5.0 Potential Radiation Doses from 1996 Hanford Operations

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During 1996, radionuclides reached the environment in gaseous and liquid effluents from Hanford Site operations. Monitored gaseous effluents were released from operating stacks and ventilation exhausts. Other potential sources include fugitive emissions from contaminated soil areas and unmonitored facilities. Liquid effluents were released from operating waste-water treatment facilities and from contaminated groundwater seeping into the Columbia River.

Potential radiological doses to the public from these releases were evaluated in detail to determine compliance with pertinent regulations and limits. The radiological impacts of 1996 Hanford operations were assessed in terms of the following:

- dose to a hypothetical maximally exposed individual at an offsite location
- maximum dose rate from external radiation at a publicly accessible location on or within the site boundary
- dose to an avid sportsman who consumes wildlife exposed to radionuclides onsite
- dose to the population residing within 80 km (50 mi) of the Hanford operating areas
- absorbed dose rate (rad/d) received by animals caused by radionuclide releases to the Columbia River.

It is generally accepted that radiological dose assessments should be based on direct measurements of radiation dose rates and radionuclide concentrations in the surrounding environment. However, the amounts of most radioactive materials released during 1996 from Hanford sources were generally too small to be measured directly once they were dispersed in the offsite environment. For many of the measurable radionuclides, it was difficult to identify the contributions from Hanford sources in the presence of contributions from worldwide fallout and from naturally occurring uranium and its decay products. Therefore, in nearly all instances, offsite doses were estimated using the GENII computer code Version 1.485 (Napier et al. 1988) and Hanford Site-specific parameters listed in Appendix D and in Bisping (1997) to calculate concentrations of radioactive materials in the environment from effluent releases reported by the operating contractors.

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. During 1996, tritium and iodine-129 were found in the Columbia River downstream of Hanford at greater concentrations than predicted based on direct discharge from the 100 Areas. All other concentrations of radionuclides were lower than those predicted from known releases. Riverbank spring water containing these radionuclides is known to enter the river along the portion of shoreline extending from the Old Hanford Townsite to downstream of the 300 Area (see Section 4.2, "Surface Water and Sediment Surveillance" and Section 4.8, "Groundwater Protection and Monitoring Program"). No direct discharges from the 300 Area to the Columbia River were reported in 1996.

The estimated dose[(a)] to the maximally exposed offsite individual from Hanford operations in 1996 was 0.007 mrem (7×10^{-5} mSv) compared to 0.02 mrem (2×10^{-4} mSv) reported for 1995. The dose to the local population of 380,000 (Beck et al. 1991) from 1996 operations was 0.2 person-rem (0.002 person-Sv) compared to 0.3 person-rem (0.003 person-Sv) reported for 1995.

(a) Unless stated otherwise, the term "dose" in this section is the "total effective dose equivalent" (see Appendix B, "Glossary").

The 1996 average dose to the population was approximately 0.0005 mrem (5×10^{-6} mSv) per person. The current DOE radiation dose limit (DOE Order 5400.5) for an individual member of the public is 100 mrem/yr (1 mSv/yr) from all pathways and 10 mrem/yr (0.1 mSv/yr) from airborne radionuclide emissions (40 CFR 61). The national average dose from natural sources is 300 mrem/yr (3 mSv/yr). Thus, 1996 Hanford emissions potentially contributed to the maximally exposed individual a dose equivalent to only 0.007% of the DOE dose limit, or 0.002% of the average dose received from natural radioactivity in the environment. For the average member of the local population, these contributions were approximately 0.0005% and 0.0002%, respectively.

The uncertainty associated with the radiological dose calculations on which this report is based has not been quantified. However, when Hanford-specific data were not available for parameter values (e.g., vegetation uptake and consumption factors), conservative values were selected from the literature for use in environmental transport models. Thus, radiological doses calculated using environmental models should be viewed as hypothetical maximum estimates of doses resulting from Hanford operations.

Maximally Exposed Individual Dose

The maximally exposed individual is a hypothetical person who lives at a location and has a lifestyle such that it is unlikely that other members of the public would receive higher radiation doses. This individual's diet, dwelling place, and other factors were chosen to maximize the combined doses from all reasonable environmental pathways of exposure to radionuclides in Hanford effluents. In reality, such a combination of maximized parameters is unlikely to apply to any one individual.

The location of the 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. Historically, two separate locations have been used to assess the dose to the maximally exposed individual: the Ringold area, 26 km (16 mi) east of the 200 Areas separation facilities, and the Riverview irrigation district across the river from Richland (Figure 5.0.1). The Ringold location is closer than Riverview to Hanford facilities that historically were major contributors of airborne effluents. At Riverview, the maximally exposed individual has the highest exposure to radionuclides in the Columbia River.

