6.0 Potential Radiation Doses from 1994 Hanford Operations

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Present and past operations at Hanford have resulted in the release of radionuclides into the surrounding environment. Members of the public are potentially exposed to low levels of radiation from these effluents through a variety of pathways. The potential radiation doses[(a)] to the public in 1994 from Hanford operations were calculated for the hypothetical MEI and for the general public residing within 80 km (50 mi) of the Hanford Site. These doses were calculated from effluent releases reported by the operating contractors, and radionuclide measurements in environmental media, using Version 1.485 of the GENII code (Napier et al. 1988a, 1988b, 1988c) and Hanford Site-specific parameters listed in Appendix D and by Bisping (1995).

The potential dose to the MEI in 1994 from Hanford operations was 0.05 mrem (5×10^{-4} mSv) compared to 0.03 mrem (3×10^{-4} mSv) reported for 1993. The potential dose to the local population of 380,000 persons (Beck et al. 1991) from 1994 operations was 0.6 person-rem (0.006 person-Sv), compared to 0.4 person-rem (0.004 person-Sv) reported for 1993. The 1994 average dose to the population was 0.002 mrem (2×10^{-5} mSv) per person. The current DOE radiation dose limit for an individual member of the public is 100 mrem/yr (1 mSv/yr), and the national average dose from natural sources is 300 mrem/yr (3 mSv/yr). During 1994, the MEI potentially received 0.05% of the DOE dose limit and 0.02% of the natural background average dose. The average individual potentially received 0.002% of the standard and 5×10^{-4}% of the 300 mrem/yr received from typical natural sources.

The small additional dose to the MEI in 1994 was a result of increased concentrations of uranium isotopes measured in Columbia River water collected downstream of the Hanford site and of continued experimental work in the 300 Area. This work entailed the release of radon isotopes (160 Ci of radon-220 and 1.2 Ci of radon-222) to the atmosphere from the 327 Building ventilation system (see Table 3.1.1). The new MEI location chosen for the 1993 dose calculations [1.5 km across the river (east) from the 300 Area] was retained for 1994.

During 1994, radionuclides reached the environment in gaseous and liquid effluents from present and past Hanford operations. Gaseous effluents were released from operating stacks and ventilation exhausts. Liquid effluents were released from operating waste-water treatment facilities and in seepage of contaminated ground water into the Columbia River. These radioactive materials were then transported throughout the environment by wind and the Columbia River. Eventually, animals and people can be exposed to these radionuclides through external exposure and inhalation and ingestion of contaminated air, water, and foodstuffs. Because of the many variables involved in the transport of the radionuclides in the environment and differing living habits of people, the assumptions used to describe the exposure scenarios are conservative (i.e., the doses are likely to be overestimated).

Potential radiation doses to the public from these releases were evaluated in detail to determine compliance with pertinent regulations and limits. The potential radiological impacts of 1994 Hanford operations were assessed in terms of the following:

- dose to a hypothetical MEI 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 operating areas

(a) Unless stated otherwise, the term "dose" in this chapter is the "effective dose equivalent" (see Glossary).

- absorbed dose rate (rad/d) potentially received by animals associated with contaminant releases to the Columbia River.

To the extent possible, radiation dose assessments should be based on direct measurements of radiation dose rates and radionuclide concentrations in the surrounding environment. The amounts of most radioactive materials released during 1994 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, potential offsite doses were estimated using environmental pathway models that calculate concentrations of radioactive materials in the environment from effluent releases reported by the operating contractors.

As in the past, the differences in measured concentrations of certain radionuclides in samples of Columbia River water collected upstream and downstream of the Hanford Reach were used to estimate the doses to the public from these radionuclides entering the river with riverbank seepage of ground water. During 1994, iodine-129, tritium, and isotopes of uranium were found in the Columbia River downstream of Hanford at greater concentrations than predicted from direct discharge from the 100 and 300 Areas.

Although the uncertainty associated with the radiation dose calculations has not been quantified, whenever Hanford-specific data were not available for parameter values (for example, vegetation uptake and consumption factors), conservative values were selected from the literature for use in environmental transport models. Thus, radiation doses calculated using environmental models should be viewed as maximum estimates of potential doses resulting from Hanford operations.

Maximally Exposed Individual Dose

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

The location selected for the MEI can vary from year to year depending on the relative importance of the several sources of radioactive effluents released to the air and to the Columbia River from Hanford facilities. Historically, two separate locations in the Hanford environs have been identified as potential sites for the MEI: 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 6.0.1). The principal differences between the two MEI locations are that Ringold is closer than Riverview to the Hanford facilities, which had been the major contributors of airborne effluents in the past, but the MEI at Ringold does not drink water derived from the Columbia River. The MEI at Riverview, although farther from the Hanford sources of airborne radionuclides, can be exposed to the one additional pathway of irrigation water derived from the Columbia River.

