5.0 Potential Radiological Doses from 2001 Hanford Operations

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During 2001, potential radiological doses to the public and biota from Hanford Site operations were evaluated in detail to determine compliance with pertinent regulations and limits. The potential sources of radionuclide contamination included gaseous emissions from stacks and ventilation exhausts, liquid effluents from operating wastewater treatment facilities, and contaminated groundwater seeping into the Columbia River. Other potential sources included fugitive emissions from contaminated soil areas and facilities. The methods used to calculate the potential doses are detailed in Appendix E.

The radiological impact of 2001 Hanford Site operations was assessed in terms of the:

- dose to a hypothetical, maximally exposed individual at an offsite location using a multimedia pathway assessment (U.S. Department of Energy [DOE] Order 5400.5; see Section 5.0.1)
- collective dose to the population residing within 80 kilometers (50 miles) of Hanford Site operating areas (see Section 5.0.2)
- dose for air pathways, using U.S. Environmental Protection Agency (EPA) methods, for comparison to the *Clean Air Act* standards in 40 CFR 61, Subpart H (see Section 5.0.3)
- maximum dose rate from external radiation at a publicly accessible location at or just within the site boundary (see Section 5.0.4.1)
- dose to an avid sportsman who consumes wildlife that may have been contaminated with radionuclides originating on the site (see Section 5.0.4.2)
- inhalation dose associated with measured radionuclide concentrations in air (see Section 5.0.4.4)
- absorbed dose received by animals exposed to radionuclide releases to the Columbia River and to radionuclides in onsite surface water bodies (see Section 5.0.6).

It is generally accepted that radiological dose assessments should be based on direct measurements of radiation dose rates and radionuclide concentrations. However, the amounts of most radioactive materials released during 2001 from Hanford Site sources were generally too small to be measured directly once they were dispersed in the offsite environment. For many of the radionuclides present in measurable amounts, it was difficult to separate the contributions from Hanford sources from the contributions from worldwide fallout and from naturally occurring uranium and its decay products. Therefore, in nearly all instances, offsite doses were estimated using GENII - The Hanford Environmental Radiation Dosimetry Software System, Version 1.485 (PNL-6584) and the Hanford Site-specific parameters listed in Appendix E and in PNNL-13910, APP. 1. As a comparison, air surveillance data were used to assess the maximum inhalation doses at onsite and offsite monitoring stations.

As in the past, radiological doses from the water pathway were calculated based on the differences in radionuclide concentrations between upstream and downstream sampling points on the Columbia River. During 2001, tritium, technetium-99, iodine-129, and uranium isotopes were found in the Columbia River downstream of Hanford at greater levels than predicted based on direct discharges from the 100 Areas (see Section 4.2 and Appendix B). All other radionuclide concentrations were lower than those predicted from known releases. Riverbank spring water, containing radionuclides, is known to enter the river along the portion of shoreline extending from the 100-B/C Area downstream to the 300 Area (see Sections 4.2 and 7.1). No direct discharge of radioactive materials from the 300 Area to the Columbia River was reported in 2001.

5.0.1 Maximally Exposed Individual Dose (Offsite Resident)

The maximally exposed individual is a hypothetical person who lives at a location and has a lifestyle that makes it unlikely that any other member of the public would receive a higher radiological dose. This individual's exposure pathways were chosen to maximize the combined doses from all reasonable environmental routes of exposure to radionuclides in Hanford Site effluents and emissions using a multimedia pathway assessment (DOE Order 5400.5). In reality, such a combination of maximized parameters is highly unlikely to apply to any single individual.

The location of the hypothetical maximally exposed individual can vary from year to year, depending on the relative contributions of the several sources of radioactive effluents released to the air and to the Columbia River from Hanford facilities (Figure 5.0.1). In 2001, the dose assessment determined that the DOE maximally exposed individual was located across the Columbia River from the 300 Area, at Sagemoor (see Figure 5.0.1). For the calculation, it was assumed that this individual:

- inhaled and was submersed in airborne radionuclides
- received external exposure to radionuclides deposited on the ground
- ingested locally grown food products that had been irrigated with water from the Columbia River
- used the Columbia River for recreational purposes, resulting in direct exposure from water and radionuclides deposited on the shoreline
- ingested locally caught fish.

Doses were calculated using effluent data in Tables 3.1.1 and 3.1.4 and the calculated quantities of radionuclides assumed to be present in the Columbia River from riverbank springs. The estimated releases to the river from these sources were derived from the difference between the upstream and downstream concentrations. These radionuclides were assumed to enter the river through groundwater seeps between the 100-B/C Area and the 300 Area.

The calculated doses for the DOE maximally exposed individual in 2001 are summarized in Table 5.0.1. Site-specific parameters for food pathways, diet, and recreational activity used for the dose calculations are contained in Appendix E (Tables E.1, E.2, and E.4, respectively).

Historically at Hanford, there has been one primary expression of radiological risk to an offsite individual: this is the maximally exposed individual dose. However, the maximally exposed individual dose is currently calculated by two different methods in response to two different requirements:

- One maximally exposed individual dose computation is required by DOE Order 5400.5 and is calculated using the GENII computer code. This calculation considers all reasonable environmental pathways (e.g., air, water, food) that maximize a hypothetical individual offsite exposures to Hanford's radiological effluents and emissions.
- A second estimate of maximally exposed individual dose is required by the *Clean Air Act* and is calculated using an EPA dose modeling computer code (CAP-88) or other methods accepted by EPA for estimating offsite exposure. This offsite dose is based solely on an airborne radionuclide emissions pathway and considers Hanford's stack emissions and emissions from diffuse and unmonitored sources (e.g., windblown dust).