Since 1993, a third location across from the 300 Area has been considered. Because of the shift in site operations from strategic materials production to the current mission of research and environmental restoration, the significance of the air emissions from the 200 Areas production facilities has decreased relative to those from the 300 Area. Therefore, a receptor directly across the river from the 300 Area, at Sagemoor, would be maximally exposed to airborne radionuclides from those facilities. The applicable exposure pathways for each of these locations are described in the following.

The Ringold location is situated to maximize air pathway exposures from emissions at the 200 Areas, including direct exposure to the plume, inhalation, external exposure to radionuclides that deposit on the ground, and ingestion of locally grown food products. In addition, it is assumed that individuals at Ringold irrigate their crops with water taken from the Columbia River downstream of where groundwater enters the river from the 100 and 200-East Areas (see Figure 4.8.17). This results in additional exposures from ingestion of irrigated food products and external irradiation from radionuclides deposited on the ground by irrigation. Recreational use of the Columbia River is also considered for this individual, resulting in direct exposure from water and radionuclides deposited on the shoreline and internal dose from ingestion of locally caught fish.

The Riverview receptor is assumed to be exposed via the same pathways as the individual at Ringold, except that irrigation water from the Columbia River may contain radionuclides that enter the river at the 300 Area, in addition to those from upstream release points. This individual is also assumed to obtain domestic water from the river via a local water treatment system. Exposure to this individual from the air pathway is typically lower than exposure at Ringold because of the greater distance from the major onsite emission sources.

The individual at Sagemoor, assumed to be located 1.5 km (1 mi) directly across the Columbia River from the 300 Area, receives the maximum exposure to airborne effluents from the 300 Area, including the same pathways as the individual at Ringold. Domestic water at this location comes from a well rather than from the river, and wells in this region are not contaminated by radionuclides of Hanford origin (Washington State

