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DETERMINATION OF KEY RADIONUCLIDES AND
PARAMETERS RELATED TO DOSE FROM THE
COLUMBIA RIVER PATHWAY

Hanford Environmental Dose
Reconstruction Project

- Calculation 009

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March 1993

Prepared for the
Technical Steering Panel and the
Centers for Disease Control and Prevention
Under Contract 200-92-0503 (CDC)/18620 (BNW)

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PREFACE

The Hanford Environmental Dose Reconstruction (HEDR) Project was prompted by mounting concern about possible detrimental health effects to the public from more than 40 years of nuclear operations at the Hanford Site. The primary objective of the HEDR Project is to estimate the radiation dose (with descriptions of the uncertainties inherent in such estimates) that individuals could have received as a result of emissions since 1944 from the U.S. Department of Energy's (DOE) Hanford Site near Richland, Washington. An independent Technical Steering Panel (TSP) directs the work on the project, which is conducted by Battelle Pacific Northwest Laboratories (BNW) under contract with the Centers for Disease Control and Prevention (CDC).

The HEDR Project work is conducted under several technical and administrative tasks, among which is the Technical Integration Task. Members of the Technical Integration Task provide technical overview of the project to ensure that appropriate technical activities are planned, that appropriate information is generated, and that technical task work is integrated effectively for performing the final dose calculations.

This report documents one of a series of scoping calculations performed as part of the HEDR Project. These scoping calculations are intended to provide provisional information to the HEDR TSP to allow timely direction of efforts.

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1.0 INTRODUCTION

A series of scoping calculations has been undertaken to evaluate the absolute and relative contributions of different radionuclides and exposure pathways to doses that may have been received by individuals living in the vicinity of the Hanford Site. These scoping calculations may include some radionuclides and pathways that were included in the Phase I Columbia River pathway dose evaluations, as well as other potential exposure pathways being evaluated for possible inclusion in future Hanford Environmental Dose Reconstruction Project (HEDR) modeling efforts.

1.1 PURPOSE AND SCOPE

This scoping calculation (Calculation 009) examines the contributions of numerous radionuclides to dose via environmental exposures and accumulation in water, fish, and other aquatic biota. This study builds on the work initiated by Napier and Brothers (1992a, 1992b) and continued by Walters, Dirkes, and Napier (1992). Addressed in these calculations are the contributions to effective dose from 1) external exposure to contaminated river water, 2) ingestion of contaminated drinking water, and 3) ingestion of contaminated resident Columbia River fish. Additional information on contamination of anadromous fish and waterfowl is provided.

Recommendations determined from scoping calculations are provided to the HEDR Technical Steering Panel (TSP) with the intent of providing a definitive technical basis to assist in deciding whether specific radionuclides and exposure pathways should or should not be included in the tools used for the HEDR dose estimation process for individuals. Recommendations are provided also on level of effort required for river transport modeling, including spatial and temporal resolution, and propagation of uncertainties through the calculation.

1.2 REPORT FORMAT

This report is organized to provide information in the same logical order as that encountered in performing a dose-related calculation. Thus, the

initial sections are on source term (amount of material released to the Columbia River), environmental transport and dispersion (estimation of radionuclide concentrations in river water at various downstream locations), and environmental accumulation (estimation of radionuclide concentrations in fish and drinking water). This is followed by sections on dose calculation methods, doses in the nearest metropolitan area (the Tri-Cities), the uncertainties in those doses, and additional dose estimates for areas further downriver. Special sections are provided for doses resulting from consumption of anadromous fish (salmon and steelhead) and waterfowl (ducks). The report concludes with some observations made on the data currently in hand, and makes some recommendations for optimal ways to proceed with the overall HEDR Project calculations. Several appendices are included. The first provides a data listing of the source terms used. The second provides a summarized listing of the doses reported in the Hanford Site annual reports from 1958 through 1972. The last documents the spreadsheet calculations performed to support the discussions within the body of the report.

1.3 DATA QUALITY OBJECTIVES

Five Data Quality Objectives (DQOs) are established for this task. They encompass accuracy, precision, completeness, representativeness, and comparability.

The DQO for accuracy is to incorporate physical phenomena as accurately as does any other nationally known code for similar use. This was met by using algorithms derived from existing codes where possible, and creating a few new algorithms where none yet are used in the current generation of dosimetry models. These have been reviewed by experts in the field.

The objective of the DQO for precision is to make uncertainties of code and input information integral parts of the calculation. This was achieved by using a Monte Carlo implementation of the spreadsheet to evaluate critical components of the model. The results are discussed in Section 7 of the text and presented in Appendix C.

The DQO for completeness is to provide estimates for all currently identified pathways within the HEDR Project domain. This DQO was addressed in

the recommendations made by Napier and Brothers (1992a, Section 6). The pathways and domain recommended in Napier and Brothers are addressed in additional detail in this report.

The DQO for representativeness states that the codes should represent all known pathway phenomena, lifestyles, food habits, agricultural practices, and physical phenomena. The purpose of this report is to address these topics and propose the level of detail to which they should be included in the river pathway codes.

The DQO for comparability states that models developed by the project should compare to within factors of two to three of internationally accepted models. The purpose of this report is to lay out the points for which comparability will be measured.

2.0 SOURCE TERM INFORMATION

Over the summer of 1992, Dr. Maurice Robkin of the HEDR Technical Steering Panel compiled available information on radionuclide releases to the Columbia River from each of the eight Hanford plutonium production reactors. Dr. Robkin supplied this information in the form of eight separate EXCEL[®] (Microsoft 1992) spreadsheets. These spreadsheets also included a good deal of additional material that was not required for the study reported here, so the spreadsheets were simplified and combined. Some short-lived radionuclides were intentionally omitted in this simplification. The complete monthly source terms for each reactor are provided in Appendix A.

The spreadsheets prepared by Dr. Robkin had entries for as many as 35 radionuclides, not all of which were available for all reactors or for all time periods. Several radionuclides, with either very short half lives, very small inventories, or large blocks of unavailable data, were omitted from the calculations made for this report. A few others were omitted because they were too generally described (e.g., IRON, R.E.+Y, IODINE), and usually the component parts were listed individually. The radionuclides included and excluded are listed in Table 2.1. The excluded radionuclides were first evaluated on the basis of amount and dose factor. Their omission should not affect the findings of this report because their contribution to dose will be overwhelmed by the contributions of the included radionuclides.

For use in scoping calculations, the releases from each reactor were simply summed. This resulted in a composite table of monthly estimates of the releases of 19 radionuclides by month for the entire period from reactor startup through final shutdown. Estimates are not available for all radionuclides for all times. For this study, no attempt was made to adjust for missing data. In addition, there is some inconsistency in the data regarding inclusion or omission of holdup times in retention basins prior to discharge to the Columbia River. For this scoping study, all values are assumed to be reported as discharge to the river, not to the holding basins. For certain radionuclides in certain years, this will result in an overestimate of the releases. As will be demonstrated, this inconsistency has minimal impact on the reported doses.

Historical release estimates improved with the passage of time and the development of better monitoring techniques. The releases were best defined in the later years of reactor operation. For this scoping study, only the period from 1959 through 1971 was evaluated in detail.

Any estimate of doses requires an estimate of source term. The calculations herein would not have been possible without the efforts of Dr. Robkin to compile the data.

TABLE 2.1. Radionuclides (and Other Identifiers) from Dr. Robkin's Spreadsheets Included in or Omitted from Calculations

<u>Included</u>		<u>Excluded</u>	
Na-24	Zn-69	Beta	Ba-140
P-32	Zn-69m	Si-31	La-140
Ca-45	Ga-72	Mo-99	Eu-152m
Sc-46	Sr-89	R.E.+Y	Eu-152
Mn-56	Sr-90	IRON	Sm-153
Cu-54	Y-90	Sr-91	
As-76	Y-93	STRONTIUM	
Cr-51	Zr-95/Nb-95	I-133	
Co-60	I-131	IODINE	
Zn-65	Np-239	Ba-139	

3.0 DERIVATION OF DOWNRIVER CONCENTRATIONS OF RADIONUCLIDES IN WATER

A simple model accounting for dilution and decay of radionuclides as they are carried downstream by the river was developed for the analyses in this report. Dilution is based on the flow rates of the Columbia River at various locations, and the travel times were estimated from available data.

3.1 DILUTION

The spreadsheets provided by Dr. Robkin for source terms also contained a column of monthly flow rates of the Columbia River at the Hanford Site. This information formed the basis of the dilution portion of the transport calculation. For locations above the influx of the Snake River (e.g., the Tri-Cities), this was taken as the monthly dilution volume. Radionuclides were assumed to be uniformly distributed within this flow.

For areas further downriver, additional corrections were made on the basis of the annual average flow rates of Columbia River tributaries. Walters et al. (1992, Chapter 3.0) provides the mean annual discharge rates of the major tributaries of each stretch of the river. The annual average flow of the Columbia in the vicinity of Hanford is 121,512 cubic feet per second (cfs). By McNary Dam, this is increased by input from the Yakima, Snake, and Walla Walla Rivers to about 180,000 cfs. The John Day, Deschutes, and Klickitat Rivers increase the average flow to 189,000 cfs by Bonneville Dam. Below Bonneville, the Willamette, Lewis, and Cowlitz Rivers increase the flow to almost 240,000 cfs. These values were used in the spreadsheet to account for dilution in these stretches of the river. This was done using the ratio of flow rates as a simple multiplier for each location; the ratios were not varied by month.

3.2 TRAVEL TIME AND RADIOLOGICAL DECAY

Information on downriver flow times from the reactors to points as far as Astoria, Oregon, are presented in Walters et al. (1992, page 8.11). This information is a summary of two tracer studies made using decay of sodium-24 and the advance of a peak concentration of iodine-131 (Nelson, Perkins, and Haushild 1966). A portion of that information is shown in Figure 3.1.

FIGURE 3.1. Travel Time from 100-D Reactor to Selected Downstream Locations

The information in Figure 3.1 was evaluated to determine if it could be used to generate generalized flow-time curves for use at intermediate discharges. The curves were roughly exponential, so a simple fit was made to the data for each location of interest. The following equations were generated for travel time as a function of river discharge at Hanford in cubic feet per second (CFS):

$$\text{Pasco (days)} = e^{(-2.3E-6 \text{ CFS} + 0.0688)} \quad (\text{Eqn. 1})$$

$$\text{Umatilla (days)} = e^{(-4.0E-6 \text{ CFS} + 1.8667)} \quad (\text{Eqn. 2})$$

$$\text{The Dalles (days)} = e^{(-3.9E-6 \text{ CFS} + 2.3374)} \quad (\text{Eqn. 3})$$

$$\text{Vancouver (days)} = e^{(-3.9E-6 \text{ CFS} + 2.7679)} \quad (\text{Eqn. 4})$$

These equations all have similar form, and it can be seen that the slopes of the lines are essentially the same, but the intercept changes with location.

These details provide some assurance that the simple model developed here should provide reasonable accuracy for determining travel time to the locations of interest within the limits of accuracy required for this scoping calculation.

3.3 FACTORS NOT CONSIDERED

The simple surface-water transport model described here does not account for a number of known effects. The simple model makes no correction for the changing dimensions of the plume of contamination within the river as it moves downstream from the sources. This is not thought to be a significant source of potential error for locations downstream of the Tri-Cities, but for the stretch of the Columbia River immediately below the reactor outfalls, plume spreading and mixing does influence the radionuclide distribution in the river. The simple model also makes no correction for losses of radionuclides through processes other than radiological decay. Although a few radionuclides behave as totally dissolved materials, most others are affected to some degree by removal in sediments and biota.

In general, the assumptions made in the simple model should tend to overstate the concentration of radionuclides in the river water. Neglect of removal processes will overstate the immediate concentrations, but may tend to miss instances of sediment resuspension and transport during high-flow events. However, because of decay, and the added dilution available in high-flow events, the overall integrated concentration will be overestimated. Not considering plume effects should have minimal impact on estimation of radionuclide concentrations in fish, since fish are free to swim into and out of the plumes, and, on average, should act as integrators across the entire concentration range. There will be some regular bias of estimates of radionuclide concentration in drinking water. By the time the plumes reach the Richland city water intake, this bias will be less than a factor of two.

3.4 COMPARISONS TO MONITORED DATA

Monitoring data are available for some locations and time periods. Table 3.1 presents a selection of these data, taken from Walters et al. (1992, Sections 7 and 10). Graphical representations of these data are provided for

TABLE 3.1. Concentrations of Selected Radionuclides as a Function of Downriver Distance

<u>Radionuclide</u>	<u>Richland</u>	<u>Pasco</u>	<u>McNary</u>	<u>Bonneville</u>	<u>Vancouver</u>	<u>Astoria</u>
River Mile	340	330	292	145	105	10
Miles from Priest Rapids	58	68	106	253	293	388
P-32						
1964	300	200	70	28	50	na
1965	140	87 ^(a)	48	23	na	18
1966	140	na	76	23	na	11
Miles from Priest Rapids	58	68	106	253	293	388
Zn-65						
1964	450	240	77	63	55.8	<35
1965	180	160	68	70	na	<35
1966	200	na	61	43	na	<35
Miles from Priest Rapids	58	68	106	253	293	388
Cr-51						
1964	12,000	6,800	3,478	2,400	3,317	1,500
1965	7,000	4,100	2,264	1,700	na	930
1966	3,600		1,849	1,300	na	1,600
Miles from Priest Rapids	58	68	106	253	293	388
I-131						
1964	19	12	6.7	5	4.2	na
1965	10	7	3.9	3	na	na
1966	18	na	7.1	3	na	na

(a) na = not available

phosphorous-32, zinc-65, chromium-51, and iodine-131 in Figures 3.2 through 3.5, respectively. These figures show that, for all radionuclides considered, the concentrations decrease rapidly from Richland through the McNary Dam area, and then change only slowly further downstream. This results from several factors. The plumes are not always fully dispersed in the Richland area, but are more so when near Pasco. The influx of the large tributary flow of the Snake River between Pasco and McNary acts to dilute the flow. Tributaries below the Snake are generally much smaller, and have a lesser impact. These figures track with the predictions made with the simple model described above.

The slow rate of change below McNary Dam suggests that adequate coverage of the river concentrations throughout these stretches can be achieved by focusing on relatively fewer locations.

FIGURE 3.2. P-32 Concentration vs. Downriver Distance

FIGURE 3.3. Zn-65 Concentration vs. Downriver Distance

FIGURE 3.4. Cr-51 Concentration vs. Downriver Distance

FIGURE 3.5. I-131 Concentration vs. Downriver Distance

4.0 DERIVATION OF RADIONUCLIDE CONCENTRATIONS IN RESIDENT FISH

Although it is often an oversimplification, the concentration of radionuclides in fish can be related to the concentrations of those radionuclides in water by means of a bioaccumulation factor (pCi/kg of fish flesh per pCi/L of water). For this scoping study, annual average bioaccumulation factors were used. These were based on HEDR Phase I inputs and newer information.

4.1 HEDR PHASE I INPUTS

Calculations of concentrations of radionuclides in resident fish for HEDR Phase I dose estimates were made on several bases. The data for the 1964-1966 time period were sufficiently complete to allow direct use of the concentration distributions as input to the model for zinc-65 (Zn-65) and phosphorus-32 (P-32). Fish species were consolidated into three classes: bottom-feeding omnivores, first-order predators (eaters of aquatic insects, invertebrates, etc.), and second-order predators (eaters of small fish, larger aquatic invertebrates, etc.). These were grouped as follows:

<u>Omnivores</u>	<u>1st Predators</u>	<u>2nd Predators</u>
Whitefish	Bluegill	Trout
Bullhead	Perch	Bass
Catfish	Crappie	
Sturgeon		
Carp		
Sucker		

There were sufficient data from the Columbia River from the year 1961 to allow derivation of seasonally dependent concentration ratios for arsenic-76 (As-76) and neptunium-239 (Np-239). There was not a notable difference among species, so these were assigned to each class, with normal distributions, as follows:

<u>Season</u>	<u>Np-239</u>	<u>As-76</u>
Jan/Feb/Mar	40 ± 25	200 ± 150
Apr/May	30 ± 20	80 ± 50
Jun/Jul/Aug	13 ± 5	100 ± 60
Sep/Oct	20 ± 10	160 ± 70
Nov/Dec	40 ± 25	400 ± 250

Finally, for the short-lived radionuclides copper-64 (Cu-64), manganese-56 (Mn-56), sodium-24 (Na-24), and the biologically inactive chromium-51 (Cr-51), only minor accumulations were seen in fish. These were dealt with through time- and species-invariant concentration ratios, as follows:

Cu-64	10
Mn-56	70
Na-24	1
Cr-51	5

4.2 BIOACCUMULATION USED IN WALTERS ET AL. (1992)

The bioaccumulation factors used in Walters et al. (1992, page 10.7) are shown in Table 4.1. These can be seen to follow the HEDR Phase I values for most radionuclides. The P-32 and Zn-65 values in Walters et al. were selected to approximate the results seen in HEDR Phase I using measured distributions.

TABLE 4.1. Freshwater Fish Bioaccumulation Factors Used in Walters et al. (1992, Chapter 10)

<u>Element</u>	<u>Bioaccumulation Factor (L/kg)</u>
Arsenic	200
Chromium	5
Cobalt	330
Copper	10
Iodine	15
Manganese	70
Neptunium	25
Phosphorus	170
Ruthenium	10
Scandium	2
Sodium	1
Strontium	30
Zinc	64
Zirconium	330

4.3 VALUES SELECTED FOR THIS ANALYSIS

The source term spreadsheets prepared by Dr. Robkin included numerous radionuclides not considered in either HEDR Phase I (PNL 1990) or the literature review of Walters et al. (1992). In addition, some questions had been raised about the appropriateness of the selected bioaccumulation factors used previously. Therefore, additional bioaccumulation factors were acquired for the radionuclides phosphorous-32 (P-32), calcium-45 (Ca-45), gallium-72 (Ga-72), and isotopes of yttrium (Y-90 and Y-93).

The bioaccumulation factors used were the defaults for the GENII computer code (Napier et al. 1988, Vol.3, p.5.769) for isotopes of calcium, gallium, and yttrium. These values are 200 for calcium-45, 100 for gallium-72, and 25 for yttrium-90 and yttrium-93. Additional efforts were

directed toward refining the bioaccumulation factor for phosphorous-32, which is one of the most important radionuclides from a dosimetric standpoint.

Many thousands of fish have been monitored in the Hanford stretch of the Columbia River. Sufficient data exist to provide a good basis for understanding the bioaccumulation of phosphorous-32 in several species of fish. The Rocky Mountain Whitefish is a game fish that routinely accumulated large body burdens of phosphorous-32 during Hanford operations. Over a large number of observations, the annual average bioaccumulation of phosphorous-32 in such whitefish was approximately 1700. There are locations and time periods where the bioaccumulation can be over an order of magnitude greater than this value, but over a long period this is a good approximation. Using the class groupings of Phase I, on the other hand, monthly average bioaccumulation factors of omnivores (including whitefish) range from about 660 to 8000 over the course of a year; first-order predators' average, monthly bioaccumulation factors range from about 44 to 4700; and second-order predators range from about 50 to 2400 over a year. The Hanford Site annual reports (e.g., Foster and Wilson 1965, pages 38-39) assumed that the "maximum individual" ate preferentially from the predator fish, not whitefish, and used the annual average of those types of fish--with a resulting bioaccumulation of about 170.

For this report, a value of 1700 for phosphorous-32 is generally used. As an annual average, this is more representative of whitefish than of a distribution of species. This will tend to overstate the importance of phosphorous-32 in the doses, but will simultaneously tend to put an upper bound on the potential dose from regular consumption of resident fish. Additionally, some checks were made to assure that potentially overstating the importance of phosphorous-32 would not mask the contributions of other radionuclides. The overall dose results were sufficiently robust, dominated by sufficiently few radionuclides, that the selection of value for the phosphorous-32 bioaccumulation factor does not influence the selection of other key radionuclides.

5.0 DOSE CALCULATION METHODS

Spreadsheet calculations were made for estimating monthly dose to individuals at several locations downriver from Hanford for the period 1959 through 1971. These included doses from external exposure via swimming and boating, ingestion exposure via drinking water, and ingestion exposure via consumption of fish. The equations for each of these types of exposure are defined in this section.

5.1 EXTERNAL DOSES

Doses were calculated for external exposure during swimming and boating. Based on the results of Walters et al. (1992, Chapter 10), no other external pathways were considered. Doses were based on the concentration of radionuclides in water at the location of interest. External doses were calculated as:

$$D_{\text{Ext}} = \sum_{i=1}^n W_i (T_s + 0.5 T_b) DF_{\text{Ext},i} \quad (\text{Eqn. 5})$$

where W_i = the concentration of radionuclide i in water for the current month, Ci/L

T_s = the number of hours spent swimming

T_b = the number of hours spent boating

DF_i = the external dose rate factor for radionuclide i , rem/h per Ci/L. Note that the factor of 0.5 multiplied by the hours spent boating is an implicit assumption that the dose rate in a boat is one-half that of swimming.

