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A Comparison of Environmental Radiation Doses Estimated for Hanford Operations, 1977 Through 1982

W. D. McCormack
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December 1983

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
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A COMPARISON OF ENVIRONMENTAL RADIATION DOSES ESTIMATED FOR HANFORD OPERATIONS, 1977 THROUGH 1982

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Pacific Northwest Laboratory
Richland, Washington 99352

PREFACE

The Hanford Environmental Surveillance Program is conducted by the Pacific Northwest Laboratory under contract to the U.S. Department of Energy. Included in program objectives is the assessment of dose impacts to the uncontrolled public from site operations.

This document presents a comparison of environmental radiation dose equivalents calculated based on Hanford operations for the 5-year period, 1977 through 1981 to those currently calculated for 1982. While the Hanford Environmental Surveillance Program has not identified measurable dose impacts from site operations during these years, radiation doses have been calculated to provide a basis for evaluating and comparing these operations. All radiation doses presented in this report have been calculated using computerized environmental dose models and annual operating effluents reported by the Hanford contractors. Because the data and models used in calculating environmental dose equivalents have improved since the original 1977 through 1981 calculations were performed, these doses were recalculated for this comparison. Previous evaluations of potential offsite impact due to Hanford operations were reported in the following issues of the annual Environmental Surveillance Report at Hanford:

CY 1982, M. J. Sula, et al. (1983), PNL-4657
CY 1981, M. J. Sula, et al. (1982), PNL-4211
CY 1980, M. J. Sula and P. J. Blumer (1981), PNL-3728
CY 1979, J. R. Houston and P. J. Blumer (1980), PNL-3283
CY 1978, J. R. Houston and P. J. Blumer (1979), PNL-2932
CY 1977, J. R. Houston and P. J. Blumer (1978), PNL-2614

SUMMARY

One of the primary objectives of the Hanford Environmental Surveillance Program is to annually evaluate offsite environmental radiation dose equivalents based on Hanford operations. The intent of this report is to compare the calculated dose equivalents for the years 1977 through 1981 to those calculated for 1982. The comparison revealed a downward trend in calculated offsite doses over the period 1977 through 1982, due primarily to reported reduced effluent releases, changes in effluent reporting methods, and increased Columbia River flow over this period. The calculated doses verify the surveillance program findings that potential offsite radiation doses due to Hanford Operations are small and well below our ability to detect in the environment.

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INTRODUCTION

Environmental surveillance for the purpose of identifying impacts resulting from onsite activities has been an essential part of operations at Hanford for the past 40 years. Since 1958, the evaluation of offsite impact has included estimates of potential radiation dose equivalents (herein after referred to simply as dose) to members of the public. These evaluations verify that the health and safety of the public is not being jeopardized and that applicable regulations are being complied with.

During the peak period of Hanford operations, elevated concentrations of several Hanford-related radionuclides were detectable in the environment. Evaluations of radiological impact on the public, performed during this period, were based on measured concentrations in environmental media and estimates of public exposure and consumption. However, as effluent treatment systems were improved and the number of operating facilities was reduced, Hanford contributions to environmental concentrations of radionuclides became increasingly difficult to detect. By the early 1970s it was no longer possible to estimate offsite radiation doses from Hanford operations on the basis of direct measurements in the environment.

Computerized environmental dose models were used to evaluate potential radiation dose impacts for CY 1974 and subsequent years. These models, in conjunction with reported annual operating effluents, were used to predict environmental transport of effluents and concentrations in exposure pathways. From this information potential radiation doses to the population could then be calculated.

Because environmental dose estimation techniques are continually being improved, dose assessments may differ slightly from one year to the next and thus may not always be strictly comparable. In this report, which provides a comparison of estimated Hanford offsite dose impacts from operations during the years 1977 through 1982, all doses have been recalculated using the current techniques employed in the 1982 calculations. In addition, where improved or more accurate data had become available, they were substituted for data previously used in the calculations for prior years.

ENVIRONMENTAL DOSE MODELS AND CALCULATED DOSES

Consistent with the requirements of DOE Order 5484.1 (USDOE 1981), evaluations of Hanford radiologic impact are "as accurate and realistic as practical" while ensuring that no significant source of potential exposure is overlooked. Assessment of impact in terms of dose provides a means for expressing radiation impact independent of the type or source of radiation and the means by which exposure is incurred.

While the preferred method of determining environmental dose impact is direct measurement of radionuclide concentrations in air, water, and foodstuffs as close to the receptor as possible, recent Hanford operating effluents have been small and have not produced a measurable effect on background levels in the environment. Because the need to provide a perspective of site operations in terms of dose impact remains, models are used to estimate the potential magnitude of offsite doses at levels below our ability to detect in the environment. The calculation models are empirical and represent best estimates of various environmental and dosimetric processes, which include dispersion of pollutants, pathway transfer and accumulation, population exposure, and radiation dosimetry. Each model requires extensive site specific and generic data as well as parameters that are input to describe the exposure scenario.

The accuracy of calculated doses is largely dependent upon the applicability of the models to each exposure situation, the ability to acquire representative input data, and the validity of the assumed exposure scenario. These factors combine to produce a relatively high level of uncertainty in the calculation results that is compensated for by selecting conservative values (values which would tend to overestimate doses) for the data and parameters used with the models. The resultant doses are considered to be conservatively calculated best estimates of potential radiation dose that could result from environmental releases of radioactive materials.

For certain types of exposure pathways, the dose results from the inhalation or ingestion of radionuclides in the air, water, foods, etc., such that the radionuclides may be metabolically absorbed by the body and retained for some time. In addition, long-lived radionuclides may be deposited on the ground and become a source of long-term exposure. To fully account for the dose received in these cases, the dose impact of Hanford operations is expressed as the "50-year cumulative dose."

The 50-year cumulative dose is an estimate of the accumulated dose received over a period of 50 years following releases to the environment. The calculation considers exposure to radionuclides during the year of their release via inhalation, ingestion and external exposure as well as continued exposure (50 years), to long-lived radionuclides deposited on the ground, via ingestion of locally grown crops. The cumulative dose thus considers the long-term residency of the maximum exposed individual (MI) or 80-km population (see explanation of these terms in Appendix A) for which it is calculated.

The models, data and assumptions used in performing these calculations are described in greater detail in Appendix A.

COMPARISON OF CALCULATED RADIATION DOSES FROM 1977 THROUGH 1982

Comparisons of estimated radiation doses calculated from Hanford operations during the years 1977 through 1982 are provided in the sections that follow. Although the Hanford Environmental Surveillance Program has not identified measurable dose impacts from site operations during these years, radiation doses have been calculated to provide a basis for evaluating and comparing these operations. In addition, while comparisons of offsite doses are made between operating years and trends in doses and reported effluents are identified, the calculated doses presented here are in all cases very low and negligible in comparison to levels of actual impact and other sources of radiation including natural background.

The doses presented for each year of Hanford operation have been calculated on a consistent basis allowing direct comparisons between years. Comparisons are discussed separately for the maximum exposed individual (MI) and the 80-km population. In Appendix B, the calculated doses are further broken down by exposure pathway and operating area.

MAXIMUM EXPOSED INDIVIDUAL

The MI whole body and organ doses calculated for the period 1977 through 1982, and summarized in Table 1, were well below applicable DOE guidelines for radiation dose to maximally exposed offsite individuals. The organ dose constituting the largest fraction of its respective limit (the critical organ) was bone, for which 3 mrem was calculated due to 1977 and 1979 operations. The DOE Order 5480.1 (USDOE 1980) limit on dose to the bone of an MI is 1500 mrem.

