5.0 Potential Radiological Doses from 2003 Hanford Site Operations

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Potential radiological doses to the public and selected biota from Hanford Site operations were evaluated during 2003 to determine compliance with applicable regulations, standards, and U.S. Department of Energy (DOE) limits. The potential sources of radionuclide contamination included gaseous and particulate emissions from stacks and ventilation exhausts, contaminated fugitive dust, liquid effluent from operating wastewater treatment facilities, and contaminated groundwater seeping into the Columbia River. The methods used to calculate the potential doses are presented in Appendix E.

The radiological impact of 2003 Hanford Site operations was assessed in terms of the following criteria:

- Dose to a hypothetical, maximally exposed individual at an offsite location using an all pathways assessment (DOE Order 5400.5; Section 5.0.1).
- Collective dose to the population residing within 80 kilometers (50 miles) of active areas on the Hanford Site (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 Title 40, Code of Federal Regulations, Part 61 (40 CFR 61), Subpart H (Section 5.0.3).
- Maximum dose rate from external radiation at a publicly accessible location at the site boundary (Section 5.0.4.1).
- Dose to an avid sportsman who consumes wildlife that may have been contaminated with radionuclides originating on the site (Section 5.0.4.2).
- Inhalation dose associated with measured radionuclide concentrations in air (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 (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 amount of most radioactive materials released during 2003 from Hanford Site sources was generally too small to be measured directly once it was dispersed in the offsite environment. For many of the radionuclides present in measurable amounts, it was not possible to separate the contributions from Hanford sources from the contributions from fallout and from naturally occurring uranium and its decay products. As a consequence, offsite doses were estimated using release estimates of individual radionuclides and the GENII computer code (*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-14687, APP. 1. As a comparison, air surveillance data were used to assess the maximum inhalation doses at onsite and offsite monitoring stations.

Radiological doses associated with the water pathway were calculated based on the differences in radionuclide concentrations between upstream and downstream sampling points on the Columbia River. During 2003, tritium, technetium-99, iodine-129, and uranium isotopes were found in the Columbia River downstream of Hanford at higher levels than predicted based on direct discharges from the 100-K Area permitted outfall (Section 4.2 and Appendix C). 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 (Sections 4.2 and 6.0.3). No direct discharge of radioactive materials from the 300 Area to the Columbia River was reported during 2003.

5.0.1 Maximally Exposed Individual Dose (Offsite Resident)

The maximally exposed individual is a hypothetical person who is postulated to live at a particular location and have a lifestyle that makes it unlikely that any other member of the public would have received a higher radiological dose from Hanford releases during 2003. This individual's exposure pathways were chosen to maximize the combined doses from all reasonable environmental routes of exposure to radionuclides originating from the Hanford Site using an all pathways assessment (DOE Order 5400.5). In reality, it would be unreasonable to assume that such a combination of maximum values would apply to the exposure pathways for any individual in the Hanford environs.

The location of the hypothetical maximally exposed individual varies from year to year, depending on the relative contributions of the several sources of radioactive effluent released to the air and to the Columbia River from Hanford facilities (Figure 5.0.1). During 2003, the dose assessment determined that the maximally exposed individual was located across the Columbia River (east of the Hanford Site) at Sagemoor (Figure 5.0.1). For the calculation, the following assumptions for this individual was used:

- Was submersed in and inhaled 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 Hanford Site effluent data (Tables 3.1.1 and 3.1.4) and the calculated quantities of radionuclides taken to be present in the Columbia River from riverbank spring discharges. The estimated releases to the river from these sources were derived from the difference between the upstream and downstream concentrations in Columbia River water. These radionuclides were assumed to enter the river through shoreline groundwater seeps between the 100-B/C Area and the 300 Area.

During 2003, the all pathway dose to the maximally exposed individual at Sagemoor was calculated to be 0.06 mrem (0.6 μSv) per year (Table 5.0.1). This dose was

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 exposure to Hanford's radiological effluent 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 the 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 dose from both methods has historically been significantly lower than health-based exposure criteria.

The 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.