The dose rate factors were taken from DOE (1988a). Those used are tabulated in Table 5.1.

TABLE 5.1. External Dose Rate Factors, Internal Dose Factors, and Drinking Water Cleanup Factors used in the Calculations

<u>Radionuclide</u>	<u>External (mrem/yr per $\mu\text{Ci}/\text{m}^3$)</u>	<u>Internal (rem/μCi)</u>	<u>Drinking Water Transmission</u>
Na-24	51.6	1.4E-3	0.9
P-32	0	7.7E-3	0.4
Ca-45	2.09E-10	3.0E-3	1
Sc-46	22.8	5.6E-3	0.3
Mn-56	20.1	9.5E-4	0.5
Cu-64	2.06	4.3E-4	1
As-76	4.79	4.8E-3	0.7
Cr-51	0.347	1.3E-4	1
Co-60	28.2	1.0E-2	0.2
Zn-65	6.56	1.4E-2	0.4
Zn-69	6.52E-5	8.5E-5	0.4
Zn-69m	4.52	1.2E-3	0.4
Ga-72	32.6	4.4E-3	1
Sr-89	1.55E-3	8.7E-3	0.2
Sr-90	0	1.3E-1	0.2
Y-90	0	1.0E-2	0.2
Y-93	1.05	4.5E-3	0.2
Zr-95/Nb-95	16.8	5.6E-3	0.7
Np-239	1.89	2.9E-3	0.7
I-131	4.17	5.2E-2	0.8

5.2 INGESTION DOSES

Ingestion doses were estimated for consumption of drinking water and for consumption of resident fish. The drinking water dose, D_{dw} , was estimated as

$$D_{dw} = \sum_{i=1}^n W_i F_i U_w DF_{ing,i} e^{-\lambda_i 0.5} \quad (\text{Eqn. 6})$$

where U_w = the water consumption rate, liters/month

F_i = the water treatment transmission fraction, presented for each radionuclide i in Table 5.1, dimensionless

$DF_{ing,i}$ = the ingestion dose factor, rem/Ci, presented in Table 5.1

λ_i = decay constant for radionuclide i , day^{-1}

0.5 = assumed half-day holdup in water treatment and distribution system and other terms are as previously defined. The ingestion dose factors used in most calculations are for effective dose equivalent, taken from DOE (1988b) or EPA (1988).

Doses from ingestion of resident fish, D_{fish} , were estimated using a similar equation:

$$D_{fish} = \sum_{i=1}^n W_i B_i U_f DF_{ing,i} e^{-\lambda_i 1} \quad (\text{Eqn. 7})$$

where B_i = the bioaccumulation factor for radionuclide i , L/kg

U_f = the consumption rate of fish, kg/m

1 = assumed one-day average delay from catch to consumption

and other terms are as previously defined. The one-day holdup assumed for fish acts as a sort of buffer on the influence of the short-lived radionuclides on dose from fish. No holdup corrections were used in HEDR Phase I (PNL 1990) or Walters et al. (1992).

5.3 INDIVIDUAL EXPOSURE PARAMETERS

Doses are estimated for two categories of individual. The first represents a "typical" or "average" member of the local population. This type of individual will approximate most of the people in the area who have any contact with the contamination of the Columbia River. This type of individual has only casual contact with the river itself; his predominant exposures result from consumption of treated municipal drinking water. The second is more of a "maximum individual" or "average member of the critical group." This second category of individual includes those who have more direct contact with the river water and eat fish from the river on a regular basis. The great majority of the population has essentially no direct contact with the Columbia River or its fish on a routine basis. There is no commercial fishery downstream of Hanford along the river before the Pacific Ocean. Only people who fish for recreation or for subsistence consumption will fit into the second category.

The pathways considered here are a subset of those in Walters et al. (1992, Section 10). The parameters have been chosen to be compatible with that source. These are also compatible with most recent Hanford Site annual reports, and with the HEDR Phase I Columbia River Pathway Report (PNL 1990, Section 3). The exposure parameters are summarized in Table 5.2.

The value of 40 kg/yr for consumption of resident fish by the "maximum" group is based on the results of surveys performed in the Tri-Cities area in the 1960s. It is not the maximum conceivable consumption rate, but it is considered to be at the upper end of the range for recreational consumers. Forty kg/yr represents approximately 200 meals of 200 grams (nearly half a pound) each. It is very close to the 95th percentile value for all fish consumers reported in the 1977 USDA Food Consumption Survey (Pao et al. 1982, page 264), which is recommended as the default fish ingestion rate for subsistence fishermen by the EPA Office of Emergency and Remedial Response (EPA 1991, page 8). This value was used in an attempt to consider the TSP's desire to use reasonable, not extreme, data for the purposes of making decisions (Shleien 1992). The value of 2 kg/year for consumption of resident fish by the "typical" group was selected to provide a non-zero, reasonable

lower bound. The actual "average" consumption of Columbia River fish in residents of the Columbia Basin is much lower than this value.

Drinking water has an assumed holdup period in the drinking water distribution system of 12 hr. Fish are assumed to be eaten within 1 day of catch. These minimal holdup times will tend to overemphasize the short-lived radionuclides for those instances where the food is stored before consumption.

TABLE 5.2. Exposure Pathway Parameters Assumed

<u>Pathway</u>	<u>"Maximum Individual"</u>	<u>"Average" Individual</u>
Boating	500 hr/yr	5 hr/yr
Swimming	100 hr/yr	10 hr/yr
Drinking	730 L/yr	440 L/yr
Fish Consumption	40 kg/yr	2 kg/yr

6.0 DOSES IN THE TRI-CITIES

The methods and input described in the previous sections were used to estimate monthly radiation doses to people living along the Columbia River during the period from 1959 through 1971. These doses were used to scope the potential peak year dose rate and potential for cumulative dose, the probable radionuclides of concern, and the pathways and parameters of interest. Some selected comparisons were made to estimates from other sources in an attempt to benchmark and validate these estimates.

6.1 11-YEAR CUMULATIVE DOSE

The total monthly doses estimated for a maximally exposed Tri-Cities resident is shown in Figure 6.1. The spreadsheet from which this figure is derived is presented in its entirety in Appendix C. The annual cycle of river dilution is readily apparent in this figure (high flows in the spring and early summer, low flows in the fall and winter). The decreasing source term from the late 1950s through the final shutdown of the last reactor in 1971 is also obvious.

A number of simplifying assumptions were made to produce this figure. First, all exposures are assumed to be the same across the months. That is, the individual is assumed to eat the same amount of fish each month, and to swim and boat equal amounts each month. Because it is unlikely that anyone would actually have such a lifestyle, in order to apportion the activities more realistically, more exposure should occur in the summer months and less in the winter. This would tend to even out the month-to-month variability in the result presented, by reducing exposures in the colder, low-dilution months and increasing it in the warmer, high-dilution months.

If the TSP dose decision level of 100 mrem/yr were divided into 12 equivalent monthly increments, an "effective monthly level" of about 8 mrem would result. Inspection of Figure 6.1 reveals that only a few months around the years 1960-1961 are estimated to exceed that level. The dose rates of this figure were used to select the year 1961 as a year representing the period of greatest potential impact: it appears to be higher than the years

FIGURE 6.1. Tri-Cities Maximum Individual Total Monthly Doses, 1959-1971

1964-1966, used in HEDR Phase I calculations, by as much as a factor of 2. It should be noted, however, that the calculations for this figure were performed for the Richland location, but that the Richland Columbia River water treatment plant did not become operational until late in 1963. Thus the doses shown here are over-reported in that sense.

This spreadsheet shows that the pathway of greatest importance to dose over this period is consumption of fish (see detail in Appendix C). Dose from either external exposure or drinking water over the entire 11 years illustrated does not sum to the TSP's annual dose decision level. The radionuclides dominating the dose are sodium-24 (from drinking water), phosphorous-32 (from fish), arsenic-76 (from drinking water and fish), zinc-65 (from fish), and neptunium-239 (from drinking water and fish). Increased

holdup times for the fish between catch and consumption would tend to lower the importance of phosphorus-32, arsenic-76, and neptunium-239.

6.2 PEAK YEAR DOSE RATES

A more detailed look at the dose results for the indicated peak year, 1961, is provided in Table 6.1. This table reproduces the summaries of the 1961 Tri-City spreadsheets for maximum and average individuals provided in Appendix C. The dose to the maximum individual can be seen to be dominated by the fish-ingestion pathway, which provides over 85% of the annual dose. The dominant radionuclides for the maximum individual are phosphorus-32, arsenic-76, and zinc-65. The dose to the average individual is evenly split between drinking water and fish. (Recall that the average individual is assumed to eat 2 kg/yr of fish for this example.) Added to the list of important radionuclides for this type of person are those that contribute mostly through the drinking water, sodium-24 and neptunium-239.

6.3 COMPARISONS TO HISTORICAL DOSE ESTIMATES

The Hanford Site annual report for the year 1964 (Foster and Wilson 1965, pp. 38-45) provides one of the best early descriptions of the radionuclides and pathways considered contemporaneously to be important. A set of calculations was made with the spreadsheet developed for this report for that year. A special calculation was made, replacing the current dose factors with dose factors similar to those used in 1964 for the gastrointestinal (GI) tract/lower large intestine. This special case was used to compare with the 1964 estimate of GI-tract dose to the typical individual in Richland from drinking municipal water. This was the first full year of operation of the "new" Richland city water plant on the Columbia River and, thus, the first time period for which such a comparison can be made.

Foster and Wilson provide the relative and absolute contributions to GI tract dose by radionuclide from drinking city water (Foster and Wilson 1965, p. 16). This is based entirely on measurements taken of Richland water after

TABLE 6.1. Radionuclides and Pathways Contributing to Maximum and Average Individual Dose (rem)

Average	Na-24	P-32	Ca-45	Sc-46	Mn-56	Cu-64	As-76	Cr-51	Zn-65	Zn-69	Zn-69m	Ga-72	Sr-89	Sr-90	Y-90	Y-93	Mp-239	I-131	Total
External	3.96E-04	0.00E+00	1.64E-18	1.29E-06	1.84E-05	8.75E-06	9.08E-06	4.67E-06	5.46E-06	2.36E-16	1.55E-06	4.51E-05	6.51E-12	0.00E+00	0.00E+00	9.48E-07	5.74E-06	4.96E-08	4.97E-04
Drinking	1.71E-03	3.26E-04	7.25E-06	2.93E-05	5.27E-06	2.93E-04	1.43E-03	5.33E-04	1.44E-03	4.79E-15	2.77E-05	1.04E-03	2.24E-06	2.69E-06	5.07E-04	1.10E-04	1.64E-03	1.49E-04	9.11E-03
Fish	6.14E-06	6.19E-03	6.62E-06	8.90E-07	1.32E-07	6.96E-06	1.37E-03	1.20E-05	1.05E-03	4.43E-19	1.11E-05	2.64E-04	1.53E-06	1.84E-06	2.55E-04	2.77E-05	2.32E-04	1.22E-05	9.43E-03
Total	2.12E-03	6.51E-03	1.39E-05	3.15E-05	2.38E-05	3.09E-04	2.81E-03	5.50E-04	2.49E-03	5.03E-15	4.04E-05	1.35E-03	3.77E-06	4.53E-06	7.61E-04	1.39E-04	1.89E-03	1.61E-04	1.90E-02
%	11%	34%	0%	0%	0%	2%	15%	3%	13%	0%	0%	7%	0%	0%	4%	1%	10%	1%	100%

Maximum	Na-24	P-32	Ca-45	Sc-46	Mn-56	Cu-64	As-76	Cr-51	Zn-65	Zn-69	Zn-69m	Ga-72	Sr-89	Sr-90	Y-90	Y-93	Mp-239	I-131	Total
External	1.11E-02	0.00E+00	4.60E-17	3.63E-17	5.16E-05	2.45E-04	2.54E-04	1.31E-04	1.53E-04	6.61E-15	4.34E-05	1.26E-03	1.82E-10	0.00E+00	0.00E+00	2.66E-05	1.61E-04	1.39E-06	1.39E-02
Drinking	2.84E-03	5.41E-04	1.20E-05	4.86E-05	8.74E-05	4.86E-04	2.38E-03	8.85E-04	2.38E-03	7.96E-15	4.60E-05	1.73E-03	3.72E-06	4.46E-06	8.41E-04	1.83E-04	2.72E-03	2.47E-04	1.51E-02
Fish	1.23E-04	1.24E-01	1.32E-04	1.78E-05	2.65E-06	1.39E-04	2.74E-02	2.41E-04	2.10E-02	8.87E-18	2.22E-04	5.28E-03	3.05E-05	3.69E-05	5.01E-03	5.53E-04	4.63E-03	2.45E-04	1.89E-01
Total	1.41E-02	1.24E-01	1.45E-04	1.03E-04	5.27E-04	8.70E-04	3.00E-02	1.26E-03	2.35E-02	1.46E-14	3.11E-04	8.27E-03	3.43E-05	4.13E-05	5.93E-03	7.62E-04	7.52E-03	4.94E-04	2.18E-01
%	6%	57%	0%	0%	0%	0%	14%	1%	11%	0%	0%	4%	0%	0%	3%	0%	3%	0%	100%

TABLE 6.2. Comparison of Contributions to 1964 GI Tract Dose from Richland City Drinking Water

<u>Total Dose</u>	<u>Foster and Wilson 1965 50 mrem</u>	<u>This Report 40 mrem</u>
As-76	33%	40%
Np-239	28%	22%
Na-24	19%	16%
Cu-64	9.3%	9.2%
Cr-51	6.1%	9.0%
Others	4.3%	3.8%

purification. A comparison is given in Table 6.2 of the 1964 measurements and the current spreadsheet estimate. The close agreement on magnitude and contributing radionuclides provides assurance that the simple models being used here are valid.

6.4 COMPARISON TO IN-VIVO BIOASSAY DATA

The Hanford Site instituted routine use of in-vivo bioassay techniques (whole-body counting) for workers around 1959. Since that time, well over 40,000 separate measurements have been made. Included in the various measurements are gamma photopeak identifications for several radionuclides released to the Columbia River from the once-through reactors. The HEDR staff have performed some initial investigations of these data. Over 20,000 records include data on sodium-24 and zinc-65 between 1959 and 1971. A summary of the range of whole-body counts (25th percentile, median, and 75th percentile) for zinc-65 is shown in Figure 6.2. Over 20,000 measurements are represented in this figure. The full range of observations for any one month is fairly wide. For most months, there is a large number of observations above the detection level, with a few isolated high values. Essentially everyone monitored had some level of Hanford-related contamination present. Because only a fraction of the workforce would have been directly exposed to the sources of zinc-65 and sodium-24 in routine work, it may reasonably be assumed that a large part of the background level of counts is directly related to exposure of members of the workforce to environmental contamination via Columbia River pathways.

FIGURE 6.2. Distribution of Monthly Measurements of Body Burden of Zn-65 in Hanford Worker Population

A formal statistical analysis of the worker bioassay data has not been performed, but a few observations on the available data are possible. First, the data do not form a normal, lognormal, or other common distribution. It is likely that the data are representative of several populations: exposed workers, recreational fishermen, people exposed via drinking water in Richland and Pasco, and people with little exposure (those who lived in areas not served by Columbia River sources, such as Benton City or Yakima). Second, the median values for body burden are around 4 nCi, which correspond to dose rates of about 0.4 mrem/yr. The highest body burden reported is an isolated, single-month value of about 310 nCi, which corresponds to a dose rate of 26 mrem/yr. The second highest is a single 230 nCi. There is a series between 100-300 nCi in 1961-1962, reported in Foster and Honstead (1967). This series represents repeated measurements on a single individual intentionally consuming Columbia River whitefish on a weekly basis. All other values are below 100 nCi. It is apparent that within this large group of

people living in the most highly-contaminated region, the doses were not in excess of the TSP dose decision level, and are actually less than the estimate made in the scoping calculations used in this report. This also serves as assurance that the dose estimates made here are not underestimates.

7.0 UNCERTAINTY ESTIMATES FOR DOSE IN THE TRI-CITIES

The dose estimates discussed in Section 6 are based on a series of equations and parameters, each of which has some variability and uncertainty. The basic case of the 1961 maximum individual was used as the basis for an estimate of the uncertainty caused by the input of uncertain parameters. A stochastic simulation was performed using the commercial sensitivity and uncertainty software package Crystal Ball[®] (Decisioneering 1992). The Crystal Ball[®] software allows Monte Carlo evaluation of relatively complex input spreadsheets, by performing repetitive solutions of the spreadsheet with varying input parameters.

7.1 OVERALL UNCERTAINTY

Fifty-eight parameters were allowed to vary over ranges appropriate for their nature. All the ingestion dose factors were assumed to be lognormally distributed with a geometric standard deviation (GSD) of about 2; these were truncated at the 1st and 99th percentiles. Bioaccumulation factors were generally assumed to have triangular distributions, and to vary between one-half and twice their nominal values. A particular exception was made for the bioaccumulation factor for phosphorous-32, which was given a lognormal distribution with a mean of 1700 and a GSD of 2. Drinking water treatment transmission fractions were given fairly narrow uniform distributions. Individual exposure parameters were set up to simulate the distribution that might be expected in the public at large: skewed heavily toward low exposures, but with the small potential for very large exposure times or consumption rates. The fish-ingestion distribution was given a discrete step-function distribution based on actual survey data for fish eaters in Washington State (Pierce et al. 1981 as reported in EPA 1989, p. 2-38). The parameters describing the dilution and decay of the source term in the Columbia River were also allowed to vary.

The output results investigated were the dose by pathway, the total dose, and the percent contribution to total dose by radionuclide. The results supported the inference made earlier that certain radionuclides could essentially be dropped from the calculation without loss of information.

These include calcium-45, scandium-46, manganese-56, chromium-51, zinc-69, zinc-69 metastable, strontium-89, and strontium-90. In 200 realizations, these radionuclides never contributed more than a few percent to the overall total dose. Of the remaining nuclides, sodium-24, phosphorus-32, arsenic-76, zinc-65, and neptunium-239 had the potential to contribute up to 20% of the total for any single realization at the 95% confidence level. The overall range of potential doses was actually rather narrow, as was seen in the original Columbia River Pathway Report (PNL 1990, Section 3). The 5th to 95th percentile range ran from 11 mrem to 270 mrem, with a median at 35 mrem and a mean of about 67 mrem. This indicates a variation of about a factor of five or less about the mean.

7.2 PARAMETERS CONTRIBUTING TO UNCERTAINTY

The Crystal Ball[®] software has limited capabilities for performing sensitivity analyses. It allows for one or more of the input variables to be set to a nominal value and the entire calculation to be redone. Initial analysis of the output indicated to the authors that it was likely that the overall uncertainty distribution being calculated was dominated by only a few parameters. Two parameters appeared to be controlling the uncertainty distribution: the fish-consumption rate and the phosphorous-32 bioaccumulation factor. Because the fish-consumption rate was input as the population distribution, with a very wide range, it is reasonable that this would appear. The output is essentially linear with respect to this parameter. The effect of the phosphorous-32 bioaccumulation factor also follows logically from the input. The fish concentrations, and the fish dose, are also linear in this parameter.

7.3 PARAMETERS NOT CONTRIBUTING TO UNCERTAINTY

An additional sensitivity run was made with the variables controlling the dilution and decay of radionuclides in the Columbia River set to their nominal values. This had the unexpected effect of lowering the mean and median doses by a factor of about 0.6, and of decreasing the overall 5th to 95th percentile range by about the same factor. This result was caused by the model's using only a single value for the travel time (rather than computing

one) and by its focusing on one that was slightly longer than the average in the earlier realizations. Thus, radiological decay was slightly overestimated for this case. However, this indicates that the uncertainty in the overall dose contributed by the river transport and dispersion model is actually rather small--at most a factor of about 2 in the overall answer.

8.0 DOSES DOWNRIVER OF THE TRI-CITIES

The spreadsheets were used to estimate doses to maximally exposed individuals at locations downriver of the Tri-Cities. The same individual definitions were used, but credit was taken for additional dilution and decay of the radionuclides as they were transported downstream.

8.1 PEAK YEAR DOSES

Doses to the maximum individual for 1961 were estimated for Umatilla, The Dalles, and Vancouver. The detailed results are provided in Appendix C. A summary of the results is shown in Figure 8.1. Figure 8.1 illustrates the impact of the additional dilution and decay at increasing distances. An interesting feature of the curve shown in Figure 8.1 is the similarity to the curves of monitored radionuclide concentration shown in Section 3.4. It is apparent that conditions along the Columbia, below the influx of the Snake River, are fairly stable. This implies that modeling of the Columbia below about McNary Dam need not be performed on a detailed spatial scale. Estimates made within 50 miles of a given location can probably serve as surrogates within the uncertainty of the other parameters.

