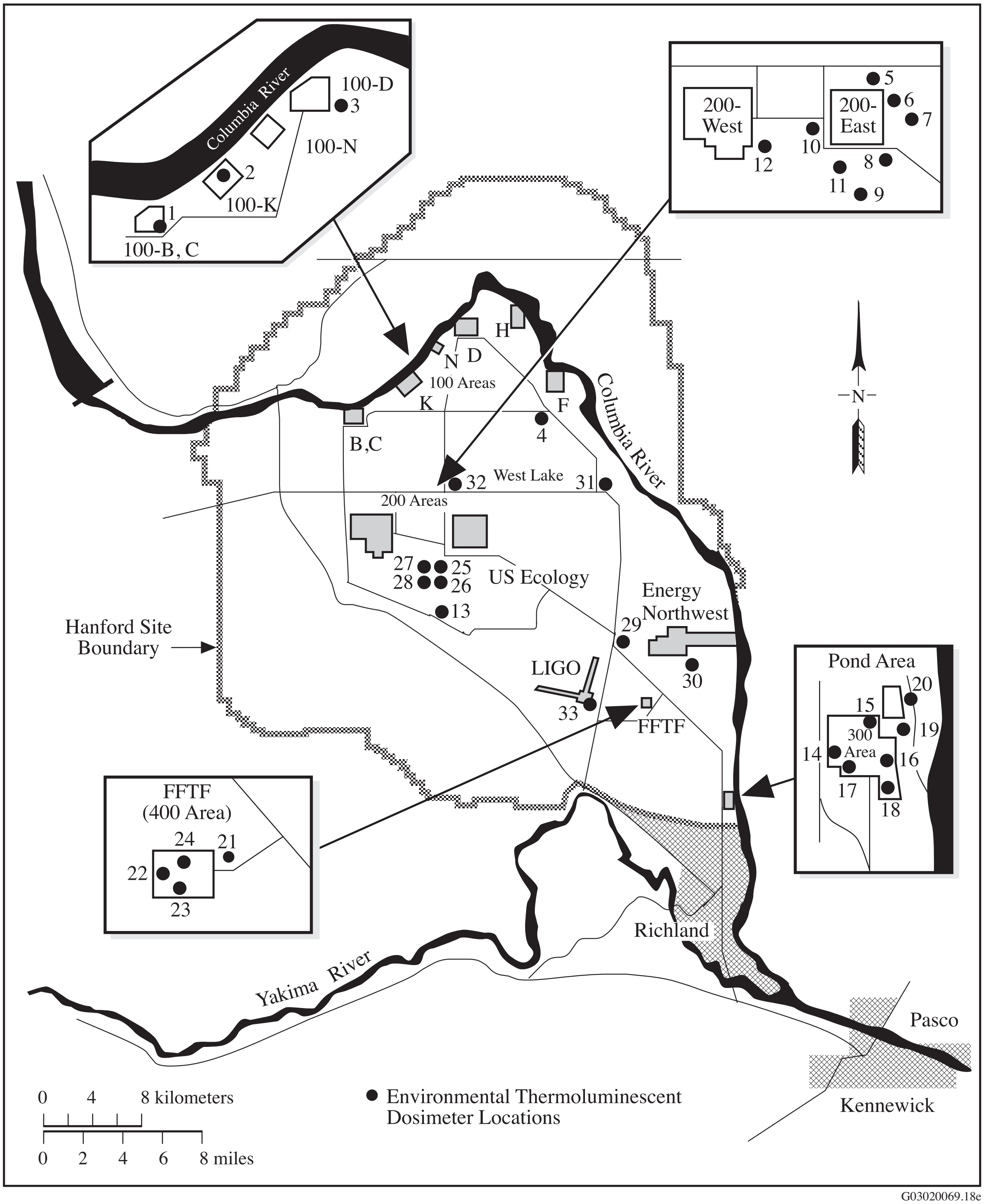

Figure 4.6.1. Surface Environmental Surveillance Project Thermoluminescent Dosimeter Locations (and Station Numbers) on the Hanford Site, 2002 (see Appendix B, Table B.10 for station names)