Because the DOE and EPA computer codes use different input parameters, the location and predicted dose of each agency's maximally exposed individual may be different. However, the estimated doses from both methods have historically been significantly lower than health-based exposure criteria.

Recently, DOE has allowed private businesses to locate their activities and personnel on the Hanford Site. This has created the need to calculate a maximum onsite occupational dose for an individual who is employed by a non-DOE business and works within the boundary of the Hanford Site. This dose is based on a mix of air emission modeling data, the individual's exposure at an onsite work location, and the individual's potential offsite exposure.

Another way to estimate risk is to calculate the collective dose. This dose is based on exposure to Hanford radiological contaminants through the food, water, and air pathways and is calculated for the population residing within 80 kilometers (50 miles) of the Hanford Site operating areas. The collective dose is reported in units of person-rem (person-sievert), which is the average estimated individual dose multiplied by the total number of people in the population.

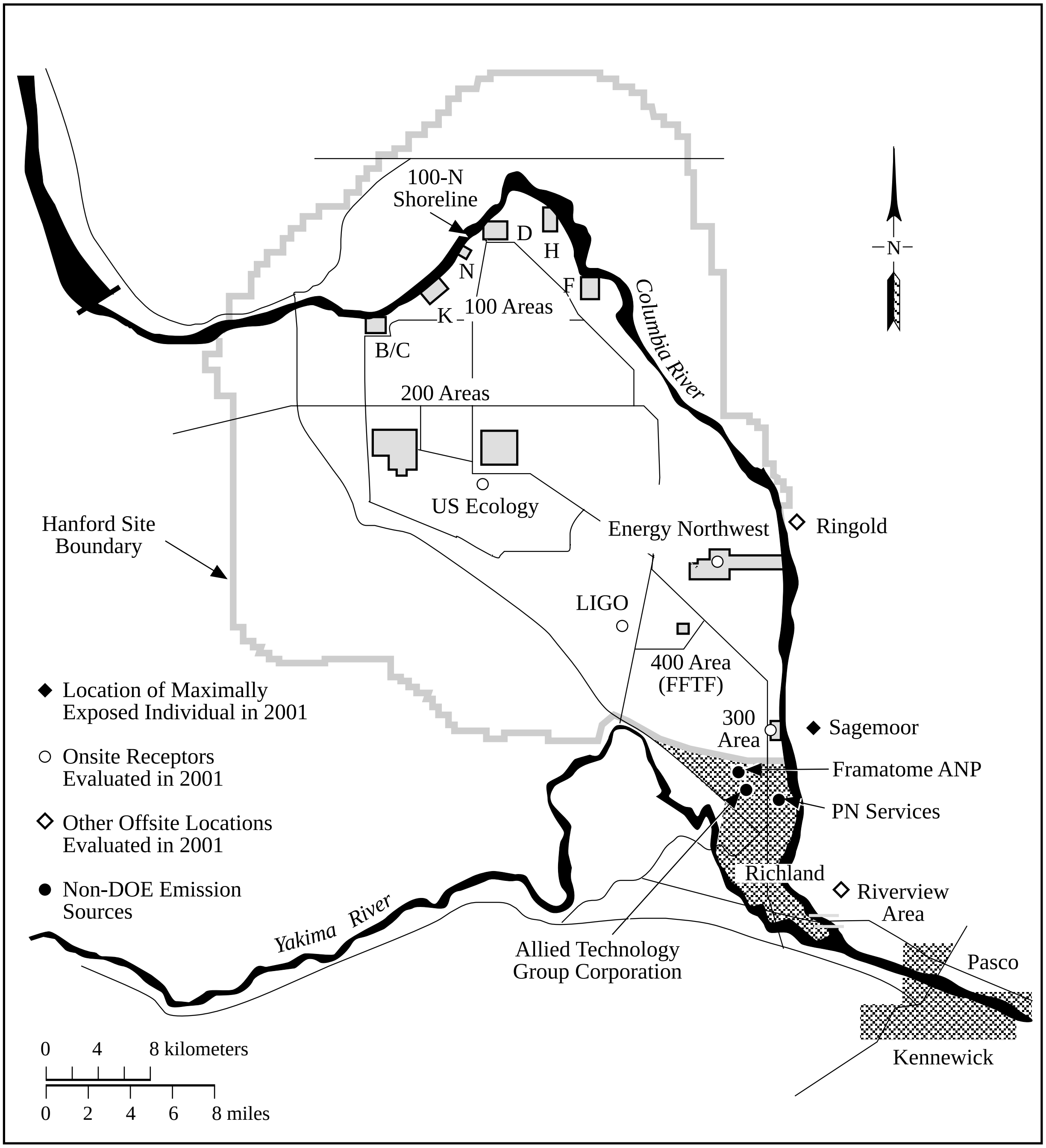

Figure 5.0.1. Locations Important to Dose Calculations

Table 5.0.1. Dose to the Hypothetical, Maximally Exposed Individual Residing at Sagemoor from 2001 Hanford Operations