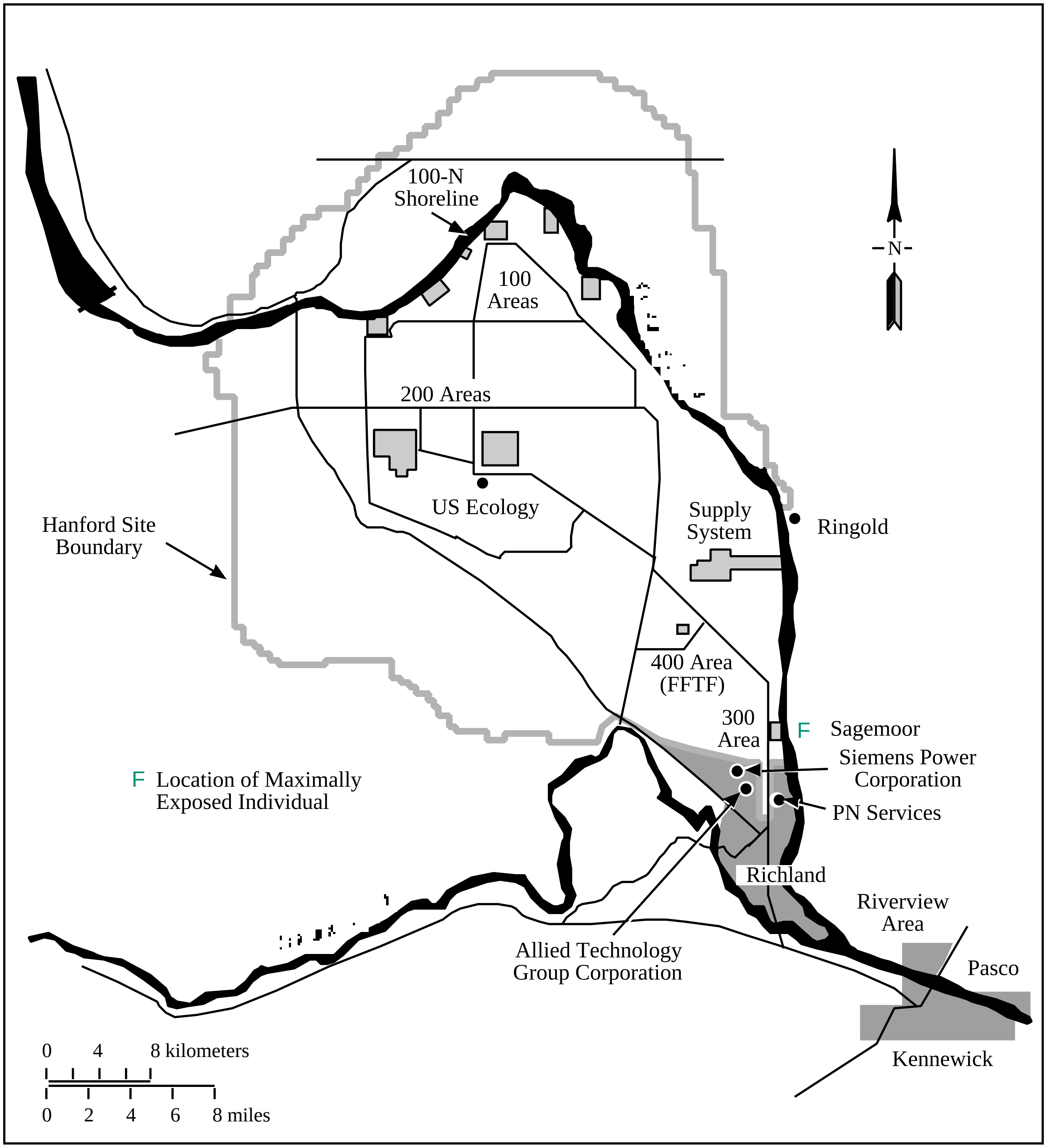

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Figure 5.0.1. Locations Important to Dose Calculations

Department of Health 1988). Although the farms located across from the 300 Area obtain irrigation water from upstream of the Hanford Site, the conservative assumption was made that the diet of the maximally exposed individual residing 1.5 km (1 mi) east of the 300 Area consisted totally of foods purchased from the Riverview area, which could contain radionuclides present in both liquid and gaseous effluents. The added contribution of radionuclides in the Riverview irrigation water maximizes the calculated dose from the air and water pathways combined.

The 1996 hypothetical maximally exposed individual at Sagemoor was calculated to have received a higher dose than a maximally exposed individual located at either Ringold or Riverview. Radiological doses to the maximally exposed individual were calculated using the effluent data in Tables 3.1.1 and 3.1.4. Quantities of radionuclides assumed to be present in the Columbia River from riverbank springs were also calculated for input to the GENII code. 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 Old Hanford Townsite and the 300 Area.

The calculated doses for the maximally exposed individual are summarized in Table 5.0.1. These values include the doses received from exposure to liquid and airborne effluents during 1996, as well as the future, or committed dose from radionuclides that were inhaled or ingested during 1996. As releases from facilities and the doses from these sources decrease, the contribution of diffuse sources such as wind-blown contaminated soil becomes relatively more significant. An upper estimate of the dose from diffuse sources is discussed in a following subsection ("Comparison with Clean Air Act Standards"). The estimated dose from diffuse sources was similar to the dose reported in Table 5.0.1 for measured emissions. Site-specific parameters for food pathways, diet, and recreational activity used for the dose calculations are contained in Appendix D.

The total radiological dose to the hypothetical maximally exposed individual in 1996 was calculated to be 0.007 mrem (7×10^{-5} mSv) compared to 0.02 mrem (2×10^{-4} mSv) calculated for 1995. The primary pathways contributing to this dose (and the percentage of all pathways) were the following:

- inhalation of airborne radionuclides (54%), principally iodine-129 released from the 200 Areas and radon-220 (lead-212) released from the 300 Area

Table 5.0.1. Dose to the Hypothetically Maximally Exposed Individual Residing 1.5 km (1 mi) East of the 300 Area from 1996 Hanford Operations

		Operating Area Contribution Dose, mrem				
Effluent	Pathway	100 Areas	200 Areas	300 Area	400 Area	Pathway Total
Air	External	3.7×10^{-8}	9.3×10^{-7}	5.7×10^{-5}	2.1×10^{-8}	5.8×10^{-5}
	Inhalation	1.3×10^{-5}	3.3×10^{-4}	3.6×10^{-3}	1.6×10^{-5}	4.0×10^{-3}
	Foods	3.0×10^{-7}	4.2×10^{-4}	8.7×10^{-5}	2.8×10^{-5}	5.4×10^{-4}
	Subtotal air	1.3×10^{-5}	7.5×10^{-4}	3.7×10^{-3}	4.4×10^{-5}	4.6×10^{-3}
Water	Recreation	4.0×10^{-6}	4.6×10^{-6}	0.0[(a)]	0.0	8.6×10^{-6}
	Foods	2.7×10^{-4}	2.1×10^{-3}	0.0	0.0	2.4×10^{-3}
	Fish	3.3×10^{-4}	1.4×10^{-4}	0.0	0.0	4.7×10^{-4}
	Drinking water	0.0	0.0	0.0	0.0	0.0
	Subtotal water	6.0×10^{-4}	2.2×10^{-3}	0.0	0.0	2.8×10^{-3}
Combined total		6.2×10^{-4}	3.0×10^{-3}	3.7×10^{-3}	4.4×10^{-5}	7.4×10^{-3}

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

- consumption of food irrigated with Columbia River water containing radionuclides (32%), principally tritium and strontium-90.