FIGURE 8.1. 1961 Dose As a Function of Downriver Distance

8.2 CONTRIBUTING RADIONUCLIDES

As the contaminant plume progressed downstream, decay of the short-lived material resulted in changing radionuclide spectra at increasingly distant locations. This resulted in a change in the relative importance of the remaining radionuclides, as illustrated in Table 8.1. As the short-lived sodium-24, neptunium-239, and arsenic-76 decay, the relative importance of the zinc-65 and the phosphorous-32 increase. The relative importance of the radionuclides not listed remains very low, contributing 2% or less to the total dose. Below about McNary Dam, the only radionuclides of dosimetric consequence are zinc-65 and phosphorous-32. Part of the reason that the phosphorous-32 is such a large contributor is the high bioaccumulation factor (1700) used for phosphorus in this analysis. However, lowering this by even an order of magnitude would not significantly change the conclusions drawn here.

TABLE 8.1. Relative Contributions to Maximum Individual Dose of Various Radionuclides As a Function of Downriver Distance

<u>Total Dose</u>	<u>Tri-Cities 220 mrem</u>	<u>Umatilla 93 mrem</u>	<u>The Dalles 77 mrem</u>	<u>Vancouver 52 mrem</u>
P-32	57%	75%	77%	75%
Zn-65	11%	17%	19%	23%
As-76	14%	2%	1%	0%
Na-24	6%	0%	0%	0%
Np-239	3%	2%	1%	0%

8.3 INCLUSION OF WILLAPA BAY OYSTERS

A recommendation of Napier and Brothers (1992a, p. 6.2) was to include Pacific Ocean shellfish in the dose calculations using monitoring data, to avoid the need to model the dispersion of radionuclides in the ocean beyond the Columbia River. However, radionuclide data for oysters are not available for all years. Figure 8.2 shows a summary of available monitoring data on zinc-65, the primary contaminant found in Willapa Bay oysters. These data are compared in Figure 8.2 to the source term information summarized from the

FIGURE 8.2. Annual Releases of Zinc-65 from Hanford Compared to Annual Average Concentrations in Willapa Bay Oysters

spreadsheet inputs developed for this report. A very strong correlation can be observed between the amount of zinc-65 released to the Columbia River at Hanford and the concentrations measured in the oysters.

It is apparent that the HEDR Project should be able to adequately estimate oyster concentrations as a function of release rate. Some additional work needs to be done to explain the apparent inconsistency in the early years between release and concentration. This could be due to inaccurate source terms at this point, slightly imprecise initial measurements of the oysters, or other reasons. However, the available data should allow projections of the oyster concentrations to within a factor of less than four, which will be more than adequate for most purposes.

As with the other ingestion pathways, dose will be a function of both the contaminant concentrations and the consumption rate of the oysters. The concentrations presented in Figure 8.2 for 1962, the highest period shown, imply a dose of about 1 mrem/kg of oysters consumed. Only people consuming very large quantities of oysters (200 lb/yr will approach the TSP's dose decision level via this exposure pathway.

9.0 ANADROMOUS FISH

Walters et al. (1992, p. 10.4-10.5) reported very limited availability of data on radionuclide concentrations in anadromous fish (salmon and steelhead). The HEDR Project staff have continued to search for additional salmon data, with some success. Both Hanford-originated data and data from other sources have been identified.

9.1 NEWLY ACQUIRED DATA

Data have been assembled from the Hanford environmental monitoring database. Samples of zinc-65 and phosphorous-32 concentrations and "apparent" bioaccumulation factors are provided in Tables 9.1, for salmon, and 9.2, for steelhead. The data in these tables show that salmon, and most steelhead, accumulate zinc-65 to much lower levels than do resident fish. They also show that bioaccumulation of phosphorous-32 is somewhat more variable, but much lower than resident whitefish and other omnivores. The apparent increase in bioaccumulation of zinc-65 in steelhead near Ringold requires additional investigation--but Ringold is a currently popular spot for steelhead fishing. It is possible that some steelhead interrupt their migration to feed in the area near Ringold, and thus accumulate some phosphorous-32 there.

The data presented in Walters et al. (1992, Section 10.2) were interpreted to mean that salmon entering the Columbia River from the Pacific Ocean already had a measurable body burden of Hanford-related radionuclides roughly equivalent to that expected for a resident fish at Astoria. Unpublished data supplied by Dr. N. F. Kujala (personal communication, B.G. Blaylock to B.A. Napier, December 1992) carry this idea further. Dr. Kujala provided analyses that indicate that the varying concentrations of zinc-65 and manganese-54 could be related to the areas in the Pacific where the salmon had been feeding. He also suggests that these differences in ratios of zinc-65 and manganese-54 could be used to differentiate varying runs of salmon. This difference was noticeable even in the fish were from far upstream of the waters influenced by the continuing releases. These observations support both the fact that the salmon are reentering the Columbia contaminated with

TABLE 9.1. Apparent Bioaccumulation Factors Derived for Phosphorous-32 and Zinc-65 in Salmon

Year	Month	Phosphorous-32 (Priest Rapids to McNary)			Zinc-65 Woody Island		
		Fish (pCi/g)	Water ^(b) (pCi/L)	BF (L/kg)	Fish (pCi/g)	Water ^(b) (pCi/L)	BF (L/kg)
1961	11	-(a)	230	<4			
1963	4				0.4	327	1.2
1964	3				1.0	305	3.3
	9	16	108	148			
1965	1	-	108	<5			
	4		219		0.2	460	0.4
	4				0.1	460	0.2
	4				0.9	460	2.0
	10	130	190	684	0.3	460	0.7
	10	2	190	10			
	11	2	167	12			
1966	3				-	151	<0.7
	3				-	151	<0.7
	3				-	151	<0.7
	3				0.1	151	0.7
	4				-	151	<0.7
	4				-	151	<0.7
1967	4				0.1	319	0.3
	4				-	319	<0.3
	4				-	319	<0.3
	4				-	319	<0.3
	4				-	319	<0.3
	10	-	190	<5			
	10	186	190	980			
1968	4				0.2	162	1.2
	4				-	162	<0.6
	4				0.4	162	2.5
	5				0.2	97	2.1
1969	3				0.1	111	0.9
1970	3				0.2	42	0.9
	4				-	28	4.8
	4				-	28	<3.6
	4				-	28	<3.6
	4				-	28	<3.6
Ave.				230±380			1.6±1.6

(a) A dash (-) indicates that the sample was less than detectable.

(b) Water concentrations estimated for TriCity area from spreadsheet developed for this report.

TABLE 9.2. Apparent Bioaccumulation Factors Derived from Phosphorous-32 and Zinc-65 in Steelhead

Phosphorous-32					Zinc-65		
Year	Month	Fish (pCi/g)	Water ^(b) (pCi/L)	BF (L/kg)	Fish (pCi/g)	Water ^(b) (pCi/L)	BF (L/kg)
(at Coyote Rapids)							
1964	1	-(a)	290	<3.5	-	245	<0.4
	2	-	290	<4.2	-	256	<0.4
	3	-	323	<3.0	-	305	<0.3
	8	-	52	<2.0	-	95	<1
	8	3	52	58	-	95	<1
	8	5	52	96	7	95	<4
	8	7	108	65	-	201	<0.5
	9	16	108	150			
	1965	1	-			-	244
9		-	139	<7.2	1.2	122	9.8
9		4	139	29	4	122	33
10		32	190	168	0.3	70	4.3
1966	1	3	164	18	-	132	<1
	1	3	164	18	-	132	<1
	3	5	168	30	0.3	151	2
	3	-	168	<6	0.9	151	6
	3	-	168	<6	11	151	<3
	9	-	130	<7.7			
	9	-	130	<7.7			
	9	-	130	<7.7			
	9	-	130	<7.7			
	10	-	119	<8.4		277	
	10	-	119	<8.4		277	<0.4
							<0.4
1967	10	1	131	7.6	0.3	134	2.2
	10	-	131	<7.6	0.9	134	6.7
	10	-	131	<7.6	-	134	0.7
Ave.				27±46	10±21		
(at Ringold)							
1961	10	1600	191	8370	160	319	500
1964	8	550	52	10570	70	95	740
	8	2200	52	42300	44	95	463
	12	420	206	2040	65	235	275
	12			2810	62	235	260
1965	8	110	63	1750	42	69	610
	8	11	63	175	-	69	<2
Ave.				9700±15000	407±247		

(a) A dash (-) indicates that the sample was less than detectable.

(b) Water concentrations estimated for TriCity area from spreadsheet developed for this report.

radionuclides accumulated in the ocean as well as the relatively small uptake received during their upriver migrations.

A very large database of salmon measurements has been tentatively identified. A former Battelle employee has indicated that he operated an unofficial salmon-sampling project throughout the Northwest for several years and that concentration measurements are available. HEDR staff are following up on that information at this time. The nature and quality of this information have not yet been determined.

9.2 POTENTIAL FOR DOSE ESTIMATES

Information acquired to date supports the conjecture that radionuclide concentrations in returning migratory species are lower than those found in resident species. No information has been found that suggests that the migratory species have concentrations greater than those of the resident species. This being the case, it is possible to place upper bounds on the potential doses resulting from consumption of salmon as being no higher than doses resulting from equivalent consumption of resident fish. Evidence points toward the approach initially presented in Walters et al. (1992, Section 10.2) of determining the concentration of radionuclides in returning migratory fish as they enter the mouth of the Columbia River, and continuing to use that value as representative upstream.

10. WATERFOWL

Starting with the annual report for 1957, the Hanford Site staff reported on monitoring results showing elevated levels of Columbia River radionuclides in ducks and other waterfowl (see annual summaries provided in Appendix B). Between 1957 and about 1970, consumption of these waterfowl had a potential to result in relatively high doses, mostly from phosphorous-32 and with a lesser contribution from zinc-65. Off of the immediate vicinity of the Hanford Site, between 5% and 10% of the ducks sampled contained measurable quantities of Hanford-originated radionuclides, presumably attributable to exposures along the Columbia River.

10.1 MODEL FOR ESTIMATING CONCENTRATIONS IN DUCKS

There are two general types of ducks and other waterfowl: those that eat water plants and those that eat small fish and invertebrates. (This differs from the more commonly used differentiation between surface-feeding--i.e., dabbling--and diving ducks.) This is not usually an exclusive division, since most will eat both plants and insects or small fish, but it can be used for the purposes of example.

The basic model is that described by Baker and Soldat (1992, p. 5). The concentration of radionuclides in the duck is proportional to the concentration of radionuclides in its food. This may be written in terms of the water concentration of radionuclide i , W_i , the bioaccumulation factor of the primary organism (plant or fish), and some metabolic parameters of the duck, as

$$C_{\text{duck}, i} = \frac{W_i b_i U f_1}{m} \frac{(1 - e^{-\lambda_i T})}{\lambda_i} \quad (\text{Eqn. 8})$$

where b_i = the bioaccumulation factor of the primary organism
 U = the uptake rate of the primary organism by the duck, kg/d
 f_1 = the fraction of radionuclide initially retained in the body of the duck, dimensionless
 m = the mass of the duck, kg

λ_i = the effective decay constant of the radionuclide in the duck, made up of the biological loss rate constant and the radiological decay constant, d^{-1} , as $\lambda_i = \lambda_r + \ln(2)/t_{bio}$, where t_{bio} is the biological half time in the organism, d.

T = the period of exposure of the duck to the contaminated food source, days.

In addition to the bioaccumulation factor for fish, this model requires estimates of several other parameters. In the absence of specific data, these are taken to be those of Standard Man. Representative parameters used in the calculation are presented in Table 10.1.

TABLE 10.1. Parameters Required for Implementing the Duck Model

<u>Nuclide</u>	<u>River Plant Bioaccumulation</u>	<u>f1 Retention Fraction</u>	<u>Biological Half Time, d</u>
Na-24	100	1	11
P-32	500,000	0.8	257
Ca-45	1,000	0.3	16,400
Sc-46	10,000	1.0E-4	30
Mn-56	10,000	0.1	17
Cu-64	2,000	0.5	80
As-76	200	0.5	280
Cr-51	4,000	0.1	616
Zn-65	20,000	0.5	933
Zn-69	20,000	0.5	933
Ga-72	1	3.0E-4	550
Sr-89	3,000	0.3	4,000
Sr-90	3,000	0.3	4,000
Y-90	5,000	1.0E-4	14,000
Y-93	5,000	1.0E-4	14,000
Np-239	300	0.001	39,000

10.2 DOSE IMPLICATIONS

With this model, dose estimates were made for consumption of 1 kg/month of duck meat. Details are provided in Appendix C. The conclusion is similar to that drawn from the monitoring data: phosphorous-32 and zinc-65 are the radionuclides of concern, and there is a potential for relatively large doses from the isolated cases of highly contaminated ducks.

As with the other models, the dose is linear with the assumed consumption rate. In this case, it is necessary to know both the consumption and the type of duck being consumed. The case is directly analogous to that for consumption of Columbia River fish: i.e., the dose estimate is directly dependent on the quality of the information obtained on consumption rates. At this time, all that can be supported is the need for additional information from individuals about their own food habits regarding waterfowl hunting and consumption. The potential magnitude of the doses supports including the model in the overall river-dose estimating capability. The model implementation should include a "probability-of-exposure" factor to account for the likelihood of consuming uncontaminated migratory waterfowl.

11. OBSERVATIONS AND RECOMMENDATIONS

Recommendations determined from scoping calculations are provided to the HEDR Technical Steering Panel with the intent of providing a definitive technical basis to assist in deciding whether specific radionuclides and exposure pathways should or should not be included in the tools used for the HEDR dose estimation process for individuals. Recommendations are provided also on the level of effort required for river-transport modeling, including spatial and temporal resolution, and propagation of uncertainties through the calculation.

11.1 INCLUDED RADIONUCLIDES

The scoping studies indicate that the following radionuclides should be included in the modeling efforts for dosimetric purposes: sodium-24, phosphorous-32, arsenic-76, zinc-65, and neptunium-239. For areas below about McNary Dam, only phosphorous-32 and zinc-65 need to be carried. Beyond the mouth of the Columbia River, only zinc-65 need be considered. Consideration of these radionuclides should account for greater than 95% of the total dose at any location for any time for exposures approaching or exceeding the TSP dose decision level.

11.2 SPATIAL RESOLUTION

On the basis of the monitoring results shown in Section 3.3 and the dose results shown in Section 8.1, about 3 to 4 locations between Ringold and McNary Dam, and perhaps 5 locations between McNary Dam and the mouth of the Columbia River, plus Willapa Bay, should be sufficient to provide accurate dose estimates to any individual. The rate of change of radionuclide concentration in river water is slow, and additional fine detail is not warranted.

11.3 MODELING TECHNIQUES

The nature of the results gives suggestions for simplifying the modeling of downriver doses.

11.3.1 River Transport

The river transport model does not contribute a significant amount of uncertainty to the overall uncertainty in the answer. In the overall calculation from source term through dose, river transport acts as a "pipe" with relatively well-understood characteristics. The variability that this submodel adds to the final result is small. It should be possible to treat the river transport as a deterministic calculation. This means that 100 realizations of the transport model are not required. Scoping studies can be performed with the transport model for limited time/space combinations, and the results extrapolated for application within the overall dose calculation framework. The greatest impact of implementing this recommendation would be on the estimation of concentrations of short-lived radionuclides close to the release points, which will have only secondary importance for most scenarios of exposure.

11.3.2 Anadromous Fish

Follow-up work needs to be performed to ascertain whether the potential Hanford historical salmon database supports the contention that concentration estimates made for the Columbia River mouth are adequate for the rest of the river system. If this contention is adequate, then dose estimates for people consuming salmon can be made for any location on the basis of the river mouth conditions.

11.3.3 Propagation of Uncertainty

The overall degree of uncertainty around the individual dose calculations for the river pathway is much smaller than that for the atmospheric pathway. The key uncertainties will involve individual-specific parameters of lifestyle and consumption rates, rather than environmental concentrations. This supports a very simple accumulation and dose model for river water and resident fish.

11.3.4 Level of Detail Required

The doses estimated for the "average," "typical," or "median" individual are all well below the TSP dose decision level. Only members of certain "critical groups" have the potential for exceeding the dose decision level.

In general, these are people who consumed very large amounts of fresh fish, seafood, or game birds. The level of detail applied to the dose estimates for this pathway should, therefore, be scaled to the needs of this group. The areas of most concern are consumption of resident fish, waterfowl, and salmon (which could possibly be bounded using resident fish data).

11.4 KEY INDIVIDUAL-SPECIFIC DATA NEEDS

The major unknowns in calculating doses for the Columbia River Pathway are those related to individual consumption. It is important know not only total consumption, but species or category of fish and ducks. This will effect the selection of appropriate bioaccumulation factors. It is additionally very important to determine representative food-preparation habits, especially the length of holdup time from harvest to consumption. With the number of short-lived activation products adding to the dose, a large reduction in dose will result if the foods are not eaten fresh.

In order to capture the individual variability in these consumption-related parameters, it is recommended that some of the doses calculated for the Columbia River pathway be presented as figures of dose versus consumption rate. This will allow the TSP to evaluate the sensitivity of the doses to these parameters and supply information to the public about the reasons for the project uncertainty in the final results.

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APPENDIX A

INDIVIDUAL REACTOR SOURCE TERMS

[illegible]

A.3

May-65	HL-RLA-2428	6.20E+00	8.80E+01	1.47E+02	5.00E+00	8.20E+01
Jun-65	HL-RLA-2428	4.80E+00	6.40E+01	1.50E+02	4.00E+00	6.00E+01
Jul-65	DUN-110	3.50E+00	4.70E+01	1.87E+02	2.80E+00	4.20E+01
Aug-65	DUN-110	3.40E+00	5.71E+01	1.88E+02	1.70E+00	4.30E+01
Sep-65	DUN-110	3.80E+00	1.70E+01	1.88E+02	2.80E+00	4.00E+01
Oct-65	DUN-658	5.00E+00	1.32E+02	1.84E+02	1.30E+00	6.30E+01
Nov-65	DUN-658	6.40E+00	1.08E+02	1.84E+02	1.20E+00	5.20E+01
Dec-65	DUN-658	7.80E+00	8.80E+01	1.81E+02	3.40E+00	4.80E+01
Jan-66	DUN-1035	6.10E+00	4.00E+01	1.50E+02	2.20E+00	3.80E+01
Feb-66	DUN-1035	4.10E+00	3.60E+01	1.35E+02	2.10E+00	2.80E+01
Mar-66	DUN-1035	8.00E+00	4.90E+01	1.52E+02	3.50E+00	2.80E+01
Apr-66	DUN-1035	5.80E+00	4.70E+01	1.32E+02	6.22E+00	4.20E+01
May-66	N-1015 SUP1	8.80E+00	5.40E+01	1.87E+02	3.80E+00	6.00E+01
Jun-66	N-1015 SUP1	4.70E+00	4.10E+01	1.22E+02	2.80E+00	3.40E+01
Jul-66	N-1015 SUP2	1.20E+00	1.20E+01	3.50E+01	1.20E+00	1.00E+01
Aug-66	N-1015 SUP2	8.00E+01	7.80E+00	2.40E+01	5.00E+01	8.00E+00
Sep-66	N-1015 SUP2	3.90E+00	3.80E+01	1.37E+02	3.80E+00	3.00E+01
Oct-66	N-1015 SUP3	4.10E+00	3.90E+01	1.37E+02	1.70E+00	1.00E+01
Nov-66	N-1015 SUP3	2.50E+00	3.50E+01	1.24E+02	2.80E+00	8.00E+00
Dec-66	N-1015 SUP3	2.23E+02	3.30E+01	1.37E+02	3.30E+00	3.00E+01
Jan-67	DUN-5405	2.73E+02	3.50E+01	1.41E+02	2.80E+00	2.80E+01
Feb-67	DUN-5405	3.20E+00	2.90E+01	1.41E+02	4.10E+00	3.30E+01
Mar-67	DUN-5405	1.72E+02	2.30E+01	7.70E+01	2.40E+00	1.90E+01
Apr-67	DUN-5405	2.88E+02	4.80E+01	1.32E+02	4.00E+00	3.10E+01
May-67	DUN-5405	4.20E+00	2.80E+01	8.80E+01	1.90E+00	5.20E+01
Jun-67	DUN-5405	3.60E+00	6.20E+01	1.37E+02	2.40E+00	4.80E+01
Jul-67	DUN-5405	2.30E+02	2.80E+01	1.81E+02	6.20E+00	4.20E+01
Aug-67	DUN-5405	2.38E+02	3.80E+01	1.43E+02	2.80E+00	4.80E+01
Sep-67	DUN-5405	2.04E+02	2.70E+01	1.28E+02	1.40E+00	3.30E+01
Oct-67	DUN-5405	4.10E+00	2.70E+01	1.28E+02	1.40E+00	3.80E+01
Nov-67	DUN-5405	3.70E+00	4.50E+01	1.31E+02	2.30E+00	4.40E+01
Dec-67	DUN-5405	3.70E+00	3.80E+01	1.57E+02	1.80E+00	5.30E+01
Jan-68	DUN-5405	2.92E+02	8.20E+01	1.83E+02	3.80E+00	3.00E+01
Feb-68	DUN-5405	2.22E+02	3.80E+01	9.30E+01	1.30E+00	