During 1994, the hypothetical MEI (assumed to be located 1.5 km [1 mi] directly across the Columbia River from the 300 Area) was calculated to have received a slightly higher dose in 1994 than an MEI located at either Ringold or Riverview. The farms located across from the 300 Area use water obtained from the Columbia Irrigation System far upstream of the Hanford Site for irrigation and well water for sanitary purposes. Foods grown there would only contain radionuclides released with airborne effluents of Hanford origin. Therefore, the conservative assumption was made that the diet of the MEI residing across from the 300 Area consisted totally of foods purchased from the Riverview area, which could contain radionuclides present in both liquid and gaseous effluents from Hanford. The added contribution of the radionuclides in the Riverview irrigation water maximizes the calculated dose from all air and water pathways combined.

The following exposure pathways were included in the calculation of doses potentially received by the hypothetical MEI for 1994: inhalation of and submersion in air downwind of the Site, consumption of foods contaminated by radionuclides deposited from the air and by irrigation with water from the

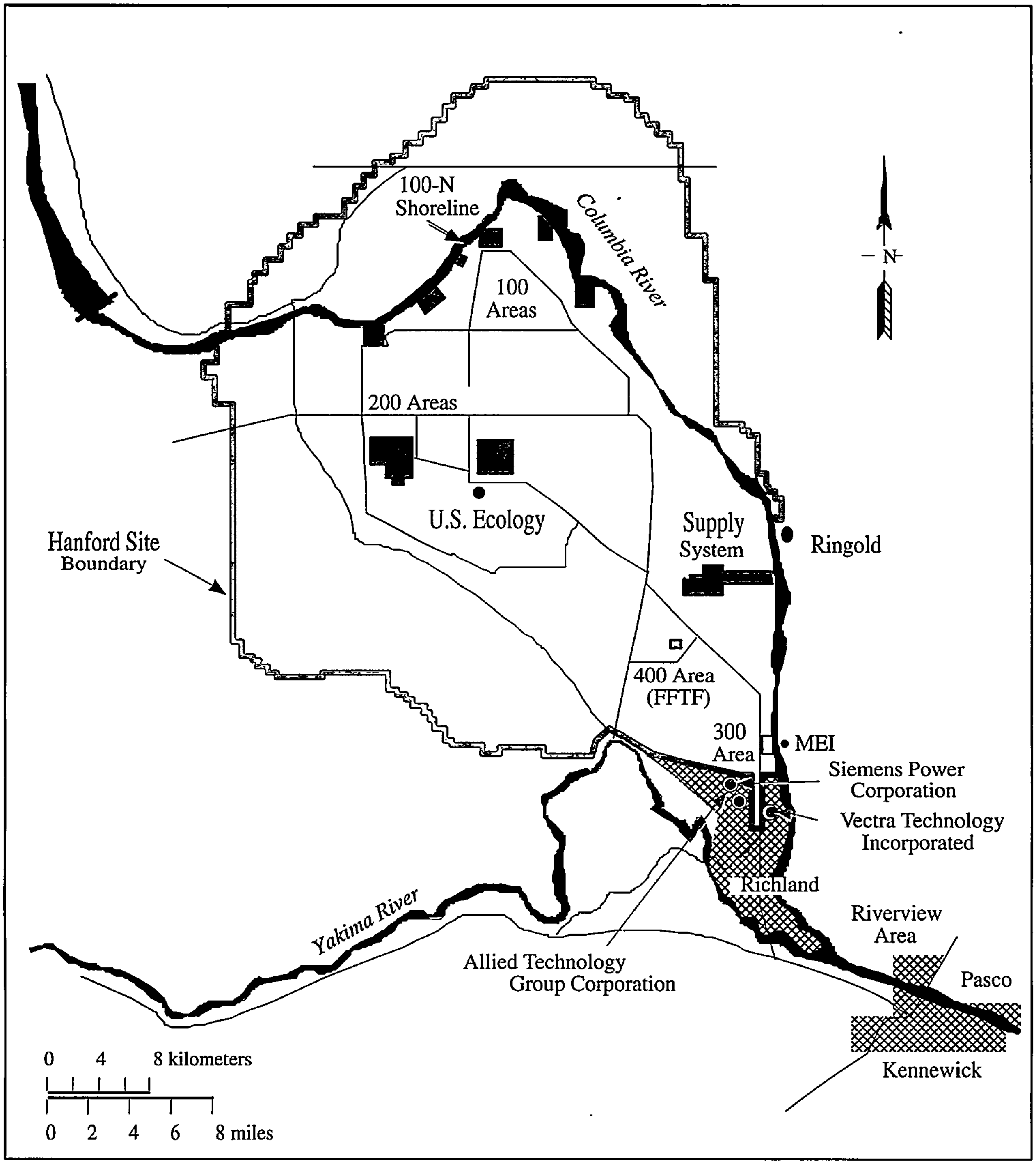

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Figure 6.0.1 Locations Important to Dose Calculations