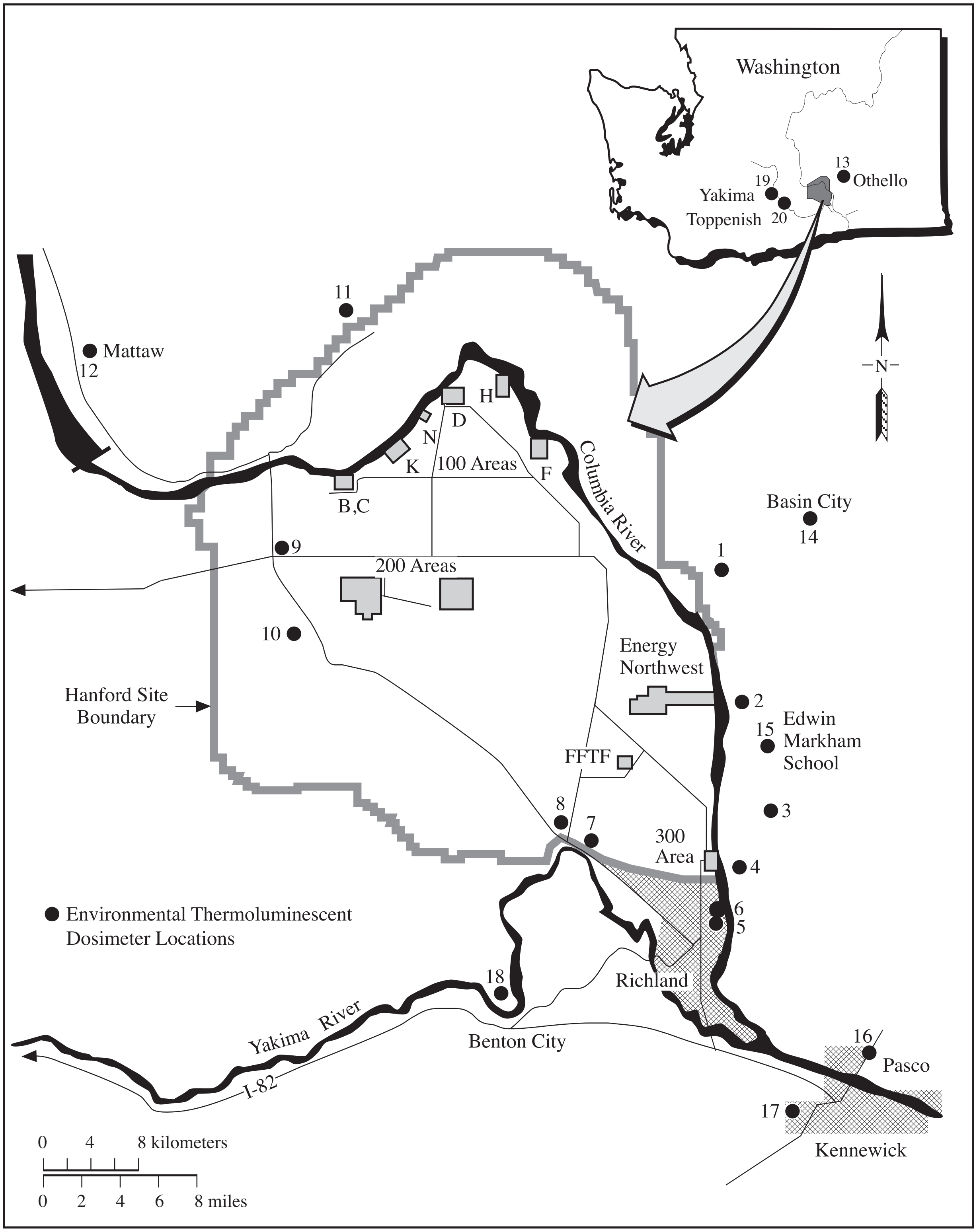

Figure 4.6.2. Community, Distant, and Perimeter Thermoluminescent Dosimeter Locations (and Station Numbers) Around the Hanford Site, 2002 (see Appendix B, Table B.10 for station names)