The DOE radiological dose limit for any member of the public from all routine DOE operations is 100 mrem/yr (1 mSv/yr) (40 CFR 61). The dose calculated for the maximally exposed individual for 1997 was 0.007% of the DOE limit. Thus, the Hanford Site was in compliance with applicable state and federal regulations.

The doses from Hanford operations for the maximally exposed individual for 1992 through 1996 are illustrated in Figure 5.0.2. During each year, the doses were estimated using methods and computer codes previously described. In 1992, the maximally exposed individual was located at Riverview. For 1993 through 1996, the hypothetical maximally exposed individual was located across the Columbia River from the 300 Area at Sagemoor.

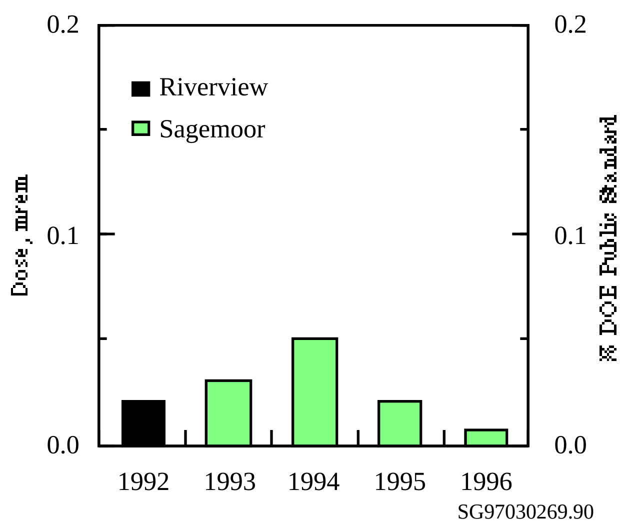

Figure 5.0.2. Calculated Effective Dose Equivalent to the Hypothetical Maximally Exposed Individual, 1992 Through 1996

Special Case Exposure Scenarios

Exposure parameters used to calculate the dose to the maximally exposed individual are selected to define a high-exposure scenario that is unlikely to occur. Such a scenario does not necessarily result in the highest conceivable radiological dose. Low-probability exposure scenarios exist that could result in somewhat higher doses.

Three scenarios that could potentially lead to larger doses include 1) an individual who would spend time at the site boundary location with the maximum external radiation dose rate, 2) a sportsman who might consume contaminated wildlife that migrated from the site, and 3) a consumer of drinking water at the Fast Flux Test Facility.

Maximum "Boundary" Dose Rate

The "boundary" radiation dose rate is the external radiation dose rate measured at publicly accessible locations on or near the site. The boundary dose rate was determined from radiation exposure measurements using thermoluminescent dosimeters at locations of expected elevated dose rates onsite and at representative locations offsite. These boundary dose rates should not be used to calculate annual doses to the general public because no one can actually reside at any of these boundary locations. However, these rates can be used to determine the dose to a specific individual who might spend some time at that location.

External radiation dose rates measured in the vicinity of the 100-N, 200, 300, and 400 (Fast Flux Test Facility) Areas are described in Section 4.7, "External Radiation Surveillance." The 200 Areas results were not used because these locations are not accessible to the public. Radiation measurements made at the 100-N Area shoreline (see Figure 5.0.1) were consistently above the background level and represent the highest measured boundary dose rates. The Columbia River provides public access to an area within a few hundred meters (feet) of the N Reactor and supporting facilities.

The dose rate at the location with the highest exposure rate along the 100-N shoreline during 1996 was 0.02 mrem/h (2 x 10^{-4} mSv/h), or about twice the average background dose rate of 0.01 mrem/h (1 x 10^{-4} mSv/h) normally observed at offsite shoreline locations. Therefore, for every hour someone spent at the 100-N Area shoreline during 1996, the external radiological dose received from Hanford operations would be approximately 0.01 mrem (1 x 10^{-4} mSv) above the natural background dose. If an individual spent an hour at this location, a dose would be received that is similar to the annual dose calculated for the hypothetical maximally exposed individual at Sagemoor. The public can approach the shoreline by boat but they are legally restricted from stepping onto the shoreline. Therefore, an individual is unlikely to remain on or near the shoreline for an extended period of time.

Sportsman Dose

Wildlife have access to areas of the site that contain radioactive materials, and some do become contaminated. Sometimes contaminated wildlife travel offsite. Sampling is conducted onsite to estimate the maximum contamination levels that might possibly exist in animals hunted offsite. Because this scenario has a relatively low probability of occurring, these doses are not included in the maximally exposed individual calculation.

Listed below are estimates of the radiological doses that could have resulted if wildlife containing the maximum concentrations measured in onsite wildlife in 1996 migrated offsite, were hunted, and were eaten.