Columbia River, direct exposure to radionuclides deposited on the ground, consumption of fish taken from the Columbia River, and external radiation during recreation activities on the Columbia River and its shoreline. The MEI for 1994 was postulated to be an individual who: .

- was a resident of the closest farm 1.5 km (1 mi) across the Columbia River from the 300 Area

- consumed foodstuffs irrigated with Columbia River water grown in the Riverview Irrigation District
- used the Columbia River extensively for boating, swimming, and fishing and consumed the fish caught
- drank well water that did not contain radionuclides of Hanford origin
- was exposed via inhalation and external exposure to the airborne radionuclides released from Hanford facilities.

Radiation doses to the MEI were calculated using the effluent data in Sections 3.1, Tables 3.1.1, 3.2.1, and 3.2.2, and measured quantities of radionuclides assumed to be present in the Columbia River from riverbank springs as input to the GENII code. The calculated doses for the MEI are summarized in Table 6.0.1. These values include the potential doses received from exposure to liquid and airborne effluents during 1994, as well as the future dose from radionuclides that were deposited in the body during 1994 via inhalation and ingestion. 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"). This contribution is not included in the MEI dose. Site-specific parameters for food pathways, diet, and recreational activity used for the dose calculations are contained in Appendix D.

The total potential radiation dose to the hypothetical MEI in 1994 was calculated to be 0.05 mrem (5×10^{-4} mSv) compared to 0.03 mrem (3×10^{-4} mSv) calculated for in 1993. The primary pathways contributing to this dose as determined by the computer calculations were

- consumption of fish containing radionuclides, principally isotopes of uranium, from the Columbia River (33%)
- consumption of food irrigated with Columbia River water containing radionuclides, principally tritium and uranium (27%)
- inhalation of airborne radionuclides, principally the iodine-129 released from the 200 Area (20%).

The DOE radiation dose limit for any member of the public from all routine DOE operations is 100 mrem/yr (1 mSv/yr). The dose calculated for the MEI for 1994 was 0.05% of the DOE limit.

The doses from Hanford operations for the MEI for 1990 through 1994 are illustrated in Figure 6.0.2.

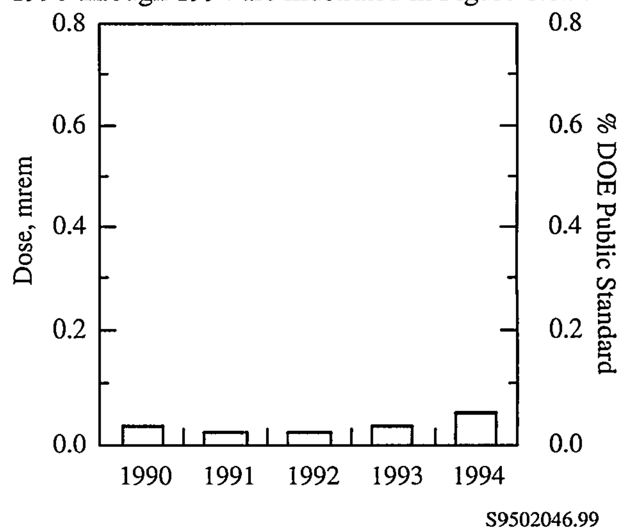

Figure 6.0.2 Calculated Effective Dose Equivalent to the Hypothetical Maximally Exposed Individual, 1990 Through 1994

During each year the doses were estimated using methods and computer codes that were state-of-the-art at the time. During the period of 1990 through 1992, the MEI was located at either Ringold or Riverview, whichever location represented the maximum hypothetical dose. For 1993 and 1994, the hypothetical MEI was located across the Columbia River from the 300 Area.