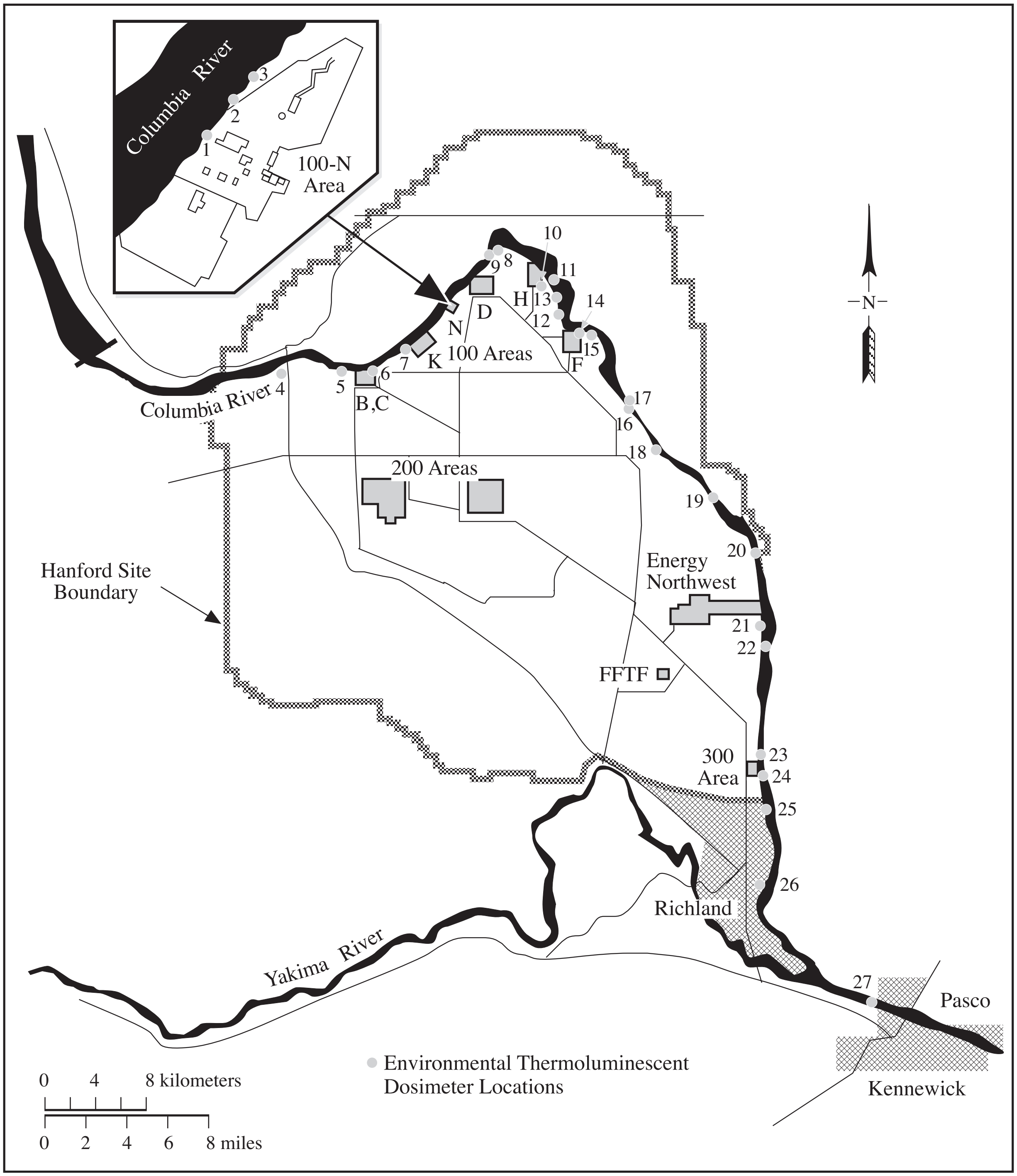

Figure 4.6.3. Hanford Site Surface Environmental Surveillance Project Thermoluminescent Dosimeter Locations (and Station Numbers) Along the Columbia River, 2002 (see Appendix B, Table B.10 for station names)