		Dose Contributions from Operating Areas, mrem				
Effluent	**Pathway**	**100 Areas**	**200 Areas**	**300 Area**	**400 Area**	**Pathway Total**
Air	External	3.5×10^{-9}	2.0×10^{-7}	9.1×10^{-8}	1.9×10^{-8}	3.1×10^{-7}
	Inhalation	8.9×10^{-7}	3.4×10^{-4}	3.4×10^{-3}	4.5×10^{-6}	3.7×10^{-3}
	Foods	3.7×10^{-8}	9.1×10^{-5}	3.9×10^{-3}	2.0×10^{-6}	4.0×10^{-3}
	Subtotal air	9.3×10^{-7}	4.3×10^{-4}	7.3×10^{-3}	6.5×10^{-6}	7.7×10^{-3}
Water	Recreation	1.9×10^{-6}	6.2×10^{-11}	0.0[(a)]	0.0	1.9×10^{-6}
	Foods	9.5×10^{-4}	3.8×10^{-9}	0.0	0.0	9.5×10^{-4}
	Fish	7.7×10^{-4}	4.2×10^{-9}	0.0	0.0	7.7×10^{-4}
	Drinking water	0.0	0.0	0.0	0.0	0.0
	Subtotal water	1.7×10^{-3}	8.1×10^{-9}	0.0	0.0	1.7×10^{-3}
Combined total		1.7×10^{-3}	4.3×10^{-4}	7.3×10^{-3}	6.5×10^{-6}	9.4×10^{-3}

(a) Zeros indicate no dose contribution to maximally exposed individual through water pathway.

In 2001, the total dose to the DOE maximally exposed individual at Sagemoor was calculated to be 0.009 mrem/yr (9×10^{-5} mSv/yr). The primary pathways contributing to this dose (and the percentage of all pathways) were:

- the consumption of food products grown downwind of Hanford (42%) and inhalation of air downwind of Hanford (39%), exposed principally to airborne releases of tritium from the 300 Area
- the consumption of fish from the Columbia River (10%) or foods irrigated with water withdrawn downstream of Hanford (8%), containing principally strontium-90.

The dose calculated for the maximally exposed individual for 2001 was 0.009% of the DOE limit of 100 mrem/yr (1 mSv/yr) specified in DOE Order 5400.5. For comparison purposes, the doses from Hanford operations for the maximally exposed individuals for 1997 through 2001 are illustrated in Figure 5.0.2.

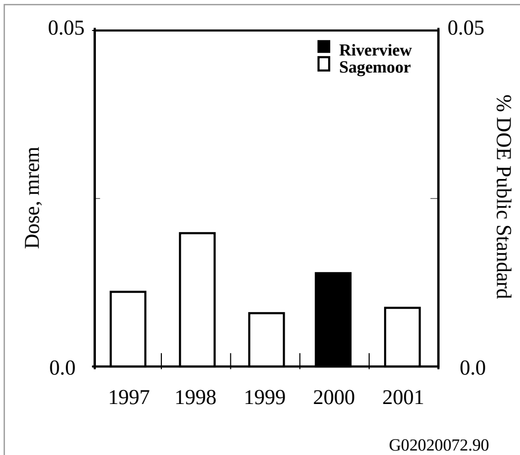

Figure 5.0.2. Calculated Dose to the Hypothetical, Maximally Exposed Individual, 1997 through 2001

5.0.2 Collective Dose

The regional collective dose from 2001 Hanford Site operations was estimated by calculating the radiological dose to the population residing within an 80-kilometer (50-mile) radius of the onsite operating areas. Collective dose is defined as the sum of doses to all individual members of the public within 80 kilometers (50 miles) of the operating areas at Hanford. In 2001, the collective dose calculated for the population was 0.4 person-rem/yr (0.004 person-Sv/yr), a slight increase from the 2000 collective dose (0.3 person-rem/yr [0.003 person-Sv/yr]) (Table 5.0.2). Summaries of technical details for the calculations of dose from airborne releases are given in Appendix E, Tables E.5 to E.9.

Table 5.0.2. Collective Dose to the Population from 2001 Hanford Operations

		Dose Contributions from Operating Areas, person-rem				
Effluent	Pathway	100 Areas	200 Areas	300 Area	400 Area	Pathway Total
Air	External	7.1×10^{-7}	2.2×10^{-5}	9.2×10^{-7}	9.6×10^{-7}	2.5×10^{-5}
	Inhalation	2.7×10^{-4}	5.4×10^{-2}	5.1×10^{-2}	3.4×10^{-4}	1.1×10^{-1}
	Foods	1.1×10^{-5}	1.3×10^{-2}	2.8×10^{-1}	2.3×10^{-4}	2.9×10^{-1}
	Subtotal air	2.8×10^{-4}	6.7×10^{-2}	3.3×10^{-1}	5.7×10^{-4}	4.0×10^{-1}
Water	Recreation	1.4×10^{-5}	3.0×10^{-10}	0.0[(a)]	0.0	1.4×10^{-5}
	Foods	9.9×10^{-4}	3.9×10^{-9}	0.0	0.0	9.9×10^{-4}
	Fish	2.9×10^{-4}	1.6×10^{-9}	0.0	0.0	2.9×10^{-4}
	Drinking water	2.4×10^{-3}	4.6×10^{-8}	0.0	0.0	2.4×10^{-3}
	Subtotal water	3.7×10^{-3}	5.2×10^{-8}	0.0	0.0	3.7×10^{-3}
Combined total		4.0×10^{-3}	6.7×10^{-2}	3.3×10^{-1}	5.7×10^{-4}	4.0×10^{-1}

(a) Zeros indicate no dose contribution to the population through the water pathway.

Primary pathways contributing to the 2001 collective dose included:

- inhalation of radionuclides (28%) that were released to the air, principally tritium from 300 Area stacks and plutonium isotopes emitted from 200 Areas stacks
- consumption of foodstuffs (72%) contaminated with radionuclides, principally tritium from 300 Area stacks and plutonium isotopes emitted from 200 Areas stacks.

