**Offsite Radiation Doses from
Hanford Operations for the
Years 1983 through 1987:
A Comparison of Results
Calculated by Two Methods**

J. K. Soldat

October 1989

**Prepared for the U.S. Department of Energy
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**Pacific Northwest Laboratory
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Pacific Northwest Laboratory
Richland, Washington 99352

PREFACE

The Hanford environmental monitoring program is conducted by the Pacific Northwest Laboratory (PNL)(a) for the U.S. Department of Energy, Richland Operations Office (DOE/RL). One of the objectives of the monitoring program is the assessment of the radiation doses from Hanford Site operations potentially received by the general public residing in the vicinity. The results of these evaluations have been reported annually and were summarized by Soldat, Price, and McCormack (1986) for the period 1957 through 1984.

Potential radiation doses for the calender years (CY) 1983-1987 have been calculated by PNL and reported in annual reports entitled Environmental Monitoring (or Surveillance) at Hanford for the Year 198- for those years listed below.

CY 1983: K.R. Price et al., 1984, PNL-5038

CY 1984: K.R. Price et al., 1985, PNL-5407

CY 1985: K.R. Price (ed.), 1986, PNL-5817

CY 1986: No author listed, 1987, PNL-6120

CY 1987: R.E. Jaquish and P.J. Mitchell (eds.), 1988, PNL-6464

This report compares the radiation doses potentially received by members of the public in the vicinity of Hanford, which were previously reported in the annual reports for the years 1983 through 1987 with doses recalculated for those years with the new computer code GENII (Napier et al. 1988) that employs the dosimetric system and metabolic data in ICRP Publications 26 and 30 (ICRP 1977, ICRP 1977-1982). The results of the previous comparison of radiation doses calculated by different methods are reported by McCormack et al. (1983) for the years 1977-1982.

(a) The Pacific Northwest Laboratory is operated for the U.S. Department of Energy by Battelle Memorial Institute under Contract DE-AC06-76RLO 1830.

SUMMARY

This report compares the results of the calculation of potential radiation doses to the public by two different environmental dosimetric systems for the years 1983 through 1987. Both systems project the environmental movement of radionuclides released with effluents from Hanford operations; their concentrations in air, water, and foods; the intake of radionuclides by ingestion and inhalation; and, finally, the potential radiation doses from radionuclides deposited in the body and from external sources.

The first system, in use for the past decade at Hanford, calculates radiation doses in terms of 50-year cumulative dose equivalents to body organs and to the whole body, based on the methodology defined in ICRP Publication 2. This system uses a suite of three computer codes: PABLM, DACRIN, and KRONIC.

In the new system, 50-year committed doses are calculated in accordance with the recommendations of the ICRP Publications 26 and 30, which were adopted by the U.S. Department of Energy (DOE) in 1985. This new system calculates dose equivalent (DE) to individual organs and effective dose equivalent (EDE). The EDE is a risk-weighted DE that is designed to be an indicator of the potential health effects arising from the radiation dose.

The potential radiation doses to the population residing within 80 km of Hanford and to the hypothetical maximally exposed individual (MI) located at the Riverview irrigation district west of Pasco, Washington, were recalculated for the years 1983-1987 using a modified Version 1.272 of the GENII computer code. An additional set of dose calculations was made for the same 5 years for a different hypothetical MI located along the Columbia River at Ringold, which is much closer to the sources of gaseous effluents released to the atmosphere than Riverview.

In addition, the original computer output records used for the 1983-1986 annual reports were consulted to extract the previously unreported 50-year committed dose equivalents as calculated from the older methodology in ICRP Publication 2. These results are more directly comparable with the 50-year committed doses calculated using the new system defined in ICRP Publications 26 and 30.

Comparison of the results of the various methods of calculation are complicated by the fact that, not only are the internal dose calculation schemes different, but the values of many of the metabolic and environmental parameters have been updated in the newer system. In addition, operations at Hanford facilities have changed significantly during the 5-year period so that the quantity and the composition of the radionuclides being released to the environment changed. Nevertheless, several relationships between the various types of calculations are evident:

Whole-Body and EDE Doses to the Maximally Exposed Individual

- Old Cumulative Dose Versus Old Committed Dose. The old cumulative whole-body doses are an order of magnitude higher than the old committed doses. The principal reason for the higher cumulative dose is the residual ^{90}Sr in irrigated soil during the extra 49 years following the year of release and in ingested foodstuffs grown therein, which are included in the cumulative dose calculations.
- Old Committed Dose Versus New Committed Dose. The old committed dose is generally higher than the new committed dose by up to a factor of two. However, the comparisons here are between two somewhat different entities, i.e., whole-body dose versus EDE.
- Ringold MI Versus Riverview MI. The ratio of the EDE at Ringold to that at Riverview is about 2:1. The thyroid dose, which is highly dependent on the ^{129}I released to the atmosphere from the PUREX stack, weights the EDE more at Ringold than at Riverview.

Whole-Body and EDE Doses to the 80-km Population Doses

- Old Cumulative Dose Versus Old Committed Dose. The old cumulative doses were calculated to be 1.5 times the old committed doses. This is a much smaller ratio than found for the MI. The ratio is higher for the MI because of the assumption that a large fraction of his food supply is irrigated with water drawn from the Columbia River below Hanford. Such irrigated foodstuffs are available only in limited quantities for the 80-km population.
- Old Committed Dose Versus New Committed Dose. The old committed dose is generally about 0.5 times the new committed dose, just the opposite of the ratio noted for the MI. Once again, the difference in the ratios can be attributed, at least in part, to the difference in the relative quantity of irrigated food that is consumed. However, the comparisons here are between somewhat different entities, i. e., whole body versus EDE.

ACKNOWLEDGMENTS

This report was prepared under the direction of the Surface Environmental Monitoring Project, Office of Hanford Environment, R. E. Jaquish, project manager. The work is sponsored by the Environmental Oversight Branch, U.S. Department of Energy, Richland Operations Office. The following persons contributed to the preparation of this report: M. Cross, word processor; J. R. Weber, editor; R. G. Schreckhise and W. D. McCormack, reviewers.

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INTRODUCTION

Environmental surveillance and monitoring have been conducted at the Hanford Site for the past 45 years to identify potential health and environmental impacts from Site operations. Since 1957, radiation doses potentially received by members of the public have been calculated and reported annually.(a) A comparison of results reported for the years 1983 through 1987 with doses recalculated with the computer code GENII (Napier et al. 1988) is provided in this document.

During the period of reporting, there have been changes in the methods of determining potential impacts and in the units in which the dose to the public has been expressed. During the early years of Hanford operations, concentrations of radionuclides in environmental media attributable to Hanford operations were detectable above the background levels of naturally occurring and fallout radionuclides. During this period, evaluations of the potential radiation exposure to the public were based on measurements of radionuclides in environmental media and studies of diets and recreation habits of the public in the vicinity of the Hanford Site. However, as effluent treatment systems were improved and the number of operating facilities was reduced, Hanford contributions to the environmental levels of radionuclides became increasingly difficult to differentiate from background levels. By the early 1970s, it was no longer feasible to estimate potential offsite radiation doses from Hanford operations solely on the basis of direct measurements of environmental media.

Environmental transport and dosimetry models were used to estimate radiation doses in the vicinity of Hanford beginning in 1974. These models, in conjunction with concentrations of radionuclides in Hanford effluents, were used to project concentrations of radionuclides in environmental media to which the public might be exposed. From these results, the potential radiation doses to the public were calculated.

(a) The results of these evaluations were summarized by Soldat, Price, and McCormack (1986) for the period 1957 through 1984.

Beginning in 1977, radiation doses were calculated in terms of a 50-year cumulative dose equivalent. This cumulative dose accounted for the internal and external exposure resulting from the radionuclides that remained in the environment during the 49-year period following the year of release. This system for calculating environmental radiation dose was not required by the then-existing standards. However, it was used because it provided a more realistic method of estimating long-term doses than any other existing environmental dosimetry model. It provided a conservative method of accounting for residual levels of radionuclides in the environment that were too low to measure.

Beginning in 1985, the evaluation of potential radiation exposure of the public in the vicinity of Hanford was evaluated in terms of a newer quantity: effective dose equivalent (EDE), as recommended by the International Commission on Radiation Protection (ICRP) in Publication 26 (ICRP 1977) and adopted by the U.S. Department of Energy (DOE) in 1985.^(a) The EDE calculation includes the 50-year committed dose (i.e., the internal dose received over the ensuing 50-year period from the radionuclides taken into the body during the year of effluent release) and the dose received from external exposure to radionuclides released to the environment during that year. The EDE is calculated by summing the products of the individual 50-year committed organ doses and appropriate weighting factors. The weighting factors are intended to relate the fractional contribution that irradiation of a particular organ makes to the total health risk to an individual from uniform whole-body external irradiation. Thus, the EDE concept is intended to provide dose equivalent values that are more directly relatable to potential health effects of radiation exposure than the previously used dosimetry methods. The ICRP also recommended updated values for the metabolic and physical parameters used in the dose calculations.