Table 4.6.1. Dose Rates (mrem/yr[a]) Measured by Thermoluminescent Dosimeters on the Hanford Site, 2002 Compared to Previous 5 Years

		2002		1997-2001		
Location	Map Location[(b)]	Maximum[(c)]	Mean[(d)]	No. of Samples	Maximum[(c)]	Mean[(d)]
100 Areas	1 - 4	87 ± 7	83 ± 5	13	88 ± 8	81 ± 3
200 Areas	5 - 13	95 ± 6	87 ± 3	41	98 ± 6	88 ± 2
300 Area	14 - 20	107 ± 6	87 ± 6	30	89 ± 7	82 ± 1
400 Area	21 - 24	88 ± 5	84 ± 2	20	89 ± 7	83 ± 1
600 Area	25 - 33	99 ± 7	86 ± 4	32	137 ± 31	91 ± 5
Combined onsite	1 - 33	107 ± 6	86 ± 2	136	137 ± 31	86 ± 1

(a) Multiply by 10 to convert to µSv/yr.
(b) All station locations are shown on Figure 4.6.2 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 4.6.2. Dose Rates (mrem/yr[a]) Measured by Thermoluminescent Dosimeters at Perimeter and Offsite Locations of the Hanford Site, 2002 Compared to Previous 5 Years

		2002		1997-2001		
Location	Map Location[(b)]	Maximum[(c)]	Mean[(d)]	No. of Samples	Maximum[(c)]	Mean[(d)]
Perimeter	1 - 11	104 ± 32	93 ± 4	48	106 ± 8	90 ± 2
Community	12 - 18	87 ± 9	80 ± 3	40	90 ± 9	79 ± 2
Distant	19 - 20	72 ± 5	72 ± 1	10	75 ± 9	71 ± 1

(a) Multiply by 10 to convert to µSv/yr.
(b) All station locations are shown on Figure 4.6.2 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).

by Pacific Northwest National Laboratory dosimeters on the Hanford Site during 2002 (107 ± 6 mrem [1.07 ± 0.06 mSv] per year) was detected at the newly established (2002) location on the north side of the 300 Area (location 17 in Figure 4.6.1). The 5-year maximum onsite dose rate (137 ± 31 mrem [1.37 ± 0.31 mSv] per year) was measured during 1997 near the US Ecology low-level waste disposal facility.

Offsite Results. Table 4.6.2 shows the maximum and average dose rates for perimeter and offsite locations measured in 2002 and the previous 5 years. The average perimeter dose rate was 93 ± 4 mrem (0.93 ± 0.04 mSv) per year in 2002; the maximum was 104 ± 32 mrem (1.04 ± 0.32 mSv) per year. The 5-year perimeter average dose rate was 90 ± 2 mrem (0.90 ± 0.02 mSv) per year and the 5-year maximum was 106 ± 8 (1.06 ± 0.08 mSv) per year. The location of this year's maximum perimeter dosimeter result was Rattlesnake Springs (location number 10 on Figure 4.6.2). 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

Table 4.6.3. Dose Rates (mrem/yr[a]) Measured by Thermoluminescent Dosimeters Along the Hanford Reach of the Columbia River, 2002 Compared to Previous 5 Years

Location	Map Location[b]	2002 Maximum[c]	2002 Mean[d]	1997-2001 No. of Samples	1997-2001 Maximum[c]	1997-2001 Mean[d]
100-N Area shoreline	1 - 3	100 ± 7	92 ± 8	18	153 ± 61	115 ± 14
Typical shoreline	4 - 27	98 ± 13	86 ± 3	107	102 ± 15	86 ± 2
All shoreline	1 - 27	100 ± 7	87 ± 3	125	153 ± 61	90 ± 3

(a) Multiply by 10 to convert to μSv/yr.
(b) All station locations are shown on Figure 4.6.2 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).