1.26E+03
1.54E+03
8.63E+02
2.44E+03
2.04E+03
3.02E+03
4.88E+03
2.68E+03
1.52E+03
1.59E+03
1.50E+03
1.56E+03
1.04E+03

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Jun 59	W 64552/HW 63853	5 22E+00	2 68H+01	5 20E+01	1 74E+03	1 74E+02	1 18E+02	2 04E+02	8 20E+00	1 80E+01	2 00E+02	4 00E+02	7 80E+00	6 89E+01
Jul 59	W 64552/HW 63853	4 74E+00	2 91E+01	3 80E+01	2 56E+03	1 67E+02	1 10E+02	1 89E+02	7 00E+00	1 60E+01	1 45E+01	6 00E+02	6 70E+00	6 84E+01
Aug 59	W 64552/HW 63853	5 13E+00	2 75E+01	8 10E+01	3 98E+00	5 72E+03	6 46E+02	1 39E+02	7 40E+00	2 00E+01	1 90E+01	5 80E+02	8 70E+00	6 72E+01
Sep 59	W 64552/HW 63853	4 55E+00	2 07E+01	8 60E+01	1 81E+03	4 20E+02	2 20E+02	1 35E+02	8 90E+00	9 80E+00	6 40E+02	4 00E+00	7 10E+00	7 24E+01
Oct 59	W 64552/HW 63853	1 31E+01	2 60E+01	1 18E+00	3 70E+03	9 85E+02	6 87E+01	4 45E+01	8 60E+00	3 50E+00	7 80E+02	3 20E+01	1 40E+01	9 77E+01
Nov 59	W 64552/HW 63853	6 30E+00	3 27E+01	1 84E+00	6 49E+00	3 70E+03	1 08E+03	1 15E+02	8 90E+00	3 40E+00	1 30E+01	9 30E+01	2 30E+01	1 02E+02
Dec 59	W 64552/HW 63853	7 60E+00	3 50E+01	1 98E+00	6 63E+03	8 27E+02	1 37E+02	2 08E+02	3 50E+01	1 32E+01	2 16E+01	1 10E+01	1 40E+01	
Jan 60	W 64552/HW 63853	7 10E+00	2 60E+01	5 50E+01	2 21E+00	2 84E+03	5 03E+01	2 00E+02	3 90E+01	1 30E+01	8 10E+02	4 20E+02	1 40E+01	
Feb 60	W 64624	7 20E+00	2 40E+01	5 40E+01	2 88E+01	2 50E+02	5 20E+01	2 00E+02	1 70E+01	1 30E+01	8 70E+02	9 70E+03	1 91E+01	
Mar 60	W 64624	8 10E+00	2 70E+01	5 20E+01	2 88E+01	2 50E+02	5 20E+01	2 00E+02	1 70E+01	1 30E+01	8 70E+02	9 70E+03	1 91E+01	
Apr 60	W 64653	7 20E+00	2 40E+01	5 40E+01	2 88E+01	2 50E+02	5 20E+01	2 00E+02	1 70E+01	1 30E+01	8 70E+02	9 70E+03	1 91E+01	
May 60	W 64653	5 70E+00	2 30E+01	8 40E+01	2 88E+01	2 50E+02	5 20E+01	2 00E+02	1 70E+01	1 30E+01	8 70E+02	9 70E+03	1 91E+01	
Jun 60	W 70733	5 34E+00	2 89E+01	8 24E+01	2 88E+01	2 50E+02	5 20E+01	2 00E+02	1 70E+01	1 30E+01	8 70E+02	9 70E+03	1 91E+01	
Jul 60	W 70733	4 51E+00	2 56E+01	6 10E+01	2 88E+01	2 50E+02	5 20E+01	2 00E+02	1 70E+01	1 30E+01	8 70E+02	9 70E+03	1 91E+01	
Aug 60	W 70733	1 13E+01	3 38E+01	4 07E+00	2 88E+01	2 50E+02	5 20E+01	2 00E+02	1 70E+01	1 30E+01	8 70E+02	9 70E+03	1 91E+01	
Sep 60	W 70733	5 74E+00	4 12E+01	5 07E+01	2 88E+01	2 50E+02	5 20E+01	2 00E+02	1 70E+01	1 30E+01	8 70E+02	9 70E+03	1 91E+01	
Oct 60	W 70733	2 89E+00	2 24E+01	8 33E+01	2 88E+01	2 50E+02	5 20E+01	2 00E+02	1 70E+01	1 30E+01	8 70E+02	9 70E+03	1 91E+01	
Nov 60	W 70733	5 68E+00	2 30E+01	4 82E+00	2 88E+01	2 50E+02	5 20E+01	2 00E+02	1 70E+01	1 30E+01	8 70E+02	9 70E+03	1 91E+01	
Dec 60	W 70733	1 18E+01	2 84E+01	3 13E+01	2 56E+03	1 67E+02	1 10E+02	1 89E+02	7 00E+00	1 60E+01	1 45E+01	6 00E+02	6 70E+00	6 84E+01
Jan 61	W 70733	3 74E+02	9 65E+00	3 83E+01	3 98E+00	5 72E+03	6 46E+02	1 39E+02	7 40E+00	2 00E+01	1 90E+01	5 80E+02	8 70E+00	6 72E+01
Feb 61	W 70733	6 15E+02	2 18E+01	8 50E+01	1 81E+03	4 20E+02	2 20E+02	1 35E+02	8 90E+00	3 50E+00	7 80E+02	3 20E+01	1 40E+01	9 77E+01
Mar 61	W 70733	3 79E+02	2 42E+01	5 33E+01	2 68E+00	3 70E+03	1 08E+03	1 15E+02	8 90E+00	3 40E+00	1 30E+01	9 30E+01	2 30E+01	1 02E+02
Apr 61	W 70733	4 77E+02	1 23E+01	3 27E+01	6 49E+00	3 70E+03	1 08E+03	1 15E+02	8 90E+00	3 40E+00	1 30E+01	9 30E+01	2 30E+01	1 02E+02
May 61	W 70733	6 01E+02	2 35E+01	3 94E+01	1 98E+00	6 63E+03	8 27E+02	1 37E+02	2 08E+02	3 50E+01	1 32E+01	2 16E+01	1 40E+01	
Jun 61	W 70733	1 30E+02	1 25E+01	5 12E+01	2 21E+00	2 84E+03	5 03E+01	2 00E+02	1 70E+01	1 30E+01	8 70E+02	9 70E+03	1 91E+01	
Jul 61	W 70733	4 18E+02	7 01E+00	3 02E+01	2 88E+01	2 50E+02	5 20E+01	2 00E+02	1 70E+01	1 30E+01	8 70E+02	9 70E+03	1 91E+01	
Aug 61	W 70733	4 80E+02	8 00E+00	8 60E+01	2 88E+01	2 50E+02	5 20E+01	2 00E+02	1 70E+01	1 30E+01	8 70E+02	9 70E+03	1 91E+01	
Sep 61	W 70733	2 60E+02	8 00E+01	1 30E+01	2 88E+01	2 50E+02	5 20E+01	2 00E+02	1 70E+01	1 30E+01	8 70E+02	9 70E+03	1 91E+01	
Oct 61	W 70733	1 90E+02	2 30E+00	1 90E+02	2 88E+01	2 50E+02	5 20E+01	2 00E+02	1 70E+01	1 30E+01	8 70E+02	9 70E+03	1 91E+01	
Nov 61	W 70733	2 90E+02	3 20E+00	8 00E+02	2 88E+01	2 50E+02	5 20E+01	2 00E+02	1 70E+01	1 30E+01	8 70E+02	9 70E+03	1 91E+01	
Dec 61	W 70733	3 30E+02	2 70E+00	5 00E+02	2 88E+01	2 50E+02	5 20E+01	2 00E+02	1 70E+01	1 30E+01	8 70E+02	9 70E+03	1 91E+01	
Jan 62	W 75023	2 20E+02	2 80E+00	1 00E+02	8 40E+02	2 30E+02	2 30E+02	2 30E+02	2 30E+02	2 30E+02	2 30E+02	2 30E+02	2 30E+02	2 30E+02
Feb 62	W 75023	4 20E+02	3 80E+00	9 00E+02	1 34E+03	5 50E+02	4 10E+01	5 10E+02	1 50E+01	1 50E+01	2 90E+01	8 30E+01	2 80E+01	1 30E+02
Mar 62	W 75023	5 40E+02	3 80E+00	3 40E+01	2 00E+03	4 50E+02	4 60E+01	5 40E+02	1 20E+01	1 20E+01	2 90E+01	8 30E+01	2 80E+01	1 30E+02
Apr 62	W 75023	3 80E+02	3 80E+00	4 00E+02	2 80E+03	3 80E+02	4 40E+01	1 60E+02	1 20E+01	1 20E+01	2 90E+01	8 30E+01	2 80E+01	1 30E+02
May 62	W 75023	4 50E+02	3 70E+00	3 00E+02	1 10E+04	3 40E+01	5 00E+01	1 70E+02	1 80E+01	1 80E+01	2 90E+01	8 30E+01	2 80E+01	1 30E+02
Jun 62	W 75023	5 10E+02	4 10E+00	4 00E+02	2 20E+03	3 30E+02	3 90E+01	1 70E+02	8 10E+00	3 00E+00	3 00E+00	2 30E+01	1 50E+01	8 00E+01
Jul 62	W 75023	1 80E+02	8 00E+01	4 00E+02	8 70E+03	3 60E+02	3 00E+01	1 50E+02	7 80E+00	1 10E+01	1 10E+01	1 10E+01	1 10E+01	5 40E+00
Aug 62	W 78103	2 40E+02	1 70E+00	2 40E+02	2 80E+03	3 60E+02	1 80E+01	1 30E+02	3 80E+00	9 80E+00	3 00E+00	3 00E+00	3 00E+00	3 00E+00
Sep 62	W 78103	3 80E+02	3 00E+00	3 00E+00	3 90E+03	7 20E+02	3 10E+01	1 30E+02	4 00E+02	8 00E+00	5 70E+01	1 40E+00	9 10E+01	1 40E+00
Oct 62	W 76894	3 10E+02	3 80E+00	2 70E+03	2 70E+03	4 10E+02	3 40E+01	3 00E+02	5 00E+02	7 20E+00	4 20E+01	1 40E+00	9 10E+01	1 40E+00
Nov 62	W 76894	2 90E+02	2 20E+00	3 50E+03	3 50E+03	4 00E+02	2 20E+01	2 60E+02	6 00E+02	6 00E+00	4 00E+00	2 00E+00	5 20E+00	2 00E+00
Dec 62	W 76894	4 30E+01	3 40E+01	1 70E+02	1 70E+02	5 00E+01	1 70E+00	1 50E+01	2 00E+01	2 00E+01	1 30E+01	4 50E+01	3 20E+01	4 50E+01
Jan 63	W 77768	3 30E+02	2 10E+00	2 00E+03	2 00E+03	3 90E+02	1 80E+01	2 00E+02	2 00E+02	2 00E+02	1 30E+01	4 50E+01	3 20E+01	4 50E+01
Feb 63	W 77768	2 80E+02	2 10E+00	1 50E+03	1 50E+03	3 90E+02	1 80E+01	2 00E+02	2 00E+02	2 00E+02	1 30E+01	4 50E+01	3 20E+01	4 50E+01
Mar 63	W 77768	6 80E+02	1 80E+00	1 80E+02	1 80E+03	3 90E+02	1 80E+01	2 00E+02	2 00E+02	2 00E+02	1 30E+01	4 50E+01	3 20E+01	4 50E+01
Apr 63	W 76820	2 60E+02	5 00E+00	8 00E+02	1 80E+03	3 90E+02	1 80E+01	2 00E+02	2 00E+02	2 00E+02	1 30E+01	4 50E+01	3 20E+01	4 50E+01
May 63	W 76820	2 80E+02	3 70E+00	2 80E+02	9 70E+03	4 40E+02	5 80E+01	2 60E+02	2 00E+01	2 00E+01	1 30E+01	4 50E+01	3 20E+01	4 50E+01
Jun 63	W 76820	4 30E+02	3 80E+00	3 40E+02	2 80E+03	4 40E+02	5 80E+01	2 60E+02	2 00E+01	2 00E+01	1 30E+01	4 50E+01	3 20E+01	4 50E+01
Jul 63	W 76820	3 40E+02	3 80E+00	3 40E+02	2 80E+03	4 40E+02	5 80E+01	2 60E+02	2 00E+01	2 00E+01	1 30E+01	4 50E+01	3 20E+01	4 50E+01
Aug 63	W 76820	2 80E+02	2 70E+00	2 80E+02	2 80E+03	4 40E+02	5 80E+01	2 60E+02	2 00E+01	2 00E+01	1 30E+01	4 50E+01	3 20E+01	4 50E+01
Sep 63	W 76820	3 40E+02	3 80E+00	3 40E+02	2 80E+03	4 40E+02	5 80E+01	2 60E+02	2 00E+01	2 00E+01	1 30E+01	4 50E+01	3 20E+01	4 50E+01
Oct 63	W 76820	2 80E+02	2 70E+00	2 80E+02	2 80E+03	4 40E+02	5 80E+01	2 60E+02	2 00E+01	2 00E+01	1 30E+01	4 50E+01	3 20E+01	4 50E+01
Nov 63	W 80706	2 80E+02	4 50E+00	2 80E+02	2 80E+03	4 40E+02	5 80E+01	2 60E+02	2 00E+01	2 00E+01	1 30E+01	4 50E+01	3 20E+01	4 50E+01
Dec 63	W 80706	4 00E+02	6 80E+00	3 00E+03	3 00E+03	4 20E+02	6 70E+01	3 30E+02	1 00E+01	1 00E+01	1 00E+01	1 00E+01	1 00E+01	1 00E+01
Jan 64	W 81983	3 60E+02	8 40E+00	2 10E+03	2 10E+03	4 20E+02	5 60E+01	3 12E+02	1 00E+01	1 00E+01	1 00E+01	1 00E+01	1 00E+01	1 00E+01
Feb 64	W 81983	4 50E+02	8 40E+00	3 80E+02	2 10E+03	3 60E+02	6 10E+01	3 97E+02	1 00E+01	1 00E+01	1 00E+01	1 00E+01	1 00E+01	1 00E+01
Mar 64	W 81983	3 50E+02	7 80E+00	2 10E+03	2 10E+03	3 00E+02	5 10E+01	3 30E+02	8 10E+00	7 80E+00	7 80E+00	7 80E+00	7 80E+00	7 80E+00
Apr 64	W 83423	9 40E+00	9 40E+00	5 00E+00	2 80E+03	3 60E+02	7 20E+01	4 10E+02	1 35E+01	9 20E+00	9 20E+00	9 20E+00	9 20E+00	9 20E+00
May 64	W 83423	4 00E+00	4 00E+00	5 00E+00	2 80E+03	3 60E+02	7 20E+01	4 10E+02	1 35E+01	9 20E+00	9 20E+00	9 20E+00	9 20E+00	9 20E+00
Jun 64	W 83423	2 20E+00	2 20E+00	2 20E+00	2 80E+03	3 60E+02	7 20E+01	4 10E+02	1 35E+01	9 20E+00	9 20E+00	9 20E+00	9 20E+00	9 20E+00
Jul 64	W 83423	2 20E+00	2 20E+00	2 20E+00	2 80E+03	3 60E+02	7 20E+01	4 10E+02	1 35E+01	9 20E+00	9 20E+00	9 20E+00	9 20E+00	9 20E+00
Aug 64	W 83423	2 20E+00	2 20E+00	2 20E+00	2 80E+03	3 60E+02	7 20E+01	4 10E+02	1 35E+01	9 20E+00	9 20E+00	9 20E+00	9 20E+00	9 20E+00
Sep 64	W 83423	2 20E+00	2 20E+00	2 20E+00	2 80E+03	3 60E+02	7 20E+01	4 10E+02	1 35E+01	9 20E+00	9 20E+00	9 20E+00	9 20E+00	9 20E+

Jun-66	DUN-1035 SUP1	3.30E+00	3.70E+01	2.42E+02	4.50E+00	4.90E+01
Jul-66	DUN-1035 SUP2	1.00E+00	1.40E+01	7.90E+01	1.40E+00	1.90E+01
Aug-66	DUN-1035 SUP2	1.10E+00	8.90E+00	6.90E+01	8.00E+01	1.60E+01
Sep-66	DUN-1035 SUP2	6.10E+00	5.20E+01	3.75E+02	1.09E+01	7.70E+01
Oct-66	DUN-1035 SUP3	7.10E+00	5.30E+01	2.01E+02	1.40E+01	5.80E+01
Nov-66	DUN-1035 SUP3	4.50E+00	3.80E+01	3.28E+02	8.00E+00	5.70E+01
Dec-66	DUN-1035 SUP3	5.30E+00	5.00E+01	3.69E+02	7.03E+01	8.90E+01
Jan-67	DUN-5405	4.13E+02	6.90E+01	3.59E+02	1.36E+01	8.90E+01
Feb-67	DUN-5405	4.02E+02	4.10E+01	3.29E+02	1.46E+01	8.40E+01
Mar-67	DUN-5405	3.64E+02	5.40E+01	2.84E+02	1.90E+01	5.80E+01
Apr-67	DUN-5405	4.48E+02	7.90E+01	3.35E+02	1.34E+01	7.70E+01
May-67	DUN-5405	5.36E+02	7.70E+01	4.18E+02	1.10E+01	1.00E+02
Jun-67	DUN-5405	2.50E+02	4.30E+01	2.23E+02	9.90E+00	5.90E+01
Jul-67	DUN-5405	3.67E+02	4.50E+01	3.36E+02	1.13E+01	7.70E+01
Aug-67	DUN-5405	4.78E+02	6.90E+01	3.97E+02	7.20E+00	8.50E+01
Sep-67	DUN-5405	3.08E+02	3.50E+01	2.24E+02	7.80E+00	5.10E+01
Oct-67	DUN-5405	4.12E+02	8.10E+01	3.01E+02	6.30E+00	8.90E+01
Nov-67	DUN-5405	2.67E+02	4.00E+01	2.09E+02	7.90E+00	4.90E+01
Dec-67	DUN-5405	3.61E+02	6.80E+01	2.24E+02	1.18E+01	6.70E+01
Jan-68	DUN-5405	3.20E+02	9.00E+01	1.96E+02	7.20E+00	8.90E+01
Feb-68	DUN-5405	2.68E+02	4.70E+01	1.17E+02	7.30E+00	4.50E+01
Mar-68	DUN-5405	1.07E+01	1.19E+02	2.89E+02	9.90E+00	1.21E+02
Apr-68	DUN-5405	9.30E+00	8.72E+01	1.90E+02	1.16E+01	7.40E+01
May-68	DUN-5405	1.25E+01	4.90E+01	2.34E+02	1.02E+01	7.70E+01
Jun-68	DUN-5405	7.10E+00	5.10E+01	1.74E+02	1.19E+01	7.50E+01
Jul-68	DUN-5405	7.30E+00	5.50E+01	1.69E+02	6.80E+00	6.30E+01
Aug-68	DUN-5405	6.60E+00	5.30E+01	1.73E+02	8.00E+00	8.60E+01
Sep-68	DUN-5405	6.80E+00	1.20E+01	5.20E+01	6.50E+00	2.50E+01
Oct-68	DUN-5405	5.20E+00	5.10E+01	1.69E+02	6.50E+00	8.00E+01
Nov-68	DUN-5405	4.90E+00	3.80E+01	1.28E+02	7.80E+00	5.00E+01
Dec-68	DUN-5405	5.40E+00	4.90E+01	1.40E+02	7.20E+00	5.50E+01
Jan-69	DUN-6035	3.30E+00	2.97E+01	6.49E+01	4.90E+00	3.07E+01
Feb-69	DUN-6035	6.00E+00	4.17E+01	1.09E+02	7.90E+00	5.07E+01
Mar-69	DUN-6035	6.90E+00	6.95E+01	7.97E+01	8.50E+00	6.71E+01
Apr-69	DUN-6035	1.05E+01	1.48E+02	1.29E+02	1.34E+01	1.45E+02
May-69	DUN-6035					
Jun-66	DUN-1035 SUP1	3.30E+00	3.70E+01	2.42E+02	4.50E+00	4.90E+01
Jul-66	DUN-1035 SUP2	1.00E+00	1.40E+01	7.90E+01	1.40E+00	1.90E+01
Aug-66	DUN-1035 SUP2	1.10E+00	8.90E+00	6.90E+01	8.00E+01	1.60E+01
Sep-66	DUN-1035 SUP2	6.10E+00	5.20E+01	3.75E+02	1.09E+01	7.70E+01
Oct-66	DUN-1035 SUP3	7.10E+00	5.30E+01	2.01E+02	1.40E+01	5.80E+01
Nov-66	DUN-1035 SUP3	4.50E+00	3.80E+01	3.28E+02	8.00E+00	5.70E+01
Dec-66	DUN-1035 SUP3	5.30E+00	5.00E+01	3.69E+02	7.03E+01	8.90E+01
Jan-67	DUN-5405	4.13E+02	6.90E+01	3.59E+02	1.36E+01	8.90E+01
Feb-67	DUN-5405	4.02E+02	4.10E+01	3.29E+02	1.46E+01	8.40E+01
Mar-67	DUN-5405	3.64E+02	5.40E+01	2.84E+02	1.90E+01	5.80E+01
Apr-67	DUN-5405	4.48E+02	7.90E+01	3.35E+02	1.34E+01	7.70E+01
May-67	DUN-5405	5.36E+02	7.70E+01	4.18E+02	1.10E+01	1.00E+02
Jun-67	DUN-5405	2.50E+02	4.30E+01	2.23E+02	9.90E+00	5.90E+01
Jul-67	DUN-5405	3.67E+02	4.50E+01	3.36E+02	1.13E+01	7.70E+01
Aug-67	DUN-5405	4.78E+02	6.90E+01	3.97E+02	7.20E+00	8.50E+01
Sep-67	DUN-5405	3.08E+02	3.50E+01	2.24E+02	7.80E+00	5.10E+01
Oct-67	DUN-5405	4.12E+02	8.10E+01	3.01E+02	6.30E+00	8.90E+01
Nov-67	DUN-5405	2.67E+02	4.00E+01	2.09E+02	7.90E+00	4.90E+01
Dec-67	DUN-5405	3.61E+02	6.80E+01	2.24E+02	1.18E+01	6.70E+01
Jan-68	DUN-5405	3.20E+02	9.00E+01	1.96E+02	7.20E+00	8.90E+01
Feb-68	DUN-5405	2.68E+02	4.70E+01	1.17E+02	7.30E+00	4.50E+01
Mar-68	DUN-5405	1.07E+01	1.19E+02	2.89E+02	9.90E+00	1.21E+02
Apr-68	DUN-5405	9.30E+00	8.72E+01	1.90E+02	1.16E+01	7.40E+01
May-68	DUN-5405	1.25E+01	4.90E+01	2.34E+02	1.02E+01	7.70E+01
Jun-68	DUN-5405	7.10E+00	5.10E+01	1.74E+02	1.19E+01	7.50E+01
Jul-68	DUN-5405	7.30E+00	5.50E+01	1.69E+02	6.80E+00	6.30E+01
Aug-68	DUN-5405	6.60E+00	5.30E+01	1.73E+02	8.00E+00	8.60E+01
Sep-68	DUN-5405	6.80E+00	1.20E+01	5.20E+01	6.50E+00	2.50E+01
Oct-68	DUN-5405	5.20E+00	5.10E+01	1.69E+02	6.50E+00	8.00E+01
Nov-68	DUN-5405	4.90E+00	3.80E+01	1.28E+02	7.80E+00	5.00E+01
Dec-68	DUN-5405	5.40E+00	4.90E+01	1.40E+02	7.20E+00	5.50E+01
Jan-69	DUN-6035	3.30E+00	2.97E+01	6.49E+01	4.90E+00	3.07E+01
Feb-69	DUN-6035	6.00E+00	4.17E+01	1.09E+02	7.90E+00	5.07E+01
Mar-69	DUN-6035	6.90E+00	6.95E+01	7.97E+01	8.50E+00	6.71E+01
Apr-69	DUN-6035	1.05E+01	1.48E+02	1.29E+02	1.34E+01	1.45E+02
May-69	DUN-6035					