The Hanford annual environmental monitoring reports for calendar years 1983 and 1984 reported the radiation doses calculated in terms of the 50-year cumulative dose to individual organs and to the whole body. The cumulative doses were calculated using the codes PABLM (Napier, Kennedy, and Soldat

(a) Memo from W. A. Vaughan, Assistant Secretary for Environment, Safety and Health, U.S. Department of Energy, to DOE Field Offices, August 5, 1985.

1980), DACRIN (Houston, Strenge, and Watson 1974), and KRONIC (Strenge and Watson 1973). For the years 1985 and 1986, two types of doses were reported: the 50-year cumulative dose and the 50-year committed dose to individual body organs along with the EDE. The new doses were estimated using a temporary computer code, PABKID, that simply replaced the dose conversion factors in the codes used in 1983 and 1984 with the new dose conversion factors recommended by the ICRP (ICRP 1977, 1979-1982).

For the year 1987, the annual report included only the types of doses provided by Version 1.194 of the computer code GENII (Napier et al. 1988), which was designed to fully implement the recommendations of the ICRP. This code contains an improved, internally coded atmospheric transport and dispersion model and updated environmental transfer parameters.

The changes that have been made to the Hanford environmental transport and dosimetry codes since 1984 may in themselves result in differences in the potential radiation doses to the public from Hanford operations as reported in the annual environmental monitoring reports.

All of the radiation doses calculated by either method and reported here for the period 1983-1987 are small compared to the DOE limit of 100 mrem/yr EDE.(a) The doses are also small compared to the limits in 40 CFR 61 for releases of radionuclides to the atmosphere, viz., 25 mrem/yr dose equivalent to the whole body, and 75 mrem/yr dose equivalent to any body organ (EPA 1983).

(a) Memo from W. A. Vaughan, Assistant Secretary for Environment, Safety and Health, U.S. Department of Energy, to DOE Field Offices, August 5, 1985.

RECALCULATION OF PREVIOUSLY REPORTED DOSES
WITH VERSION 1.272 OF GENII

To compare the results of the two dose calculation methods and to identify the reasons for any differences, potential radiation doses previously reported in the annual reports for 1983-1987 (Price et al. 1984, Price et al. 1985, Price 1986, PNL 1987, Jaquish and Mitchell 1988) were recalculated using a modified(a) Version 1.272 of the GENII code (Napier et al. 1988). Data from the previous reports were supplemented and corrected in several ways to render the recalculations more comparable and accurate. The previously published doses were reported to only one significant figure. To aid in the comparison with the doses calculated using Version 1.272 of the GENII code, the previously published values were converted to two significant figures using the original computer outputs for 1983-1987. In the process, a few typographical errors in the previously reported doses were found and corrected. The reconstructed doses are listed in Tables A.1 through A.14 in Appendix A.

In addition, the annual averages of measurements for certain radionuclides in samples of Columbia River water collected downstream of the site were higher than the measured background levels. The differences between the two sets of measurements were attributed to Hanford operations and were used as additional input data to the GENII computer code.

Potential radiation doses were calculated for the population residing within 80 km of the Hanford Site and, as in past years, for a hypothetical, maximally exposed individual (MI) residing in the Riverview irrigation district west of Pasco, Washington, which is about 27 miles southeast of the PUREX stack (Figure 1). The doses to the population and the MI were calculated assuming the following pathways of exposure:

-
- (a) The modification consisted of replacing the dose factors for exposure to soil contaminated uniformly throughout a 15-cm plow layer with the dose factors for exposure to contaminated surface soil as found in Napier, Kennedy, and Soldat (1980). The modified dose factors are those previously used for the 1983-1987 annual reports.

FIGURE 1. Hanford Site and Environs

- inhalation of radionuclides in the air
- external exposure to radionuclides in the air and deposited on the soil
- consumption of locally grown foods (i.e., plant and animal products that were exposed to atmospheric releases and irrigated with Columbia River water)
- ingestion of Columbia River water
- consumption of fish from the Columbia River
- external exposure while swimming, boating, and fishing on the Columbia River.

The results of these dose calculations are presented in Tables B.1 through B.10 in Appendix B.

Because the importance of the river pathways has decreased in the past few years as the releases of radionuclides to the river have decreased, it was determined that MI location should now be sited closer than Riverview to some of the Hanford sources of atmospheric effluents. Thus, an additional set of radiation dose calculations was performed for a hypothetical MI located at Ringold, an area on the east side of the Columbia River about 15 miles east-southeast of the Hanford PUREX facility stack. Because river water is used for some irrigation at Ringold, it was assumed that all water used for irrigation and all animal drinking water was drawn from the Columbia River. However, humans' drinking water at Ringold is drawn from deep wells not influenced by Columbia River water. The aquatic recreation pathways are applicable regardless of the place of residence. The results of the calculations of the potential radiation dose to the MI at Ringold are presented in Tables C.1 through C.5 in Appendix C.

Tables 1 through 10 compare the radiation doses calculated with Version 1.272 of the GENII code to those previously reported in the Hanford annual environmental monitoring reports or calculated by other codes. Tables 1 through 5 compare values for the MI and Tables 6 through 10 for the 80-km population. The original computer runs used to prepare the 1983-1987 Hanford annual reports were used to modify the previously reported 50-year cumulative dose values to two significant figures.

The original computer runs also contain the previously unreported calculations of the 50-year committed doses for both the MI and the population. These committed doses were extracted from the runs and are also listed in the tables.

TABLE 1. Comparison of Whole-Body and Effective Dose Equivalents (mrem) to the Maximally Exposed Individual (MI), Calculated by Different Codes for 1983-1987(a)

Year	Cumulative WB Dose PABLM(b)	Committed WB Dose PABLM(c)	MI at Riverview			MI at Ringold
			EDE PABK1D(d) Version 1.0	EDE GENII Version 1.194	EDE GENII Version 1.272	EDE GENII Version 1.272
1983	1.0	0.16	---	---	0.049	0.11
1984	2.1	0.32	---	---	0.082	0.13
1985	2.8	0.41	0.12	---	0.12	0.22
1986	2.4	0.14	0.089	---	0.093	0.19
1987	---	---	---	0.050	0.049	0.080

- (a) Whenever possible, the original computer output sheets were consulted to convert the originally reported dose values from one significant figure to two and to extract the values of committed whole-body dose in column 3.
- (b) A suite of codes, including PABLM, DACRIN, and KRONIC, were used to calculate the 50-year cumulative dose equivalents to the whole body (WB) and various organs from effluents released during the stated year.
- (c) The suite of codes listed under (b) was used to calculate the 50-year committed dose equivalents for the whole body and various organs from the effluents released during the stated year.
- (d) PABK1D was a temporary code that replaced dose factors derived from ICRP Publication 2 that were previously used in the suite of codes listed under (b) with dose factors given in ICRP Publication 30.

TABLE 2. Comparison of Skeletal Bone and Bone Surface Dose Equivalents (mrem) to the Maximally Exposed Individual (MI), Calculated by Different Codes for 1983-1987(a)

Year	MI at Riverview					MI at Ringold
	Skeletal Bone		Bone Surface, Committed Dose			Bone Surface
	Cumulative	Committed				Committed Dose
	Dose PABLM(b)	Dose PABLM(c)	PABK10(d) Version 1.0	GENII Version 1.194	GENII Version 1.272	GENII Version 1.272
1983	3.8	0.57	---	---	0.21	0.26
1984	7.8	1.2	---	---	0.42	0.49
1985	10	1.5	0.72	---	0.55	0.72
1986	9.2	0.45	0.58	---	0.44	0.53
1987	---	---	---	0.14	0.14	0.15

- (a) Whenever possible, the original computer output sheets were consulted to convert the originally reported dose values from one significant figure to two and to extract the values of committed dose in column 3.
- (b) A suite of codes, including PABLM, DACRIN, and KRONIC, were used to calculate the 50-year cumulative dose equivalents to the whole body and various organs from effluents released during the stated year.
- (c) The suite of codes listed under (b) was used to calculate the 50-year committed dose equivalents for the whole body and various organs from the effluents released during the stated year.
- (d) PABK1D was a temporary code that replaced dose factors (derived from ICRP Publication 2) previously used in the suite of codes listed under (b) with dose factors given in ICRP Publication 30.

TABLE 3. Comparison of Lung Dose Equivalents (mrem) to the Maximally Exposed Individual (M1), Calculated by Different Codes for 1983-1987(a)

Year	Cumulative Dose PABLM(b)	M1 at Riverview Committed Dose				MI at Ringold Committed Dose
		PABLM(c)	PABKID(d)	GENII	GENII	GENII
			Version 1.0	Version 1.194	Version 1.272	
1983	0.015	0.0080	---	---	0.034	0.097
1984	0.025	0.022	---	---	0.057	0.12
1985	0.041	0.034	0.072	---	0.087	0.21
1986	0.023	0.015	0.032	---	0.046	0.13
1987	---	---	---	0.015	0.015	0.020

- (a) Whenever possible, the original computer output sheets were consulted to convert the originally reported dose values from one significant figure to two and to extract the values of committed dose in column 3.
- (b) A suite of codes, including PABLM, DACRIN, and KRONIC, were used to calculate the 50-year cumulative dose equivalents to the whole body and various organs from effluents released during the stated year.
- (c) The suite of codes listed under (b) was used to calculate the 50-year committed dose equivalents for the whole body and various organs from the effluents released during the stated year.
- (d) PABKID was a temporary code that replaced dose factors (derived from ICRP Publication 2) previously used in the suite of codes listed under (b) with dose factors given in ICRP Publication 30.