(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.

The average background dose rate (measured in distant communities) in 2002 was 72 ± 1 mrem (0.72 ± 0.01 mSv) per year compared to the previous year's average of 72 ± 2 mrem (0.72 ± 0.02 mSv) per year (PNNL-13910) and the 5-year average of 71 ± 1 mrem (0.71 ± 0.01 mSv) per year.

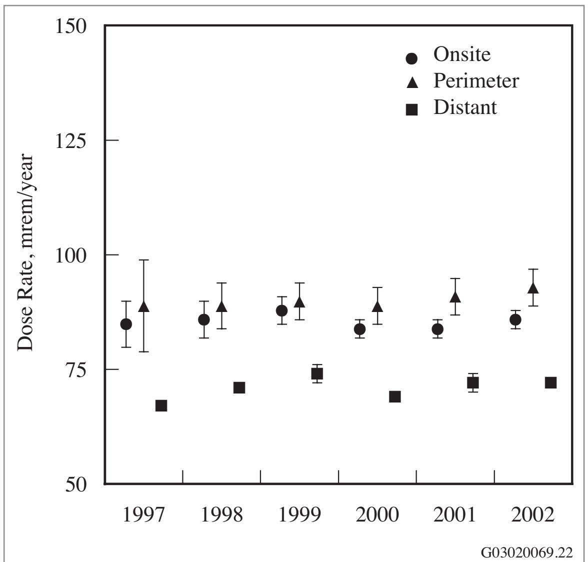

Figure 4.6.4. Annual Average Dose Rates (±2 standard error of the mean) at Onsite, Perimeter, and Distant Locations of the Hanford Site, 1997 through 2002

Figure 4.6.4 displays a comparison of dose rates between onsite, perimeter, and distant thermoluminescent dosimeter locations from 1997 through 2002.

Columbia River Shoreline Results. During 2002, dose rates along the Columbia River shoreline near the 100-N Area were about the same as the typical shoreline dose rates (Table 4.6.3). Higher dose rates historically measured along the 100-N Area shoreline were attributed to waste management practices in that area (PNL-3127). The shoreline location of the highest average thermoluminescent dosimeter reading was along the 100-N Area shoreline. The 2002 maximum annual 100-N Area shoreline dose rate was 100 ± 7 mrem (1.00 ± 0.07 mSv) per year, which is significantly different from the maximum of 129 ± 6 mrem (1.29 ± 0.06 mSv) per year measured in 2001 (PNNL-13910), but is not significantly different than the 5-year maximum of 153 ± 61 mrem (1.53 ± 0.61 mSv) per year measured during 1997. They are not considered different because of the overlap between the two distributions. The 5-year maximum was measured along the 100-N Area shoreline. Over the past 5 years, the maximum dose rates along the 100-N Area shoreline have decreased as a result of cleanup efforts in the 100-N Area (Figure 4.6.5). 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 Chapter 5.

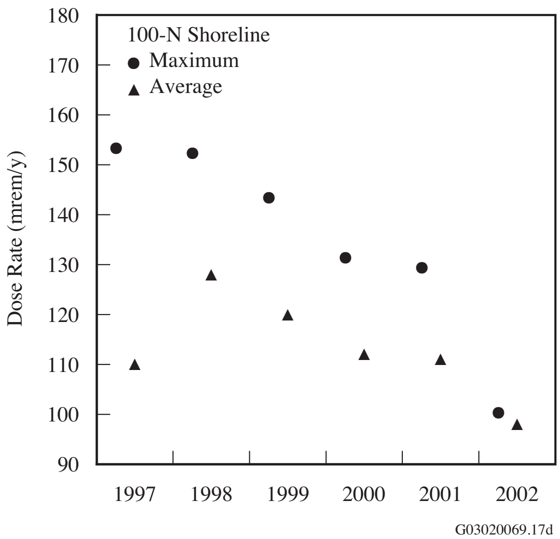

Figure 4.6.5. Maximum and Average External Dose Rates Measured Along the Columbia River at 100-N Area Shoreline Locations on the Hanford Site, 1997 through 2002