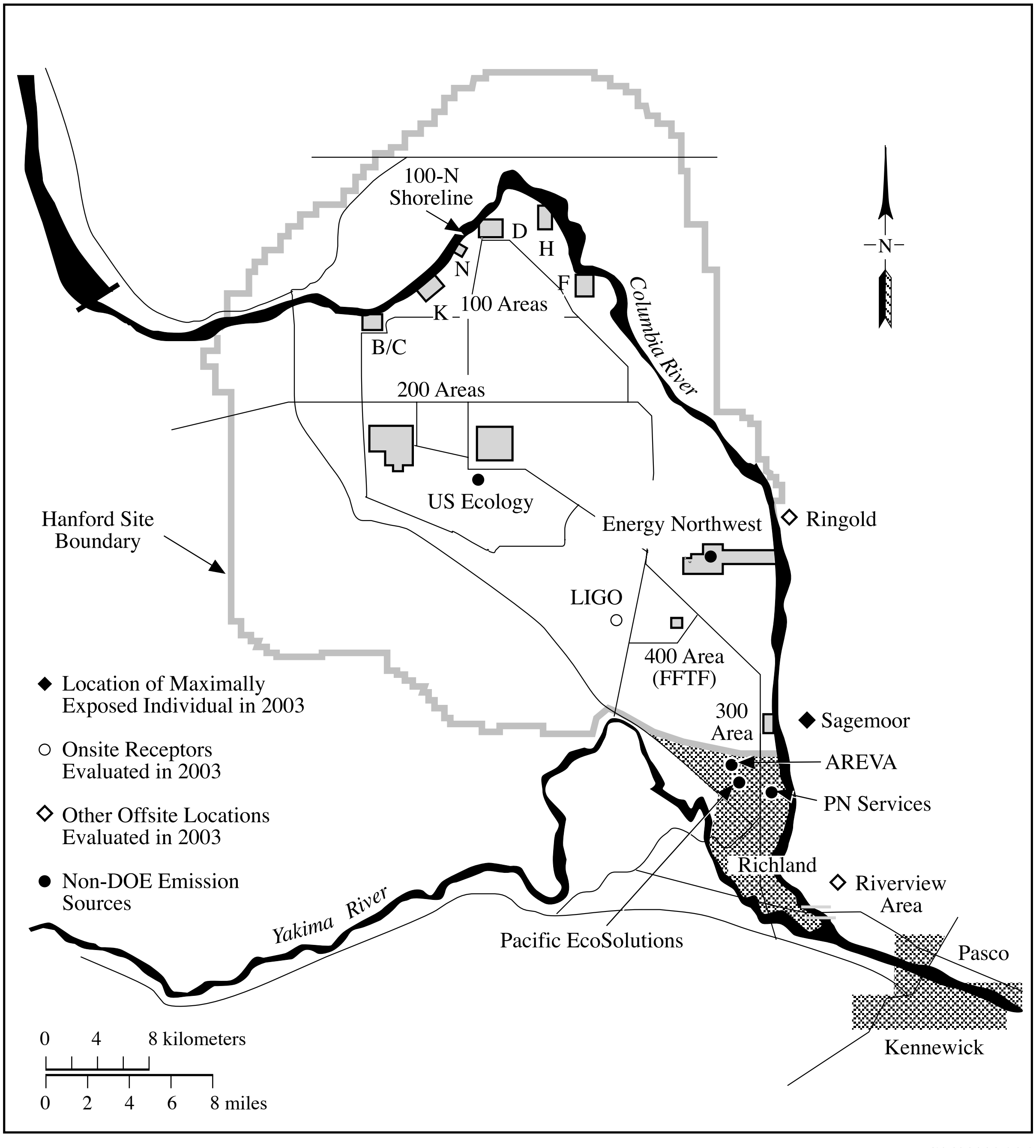

Figure 5.0.1. Locations Important to Dose Calculations at the Hanford Site

Table 5.0.1. Dose to the Hypothetical, Maximally Exposed Individual Residing at Sagemoor from 2003 Hanford Site Operations