TABLE 4. Comparison of GI Tract-LLI Dose Equivalents (mrem) to the Maximally Exposed Individual (MI), Calculated by Different Codes for 1983-1987(a)

Year	Cumulative Dose PABLM(b)	MI at Riverview Committed Dose			MI at Ringold Committed Dose	
		PABLM(c)	PABKID(d)	GENII	GENII	GENII
			Version 1.0	Version 1.194	Version 1.272	Version 1.272
1983	0.16	0.075	---	---	0.070	0.13
1984	0.29	0.12	---	---	0.087	0.13
1985	0.35	0.14	0.095	---	0.11	0.19
1986	0.27	0.071	0.049	---	0.080	0.14
1987	---	---	---	0.029	0.029	0.030

- (a) Whenever possible, the original computer output sheets were consulted to convert the originally reported dose values from one significant figure to two and to extract the values of committed dose in column 3.
- (b) A suite of codes, including PABLM, DACRIN, and KRONIC, were used to calculate the 50-year cumulative dose equivalents to the whole body and various organs from effluents released during the stated year.
- (c) The suite of codes listed under (b) was used to calculate the 50-year committed dose equivalents for the whole body and various organs from the effluents released during the stated year.
- (d) PABKID was a temporary code that replaced dose factors (derived from ICRP Publication 2) previously used in the suite of codes listed under (b) with dose factors given in ICRP Publication 30.

TABLE 5. Comparison of Thyroid Dose Equivalents (mrem) to the Maximally Exposed Individual (MI), Calculated by Different Codes for 1983-1987(a)

Year	Cumulative Dose PABLM(b)	MI at Riverview Committed Dose			MI at Ringold Committed Dose	
		PABLM(c)	PABKID(d)	GENII	GENII	GENII
			Version 1.0	Version 1.194	Version 1.272	Version 1.272
1983	0.090	0.084	---	---	0.084	0.15
1984	0.82	0.49	---	---	0.33	0.44
1985	1.9	0.86	0.98	---	0.78	1.3
1986	2.2	0.72	0.90	---	0.79	1.6
1987	---	---	---	0.86	0.91	1.8

- (a) Whenever possible, the original computer output sheets were consulted to convert the originally reported dose values from one significant figure to two and to extract the values of committed dose in column 3.
- (b) A suite of codes, including PABLM, DACRIN, and KRONIC, were used to calculate the 50-year cumulative dose equivalents to the whole body and various organs from effluents released during the stated year.
- (c) The suite of codes listed under (b) was used to calculate the 50-year committed dose equivalents for the whole body and various organs from the effluents released during the stated year.
- (d) PABKID was a temporary code that replaced dose factors (derived from ICRP Publication 2) previously used in the suite of codes listed under (b) with dose factors given in ICRP Publication 30.

TABLE 6. Comparison of Whole Body and Effective Dose Equivalents (person-rem) to the 80-km Population, Calculated by Different Codes for 1983 Through 1987(a)

<u>Year</u>	<u>Cumulative WB Dose PABLM(b)</u>	<u>Committed WB Dose PABLM(c)</u>	<u>EDE PABKID(d) Version 1.0</u>	<u>EDE GENII Version 1.194</u>	<u>EDE GENII Version 1.272</u>
1983	3.8	3.0	---	---	6.4
1984	5.2	3.3	---	---	7.3
1985	7.0	4.3	9.0	---	10
1986	7.7	5.1	8.6	---	12
1987	---	---	---	4.3	4.2

- (a) Whenever possible, the original computer output sheets were consulted to convert the originally reported dose values from one significant figure to two and to extract the values of committed dose in column 3.
- (b) A suite of codes, including PABLM, DACRIN, and KRONIC, were used to calculate the 50-year cumulative dose equivalents to the whole body (WB) and various organs from effluents released during the stated year.
- (c) The suite of codes listed under (b) was used to calculate the 50-year committed dose equivalents for the whole body and various organs from the effluents released during the stated year.
- (d) PABKID was a temporary code that replaced dose factors derived from ICRP Publication 2 that were previously used in the suite of codes listed under (b) with dose factors given in ICRP Publication 30.

TABLE 7. Comparison of Skeletal Bone and Bone Surface Dose Equivalents (person-rem) to the 80-km Population, Calculated by Different Codes for 1983-1987(a)

Year	Skeletal Bone		Bone Surface, Committed Dose		
	Cumulative Dose PABLM(b)	Committed Dose PABLM(c)	PABK1D(d) Version 1.0	GENII Version 1.194	GENII Version 1.272
1983	7.0	4.2	---	---	6.7
1984	13	7.1	---	---	17
1985	19	11	31	---	26
1986	16	8.4	13	---	16
1987	---	---	---	2.2	2.3

(a) Whenever possible, the original computer output sheets were consulted to convert the

TABLE 8. Comparison of Lung Dose Equivalents (person-rem) to the 80-km Population, Calculated by Different Codes for 1983-1987(a)

Year	Cumulative Dose PABLM(b)	Committed Dose			
		PABLM(c)	PABKID(d) Version 1.0	GENII Version 1.194	GENII Version 1.272
1983	3.0	3.0	---	---	7.0
1984	4.3	4.2	---	---	9.8
1985	7.8	7.2	13	---	13
1986	6.1	5.4	7.5	---	11
1987	---	---	---	1.1	0.97

- (a) Whenever possible, the original computer output sheets were consulted to convert the originally reported dose values from one significant figure to two and to extract the values of committed dose in column 3.
- (b) A suite of codes, including PABLM, DACRIN, and KRONIC, were used to calculate the 50-year cumulative dose equivalents to the whole body and various organs from effluents released during the stated year.
- (c) The suite of codes listed under (b) was used to calculate the 50-year committed dose equivalents for the whole body and various organs from the effluents released during the stated year.
- (d) PABKID was a temporary code that replaced dose factors (derived from ICRP Publication 2) previously used in the suite of codes listed under (b) with dose factors given in ICRP Publication 30.

TABLE 9. Comparison of GI Tract-LLI Dose Equivalents (person-rem) to the 80-km Population, Calculated by Different Codes for 1983-1987(a)

Year	Cumulative Dose PABLM(b)	Committed Dose			
		PABLM(c)	PABKID(d) Version 1.0	GEN11 Version 1.194	GEN11 Version 1.272
1983	2.8	2.7	---	---	6.4
1984	3.0	2.7	---	---	5.8
1985	4.2	3.5	3.7	---	6.6
1986	5.1	4.6	4.5	---	8.7
1987	---	---	---	0.73	0.61

- (a) Whenever possible, the original computer output sheets were consulted to convert the originally reported dose values from one significant figure to two and to extract the values of committed dose in column 3.
- (b) A suite of codes, including PABLM, DACRIN, and KRONIC, were used to calculate the 50-year cumulative dose equivalents to the whole body and various organs from effluents released during the stated year.
- (c) The suite of codes listed under (b) was used to calculate the 50-year committed dose equivalents for the whole body and various organs from the effluents released during the stated year.
- (d) PABKID was a temporary code that replaced dose factors (derived from ICRP Publication 2) previously used in the suite of codes listed under (b) with dose factors given in ICRP Publication 30.

TABLE 10. Comparison of Thyroid Dose Equivalents (person-rem) to the 80-km Population, Calculated by Different Codes for 1983-1987(a)

Year	Cumulative Dose PABLM(b)	Committed Dose			
		PABLM(c)	PABKID(d) Version 1.0	GENII Version 1.194	GENII Version 1.272
1983	7.0	7.0	---	---	9.1
1984	43	21	---	---	25
1985	200	80	98	---	74
1986	250	100	120	---	110
1987	---	---	---	110	110

- (a) Whenever possible, the original computer output sheets were consulted to convert the originally reported dose values from one significant figure to two and to extract the values of committed dose in column 3.
- (b) A suite of codes, including PABLM, DACRIN, and KRONIC, were used to calculate the 50-year cumulative dose equivalents to the whole body and various organs from effluents released during the stated year.
- (c) The suite of codes listed under (b) was used to calculate the 50-year committed dose equivalents for the whole body and various organs from the effluents released during the stated year.
- (d) PABKID was a temporary code that replaced dose factors (derived from ICRP Publication 2) previously used in the suite of codes listed under (b) with dose factors given in ICRP Publication 30.

DISCUSSION OF RESULTS

Interpretation of the differences in the potential offsite radiation doses that were calculated for this report is complicated by the fact that not only is the dose calculation scheme different in the new methodology from that previously used, but the values of many of the environmental parameters have been updated in the GENII code. In addition, operations at several Hanford facilities changed significantly during the five-year period under consideration. Therefore, the quantities and composition changed in the mixture of radionuclides released to the environment.