The 80-kilometer (50-mile) collective doses attributed to Hanford operations from 1997 through 2001 are compared in Figure 5.0.3. Collective doses reported for 2001 are based on population data from the 2000 census, whereas doses for 1997 to 2000 were based on the 1990 census. Between 1990 and 2000, the population within 80 kilometers (50 miles) of the major operating areas on the Hanford Site increased by 24% to 29%. This change accounts for part of the increase in collective dose from 2000 to 2001 shown in Figure 5.0.3.

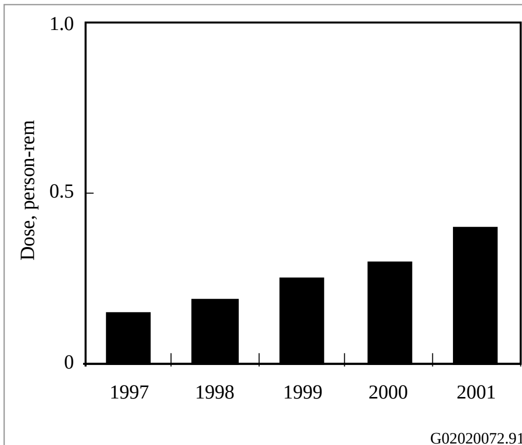

Figure 5.0.3. Collective Dose to the Population within 80 Kilometers (50 Miles) of the Hanford Site, 1997 through 2001

The average individual dose from 2001 Hanford Site operations based on a population of 486,000 within 80 kilometers (50 miles) was 0.0008 mrem/yr (0.008 µSv/yr). To place this estimated dose into perspective, it may be compared with doses received from other routinely encountered sources of radiation such as natural terrestrial and cosmic background radiation, medical treatment and x-rays, natural radionuclides in the body, and inhalation of naturally occurring radon. The national annual average radiological dose from these other sources is illustrated in Figure 5.0.4. The estimated annual average individual dose to members of the public from Hanford Site sources in 2001 was ~0.0003% of the estimated annual individual dose (300 mrem) received from natural background sources.

The doses from Hanford effluents to the DOE maximally exposed individual and to the population within 80 kilometers (50 miles) are compared to appropriate standards and natural background radiation in Table 5.0.3. This table shows that the calculated radiological doses from Hanford Site operations in 2001 were a small percentage of the standards and of doses from natural background sources.

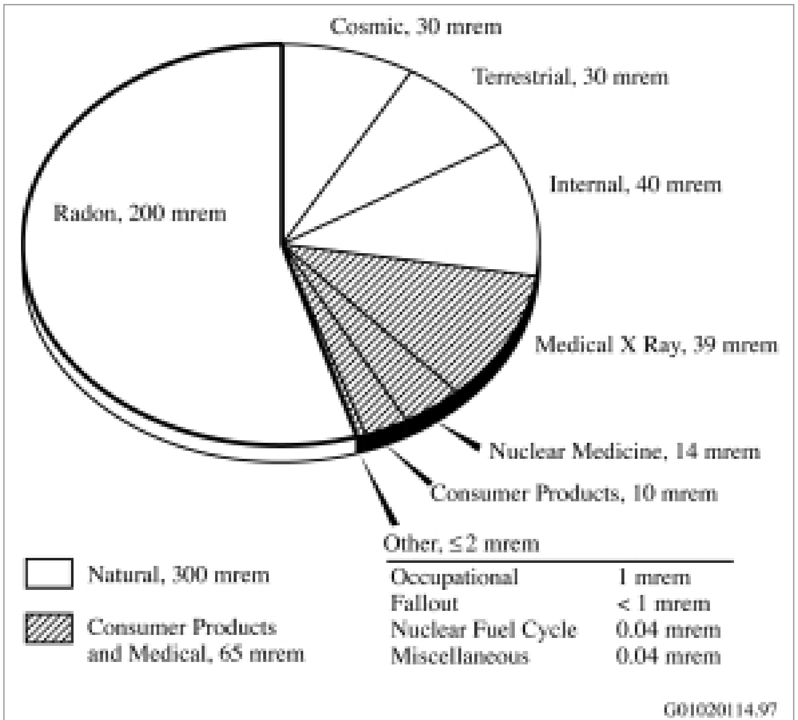

Figure 5.0.4. National Annual Average Radiological Doses from Various Sources (National Council on Radiation Protection and Measurements 1987)

Table 5.0.3. Comparison of Doses to the Public from Hanford Effluents to Federal Standards and Natural Background

Standard	Hanford Dose[a]	Hanford Dose Percent of Standard
DOE - 100 mrem/yr all pathways MEI[b,c]	0.009 mrem/yr	0.009
EPA - 10 mrem/yr air pathway MEI[d]	0.12 mrem/yr	1.2
Background Dose		
300 mrem/yr average U.S. individual[e]	0.009 mrem/yr	0.003
110,000 person-rem/yr to population within 80 km (50 mi)	0.4 person-rem/yr	0.0004

(a) To convert the dose values to mSv or person-Sv, divide by 100.
(b) DOE Order 5400.5.
(c) MEI = Maximally exposed individual.
(d) 40 CFR 61.
(e) National Council on Radiation Protection and Measurements (1987).

5.0.3 Compliance with Clean Air Act Standards

In addition to complying with the all-pathways dose limits established by DOE Order 5400.5, DOE facilities are required to demonstrate that they comply with standards established by the EPA for airborne radionuclide emissions under the *Clean Air Act* in 40 CFR 61, Subpart H. This regulation specifies that no member of the public shall receive a dose greater than 10 mrem/yr (0.1 mSv/yr) from exposure to airborne radionuclide emissions, other than radon, released at DOE facilities. Whereas DOE uses the GENII computer code at Hanford to determine dose to the all-pathways maximally exposed individual, EPA requires the use of CAP-88 (EPA 402-R-00-004) or other EPA-approved models to demonstrate compliance with the requirements in 40 CFR 61, Subpart H. The assumptions embodied in the CAP-88 code differ slightly from standard assumptions used with the GENII code. Therefore, air pathway doses calculated by the two codes may differ somewhat. In addition, the maximally exposed individual for air pathways may be evaluated at a different location from the all-pathways maximally exposed individual discussed in Section 5.0.1 because of the relative contributions from each exposure pathway.