Whole Body Dose

Calculated MI whole body doses did not exhibit a clear trend during the comparison period. The highest whole body dose was calculated for 1977 at 0.8 mrem and the lowest was 0.5 mrem for both 1978 and 1981. The primary pathway contributing to the calculated whole body dose was irrigated foodstuffs with ^{90}Sr the critical nuclide. While reported ^{90}Sr in N Reactor liquid

TABLE 1. Comparison of Estimated Maximum Individual Doses Due to Hanford Operations 1977 through 1982

	50-Year Cumulative Dose (mrem)[a]					
Organ	1977	1978	1979	1980	1981	1982
Whole Body	0.8	0.5	0.6	0.6	0.5	0.7
Bone	3	2	3	2	2	2
Lung	0.03	0.02	0.5	<0.01	0.01	0.02
Thyroid	0.4	1	0.4	0.2	0.2	0.2
GI[b]	0.2	0.1	0.1	0.1	0.06	0.07

(a) Total dose to each organ from exposure to all available pathways.
(b) Gastrointestinal Tract (lower large intestine).

effluent increased during this period, the mean annual flow rate of the Columbia River had also increased. The result is that calculated ^{90}Sr concentrations in the river and irrigation water have remained relatively constant.

Bone Dose

MI bone doses were calculated to result from exposure to small quantities of long lived ^{90}Sr and plutonium contained in Hanford effluents. These materials are modeled to persist in the environment and tend to concentrate in the bone following ingestion. As with whole body doses, the primary pathway to bone dose is ingestion of foodstuffs irrigated with Columbia River water containing ^{90}Sr discharged during N Reactor operations. The highest bone doses were 3 mrem for 1977 and 1979 and 2 mrem for the remaining operating years.

The bone doses due to ^{90}Sr in irrigation water remained constant at approximately 2 mrem for the years 1978 through 1982. The higher value of 3 mrem in 1977 was attributable to relatively higher releases of ^{90}Sr in liquid effluent and the lowest mean annual Columbia River flow rate of this comparison period. The total bone dose from 1979 operations was calculated to be 3 mrem due to additional contributions from the 300 Area. During 1979, reported 300 Area effluents included a small amount of plutonium released from the 303C Facility, which resulted in an additional 0.5 mrem calculated bone dose due to inhalation exposure.

Lung Dose

Except for 1979 when reported 300 Area effluents contained a larger than usual amount of plutonium, the MI organ receiving the lowest radiation doses was the lung. The lung dose for 1979 was calculated as 0.5 mrem, which was the highest lung dose of this 6-year period. Lung doses for the other years ranged from <0.01 mrem to 0.03 mrem.

With the exception of 1979 operations, the dominant source of MI lung dose was external exposure to radioactive noble gases. For the years other than 1979, the calculated MI lung doses follow the same trend as noble gases reported in N Reactor effluents; a decrease from 1977 to 1980 followed by an increase from 1980 to 1982.

It is interesting to note that dose to the MI lung, an internal organ, is primarily the result of external radiation. All other MI organ doses, including whole body, are predominated by radionuclides metabolically absorbed following ingestion and inhalation.

Thyroid Dose

Thyroid dose is almost exclusively the result of exposure to radioactive iodine. In the case of the Hanford MI, thyroid dose was calculated to be due to ingestion of foodstuff contaminated by radioiodine deposited on the ground via irrigation and airborne deposition. Thyroid doses for the MI decreased in 1980 in response to reduced quantities of radioiodine (primarily ^{131}I) in reported Hanford effluents.

The primary source of ^{131}I during the period 1977 through 1982 was N Reactor liquid effluent. Reported quantities of ^{131}I in N Reactor discharges to the Columbia River decreased from a level of 4 to 5 Ci/yr during 1977 through 1979 to approximately 2 Ci/yr during 1980 through 1982. In addition, the mean annual Columbia River flow rate increased during this same period, affording additional dilution of effluents.

During 1978, MI thyroid dose due to N Reactor effluents was overshadowed by the thyroid dose calculated due to small amounts of ^{129}I released from the 300 Area. Approximately 0.6 mCi of ^{129}I were reported in the 300 Area effluents during 1978 as a result of the Commercial Nuclear Waste Vitrification Project. While this was a relatively small quantity, the extremely long half life of ^{129}I was significant when considering the 50 year cumulative dose. The thyroid dose due to 300 Area ^{129}I was approximately 0.7 mrem compared to 0.3 mrem due to N Reactor iodine effluent.

Gastrointestinal Tract Dose

Calculated doses to the MI gastrointestinal tract (GI) ranged from 0.1 to 0.2 mrem for operating years 1977 through 1980, but dropped significantly in 1981 and 1982 to 0.06 and 0.07 mrem, respectively. The radionuclides responsible for these GI doses via the primary pathways of irrigated foodstuffs and fish consumption were ^{90}Sr and ^{95}Nb. From 1977 through 1980 each radionuclide contributed approximately half of the calculated doses and each was reported at fairly constant levels in N Reactor liquid effluents. In 1981 the reported ^{95}Nb decreased by almost an order of magnitude and in 1982 was not reported as being present in the effluent. In addition, during 1981 and 1982, the river flow rate increased by approximately one third which resulted in greater dilution and hence a decrease in the calculated GI doses due to ^{90}Sr releases.

80-km POPULATION

While no regulatory limits exist for collective radiation dose to the general population, a comparison can be made between the collective radiation doses from Hanford operations (shown in Table 2) during 1977 through 1982, and those from natural background radiation. Natural background radiation (Oakley 1972) contributes approximately 34,000 man-rem annually to the population within 80-km of Hanford facilities, considerably more than any Hanford related dose.

Whole Body Dose

Calculated whole body dose to the population exhibited a clear trend during the years of comparison. Calculated doses were highest in 1977 and 1978 at 7 man-rem, declining to a low of 2 man-rem in 1980, and gradually increasing to 4 man-rem by 1982. This same trend appeared in the pattern of noble gases in N Reactor effluents. The primary pathway for calculated whole body dose in most years was, indeed, submersion in radioactive noble gases from N Reactor operation, especially ^{41}Ar.

A substantial portion of the higher doses calculated for 1977 and 1978 was attributable to airborne deposition of 200 Area effluents on foodstuffs. Reported 200 Area gross beta effluent for those years was conservatively considered to be all ^{90}Sr. However, additional analyses in subsequent years determined that reported gross beta was instead, primarily ^{137}Cs, resulting in a significant reduction in calculated doses. Had the additional analyses been available for 1977 and 1978, population whole body dose from 200 Area effluents would have been calculated to be much lower.

Bone Dose

As with MI dose, the critical organ for the population was the bone. The highest doses, calculated for both 1977 and 1978, are in part due to the reported 200 Area gross beta releases which were assumed to be ^{90}Sr. As explained in the whole body dose discussion, the ability to distinguish between the ^{90}Sr and ^{137}Cs components of the gross beta in subsequent years significantly reduced the calculated doses. This is especially true in the case of bone dose, as ^{90}Sr was the critical radionuclide for bone.

TABLE 2. Comparison of Estimated 80-km Population Doses Due to Hanford Operations 1977 through 1982

	50-Year Cumulative Dose (man-rem)[a]					
Organ	1977	1978	1979	1980	1981	1982
Whole Body	7	7	4	2	3	4
Bone	20	20	10	5	5	7
Lung	6	5	5	1	3	4
Thyroid	13	12	12	4	5	7
GI[b]	4	3	3	<1	3	3

(a) Total dose to each organ from exposure to all available pathways.
(b) Gastrointestinal Tract (lower large intestine).

Several exposure pathways were dominant in calculating bone dose. One was external exposure due to submersion in air containing radioactive noble gases from N Reactor operation. The trend of doses due to this pathway closely followed the trend of noble gas releases. Ingestion of foodstuffs irrigated by Columbia River water and contaminated by deposition of airborne effluents was also an important pathway. The increased quantity of plutonium in reported 300 Area air effluents for 1979 provided an additional contribution of approximately 1.5 man-rem to the calculated population bone dose during that year.

Lung Dose

Calculated population lung dose exhibited the same general trend observed for the other organs. As was the case with the other organs, lung doses calculated for 1977 and 1978 are higher compared to other years due to the interpretation of reported 200 Area gross beta values as ^{90}Sr for purposes of dose calculations. The primary source of lung dose in all years was external radiation exposure from submersion in noble gases released during N Reactor operation. Following the general trend of N Reactor operation, calculated lung dose decreased to a low of 1 man-rem in 1980 and gradually increased again through 1982. The increased release of plutonium from the 300 Area reported in 1979 contributed an additional 1.4 man-rem to lung dose that year.