		Dose Contributions from Operating Areas, mrem				
Effluent	**Pathway**	**100 Areas**	**200 Areas**	**300 Area**	**400 Area**	**Pathway Total**
Air	External	5.3×10^{-9}	1.7×10^{-7}	6.3×10^{-5}	1.6×10^{-8}	6.3×10^{-5}
	Inhalation	8.4×10^{-6}	6.8×10^{-5}	1.5×10^{-2}	2.5×10^{-6}	1.5×10^{-2}
	Foods	1.4×10^{-7}	8.2×10^{-5}	7.4×10^{-4}	4.8×10^{-6}	8.3×10^{-4}
	Subtotal air	8.5×10^{-6}	1.5×10^{-4}	1.6×10^{-2}	7.3×10^{-6}	1.6×10^{-2}
Water	Recreation	6.2×10^{-7}	1.1×10^{-4}	0.0[(a)]	0.0	1.1×10^{-4}
	Foods	3.2×10^{-4}	3.1×10^{-2}	0.0	0.0	3.1×10^{-2}
	Fish	2.6×10^{-4}	7.7×10^{-3}	0.0	0.0	8.0×10^{-3}
	Drinking water	0.0	0.0	0.0	0.0	0.0
	Subtotal water	5.8×10^{-4}	3.9×10^{-2}	0.0	0.0	3.9×10^{-2}
Combined total		5.9×10^{-4}	3.9×10^{-2}	1.6×10^{-2}	7.3×10^{-6}	5.5×10^{-2}

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

0.06% of the DOE's all pathway dose limit of 100 mrem (1 mSv) per year (Figure 5.0.2.). The principal pathways contributing to this dose and the percentage of the total dose the pathway represents are listed below:

- Consumption of foods irrigated with water withdrawn downstream of Hanford (56%).
- Consumption of fish from the Columbia River (14.5%).
- Inhalation of air downwind of Hanford (27%).
- Consumption of food products grown downwind of Hanford (1.5%).

5.0.2 Collective Dose

The regional collective dose from 2003 Hanford Site sources was estimated by calculating the radiological dose to the population residing within an 80-kilometer (50-mile) radius of onsite facilities. During 2003, the collective dose calculated for the population was 0.5 person-rem (0.005 person-Sv) per year, slightly higher than the 2002 collective dose (0.3 person-rem [0.003 person-Sv]) per year (Table 5.0.2) (Appendix E, Tables E.5 to E.9). Using the EPA's factor of 0.0006 latent cancer fatalities per person-rem, no fatalities would be expected from the 2003 collective population dose.

Primary pathways contributing to the 2003 collective dose included

- The consumption of water withdrawn from the Columbia River (42%).
- The inhalation of radionuclides (38%) that were released to the air.
- The consumption of foodstuffs (13%) contaminated with radionuclides.

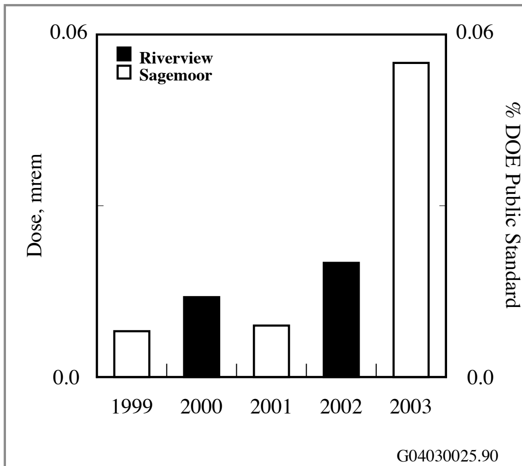

Figure 5.0.2. Calculated Dose to the Hypothetical, Maximally Exposed Individual at the Hanford Site, 1999 through 2003

Table 5.0.2. Collective Dose to the Population from 2003 Hanford Site Operations

Effluent	Pathway	Dose Contributions from Operating Areas, person-rem: 100 Areas	200 Areas	300 Area	400 Area	Pathway Total
Air	External	8.8×10^{-7}	1.7×10^{-5}	1.1×10^{-3}	8.2×10^{-7}	1.1×10^{-3}
	Inhalation	2.1×10^{-3}	1.0×10^{-2}	1.8×10^{-1}	1.8×10^{-4}	1.9×10^{-1}
	Foods	3.8×10^{-5}	1.2×10^{-2}	5.2×10^{-2}	6.0×10^{-4}	6.5×10^{-2}
	Subtotal air	2.1×10^{-3}	2.2×10^{-2}	2.3×10^{-1}	7.8×10^{-4}	2.6×10^{-1}
Water	Recreation	4.7×10^{-6}	6.3×10^{-4}	0.0[a]	0.0	6.3×10^{-4}
	Foods	3.3×10^{-4}	2.9×10^{-2}	0.0	0.0	2.9×10^{-2}
	Fish	9.7×10^{-5}	2.9×10^{-3}	0.0	0.0	3.0×10^{-3}
	Drinking water	8.0×10^{-4}	2.1×10^{-1}	0.0	0.0	2.1×10^{-1}
	Subtotal water	1.2×10^{-3}	2.4×10^{-1}	0.0	0.0	2.4×10^{-1}
Combined total		3.4×10^{-3}	2.6×10^{-1}	2.3×10^{-1}	7.8×10^{-4}	5.0×10^{-1}

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

Collective population doses reported for 2003 are based on population data from the 2000 census (Figure 5.0.3). 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.