The EPA regulation also requires that each DOE facility submit an annual report to EPA that supplies information about atmospheric emissions for the preceding year and their potential offsite dose. For more detailed information about 2001 air emissions on the Hanford Site, refer to DOE's report to EPA (DOE/RL-2002-20).

Maximum Dose to Non-DOE Workers on the Site. The DOE Richland Operations Office received guidance from EPA Region 10 and the Washington State Department of Health that, in demonstrating compliance with the 40 CFR 61 standards, it should evaluate potential doses to non-DOE employees who work on the Hanford Site, but who are not under direct DOE control. Accordingly, the doses to members of the public employed at non-DOE facilities that were outside access-controlled areas on the Hanford Site were evaluated for the 2001 EPA air emissions report (DOE/RL-2002-20). These locations included the Columbia Generating Station operated by Energy Northwest, the Laser Interferometer Gravitational Wave Observatory (LIGO) operated by the University of California, a commercial metal extrusion facility in the 313 Building at the north end of the 300 Area (leased until January 2002), and a research laboratory on the west side of the 300 Area leased to Washington State University (see Figure 5.0.1). Because 300 Area emissions accounted for the majority of the air pathway dose during 2001, a person working in the commercial metal extrusion facility in the 300 Area received the highest dose for non-DOE employees who worked on the Hanford Site. The dose was calculated to be 0.12 mrem/yr (0.0012 mSv/yr), assuming full-time occupancy at that location for the year.

EPA guidance does not currently permit adjustment of doses calculated using the CAP-88 code to account for less than full-time occupancy at locations within the site boundary. However, if a realistic occupancy period of 2,000 hours per year were assumed for workers at onsite non-DOE facilities, the doses to individuals at any of the locations evaluated would be lower than the dose to the maximally exposed offsite individual that has historically been evaluated for compliance with the EPA standard. Methods to estimate doses to individuals within the site boundary are currently under discussion by DOE and EPA.

Maximum Dose to an Offsite Maximally Exposed Individual. In 2001, the maximally exposed offsite individual for air pathways using EPA specified methods was determined to be at a location in the Sagemoor area of Franklin County, ~1.5 kilometers (~1 mile) directly across the Columbia River from the 300 Area (see Figure 5.0.1). The potential air pathway dose from stack emissions to a maximally exposed individual at that location was calculated to be 0.048 mrem/yr (0.00048 mSv/yr), which represented <0.5% of the EPA standard. This corresponds to the dose for offsite individuals calculated for previous annual air emission reports to EPA.

Dose from Diffuse and Fugitive Sources of Airborne Radionuclides. The December 15, 1989, revisions to the *Clean Air Act* (40 CFR 61, Subpart H) required DOE facilities to estimate the dose to a member of the public for radionuclides released from all potential sources of airborne radionuclides. DOE and EPA interpreted the regulation to include diffuse and fugitive sources as well as monitored point sources (i.e., stacks). EPA has not specified or approved methods to estimate air emissions from diffuse sources, and standardization has been difficult because of the wide variety of such sources at DOE sites. The method developed at Hanford to estimate potential diffuse source emissions is based on environmental surveillance measurements of airborne radionuclides at the site perimeter, as described in DOE/RL-2002-20. During 2001, the estimated dose to a maximally exposed individual at a location in the Sagemoor area from diffuse sources was 0.38 mrem/yr (0.0038 mSv/yr). The dose to a non-DOE worker in the 300 Area from diffuse and fugitive sources would be similar to, or lower than, the dose at the site perimeter. Therefore, the potential combined dose from stack emissions and diffuse sources during 2001 was well below the EPA 10 mrem/yr (0.1 mSv/yr) standard for either onsite or offsite members of the public.

5.0.4 Special Case Dose Estimates

The parameters used to calculate the dose to the DOE maximally exposed individual were selected to provide a scenario yielding a reasonable upper (or bounding) estimate of the dose. However, such a scenario may not have necessarily resulted in the highest conceivable radiological dose. Other low-probability exposure scenarios existed that could have resulted in somewhat higher doses. Four scenarios that could have potentially lead to larger doses included (1) an individual who spent time at the site boundary location with the maximum external radiological dose rate, (2) a sportsman who consumed contaminated wildlife that migrated from the site, (3) a person who drank water at the Fast Flux Test Facility in the 400 Area, and (4) an individual who breathed the measured radionuclide concentrations in air for an entire year. The potential doses resulting from these scenarios are examined in the following sections.

5.0.4.1 Maximum "Boundary" Dose Rate

The boundary radiological dose rate is the external radiological dose rate measured at publicly accessible locations at or near the Hanford Site boundary. The maximum boundary dose rate was determined from radiation exposure measurements using thermoluminescent dosimeters at locations where elevated dose rates might be expected on the site and at representative locations off the site. These boundary dose rates were not used to calculate annual doses to the general public because no one could actually reside at any of these boundary locations. However, these rates were used to determine the dose to a specific individual who might have spent some time at that location.

External radiological dose rates measured in 2001 are described in Section 4.6. Radiation measurements made along the 100-N Area shoreline (see Figure 5.0.1) were consistently above background levels and represented the highest measured boundary dose rates. The Columbia River provided public access to within ~100 meters (~330 feet) of the N Reactor and supporting facilities at this location.