Thyroid Dose

In general, the same trend observed for other population doses was exhibited for thyroid dose during the years of comparison. The highest calculated doses (12 to 13 man-rem) occurred in 1977 through 1979, dropping to a low of 1 man-rem in 1980, and increasing again through 1982. The primary contributions to this dose were from submersion in air effluents from N Reactor and ingestion of foodstuffs contaminated by deposition of airborne effluents from N Reactor. In the case of ingestion, the critical radionuclide was ^{131}I while radioactive noble gases (primarily ^{41}Ar) dominated air submersion. Trends in contributions from both primary pathways closely followed actual ^{131}I and noble gas trends in air emissions. The slightly higher dose in 1978 was attributed to increased releases of ^{129}I reported in 300 Area air effluents from the Commercial Nuclear Waste Vitrification Project. Liquid releases of ^{131}I were elevated in 1977 through 1979, resulting in more noticeable doses calculated from drinking water during those years.

Gastrointestinal Tract Dose

Doses to the GI were the lowest organ doses calculated for the general population during the years examined. These doses resulted from submersion in radioactive noble gases released during the operation of N Reactor, and dose trends reflected that relationship.The highest dose of 4 man-rem occurred in 1977 when N Reactor operated for the longest time period of the 6-years and noble gas production rate was elevated. The lowest dose of <1 man-rem occurred during the year of shortest N Reactor operation, 1980, which coincided with a reduction in noble gas production rate. The remaining years exhibited a dose of approximately 3 man-rem.

CONCLUSION

As previously stated, the Hanford Environmental Surveillance Program has not identified any measurable dose impacts from Hanford operations during the years 1977 through 1982. Radiation doses were calculated to provide a basis for evaluating and comparing these operations and were in all cases very low and negligible compared to levels of actual impact and other sources of radiation including natural background. Comparison of calculated dose impacts from annual Hanford operations is not a straightforward process. The relative dose contributions of environmental pathways change from year to year as the magnitude and composition of operating effluents vary. In addition the degree of effluent dilution following release is dependent upon a variable environment. Meteorologic conditions, Columbia River flow rate, and population magnitude and location all combine to influence the magnitude and source of calculated offsite doses.

In general, calculated offsite doses due to Hanford operations decreased over the period 1977 through 1982. In some cases this was due to an actual reduction in reported effluents used as source terms in the calculations (i.e., N Reactor ^{131}I effluent) while in others, it was due to changes in effluent reporting methods (i.e., 200 Area gross beta breakdown to ^{90}Sr and ^{137}Cs components). Additional decreases in calculated doses were attributable to increasing Columbia River flow rates during this period.

With the exception of dose to the lung, calculated MI doses were dominated by the irrigated foodstuffs pathway. Critical radionuclides were ^{90}Sr and ^{131}I in N Reactor liquid effluents. The MI lung doses were dominated by direct exposure to radioactive noble gases in N Reactor airborne effluents. The critical MI organ for each year of this comparison was the bone.

Population doses, in contrast with the MI, were dominated by airborne effluents. While the assumed MI is exposed more or less equally to liquid and airborne pathways, only 2,000 of the 340,000 population within 80 km are estimated to be exposed to irrigated foodstuffs. The primary exposure pathways contributing to the population doses were air submersion and ingestion of foodstuffs contaminated by airborne effluents deposited on the ground. The critical radionuclides were radioactive noble gases, ^{131}I in N Reactor airborne effluents and ^{90}Sr in 200 Area airborne effluents. As with the MI, the critical organ for the general population was the bone in all years but 1979; in that year the critical organ was calculated to be thyroid.

The doses presented in this report for the years 1977 through 1981 differ to some extent from those originally reported. Consistent with the then available environmental dose calculating capabilities, the original calculations did not include consideration of the persistence of long-lived radionuclides in environmental pathways beyond the year of their release. Thus, dose impacts were recalculated using presently available methodologies (see Appendix A). In addition, where more appropriate or accurate data had become available, they were used in these calculations.

Although the recalculated doses vary somewhat from the values previously reported, the conclusions remain unchanged: radiological doses attributable to Hanford operations are well below applicable guidelines and contribute only a small fraction of the dose received by the public from naturally occurring radiations. A comparison of the recalculated doses to those previously reported for Hanford operations during 1977 through 1981 is provided in Table A.11 of Appendix A.

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APPENDIX A

ENVIRONMENTAL DOSE CALCULATIONS AND CALCULATION DOCUMENTATION

APPENDIX A

ENVIRONMENTAL DOSE CALCULATIONS AND CALCULATION DOCUMENTATION

The evaluation of potential radiation dose impacts of Hanford operations is accomplished through the use of computerized dose calculation models. The models allow estimation of potential offsite doses at levels which, due to the nature of site operations, are below our ability to detect in the environment. Because the calculation process is complex and input data are extensive, this Appendix provides descriptions of the generic calculational process and the specific calculations performed for Hanford as well as documentation of the key calculation inputs and data.

GENERIC CALCULATION PROCESS

The calculations address potential radiation doses due to inhalation of and submersion in airborne materials, ingestion of foodstuffs contaminated by deposition of airborne materials and by irrigation with Columbia River water, and direct exposure to radionuclides that have deposited on the ground or are contained in the Columbia River.

A general description of the calculation process is provided below for doses due to airborne effluents and due to liquid effluents.

Airborne Effluents

The dilution and transport of airborne effluents is calculated based upon onsite measurements of wind speed and direction and atmospheric stability (which affects the degree of mixing). Curie quantities of radionuclides contained in the annual effluents are input to the atmospheric dispersion model which calculates annual average air concentrations (Ci/m^3) at specified locations in the environment. Doses due to inhalation and air submersion are calculated directly from these air concentrations on the basis of an average adult inhalation rate (2.5×10^{-4} m^3/sec) and continuous occupancy (8760 hr/yr).

In order to estimate potential ingestion doses, the areal deposition rate ($Ci/m^2 \cdot sec$) of airborne materials is calculated using a settling velocity (m/sec). The products of this calculation are estimates of radionuclide curies deposited directly on plant surfaces and on the ground. Transfer factors are used to calculate the fraction of deposited activity (both plant surface and ground) which ultimately transfers to the edible portion of the crop. Adult annual consumption rates (kg/yr) are used to estimate the intake of radionuclides via each foodstuff for the purpose of calculating the resultant doses. In the case of milk, eggs, meat, etc., the animal consumption rate and additional transfer factor are included in the calculation.

An external dose due to direct exposure to ground deposited radioactivity (vs. ingestion of foodstuffs) is calculated assuming outdoor exposure for one half the year (4383 hr).

Liquid Effluents

Radionuclides discharged to the Columbia River are mixed with the river's flow. Concentrations at the point of public exposure are calculated on the basis of complete mixing at the mean annual flowrate.

Deposition of activity on crops and farm land is estimated using an irrigation rate (ℓ/m^2) and the calculated concentrations in the river (Ci/ℓ). Transfer factors, annual consumptions, and direct exposure time, as described for airborne effluents, are used to calculated potential ingestion and direct exposure doses.

Drinking water doses are calculated by applying water treatment system cleanup factors to the estimated river concentrations. The annual drinking water consumption rate (ℓ/yr) is then used to calculate the intake of radionuclides from which dose is calculated.

External radiation doses are calculated for exposure to radionuclides in the river and deposited on the river shoreline. Calculated river concentrations are used to estimate the dose due to submersion while swimming and to surface exposure while boating. External doses received on the shoreline are calculated assuming a narrow band of surface contamination deposited by the river.

Radionuclide concentrations in local fish are estimated using bioaccumulation factors which account for the buildup of radionuclides in fish exposed to the calculated river concentrations during the course of an operating year. An annual consumption rate (kg/yr) of fish by local residents is used to estimate the ingestion of radionuclides for the purpose of calculating radiation dose.