Nevertheless, several relationships are evident among the results of the various dose calculation systems. The discussion that follows identifies the differences between the old cumulative dose and the old committed dose values, between the old committed dose and the new committed dose, and between the new committed doses for the MI at Riverview and at Ringold.

OLD CUMULATIVE DOSE VERSUS OLD COMMITTED DOSE

Potential Radiation Doses to the MI at Riverview

- Whole Body. The old cumulative whole-body doses are about an order of magnitude higher than the old committed doses (see Table 1). The principal reason is the ^{90}Sr remaining in irrigated soil during the extra 49 years following the year of release and in ingested foodstuffs grown therein, which are included in the cumulative dose calculations.
- Skeletal Bone. As they were for the whole-body, the old cumulative bone doses are higher by about one order of magnitude than the old committed bone doses (see Table 2). The reason is the same as for the whole-body, residual ^{90}Sr in the irrigated soil and foods during the extra 49 years of ingestion, accounted for in the cumulative dose calculations.
- Lung. The lung doses result principally from inhalation and external radiation exposure to radionuclides in the airborne plume. Since no resuspension from ground back to the air was included in the old cumulative dose calculations, no inhalation and air submer-sion exposures were calculated for the 49 years after the releases to the atmosphere have occurred. As a result, the total cumulative doses to the lung from all pathways combined are calculated to be only slightly higher than the old committed dose (see Table 3). The small increase is attributed to the few radionuclides that contribute to the lung dose through the ingestion pathway. For

1983, the ratio of the cumulative dose to the committed dose was about 2:1. The PUREX facility was restarted late in 1983, and the atmospheric effluents made a smaller contribution that year than during the succeeding 4 years.

- GI Tract. The old cumulative doses are about twice as high as the old committed doses (see Table 4).
- Thyroid. The old cumulative doses are a factor of 2 to 3 times the old committed dose, except for 1983 (see Table 5). The PUREX facility restarted late in 1983, and no ^{129}I was reportedly released to the atmosphere that year. This radionuclide has a long half-life and contributes to the doses accumulated during the extra 49 years of ingestion.

Potential Radiation Doses to the 80-km Population

- Whole Body. The old cumulative doses were a factor of 1.5 times the old committed doses (see Table 6). The ratio was higher for the MI because of the assumption that a large fraction of his food supply is irrigated with water drawn from the Columbia River below Hanford; however, such irrigated foodstuffs are available only in limited quantities for the 80-km population.
- Skeletal Bone. For the skeletal bone, the older cumulative doses were calculated to be 1.5 times the old committed doses (see Table 7). The reason is the same as that for the whole-body doses.
- Lung. The relationship found for the population lung doses (see Table 8) is very similar to that found for the MI. The total cumulative doses to the lung from all pathways combined are nearly identical to the old committed doses.
- GI Tract. In contrast to the findings for the MI, the old cumulative doses for the population are about equal to the old committed doses (see Table 9). This difference between the population and the MI reflects the large fraction of the diet of the MI that is obtained from irrigated food.
- Thyroid. The same relationship between the cumulative and committed doses was found for the population (see Table 10) as for the MI. That is, the cumulative doses were about twice as high as the old committed dose, except for 1983, when no ^{129}I was reportedly released to the atmosphere.

OLD COMMITTED DOSE VERSUS NEW COMMITTED DOSE

Potential Radiation Doses to the MI at Riverview

- Whole Body/EDE. The old committed doses are generally higher than the new committed doses by up to a factor of three (see Table 1).

However, this comparison is between two somewhat different entities -- whole body versus EDE.

- Skeletal Bone. As with the whole body dose, the old committed doses are generally higher than the new committed doses by up to a factor of three (see Table 3). Again, the comparison is between two different entities -- skeletal bone versus bone surface.
- Lung. Because of revisions to the lung model used in the new ICRP 26/30 dosimetry system, the new committed radiation doses from inhalation are three times higher than the old committed doses and twice the old cumulative doses (see Table 4).
- GI Tract. The new committed doses are nearly equal to the older committed GI tract doses even though a different GI tract model is used in the new dosimetry system (see Table 4). The new model assumes complete mixing in the each compartment of the digestive tract rather than the plug flow used in the older model.
- Thyroid. There are only small differences between the old and the new committed doses, probably because only minor changes have been made in the metabolic and dosimetric parameters for the radioiodine isotopes in the thyroid in the new system (see Table 6).

Potential Radiation Doses to the 80-km Population

- Whole Body/EDE. The new committed doses are about a factor of 2 higher than the old committed doses (see Table 6). This is just the opposite of the ratio noted for the MI, partly because of the difference between the quantity of irrigated food that is consumed by the MI and the average member of the population. However, the comparison is between two somewhat different entities -- whole body versus EDE.
- Skeletal Bone/Bone Surface. The new committed doses are about a factor of 2 higher than the old committed dose (see Table 7). As with the whole body, this ratio is the opposite of the ratio noted for the MI. Once again, the difference in the ratios can be attributed to the difference in the relative quantity of irrigated food that is consumed. The comparison is between somewhat different entities -- skeletal bone versus bone surface.
- Lung. Once again, because of revisions to the lung model used in the new dosimetry system, the new committed radiation doses from inhalation are not only twice as high as the old committed doses, but are also twice as high as the old cumulative doses (see Table 8).
- GI Tract. The new committed GI Tract doses are a factor of 2 higher than the old committed doses (see Table 9). The two types of committed doses are nearly equal for the MI. There is a difference in the radionuclide content in the diet of the MI and

the population, resulting from the difference in the proportion of their diets that are assumed to be supplied by irrigated foods. This dietary difference is apparently accentuated by the revised GI tract model used in the new dosimetry system.

- Thyroid. There are only small differences between the old and the new committed doses, probably because only minor changes have been made in the metabolic and dosimetric parameters for the radioiodine isotopes in the thyroid in the new system (see Table 10).

COMMITTED DOSE: RIVERVIEW MI VERSUS RINGOLD MI

- EDE. The ratio of the EDE at Ringold to that at Riverview is about 2:1 (see Table 1). The thyroid dose, which is highly dependent on the ^{129}I released to the atmosphere from the PUREX stack, accounts for the greater EDE at Ringold than at Riverview.
- Bone Surface. The bone surface doses for the MI are only slightly greater at Ringold than at Riverview (see Table 2). These doses are more dependent upon the aquatic pathways of exposure, which are nearly identical at the two MI locations.
- Lung. The lung dose is related to the concentrations of radionuclides in the air, and the projected air concentrations of radionuclides from operations at PUREX and at 100-N are higher at Ringold than at Riverview. Therefore, the MI lung dose at Ringold is about twice that at Riverview for all 5 years (see Table 3).
- GI Tract. The ratio of the MI doses at Ringold to those at Riverview was about 1.7:1 until 1987, when the ratio decreased to 1 (see Table 4). The decrease resulted from the decreased releases of radionuclides to the river from the N Reactor.
- Thyroid. The ratio of the MI thyroid doses at Ringold to those at Riverview is about 2:1 (see Table 5), as a result of the higher projected air concentrations of radionuclides at Ringold, principally ^{129}I from PUREX.

CONCLUSIONS

In general, the new ICRP dosimetry system, as recently adopted by DOE, calculates lower radiation doses than did the system of codes previously used at Hanford for calculating the old cumulative doses. However, the committed doses for the MI calculated with the new system are higher than those calculated with the old system for some organs and lower for others. The new committed doses calculated for the EDE/whole body and the bone are about one-third of the old committed doses. For the lung, the new committed doses are about three times the old committed doses; for the thyroid, the two calculations yield nearly equal doses.

For the population, the new committed doses for most organs are about twice the old committed doses. The one exception is the thyroid, where the two are nearly equal. The differences in the ratios between the MI and the population result partially from the differences in the quantities of irrigated foods consumed by the MI and by the average member of the population.

The code GENII implements the new ICRP dosimetry system and has been designated as the code to be used for calculating potential radiation doses for the Hanford Annual Environmental Monitoring reports. The GENII code is also the primary code used by PNL for calculating potential radiation doses to the public from routine and accidental releases for safety analysis reports, environmental impact statements, and other environmental documentation at Hanford.

The GENII code has the following positive features:

- It incorporates the new ICRP dosimetry, as approved by the DOE, including the concept of the EDE and the revised GI tract model.
- It uses an improved atmospheric transport model that treats radionuclide decay in transit more realistically than the previous PNL model.
- It has the ability to calculate radiation doses from concentrations of radionuclides measured in the environment.
- It incorporates updated environmental transfer factors.

- It addresses a comprehensive list of radionuclides for environmental transport and external and internal dosimetry, to which others can be added if necessary.
- It encompasses all the radiation exposure pathways required for evaluation of potential radiation doses for the MI and the surrounding population from Hanford operations.

In addition, the results of this study indicate that under the existing operations at Hanford, the hypothetical MI should be assumed to reside at Ringold for the near future. Hanford operations should be reviewed periodically to determine if the location at which the MI is assumed to be residing is still the proper one.