The average estimated individual dose from 2003 Hanford Site operations based on a population of 486,000 within 80 kilometers (50 miles) was 0.001 mrem (10 nSv) per year.

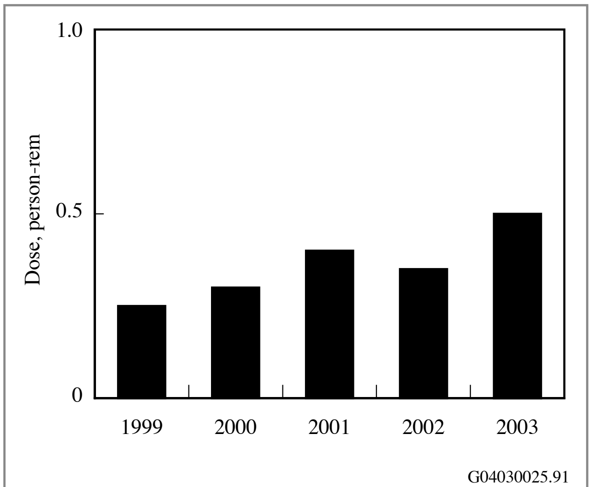

Figure 5.0.3. Collective Dose to the Population within 80 Kilometers (50 Miles) of the Hanford Site, 1999 through 2003

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 and natural radionuclides in the body, nominally approximately 100 mrem (1 mSv) per year (Figure 5.0.4). The estimated average individual dose to members of the public from Hanford Site sources during 2003 was approximately 0.0003% of the estimated annual individual dose received from natural background sources (300 mrem [3 mSv]). The calculated radiological doses from Hanford Site operations in 2003 were a small percentage of the standards and of doses from natural background sources (Table 5.0.3).

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 (0.1 mSv) per year from exposure to airborne radionuclide emissions, other than radon, released at DOE facilities. Whereas the DOE uses the GENII computer code at Hanford to determine dose to the all-pathways maximally exposed

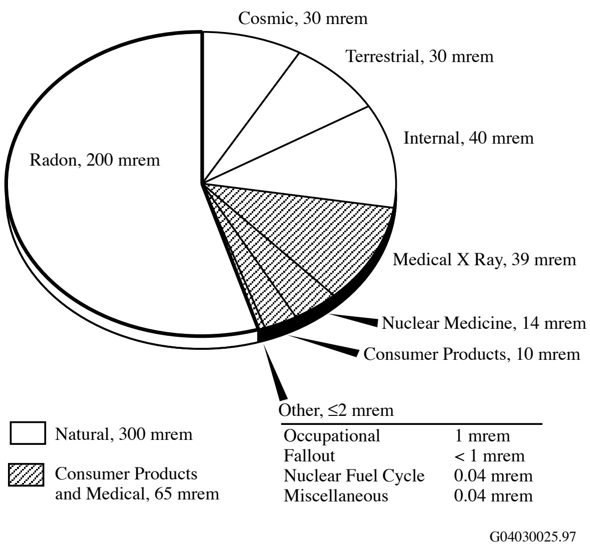

Figure 5.0.4. National Annual Average Radiological Doses from Various Sources (National Council on Radiation Protection and Measurements 1987)

individual, the 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 because of the relative contributions from each exposure pathway (Section 5.0.1).

The EPA regulation also requires that each DOE facility submit an annual report to the EPA that supplies information about atmospheric emissions for the preceding year and their potential offsite dose. For more detailed information about 2003 air emissions on the Hanford Site, refer to the DOE's report to the EPA (DOE/RL-2004-09).

Maximum Dose to an Offsite Maximally Exposed Individual. During 2003, 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, approximately 1.5 kilometers (1 mile) directly across the Columbia River from the 300 Area (Figure 5.0.1). The potential air pathway dose from stack emissions to a maximally exposed individual at that location was calculated by using the CAP-88 code to be 0.022 mrem (0.00022 mSv) per year, which represented less than 0.3% of the EPA standard. This is similar to the offsite individual doses calculated for the EPA in previous years and to the air pathway doses for stack emissions in Table 5.0.1.