HANFORD ENVIRONMENTAL DOSE CALCULATIONS

The offsite impact of Hanford operations is evaluated in terms of the potential radiation dose to an assumed maximum exposed individual (MI) and the population residing within 80-km of the Hanford operating areas. While these two calculations are performed on a common basis, their objectives and specific techniques are distinct. Separate discussions are provided below the MI and 80-km population.

Maximum Exposed Individual

The assessment of MI organ doses provides an estimate of the maximum radiation doses that a member of the public could receive from long-term exposure to Hanford operations and effluents.

The Hanford MI is located such that the combined impact from all Hanford operations and effluents is maximized. The MI is hypothetical in that an actual individual is not identified but is realistic to the extent that all exposure pathways are credible. During 1977, 1978 and 1980 through 1982, the MI was assumed to reside approximately 13 km SSE of the 300 Area. At this location the MI was assumed to:

- consume foodstuffs grown in the northwestern part of the Riverview district using Columbia River water for irrigation
- drink sanitary water obtained from the Columbia River

- use the Columbia River extensively for recreational activities including boating, swimming and fishing as well as consumption of the fish.

The location of maximum combined impact was changed during 1979 due to a shift in the relative impacts of operating area effluents. The maximum individual for 1979 operations was postulated to reside 1.6 km east of the 300 Area. At this location the MI was assumed to grow and consume foodstuffs irrigated by Columbia River water and to continue to use the Columbia River for recreation. However, because no sanitary water supply in this location drew from the Columbia River, this pathway was not included. Despite the loss of drinking water contributions to the MI doses, proximity to the 300 Area during 1979 resulted in this location being the overall offsite maximum.

80-km Population

The collective population dose represents the summed products of average dose and number of individuals involved for all possible pathways and as such is an estimate of the overall impact of Hanford operations. The same pathways of exposure considered in the MI calculations are used for calculating collective population doses. However, unlike the other exposure pathways, potential dose from river related pathways is limited to that portion of the full 80-km population actually using river water. These pathways include drinking water, irrigated foodstuff, fish consumption and river recreation and are described as follows (McCormack 1982):

- Drinking Water--The cities of Richland and Pasco obtain their municipal water from the Columbia River downstream from Hanford. The city of Kennewick began drawing a portion of its municipal water from the river in 1980, receiving 40% from this source during 1981 and 1982. Prior to 1981, the total affected population was approximately 50,000. This total increased to approximately 70,000 during 1981 and 1982.
- Irrigated Foodstuff--Columbia River water is used for irrigating home vegetable gardens in the Riverview District of Franklin County of Pasco. Approximately 2,000 people are estimated to be affected.

- River Recreation--These activities include swimming, boating and shoreline recreation. The population residing adjacent to the river within 80 km of Hanford is assumed to be affected by these pathways and is estimated to number 125,000.
- Fish Consumption--Population doses due to consumption of fish obtained locally from the Columbia River are based on an estimated total annual catch of 15,000 kg/yr without reference to a specific portion of the population.

DOSE CALCULATION DOCUMENTATION

Input data necessary to perform dose calculations are extensive. Calculations based on measured effluent releases require data describing initial transport through the atmosphere or river, transfer or accumulation in terrestrial and aquatic pathways, public exposure, and dosimetry. The bulk of this data is described in Appendix E of Environmental Surveillance at Hanford for CY-1982, Sula et al. (1983). The computerized programs used to perform the dose calculations have been identified for use in the Hanford environmental dose calculations and are documented separately (Houston, Strenge, and Watson 1974; Strenge and Watson 1973; Napier, Kennedy and Soldat 1980). Documentation of the calculations performed for this report is provided in Tables A.1 through A.5. Tables A.6 through A.10 list the reported annual operating effluents used as source terms for these calculations. Table A.11 provides a comparison of the recalculated doses for Hanford operations during 1977 through 1981 to those previously reported.

TABLE A.1. Documentation of 100 Area Airborne Release Dose Calculations

Facility name:	100 Area	
Releases:	See Table A.6	
Meteorological conditions:	1982 annual average, calculated from data collected at 100 N Area and the Hanford Meteorological Station from 1-82 through 12-82.	
Dispersion model:	Gaussian, Hanford parameters (ERDA 1975)	
X/Q:	1977, 1978, 1980-1982	1979
MI (sec/m^3)		
Direct Airborne:	$4.2X10^{-9}$, 53 km SSE	$5.4X10^{-9}$, 41 km SSE
Foodstuff:	$5.4X10^{-9}$, 41 km SSE	$5.4X10^{-9}$, 41 km SSE
80-km Population: ($person\ sec/m^3$)	All years, 1.7×10^3	
Release height:	82.3 meters effective (60.96 meters actual stack height)	
Population:	340,000	
Computer code:	DACRIN, Rev. 1.2, 1980	
Calculated dose:	Chronic inhalation, maximum individual and 80-km population, 50-year dose commitment	
Files addressed:	Organ Data Library, Rev. 2-5-81 Radionuclide Library, Rev. 1-15-81	
Computer code:	PABLM, Rev. 2.2, 10-1-80	
Calculated Dose:	Chronic ingestion and ground contamination exposure, maximum individual and 80-km population, 50-year cumulative dose	
Files addressed:	Radionuclide Library, Rev. 1-15-81 Food Transfer Library, Rev. 8-26-82 Organ Data Library, Rev. 2-5-81 Ground Dose Factor Library, Rev. 3-15-78	
Computer code:	KRONIC, Rev. 3-11-83	
Calculated dose:	Chronic air submersion, maximum individual and 80-km population, first year dose	
File addressed:	RNDBET GISLIB	

TABLE A.2. Documentation of 100 Area Liquid Release Dose Calculations

Facility name:	100 Area
Releases:	See Table A.7
River flow:	1977, 84,500 cfs; 1978, 117,200 cfs; 1979, 99,700 cfs; 1980, 102,000 cfs; 1981, 132,000 cfs; 1982, 140,000 cfs
Mixing ratio:	1
Reconcentration formula:	3
Shore-width factor:	0.2
Population:	Drinking water pathway--1977 through 1980, 50,000; 1981 and 1982, 70,000 Fish and direct exposure--All years 125,000 Irrigated foodstuff-All years 2000
Computer code:	PABLM, REV. 2.2, 10-1-80
Calculated dose:	Chronic ingestion, direct exposure to water and shoreline, maximum individual and 80-km population, 50-year dose commitment[a]
Files addressed:	Radionuclide Library, Rev. 1-15-81 Organ Data Library, Rev. 2-5-81 Hanford Specific Bio. Accum. Library Ground Dose Factor Library, Rev. 3-15-78
Computer code:	PABLM, Rev. 2.2, 10-1-80
Calculated dose:	Chronic ingestion and ground contamination, maximum individual and 80-km population, 50-year cumulative dose
Files addressed:	Radionuclide Library, Rev. 1-15-81 Food Transfer Library, Rev. 8-26-82 Organ Data Library, Rev. 2-5-81 Ground Dose Factor Library, Rev. 3-15-78