The highest dose rate along the 100-N Area shoreline during 2001 was 0.015 mrem/h (0.00015 mSv/h), or ~1.5 times the average dose rate of 0.01 mrem/h (0.0001 mSv/h) normally observed at other shoreline locations. Therefore, for every hour someone spent near the 100-N Area shoreline during 2001, the external radiological dose received from Hanford operations was ~0.005 mrem (~0.00005 mSv) above the average shoreline dose rate. If an individual had spent 2 hours at that location, he or she would have received a dose comparable to the annual dose calculated for the hypothetical maximally exposed individual at Sagemoor. Members of the public could reach the 100-N shoreline by boat and could have legally occupied the shoreline area below the high water line. However, the topography of the shoreline below the high water line near the 100-N Area is very rocky and visitors are not likely to remain on shore for extended periods.

5.0.4.2 Sportsman Dose

Wildlife have access to areas of the Hanford Site that are contaminated with radioactive materials. Sometimes wildlife acquire radioactive contamination and migrate off the site. Wildlife sampling was conducted on the site to estimate the maximum contamination levels that might have existed in animals from Hanford that were hunted off the site. Because this scenario had a relatively low probability of occurrence, this pathway was not considered in the maximally exposed individual calculation.

Radionuclide concentrations in most consumable portions of wildlife obtained within the Hanford Site boundary were below contractual detection limits for gamma-emitting radionuclides, except for naturally occurring potassium-40 and for cesium-137 in one goose sample collected at a background location (see Section 4.5). The radiological dose to a person consuming 1 kilogram (2.2 pounds) of that goose was calculated to be ~7 μrem (~0.07 μSv). Strontium-90 was the only radionuclide, possibly of Hanford origin, detected in wildlife samples in 2001 and was only found in bone samples. Because bone is not consumed by humans, a dose to a sportsman from this pathway was viewed as relatively implausible and was not included in this report.

5.0.4.3 Onsite Drinking Water

During 2001, groundwater was used as drinking water by workers at the Fast Flux Test Facility in the 400 Area, and Columbia River water was used as a drinking water source in the 100-B, 100-D, 100-K, and 200 Areas. Therefore, these water supplies were sampled and analyzed throughout the year in accordance with applicable drinking water regulations (40 CFR 141). All annual average radionuclide concentrations measured during 2001 were below applicable drinking water standards. However, tritium in the Fast Flux Test Facility groundwater wells was detected at levels greater than typical background values (see Section 4.3 and Appendix E).

Based on the measured concentrations, the potential annual dose to Fast Flux Test Facility workers (an estimate derived by assuming a consumption of 1 liter [0.26 gallon] per day for 240 working days) would be ~0.02 mrem (~0.2 µSv). This dose is well below the drinking water dose limit of 4 mrem/yr (40 µSv/yr) for public drinking water supplies.

5.0.4.4 Inhalation Doses for Entire Year

Air surveillance data presented in Section 4.1 (Tables 4.1.2 and 4.1.3) were used to determine radiological doses from inhaling radionuclides in air. A nominal inhalation rate of 23 cubic meters (812 cubic feet) per day of air and an exposure period of 8,766 hours (365 days) were assumed for all offsite calculations. For onsite locations, the exposure period was reduced to 2,000 hours (250 8-hour workdays) to simulate a typical work year, and the breathing rate was increased to 28.8 cubic meters (1,017 cubic feet) per day to account for light duty work.

Table 5.0.4 presents radiological inhalation doses, in millirem per year, to hypothetical offsite individuals

Table 5.0.4. Inhalation Doses based on 2001 Air Surveillance Data[(a)]

Radionuclide	Location	Dose Based on Maximum Air Data (mrem/yr)[(b,c)]
Tritium	Onsite	1.6×10^{-3}
	Perimeter	1.9×10^{-2}
	Nearby communities	4.3×10^{-3}
	Distant communities	2.5×10^{-3}
Cobalt-60	Onsite	9.4×10^{-4}
	Perimeter	1.1×10^{-3}
	Nearby communities	8.5×10^{-4}
	Distant communities	5.6×10^{-4}
Strontium-90	Onsite	5.7×10^{-4}
	Perimeter	6.6×10^{-4}
	Nearby communities	5.8×10^{-4}
	Distant communities	1.5×10^{-4}
Iodine-129	Onsite	6.2×10^{-6}
	Perimeter	1.2×10^{-6}
	Nearby communities	0.0×10^{0}
	Distant communities	1.2×10^{-7}
Cesium-137	Onsite	3.0×10^{-5}
	Perimeter	1.7×10^{-4}
	Nearby communities	1.2×10^{-4}
	Distant communities	1.1×10^{-4}
Plutonium-238	Onsite	3.0×10^{-3}
	Perimeter	2.3×10^{-3}
	Nearby communities	2.8×10^{-3}
	Distant communities	3.7×10^{-4}
Plutonium-239/240	Onsite	2.3×10^{-2}
	Perimeter	1.4×10^{-2}
	Nearby communities	3.7×10^{-3}
	Distant communities	4.4×10^{-3}
Uranium-234	Onsite	7.9×10^{-3}
	Perimeter	7.0×10^{-2}
	Nearby communities	4.2×10^{-2}
	Distant communities	2.9×10^{-2}
Uranium-235	Onsite	4.3×10^{-4}
	Perimeter	2.7×10^{-3}
	Nearby communities	6.1×10^{-3}
	Distant communities	6.8×10^{-4}
Uranium-238	Onsite	9.5×10^{-3}
	Perimeter	5.0×10^{-2}
	Nearby communities	5.2×10^{-2}
	Distant communities	2.5×10^{-2}
Totals	Onsite	4.7×10^{-2}
	Perimeter	1.6×10^{-1}
	Nearby communities	1.1×10^{-1}
	Distant communities	6.2×10^{-2}