Maximum Dose to Non-DOE Workers on the Site. The DOE Richland Operations Office received guidance from the EPA's Region 10 office and 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

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

Standard	Hanford Dose[(a)]	Hanford Dose Percent of Standard
DOE - 100 mrem/yr all pathways MEI[(b,c)]	0.06 mrem/yr	0.06
EPA - 10 mrem/yr air pathway MEI[(d)]	0.022 mrem/yr	0.22
Background Dose		
300 mrem/yr average U.S. individual[(e)]	0.001 mrem/yr	0.0003
144,000 person-rem/yr to population within 80 km (50 mi)	0.5 person-rem/yr	0.0003

(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).

non-DOE facilities that were outside access-controlled areas on the Hanford Site (those requiring DOE access authorization for entry) were evaluated for the 2003 EPA air emissions report (DOE/RL-2004-09). These locations included the Columbia Generating Station operated by Energy Northwest and the Laser Interferometer Gravitational Wave Observatory (LIGO) operated by the University of California (Figure 5.0.1). Of those locations, an employee at the Columbia Generating Station received the highest dose for non-DOE employees who worked on the Hanford Site. The dose from stack emissions calculated using the CAP-88 code was 0.0035 mrem (0.000035 mSv) per year, assuming full-time occupancy.

EPA guidance does not currently allow for 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 selected 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 reported for the Columbia Generating Station. In 2003, the estimated doses to non-DOE onsite workers were lower than the doses to offsite individuals for all locations.

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. The DOE and EPA interpreted the regulation to include diffuse and fugitive sources as well as monitored point sources (i.e., stacks). The EPA has not specified or approved standardized methods to estimate air emissions from diffuse sources 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 (DOE/RL-2004-09). During 2003, the estimated dose from diffuse sources to a maximally exposed individual at a location in the Sagemoor area was calculated using the CAP-88 code to be 0.062 mrem (0.00062 mSv) per year. This is consistent with results for recent years, where the dose from diffuse sources has been greater than the dose from stack emissions because radionuclide emissions from operating Hanford facilities are currently very low. The dose to an onsite non-DOE worker 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 2003 was well below the EPA 10 mrem (0.1 mSv) per year standard for either onsite or offsite members of the public.

5.0.4 Special Case Dose Estimates

Special case dose scenarios that may be of interest include four scenarios that could have potentially led 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 at various locations who breathed the measured radionuclide concentrations in air for an entire year. The potential doses resulting from these scenarios are presented 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 during 2003 were made along the 100-N Area shoreline (Figure 5.0.1) (Section 4.6). The measurements were consistently above background levels and represented the highest measured boundary dose rates. Use of the Columbia River provides public access to within approximately 100 meters (330 feet) of the N Reactor and supporting facilities at this location. Members of the public could reach the 100-N Area 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 N Reactor area is very rocky and visitors are not likely to remain on shore for extended periods.

The highest dose rate along the 100-N Area shoreline during 2003 was approximately 0.011 mrem (0.11 μSv) per hour, or 10% higher than the average dose rate of 0.01 mrem (0.1 μSv) per hour normally observed at other shoreline locations. Therefore, for every hour someone spent near the 100-N Area shoreline during 2003, the external radiological dose received from Hanford operations was approximately 0.001 mrem (0.01 μSv) above the average shoreline dose rate. If an individual had spent 60 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.

5.0.4.2 Sportsman Dose

Wildlife have access to areas of the Hanford Site that are contaminated with radioactive materials. Hypothetically, wildlife could acquire radioactive contamination and migrate off the site. Wildlife sampling was conducted on the site to estimate the maximum contamination levels that could 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.

Strontium and uranium isotopes were detected in honey samples collected from the East Wahluke Area and the Yakima Valley; however, no difference in strontium-90 concentrations was detected (Section 4.4.5). The East Wahluke area honey sample did have a minute amount of uranium detected (0.004 ± 0.0004 pCi/g). The radiological dose to a person consuming 1 kilogram (2.2 pounds) of the honey containing the maximum measured concentrations of uranium and strontium was calculated to be 0.01 mrem (0.001 mSv). Although honey is not considered wildlife, the consumption of this agricultural product is included here.