4.6.2 Radiological Survey Results

During 2002, Bicron® Microrem meters and Geiger counters were used to perform radiological surveys at selected Columbia River shoreline locations. These surveys provide a coarse screening for elevated radiation fields. The highest dose rate measured with the Bicron® Microrem meter (70 μrem [0.7 (μSv] per hour) was measured in September along the 100-N Area shoreline; the lowest dose rate measured with the Bicron® Microrem meter was 0.4 μrem (0.004 μSv) per hour and was recorded at the south end of Vernita Bridge (location 4 on Figure 4.6.3) in June. The 70 μrem (0.7 μSv) per hour is abnormally high, ~350% higher than the maximum shoreline survey result reported last year and 700% higher than any other shoreline recorded Bicron® Microrem meter measurement made during 2002. The thermoluminescent dosimeter result for the quarter at the 100-N Area shoreline did not corroborate the high Bicron® Microrem meter reading. Likewise, the lowest Bicron® Microrem meter reading, 0.4 μrem per hour, did not agree with the thermoluminescent dosimeter reading obtained at the Vernita Bridge Station. The highest reported count rate measured with the Geiger counter in ground level surveys (100 counts per minute) was measured at various locations and in multiple yearly quarters. The lowest ground level count rate (50 counts per minute) was recorded at the several locations throughout the year.

4.6.3 Pressurized Ionization Chamber Results

Gamma radiation levels were monitored with pressurized ionization chambers at four community-operated air-monitoring stations during 2002 (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 (locations 37 on Figure 4.1.1 and 15, 14, and 20, respectively, on Figure 4.6.2). 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 information for the teachers who manage the stations.

Data collection systems consist of computers, data loggers, and modems or radiotelemetry instruments. The computers at Leslie Groves Park and Heritage College are accessed using telephone modems and data are obtained directly from the station. The computers at Edwin Markham Elementary School and Basin City Elementary School are connected by radiotelemetry to a computer at the Hanford Meteorology Station (near the 200-West Area). These data are summarized and posted on the Internet (Section 8.4).

Readings at the Leslie Groves Park and Heritage College stations were collected every 5 seconds and an average reading was recorded every hour. Data at Basin City and Edwin Markham School were collected every second and averaged every 15 minutes. The 15-minute averages were then used to generate a 60-minute average. The measurements at all four locations were made with Reuter-Stokes Model RSS-121 pressurized ionization chambers (Table 4.6.4).

Average hourly exposure rates ranged from a maximum of 41.9 μR per hour (88.4 pW/kg per second) at Edwin Markham School during September to a minimum of 1.0 μR per hour (2.1 pW/kg per second) in Leslie Groves Park in

Table 4.6.4. Average Exposure Rates[a] Measured by Pressurized Ionization Chambers at Four Locations Around the Hanford Site,[b] 2002