- The dose from eating 1 kg (2.2 lb) of deer meat that contains the maximum concentration of cesium-137 (0.025 pCi/g) measured in a deer collected onsite is estimated to be 1 x 10^{-3} mrem (1 x 10^{-5} mSv).

- The dose from eating 1 kg (2.2 lb) of bass meat that contains the maximum concentrations of cesium-137 (0.02 pCi/g) measured in bass collected from the Hanford Reach of the Columbia River is estimated to be 1 x 10^{-3} mrem (1 x 10^{-5} mSv).

- The dose from eating 1 kg (2.2 lb) of pheasant meat that contains the maximum concentration of cesium-137 (0.0047 pCi/g) measured in a pheasant collected onsite is estimated to be 2 x 10^{-4} mrem (2 x 10^{-6} mSv).

These are very low doses, and qualitative observations suggest that the significance of this pathway is further reduced because of the relatively low migration offsite (Eberhardt et al. 1982) and the inaccessibility of onsite wildlife to hunters. The methodology for calculating doses from consumption of wildlife was to multiply the maximum concentration measured in edible tissue by a dose conversion factor for ingestion of that tissue, which is addressed in more detail in Soldat et al. (1990).

Fast Flux Test Facility Drinking Water

During 1996, groundwater was used as drinking water by workers at the Fast Flux Test Facility. Therefore, this water was sampled and analyzed throughout the year in accordance with applicable drinking water regulations (40 CFR 61). All annual average radionuclide concentrations measured during 1996 were well below applicable drinking water standards, but concentrations of tritium were detected at levels greater than typical background values (see Section 4.3, "Hanford Site Drinking Water Surveillance"). Based on the measured concentrations, the potential dose to Fast Flux Test Facility workers (an estimate derived by assuming a consumption of 1 L/d (0.26 gal/d) for 240 working days), the worker would receive an effective dose equivalent of <0.2 mrem (<0.002 mSv). The doses calculated here are well below the drinking water pathway dose limit of 4 mrem for public drinking water supplies operated by DOE.

Comparison with Clean Air Act Standards

Limits for radiation dose to the public from airborne emissions from DOE facilities are provided in 40 CFR 61, Subpart H. The regulation specifies that no member of the public shall receive a dose of more than 10 mrem/yr (0.1 mSv/yr) from exposure to airborne radionuclide effluents, other than radon, released at DOE facilities (EPA 1989). The regulation also requires that each DOE facility submit an annual report that supplies information about atmospheric emissions for the preceding year and their potential offsite impacts. The following summarizes information that is provided in more detail in the 1996 air emissions report (Gleckler et al. 1997).

The 1996 air emissions from monitored Hanford facilities, including radon-220 and radon-222 releases from the 300 Area, resulted in a potential dose to a maximally exposed individual across from the 300 Area of 0.005 mrem (5 x 10^{-5} mSv), which represents 0.05% of the standard. Of this total, radon emissions from the 327 Building contributed 0.003 mrem (3 x 10^{-5} mSv), and nonradon emissions from all monitored stack sources contributed 0.002 mrem (2 x 10^{-5} mSv). Therefore, the estimated annual dose from monitored stack releases at the Hanford Site during 1996 was well below the Clean Air Act standard. The Clean Air Act requires the use of CAP-88 (Parks 1992) or other EPA models to demonstrate compliance with the standard, and the assumptions embodied in these codes differ slightly from standard assumptions used at the Hanford Site for reporting to DOE via this report. Nevertheless, the result of calculations performed with CAP88-PC for air emissions from Hanford facilities agrees well with that calculated using the GENII code (0.005 mrem or 5 x 10^{-5} mSv for air pathways).

The December 15, 1989 revisions to the Clean Air Act (40 CFR 61, Subpart H) require 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 have interpreted the regulation to include diffuse and unmonitored sources as well as monitored point sources. The EPA has not specified or approved methods for estimating emissions from diffuse sources, and standardization is difficult because of the wide variety of such sources at DOE sites. Estimates of potential diffuse source emissions at the Hanford Site have been developed using environmental surveillance measurements of airborne radionuclides at the site perimeter.

During 1996, the estimated dose from diffuse sources to the maximally exposed individual across the river from the 300 Area was 0.03 mrem (3×10^{-4} mSv), which was greater than the estimated dose at that location from stack emissions (0.005 mrem or 5×10^{-5} mSv). Doses at other locations around the Hanford Site perimeter ranged from 0.02 to 0.06 mrem (2×10^{-4} to 6×10^{-4} mSv). Based on these results, the combined dose from stack emissions and diffuse and unmonitored sources during 1996 was well below the EPA standard.