The radiological dose to a person consuming 1 kilogram (2.2 pounds) of Canada goose (*Branta canadensis*) breast meat containing the maximum measured concentration of cesium-137 (Section 4.5.1.2) was calculated to be approximately 3 μrem (0.03 μSv). Strontium-90 and cesium-137 were the only radionuclides, possibly of Hanford origin, detected in Canada goose samples during 2003 and strontium-90 was only found in bone samples. Because bone is not normally consumed by humans, a dose to a sportsman from this pathway was viewed as relatively implausible and was not included in this report.

The radiological dose to a person consuming 1 kilogram (2.2 pounds) of cottontail rabbit (*Sylvilagus nuttallii*) leg meat containing the maximum concentration of cesium-137 (Section 4.5.1.3) was calculated to be approximately 5 μrem (0.05 μSv). Strontium-90 was found in rabbit bone samples but because bone is not normally consumed by humans, a dose to a sportsman from this pathway was viewed as relatively implausible and was not included in this report. Samples of Asiatic clams (*Corbicula fluminea*) and crayfish (*Pacificastus leniusculus*) were also positive for radioactivity (Section 4.52); however, these organisms are not normally consumed by local residents, so a dose calculation for ingestion of these organisms is not reported here.

5.0.4.3 Onsite Drinking Water

During 2003, 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 2003 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 (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 250 working days) would be approximately 0.15 mrem (1.5 μSv). This dose is well below the benchmark drinking water standard of 4 mrem (40 μSv) per year for public drinking water supplies.

5.0.4.4 Inhalation Doses for Entire Year

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 (Tables 4.1.1 and 4.1.2). 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.

Radiological inhalation doses to hypothetical offsite individuals modeled to be in the same location for the entire year and to onsite individuals located near air surveillance stations during their workday are presented in Table 5.0.4. The average air concentrations (Table 4.1.2) were used in the calculations and assumed to be constant for the year-long evaluation period. Inhalation doses calculated using this method ranged from 0.066 mrem (0.00066 mSv) at nearby community locations to 0.00000074 mrem (0.0000074 µSv) at the site perimeter. The nearby community results were comparable to doses calculated using a slightly different method associated with the EPA's CAP-88 computer code and reported for the diffuse source calculations (Section 5.0.3).

Table 5.0.4. Calculated Inhalation Doses On and Around the Hanford Site Based on 2003 Average Air Surveillance Data[(a)]

Radionuclide	Location	Average Air Data (mrem/yr)[(b,c)]
Tritium	Onsite	9.90×10^{-4}
Iodine-129	Onsite	7.24×10^{-6}
	Perimeter	7.40×10^{-7}
	Distant communities	3.78×10^{-8}
Uranium-234	Nearby communities	3.82×10^{-2}
	Distant communities	2.18×10^{-2}
Uranium-238	Nearby communities	2.82×10^{-2}
	Distant communities	1.91×10^{-2}
Totals	Onsite	9.97×10^{-4}
	Perimeter	7.40×10^{-7}
	Nearby communities	6.64×10^{-2}
	Distant communities	4.10×10^{-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.

5.0.5 Doses from Non-DOE Sources

DOE Order 5400.5, Section II, paragraph 7, has a reporting requirement for a combined DOE and other manmade doses that exceeds 100 mrem (1 mSv) per year. During 2003, 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 AREVA; a commercial, low-level, radioactive waste treatment facility operated near the site by Pacific EcoSolutions (formerly Allied Technology Group Corporation); and a commercial decontamination facility operated near the site by PN Services (Figure 5.0.1).

The 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 (0.1 mSv) per year 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 2003 individual dose from their combined activities was on the order of 0.0023 mrem (0.000023 mSv) per year. Therefore, the combined annual dose from Hanford area non-DOE and DOE sources to a member of the public for 2003 was well below any regulatory dose limit.

5.0.6 Dose Rates to Animals

Upper estimates have been made of the radiological dose to 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 were evaluated using the RESRAD-BIOTA computer code (a screening method to estimate radiological doses to aquatic and terrestrial biota). The RESRAD-BIOTA computer code initially compares radionuclide concentrations in soil, water, or sediment measured by routine surveillance programs to a set of biota concentration guides (e.g., soil or water concentrations that result in a dose rate of 1 rad [10 mGy] per day for aquatic biota or 0.1 rad [1.0 mGy] per day for terrestrial organisms). The process involves two screening tiers. Tier 1 is a screening assessment based on maximum measured radionuclide concentrations, and Tier 2 is a screening assessment based on mean measured radionuclide concentrations.