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APPENDIX A

DOSES TO MAXIMALLY EXPOSED INDIVIDUAL AT RIVERVIEW AND POPULATION,
REPORTED IN HANFORD ANNUAL ENVIRONMENTAL REPORTS, 1983-1987

TABLE A.1. Radiation Doses (mrem) to the Maximally Exposed Individual at Riverview from 1983 Hanford Operations (PNL-5038)(a)

Pathway	50-Year Cumulative Dose					Thyroid
	Whole Body	GI/LLI(b)	Bone	Lung	Adult	Infant
Direct Air(c)	0.0037	0.0036	0.0048	0.0063	0.0039	<0.01
Foodstuffs(d)	0.97	0.088	3.8	0.00058	0.055	0.3
Drinking Water	0.0053	0.0011	0.020	0.00008	0.012	0.04
Fish/River External	<u>0.056</u>	<u>0.065</u>	<u>0.18</u>	<u>0.0079</u>	<u>0.019</u>	<u>--</u>
Total	1.0	0.16	3.8	0.015	0.090	0.3

(a) Originally reported to one significant figure.

(b) Gastrointestinal tract (lower large intestine).

(c) Includes inhalation, submersion, and direct exposure to ground contamination.

(d) Includes consumption of foodstuffs contaminated via irrigation water and deposition from the air.

TABLE A.2. Radiation Doses (person-rem) to the 80-km Population from 1983 Hanford Operations (PNL-5038)(a)

Pathway	50-Year Cumulative Dose				
	Whole Body	GI/LLI(b)	Bone	Lung	Thyroid
Direct Air(c)	2.6	2.6	2.8	2.9	2.7
Foodstuffs(d)	0.91	0.054	3.2	0.046	4.1
Drinking Water	0.23	0.045	0.84	0.0034	0.050
Fish/River External	<u>0.047</u>	<u>0.051</u>	<u>0.092</u>	<u>0.029</u>	<u>0.034</u>
Total(d)	3.8	2.8	7.0	3.0	7.0

- (a) Originally reported to one significant figure.
- (b) Gastrointestinal tract (lower large intestine).
- (c) Includes inhalation, submersion, and direct exposure to ground contamination.
- (d) Includes consumption of foodstuffs contaminated via irrigation water and deposition from the air.

TABLE A.3. Radiation Doses (mrem) to the Maximally Exposed Individual at Riverview from 1984 Hanford Operations (PNL-5047)(a)

<u>Pathway</u>	<u>50-Year Cumulative Dose</u>					<u>Thyroid</u>
	<u>Whole Body</u>	<u>GI/LLI(b)</u>	<u>Bone</u>	<u>Lung</u>	<u>Adult</u>	<u>Infant</u>
Direct Air(c)	0.0074	0.0070	0.017	0.016	0.0081	<0.01
Foodstuffs(d)	2.0	0.18	7.5	0.0011	0.70	2
Drinking Water	0.011	0.0022	0.040	0.00005	0.053	0.2
Fish/River External	<u>0.10</u>	<u>0.098</u>	<u>0.34</u>	<u>0.0077</u>	<u>0.059</u>	<u>--</u>
Total	2.1	0.29	7.8	0.025	0.82	3

(a) Originally reported to one significant figure.

(b) Gastrointestinal tract (lower large intestine).

(c) Includes inhalation, submersion, and direct exposure to ground contamination.

(d) Includes consumption of foodstuffs contaminated via irrigation water and deposition from the air.

TABLE A.4. Radiation Doses (person-rem) to the 80-km Population from 1984 Hanford Operations (PNL-5047)(a)

Pathway	50-Year Cumulative Dose				
	Whole Body	GI/LLI(b)	Bone	Lung	Thyroid
Direct Air(c)	2.6	2.6	4.3	4.2	2.5
Foodstuffs(d)	2.0	0.27	7.2	0.062	38
Drinking Water	0.47	0.094	1.7	0.0022	2.2
Fish/River External	<u>0.060</u>	<u>0.056</u>	<u>0.15</u>	<u>0.022</u>	<u>0.041(e)</u>
Total	5.2	3.0	13	4.3	43

(a) Originally reported to one significant figure.

(b) Gastrointestinal tract (lower large intestine).

(c) Includes inhalation, submersion, and direct exposure to ground contamination.

(d) Includes consumption of foodstuffs contaminated via irrigation water and deposition from the air.

(e) Originally reported as 0.1.

TABLE A.5. Radiation Doses (mrem) to the Maximally Exposed Individual at Riverview from 1985 Hanford Operations (PNL-5817)(a)

Pathway	50-Year Cumulative Dose					Thyroid
	Whole Body	GI/LLI(b)	Bone	Lung	Adult	Infant
Direct Air(c)	0.0085	0.0078	0.029	0.029	0.013	0.011
Foodstuffs(d)	2.6	0.23	9.5	0.0012	1.7	2.7
Drinking Water	0.014	0.0035	0.052	0.00015	0.064	0.18
Fish/River External	<u>0.14</u>	<u>0.11</u>	<u>0.45</u>	<u>0.011</u>	<u>0.074</u>	<u>--</u>
Total	2.8	0.35	10	0.041	1.9	2.9

(a) Originally reported to one significant figure.

(b) Gastrointestinal tract (lower large intestine).

(c) Includes inhalation, submersion, and direct exposure to ground contamination.

(d) Includes consumption of foodstuffs contaminated via irrigation water and deposition from the air.

TABLE A.6. Radiation Doses (person-rem) to the 80-km Population from 1985 Hanford Operations (PNL-5817) (a)

<u>Pathway</u>	<u>Whole Body</u>	<u>50-Year Cumulative Dose</u>			
		<u>GI/LLI^(b)</u>	<u>Bone</u>	<u>Lung</u>	<u>Thyroid</u>
Direct Air ^(c)	3.6	3.5	7.9	7.7	4.6
Foodstuffs ^(d)	2.7	0.45	8.8	0.11	190
Drinking Water	0.60	0.15	2.2	0.0064	2.7
Fish/River External	<u>0.082</u>	<u>0.072</u>	<u>0.20</u>	<u>0.035</u>	<u>0.059</u>
Total	7.0	4.2	19	7.8	200

(a) Originally reported to one significant figure.

(b) Gastrointestinal tract (lower large intestine).

(c) Includes inhalation, submersion, and direct exposure to ground contamination.

(d) Includes consumption of foodstuffs contaminated via irrigation water and deposition from the air.

TABLE A.7. Radiation Doses (mrem) to the Maximally Exposed Individual at Riverview from 1985 Hanford Operations Calculated with Version 1.0 of PABKID (PNL-5817)(a)

Pathway	Committed Dose Equivalent					Effective Dose Equivalent(c)
	Red Marrow	Bone Surface	Lung	GI/LLI(b)	Thyroid	
Direct Air(d)	0.014	0.13	0.053	0.0038	0.010	0.017
Air-Food(e)	0.0026	0.0034	0.0024	0.0040	0.65	0.022
Irrigated Food(f)	0.18	0.39	0.00065	0.0072	0.19	0.040
Drinking Water	0.0096	0.021	0.00022	0.0025	0.058	0.0039
Fish/River External	<u>0.089</u>	<u>0.18</u>	<u>0.012</u>	<u>0.074</u>	<u>0.072</u>	<u>0.034</u>
Total	0.29	0.72	0.068	0.091	0.98	0.12

- (a) Originally reported to one significant figure.
 (b) Gastrointestinal tract (lower large intestine).
 (c) Effective dose is compiled from the product of each organ's dose and its weighting factor and includes some organs not shown here.
 (d) Includes inhalation, submersion, and direct exposure to ground deposition.
 (e) Includes consumption of foodstuffs contaminated via deposition from the air.
 (f) Includes consumption of foodstuffs contaminated via irrigation water.

TABLE A.8. Radiation Doses (person-rem) to the 80-km Population from 1985 Hanford Operations Calculated with Version 1.0 of PABKID (PNL-5817)(a)

Pathway	Committed Dose Equivalent					Effective Dose Equivalent(c)
	Red Marrow	Bone Surface	Lung	GI/LL1(b)	Thyroid	
Direct Air(d)	5.0	29	13	3.0	4.3	5.6
Air-Food(e)	0.32	0.39	0.31	0.46	91	3.0
Irrigated Food(f)	0.17	0.38	0.00084	0.0053	0.21	0.039
Drinking Water	0.40	0.88	0.0094	0.10	2.5	0.17
Fish/River External	<u>0.037</u>	<u>0.072</u>	<u>0.0085</u>	<u>0.031</u>	<u>0.030</u>	<u>0.017</u>
Total	5.9	31	13	3.6	98	8.9

- (a) Originally reported to one significant figure.
 (b) Gastrointestinal tract (lower large intestine).
 (c) Effective dose is compiled from the product of each organ's dose and its weighting factor and includes some organs not shown here.
 (d) Includes inhalation, submersion, and direct exposure to ground deposition.
 (e) Includes consumption of foodstuffs contaminated via deposition from the air.
 (f) Includes consumption of foodstuffs contaminated via irrigation water.