(a) Onsite inhalation dose calculations were based on 2,000-hour exposure period and 1.2 m^3/h breathing rate; all offsite inhalation dose calculations were based on a 8,766-hour exposure period and a 0.958 m^3/h breathing rate.
(b) Includes contributions from DOE activities as well as contributions from atmospheric fallout, naturally occurring radionuclides, and non-DOE facilities on and near the site.
(c) To convert to international metric system units (mSv/yr), divide reported values by 100.

modeled to be in the same location for the entire year and to onsite individuals located near air surveillance stations during their workday. The maximum air concentrations utilized in the calculations were assumed to be constant for the year-long evaluation period. Inhalation doses calculated using this method ranged from 0.047 mrem (0.00047 mSv) at onsite locations to 0.16 mrem (0.0016 mSv) at the site perimeter. These were comparable to doses reported for air pathways in Section 5.0.3.

5.0.5 Doses from Non-DOE Sources

DOE Order 5400.5, Section II, paragraph 7, has a reporting requirement for combined DOE and other manmade doses exceeding 100 mrem/yr (1 mSv/yr). In 2001, various non-DOE industrial sources of public radiation exposure existed on or near the Hanford Site. These included a commercial low-level radioactive waste burial ground at Hanford operated by US Ecology; a nuclear power-generating station at Hanford operated by Energy Northwest; a nuclear-fuel production plant operated near the site by Framatome ANP Richland, Inc.; a commercial, low-level, radioactive waste treatment facility operated near the site by Allied Technology Group; and a commercial decontamination facility operated near the site by PN Services (see Figure 5.0.1).

DOE maintains an awareness of these other sources of radiation, which, if combined with the DOE sources, might have the potential to cause a dose exceeding 10 mrem/yr (0.1 mSv/yr) to any member of the public. With information gathered from these companies (via personal communication and annual reporting), it was conservatively estimated that the total 2001 individual dose from their combined activities was on the order of 0.05 mrem/yr (5×10^{-4} mSv/yr). Therefore, the combined dose from Hanford area non-DOE and DOE sources to a member of the public for 2001 was well below any regulatory dose limit.

5.0.6 Dose Rates to Animals

Conservative (upper) estimates have been made of the radiological dose to native aquatic organisms in accordance with the DOE Order 5400.5 interim requirement for management and control of liquid discharges. The current limit for dose to aquatic biota is 1 rad (10 mGy) per day. The proposed limit for terrestrial biota is 0.1 rad (1 mGy) per day. Surveillance data from Columbia River shoreline springs, the Fast Flux Test Facility pond, and West Lake were evaluated using the RAD-BCG Calculator (a screening method to estimate radiological doses to aquatic and terrestrial biota). The RAD-BCG Calculator[a] (DOE 2000) is an Excel spreadsheet that initially compares radionuclide concentrations measured by routine surveillance programs to a set of conservative biota concentration guides (e.g., 1 rad [10 mGy] per day for aquatic biota). For samples containing multiple radionuclides, a sum of fractions is calculated to account for the contribution to dose from each radionuclide relative to the dose guideline. If the sum of fractions exceeds 1.0, then the dose guideline has been exceeded.

The biota concentration guides are very different from the derived concentration guides that are used to assess radiological doses to humans. If the estimated dose exceeds the guideline (sum of fractions >1.0), additional calculations are performed to more accurately evaluate exposure of the biota to the radionuclides. The process may culminate in a site-specific assessment requiring additional sampling and study of exposure.

Maximum concentrations of radionuclides in Columbia River and onsite pond sediment, and river-bank springs and pond water were evaluated using the RAD-BCG Calculator. The results indicated that all spring data resulted in doses below the guidelines (sum of fractions <1.0) (Table 5.0.5). Subsequent evaluations using the RAD-BCG Calculator, site-specific concentration factors derived from special surveillance data, and field survey data gathered to document pond use by shorebirds and other wildlife provided a more accurate sum of fractions (0.02). Radiological doses to plants and animals were also evaluated and were determined to be below guidelines based on the available data. The RAD-BCG Calculator was a useful tool for initially screening sites for biota doses and then for focusing on the sites where the likelihood of exceeding proposed guidelines was greatest.

(a) Memorandum from Dr. David Michaels (Assistant Secretary for Environmental, Safety, and Health) to Distribution, *Availability of DOE Technical Standard, "A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota (Project ENVR-0011)," for use in DOE Compliance and Risk Assessment Activities*, dated July 19, 2000.

Table 5.0.5. Results of RAD-BCG Calculator[a] Screenings

Location	Initial Screen (Sum of Fractions Value)	Pass or Fail
100-F Slough	3.2×10^{-2}	Pass
Hanford Slough	2.5×10^{-2}	Pass
McNary Dam	2.1×10^{-1}	Pass
Priest Rapids Dam	1.5×10^{-1}	Pass
Richland	3.6×10^{-2}	Pass
100-B Spring	8.9×10^{-2}	Pass
100-D Spring[b]	2.0×10^{-3}	Pass
100-F Spring	1.1×10^{-1}	Pass
100-H Spring[b]	6.2×10^{-2}	Pass
100-K Spring[b]	2.2×10^{-5}	Pass
100-N Spring	2.1×10^{-4}	Pass
300 Area Spring	7.3×10^{-1}	Pass
Hanford Town Site Springs[b]	1.8×10^{-2}	Pass
Vernita Bridge Spring[b]	2.0×10^{-3}	Pass

(a) A screening method to estimate radiological doses to aquatic and terrestrial biota.
(b) No sediment data used; only water data for screening.