For sediment or water samples containing multiple radionuclides, a sum of fractions is calculated to account for the contribution to dose from each radionuclide relative to its corresponding dose guideline. If the sum of fractions for the maximum radionuclide concentrations exceeds 1.0 (Tier 1), then the dose guideline has been exceeded and the screening assessment has failed. The second tier of screening, where mean radionuclide concentrations are employed, is then conducted.

The biota concentration guides (DOE-STD-1153-2002) are very different from the DOE derived concentration guides (DOE Order 5400.5) that are used to assess radiological doses to humans. If the estimated screening value exceeds the guideline (Tiers 1 and 2 sum of fractions greater than 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.

Table 5.0.5. Results of RESRAD-BIOTA[(a)] Screenings at the Hanford Site, 2003

Location	Tier 1 Screen Sum of Fraction	Pass or Fail
100-B Area Spring	0.091	Pass
100-D Area	0.0013	Pass
100-F Area Slough	0.043	Pass
100-F Area Spring	0.073	Pass
100-H Area Spring	0.063	Pass
100-K Area Spring	0.049	Pass
100-N Area	0.0002	Pass
300 Area Springs	0.79	Pass
Hanford Town Site Slough	0.058	Pass
White Bluffs Slough	0.002	Pass
McNary Dam	0.20	Pass
Priest Rapids Dam	0.16	Pass
Richland	0.058	Pass

(a) A screening method to estimate radiological doses to aquatic and terrestrial biota.

During 2003, biota dose assessments were conducted by operational areas (Table 5.0.5) and for special situations.

Maximum concentrations of radionuclides in Columbia River sediment and riverbank spring water were evaluated using the RESRAD-BIOTA computer code. Riverbank springs carry groundwater contaminants into the Columbia River at greater concentrations than observed in river water and provide another level of conservatism in the biota dose assessment process. The results indicate that all spring data from the 100 Areas, Hanford town site, and 300 Areas resulted in doses below the guidelines in the Columbia River (sum of fractions less than 1.0) (Table 5.0.5).

5.0.7 Radiological Dose in Perspective

Two scientific studies (National Research Council 1990; United Nations Science Committee on the Effects of Atomic Radiation 1988) were performed to estimate the possible risk from exposure to low levels of radiation. These studies provided information to government and scientific organizations and recommended 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, for radiation protection purposes, regulatory agencies have prudently assumed that the probability 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 exposure, or radium dial painters). This concept is known as the linear no threshold hypothesis. Under these assumptions, even the dose from natural background radiation, which is hundreds of times greater than the dose from current Hanford Site releases, increases each person's probability or chance of developing a detrimental health effect.

Scientists do not 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 even suggested that low radiological doses might be beneficial (Sagan 1987). Because cancer may be caused by many agents other than radon, e.g., genetic defects, immune system suppression, exposure to chemicals, some scientists doubt that the risk from low-level radiation exposure can ever be proven conclusively. In keeping with guidance from the EPA, the DOE uses an occurrence rate of 0.0006 latent cancer fatalities per rem of exposure (EPA 520/1-89-005). Thus, in a population receiving 1,700 person-rem (17 person-Sv), one latent fatal cancer would be predicted to occur. 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. The estimated risks from various radiological doses to the risks of some activities encountered in everyday life (Table 5.0.6). Some activities are considered approximately equal in risk to that from the dose received by the maximally exposed individual from monitored Hanford effluent during 2003 (Table 5.0.7).

Table 5.0.6. Estimated Risk from Various Activities and Exposure[(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 0.6×10^{-6}
Dose to the maximally exposed individual living near Hanford	0 to 0.02×10^{-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 0.02-mrem (0.002-mSv) Dose Calculated for the Hanford Site's 2003 Maximally Exposed Individual

Driving or riding in a car 8 km (5 mi)
Smoking less than 1/15 of a cigarette
Flying approximately 20 km (12.7 mi) on a commercial airliner
Eating approximately 6 tbsp of peanut butter
Eating one 1.4-kg (48-oz) charcoal-broiled steak
Drinking 8 L (approximately 2.1 gal) of chlorinated tap water
Being exposed to natural background radiation for 96 min in a typical terrestrial location
Drinking approximately 0.14 L (4.8 oz) of wine or 0.4 L (14 oz) of beer

5.0.8 References

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