Table 6.0.1 Dose (mrem) to the Hypothetically Maximally Exposed Individual Residing across from the 300 Area from 1994 Hanford Operations

		Operating Area Contribution Dose, mrem[(a,b)]				
Effluent	Pathway	100 Areas	200 Areas	300 Area	400 Area	Pathway Total
Air	External[(c)]	7.9×10^{-8}	2.8×10^{-6}	1.3×10^{-4}	2.5×10^{-8}	1.3×10^{-4}
	Inhalation	2.3×10^{-5}	6.4×10^{-4}	9.8×10^{-3}	1.9×10^{-5}	1.0×10^{-2}
	Foods[(d)]	6.5×10^{-7}	1.5×10^{-3}	3.3×10^{-5}	6.3×10^{-8}	1.5×10^{-3}
	Total Air	2.4×10^{-5}	2.1×10^{-3}	1.0×10^{-2}	1.9×10^{-5}	1.2×10^{-2}
Water	Recreation[(e)]	9.7×10^{-7}	2.0×10^{-4}	2.1×10^{-8}	0.0[(f)]	2.0×10^{-4}
	Foods[(g)]	3.9×10^{-4}	1.4×10^{-2}	6.2×10^{-6}	0.0	1.4×10^{-2}
	Fish[(h)]	3.2×10^{-4}	1.7×10^{-2}	5.4×10^{-6}	0.0	1.7×10^{-2}
	Drinking Water	2.4×10^{-5}	6.7×10^{-3}	5.1×10^{-7}	0.0	6.7×10^{-3}
	Total Water	7.3×10^{-4}	3.8×10^{-2}	1.2×10^{-5}	0.0	3.9×10^{-2}
	Combined Total	7.6×10^{-4}	4.0×10^{-2}	1.0×10^{-2}	1.9×10^{-5}	5.1×10^{-2}

(a) To convert these dose values to mSv, divide them by 100.
(b) Values rounded after adding.
(c) Includes air submersion and exposure to ground-deposited radionuclides.
(d) Includes consumption of all foodstuffs contaminated via deposition from the air.
(e) External exposure during river recreation plus inadvertent ingestion of water while swimming.
(f) There are no releases to the river from the 400 Area.
(g) Includes consumption of all foodstuffs contaminated via irrigation water.
(h) Consumption of fish taken from the Columbia River.

Special Case Exposure Scenarios

While characteristics that define the standard and historical MEI are selected to define a high-exposure scenario that is unlikely to occur, they do not necessarily represent the scenario with the highest conceivable radiation dose. Low-probability exposure scenarios exist that could conceivably result in somewhat higher doses. Two potential scenarios include an individual who could spend time at the Site boundary location with the maximum external radiation dose rate, and a sportsman who might obtain contaminated wildlife that migrated from the Site. These special cases are discussed below, as is the potential dose from consumption of drinking water at the FFTF Visitors Center.

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 TLDs 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 (FFTF) Areas are described in Section 5.7, "External Radiation Surveillance." The 200 Areas results were not used because these locations are not accessible to the general public. Radiation measurements made at the 100-N Area shoreline (Figure 6.0.1) 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 of the N Reactor and supporting facilities.

The annual average dose rate at the location with the highest exposure rate along the 100-N shoreline during 1994 was 0.03 mrem/h (3×10^{-4} mSv/h), or about 0.02 mrem/h (2×10^{-4} mSv/h) above the average background dose rate of 0.01 mrem/h (1×10^{-4} mSv/h) normally observed at offsite shoreline locations. Therefore, for every hour someone spent at the 100-N Area shoreline during 1994, the external radiation dose received from Hanford operations would be about 0.02 mrem (2×10^{-4} mSv). This dose would be in addition to the annual dose calculated for the hypothetical MEI. The public can approach the shoreline by boat, but they are legally restricted from stepping onto the shoreline.

The FFTF Visitors Center, located southeast of the FFTF Reactor building (Figure 6.0.1), was opened to the public during the first 9 months of 1994. Dose rates measured at this location continued to be essentially equal to normal background radiation levels in the vicinity of Hanford (0.01 mrem/h [1×10^{-4} mSv/h]).

Sportsman Dose

Wildlife have access to areas of the Site that contain contamination and could thereby become contaminated. The potential also exists for contaminated wildlife to move offsite. For this reason, sampling is conducted onsite to estimate maximum contamination that might possibly exist in animals hunted offsite. This is a unique and relatively low probability scenario that is not included in the MEI calculation.

Listed below are examples of the estimated radiation doses that could have resulted if wildlife containing the maximum concentrations measured in onsite wildlife in 1994 migrated offsite, were hunted, and were consumed. 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 and the inaccessibility of onsite wildlife to hunters. Not all of the maximum values were observed in the same animal of each species sampled. However, the maximum values were compounded to arrive at an upper limit to the potential concentrations. These doses would be in addition to the MEI dose.