DINUT:		Activity released from D reactor																		
DATE	REFERENCE	Na-24	P-32	Ca-45	Sc-46	Mn-56	Cu-64	As-76	Cr-51	Co-60	Zn-65	Zn-69m	Zn-69	Ga-72	Sr-89	Sr-90	Y-90	Y-83	Zr-95	Nb-239
		1.50E+01			2.01E+03	2.59E+00	1.27E+01	2.63E+01					9.33E-01	1.41E+01			6.41E+01	1.02E+01	1.64E+03	5.65E+03
	ACTIVITY/FLO	C/d	C/d	C/d	C/d	C/d	C/d	C/d	C/d	C/d	C/d	C/d	C/d	C/d	C/d	C/d	C/d	C/d	C/d	C/d
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W-47261 RELV
HW-47811

9843/HW-63653
9843/HW-63653

HW-50789
HW-51387

3653/HW-63653
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1.60E+00
9.88E-01
1.44E+00
2.80E+00
2.87E+00
1.70E+00
7.92E-01
1.38E+00
1.47E+00
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1.08E+02
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1.10E+02
7.28E+01
8.92E+01
3.88E+01

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7.90E+00
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1.81E-03
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4.88E-03
2.38E-03

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9.18E-02
3.58E-02
9.23E-02

1.77E-03
1.34E-02
7.20E-03

7.68E+01
1.81E+02
1.34E+02
8.93E+01
7.23E+01
1.03E+02
1.04E+02
1.30E+02
1.38E+02
1.48E+02
9.77E+01
1.01E+02
7.16E+01

A.10

Jul 65	LUN 110	1.20E+00	2.30E+01	8.90E+01	4.20E+00
Aug 65	DUN 110	8.70E+01	2.23E+01	1.06E+02	4.40E+00
Sep 65	DUN 110	1.40E+00	2.20E+01	1.17E+02	3.30E+00
Oct 65	DUN 658	2.00E+00	2.80E+01	1.11E+02	1.80E+00
Nov 65	DUN 658	1.20E+00	1.90E+01	5.00E+01	1.20E+00
Dec 65	DUN 658	3.40E+00	4.50E+01	1.43E+02	6.70E+00
Jan 66	DUN 1035	2.90E+00	2.80E+01	1.27E+02	5.70E+00
Feb 66	DUN 1035	3.80E+00	5.00E+01	1.28E+02	4.90E+00
Mar 66	DUN 1035	4.00E+00	5.40E+01	1.23E+02	5.40E+00
Apr 66	N 1035 SUP1	3.40E+00	5.80E+01	1.51E+02	6.20E+00
May 66	N 1035 SUP1	2.60E+00	3.50E+01	1.45E+02	2.25E+01
Jun 66	N 1035 SUP1	1.90E+00	4.80E+01	1.38E+02	3.80E+00
Jul 66	N 1035 SUP2	5.00E+01	7.00E+00	2.30E+01	1.40E+00
Aug 66	N 1035 SUP2	4.00E+01	7.00E+00	3.90E+01	1.10E+00
Sep 66	N 1035 SUP2	1.40E+00	2.50E+01	1.12E+02	4.80E+00
Oct 66	N 1035 SUP2	1.60E+00	3.30E+01	1.58E+02	7.80E+00
Nov 66	N 1035 SUP2	1.90E+00	1.70E+01	1.15E+02	7.10E+00
Dec 66	N 1035 SUP2	3.50E+00	3.20E+01	1.57E+02	6.70E+00
Jan 67	DUN 5405	3.70E+00	3.10E+01	1.28E+02	8.00E+00
Feb 67	DUN 5405	4.60E+00	2.80E+01	1.38E+02	8.70E+00
Mar 67	DUN 5405	5.90E+00	3.80E+01	1.05E+02	1.08E+01
Apr 67	DUN 5405	6.50E+00	8.50E+01	1.48E+02	9.50E+00
May 67	DUN 5405	1.50E+01	5.80E+01	1.45E+02	8.00E+00
Jun 67	DUN 5405		7.10E+01	3.91E+02	8.50E+00
Jul 67	DUN 5405				

[illegible]

A.13

A.14

[illegible]

Sep-51 4203/HW-32141
Oct-51 4203/HW-32141
Nov-51 4203/HW-32141
Dec-51 4203/HW-32141
Jan-52 5966/HW-32141
Feb-52 5966/HW-32141
Mar-52 5966/HW-32141
Sep-47 HW-27510
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Oct-53 7510/HW-32141
Nov-53 7510/HW-32141
Dec-53 7510/HW-32141
Jan-54 7510/HW-32141

A.17

Jan 61	HW-70735	6.79E+00	1.31E-01	1.70E+00	3.05E+03	2.42E+02	5.59E+01	9.90E+00	2.49E+01	8.41E+01	4.70E-02	7.00E-03	1.29E+01	2.79E+01	8.97E+01
Mar 61	HW-70735	1.50E+01	1.29E-01	2.30E+01	6.08E+03	2.30E+02	2.91E+02	4.74E+02	4.10E+01	2.40E+01	4.60E-02	7.00E-03	1.25E+01	2.72E+01	8.87E+01
Apr 61	HW-70735	1.11E+01	2.07E-01	6.10E+00	7.59E+03	3.10E+02	2.98E+01	9.43E+02	8.90E+01	8.90E+01	4.10E-02	8.00E-03	3.64E+01	1.66E+02	1.78E+01
May 61	HW-70735	4.13E+00	2.42E-01	2.32E+03	4.04E+02	1.71E+01	2.41E+01	3.31E+02	5.57E+01	8.90E+01	4.10E-02	8.00E-03	3.64E+01	1.66E+02	1.78E+01
Jun 61	HW-70735	3.00E+00	3.40E-02	2.68E+03	2.47E+02	1.68E+01	1.46E+02	2.80E+01	4.39E+01	1.11E+02	4.70E-02	1.30E-02	5.39E+01	1.01E+02	4.72E+01
Jul 61	HW-73073	2.60E+00	5.00E-02	1.90E+03	2.20E+02	1.40E+01	1.30E+02	1.30E+02	1.70E+00	5.81E+01	5.10E-02	1.40E-02	8.45E+00	2.99E+01	1.92E+01
Aug 61	HW-73073	2.80E+00	3.30E-01	1.30E+03	3.00E+02	2.20E+01	2.70E+01	2.20E+01	7.20E+00	4.30E+01	1.35E+00	1.00E-02	8.50E+00	3.80E+01	1.70E+01
Sep 61	HW-73073	4.20E+00	3.00E-01	1.50E+03	1.90E+02	2.10E+01	7.90E+02	2.20E+01	5.40E+00	5.90E+01	1.10E+01	3.60E+01	1.10E+01	3.50E+01	2.80E+02
Oct 61	HW-73073	2.50E+00	8.00E-02	9.80E+03	1.90E+02	1.50E+01	1.30E+02	3.50E+00	8.10E+00	8.00E+00	1.10E+01	3.60E+01	3.50E+01	3.80E+01	3.80E+01
Nov 61	HW-73073	3.20E+00	1.90E-01	1.20E+03	2.20E+01	2.90E+01	3.20E+02	3.20E+01	4.00E+00	8.00E+00	1.00E+01	3.60E+01	3.60E+01	3.60E+01	9.30E+01
Dec 61	HW-73073	2.80E+00	3.00E-02	8.40E+02	3.90E+02	2.60E+01	4.30E+02	2.60E+01	2.90E+01	2.60E+01	2.90E+01	2.60E+01	2.60E+01	2.60E+01	6.30E+01
Jan 62	HW-75023	2.40E+00	1.00E-02	6.00E+03	4.10E+02	1.70E+01	1.10E+03	2.60E+01	2.60E+01	2.60E+01	2.90E+01	2.60E+01	2.60E+01	2.60E+01	6.80E+01
Feb 62	HW-75023	2.20E+00	2.00E-02	8.20E+02	2.50E+02	1.20E+01	2.50E+02	9.00E+00	2.60E+01	2.60E+01	2.90E+01	2.60E+01	2.60E+01	2.60E+01	6.80E+01
Mar 62	HW-75023	3.00E+00	4.00E-01	2.10E+04	3.50E+02	4.90E+01	3.30E+03	5.00E+00	1.90E+01	1.90E+01	1.90E+01	1.90E+01	1.90E+01	1.90E+01	5.30E+01
Apr 62	HW-75023	2.90E+02	1.60E+03	2.40E+03	1.90E+02	4.90E+01	1.10E+03	5.70E+01	7.00E+01	1.10E+01	1.10E+01	1.10E+01	1.10E+01	1.10E+01	4.80E+01
May 62	HW-75021	2.30E+00	6.00E-01	2.40E+03	2.40E+02	2.40E+01	1.90E+02	1.90E+02	1.90E+01	1.90E+01	1.90E+01	1.90E+01	1.90E+01	1.90E+01	3.20E+01
Jun 62	HW-75023	2.90E+00	7.20E-01	3.00E+03	2.40E+02	2.40E+01	5.60E+02	3.50E+01	1.50E+01	2.00E+00	2.00E+00	2.00E+00	2.00E+00	2.00E+00	5.60E+01
Jul 62	HW-78103	2.20E+02	1.90E+03	1.80E+03	2.60E+02	1.30E+01	4.80E+02	1.10E+00	3.80E+01	3.20E+01	3.20E+01	3.20E+01	3.20E+01	3.20E+01	5.60E+01
Aug 62	HW-78103	2.80E+02	2.50E+03	3.40E+02	3.40E+02	1.80E+01	7.00E+02	2.20E+01	2.20E+01	2.20E+01	2.20E+01	2.20E+01	2.20E+01	2.20E+01	5.20E+01
Sep 62	HW-78103	2.50E+02	1.60E+03	1.90E+02	1.90E+02	1.30E+01	3.40E+02	1.40E-01	2.20E+01	4.30E+01	4.30E+01	4.30E+01	4.30E+01	4.30E+01	7.00E+01
Oct 62	HW-78894	1.90E+02	2.40E+03	3.40E+03	4.60E+02	1.30E+01	1.50E+02	4.30E-01	1.00E+01	1.00E+01	1.00E+01	1.00E+01	1.00E+01	1.00E+01	2.40E+00
Nov 62	HW-78894	2.60E+00	3.40E+03	3.70E+02	2.00E+01	3.50E+02	3.50E+02	1.70E+00	1.50E+01	1.50E+01	1.50E+01	1.50E+01	1.50E+01	1.50E+01	2.00E-01
Dec 62	HW-78894	2.40E+02	2.40E+03	8.60E+02	1.50E+02	1.50E+01	7.00E+01	4.00E-02	3.40E+00	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.80E+01
Jan 63	HW-77768	1.20E+02	1.80E+00	2.20E+03	3.10E+02	3.80E+01	1.60E+02	4.00E-02	7.30E+00	2.50E+01	2.50E+01	2.50E+01	2.50E+01	2.50E+01	3.00E-01
Feb 63	HW-77768	2.30E+02	3.20E+02	2.20E+03	3.00E+02	6.80E+01	1.60E+02	5.00E-02	4.60E+00	1.90E+01	1.90E+01	1.90E+01	1.90E+01	1.90E+01	1.40E+00
Mar 63	HW-77768	2.80E+02	5.20E+00	3.80E+03	3.00E+02	4.60E+01	1.09E+02	8.00E-02	6.70E+00	2.80E+01	2.80E+01	2.80E+01	2.80E+01	2.80E+01	7.80E+01
Apr 63	HW-78820	2.80E+02	6.00E+00	3.30E+03	2.70E+02	3.70E+01	1.37E+02	7.00E-02	8.60E+00	2.20E+01	2.20E+01	2.20E+01	2.20E+01	2.20E+01	6.00E+01
May 63	HW-78820	2.80E+02	4.50E+00	1.80E+02	1.40E+02	2.70E+01	1.70E+01	8.00E-02	3.50E+00	3.20E+01	3.20E+01	3.20E+01	3.20E+01	3.20E+01	8.00E+01
Jun 63	HW-78820	1.50E+02	3.40E+00	2.40E+03	1.10E+02	2.20E+01	1.90E+01	1.00E-02	2.70E+00	2.60E+01	2.60E+01	2.60E+01	2.60E+01	2.60E+01	2.00E-01
Jul 63	HW-78348	2.10E+02	3.40E+00	2.70E+03	3.00E+02	3.80E+01	2.80E+02	1.00E-01	2.00E+00	3.50E+01	3.50E+01	3.50E+01	3.50E+01	3.50E+01	8.90E+01
Aug 63	HW-78348	2.70E+02	3.80E+00	3.20E+03	3.40E+02	4.80E+01	2.80E+02	2.00E-01	2.20E+00	3.00E+01	3.00E+01	3.00E+01	3.00E+01	3.00E+01	7.50E+01
Sep 63	HW-78348	2.40E+02	4.20E+00	3.20E+03	3.40E+02	5.20E+01	2.50E+02	1.00E-01	2.20E+00	3.80E+01	3.80E+01	3.80E+01	3.80E+01	3.80E+01	6.70E+01
Oct 63	HW-80708	2.40E+02	2.20E+03	2.80E+02	2.80E+02	4.60E+01	2.10E+02	2.00E-01	2.30E+00	4.10E+01	4.10E+01	4.10E+01	4.10E+01	4.10E+01	5.80E+01
Nov 63	HW-80708	2.00E+02	4.30E+00	1.80E+03	2.60E+02	4.80E+01	2.40E+02	1.00E-01	2.50E+00	4.50E+01	4.50E+01	4.50E+01	4.50E+01	4.50E+01	8.20E+01
Dec 63	HW-80708	2.20E+02	4.20E+00	2.90E+02	2.90E+02	5.30E+01	2.40E+02	1.00E-01	2.50E+00	3.00E+01	3.00E+01	3.00E+01	3.00E+01	3.00E+01	8.20E+01
Jan 64	HW-81863	2.80E+02	2.00E+02	2.80E+03	1.60E+02	5.80E+01	2.25E+02	1.00E-01	2.60E+00	3.80E+01	3.80E+01	3.80E+01	3.80E+01	3.80E+01	8.90E+01
Feb 64	HW-81863	2.30E+02	5.90E+00	6.40E+01	3.90E+02	6.40E+01	2.33E+02	1.00E-01	2.90E+00	2.80E+02	2.80E+02	2.80E+02	2.80E+02	2.80E+02	7.50E+01
Mar 64	HW-81863	2.30E+02	6.30E+00	6.30E+01	6.50E+01	1.78E+02	6.50E+01	8.60E+00	2.80E+00	2.80E+00	2.80E+00	2.80E+00	2.80E+00	2.80E+00	1.20E+02
Apr 64	HW-83423	2.70E+02	6.30E+00	6.30E+01	6.50E+01	1.78E+02	6.50E+01	8.60E+00	2.80E+00	2.80E+00	2.80E+00	2.80E+00	2.80E+00	2.80E+00	1.20E+02
May 64	HW-83423	6.50E+00	6.50E+00	6.50E+00	6.50E+00	6.50E+00	6.50E+00	6.50E+00	6.50E+00	6.50E+00	6.50E+00	6.50E+00	6.50E+00	6.50E+00	6.50E+00
Jun 64	HW-83423	3.40E+00	3.40E+00	3.40E+00	3.40E+00	3.40E+00	3.40E+00	3.40E+00	3.40E+00	3.40E+00	3.40E+00	3.40E+00	3.40E+00	3.40E+00	3.40E+00
Jul 64	RL-REA-43	1.30E+00	1.30E+00	1.30E+00	1.30E+00	1.30E+00	1.30E+00	1.30E+00	1.30E+00	1.30E+00	1.30E+00	1.30E+00	1.30E+00	1.30E+00	1.30E+00
Aug 64	RL-REA-43	1.70E+00	1.70E+00	1.70E+00	1.70E+00	1.70E+00	1.70E+00	1.70E+00	1.70E+00	1.70E+00	1.70E+00	1.70E+00	1.70E+00	1.70E+00	1.70E+00
Sep 64	RL-REA-43	1.20E+00	1.20E+00	1.20E+00	1.20E+00	1.20E+00	1.20E+00	1.20E+00	1.20E+00	1.20E+00	1.20E+00	1.20E+00	1.20E+00	1.20E+00	1.20E+00
Oct 64	RL-REA-438	1.80E+00	1.80E+00	1.80E+00	1.80E+00	1.80E+00	1.80E+00	1.80E+00	1.80E+00	1.80E+00	1.80E+00	1.80E+00	1.80E+00	1.80E+00	1.80E+00
Nov 64	RL-REA-438	3.30E+00	3.30E+00	3.30E+00	3.30E+00	3.30E+00	3.30E+00	3.30E+00	3.30E+00	3.30E+00	3.30E+00	3.30E+00	3.30E+00	3.30E+00	3.30E+00
Dec 64	RL-REA-438	7.90E+00	7.90E+00	7.90E+00	7.90E+00	7.90E+00	7.90E+00	7.90E+00	7.90E+00	7.90E+00	7.90E+00	7.90E+00	7.90E+00	7.90E+00	7.90E+00
Jan 65	RL-REA-2028	4.10E+00	4.10E+00	4.10E+00	4.10E+00	4.10E+00	4.10E+00	4.10E+00	4.10E+00	4.10E+00	4.10E+00	4.10E+00	4.10E+00	4.10E+00	4.10E+00
Feb 65	RL-REA-2028	1.33E+01	1.33E+01	1.33E+01	1.33E+01	1.33E+01	1.33E+01	1.33E+01	1.33E+01	1.33E+01	1.33E+01	1.33E+01	1.33E+01	1.33E+01	1.33E+01
Mar 65	RL-REA-2028	1.51E+01	1.51E+01	1.51E+01	1.51E+01	1.51E+01	1.51E+01	1.51E+01	1.51E+01	1.51E+01	1.51E+01	1.51E+01	1.51E+01	1.51E+01	1.51E+01
Apr 65	RL-REA-2428	8.90E+00	8.90E+00	8.90E+00	8.90E+00	8.90E+00	8.90E+00	8.90E+00	8.90E+00	8.90E+00	8.90E+00	8.90E+00	8.90E+00	8.90E+00	8.90E+00
May 65	RL-REA-2428	4.40E+00	4.40E+00	4.40E+00	4.40E+00	4.40E+00	4.40E+00	4.40E+00	4.40E+00	4.40E+00	4.40E+00	4.40E+00	4.40E+00	4.40E+00	4.40E+00
Jun 65	RL-REA-2428	6.00E+01	6.00E+01	6.00E+01	6.00E+01	6.00E+01	6.00E+01	6.00E+01	6.00E+01	6.00E+01	6.00E+01	6.00E+01	6.00E+01	6.00E+01	6.00E+01
Jul 65	RL-REA-2428	7.30E+01	7.30E+01	7.30E+01	7.30E+01	7.30E+01	7.30E+01	7.30E+01	7.30E+01	7.30E+01	7.30E+01	7.30E+01	7.30E+01	7.30E+01	7.30E+01
Aug 65	RL-REA-2428	7.40E+01	7.40E+01	7.40E+01	7.40E+01	7.40E+01	7.40E+01	7.40E+01	7.40E+01	7.40E+01	7.40E+01	7.40E+01	7.40E+01	7.40E+01	7.40E+01
Sep 65	RL-REA-2428	6.00E+01	6.00E+01	6.00E+01	6.00E+01	6.00E+01	6.00E+01	6.00E+01	6.00E+01	6.00E+01	6.00E+01	6.00E+01	6.00E+01	6.00E+01	6.00E+01