TABLE A.9. Radiation Doses (mrem) to the Maximally Exposed Individual at Riverview from 1986 Hanford Operations (PNL-6120)(a)

Pathway	50-Year Cumulative Dose					
	Whole Body	GI/LLI(b)	Bone	Lung	Thyroid	
					Adult	Infant
Direct Air(c)	0.012	0.012	0.013	0.019	0.017	0.020
Air-Food(d)	0.0033	0.0011	0.0026	0.00025	2.1	1.6
Irrigated Foods(e)	2.3	0.21	8.7	0.00019	0.0050	--
Drinking Water	0.013	0.0025	0.047	0.00011	0.0016	0.032
Fish/River External	<u>0.11</u>	<u>0.041</u>	<u>0.39</u>	<u>0.0032</u>	<u>0.0038</u>	<u>--</u>
Total	2.4	0.27	9.2	0.023	2.2	1.6

(a) Originally reported to be significant figure.

(b) Gastrointestinal tract (lower large intestine).

(c) Includes inhalation, submersion, and direct exposure to ground contamination.

(d) Includes consumption of foodstuffs contaminated via deposition from the air.

(e) Includes consumption of foodstuffs contaminated via irrigation water.

TABLE A.10. Radiation Doses (person-rem) to the 80-km Population from 1986 Hanford Operations (PNL-6120) (a)

<u>Pathway</u>	<u>50-Year Cumulative Dose</u>				
	<u>Whole Body</u>	<u>GI/LLI(b)</u>	<u>Bone</u>	<u>Lung</u>	<u>Thyroid</u>
Direct Air(c)	4.8	4.7	6.8	6.1	6.1
Air-Food(d)	0.36	0.10	0.27	0.023	240
Irrigated Foods(e)	2.0	0.17	7.3	0.00022	0.0053
Drinking Water	0.54	0.11	2.0	0.0047	0.069
Fish/River External	<u>0.050</u>	<u>0.024(f)</u>	<u>0.16</u>	<u>0.0096</u>	<u>0.0048</u>
Total	7.7	5.1	16	6.1	250

- (a) Originally reported to one significant figure.
 (b) Gastrointestinal tract (lower large intestine).
 (c) Includes inhalation, submersion and direct exposure to ground contamination.
 (d) Includes consumption of foodstuffs contaminated via deposition from the air.
 (e) Includes consumption of foodstuffs contaminated via irrigation water.
 (f) Originally reported as 0.2

TABLE A.11. Radiation Doses (mrem) to the Maximally Exposed Individual at Riverview from 1986 Hanford Operations Calculated with Version 1.0 of PABKID (PNL-6120)(a)

Pathway	Committed Dose Equivalent					Effective Dose Equivalent(c)
	Red Marrow	Bone Surface	Lung	GI/LLI(b)	Thyroid	
Direct Air(d)	0.0093	0.044	0.023	0.0065	0.014	0.011
Air-Food(e)	0.00060	0.00081	0.00055	0.0013	0.86	0.026
Irrigated Food(f)	0.16	0.36	0.00031	0.0042	0.0047	0.031
Drinking Water	0.0087	0.019	0.00014	0.0016	0.0015	0.0019
Fish/River External	<u>0.074</u>	<u>0.16</u>	<u>0.0042</u>	<u>0.028</u>	<u>0.0056</u>	<u>0.019</u>
Total	0.25	0.58	0.028	0.042	0.89	0.089

(a) Originally reported to one significant figure.

(b) Gastrointestinal tract (lower large intestine).

(c) Effective dose is compiled from the product of each organ's dose and its weighting factor and includes some organs not shown here.

(d) Includes inhalation, submersion, and direct exposure to ground deposition.

(e) Includes consumption of foodstuffs contaminated via deposition from the air.

(f) Includes consumption of foodstuffs contaminated via irrigation water.

TABLE A.12. Radiation Doses (Person-rem) to the 80-km Population from 1986 Hanford Operations Calculated with Version 1.0 of PABKID (PNL-6120) (a)

Pathway	Committed Dose Equivalent					Effective Dose Equivalent(c)
	Red Marrow	Bone Surface	Lung	GI/LLI(b)	Thyroid	
Direct Air(d)	4.6	11	7.3	4.1	5.8	4.9
Air-Food(e)	0.066	0.086	0.062	0.13	110	3.5
Irrigated Food(f)	0.16	0.34	0.00038	0.0030	0.0051	0.030
Drinking Water	0.37	0.80	0.0058	0.072	0.064	0.081
Fish/River External	<u>0.030</u>	<u>0.062</u>	<u>0.0032</u>	<u>0.012</u>	<u>0.0038</u>	<u>0.0093</u>
Total	5.3	13	7.4	4.4	120	8.5

- (a) Originally reported to one significant figure.
 (b) Gastrointestinal tract (lower large intestine).
 (c) Effective dose is compiled from the product of each organ's dose and its weighting factor and includes some organs not shown here.
 (d) Includes inhalation, submersion, and direct exposure to ground deposition.
 (e) Includes consumption of foodstuffs contaminated via deposition from the air.
 (f) Includes consumption of foodstuffs contaminated via irrigation water.

TABLE A.13. Radiation Doses (mrem) to the Maximally Exposed Individual at Riverview from 1987 Hanford Operations Calculated with Version 1.194 of GENII (PNL-6464)(a)

Pathway	Committed Dose Equivalent					Effective Dose Equivalent(c)
	Red Marrow	Bone Surface	Lung	GI/LLI(b)	Thyroid	
Direct Air(d)	0.0031	0.0087	0.0038	0.0014	0.0075	0.0022
Air-Food(e)	0.0012	0.0010	0.00099	0.0011	0.84	0.026
Irrigated Food(f)	0.035	0.074	0.0034	0.013	0.0073	0.010
Drinking Water	0.0053	0.0071	0.0028	0.0035	0.0033	0.0030
Fish/River External	<u>0.025</u>	<u>0.050</u>	<u>0.0041</u>	<u>0.010</u>	<u>0.0046</u>	<u>0.0085</u>
Total	0.066	0.14	0.015	0.029	0.86	0.050

- (a) Originally reported to one significant figure.
 (b) Gastrointestinal tract (lower large intestine).
 (c) Effective dose is compiled from the product of each organ's dose and its weighting factor and includes some organs not shown here.
 (d) Includes inhalation, submersion, and direct exposure to ground deposition.
 (e) Includes consumption of foodstuffs contaminated via deposition from the air.
 (f) Includes consumption of foodstuffs contaminated via irrigation water.

TABLE A.14. Radiation Doses (person-rem) to the 80-km Population from 1987 Hanford Operations Calculated with Version 1.194 of GENII (PNL-6464) (a)

Pathway	Committed Dose Equivalent					Effective Dose Equivalent(c)
	Red Marrow	Bone Surface	Lung	GI/LLI(b)	Thyroid	
Direct Air(d)	0.57	1.8	0.88	0.47	1.7	0.62
Air-Food(e)	0.11	0.10	0.084	0.094	110	3.5
Irrigated Food(f)	0.035	0.072	0.0038	0.014	0.0097	0.010
Drinking Water	0.22	0.30	0.11	0.15	0.14	0.13
Fish/River External	<u>0.011</u>	<u>0.019</u>	<u>0.0029</u>	<u>0.0052</u>	<u>0.0030</u>	<u>0.0045</u>
Total	0.94	2.3	1.1	0.73	110	4.3

- (a) Originally reported to one significant figure.
 (b) Gastrointestinal tract (lower large intestine).
 (c) Effective dose is compiled from the product of each organ's dose and its weighting factor and includes some organs not shown here.
 (d) Includes inhalation, submersion, and direct exposure to ground deposition.
 (e) Includes consumption of foodstuffs contaminated via deposition from the air.
 (f) Includes consumption of foodstuffs contaminated via irrigation water.

APPENDIX B

RESULTS OF RECALCULATION OF PREVIOUSLY REPORTED DOSES
TO MAXIMALLY EXPOSED INDIVIDUAL AT RIVERVIEW AND TO POPULATION
WITH VERSION 1.272 OF GENII CODE

TABLE B.1. Radiation Doses (mrem) to the Maximally Exposed Individual at Riverview from 1983 Hanford Operations Calculated with Version 1.272 of GENII

Pathway	Committed Dose Equivalent					Effective Dose Equivalent(b)
	Red Marrow	Bone Surface	Lung	GI/LLI(a)	Thyroid	
Direct Air(c)	0.012	0.018	0.018	0.012	0.012	0.012
Air-Food(d)	0.0016	0.00098	0.0015	0.0017	0.013	0.0017
Irrigated Food(e)	0.045	0.095	0.0052	0.018	0.028	0.014
Drinking Water	0.0043	0.0078	0.0013	0.0028	0.012	0.0023
Fish/River External	<u>0.055</u>	<u>0.084</u>	<u>0.0084</u>	<u>0.035</u>	<u>0.019</u>	<u>0.019</u>
Total	0.12	0.21	0.034	0.070	0.084	0.049

(a) Gastrointestinal tract (lower large intestine).

(b) Effective dose is compiled from the product of each organ's dose and its weighting factor and includes some organs not shown here.

(c) Includes inhalation, submersion, and direct exposure to ground deposition.

(d) Includes consumption of foodstuffs contaminated via deposition from the air.

(e) Includes consumption of foodstuffs contaminated via irrigation water.