- The dose from eating 1 kg (2.2 lbs) of meat containing the maximum concentration of cesium-137 measured in a deer collected onsite is estimated to be 4×10^{-4} mrem (4×10^{-6} mSv).
- The dose from eating 1 kg (2.2 lbs) of meat containing the maximum concentration of cesium-137 and cobalt-60 measured in any game bird collected onsite is estimated to be 8×10^{-3} mrem (8×10^{-5} mSv).
- The dose from eating 1 kg (2.2 lbs) of meat containing the maximum concentration of cesium-137 measured in a rabbit collected onsite is estimated to be 2×10^{-3} mrem (2×10^{-5} mSv).
- The dose from eating 1 kg (2.2 lbs) of meat containing the maximum concentrations of cesium-137 and cobalt-60 measured in bass, whitefish, or carp collected from the Hanford Reach of the Columbia River is estimated to be 7×10^{-3} mrem (7×10^{-5} mSv).
- The dose from eating 1 kg (2.2 lbs) of meat containing the concentrations of uranium isotopes measured in a composite sample of small asiatic clams collected from the Columbia River downstream of the 300 Area is estimated to be 2×10^{-2} mrem (2×10^{-4} mSv).

The methodology for calculating doses from consumption of wildlife are addressed in more detail in Soldat et al. (1990).

FFTF Visitors Center Drinking Water

During 1994, ground water was used as a drinking water source at the FFTF Visitors Center (Figure 6.0.1). This water is sampled and analyzed throughout the year in accordance with applicable drinking water regulations. Radionuclide concentrations during 1994 were well below applicable drinking water standards but concentrations of iodine-129 and tritium were detected at levels greater than typical background values. Based on these measurements, the potential dose received by a member of the public from drinking 1 L (~1 qt) of drinking water during a visit to the FFTF Visitors Center was calculated to be 4×10^{-4} mrem

(4 x 10^{-6} mSv). The maximum organ dose (thyroid) was calculated to be 5 x 10^{-4} mrem (5 x 10^{-6} mSv). These doses are very small percentages of the DOE limit of 4 mrem effective dose equivalent (0.04 mSv) from drinking water.

Comparison with Clean Air Act Standards

Limits for radiation dose to the public from airborne emissions at DOE facilities are provided in 40 CFR 61, Subpart H, of the Clean Air Act Amendments. The regulation specifies that no member of the public shall receive a dose of more than 10 mrem/yr (0.1 mSv/yr) (EPA 1989) from exposure to airborne radionuclide effluents (other than radon) released at DOE facilities. It 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 1994 air emissions report (Diediker et al. 1995).

The 1994 air emissions from monitored Hanford facilities including radon releases from the 300 Area resulted in a potential dose to an MEI across from the 300 Area of 0.01 mrem (1 x 10^{-4} mSv), which is 0.1% of the limit. Of this total, radon emissions from the 300 Area contributed 0.007 mrem and nonradon emissions from all stack sources contributed 0.005 mrem. Therefore, the estimated annual dose from monitored stack releases at the Hanford Site during 1994 was well below the Clean Air Act standard. The Clean Air Act requires the use of CAP-88-PC 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 document. Nevertheless, the result of calculations performed with CAP-88-PC for air emissions from Hanford facilities agrees reasonably well with that calculated using the GENII code (0.01 mrem or 1 x 10^{-4} mSv).

The 1990 amendments to the Clean Air Act (40 CFR 61, Subpart H) also require DOE facilities to estimate the dose to a member of the public for radionuclides released from diffuse and unmonitored sources as well as from 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 1994, the dose to the MEI across the river from the 300 Area was 0.05 mrem (5 x 10^{-4} mSv), which was greater than the estimated dose at that location from stack emissions (0.01 mrem or 1 x 10^{-4} mSv). Doses at other locations around the Hanford Site perimeter ranged from 0.02 to 0.08 mrem (2 x 10^{-4} to 8 x 10^{-4} mSv). Based on these results, the combined dose from stack emissions and diffuse and unmonitored sources during 1994 was much less than the EPA standard.

Population Dose

Pathways of exposure to the population from releases of radionuclides to the atmosphere include inhalation, air submersion, and consumption of contaminated food. Pathways of exposure associated with Hanford-generated radionuclides present in the Columbia River include consumption of drinking water, fish, and irrigated foods, and external exposure during aquatic recreation. The regional population dose from 1994 Hanford operations was estimated by calculating the radiation 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 6.0.2. Food pathway, dietary, residency, and recreational activity assumptions for these calculations are given in Appendix D.