INPUT DATE	REF/HEN/EN-1	Activity released from H reactor		Ca-45	Sc-46	Mn-56	Cu-64	As-76	Cr-51	Co-60	Zn-65	Zn-69	Zn-69m	Ga-72	Sr-89	Sr-90	Y-90	Y-83	Zr-85	Nb-239
		Na-24	F-32																	
	ACTIVITY/FLO	C/d	C/d	C/d	C/d	C/d	C/d	C/d	C/d	C/d	C/d	C/d	C/d	C/d	C/d	C/d	C/d	C/d	C/d	C/d
Oct-49	HW-170C3																			
Nov-49	HW-170C3																			
Dec-49	HW-170C3																			
Oct-51	4203/HW-32141																			
Nov-51	4203/HW-32141																			
Dec-51	4203/HW-32141																			
Jan-52	5866/HW-32141																			
Feb-52	5866/HW-32141																			
Mar-52	5866/HW-32141																			
Oct-49	HW-27510																			
Nov-49	HW-27510																			
Dec-49	HW-27510																			
Jan-50	HW-27510																			
Feb-50	HW-27510																			
Mar-50	HW-27510																			
Apr-50	HW-27510																			
May-50	HW-27510																			
Jun-50	HW-27510																			
Jul-50	HW-27510																			
Aug-50	HW-27510																			
Sep-50	HW-27510																			
Oct-50	HW-27510																			
Nov-50	HW-27510																			
Dec-50	HW-27510																			
Jan-51	7510/HW-32141																			
Feb-51	7510/HW-32141																			
Mar-51	7510/HW-32141																			
Apr-51	7510/HW-32141																			
May-51	7510/HW-32141																			
Jun-51	7510/HW-32141																			
Jul-51	7510/HW-32141																			
Aug-51	7510/HW-32141																			
Sep-51	7510/HW-32141																			
Oct-51	7510/HW-32141																			
Nov-51	7510/HW-32141																			
Dec-51	7510/HW-32141																			
Jan-52	7510/HW-32141																			
Feb-52	7510/HW-32141																			
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Apr-52	7510/HW-32141																			
May-52	7510/HW-32141																			
Jun-52	7510/HW-32141																			
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[illegible]

Oct 61	HW 7307/3	4.80E+02	4.90E+00	1.00E-01	2.60E+03	4.60E+02	3.80E+01	4.50E+02	3.80E+00	1.40E+01	4.20E+01	1.10E+01	3.20E+01	8.00E+00	3.80E+01
Nov 61	HW 7307/3	5.50E+02	6.90E+00	4.00E-02	2.35E+03	2.60E+02	4.50E+01	4.20E+02	8.00E+00	2.60E+01	3.20E+01	8.00E+00	5.20E+01	6.00E+00	5.70E+01
Dec 61	HW 7307/3	7.30E+02	9.50E+00	4.90E-01	3.00E+03	2.50E+02	4.70E+01	6.20E+02	8.00E+00	2.60E+01	3.20E+01	9.10E+00	4.30E+01	7.40E+01	7.40E+01
Jan 62	HW 7502/3	9.80E+02	1.40E+01	4.70E-01	5.20E+03	8.80E+02	6.80E+01	8.70E+02	6.80E+01	4.10E+01	3.10E+01	1.20E+01	3.90E+01	1.50E+01	1.10E+02
Feb 62	HW 7502/3	1.10E+03	1.93E+01	6.50E-01	9.60E+03	1.40E+03	1.50E+02	7.20E+02	3.50E+01	8.20E+01	3.50E+01	3.90E+01	2.40E+02	2.80E+02	2.80E+02
Mar 62	HW 7502/3	1.40E+03	1.80E+01	5.40E-01	4.50E+04	1.80E+02	1.20E+02	1.60E+03	9.00E+01	1.60E+02	4.40E+01	3.70E+01	1.10E+02	2.20E+02	2.20E+02
May 62	HW 7502/3	1.00E+03	1.60E+01	2.20E+00	1.00E+04	1.00E+03	5.90E+01	1.40E+03	2.20E+01	9.00E+01	7.20E+00	8.60E+01	2.70E+02	2.20E+02	2.20E+02
Jun 62	HW 7502/3	1.60E+03	1.20E+01	1.10E-01	2.50E+04	7.80E+02	4.80E+01	6.30E+03	1.60E-01	2.20E+01	4.20E+01	2.70E+00	8.10E+01	5.60E+01	5.60E+01
Jul 62	HW 7810/3	6.70E+02	9.10E+00	6.60E+03	3.50E+01	3.50E+02	2.50E+01	3.50E+02	1.80E+01	1.10E+01	4.20E+01	1.40E+02	1.20E+01	3.70E+00	3.70E+00
Aug 62	HW 7810/3	8.10E+02	1.23E+01	6.40E+03	5.30E+02	4.00E+01	4.00E+01	6.30E+02	2.10E-01	1.20E+01	1.50E+02	1.40E+02	1.50E+02	3.20E+00	3.20E+00
Sep 62	HW 7810/3	7.80E+02	1.15E+01	5.50E+03	4.00E+02	3.80E+01	3.80E+01	3.30E+02	2.10E-01	2.30E+01	8.30E+01	1.40E+02	8.30E+01	2.80E+00	2.80E+00
Oct 62	HW 7898/4	7.20E+02	8.80E+00	4.50E+03	9.50E+02	4.10E+01	4.10E+01	4.60E+02	6.00E-02	1.40E+01	6.90E+01	1.40E+01	6.90E+01	1.80E+01	1.80E+01
Nov 62	HW 7898/4	3.80E+02	4.30E+00	6.40E+02	2.50E+02	2.60E+01	2.60E+01	7.60E+02	4.80E-01	2.70E+01	1.60E+01	1.60E+01	1.60E+01	9.10E-01	9.10E-01
Dec 62	HW 7898/4	4.80E+02	1.00E+01	4.20E+03	1.20E+03	3.70E+01	3.70E+01	3.80E+02	8.00E-02	2.30E+01	4.50E+01	4.50E+01	4.50E+01	8.00E-01	8.00E-01
Jan 63	HW 7776/8	6.00E+02	1.10E+01	3.77E+02	4.70E+01	3.50E+01	3.50E+01	2.60E+02	3.00E+02	1.40E+01	3.50E+01	3.50E+01	3.50E+01	3.00E+00	3.00E+00
Feb 63	HW 7776/8	8.80E+02	8.10E+00	2.60E+03	2.60E+02	3.20E+01	3.20E+01	3.10E+02	8.00E-02	2.30E+01	4.50E+01	4.50E+01	4.50E+01	8.00E-01	8.00E-01
Mar 63	HW 7776/8	6.00E+02	1.20E+01	7.80E+03	6.10E+02	1.08E+02	1.08E+02	4.44E+02	2.00E-01	9.00E+00	3.50E+01	3.50E+01	3.50E+01	3.00E+00	3.00E+00
Apr 63	HW 7882/0	8.00E+02	1.20E+01	3.90E+03	4.10E+02	1.70E+02	1.70E+02	5.70E+01	6.00E-02	1.42E+01	4.50E+01	4.50E+01	4.50E+01	3.00E-01	3.00E-01
May 63	HW 7882/0	5.80E+02	1.04E+01	7.00E+03	1.30E+02	3.40E+01	3.40E+01	2.10E+02	1.20E-01	8.00E+00	3.90E+01	3.90E+01	3.90E+01	2.70E+00	2.70E+00
Jun 63	HW 7834/8	5.10E+02	6.20E+00	6.90E+03	2.00E+02	3.80E+01	3.80E+01	2.90E+02	2.00E-01	7.60E+00	6.90E+01	6.90E+01	6.90E+01	2.00E-01	2.00E-01
Jul 63	HW 7834/8	6.10E+02	7.20E+00	7.30E+03	5.20E+02	3.40E+01	3.40E+01	2.80E+02	2.00E-01	2.80E+00	6.00E+01	6.00E+01	6.00E+01	1.00E-01	1.00E-01
Sep 63	HW 7834/8	2.80E+02	2.10E+00	2.70E+03	1.40E+02	1.10E+01	1.10E+01	1.10E+02	2.00E-01	2.80E+00	4.00E+01	4.00E+01	4.00E+01	3.00E+01	3.00E+01
Oct 63	HW 8070/8	2.70E+02	2.30E+00	2.40E+03	1.10E+02	1.30E+01	1.30E+01	1.10E+02	1.00E+00	2.50E+00	4.00E+01	4.00E+01	4.00E+01	8.10E-01	8.10E-01
Nov 63	HW 8070/8	4.60E+02	3.50E+00	2.10E+03	2.90E+02	1.80E+01	1.80E+01	1.40E+02	2.05E-01	4.20E+00	5.60E+01	5.60E+01	5.60E+01	3.80E+01	3.80E+01
Dec 63	HW 8070/8	5.20E+02	5.20E+00	2.30E+03	3.00E+02	3.40E+01	3.40E+01	1.80E+02	1.00E-01	2.20E+00	8.00E+00	8.00E+00	8.00E+00	6.00E+01	6.00E+01
Jan 64	HW 8198/3	6.90E+02	5.90E+00	2.10E+03	7.00E+01	4.80E+01	4.80E+01	2.18E+02	1.00E-01	4.80E+00	3.80E+01	3.80E+01	3.80E+01	1.20E+01	1.20E+01
Feb 64	HW 8198/3	1.60E+02	1.70E+00	3.00E+02	2.00E+02	8.00E+00	8.00E+00	2.80E+01	1.00E-01	2.80E+00	8.00E+00	8.00E+00	8.00E+00	6.00E+01	6.00E+01
Mar 64	HW 8198/3	1.01E+01	1.01E+01	3.20E+03	4.44E+02	4.50E+01	4.50E+01	1.10E+02	1.12E+01	1.12E+01	3.20E+01	3.20E+01	3.20E+01	1.40E+01	1.40E+01
Apr 64	HW 8342/3	9.40E+00	9.00E+00	4.00E+02	1.10E+02	3.40E+01	3.40E+01	1.20E+02	1.07E+01	1.07E+01	4.00E+01	4.00E+01	4.00E+01	5.00E+01	5.00E+01
May 64	HW 8342/3	9.00E+00	9.00E+00	5.60E+02	1.10E+02	2.60E+01	2.60E+01	1.10E+02	4.60E+00	4.60E+00	5.00E+01	5.00E+01	5.00E+01	4.00E+01	4.00E+01
Jun 64	HW 8342/3	4.20E+00	4.20E+00	4.20E+00	1.20E+02	2.70E+01	2.70E+01	1.20E+02	2.80E+00	2.80E+00	4.00E+01	4.00E+01	4.00E+01	3.00E+01	3.00E+01
Jul 64	RL-REA-43	4.20E+00	4.20E+00	4.20E+00	1.20E+02	1.90E+01	1.90E+01	6.00E+01	6.10E+00	6.10E+00	4.00E+01	4.00E+01	4.00E+01	3.00E+01	3.00E+01
Aug 64	RL-REA-43	3.50E+00	3.50E+00	4.20E+00	1.20E+02	6.50E+01	6.50E+01	1.20E+02	5.00E+00	5.00E+00	4.00E+01	4.00E+01	4.00E+01	3.00E+01	3.00E+01
Sep 64	RL-REA-43	3.30E+00	3.30E+00	4.20E+00	1.20E+02	6.30E+01	6.30E+01	1.40E+02	8.00E+00	8.00E+00	4.00E+01	4.00E+01	4.00E+01	3.00E+01	3.00E+01
Oct 64	IL-REA-488	6.40E+00	6.40E+00	4.20E+00	1.20E+02	3.80E+01	3.80E+01	1.30E+02	8.00E+00	8.00E+00	4.00E+01	4.00E+01	4.00E+01	3.00E+01	3.00E+01
Nov 64	IL-REA-488	7.60E+00	7.60E+00	4.20E+00	1.20E+02	2.30E+01	2.30E+01	1.30E+02	8.30E+00	8.30E+00	4.00E+01	4.00E+01	4.00E+01	3.00E+01	3.00E+01
Dec 64	IL-REA-488	6.70E+00	6.70E+00	4.20E+00	1.20E+02	1.60E+01	1.60E+01	1.20E+02	1.00E+01	1.00E+01	4.00E+01	4.00E+01	4.00E+01	3.00E+01	3.00E+01
Jan 65	RL-REA-2028	7.20E+00	7.20E+00	4.20E+00	1.20E+02	3.40E+01	3.40E+01	1.30E+02	9.00E+00	9.00E+00	4.00E+01	4.00E+01	4.00E+01	3.00E+01	3.00E+01
Feb 65	RL-REA-2028	5.40E+00	5.40E+00	4.20E+00	1.20E+02	4.80E+01	4.80E+01	1.12E+02	1.10E+01	1.10E+01	4.00E+01	4.00E+01	4.00E+01	3.00E+01	3.00E+01
Mar 65	RL-REA-2028	8.20E+00	8.20E+00	4.20E+00	1.20E+02	5.60E+01	5.60E+01	1.53E+02	7.10E+00	7.10E+00	4.00E+01	4.00E+01	4.00E+01	3.00E+01	3.00E+01
Apr 65	FL-REA-2428	8.30E+00	8.30E+00	4.20E+00	1.20E+02	4.60E+01	4.60E+01	1.07E+02	6.10E+00	6.10E+00	4.00E+01	4.00E+01	4.00E+01	3.00E+01	3.00E+01
May 65	FL-REA-2428	7.60E+00	7.60E+00	4.20E+00	1.20E+02	2.90E+01	2.90E+01	1.05E+02	4.90E+00	4.90E+00	4.00E+01	4.00E+01	4.00E+01	3.00E+01	3.00E+01
Jun 65	FL-REA-2428	7.90E+00	7.90E+00	4.20E+00	1.20E+02	5.10E+01	5.10E+01	1.28E+02	2.40E+00	2.40E+00	4.00E+01	4.00E+01	4.00E+01	3.00E+01	3.00E+01
Jul 65	DUN-110	6.40E+00	6.40E+00	4.20E+00	1.20E+02	8.00E+01	8.00E+01	1.33E+02	3.60E+00	3.60E+00	4.00E+01	4.00E+01	4.00E+01	3.00E+01	3.00E+01
Aug 65	DUN-110	6.40E+00	6.40E+00	4.20E+00	1.20E+02	5.00E+01	5.00E+01	1.27E+02	8.70E+00	8.70E+00	4.00E+01	4.00E+01	4.00E+01	3.00E+01	3.00E+01
Sep 65	DUN-110	5.90E+00	5.90E+00	4.20E+00	1.20E+02	3.30E+01	3.30E+01	1.17E+02	4.80E+00	4.80E+00	4.00E+01	4.00E+01	4.00E+01	3.00E+01	3.00E+01
Oct 65	DUN-858	7.00E+00	7.00E+00	4.20E+00	1.20E+02	5.20E+01	5.20E+01	1.16E+02	5.00E+00	5.00E+00	4.00E+01	4.00E+01	4.00E+01	3.00E+01	3.00E+01
Nov 65	DUN-858	6.90E+00	6.90E+00	4.20E+00	1.20E+02	6.80E+01	6.80E+01	1.17E+02	7.40E+00	7.40E+00	4.00E+01	4.00E+01	4.00E+01	3.00E+01	3.00E+01
Dec 65	DUN-1035	6.60E+00	6.60E+00	4.20E+00	1.20E+02	4.60E+01	4.60E+01	1.17E+02	9.20E+00	9.20E+00	4.00E+01	4.00E+01	4.00E+01	3.00E+01	3.00E+01
Jan 66	DUN-1035	9.00E+00	9.00E+00	4.20E+00	1.20E+02	6.90E+01	6.90E+01	1.00E+02	7.10E+00	7.10E+00	4.00E+01	4.00E+01	4.00E+01	3.00E+01	3.00E+01
Feb 66	DUN-1035	6.60E+00	6.60E+00	4.20E+00	1.20E+02	2.10E+03	2.10E+03	1.45E+02	1.60E+00	1.60E+00	4.00E+01	4.00E+01	4.00E+01	3.00E+01	3.00E+01
Mar 66	DUN-1035	6.60E+00	6.60E+00	4.20E+00	1.20E+02	4.80E+01	4.80E+01	1.45E+02	1.60E+00	1.60E+00	4.00E+01	4.00E+01	4.00E+01	3.00E+01	3.00E+01
Apr 66	N 1035 SUP1	7.90E+00	7.90E+00	4.20E+00	1.20E+02	1.70E+01	1.70E+01	3.20E+01	1.60E+00	1.60E+00	4.00E+01	4.00E+01	4.00E+01	3.00E+01	3.00E+01
May 66	N 1035 SUP1	3.30E+00	3.30E+00	4.20E+00	1.20E+02	4.80E+01	4.80E+01	1.40E+01	1.40E+00	1.40E+00	4.00E+01	4.00E+01	4.00E+01	3.00E+01	3.00E+01
Jun 66	N 1035 SUP1	4.80E+00	4.80E+00	4.20E+00	1.20E+02	5.10E+01	5.10E+01	1.28E+02	9.80E+00	9.80E+00	4.00E+01	4.00E+01	4.00E+01	3.00E+01	3.00E+01
Jul 66	N 1035 SUP2	1.10E+00	1.10E+00	4.20E+00	1.20E+02	6.10E+01	6.10E+01	1.28E+02	3.80E+00	3.80E+00	4.00E+01	4.00E+01	4.00E+01	3.00E+01	3.00E+01
Aug 66	N 1035 SUP2	7.00E+01	7.00E+01	4.20E+00	1.20E+02	3.40E+01	3.40E+01	6.80E+01	7.50E+00	7.50E+00	4.00E+01	4.00E+01	4.00E+01	3.00E+01	3.00E+01
Sep 66	N 1035 SUP2	6.80E+00	6.80E+00	4.20E+00	1.20E+02	4.80E+01	4.80E+01	1.43E+02	9.30E+00	9.30E+00	4.00E+01	4.00E+01	4.00E+01	3.00E+01	3.00E+01
Oct 66	N 1035 SUP3	2.50E+00	2.50E+00	4.20E+00	1.20E+02	4.80E+01	4.80E+01	1.25E+02	1.11E+03	1.11E+03	4.00E+01	4.00E+01	4.00E+01	3.00E+01	3.00E+01
Nov 66	N 1035 SUP3	7.20E+00	7.20E+00	4.20E+00											