TABLE B.2. Radiation Doses (person-rem) to the 80-km Population from 1983 Hanford Operations Calculated with Version 1.272 of GENII

Pathway	Committed Dose Equivalent					Effective Dose Equivalent(b)
	Red Marrow	Bone Surface	Lung	GI/LLI(a)	Thyroid	
Direct Air(c)	6.1	6.2	6.8	6.1	6.2	6.2
Air-Food(d)	0.11	0.087	0.011	0.12	2.3	0.17
Irrigated Food(e)	0.041	0.088	0.0017	0.016	0.028	0.011
Drinking Water	0.20	0.33	0.060	0.12	0.49	0.098
Fish/River External	<u>0.027</u>	<u>0.038</u>	<u>0.011</u>	<u>0.020</u>	<u>0.014</u>	<u>0.014</u>
Total	6.5	6.7	7.0	6.4	9.1	6.4

(a) Gastrointestinal tract (lower large intestine).

(b) Effective dose is compiled from the product of each organ's dose and its weighting factor and includes some organs not shown here.

(c) Includes inhalation, submersion, and direct exposure to ground deposition.

(d) Includes consumption of foodstuffs contaminated via deposition from the air.

(e) Includes consumption of foodstuffs contaminated via irrigation water.

TABLE B.3. Radiation Doses (mrem) to the Maximally Exposed Individual at Riverview from 1984 Hanford Operations Calculated with Version 1.272 of GENII

Pathway	Committed Dose Equivalent					Effective Dose Equivalent(b)
	Red Marrow	Bone Surface	Lung	GI/LLI(a)	Thyroid	
Direct Air(c)	0.018	0.071	0.034	0.013	0.014	0.019
Air-Food(d)	0.0025	0.0021	0.0023	0.0030	0.12	0.0058
Irrigated Food(e)	0.089	0.19	0.0054	0.032	0.094	0.026
Drinking Water	0.0088	0.017	0.0020	0.0048	0.046	0.0046
Fish/River External	<u>0.074</u>	<u>0.14</u>	<u>0.012</u>	<u>0.034</u>	<u>0.058</u>	<u>0.026</u>
Total	0.19	0.42	0.057	0.087	0.33	0.082

- (a) Gastrointestinal tract (lower large intestine).
- (b) Effective dose is compiled from the product of each organ's dose and its weighting factor and includes some organs not shown here.
- (c) Includes inhalation, submersion, and direct exposure to ground deposition.
- (d) Includes consumption of foodstuffs contaminated via deposition from the air.
- (e) Includes consumption of foodstuffs contaminated via irrigation water.

TABLE B.4. Radiation Doses (person-rem) to the 80-km Population from 1984 Hanford Operations Calculated with Version 1.272 of GENII

Pathway	Committed Dose Equivalent					Effective Dose Equivalent(b)
	Red Marrow	Bone Surface	Lung	GI/LLI(a)	Thyroid	
Direct Air(c)	6.1	16	9.5	5.3	5.7	6.3
Air-Food(d)	0.20	0.20	0.18	0.25	17	0.67
Irrigated Food(e)	0.084	0.19	0.0032	0.0030	0.097	0.023
Drinking Water	0.35	0.67	0.083	0.20	1.9	0.19
Fish/River External	<u>0.034</u>	<u>0.058</u>	<u>0.011</u>	<u>0.019</u>	<u>0.028</u>	<u>0.016</u>
Total	6.8	17	9.8	5.8	25	7.3

- (a) Gastrointestinal tract (lower large intestine).
- (b) Effective dose is compiled from the product of each organ's dose and its weighting factor and includes some organs not shown here.
- (c) Includes inhalation, submersion, and direct exposure to ground deposition.
- (d) Includes consumption of foodstuffs contaminated via deposition from the air.
- (e) Includes consumption of foodstuffs contaminated via irrigation water.

TABLE B.5. Radiation Doses (mrem) to the Maximally Exposed Individual at Riverview from 1985 Hanford Operations Calculated with Version 1.272 of GENII

Pathway	Committed Dose Equivalent					Effective Dose Equivalent(b)
	Red Marrow	Bone Surface	Lung	GI/LLI(a)	Thyroid	
Direct Air(c)	0.026	0.12	0.059	0.018	0.022	0.028
Air-Food(d)	0.0038	0.0034	0.0039	0.0050	0.51	0.019
Irrigated Food(e)	0.11	0.24	0.0066	0.039	0.12	0.033
Drinking Water	0.010	0.020	0.0020	0.0045	0.056	0.0047
Fish/River External	<u>0.093</u>	<u>0.17</u>	<u>0.015</u>	<u>0.042</u>	<u>0.070</u>	<u>0.032</u>
Total	0.25	0.55	0.087	0.11	0.78	0.12

(a) Gastrointestinal tract (lower large intestine).

(b) Effective dose is compiled from the product of each organ's dose and its weighting factor and includes some organs not shown here.

(c) Includes inhalation, submersion, and direct exposure to ground deposition.

(d) Includes consumption of foodstuffs contaminated via deposition from the air.

(e) Includes consumption of foodstuffs contaminated via irrigation water.

TABLE B.6. Radiation Doses (person-rem) to the 80-km Population from 1985 Hanford Operations Calculated with Version 1.272 of GENII

Pathway	Committed Dose Equivalent					Effective Dose Equivalent(b)
	Red Marrow	Bone Surface	Lung	GI/LLI(a)	Thyroid	
Direct Air(c)	7.3	25	13	5.9	6.8	7.8
Air-Food(d)	0.30	0.29	0.26	0.40	65	2.2
Irrigated Food(e)	0.10	0.23	0.0034	0.036	0.12	0.029
Drinking Water	0.43	0.84	0.080	0.19	2.3	0.21
Fish/River External	<u>0.043</u>	<u>0.073</u>	<u>0.014</u>	<u>0.024</u>	<u>0.034</u>	<u>0.020</u>
Total	8.2	26	13	6.6	74	10

(a) Gastrointestinal tract (lower large intestine).

(b) Effective dose is compiled from the product of each organ's dose and its weighting factor and includes some organs not shown here.

(c) Includes inhalation, submersion, and direct exposure to ground deposition.

(d) Includes consumption of foodstuffs contaminated via deposition from the air.

(e) Includes consumption of foodstuffs contaminated via irrigation water.

TABLE B.7. Radiation Doses (mrem) to the Maximally Exposed Individual at Riverview from 1986 Hanford Operations Calculated with Version 1.272 of GENII

Pathway	Committed Dose Equivalent					Effective Dose Equivalent(b)
	Red Marrow	Bone Surface	Lung	GI/LLI(a)	Thyroid	
Direct Air(c)	0.023	0.055	0.034	0.020	0.027	0.024
Air-Food(d)	0.0011	0.0015	0.00088	0.0016	0.74	0.024
Irrigated Food(e)	0.10	0.22	0.0040	0.031	0.010	0.023
Drinking Water	0.0098	0.018	0.0024	0.0042	0.0040	0.0037
Fish/River External	<u>0.072</u>	<u>0.15</u>	<u>0.0052</u>	<u>0.023</u>	<u>0.0070</u>	<u>0.019</u>
Total	0.22	0.44	0.046	0.080	0.79	0.093

(a) Gastrointestinal tract (lower large intestine).

(b) Effective dose is compiled from the product of each organ's dose and its weighting factor and includes some organs not shown here.

(c) Includes inhalation, submersion, and direct exposure to ground deposition.

(d) Includes consumption of foodstuffs contaminated via deposition from the air.

(e) Includes consumption of foodstuffs contaminated via irrigation water.

TABLE B.8. Radiation Ooses (person-rem) to the 80-km Population from 1986 Hanford Operations Calculated with Version 1.272 of GENII

Pathway	Committed Dose Equivalent					Effective Oose Equivalent(b)
	Red Marrow	Bone Surface	Lung	GI/LLI(a)	Thyroid	
Direct Air(c)	8.8	15	11	8.3	9.7	9.0
Air-Food(d)	0.10	0.16	0.079	0.15	100	3.3
Irrigated Food(e)	0.097	0.21	0.0033	0.032	0.011	0.024
Drinking Water	0.41	0.76	0.10	0.18	0.17	0.16
Fish/River External	<u>0.030</u>	<u>0.058</u>	<u>0.0044</u>	<u>0.011</u>	<u>0.0051</u>	<u>0.0095</u>
Total	9.4	16	11	8.7	110	12

- (a) Gastrointestinal tract (lower large intestine).
- (b) Effective dose is compiled from the product of each organ's dose and its weighting factor and includes some organs not shown here.
- (c) Includes inhalation, submersion, and direct exposure to ground deposition.
- (d) Includes consumption of foodstuffs contaminated via deposition from the air.
- (e) Includes consumption of foodstuffs contaminated via irrigation water.