Table 6.0.2 Dose (person-rem) to the Population from 1994 Hanford Operations

Effluent	Pathway	Operating Area Contribution Dose, person-rem[a,b] 100 Areas	200 Areas	300 Area	400 Area	Pathway Total
Air	External[c]	1.3×10^{-5}	2.4×10^{-4}	1.4×10^{-3}	8.2×10^{-7}	1.7×10^{-3}
	Inhalation	5.3×10^{-3}	8.1×10^{-2}	5.9×10^{-2}	8.8×10^{-4}	1.5×10^{-1}
	Foods[d]	1.8×10^{-4}	1.8×10^{-1}	1.6×10^{-3}	7.1×10^{-6}	1.8×10^{-1}
	Total Air	5.5×10^{-3}	2.6×10^{-1}	6.2×10^{-2}	8.9×10^{-4}	3.3×10^{-1}
Water	Recreation[e]	6.9×10^{-6}	1.0×10^{-3}	1.3×10^{-7}	0.0[f]	1.0×10^{-3}
	Foods[g]	4.1×10^{-4}	1.6×10^{-2}	6.4×10^{-6}	0.0	1.6×10^{-2}
	Fish[h]	1.2×10^{-4}	6.4×10^{-3}	2.0×10^{-6}	0.0	6.5×10^{-3}
	Drinking Water	1.0×10^{-3}	2.8×10^{-1}	2.2×10^{-5}	0.0	2.8×10^{-1}
	Total Water	1.5×10^{-3}	3.0×10^{-1}	3.1×10^{-5}	0.0	3.0×10^{-1}
	Combined Total	7.0×10^{-3}	5.6×10^{-1}	6.2×10^{-2}	8.9×10^{-4}	6.3×10^{-1}

(a) To convert these dose values to person-Sv, divide them by 100.
(b) Values rounded after adding.
(c) Includes air submersion and exposure to ground-deposited radionuclides.
(d) Includes consumption of all foodstuffs contaminated via deposition from the air.
(e) External exposure during river recreation plus inadvertent ingestion of water while swimming.
(f) There are no releases to the river from the 400 Area.
(g) Includes consumption of all foodstuffs contaminated via irrigation water and external exposure to ground contaminated via irrigation.
(h) Consumption of fish taken from the Columbia River.

The potential dose calculated for the population was 0.6 person-rem (0.006 person-Sv) in 1994, compared to 0.4 person-rem (0.004 person-Sv) in 1993. The 80-km (50-mi) population doses attributed to Hanford operations from 1990 through 1994 are compared in Figure 6.0.3.

Primary pathways contributing to the 1994 dose to the population were

- consumption of drinking water contaminated with radionuclides (principally tritium and uranium) released to the Columbia River at Hanford (44%)
- consumption of foodstuffs contaminated with radionuclides (principally iodine-129 released with gaseous effluents primarily from the PUREX Plant stack [29% of the total dose])
- inhalation of radionuclides (principally iodine-129) that were released to the air from the PUREX Plant stack (24%).

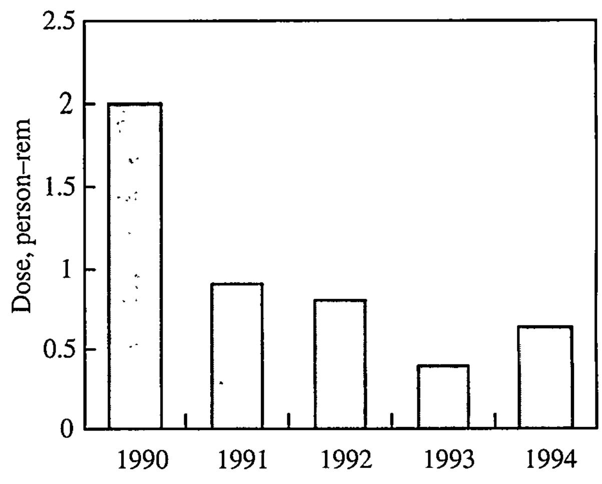

Figure 6.0.3 Calculated Effective Dose Equivalent to the Population Within 80 km (50 mi) of the Hanford Site, 1990 Through 1994

Table 6.0.3 Summary of Doses to the Public in the Vicinity of Hanford from Various Sources, 1994

Source	Maximum Individual, mrem[(a)]	80-km Population, person-rem[(a)]
All Hanford effluents[(b)]	0.05	0.6
DOE limit	100	--
Percent of DOE limit	0.05%	--
Background radiation	300	110,000
Hanford doses percent of background	0.02%	6×10^{-4}%
Doses from gaseous effluents[(c)]	0.01	--
EPA air standard	10	--
Percent of EPA standard	0.1%	--

(a) To convert the dose values to mSv or person-Sv, divide them by 100.
(b) Calculated with the GENII code (Napier et al. 1988a, 1988b, 1988c).
(c) Calculated with the EPA CAP-88-PC code.