(a) No MI drinking water pathway for 1979

TABLE A.3 Documentation of 200 Area Airborne Release Dose Calculations

Radionuclide	Half-Life	Effluents, Ci[a] 1977	1978	1979	1980	1981	1982
^{3}H (HTO)	12.3 yr	18.0	31.0	15.0	14.0	18.0	22.0
^{14}C	5700 yr	-	-	9.7	-	3.2	-
^{24}Na	15.0 hr	0.18	0.20	0.20	0.36	0.12	0.22
^{41}Ar	1.8 hr	$1.3 X 10^{5}$	$1.1 X 10^{5}$	$8.6 X 10^{4}$	$2.3 X 10^{4}$	$6.5 X 10^{4}$	$1.1 X 10^{5}$
^{51}Cr	27.8 d	0.017	0.046	0.080	0.081	-	-
^{54}Mn	303 d	0.016	0.021	0.037	0.020	0.003	0.008
^{56}Mn	2.6 hr	2.4	3.8	5.1	3.4	0.46	0.099
^{59}Fe	46.0 d	0.018	0.022	0.045	0.037	0.003	0.007
^{58}Co	71.0 d	0.0029	0.019	0.012	0.011	0.008	0.005
^{60}Co	5.3 yr	0.029	0.038	0.053	0.030	0.018	0.015
^{65}Zn	245 d	$4.6 X 10^{-4}$	0.012	0.009	0.012	0.001	-
^{76}As	26.4 hr	0.66	6.7	0.45	0.38	0.68	1.3
^{82}Br	35 hr	-	0.013	-	-	-	-
^{85m}Kr	4.4 hr	830	510	420	150	250	130
^{87}Kr	76.0 min	2500	1540	1300	500	280	520
$^{88}KrRb$	2.8 hr	2000	1200	970	370	530	550
^{89}Sr	52.7 d	0.0079	0.021	0.012	0.033	0.002	0.005
^{90}Sr	27.7 yr	$1.7 X 10^{-4}$	$7.2 X 10^{-4}$	$4 X 10^{4}$	0.0023	0.006	0.001
^{91}Sr	9.7 hr	0.58	0.95	2.4	1.7	0.18	0.33
^{95}Zr	65.0 d	0.0038	0.0078	0.01	0.0054	-	0.003
^{95}Nb	35.0 d	0.003	0.0073	0.009	0.0057	0.001	0.003
$^{97}ZrNb$	17 hr	0.0021	0.011	0.055	0.041	-	-
$^{99m}MoTc$	66.7 hr	0.62	1.0	0.39	0.53	0.26	0.29
^{103}Ru	39.5 d	0.0082	0.017	0.02	0.012	0.003	0.01
^{106}Ru	368 d	0.019	0.06	0.083	0.025	0.004	-
^{122}Sb	2.8 d	0.0054	0.0054	0.016	0.022	-	-
^{124}Sb	60.4 d	0.0033	0.003	0.0043	0.0067	0.037	-
^{125}Sb	2.7 yr	$1.4 X 10^{-4}$	$3.0 X 10^{-4}$	0.0012	-	-	-
^{132}Te	77.7 hr	0.0056	0.025	0.069	0.013	0.006	-
^{129}I	$1.7 X 10^{7}$ yr	$2.1 X 10^{-7}$	-	$2.3 X 10^{-8}$	$5.1 X 10^{-9}$	$1.9 X 10^{-8}$	-
^{131}I	8.1 d	0.55	0.47	0.54	0.21	0.097	0.25
^{132}I	2.3 hr	9.6	6.2	11.0	9.5	4.7	2.5
^{133}I	20.3 hr	4.0	3.1	3.0	1.4	0.82	1.5
^{135}I	6.7 hr	8.6	6.2	6.7	7.1	3.0	0.29
^{133}Xe	5.3 d	680	91.0	4.1	-	-	840
^{133m}Xe	2.3 d	-	1.6	-	-	-	-
^{135}Xe	9.1 hr	3400	2100	1400	480	490	610
^{134}Cs	2.1 yr	-	$9.8 X 10^{-4}$	0.011	0.0033	$7.5 X 10^{-5}$	-
^{137}Cs	30.0 yr	0.0015	0.0023	0.039	0.0055	0.01	$2.5 X 10^{-4}$
^{138}Cs	32.2 min	$1.3 X 10^{4}$	4100	5400	1900	$1.1 X 10^{4}$	$1.7 X 10^{4}$
^{140}Ba	12.8 d	0.20	0.19	0.16	0.17	0.036	-
^{140}La	40.2 hr	0.36	1.1	0.36	0.31	.078	-
^{141}Ce	32.5 d		0.0074	0.030	0.0094	-	-
$^{144}CePr$	284 d	0.030	0.057	0.060	0.046	0.11	0.05
^{147}Nd	11.1 d	0.013	0.077	0.073	0.077	0.011	-
^{153}Sm	46.8 hr	0.028	0.12	0.023	-	-	-
^{154}Eu	16.0 yr	0.010	0.032	0.0074	0.0021	0.15	-
^{155}Eu	1.8 yr	0.0062	0.071	0.014	0.013	0.026	$2.7 X 10^{-4}$
^{187}W	23.9 hr	0.069	0.34	0.094	0.13	0.10	-
^{218}Pu	86.4 yr	$1.1 X 10^{-6}$	$3.6 X 10^{-7}$	$3.4 X 10^{-7}$	$2.5 X 10^{-6}$	$1.0 X 10^{-5}$	$1.0 X 10^{-4}$
^{239}Pu	$2.4 X 10^{4}$ yr	$5.7 X 10^{-6}$	$2.2 X 10^{-6}$	$2.0 X 10^{-6}$	$1.5 X 10^{-5}$	$6.4 X 10^{-5}$	$6.2 X 10^{-4}$
^{122}Sb	2.8 d	0.0054	0.0054	0.016	0.022	-	-
^{239}Np	2.3 d	-	0.015	0.78	0.16	-	-

(a) All Ci values are as reported by operating contractors via the DOE's Effluent Information System.

TABLE A.4. Documentation of 300 Area Airborne Release Dose Calculations

Facility name:	300 Area	
Releases:	See Table A.9	
Meteorological conditions:	1982 annual average, calculated from data collected at 300 Area and the Hanford Meteorological Station from 1-82 through 12-82.	
Dispersion model:	Gaussian, Pasquill parameters	
X/Q:	1977, 1978, 1980-1982	1979
MI (Sec/m^3)		
Direct Airborne:	$8.1X10^{-8}$, 13 km SSE	$2.6X10^{-6}$, 1.6 km E
Foodstuff:	$2.6X10^{-6}$, 1.6 km E	$2.6X10^{-6}$, 1.6 km E
80-km Population: (person sec/m^3)	All years $8.1X10^{-3}$	
Release height:	Ground level	
Population:	265,000	
Computer code:	DACRIN, Rev. 1.2, 1980	
Calculated dose:	Chronic inhalation, maximum individual and 80-km population, 50-year dose commitment	
Files addressed:	Organ Data Library, Rev. 2-5-81 Radionuclide Library, Rev. 1-15-81	
Computer code:	PABLM, Rev. 2.2, 10-1-80	
Calculated Dose:	Chronic ingestion and ground contamination exposure, maximum individual and 80 km population, 50-year cumulative dose	
Files addressed:	Radionuclide Library, Rev. 1-15-81 Food Transfer Library, Rev. 8-26-82 Organ Data Library, Rev. 2-5-81 Ground Dose Factor Library, Rev. 3-15-78	
Computer code:	KRONIC, Rev. 3-11-83	
Calculated dose:	Chronic air submersion, maximum individual and 80-km population, first year dose	
Files addressed:	RNDBET GISLIB	

TABLE A.5. Documentation of 400 Area Airborne Release Dose Calculations

Facility name:	400 Area
Releases:	See Table A.10
Meteorological conditions:	1982 annual average, calculated from data collected at 400 Area and the Hanford Meteorological Station from 1-82 through 12-82.
Dispersion model:	Gaussian, Pasquill parameters
X/Q:	
MI: (sec/m^3)	
Direct Airborne:	All years 1.9 x 10^{-8}, 29 km SSE
Foodstuff:	All years 7.2 x 10^{-8}, 11 km SE
80-km Population: (person sec/m^3)	All years 6.3 x 10^{-3}
Release height:	Ground level
Population:	264,000
Computer code:	DACRIN, Rev. 1.2, 1980
Calculated dose:	Chronic inhalation, maximum individual and 80-km population, 50-year dose commitment
Files addressed:	Organ Data Library, Rev. 2-5-81 Radionuclide Library, Rev. 1-15-81
Computer code:	PABLM, Rev. 2.2, 10-1-80
Calculated dose:	Chronic ingestion and ground contamination exposure, maximum individual and 80-km population, 50-year cumulative dose
Files addressed:	Radionuclide Library, Rev. 1-15-81 Food Transfer Library, Rev. 1-15-82 Organ Data Library, Rev. 2-5-81 Ground Dose Factor Library, Rev. 3-15-78
Computer code:	KRONIC, Rev. 3-11-83
Calculated dose:	Chronic air submersion, maximum individual and 80-km population, first year dose
Files addressed:	RNDBET GISLIB