TABLE B.9. Radiation Doses (mrem) to the Maximally Exposed Individual at Riverview from 1987 Hanford Operations Calculated with Version 1.272 of GENII

Pathway	Committed Dose Equivalent					Effective Dose Equivalent(b)
	Red Marrow	Bone Surface	Lung	GI/LLI(a)	Thyroid	
Direct Air(c)	0.0016	0.0087	0.0034	0.00098	0.0071	0.0018
Air-Food(d)	0.0012	0.0010	0.00099	0.0011	0.89	0.026
Irrigated Food(e)	0.036	0.075	0.0039	0.013	0.0078	0.010
Drinking Water	0.0053	0.0071	0.0028	0.0035	0.0033	0.0031
Fish/River External	<u>0.025</u>	<u>0.050</u>	<u>0.0041</u>	<u>0.010</u>	<u>0.0046</u>	<u>0.0084</u>
Total	0.069	0.14	0.015	0.029	0.91	0.049

(a) Gastrointestinal tract (lower large intestine).

(b) Effective dose is compiled from the product of each organ's dose and its weighting factor and includes some organs not shown here.

(c) Includes inhalation, submersion, and direct exposure to ground deposition.

(d) Includes consumption of foodstuffs contaminated via deposition from the air.

(e) Includes consumption of foodstuffs contaminated via irrigation water.

TABLE B.10. Radiation Doses (person-rem) to the 80-km Population from 1987 Hanford Operations Calculated with Version 1.272 of GENII

Pathway	Committed Dose Equivalent					Effective Dose Equivalent(b)
	Red Marrow	Bone Surface	Lung	GI/LLI(a)	Thyroid	
Direct Air(c)	0.45	1.7	0.77	0.35	1.6	0.51
Air-Food(d)	0.11	0.10	0.084	0.094	110	3.5
Irrigated Food(e)	0.034	0.074	0.0038	0.014	0.0095	0.010
Drinking Water	0.22	0.30	0.11	0.15	0.14	0.13
Fish/River External	<u>0.011</u>	<u>0.019</u>	<u>0.0028</u>	<u>0.0052</u>	<u>0.0030</u>	<u>0.0045</u>
Total	0.83	2.2	0.97	0.61	110	4.2

- (a) Gastrointestinal tract (lower large intestine).
 (b) Effective dose is compiled from the product of each organ's dose and its weighting factor and includes some organs not shown here.
 (c) Includes inhalation, submersion, and direct exposure to ground deposition.
 (d) Includes consumption of foodstuffs contaminated via deposition from the air.
 (e) Includes consumption of foodstuffs contaminated via irrigation water.

APPENDIX C

RESULTS OF CALCULATION OF POTENTIAL DOSE TO MAXIMALLY EXPOSED INDIVIDUAL
AT RINGOLD WITH VERSION 1.272 OF GENII CODE

TABLE C.1. Radiation Doses (mrem) to the Maximally Exposed Individual at Ringold from 1983 Hanford Operations Calculated with Version 1.272 of GENII

Pathway	Committed Dose Equivalent					Effective Dose Equivalent(b)
	Red Marrow	Bone Surface	Lung	GI/LLI(a)	Thyroid	
Direct Air(c)	0.075	0.085	0.084	0.074	0.075	0.075
Air-Food(d)	0.0027	0.0017	0.0026	0.0029	0.029	0.0032
Irrigated Food(e)	0.042	0.092	0.0020	0.015	0.026	0.014
Drinking Water(f)	--	--	--	--	--	--
Fish/River External	<u>0.055</u>	<u>0.084</u>	<u>0.0085</u>	<u>0.035</u>	<u>0.019</u>	<u>0.019</u>
Total	0.18	0.26	0.097	0.13	0.15	0.11

(a) Gastrointestinal tract (lower large intestine).

(b) Effective dose is compiled from the product of each organ's dose and its weighting factor and includes some organs not shown here.

(c) Includes inhalation, submersion, and direct exposure to ground deposition.

(d) Includes consumption of foodstuffs contaminated via deposition from the air.

(e) Includes consumption of foodstuffs contaminated via irrigation water.

(f) No drinking water is drawn from the Columbia River at Ringold.

TABLE C.2. Radiation Doses (mrem) to the Maximally Exposed Individual at Ringold from 1984 Hanford Operations Calculated with Version 1.272 of GENII

Pathway	Committed Dose Equivalent					Effective Dose Equivalent(b)
	Red Marrow	Bone Surface	Lung	GI/LLI(a)	Thyroid	
Direct Air(c)	0.068	0.16	0.10	0.060	0.063	0.069
Air-Food(d)	0.0044	0.0037	0.0040	0.0052	0.22	0.010
Irrigated Food(e)	0.088	0.18	0.0028	0.032	0.10	0.026
Drinking Water(f)	--	--	--	--	--	--
Fish/River External	<u>0.076</u>	<u>0.14</u>	<u>0.012</u>	<u>0.034</u>	<u>0.058</u>	<u>0.026</u>
Total	0.24	0.49	0.12	0.13	0.44	0.13

- (a) Gastrointestinal tract (lower large intestine).
 (b) Effective dose is compiled from the product of each organ's dose and its weighting factor and includes some organs not shown here.
 (c) Includes inhalation, submersion, and direct exposure to ground deposition.
 (d) Includes consumption of foodstuffs contaminated via deposition from the air.
 (e) Includes consumption of foodstuffs contaminated via irrigation water.
 (f) No drinking water is drawn from the Columbia River at Ringold.

TABLE C.3. Radiation Doses (mrem) to the Maximally Exposed Individual at Ringold from 1985 Hanford Operations Calculated with Version 1.272 of GENII

Pathway	Committed Dose Equivalent					Effective Dose Equivalent(b)
	Red Marrow	Bone Surface	Lung	GI/LLI(a)	Thyroid	
Direct Air(c)	0.11	0.31	0.18	0.098	0.11	0.12
Air-Food(d)	0.0075	0.0066	0.0070	0.010	1.0	0.037
Irrigated Food(e)	0.11	0.24	0.0066	0.039	0.12	0.033
Drinking Water(f)	--	--	--	--	--	--
Fish/River External	<u>0.093</u>	<u>0.17</u>	<u>0.015</u>	<u>0.042</u>	<u>0.070</u>	<u>0.032</u>
Total	0.33	0.72	0.21	0.19	1.3	0.22

-
- (a) Gastrointestinal tract (lower large intestine).
 (b) Effective dose is compiled from the product of each organ's dose and its weighting factor and includes some organs not shown here.
 (c) Includes inhalation, submersion, and direct exposure to ground deposition.
 (d) Includes consumption of foodstuffs contaminated via deposition from the air.
 (e) Includes consumption of foodstuffs contaminated via irrigation water.
 (f) No drinking water is drawn from the Columbia River at Ringold.

TABLE C.4. Radiation Doses (mrem) to the Maximally Exposed Individual at Ringold from 1986 Hanford Operations Calculated with Version 1.272 of GENII

Pathway	Committed Dose Equivalent					Effective Dose Equivalent(b)
	Red Marrow	Bone Surface	Lung	GI/LLI(a)	Thyroid	
Direct Air(c)	0.092	0.16	0.12	0.087	0.099	0.094
Air-Food(d)	0.0023	0.0030	0.0018	0.0032	1.5	0.049
Irrigated Food(e)	0.10	0.22	0.0040	0.030	0.010	0.024
Drinking Water(f)	--	--	--	--	--	--
Fish/River External	<u>0.072</u>	<u>0.15</u>	<u>0.0052</u>	<u>0.023</u>	<u>0.0070</u>	<u>0.019</u>
Total	0.27	0.53	0.13	0.14	1.6	0.19

- (a) Gastrointestinal tract (lower large intestine).
 (b) Effective dose is compiled from the product of each organ's dose and its weighting factor and includes some organs not shown here.
 (c) Includes inhalation, submersion, and direct exposure to ground deposition.
 (d) Includes consumption of foodstuffs contaminated via deposition from the air.
 (e) Includes consumption of foodstuffs contaminated via irrigation water.
 (f) No drinking water is drawn from the Columbia River at Ringold.

TABLE C.5. Radiation Doses (mrem) to the Maximally Exposed Individual at Ringold from 1987 Hanford Operations Calculated with Version 1.272 of GENII

Pathway	Committed Dose Equivalent					Effective Dose Equivalent(b)
	Red Marrow	Bone Surface	Lung	GI/LLI(a)	Thyroid	
Direct Air(c)	0.0057	0.020	0.0095	0.0046	0.018	0.0064
Air-Food(d)	0.0025	0.0021	0.0021	0.0023	1.8	0.055
Irrigated Food(e)	0.036	0.074	0.0039	0.013	0.0078	0.010
Drinking Water(f)	--	--	--	--	--	--
Fish/River External	<u>0.025</u>	<u>0.050</u>	<u>0.0041</u>	<u>0.010</u>	<u>0.0047</u>	<u>0.0084</u>
Total	0.069	0.15	0.020	0.030	1.8	0.080

- (a) Gastrointestinal tract (lower large intestine).
 (b) Effective dose is compiled from the product of each organ's dose and its weighting factor and includes some organs not shown here.
 (c) Includes inhalation, submersion, and direct exposure to ground deposition.
 (d) Includes consumption of foodstuffs contaminated via deposition from the air.
 (e) Includes consumption of foodstuffs contaminated via irrigation water.
 (f) No drinking water is drawn from the Columbia River at Ringold.

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