Collective Dose to the Population Within 80 km (50 mi)

Exposure pathways for the general public from releases of radionuclides to the atmosphere include inhalation, air submersion, and consumption of contaminated food. Pathways of exposure for radionuclides present in the Columbia River include consumption of drinking water, fish, and irrigated foods and external exposure during aquatic recreation. The regional collective dose from 1996 Hanford operations was estimated by calculating the radiological dose to the population residing within an 80-km (50-mi) radius of the onsite operating areas. Results of the dose calculations are shown in Table 5.0.2. Food pathway, dietary, residency, and recreational activity assumptions for these calculations are given in Appendix D.

The collective dose calculated for the population was 0.2 person-rem (0.002 person-Sv) in 1996 compared to 0.3 person-rem (0.003 person-Sv) in 1995. The 80-km (50-mi) collective doses attributed to Hanford operations from 1992 through 1996 are compared in Figure 5.0.3.

Table 5.0.2. Dose to the Population from 1996 Hanford Operations

		Operating Area Contribution Dose, person-rem				
Effluent	Pathway	100 Areas	200 Areas	300 Area	400 Area	Pathway Total
Air	External	5.3×10^{-6}	7.7×10^{-5}	7.1×10^{-4}	6.6×10^{-7}	7.9×10^{-4}
	Inhalation	2.8×10^{-3}	4.4×10^{-2}	2.7×10^{-2}	7.7×10^{-4}	7.4×10^{-2}
	Foods	8.6×10^{-5}	4.6×10^{-2}	3.6×10^{-3}	2.4×10^{-3}	5.2×10^{-2}
	Subtotal air	2.9×10^{-3}	9.0×10^{-2}	3.1×10^{-2}	3.2×10^{-3}	1.3×10^{-1}
Water	Recreation	1.9×10^{-5}	5.7×10^{-5}	0.0[(a)]	0.0	7.6×10^{-5}
	Foods	2.9×10^{-4}	2.4×10^{-3}	0.0	0.0	2.7×10^{-3}
	Fish	1.2×10^{-4}	5.2×10^{-5}	0.0	0.0	1.7×10^{-4}
	Drinking water	7.5×10^{-4}	6.8×10^{-2}	0.0	0.0	6.9×10^{-2}
	Subtotal water	1.2×10^{-3}	7.1×10^{-2}	0.0	0.0	7.2×10^{-2}
Combined total		3.7×10^{-3}	1.6×10^{-1}	3.1×10^{-2}	3.2×10^{-3}	2.0×10^{-1}

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

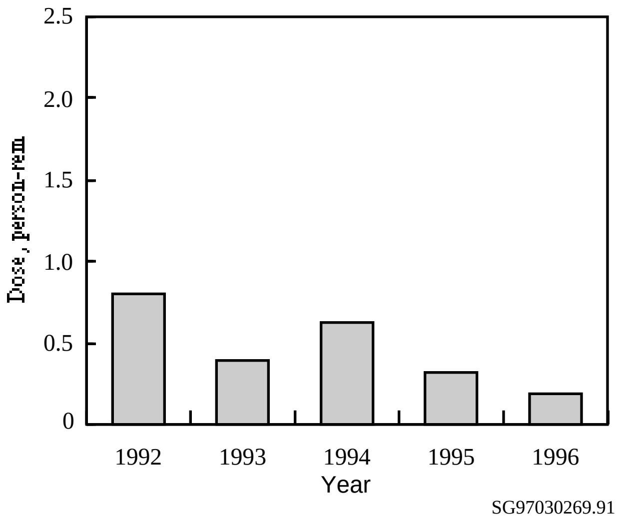

Figure 5.0.3. Calculated Effective Dose Equivalent to the Population Within 80 km (50 mi) of the Hanford Site, 1992 Through 1996

Primary pathways contributing to the 1996 dose to the population were the following:

- inhalation of radionuclides (37%) that were released to the air, principally iodine-129 from the Plutonium-Uranium Extraction Plant stack
- consumption of drinking water (35%) contaminated with radionuclides released to the Columbia River at Hanford, principally tritium and iodine-129
- consumption of foodstuffs (26%) contaminated with radionuclides released in gaseous effluents, primarily iodine-129 from the Plutonium-Uranium Extraction Plant stack.

The average per capita dose from 1996 Hanford operations based on a population of 380,000 within 80 km (50 mi) was 0.5 µrem (5 x 10^{-3} µSv). To place this dose from Hanford activities into perspective, the estimate may be compared with doses 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 average radiation doses from these other sources are illustrated in Figure 5.0.4. The estimated average per capita dose to members of the public from Hanford sources is only approximately 0.0002% of the annual per capita dose (300 mrem) from natural background sources.