5.0.7 Radiological Dose in Perspective

This section provides information to put the potential health risks associated with the release of radioactive materials from the Hanford Site into perspective. Several scientific studies (National Research Council 1980, 1990; United Nations Science Committee on the Effects of Atomic Radiation 1988) were performed to estimate the possible risk of detrimental health effects from exposure to low levels of radiation. These studies provided vital information to government and scientific organizations that recommend radiological dose limits and standards for public and occupational safety.

Although no increase in the incidence of health effects from low doses of radiation has actually been confirmed by the scientific community, regulatory agencies conservatively (cautiously) assume that the probability of these types of health effects at low doses (down to zero dose) is the same per unit dose as the health effects observed at much higher doses (e.g., in atomic bomb survivors, individuals receiving medical exposures, or radium dial painters). This concept is known as the linear no threshold hypothesis. Under these assumptions, even natural background radiation, which is hundreds of times greater than radiation from current Hanford Site releases, increases each person's probability or chance of developing a detrimental health effect.

Not all scientists agree on how to translate the available data on health effects into the numerical probability (risk) of detrimental effects from low-level radiological doses. Some scientific studies have indicated that low radiological doses may cause beneficial effects (e.g., Sagan 1987). Because cancer and hereditary diseases in the general population are caused by many sources (e.g., genetic defects, sunlight, chemicals, background radiation), some scientists doubt that the risk from low-level radiation exposure can ever be conclusively proven. In developing *Clean Air Act* regulations, EPA uses a probability value of ~4 per 10 million (0.0004) for the risk of developing a fatal cancer after receiving a dose of 1 mrem (0.01 mSv) (EPA 520/1-89-005). Additional data (National Research Council 1990) support the reduction of even this small risk value, possibly to zero, for certain types of radiation when the dose is spread over an extended time.

Government agencies are trying to determine what level of risk is safe for members of the public exposed to pollutants from industrial operations (e.g., DOE facilities, nuclear power plants, chemical plants, hazardous waste sites). All of these industries are considered beneficial to people in some way such as providing electricity, national defense, waste disposal, and consumer products.

Government agencies have a complex task to establish environmental regulations that control levels of risk to the public without unnecessarily reducing needed benefits from industry.

One perspective on risks from industry is to compare them to risks involved in other typical activities. For instance, two risks that an individual experiences when flying on an airplane are added radiological dose (from a stronger cosmic radiation field that exists at higher altitudes) and the possibility of being in an aircraft accident. Table 5.0.6 compares the estimated risks from various radiological doses to the risks of some activities encountered in everyday life. Table 5.0.7 lists some activities considered approximately equal in risk to that from the dose received by the maximally exposed individual from monitored Hanford effluents in 2001.

Table 5.0.6. Estimated Risk from Various Activities and Exposures[(a)]

Activity or Exposure Per Year	Risk of Fatality
Smoking 1 pack of cigarettes per day (lung/heart/other diseases)	$3,600 \times 10^{-6}$
Home accidents	100×10^{-6} [(b)]
Taking contraceptive pills (side effects)	20×10^{-6}
Drinking 1 can of beer or 0.12 L (4 oz) of wine per day (liver cancer/cirrhosis)	10×10^{-6}
Firearms, sporting (accidents)	10×10^{-6} [(b)]
Flying as an airline passenger (cross-country roundtrip - accidents)	8×10^{-6} [(b)]
Eating approximately 54 g (4 tbsp) of peanut butter per day (liver cancer)	8×10^{-6}
Pleasure boating (accidents)	6×10^{-6} [(b)]
Drinking chlorinated tap water (trace chloroform - cancer)	3×10^{-6}
Riding or driving in a passenger vehicle (483 km [300 mi])	2×10^{-6} [(b)]
Eating 41 kg (90 lb) of charcoal-broiled steaks (gastrointestinal tract cancer)	1×10^{-6}
Natural background radiological dose (300 mrem [3 mSv])	0 to 120×10^{-6}
Flying as an airline passenger (cross-country roundtrip - radiation)	0 to 5×10^{-6}
Dose of 1 mrem (0.01 mSv) for 70 yr	0 to 0.4×10^{-6}
Dose to the maximally exposed individual living near Hanford	0 to 0.004×10^{-6}

(a) These values are generally accepted approximations with varying levels of uncertainty; there can be significant variation as a result of differences in individual lifestyle and biological factors (Atallah 1980; Dinman 1980; Ames et al. 1987; Wilson and Crouch 1987; Travis and Hester 1990).

(b) Real actuarial values. Other values are predicted from statistical models. For radiological dose, the values are reported in a possible range from the least conservative (0) to the currently accepted most conservative value.

Table 5.0.7. Activities Comparable in Risk to the 0.009-mrem (0.0009-mSv) Dose Calculated for the 2001 Maximally Exposed Individual

- Driving or riding in a car 1 km (0.6 mi)
- Smoking less than 1/100 of a cigarette
- Flying approximately 2.2 km (1.4 mi) on a commercial airliner
- Eating approximately 2 tsp of peanut butter
- Eating one 0.15-kg (5.2-oz) charcoal-broiled steak
- Drinking 0.88 L (approximately 29 oz) of chlorinated tap water
- Being exposed to natural background radiation for 16 min in a typical terrestrial location
- Drinking approximately 0.03 L (0.5 oz) of wine or 0.09 L (1.6 oz) of beer

5.0.8 References

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