The average per capita dose from 1994 Hanford operations, based on a population of 380,000 within 80 km (50 mi), was 0.002 mrem (2×10^{-5} mSv). This dose 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 6.0.4. The estimated per capita dose to individual members of the public from Hanford sources is a small fraction (approximately 6×10^{-4}%) of the annual per capita dose (300 mrem) from natural background sources.

The doses to the MEI and to the 80-km (50-mi) population from Hanford effluents are compared to appropriate standards and natural background radiation in Table 6.0.3. This table shows that the calculated radiation doses from Hanford operations in 1994 are a small percentage of the standards and of natural background.

Doses from Other Than DOE Sources

DOE maintains an awareness of other manmade sources of radiation (other than DOE sources), which if combined with the DOE sources might have the potential to exceed a dose contribution to any member of the public of 10 mrem (0.1 mSv). Various non-DOE industrial sources of public radiation exposure exist at or near Hanford. These include the low-activity commercial radioactive waste burial ground at Hanford operated by US Ecology, the nuclear 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 Vectra Technology, Inc. (Figure 6.0.1). With information gathered from these companies, it was conservatively determined that the total 1994 individual dose from their combined activities is on the order of 0.05 mrem (5×10^{-4} mSv). Therefore, the combined dose from Hanford area non-DOE and DOE sources to a member of the public for 1994 was well below any regulatory dose limit.

Hanford Public Radiation Dose in Perspective

Several scientific studies (NRC 1980, 1990; UNSCEAR 1988) have been performed to estimate the potential risk of developing detrimental health effects from exposure to low levels of radiation. These studies have provided vital information to government and scientific organizations that recommend radiation 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, most

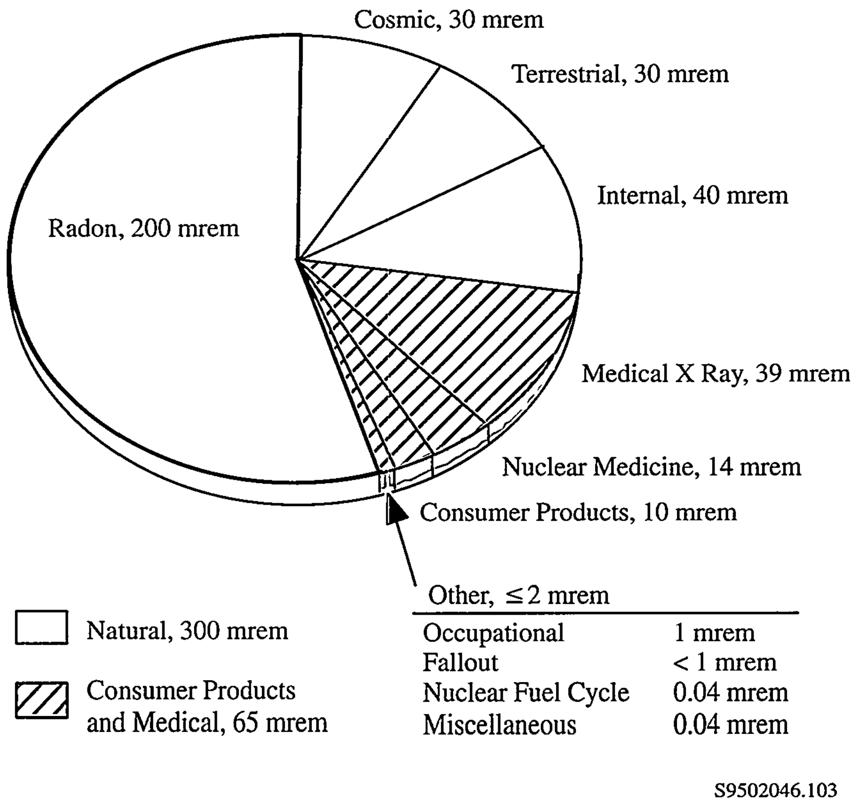

Figure 6.0.4 National Annual Average Radiation Doses from Various Sources (mrem) (NCRP 1987)

scientists accept the conservative hypothesis that low-level doses might increase the probability that certain types of effects, such as cancer, could occur. 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 of these same health effects observed historically at much higher doses (in atomic bomb victims, radium dial painters, etc.). Therefore, using conservative assumptions, one can postulate that even the natural background radiation (which is many hundreds of times greater than radiation from Hanford releases) increases each person's probability or chance of developing a detrimental health effect.