TABLE A.6 Radionuclide Composition of 100 Area Air Effluents

Radionuclide	Half-Life	Effluents, Ci[(a)] 1977	1978	1979	1980	1981	1982
^{3}H (HTO)	12.3 yr	430	330	200	88	82	360
^{24}NA	15.0 hr	1.4	-	-	-	-	-
^{32}Puc	14.3 d	0.018	0.03	0.012	0.27	0.68	0.059
^{51}Cr	27.8 d	0.19	0.14	-	0.20	-	-
^{54}Mn	303 d	0.19	0.18	0.82	0.13	0.036	0.017
^{56}Mn	2.6 hr	-	1.2	5.2	4.2	3.8	1.7
^{59}Fe	46.0 d	-	0.11	2.1	0.18	-	0.12
^{58}Co	71.0 d	0.02	0.032	0.13	0.033	0.023	-
^{60}Co	5.3 yr	1.2	0.96	0.93	0.76	0.60	0.58
^{89}Sr	52.7 d	1.5	0.40	0.58	0.94	1.2	0.6
^{90}Sr	27.7 yr	1.8	1.3	1.6	1.8	1.8	2.7
^{95}Zr	65.5 d	0.045	0.11	0.13	0.071	0.07	-
^{95}Nb	35.0 d	0.15	0.16	0.17	0.11	0.03	-
$^{99m}MoTc$	66.7 hr	1.0	2.6	1.0	0.39	0.83	2.4
^{103}Ru	39.5 d	0.25	0.38	0.52	0.59	0.038	0.15
^{106}Ru	368 d	0.68	0.57	0.45	0.65	0.34	0.31
^{124}Sb	60.4 d	0.079	0.062	0.087	0.10	0.077	-
^{125}Sb	2.7 yr	0.25	0.17	0.19	0.16	0.12	0.11
^{129}I	1.7×10^{7} yr	8.2×10^{-6}	8.2×10^{-6}	2.7×10^{-10}	6.2×10^{-6}	8.0×10^{-6}	-
^{131}I	8.1 d	4.2	4.8	5.1	2.1	2.4	2.2
^{131}I	20.3 hr	0.44	0.95	1.1	0.36	0.62	-
^{133}Xe	5.3 d	7.6	-	6.9	3.2	1.5	22
^{133m}Xe	2.3 d	-	5.7	-	-	-	-
^{137}Cs	30.0 yr	0.03	0.031	0.078	0.040	0.053	0.15
^{140}Ba	12.8 d	0.064	0.38	0.45	0.33	-	-
^{140}La	40.2 hr	0.038	4.0	2.7	0.55	-	-
^{141}Ce	32.5 d	-	0.035	0.053	0.036	-	-
$^{144}CePr$	284 d	-	0.15	-	-	0.02	-
^{147}Nd	11.1 d	-	0.17	-	0.028	-	-
^{153}Sm	46.8 hr	-	-	0.28	-	-	-
^{238}Pu	86.4 yr	0.069	1.3×10^{-4}	6.8×10^{-5}	3.5×10^{-4}	2.9×10^{-4}	4.7×10^{-4}
^{239}Pu	2.4×10^{4} yr	0.0099	0.085	5.0×10^{-6}	2.0×10^{-4}	7.3×10^{-5}	3.0×10^{-4}

(a) All Ci values are as reported by operating contractors via the DOE's Effluent Information System.

TABLE A.7 Radionuclide Composition of 100 Area Liquid Effluents

Radionuclide	Half-Life	Effluent, Ci[a] 1977	1978	1979	1980	1981	1982
^{3}H	12.3 yr	9.0	0.046	8.4	-	-	-
^{60}Co	5.3 yr	1.2×10^{-4}[b]	4.7×10^{-5}[b]	2.0×10^{-5}[b]	1.7×10^{-5}[b]	3.3×10^{-7}[b]	3.0×10^{-6}[b]
^{85}Kr	10.7 yr	-	440	1500	-	-	-
^{90}Sr	27.7 yr	2.5×10^{-4}[c]	1.1×10^{-4}[c]	7.0×10^{-5}[c]	4.5×10^{-5}[c]	4.6×10^{-5}[c]	4.6×10^{-5}[d]
^{129}I	1.7×10^{7} yr	-	5.8×10^{-4}	-	-	-	-
^{131}I	8.1 d	4.4×10^{-4}	3.5×10^{-4}	4.1×10^{-4}	6.7×10^{-4}	2.9×10^{-4}	5.1×10^{-4}
^{220}Rn	-	-	0.009	-	-	-	-
U-nat	4.4×10^{9} yr	5.2×10^{-5}	7.2×10^{-6}	2.7×10^{-5}	4.9×10^{-5}	7.5×10^{-5}	2.1×10^{-4}
^{238}Pu	86.4 yr	-	-	9.6×10^{-4}	-	-	-
^{239}Pu	2.4×10^{4} yr	3.2×10^{-5}[e]	2.8×10^{-5}[e]	4.0×10^{-4}[e]	2.7×10^{-5}[f]	4.2×10^{-5}[f]	1.9×10^{-5}
Th-nat	1.4×10^{10} yr	-	-	1.0×10^{-7}	2.3×10^{-7}	-	-
^{244}Cm	18.1 yr	8.4×10^{-8}	-	5.1×10^{-8}	-	4.5×10^{-7}	5.5×10^{-8}

(a) All Ci values are as reported by operating contractors via the DOE's Effluent Information System.
(b) Reported as mixed activation products. Cobalt-60 assumed for dose calculations.
(c) Reported as mixed fission products and unidentified beta-gamma activity. Strontium-90 assumed for dose calculations.
(d) Not reported via DOE Effluent Information System, but obtained via direct communication with Westinghouse Hanford Company personnel.
(e) Reported as gross alpha. Plutonium-239 assumed for dose calculations.
(f) Reported as ^{239}Pu and unidentifed alpha activity. Plutonium-239 assumed for dose calculations.

TABLE A.8. Radionuclide Composition of 200 Area Air Effluents

Radionuclide	Half-Life	Effluent, Ci[a]					
		1977	1978	1979	1980	1981	1982
^{90}Sr[b]	27.7 yr	0.21	0.23	0.048	0.025	0.0018	0.01
^{137}Cs[b]	30.0 yr	-	-	0.099	0.07	0.051	0.2
^{239}Pu[c]	2.4×10^{4} yr	0.0028	0.0025	4×10^{-4}	2×10^{-2}	3×10^{-4}	7×10^{-4}

(a) Except as specifically noted in this table, all Ci values are as reported by operating contractor via the DOE's Effluent Information System.

(b) Originally reported as mixed fission product gross beta. During 1983 Rockwell Hanford Operations, Effluent Controls Group, provided ^{137}Cs and ^{90}Sr components of gross beta measurement for 1979-1982. For 1977 and 1978 calculations gross beta was assumed to be ^{90}Sr.

(c) Reported as gross alpha. Plutonium-239 assumed for dose calculations.