The doses from Hanford effluents to the maximally exposed individual and to the population within 80 km (50 mi) are compared to appropriate standards and natural background radiation in Table 5.0.3. This table shows that the calculated radiological doses from Hanford operations in 1996 are a small percentage of the standards and of natural background.

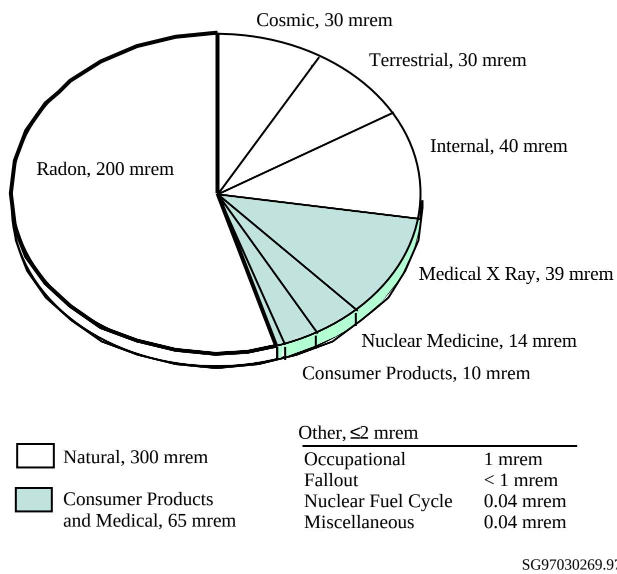

Figure 5.0.4. National Annual Average Radiation Doses from Various Sources (mrem) (National Council on Radiation Protection 1987)

Doses from Other than DOE Sources

Various non-DOE industrial sources of public radiation exposure exist at or near the Hanford Site. These include the low-activity commercial radioactive waste burial ground at Hanford operated by US Ecology, the nuclear power generating station at Hanford operated by Washington Public Power Supply System, the nuclear fuel production plant operated by Siemens Power Corporation, the commercial low-activity radioactive waste compacting facility operated by Allied Technology Group Corporation, and a commercial decontamination facility operated by PN Services (see Figure 5.0.1). DOE maintains an awareness of other manmade sources of radiation, which, if combined with the DOE sources, might have the potential to cause a dose exceeding 10 mrem (0.1 mSv) to any member of the public. With information

Table 5.0.3. Summary of Doses to the Public in the Vicinity of Hanford from Various Sources, 1996

Source	Maximum Individual, mrem[a]	Population, person-rem[a]
All Hanford effluents	0.007	0.2
DOE limit	100	--
Percent of DOE limit[b]	0.007%	--
Background radiation	300	110,000
Hanford dose percent of background	<0.01%	2 x 10^{-4}%
Doses from gaseous effluents	0.0046	--
EPA air standard[c]	10	--
Percent of EPA standard	0.046%	--

(a) To convert the dose values to mSv or person-Sv, divide by 100.
(b) DOE Order 5400.5.
(c) 40 CFR 61.

gathered from these companies, it was conservatively estimated that the total 1996 individual dose from their combined activities is on the order of 0.05 mrem (5 x 10^{-4} mSv). Therefore, the combined dose from Hanford area non-DOE and DOE sources to a member of the public for 1996 was well below any regulatory dose limit.

Hanford Public Radiation Dose in Perspective

This section provides information to put the potential health risks of radionuclide emissions 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) have been performed to estimate the possible risk of detrimental health effects from exposure to low levels of radiation. These studies have 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, some scientists accept the hypothesis that low-level doses might increase the probability of cancer or other health effects. Regulatory agencies conservatively (cautiously) assume that the probability of these types of health effects at low doses (down to zero) is proportional to the probability per unit dose of these same health effects observed historically at much higher doses (in atomic bomb victims, radium dial painters, etc.). Under these assumptions, even natural background radiation (which is hundreds of times greater than radiation from current Hanford 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 radiation doses. Some scientific studies have indicated that low radiation doses may cause beneficial effects (Health Physics Society 1987). Because cancer and hereditary diseases in the general population may be caused by many sources (e.g., genetic defects, sunlight, chemicals, and background radiation), some scientists doubt that the risk from low-level radiation exposure can ever be conclusively proved. In developing Clean Air Act regulations, the EPA uses a probability value of approximately 4 per 10 million (4 x 10^{-7}) for the risk of developing a fatal cancer after receiving a dose of 1 mrem (0.01 mSv) (EPA 1989). 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 activities (e.g., DOE facilities, nuclear power plants, chemical plants, and hazardous waste sites). All of these industrial activities are considered beneficial to people in some way such as providing electricity, national defense, waste disposal, and consumer products. These government agencies have a complex task in establishing environmental regulations that control levels of risk to the public without unnecessarily reducing needed benefits from industry.