Oct-68	DUN-5405	8.00E+00	1.11E+02	1.26E+02	8.20E+00	1.22E+02
Nov-68	DUN-5405	6.80E+00	7.60E+01	1.05E+02	8.00E+00	8.90E+01
Dec-68	DUN-5405	7.00E+00	7.40E+01	1.05E+02	8.00E+00	8.50E+01
Jan-69	DUN-6035	5.10E+00	6.41E+01	7.63E+01	9.30E+00	6.48E+01
Feb-69	DUN-6035	8.10E+00	8.86E+01	7.86E+01	1.18E+01	7.18E+01
Mar-69	DUN-6035	1.00E+01	9.60E+01	8.81E+01	1.18E+01	9.50E+01
Apr-69	DUN-6035	2.80E+00	3.08E+01	2.55E+01	3.50E+00	1.83E+01
May-69	DUN-6035	4.20E+00	1.36E+02	4.20E+00	1.02E+01	8.92E+01
Jun-69	DUN-6035	4.40E+00	1.08E+02	1.41E+02	8.00E+00	1.08E+02
Jul-69	DUN-6031	4.27E+00	5.52E+01	4.90E+01	5.20E+00	3.75E+01
Aug-69	DUN-6031	5.40E+00	5.26E+01	6.59E+01	7.80E+00	5.10E+01
Sep-69	DUN-6031	5.30E+00	8.41E+01	8.18E+01	3.60E+00	6.68E+01
Oct-69	DUN-6031	3.60E+00	5.37E+01	4.83E+01	5.40E+00	2.45E+01
Nov-69	DUN-6031	3.50E+00	4.62E+01	4.90E+01	5.90E+00	2.12E+01
Dec-69	DUN-6031	3.60E+00	5.98E+01	8.81E+01	7.20E+00	3.05E+01
Jan-70	DUN-7211	2.17E+00	3.78E+01	7.87E+01	1.27E+01	4.50E+01
Feb-70	DUN-7211		0.00E+00			
Mar-70	DUN-7211	1.07E+00	1.23E+01	1.39E+01	8.70E+00	8.30E+00
Apr-70	DUN-7211	5.45E+00	8.03E+01	8.13E+01	9.90E+00	4.82E+01
May-70	DUN-7211	1.98E+00	4.61E+01	5.77E+01	8.90E+00	5.33E+01
Jun-70	DUN-7211	1.14E+00	2.75E+01	7.05E+01	8.90E+00	8.86E+01
Jul-70						
Aug-70						
Sep-70						
Oct-70						
Nov-70						
Dec-70						
Jan-71						

KWINPUT	REFERENCE	ACTIVITY/FLO	Op-24	P-32	Ca-45	Sc-46	Mn-56	Cu-64	As-76	Cr-51	Co-60	Zn-65	Zn-69	Zn-69m	Ga-72	Si-89	Si-90	Y-93	Y-90	Zr-95	Np-239
DATE			1.50E+01	Cld	Cld	2.01E+03	Cld	Cld	2.63E+01	Cld	Cld	Cld	Cld	Cld	1.41E+01	Cld	Cld	Cld	6.41E+01	1.54E+03	Cld
Jan-55																					
Feb-55																					
Mar-55																					
Apr-55																					
May-55																					
Jun-55																					
Jul-55																					
Aug-55																					
Sep-55																					
Oct-55																					
Nov-55																					
Dec-55																					
Jan-56	HW-45092						2.29E+00														
Feb-56	HW-45092						4.43E+00														
Mar-56	HW-45092						5.65E+00														
Apr-56	HW-45092						4.50E+00														
May-56	HW-45092						2.48E+00														
Jun-56	HW-46709						2.08E+00														
Jul-56	HW-46709						1.9CZ+00														
Aug-56	HW-46709						1.48E+00														
Sep-56	W-47261 REV						1.35E+00														
Oct-56	HW-47811						9.27E-01														
Nov-56																					
Dec-56																					
Jan-57	9842/HW-63653						1.29E+01														
Feb-57	9842/HW-63653						7.23E+00														
Mar-57	9842/HW-63653						9.32E+00														
Apr-57	HW-50769						3.84E+00														
May-57	HW-51397						3.82E+00														
Jun-57	3653/HW-63653						2.00E+00														
Jul-57	3653/HW-63653						1.79E+01														
Aug-57	3653/HW-63653						1.73E+01														
Sep-57	3653/HW-63653						1.25E+00														
Oct-57	3653/HW-63653						1.38E+00														
Nov-57	3653/HW-63653						1.71E+00														
Dec-57	3653/HW-63653						9.42E+00														
Jan-58	3653/HW-63653						2.82E+00														
Feb-58	3653/HW-63653						6.35E+00														
Mar-58	3653/HW-63653						1.65E+00														
Apr-58	3653/HW-63653						2.85E+00														
May-58	3653/HW-63653						3.24E+00														
Jun-58	3653/HW-63653						1.50E+01														
Jul-58	4552/HW-8						1.05E+00														
Aug-58	4552/HW-8						1.41E+00														
Sep-58	4552/HW-8						3.98E+01														
Oct-58	4552/HW-8						3.80E+01														
Nov-58	4552/HW-8						3.80E+01														
Dec-58	4552/HW-8						3.80E+01														
Jan-59	4552/HW-8						3.80E+01														
Feb-59	4552/HW-8						3.80E+01														
Mar-59	4552/HW-8						3.80E+01														
Apr-59	4552/HW-8						3.80E+01														
May-59	4552/HW-8						3.80E+01														
Jun-59	4552/HW-8						3.80E+01														
Jul-59	4552/HW-8						3.80E+01														
Aug-59	4552/HW-8						3.80E+01														
Sep-59	4552/HW-8						3.80E+01														
Oct-59	4552/HW-8						3.80E+01														
Nov-59	4552/HW-8						3.80E+01														
Dec-59	4552/HW-8						3.80E+01														
Jan-60	HW-64824						9.00E+02														
Feb-60	HW-64824						8.10E+02														
Mar-60	HW-64824						8.10E+02														
Apr-60	HW-64824						8.10E+02														
May-60	HW-70733						5.37E-01														
Jun-60	HW-70733						5.37E-01														
Jul-60	HW-70733						5.37E-01														
Aug-60	HW-70733						5.37E-01														
Sep-60	HW-70733						5.37E-01														
Oct-60	HW-70733						5.37E-01														
Nov-60	HW-70733						5.37E-01														
Dec-60	HW-70733						5.37E-01														
Jan-61	HW-70733						5.37E-01														
Feb-61	HW-70733						5.37E-01														
Mar-61	HW-70733						5.37E-01														
Apr-61	HW-70733						5.37E-01														
May-61	HW-70733						5.37E-01														
Jun-61	HW-70733						5.37E-01														

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Jul-68	DUN-5405	1.50E+00	4.00E+00	3.90E+01	5.10E+00	1.30E+01
Aug-68	DUN-5405	1.14E+01	8.60E+01	2.03E+02	6.70E+00	1.41E+02
Sep-68	DUN-5405	1.21E+01	7.80E+01	2.06E+02	3.00E+00	1.68E+02
Oct-68	DUN-5405	5.40E+00	4.80E+01	1.09E+02	5.60E+00	6.10E+01
Nov-68	DUN-5405	4.80E+00	7.00E+01	1.52E+02	5.60E+00	1.16E+02
Dec-68	DUN-5405	6.60E+00	7.50E+01	1.40E+02	4.40E+00	1.15E+02
Jan-69	DUN-5405	8.50E+00	8.59E+01	1.35E+02	6.60E+00	9.31E+01
Feb-69	DUN-6035	9.70E+00	8.57E+01	9.48E+01	8.50E+00	8.22E+01
Mar-69	DUN-6035	1.31E+01	1.16E+02	1.12E+02	8.90E+00	1.08E+02
Apr-69	DUN-6035	1.65E+01	1.74E+02	1.86E+02	1.39E+01	1.89E+02
May-69	DUN-6035	9.10E+00	1.08E+02	8.10E+00	9.50E+00	1.09E+02
Jun-69	DUN-6035	9.60E+00	1.02E+02	1.47E+02	9.50E+00	9.99E+01
Jul-69	DUN-6035	8.60E+00	8.88E+01	1.18E+02	5.50E+00	7.23E+01
Aug-69	DUN-6035	1.06E+01	7.91E+01	1.25E+02	8.70E+00	7.44E+01
Sep-69	DUN-6035	4.30E+00	3.95E+01	8.64E+01	8.70E+00	6.39E+01
Oct-69	DUN-6035	4.10E+00	8.47E+01	5.87E+01	8.40E+00	3.78E+01
Nov-69	DUN-6035	3.00E+00	6.70E+01	8.77E+01	5.90E+00	3.89E+01
Dec-69	DUN-6035	1.10E+01	8.09E+01	1.05E+02	9.80E+00	4.93E+01
Jan-70	DUN-7211	2.74E+00	4.84E+01	7.70E+01	9.40E+00	5.20E+01
Feb-70						

APPENDIX B

SUMMARY OF HISTORICAL DOSE ESTIMATES

APPENDIX B

SUMMARY OF HISTORICAL DOSE ESTIMATES

RIVER PATHWAY DOSES OVER THE HISTORY OF HANFORD

To evaluate the importance of Columbia River exposure pathways relative to all exposure pathways and to present dose limits, the doses from Columbia River exposure pathways were abstracted from past Hanford Site annual reports (see "Bibliography of Hanford Annual Reports"). Hanford-generated radionuclides in the Columbia River resulted from effluent releases of the "once-through" reactors located along the river. The term "once-through" refers to the use of Columbia River water as a reactor coolant, which passed through the reactor once before its release back into the river.

Dose estimates are provided for the years 1956 to 1972. Doses for offsite individuals were not reported in a format consistent with the current understanding of radiation dosimetry until 1956. This was primarily the result of the invention of spectroscopy equipment that could resolve the individual radionuclides found in environmental samples. The last once-through reactor was retired in 1971.

The annual reports were reviewed to determine the doses resulting from Columbia River pathways. Doses were initially reported as the dose to the maximally exposed individual. Later reports added typical or average individuals. In order to refine the dose estimates, dietary and exposure assumptions were re-evaluated in years subsequent to the first dose estimate report. Highlights of the evolution of Hanford's environmental dosimetry and the data summarized in the table are outlined below.

Representative individuals: Until 1960, only maximum individual (MI) doses were reported. Until 1967, a "typical" (or, alternatively phrased, "average") individual dose was reported in addition to the MI dose. These pre-1987 individuals were listed as "average" or "typical" in the table to distinguish them from the more rigorously defined average and typical post-1967 individuals. A Tri-Cities dietary survey conducted in the mid-1960s prompted the more rigorous definition.

- **Bone dosimetry:** Early bone dosimetry and the concept of a committed dose were not clearly understood. The lack of confidence in the early bone dose calculations prompted the reporting of bone doses as percentage of the Maximum Permissible Rate of Intake (MPRI). MPRI's were based on the dose to the skeletal bone (i.e., the bone without the marrow, according to J. Soldat). The first year in which bone doses were not reported as %MPRI was 1968. Also, in relation to bone dosimetry, bone dose calculations may have included a modifying factor of $n=5$ for all internally deposited beta and alpha radiations, except for phosphorous-32 and radium. For many years, it's unclear when the $n=5$ was used. The important bone-seekers of Hanford are phosphorous-32 and zinc-65, plus fallout strontium-90. The MPRI is roughly equivalent to a committed dose. [In the early days, the MPRI for phosphorous-32 was $16 \mu\text{Ci/y}$. Assuming this intake rate and using ICRP-30 dose conversion factors (DCFs), the dose would be 468 mrem--much lower than the 3000 mrem dose the MPRI was thought to represent.]
- **MI doses:** The Columbia River pathway doses presented here do not exactly parallel the MI doses of the annual reports. This summary document presents the maximum doses from each pathway that were reported in the annual report. In some cases, the intake defined for the MI was not the highest intake evaluated. For example, consumption of Willapa Bay oysters is assumed to be highest on coastal areas. The annual report assumes a Tri-Cities MI did not consume the oysters at this same high rate. In these cases, the annual report evaluates the dose to the coastal individual, but reports a lower dose (as a result of a lower consumption rate) for the reported MI. This document, however, reports the coastal individual's dose from oyster consumption under the heading of the MI dose. Other inconsistencies in the reported MI dose and the MI dose listed in this document are for the external exposure pathway (the MI fisherman and MI teenager are not the same creature) and the drinking water pathway (the MI in the table always consumes, the most contaminated sanitary drinking water).
- **Reported doses:** In some cases, the doses from a specific pathway were not overtly stated in the annual report. Some of these pathway doses could be back-calculated from related measurements reported in the documents. At other times, the dose might be approximated from graphics. Hash marks indicate where these methods failed to produce a dose estimate for a specific pathway. The dose of the final years reported were so low that the dose contributions from specific Columbia River pathways were not readily discernable. Therefore, only the low doses from all pathways (river and air) were tabulated.
- **Fish and fowl:** Early reports calculated fish doses from whitefish radionuclide concentrations. Later fish doses were calculated from a weighting of various panfish (crappie, perch, and bass [1:1:6]). Early fowl doses were calculated from radionuclide concentrations in ducks. Later fowl doses considered the consumption of a variety of fowl.

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SUMMARY OF RIVER PATHWAY DOSES CALCULATED OVER THE HISTORY OF HANFORD^(a)

Year	Operating Reactors	Applicable Dose Limits	Doses from the River Pathway (mrem)	River Exposure Parameters	Events of Interest	Comments
1944	B D					
1945	B D F					
1949	B D F H					
1950	B D DR F H					
1952	B C D DR F H					
1955	B C D DR F H AE NW					
1956	B C D DR F H AE NW			DW: intake of "standard man," may assume 2200 ml/d		-DW doses calculated from the quantities released rather than water measurements.
1957	B C D DR F H AE NW	Annual maximum: 500 mrem WB or gonads 1500 mrem other tissues	M1(b) Bone Raw DW 40-50 Thyroid -25 GI 80-90 M1(b) Bone Raw DW 40-50 Thyroid 25-35 GI 290-310 Fish 290-310 --- 85-100 Wf1 370-385 --- 115-125 101 -720 -30 -510	DW: intake of "standard man," may assume 2200 ml/d Fish: 200 g/wk during Jan. Feb., Oct., Nov., Dec. Wf1: 250 g of duck		-Columbia River source of most of the environmental exposure resulting from Hanford Operations. -Doses include fallout. -DW doses calculated from the quantities released. -Foods irrigated by Columbia River water contribute < 1% of the maximum permissible dose to any organ.

(a) Abbreviations

DW drinking water, sanitary water
 ext. external exposure to radionuclides in the Columbia River
 F ext. fisherman's external exposure to radionuclides in the Columbia River
 F or fish fresh Columbia River fish, typically whitefish
 GI gastrointestinal tract
 M1 maximum individual
 M1 maximum individual
 Oysters Pacific coast oysters
 T test Richland teenager's external exposure to radionuclides in the Columbia River
 Tot. total
 WB whole body

(b) Wf1 waterfowl or wildfowl, typically duck in early years, later a mixture of land- and waterfowl
 Dose, presented as percent of the Maximum Permissible Rate of Intake and are roughly equivalent to a 50-year committed dose

Year	Operating Reactors	Applicable Dose Limits	Doses from the River Pathway (mrem)		River Exposure Parameters	Events of Interest	Comments
1958	B C D DR F H KE KW	Annual maximum:	MI (b)	Bone DW 10 13 55-65 -- WB F+WF 145-155 -- 25-35 -- Ext < 75 < 75 < 75 < 25 TOT < 235 < 185 < 25	Ext: swimming and boating for 4-6 h/d in area from Richland to Ringold		"Background and fallout contributions have been excluded "where possible." "Report contains details on activity reduction from water treatment."
1959	B C D DR F H KE KW	Annual maximum:	MI	Bone (a) DW < 300 -- 75 < 2.5 F+WF 140-165 -- 45 15 Oysters < 15 -- 10 < 2.5 Ext < 300 < 1 6 TOT < 765 < 1 136 < 26	DW: 2200 mL/d F+WF: 0.1 kg/wk of whitefish or duck Oysters: 0.1 kg/wk Ext: either 240 swimming or 480 boating per year		"Dose estimates include Sr-90 from fallout." "Report contains details on activity reduction from water treatment."
1960	B C D DR F H KE KW	Annual maximum:	MI	Bone Raw DW 48 Fish 900 Oysters --- Ext --- TOT 948 Richland resident Bone DW 0 Ext --- TOT 0 Pasco resident Bone DW 24 Ext --- TOT --- Kennewick resident Bone DW 15	MI DW: 2200 mL/d of Pasco water Fish: 10 lb/y of Columbia River whitefish Oysters: 1 lb/wk Ext: 240 h/y "on the river in the vicinity of Richland" Richland No river water or local fish Ext: 240 h on shoreline or boat Pasco DW: treated river water Kennewick DW: 2200 mL/d of Kennewick water	"Majority of Richland dose from weapons testing fallout." "Note: no waterfowl dose calculated." "There were no known circumstances of "routine consumption" of raw river water." "Water immersion measurements: Near 300 area: 1.9 mB/d Richland: 1.4 mB/d (Apr-Oct) Kennewick: 1 mB/d	

(L) Reason given: "Hunting for waterfowl is not permitted within the Reservation with 1/4 mile of the Columbia River in this part of the state except for the McNary Game Range [just south of the Snake River confluence into the Columbia River]". Also, 40% of 600 ducks bagged in the area in 1960 had detectable levels of activity and less than 15% of these had phosphorus-32 concentrations as high as that found in whitefish.

Year	Operating Reactors	Applicable Dose Limits	Doses from the River Pathway (mrem)	River Exposure Parameters	Events of Interest	Comments
1961	B C D DR F H KE KW	Annual maximum: 500 mrem WB, gonads 3000 mrem thyroid, bone 1500 mrem other tissues	<p>MI</p> <p>DW 18 WB 3</p> <p>F-WFI 75 3</p> <p>Oysters 80 (-) 25 (-)</p> <p>Ext -- 12</p> <p>101 1128 -- -25</p> <p>Ext -- -65</p> <p>Richland resident</p> <p>Bone</p> <p>DW 0 WB 0</p> <p>Ext -- --</p> <p>101 0 0 < 40</p> <p>Pasco resident</p> <p>Bone</p> <p>DW 18 WB 3</p> <p>Ext -- --</p> <p>101 12 WB 1</p>	<p>DW: 2200 mL/d (MI: Pasco water)</p> <p>F-WFI: 10 lb/y Columbia River whitefish and waterfowl</p> <p>Oysters: 1 lb/wk</p> <p>Ext: 240 h swimming or boating reported, BUT Richland water immersion dose rate measured ~2.5 mR/d.</p> <p>Richland</p> <p>101: milk from cows consuming river-irrigated pasture, oyster consumption.</p>	<p>Mutatorium on nuclear weapons testing ended in September.</p>	<p>-Most exposure due to natural sources and fallout.</p> <p>-Columbia River source of most of the environmental exposure resulting from Hanford Operations.</p> <p>-1500 SE Washington bagged ducks sampled in 1961, approx. 8% showed greater than detectable phosphorus-32.</p> <p>-an attempt was made to estimate the number of people exposed to each source.</p>
1962	B C D DR F H KE KW	Annual maximum: 500 mrem WB 1500 mrem GI 3000 mrem thyroid, bone	<p>MI</p> <p>Raw DW 63 WB 13</p> <p>F-WFI 500 -115 -40</p> <p>Oysters 11 7</p> <p>Ext -- 20</p> <p>101 -960 -468 -70</p> <p>Richland resident</p> <p>Bone</p> <p>DW 0 WB 0</p> <p>Ext -- 20</p> <p>101 0 0 20</p> <p>Pasco resident</p> <p>Bone</p> <p>Raw DW 50 WB 5.2</p> <p>DW 27 36 2</p> <p>Ext -- 14</p> <p>Kennewick resident</p> <p>Bone</p> <p>DW 12 WB 1</p>	<p>DW: 2200 mL/d (MI location = Hanford Ferry)</p> <p>F: 25 lb/y of Columbia River fish (increased from 10 lb/y)</p> <p>WFI: 1 lb of the duck with the highest phosphorus-32 concentration, which was bagged on-site</p> <p>Oysters: 0.5 lb/wk</p> <p>Ext: 240 h/y swimming, boating</p>	<p>-River water concentrations were significantly reduced in 1962 by the additional treatment of cooling water.</p> <p>-Criticality accident resulted in an airborne release; the MI from this release was 5 mR N of the 400 area on the Columbia River shore (0.001 area).</p>	<p>-Columbia River source of most of the environmental exposure resulting from Hanford Operations.</p> <p>-Doses include fallout.</p> <p>-Six percent of 102 ducks bagged offsite and sampled contained detectable activity; on-site, 30% contained detectable activity.</p> <p>-Water immersion measurements (Apr-Oct): near 300 area: 2.9 mR/d Richland: 2.1 mR/d Pasco: 1.4 mR/d</p>