TABLE A.9 Radionuclide Composition of 300 Area Air Effluents

Facility name:	200 Area
Releases:	See Table A.8
Meteorological conditions:	Annual average, calculated from data collected at the Hanford Meteorological Station for each year 1977 through 1982
Dispersion model:	Gaussian, Hanford parameters (ERDA 1975)

X/Q:

	1977	1978
MI (sec/m^3)		
Direct Airborne:	9.8×10^{-9}, 43 km SE	1.1×10^{-8}, 43 km SE
Foodstuff:	1.4×10^{-8}, 32 km SE	1.6×10^{-8}, 32 km SE
80-km Population (person sec/m^3)	1.8×10^{-3}	2.0×10^{-3}

	1979	1980
MI (sec/m^3)		
Direct Airborne:	1.6×10^{-8}, 32 km SE	1.0×10^{-8}, 43 km SE
Foodstuff:	1.6×10^{-8}, 32 km SE	1.5×10^{-8}, 32 km SE
80-km Population (person sec/m^3)	2.0×10^{-3}	1.8×10^{-3}

	1981	1982
MI (sec/m^3)		
Direct Airborne:	1.1×10^{-8}, 43 km SE	1.1×10^{-8}, 43 km SE
Foodstuff:	1.6×10^{-8}, 32 km SE	1.5×10^{-8}, 32 km SE
80-km Population (person sec/m^3)	2.1×10^{-3}	1.8×10^{-3}

Release height:	89.2 meters effective (60.96 meters actual stack height)
Population:	341,000
Computer code:	DACRIN, Rev. 1.2, 1980
Calculated dose:	Chronic inhalation, maximum individual and 80-km population, 50-yr dose commitment
Files addressed:	Organ Data Library, Rev. 2-5-81 Radionuclide Library, Rev. 1-15-81
Computer code:	PABLM, Rev. 2.2, 10-1-80
Calculated dose:	Chronic ingestion and ground contamination exposure, maximum individual and 80-km population, 50-year cumulative dose
Files addressed:	Radionuclide Library, Rev. 1-15-81 Food Transfer Library, Rev. 8-26-82 Organ Data Library, Rev. 2-5-81 Ground Dose Factor Library, Rev. 3-15-78
Computer code;	KRONIC, Rev. 3-11-83
Calculated dose:	Chronic air submersion, maximum individual and 80-km population, first year dose
Files addressed:	RNCBET GISLIB

TABLE A.10 Radionuclide Composition of 400 Area Air Effluents

		Effluent, Ci[a]					
Radionuclide	Half-Life	1977	1978	1979	1980	1981	1982
^{88}KrRb	2.8 hr					450	140
^{90}Sr	27.7 yr	-FFTF Not Operating-				$4.1X10^{-5}$[b]	$1.9X10^{-5}$
^{131}I	8.1 d					$1.3X10^{-5}$	$9.6X10^{-5}$
^{239}Pu	$2.4X10^{4}$ yr					$6.3X10^{-6}$[c]	$7.3X10^{-6}$

(a) All Ci values are as reported by operating contractors via the DOE's Effluent Information System.
(b) Reported as mixed fission products and unidentified beta-gamma activity. Strontium-90 assumed for dose calculations.
(c) Reported as ^{239}Pu and unidentified alpha activity. Plutonium-239 assumed for dose calculations.

TABLE A.11 Comparison of Recalculated Environmental Doses to those Previously Reported for Hanford Operations, 1977 through 1981[a]

Organ	Maximum Individual - mrem Recalculated/Previously Reported 1977	1978	1979	1980	1981
Whole Body	0.8/0.2	0.5/0.1	0.6/0.1	0.6/0.1	0.5/0.4
Bone	3/0.9	2/0.2	3/0.9	2/0.4	2/1
Lung	.03/0.03	0.02/0.01	0.5/0.6	<0.01/<0.01	0.01/0.02
Thyroid	0.4/0.4	1/0.5	0.4/0.4	0.2/0.2	0.2/0.1
GI	0.2/0.1	0.1/<0.01	0.1/0.02	0.1/0.02	0.06/0.05

Organ	80 km Population - man-rem Recalculated/Previously Reported 1977	1978	1979	1980	1981
Whole Body	7/3	7/2	4/2	2/<1	3/4
Bone	20/6	20/2	10/3	5/1	5/6
Lung	6/2	5/2	5/2	1/<1	3/3
Thyroid	13/6	12/5	12/5	4/2	5/4
GI	4/2	3/2	3/1	<1/<1	3/3

(a) Previously reported in Hanford Environmental Surveillance Program documents listed in the preface to this report. Previously reported doses were calculated as 50-year dose commitments while recalculated doses are 50-year cumulative dose.

APPENDIX B

EXPOSURE PATHWAYS AND OPERATING AREA BREAKDOWNS OF CALCULATED DOSES, 1977-1982

APPENDIX B

EXPOSURE PATHWAY AND OPERATING AREA BREAKDOWNS OF CALCULATED DOSES, 1977-1982

This appendix provides exposure pathway and operating area break downs of the calculated doses due to Hanford operations during 1977 through 1982. Tables B.1 through B.5 detail the pathway contributions to the total organ doses provided in Tables 1 and 2. The Tables are specific to each organ for the MI and 80-km population with the totaled doses at the bottom of each table corresponding to the organ doses provided in Tables 1 and 2. Tables B.6 through B.10 detail the operating area contributions to the calculated total organ doses.

TABLE B.1. Exposure Pathway Contributions to Calculated 50-Year Cumulative Whole Body Doses Due to Hanford Operations, 1977 through 1982

Pathway	Maximum Individual Whole Body Dose (mrem)					
	1977	1978	1979	1980	1981	1982
Direct Airborne[a]	0.01	0.01	0.04	<0.01	0.01	0.01
Foodstuffs[b]	0.7	0.4	0.5	0.6	0.4	0.6
Drinking Water	<0.01	<0.01	-	<0.01	<0.01	<0.01
River Recreation[c]	0.04	0.02	0.03	0.03	0.02	0.04
Total	0.8	0.5	0.6	0.6	0.5	0.7

Pathway	80-km Population Whole Body Dose (man-rem)					
	1977	1978	1979	1980	1981	1982
Direct Airborne	4	3	2	<1	2	3
Foodstuffs	4	4	1	<1	<1	<1
Drinking Water	<1	<1	<1	<1	<1	<1
River Recreation	*[d]	<1	<1	<1	<1	<1
Total	7	7	4	2	3	4

(a) Includes inhalation, submersion, and direct exposure to ground deposition.
(b) Includes consumption of all foodstuffs contaminated via irrigation water and dry deposition.
(c) Includes consumption of fish taken from the Columbia River.
(d) Dose was calculated to be less than 0.1 man-rem; while not reported in table, dose is included in dose total.

TABLE B.2. Exposure Pathway Contributions to Calculated 50-Year Cumulative Bone Doses Due to Hanford Operations, 1977 through 1982

Pathway	Maximum Individual Bone Dose (mrem)					
	1977	1978	1979	1980	1981	1982
Direct Airborne[a]	0.02	0.02	0.5	<0.01	0.01	0.01
Foodstuffs[b]	3	2	2	2	2	2
Drinking Water	0.02	0.01	-	0.01	0.01	0.01
River Recreation[c]	0.1	0.06	0.1	0.1	0.09	0.1
Total	3	2	3	2	2	2

Pathway	80-km Population Bone Dose (man-rem)					
	1977	1978	1979	1980	1981	1982
Direct Airborne	6	5	4	<1	2	4
Foodstuffs	13	14	5	3	2	3
Drinking Water	<1	<1	<1	<1	<1	<1
River Recreation	*[d]	<1	<1	<1	<1	<1
Total	20	20	10	5	5	7

(a) Includes inhalation, submersion, and direct exposure to ground deposition.
(b) Includes consumption of all foodstuffs contaminated via irrigation water and dry deposition.
(c) Includes consumption of fish taken from the Columbia River.
(d) Dose was calculated to be less than 0.1 man-rem; while not reported in table, dose is included in dose total.

TABLE B.3. Exposure Pathway Contributions to Calculated 50-Year Cumulative Lung Doses Due to Hanford Operations, 1977 through 1982

Pathway	Maximum Individual Lung Dose (mrem) 1977	1978	1979	1980	1981	1982
Direct Airborne[a]	0.02	0.02	0.5	<0.01	0.01	0.02
Foodstuffs[b]	<0.01	<0.01	0.01	<0.01	<0.01	<0.01
Drinking Water	<0.01	<0.01	-	<0.01	<0.01	<0.01
River Recreation[c]	<0.01	<0.01	0.01	<0.01	<0.01	<0.01
Total	0.03	0.02	0.5	<0.01	0.01	0.02

Pathway	80-km Population Lung Dose (man-rem) 1977	1978	1979	1980	1981	1982
Direct Airborne	6	4	4	1	3	4
Foodstuffs	*[d]	*	<1	*	<1	<1
Drinking Water	*	*	*	*	*	*
River Recreation	*	<1	<1	<1	*	*
Total	6	5	5	1	3	4

(a) Includes inhalation, submersion, and direct exposure to ground deposition.
(b) Includes consumption of all foodstuffs contaminated via irrigation water and dry deposition.
(c) Includes consumption of fish taken from the Columbia River.
(d) Dose was calculated to be less than 0.1 man-rem; while not reported in table, dose is included in dose total.