Scientists do not agree about 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 even indicated that low radiation doses may be beneficial (HPS 1987). Because cancer and hereditary diseases in the general population may be caused by a multitude of sources (e.g., genetic defects, sunlight, chemicals, and background radiation), some scientists doubt that the risk from low-level radiation exposure can ever be determined accurately. The EPA has used a probability value of approximately 4 per 10 million ($4 \text{ x } 10^{-7}$) for the risk of developing a fatal cancer after receiving a dose of 1 mrem (0.01 mSv) in developing Clean Air Act regulations (EPA 1989). Recent data (NRC 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 (for example, 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 the needed benefits from the industry.

The public is subjected to some incremental risks from exposure to industrial pollutants (radiological and non-radiological). These risks can be kept in perspective by comparing them to the increased risks involved in other typical activities. For instance, two added risks that an individual receives from flying on an airline are the risks of added radiation dose (stronger cosmic radiation field at higher altitude) and the possibility of being in an aircraft accident. Table 6.0.4 compares the estimated risks from various radiation doses to the risks of some activities encountered in everyday life.

Another way of looking at the risk of detrimental health effects from Hanford radioactive releases is illustrated in Table 6.0.5. Listed are some activities considered approximately equal in risk to the hypothetical risk from the potential radiation dose received by the MEI from Hanford releases in 1994.

Dose Rates to Animals

Conservative (upper) estimates have been made of the potential radiation dose to "native aquatic animal organisms," in accordance with a DOE Order 5400.5 interim requirement for management and control of liquid discharges. Potential radiation dose rates during 1994 were calculated for several possible 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 Columbia River and onsite.Because the volumetric 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 unlikely 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 dilution at only 10 to 1 by the river. Radiation doses were calculated for several different types of aquatic animals, using highly conservative assumptions and the computer code CRITR2 (Baker and Soldat 1992). The animal receiving the highest potential dose was calculated to be a duck consuming aquatic plants. However, even if such a duck spent 100% of its time in the one-tenth spring water consuming only plants growing there, it would only receive a radiation dose rate of 0.02 rad/d. This dose rate is 2% of the limit of 1 rad/d given for native aquatic animal organisms in DOE Order 5400.5.

Doses were also estimated for clams, fish, and waterfowl exposed to Columbia River water containing a mixture of all the radionuclides reaching the Columbia River from Hanford sources during 1994. The highest potential dose was 4×10^{-3} rad/d for a plant-eating duck.

Dose estimates based on the maximum concentrations of cesium-137 and cobalt-60 measured in muscle of animals collected onsite and from the Columbia River ranged from 2×10^{-7} rad/d to a mule deer to 3×10^{-6} rad/d for a pheasant.

Table 6.0.4 Estimated Risk from Various Activities and Exposures[a]

Activity or Exposure Per Year	Risk of Fatality
Riding or driving in a passenger vehicle (300 miles)	2×10^{-6}[b]
Home accidents	100×10^{-6}[b]
Drinking 1 can of beer or 4 ounces of wine per day (liver cancer/cirrhosis)	10×10^{-6}
Pleasure boating (accidents)	6×10^{-6}[b]
Firearms, sporting (accidents)	10×10^{-6}[b]
Smoking 1 pack of cigarettes per day (lung/heart/other diseases)	3600×10^{-6}
Eating 4 tablespoons of peanut butter per day (liver cancer)	8×10^{-6}
Eating 90 pounds of charcoal-broiled steaks (gastrointestinal-tract cancer)	1×10^{-6}
Drinking chlorinated tap water (trace chloroform—cancer)	3×10^{-6}
Taking contraceptive pills (side effects)	20×10^{-6}
Flying as an airline passenger (cross country roundtrip—accidents)	8×10^{-6}[b]
Flying as an airline passenger (cross country roundtrip—radiation)	0 to 5×10^{-6}
Natural background radiation dose (300 mrem, 3 mSv)	0 to 120×10^{-6}
Dose of 1 mrem (0.01 mSv)	0 to 0.4×10^{-6}
Dose to the maximally exposed individual living near Hanford in 1994 (0.05 mrem, 5×10^{-4} mSv)	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 (Ames et al. 1987; Atallah 1980; Dinman 1980; Travis and Hester 1990; Wilson and Crouch 1987).

(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 6.0.5 Activities Comparable in Risk to That from the 0.05-mrem Dose Calculated for the 1994 Maximally Exposed Individual

Driving or riding in a car 5 km (3 mi)
Smoking 1/20 of a cigarette
Flying 13 km (8 mi) on a commercial airline
Eating 4 tablespoons of peanut butter
Eating one 0.8-kg (1.8-lb) charcoal-broiled steak
Drinking about 4.8 L (5 quarts) of chlorinated tap water
Being exposed to natural background radiation for about 1.5 hours in a typical terrestrial location
Drinking about 3/4 of a can of beer or 3/4 of a glass of wine