Month		Exposure Rate, µR/h[c] (number of hourly averages) Leslie Groves Park[d]		Basin City[e]		Edwin Markham[e]		Toppenish[d]	
January	Mean	8.5	(744)	7.7	(713)	7.7	(743)	7.9	(662)
	Maximum	9.3		10.8		39.3		8.4	
	Minimum	4.1		7.4		7.2		6.8	
February	Mean	8.7	(672)	7.8	(648)	7.8	(652)	8.0	(672)
	Maximum	10.3		8.8		9.2		9.8	
	Minimum	5.7		7.3		6.6		7.4	
March	Mean	8.1	(500)	7.9	(625)	7.8	(743)	8.0	(81)
	Maximum	9.4		9.7		9.2		8.7	
	Minimum	7.7		7.6		5.8		7.7	
April	Mean	ND[f]		7.7	(692)	7.8	(720)	8.2	(530)
	Maximum	ND		9.8		9.0		9.2	
	Minimum	ND		7.3		7.4		7.7	
May	Mean	8.5	(607)	ND		7.7	(745)	8.1	(744)
	Maximum	9.0		ND		8.7		10.0	
	Minimum	3.4		ND		7.5		7.6	
June	Mean	8.4	(720)	ND		7.8	(700)	8.0	(720)
	Maximum	10.0		ND		9.3		9.9	
	Minimum	2.3		ND		7.0		7.6	
July	Mean	8.4	(654)	7.8	(682)	7.7	(622)	7.9	(744)
	Maximum	9.1		10.1		12.5		9.8	
	Minimum	7.6		7.4		7.0		7.5	
August	Mean	8.4	(616)	7.8	(737)	7.6	(745)	8.1	(744)
	Maximum	9.1		8.4		8.2		10.0	
	Minimum	3.2		7.4		7.4		7.6	
September	Mean	8.6	(720)	7.8	(738)	7.8	(751)	8.6	(719)
	Maximum	9.2		8.5		41.9		10.7	
	Minimum	5.3		7.1		7.2		7.6	
October	Mean	8.8	(744)	7.7	(320)	7.9	(695)	8.7	(744)
	Maximum	9.7		8.3		9.7		10.0	
	Minimum	1.0		7.4		7.3		7.8	
November	Mean	8.7	(720)	7.9	(644)	8.0	(628)	8.6	(720)
	Maximum	10.0		9.0		9.2		10.1	
	Minimum	1.0		7.1		7.4		7.7	
December	Mean	8.6	(744)	8.0	(693)	8.1	(702)	8.5	(730)
	Maximum	11.0		9.6		10.4		10.2	
	Minimum	1.0		7.5		7.5		7.9	

(a) Maximum and minimum values are hourly averages. Means are monthly means.
(b) Measurement locations are illustrated in Figure 4.1.1.
(c) To convert to international metric system units (picowatts per kilogram), multiply exposure rates by 2.109.
(d) Readings are stored every 60 minutes. Each 60-minute reading is an average of as many as 720 individual measurements collected at 5-second intervals.
(e) Readings were collected every second and averaged every 15 minutes. Fifteen-minute averages were used to compute 60-minute averages (as many as 3,600 individual measurements per hour).
(f) ND = No data collected; instrument problems.

October, November, and December (Table 4.6.4). Monthly mean readings were consistently between 7.3 and 8.8 μR per hour (15.4 and 18.6 pW/kg per second) at the stations near Hanford, and ranged between 7.9 and 8.7 μR per hour (16.7 and 18.3 pW/kg per second) at the distant station (Heritage College). These mean exposure rates were similar to exposure rates measured by thermoluminescent dosimeters at these locations (Table 4.6.5).

Table 4.6.5. Quarterly Average Exposure Rates (μR/h[a,b]) Measured by Thermoluminescent Dosimeters at Four Locations Around the Hanford Site,[c] 2002

Quarter Ending	Leslie Groves Park[d]	Basin City	Edwin Markham	Toppenish
March	8.83 ± 0.00	8.79 ± 0.04	8.88 ± 0.04	7.96 ± 0.13
June	8.42 ± 0.25	8.63 ± 0.08	8.46 ± 0.00	8.00 ± 0.17
September	8.50 ± 0.25	9.00 ± 0.00	8.54 ± 0.08	7.71 ± 0.04
December	8.79 ± 0.00	9.00 ± 0.25	9.33 ± 0.17	9.00 ± 0.54

(a) ± counting error.
(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.
(d) Thermoluminescent dosimeter located ~1 kilometer (0.6 mile) north of Leslie Groves Park at location 26.