One perspective on risks from industrial activities is to compare them to risks involved in other typical activities. For instance, two risks that an individual receives from flying on an airliner are the risks of added radiation dose (from a stronger cosmic radiation field that exists at higher altitudes) and the possibility of being in an aircraft accident. Table 5.0.4 compares the estimated risks from various radiation doses to the risks of some activities encountered in everyday life. Table 5.0.5 lists some activities considered approximately equal in risk to the risk from the dose received by the maximally exposed individual from monitored Hanford effluents in 1996.

Dose Rates to Animals

Conservative (upper) estimates have been made of radiological dose to "native aquatic organisms," in accordance with DOE Order 5400.5 interim requirement for management and control of liquid discharges. Possible radiological dose rates during 1996 were calculated for several exposure modes, including exposure to radionuclides in water entering the Columbia River from springs near the 100-N Area and internally deposited radionuclides measured in samples of animals collected from the river and onsite.

The animal receiving the highest potential dose from N Springs water was a duck consuming aquatic plants. Because the water flow of the springs at the 100-N Area is so low, no aquatic animal can live directly in this spring water. Exposure to the radionuclides from the springs cannot occur until the spring water has been noticeably diluted in the Columbia River. The assumption was made that a few aquatic animals might be exposed to the maximum concentration of radionuclides measured in the spring water (see Table 3.2.5) after 10-to-1 dilution by the river. Radiological doses were calculated for several different types of aquatic animals, using these highly conservative assumptions and the computer code CRITR2 (Baker and Soldat 1992). Even if a duck spent 100% of its time in the one-tenth diluted spring water and consumed only plants growing there, it would receive a radiation dose rate of 1×10^{-5} rad/d. This dose rate is 0.001% of the limit of 1 rad/d for native aquatic animal organisms established by DOE Order 5400.5 and is not expected to cause detrimental effects to animal populations.

Doses were also estimated for clams, fish, and waterfowl living in the Columbia River based on measured radionuclide concentrations in river water. The highest potential dose from all the radionuclides reaching the Columbia River from Hanford sources during 1996 was 2×10^{-4} rad/d for a duck that consumed contaminated vegetation.

Dose estimates based on the maximum concentrations of cesium-137 measured in muscle of animals collected onsite and from the Columbia River ranged from 1×10^{-7} rad/d for a pheasant to 8×10^{-7} rad/d for a mule deer.

Table 5.0.4. Estimated Risk from Various Activities and Exposures[a]

Activity or Exposure Per Year	Risk of Fatality
Riding or driving in a passenger vehicle (483 km [300 mi])	2 x 10^{-6}[b]
Home accidents	100 x 10^{-6}[b]
Drinking 1 can of beer or 0.12 L (4 oz) of wine per day (liver cancer/cirrhosis)	10 x 10^{-6}
Pleasure boating (accidents)	6 x 10^{-6}[b]
Firearms, sporting (accidents)	10 x 10^{-6}[b]
Smoking 1 pack of cigarettes per day (lung/heart/other diseases)	3,600 x 10^{-6}
Eating approximately 54 g (4 tbsp) of peanut butter per day (liver cancer)	8 x 10^{-6}
Eating 41 kg (90 lb) of charcoal-broiled steaks (gastrointestinal tract cancer)	1 x 10^{-6}
Drinking chlorinated tap water (trace chloroform—cancer)	3 x 10^{-6}
Taking contraceptive pills (side effects)	20 x 10^{-6}
Flying as an airline passenger (cross-country roundtrip—accidents)	8 x 10^{-6}[b]
Flying as an airline passenger (cross-country roundtrip—radiation)	0 to 5 x 10^{-6}
Natural background radiation dose (300 mrem, 3 mSv)	0 to 120 x 10^{-6}
Dose of 1 mrem (0.01 mSv) for 70 yr	0 to 0.4 x 10^{-6}
Dose to the maximally exposed individual living near Hanford in 1996 (0.007 mrem, 7 x 10^{-5} mSv)	0 to 0.003 x 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 radiation dose, the values are reported in a possible range from the least conservative (0) to the currently accepted most conservative value.

Table 5.0.5. Activities Comparable in Risk to the 0.007-mrem Dose Calculated for the 1996 Maximally Exposed Individual

Driving or riding in a car 0.7 km (approximately 0.5 mi)
Smoking 6/1,000 of a cigarette
Flying 2 km (approximately 1.2 mi) on a commercial airliner
Eating approximately 2/3 tbsp of peanut butter
Eating one 0.12-kg (<0.3-lb) charcoal-broiled steak
Drinking approximately 0.75 L (<1 qt) of chlorinated tap water
Being exposed to natural background radiation for approximately 13 min in a typical terrestrial location
Drinking approximately 0.038 L (1.3 oz) of beer or 0.015 L (0.5 oz) of wine