TABLE B.4. Exposure Pathway Contributions to Calculated 50-Year Cumulative Thyroid Doses Due to Hanford Operations, 1977 through 1982

Pathway	Maximum Individual Thyroid Dose (mrem) 1977	1978	1979	1980	1981	1982
Direct Airborne[a]	0.01	0.01	0.01	<0.01	0.01	0.01
Foodstuffs[b]	0.3	0.9	0.3	0.1	0.09	0.1
Drinking Water	0.06	0.05	-	0.02	0.02	0.02
River Recreation[c]	0.07	0.05	0.07	0.03	0.02	0.02
Total	0.4	1	0.4	0.2	0.2	0.2

Pathway	80-km Population Thyroid Dose (man-rem) 1977	1978	1979	1980	1981	1982
Direct Airborne	4	3	3	<1	2	3
Foodstuffs	7	8	8	3	1	3
Drinking Water	2	2	2	<1	<1	<1
River Recreation	*[d]	<1	<1	<1	<1	<1
Total	13	12	12	4	5	7

(a) Includes inhalation, submersion, and direct exposure to ground deposition.
(b) Includes consumption of all foodstuffs contaminated via irrigation water and dry deposition.
(c) Includes consumption of fish taken from the Columbia River.
(d) Dose was calculated to be less than 0.1 man-rem; while not reported in table, dose is included in dose total.

TABLE B.5. Exposure Pathway Contributions to Calculated 50-Year Cumulative GI[(a)] Doses Due to Hanford Operations, 1977 through 1982

Pathway	Maximum Individual GI Dose (mrem) 1977	1978	1979	1980	1981	1982
Direct Airborne[(b)]	0.01	0.01	0.01	<0.01	0.01	0.01
Foodstuffs[(c)]	0.08	0.04	0.06	0.06	0.04	0.06
Drinking Water	<0.01	<0.01	-	<0.01	<0.01	<0.01
River Recreation[(d)]	0.07	0.05	0.07	0.04	0.01	0.01
Total	0.2	0.1	0.1	0.1	0.06	0.07

Pathway	80-km Population GI Dose (man-rem) 1977	1978	1979	1980	1981	1982
Direct Airborne	4	3	2	<1	2	3
Foodstuffs	<1	<1	<1	<1	<1	<1
Drinking Water	*[(e)]	<1	<1	<1	<1	<1
River Recreation	*	<1	<1	<1	*	*
Total	4	3	3	<1	3	3

(a) Gastrointestinal tract (lower large intestine).
(b) Includes inhalation, submersion, and direct exposure to ground deposition.
(c) Includes consumption of all foodstuffs contaminated via irrigation water and dry deposition.
(d) Includes consumption of fish taken from the Columbia River.
(e) Dose was calculated to be less than 0.1 man-rem; while not reported in table, dose is included in dose total.

TABLE B.6. Operating Area Contributions to Calculated 50-Year Cumulative Whole Body Doses Due to Hanford Operations, 1977 through 1982

Operating Area	Maximum Individual Whole Body Dose (mrem)					
	1977	1978	1979	1980	1981	1982
100	0.7	0.4	0.6	0.6	0.5	0.7
200	0.05	0.06	0.01	0.01	<0.01	<0.01
300	0.02	<0.01	0.03	<0.01	<0.01	<0.01
400	NA[(a)]	NA	NA	NA	<0.01	<0.01
Total	0.8	0.5	0.6	0.6	0.5	0.7

Operating Area	80-km Population Whole Body Dose (man-rem)					
	1977	1978	1979	1980	1981	1982
100	4	3	3	1	2	4
200	3	4	<1	<1	<1	<1
300	<1	<1	<1	*[(b)]	*	*
400	NA	NA	NA	NA	<1	<1
Total	7	7	4	2	3	4

(a) Not analyzed.
(b) Dose was calculated to be less than 0.1 man-rem; while not reported in table, dose is included in dose total.

TABLE B.7. Operating Area Contributions to Calculated 50-Year Cumulative Bone Doses Due to Hanford Operations, 1977 through 1982

Operating Area	Maximum Individual Bone Dose (mrem)					
	1977	1978	1979	1980	1981	1982
100	3	1	2	2	2	2
200	0.2	0.2	0.05	0.02	<0.01	<0.01
300	0.04	0.01	0.5	0.01	<0.01	<0.01
400	NA[(a)]	NA	NA	NA	<0.01	<0.01
Total	3	2	3	2	2	2

Operating Area	80-km Population Bone Dose (man-rem)					
	1977	1978	1979	1980	1981	1982
100	7	4	5	3	4	6
200	13	15	3	2	<1	<1
300	<1	<1	2	<1	<1	<1
400	NA	NA	NA	NA	<1	<1
Total	20	20	10	5	5	7

(a) Not analyzed.

TABLE B.8. Operating Area Contributions to Calculated 50-Year Cumulative Lung Doses Due to Hanford Operations, 1977 through 1982

Operating Area	Maximum Individual Lung Dose (mrem)					
	1977	1978	1979	1980	1981	1982
100	0.02	0.01	0.02	0.01	0.01	0.01
200	0.01	0.01	<0.01	<0.01	<0.01	<0.01
300	<0.01	<0.01	0.5	<0.01	<0.01	<0.01
400	NA[a]	NA	NA	NA	<0.01	<0.01
Total	0.03	0.02	0.5	<0.01	0.01	0.02

Operating Area	80-km Population Lung Dose (man-rem)					
	1977	1978	1979	1980	1981	1982
100	5	3	3	<1	2	3
200	1	1	<1	<1	<1	<1
300	<1	<1	1	<1	<1	<1
400	NA	NA	NA	NA	<1	<1
Total	6	5	5	1	3	4

(a) Not analyzed.

TABLE B.9. Operating Area Contributions to Calculated 50-Year Cumulative Thyroid Doses Due to Hanford Operations, 1977 through 1982

Operating Area	Maximum Individual Thyroid Dose (mrem)					
	1977	1978	1979	1980	1981	1982
100	0.4	0.3	0.4	0.2	0.1	0.1
200	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
300	0.02	0.7	0.02	0.03	0.01	0.02
400	NA[a]	NA	NA	NA	<0.01	<0.01
Total	0.4	1	0.4	0.2	0.2	0.2

Operating Area	80-km Population Thyroid Dose (man-rem)					
	1977	1978	1979	1980	1981	1982
100	13	11	12	4	4	7
200	*[b]	*	*	*	*	<1
300	<1	1	<1	<1	<1	<1
400	NA	NA	NA	NA	<1	<1
Total	13	12	12	4	5	7

(a) Not analyzed.
(b) Dose was calculated to be less than 0.1 man-rem; while not reported in table, dose is included in dose total.

TABLE B.10. Operating Area Contributions to Calculated 50-Year Cumulative GI[a] Doses Due to Hanford Operations, 1977 through 1982

Operating Area	Maximum Individual GI Dose (mrem)					
	1977	1978	1979	1980	1981	1982
100	0.2	0.1	0.1	0.1	0.06	0.07
200	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
300	0.01	<0.01	0.01	<0.01	<0.01	<0.01
400	NA[b]	NA	NA	NA	<0.01	<0.01
Total	0.2	0.1	0.1	0.1	0.06	0.07

Operating Area	80-km Population GI Dose (man-rem)					
	1977	1978	1979	1980	1981	1982
100	4	3	2	<1	2	3
200	<1	<1	<1	<1	*	<1
300	*[c]	*	<1	*	*	*
400	NA	NA	NA	NA	<1	<1
Total	4	3	3	<1	3	3

(a) GI = Gastrointestinal Tract (lower large intestine).
(b) Not analyzed.
(c) Dose was calculated to be less than 0.1 man-rem; while not reported in table, dose is included in dose total.

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