Year	Operating Reactors	Applicable Dose Limits	Doses from the River Pathway (mrem)	River Exposure Parameters	Events of Interest	Comments
1963	B C D DR F H NE NW N	Annual maximum: 500 mrem WB 1500 mrem GI 3000 mrem thyroid, bone	MI DW: 2000 mld/d Pasco water F: 25 lb/y whitefish Oysters: 0.5 lb/wk Ext: 240 lb/y swimming, boating near Richland F_ext: 184 lb/y shoreline near Richland, "ardent fisherman" F_ext: 50 TOT: 915 149 118 "Average" Richland individual Bone DW: 24 25 1 "Average" Pasco individual Bone DW: 27 20 15 15 "Average" Kennewick individual Bone DW: < 15 5 < 1	MI: 2000 mld/d Pasco water F: 25 lb/y whitefish Oysters: 0.5 lb/wk Ext: 240 lb/y swimming, boating near Richland F_ext: 184 lb/y shoreline near Richland, "ardent fisherman" Richland DW: 1200 mld/d for 4 mos. consumption of Richland treated water Pasco and Kennewick DW: 1200 mld/d ext: 240 lb/y swimming, boating	May: KE reactor released "largest single release of fission products to date" to Columbia River. Aug: new Richland water treatment plant came online, draws Columbia River water. Sept: PUREX atmospheric release.	Hanford contributions to external dose are "not readily discernable" from fallout and natural radioactivity. "no known instance of untreated river water being consumed routinely by humans." Fisherman survey results: maximum reported consumption 200 meals/y of crappie, perch, bass, and catfish caught near Burbank. Seven percent of 299 ducks bagged offsite contained detectable activity. Hold-up time between river intake and tapwater outflow varies from hours to days. Water immersion measurements (Apr-Oct): Near 300 area: 3 mR/d Richland: 2 mR/d Pasco: 1.5 mR/d

Year	Operating Reactors	Applicable Dose Limits	Doses from the River Pathway (mrem)	River Exposure Parameters	Events of Interest	Comments
1964 (d)	B C G D K F H N E M W H	Annual maximum: 500 mrem WB 1500 mrem GI, thyroid 3000 mrem bone (1/10 occupational) Average annual: 170 mrem WB 500 mrem GI, thyroid 1000 mrem bone (1/10 occupational)	MI Dose (e) --50 F 900 Oysters --15 F-ext --- TOT --965 "Average" Richland individual Bone Dose 30 Ext -- "Average" Pasco individual Bone Dose 24 Ext -- "Average" Kennewick individual Bone Dose ~15	MI DW: 2000 mld/d F: 25 lb/y whitefish Oysters: 0.5 lb/wk F ext: 200 lb/y (at Ringold shoreline (F)) Average person DW: 1200 mld/d Ext: 240 y/y swimming, boating		<ul style="list-style-type: none"> -December, 1963, N reactor started up and went into full operation in 1964. This reactor was the first and only non-"once-through" production reactor. -Fallout Sr-90 doses excluded -"No known instance of untreated river water being consumed routinely." -Oyster dose calculated from a sample of the oysters with an added market dilution factor of 10 -No MI external dose was calculated for swimming and boating because the MI fisherman dose estimate was significantly higher. -Water immersion measurements (Apr-Oct): Richland: 2 mld/d Pasco: 1.5 mld/d -Many of the fishermen who catch whitefish prefer to smoke them. Columbia River fish most frequently consumed: Clappie, perch, bass (ratio 1:1:6)

(d) For reference to 1964 dose calculations: Wilson, R. H., and I. H. Essig. 1968. Criteria Used to Estimate Radiation Doses Received by Persons Living in the Vicinity of Hanford. Interim Report. BNL-706.

(e) Pacific Northwest Laboratory, Richland, Washington

(f) Calculated here from the average Richland resident results, however the reported MI total dose assumed ingestion of Pasco water

Soldat, Price, and McCormack. PNL-5795. 1986.

Year	Operating Reactors	Applicable Dose Limits	Doses from the River Pathway (mrem)	River Exposure Parameters	Events of Interest	Comments
1963 (g)	B C D F H KE KW N	Annual maximum: 500 mrem WB 1500 mrem GI 3000 mrem bone Average annual: 170 mrem WB 500 mrem WB 1000 mrem bone	MI Dose ³ -- F 330 Oysters 9 Ext -- F ext -- TOT 339 "Typical" Richland individual GI 35 WB 2.5 DW 24 "Typical" Pasco individual GI 13 WB < 1 DW 9 "Typical" Kennewick individual GI 1 WB < 1 DW < 3	MI DW: 2000 ml/d Richland water F: 25 lb/y panfish Oysters: 230 g/wk Ext: 240 h/y swimming, boating F ext: 500 h/y shoreline in Richland Typical individual DW: 1200 ml/d	-Three reactors retired during the year (DR, F, H). -Water immersion measurements (Apr-Oct): Richland: 2 mR/d. -Most of the fisherman shoreline dose is from Zn-65 accumulated by algae growing on the substrate at the river's edge. -Contributions from fallout tritium, strontium-90, and cesium-137 excluded from reported doses.	-Most of the environmental dose was due to natural radioactivity and fallout, rather than Hanford operations. -Water immersion measurements (Apr-Oct): Richland: 2 mR/d. -Most of the fisherman shoreline dose is from Zn-65 accumulated by algae growing on the substrate at the river's edge. -Contributions from fallout tritium, strontium-90, and cesium-137 excluded from reported doses.
1963	B C D KE KW N	Annual maximum: 500 mrem WB 1500 mrem GI 3000 mrem bone Average annual: 170 mrem WB 500 mrem WB 1000 mrem bone	MI Dose ^(c) -- F -- Oysters 12 Ext -- F ext -- TOT -- "Typical" Richland individual Bone 24 GI 31 WB 1.9 "Typical" Pasco individual Bone 3 GI 9 WB < 1 "Typical" Kennewick individual Bone < 3 GI 1 WB < 1 DW < 3	MI DW: 2000 ml/d Richland water F: 25 lb/y panfish Oysters: 50 g/d Ext: 240 h/y swimming, boating F ext: 500 h/y at Richland shoreline Typical individual DW: 1200 ml/d	-Feb. abnormal release of radioiodines into river -Jul and Aug. reactors shut down due to worker strike	-Water immersion measurements (Apr-Oct): Richland: 2 mR/d.

(g) For reference to 1965 dose calculations: Essig, I. H., and J. P. Corley 1969. Criteria Used to Estimate Radiation Doses Received by Persons Living in the Vicinity of Hanford. Interim Report 2. BNWL 1015. Pacific Northwest Laboratory, Richland, Washington.

Year	Operating Reactors	Applicable Dose Limits	Doses from the River Pathway (arcm)	River Exposure Parameters	Events of Interest	Comments
1967	B C D KE KW N	Annual maximum: 500 arcm MB 1500 arcm GI 3000 arcm bone Average annual: 170 arcm MB 500 arcm MB 1000 arcm bone	MI DW -25 F+wf1 300-90 Oysters 12 Ext -- F ext -- TOT -425 Average Richland resident Bone DW 21 F+wf1 10-14 Oyster -- Ext -- TOT -45 Typical (h) Richland individual Bone DW 15 Oyster -- Typical (h) Pasco individual Bone DW 3 Typical (h) Kennewick individual Bone DW < 3	MI DW: 2000 ml/d Richland water F: 40 kg/y WF1: 23 kg/y Oysters: 50 g/d Ext: 240 h/y swimming, waterskiing F ext: 500 h/y Pasco shoreline Average resident DW: 1860 ml/d F: 0.48 kg/y WF1: 1.24 kg/y Oyster: 1.4 kg/y with a market dilution factor of 10 Ext: 20 h/y swimming, waterskiing Typical individual DW: 1200 ml/d Oyster: 5.5 kg/y with a market dilution factor of 10	June: D reactor shutdown Redox separations plant retired.	-Columbia River source of most of the environmental exposure resulting from Hanford Operations. -Richland supplements its Columbia River water supply, at times, with well water. -fish survey catch results: 73% crappie, 16% bass, 11% perch. -Water immersion measurement (Apr-Oct): Richland: 2.5 mR/d -Shoreline dose predominantly from sediment and algal accumulations of scandium-46 and zinc-65.

(h) Typical residents were referred to in previous years as the "Average" resident. A dietary survey of Richland residents prompted the change in terminology. The parameters of previous "average" residents are consistent with the 1967 and more recent typical residents.

Year	Operating Reactors	Applicable Dose Limits	Doses from the River Pathway (arom)	River Exposure Parameters	Events of Interest	Comments
1968	B C KE NW N	<p>Maximum annual: 500 mrem WB, gonads, bone marrow (1) 1500 mrem bone (1) 1500 mrem other tissues</p> <p>Average annual: 170 mrem WB, gonads, bone marrow 500 mrem other tissues mrem bone</p>	<p>M1</p> <p>DW: 2000 ml/d F: 40 kg/y panfish Wf1: 23 kg/y Oysters: 50 g/d F_ext: 500 h/y Pasco shoreline T_ext: +300 h immersed, Richland</p> <p>Average Richland resident DW: 1860 ml/d F: 0.48 kg/y Wf1: 1.24 kg/y Oyster: 1.4 kg/y with a market reduction factor of 10 T_ext: 24 h/y T_ext: 38 h/y immersed 77 h/y shoreline</p> <p>Typical (J) Richland individual DW: 4 Bone: 2.5</p> <p>Typical (J) Pasco individual DW: 2.5 GI: 12</p>	<p>M1 DW: 2000 ml/d F: 40 kg/y panfish Wf1: 23 kg/y Oysters: 50 g/d F_ext: 500 h/y Pasco shoreline T_ext: +300 h immersed, Richland</p> <p>Average resident DW: 1860 ml/d F: 0.48 kg/y Wf1: 1.24 kg/y Oyster: 1.4 kg/y with a market reduction factor of 10 T_ext: 24 h/y T_ext: 38 h/y immersed 77 h/y shoreline</p> <p>Typical individual DW: 1200 ml/d Oyster: 5.5 kg/y with a market reduction factor of 10</p>	<p>-Feb: B-reactor retired.</p>	<p>-Columbia River source of most of the environmental exposure resulting from Hanford Operations.</p> <p>-1968 first year bone doses were presented as dose rather than MPEL and the first year bone doses included external exposure dose.</p> <p>-Water immersion measurement: Richland: 1.5 mG/d.</p>

- (1) Current dosimetrists do not have an equivalent term for what, in the past, had been referred to as the bone (as in, the dose limit to the bone). The best description for the old term is, possibly, the skeleton without the bone marrow -- 1968 marks the first year that dosimetry comparable to current methods were implemented into the annual report calculations.
- (2) Typical residents were referred to in previous years as the "Average" resident. A dietary survey of Richland residents prompted the change in terminology. The parameters of previous "average" residents are consistent with the 1967 (and more recent year's) typical residents.

Year	Operating Reactors	Applicable Dose Limits	Doses from the River pathway (mrem)	River Exposure Parameters	Events of Interest	Comments
1969	C KE KW N	Maximum annual: 500 mrem WB 1500 mrem thyroid, bone, GI Average annual: 170 mrem WB 500 mrem thyroid, bone, GI	MI DW < 1 F-Wf 1 Oysters 11 Ext -- F ext -- T ext -- T ext -- 10T --35 Average Richland resident Bone DW 5 F-Wf 1+1 Oyster -- Ext -- T ext -- 10T --7 Average Pasco resident Bone DW 3 F-Wf 1 Oyster -- Ext -- T ext -- 10T --7	MI DW: 2000 ml/d F: 40 kg/y panfish Wf: 23 kg/y Oyster: 50 g/d F ext: 500 h/y Pasco shoreline T ext: +100 h immersed, Richland Average resident DW: 1800 ml/d F: 0.48 kg/y panfish Wf: 1.24 kg/y Ext: 11 h/y immersed 21 h/y shoreline T ext: 48 h/y immersed 77 h/y shoreline	-Apr. C-reactor retired	-Columbia River source of most of the environmental exposure resulting from Hanford Operations. -Fallout and natural background radiation doses not included in reported dose estimates. -WB dose from fallout H-3, Sr-90, and Cs-137 is 5 mrem for MI and 2 mrem for Richland resident. -Richland water treatment plant was offline in January and 99% of the water used was well water. The DW doses DO NOT reflect this. -Water immersion measurements (Apr Oct): Richland: 2.7 mR/d
1970	KE KW N	Maximum annual: 500 mrem WB 1500 mrem thyroid, bone, GI Average annual: 170 mrem WB 500 mrem thyroid, bone, GI	MI (a) All pathways Bone 6 GI 2 WB 2 Average Richland resident All pathways Bone 2 GI 2 WB 1	MI DW: 2000 ml/d F: 40 kg/y panfish Wf: 23 kg/y Oysters: 50 g/d F ext: 500 h/y Pasco shoreline Average resident DW: 1800 ml/d F: 0.48 kg/y Wf: 1.24 kg/y Oysters: 1.4 kg/y with a market reduction factor of 10 Ext: 11 h immersion 21 h shoreline	-Feb. KW reactor retired -Feb-Apr and Sep: no reactors were operating.	-Water immersion measurements (Apr Oct): Richland: 0.42 mR/d -Fallout doses from ingestion pathways: MI, WB Average, WB H-3 < 1 Sr-90 4 b Cs 137 < 1

(a) Doses are to be reported as the sum of all pathways from 1970 and more recent years. Beginning in 1970, the MI and average resident doses from pathways related to the Columbia River radionuclide sources are difficult to abstract from the annual reports.

(1) Approximately 50% of this dose resulted from Columbia River sources of exposure.

Year	Operating Reactors	Applicable Dose Limits	Doses from the River Pathway (arcm)	River Exposure Parameters	Events of Interest	Comments
1971	KE	N	<p>MI All pathways Bone 3 GI 3 MB 3</p> <p>Average Richland resident All pathways Bone < 1 GI < 1 MB < 1</p>	<p>MI DW: 2000 ml/d F: 40 kg/y panfish Wfl: 23 kg/y Oysters: 50 g/d F ext: 500 h/y Pasco shoreline</p> <p>Average resident DW: 1860 ml/d F: 0.48 kg/y Wfl: 1.24 kg/y Oysters: 1.4 kg/y with a market reduction factor of 10 Ext: 11 h immersion 21 h shoreline</p>	-Jan: KE reactor retired.	<p>-Columbia River source of most of the environmental exposure resulting from Hanford Operations.</p> <p>-Many fish phosphorous-32 concentrations below the analytical limit.</p>
1972		N	<p>MI All pathways MB < 1</p> <p>Average Richland resident All pathways MB < 1</p>

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2 of 2

APPENDIX C

DETAILS OF SPREADSHEET CALCULATIONS

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DATE	Nu-24	P-32	Cs-45	Calculated for TricTubs				Cu-64	As-76	Cl-51	Co-60	Zn-65	Zn-69	Zn-69m	Ga-72	Sr-89	Sr-90	Y-90	Y-93	Zr-95	Np-239	Columbia	Estimated Travel Time days
				Cld	Cld	Cld	Cld																
Jan-59	1.04E+03	5.65E+01	2.05E+00	7.11E+00	2.53E+03	6.48E+02	6.91E+02	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03
Feb-59	1.16E+03	6.54E+01	1.91E+00	6.30E+00	4.81E+03	1.02E+03	8.98E+02	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03
Mar-59	1.78E+03	5.90E+01	1.90E+00	7.43E+00	5.19E+03	8.05E+02	6.44E+02	8.98E+02	8.98E+02	8.98E+02	8.98E+02	8.98E+02	8.98E+02	8.98E+02	8.98E+02	8.98E+02	8.98E+02	8.98E+02	8.98E+02	8.98E+02	8.98E+02	8.98E+02	8.98E+02
Apr-59	2.13E+03	4.87E+01	2.34E+00	1.10E+01	1.15E+04	1.03E+03	5.45E+02	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03
May-59	1.74E+03	3.81E+01	2.20E+00	4.59E+00	7.91E+03	1.13E+03	4.17E+02	1.48E+03	1.48E+03	1.48E+03	1.48E+03	1.48E+03	1.48E+03	1.48E+03	1.48E+03	1.48E+03	1.48E+03	1.48E+03	1.48E+03	1.48E+03	1.48E+03	1.48E+03	1.48E+03
Jun-59	1.71E+03	3.19E+01	2.14E+00	7.51E+00	6.60E+03	1.58E+03	2.84E+02	1.48E+03	1.48E+03	1.48E+03	1.48E+03	1.48E+03	1.48E+03	1.48E+03	1.48E+03	1.48E+03	1.48E+03	1.48E+03	1.48E+03	1.48E+03	1.48E+03	1.48E+03	1.48E+03
Jul-59	1.60E+03	2.76E+02	1.95E+00	1.83E+01	5.33E+03	9.31E+02	2.50E+02	1.28E+03	1.28E+03	1.28E+03	1.28E+03	1.28E+03	1.28E+03	1.28E+03	1.28E+03	1.28E+03	1.28E+03	1.28E+03	1.28E+03	1.28E+03	1.28E+03	1.28E+03	1.28E+03
Aug-59	2.04E+03	1.99E+02	1.83E+00	1.97E+01	5.34E+03	9.33E+02	2.95E+02	1.77E+03	1.77E+03	1.77E+03	1.77E+03	1.77E+03	1.77E+03	1.77E+03	1.77E+03	1.77E+03	1.77E+03	1.77E+03	1.77E+03	1.77E+03	1.77E+03	1.77E+03	1.77E+03
Sep-59	1.75E+03	3.17E+01	1.98E+00	1.50E+01	5.84E+03	1.01E+03	3.08E+02	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03	1.03E+03
Oct-59	1.24E+03	5.56E+01	2.08E+00	1.64E+00	5.25E+03	8.43E+02	4.21E+02	1.45E+03	1.45E+03	1.45E+03	1.45E+03	1.45E+03	1.45E+03	1.45E+03	1.45E+03	1.45E+03	1.45E+03	1.45E+03	1.45E+03	1.45E+03	1.45E+03	1.45E+03	1.45E+03
Nov-59	2.01E+03	9.04E+01	1.53E+01	1.84E+01	4.51E+03	8.08E+02	3.90E+02	8.79E+02	8.79E+02	8.79E+02	8.79E+02	8.79E+02	8.79E+02	8.79E+02	8.79E+02	8.79E+02	8.79E+02	8.79E+02	8.79E+02	8.79E+02	8.79E+02	8.79E+02	8.79E+02
Dec-59	2.84E+03	6.67E+01	2.01E+00	3.32E+01	4.13E+03	5.24E+02	3.98E+02	1.28E+03	1.28E+03	1.28E+03	1.28E+03	1.28E+03	1.28E+03	1.28E+03	1.28E+03	1.28E+03	1.28E+03	1.28E+03	1.28E+03	1.28E+03	1.28E+03	1.28E+03	1.28E+03
Jan-60	2.47E+03	6.51E+01	1.95E+00	7.76E+01	4.48E+00	8.05E+03	3.99E+02	1.39E+03	1.39E+03	1.39E+03	1.39E+03	1.39E+03	1.39E+03	1.39E+03	1.39E+03	1.39E+03	1.39E+03	1.39E+03	1.39E+03	1.39E+03	1.39E+03	1.39E+03	1.39E+03
Feb-60	2.35E+03	6.05E+01	2.12E+00	7.43E+00	5.19E+03	8.05E+02	6.44E+02	8.98E+02	8.98E+02	8.98E+02	8.98E+02	8.98E+02	8.98E+02	8.98E+02	8.98E+02	8.98E+02	8.98E+02	8.98E+02	8.98E+02	8.98E+02	8.98E+02	8.98E+02	8.98E+02
Mar-60	2.61E+03	6.15E+01	2.73E+00	1.32E+01	1.13E+04	8.10E+02	5.23E+02	1.52E+03	1.52E+03	1.52E+03	1.52E+03	1.52E+03	1.52E+03	1.52E+03	1.52E+03	1.52E+03	1.52E+03	1.52E+03	1.52E+03	1.52E+03	1.52E+03	1.52E+03	1.52E+03
Apr-60	3.17E+03	5.62E+01	3.14E+00	1.98E+01	1.82E+04	8.40E+02	6.13E+02	1.70E+03	1.70E+03	1.70E+03	1.70E+03	1.70E+03	1.70E+03	1.70E+03	1.70E+03	1.70E+03	1.70E+03	1.70E+03	1.70E+03	1.70E+03	1.70E+03	1.70E+03	1.70E+03
May-60	2.64E+03	5.05E+01	4.79E+00	1.58E+01	1.69E+04	1.01E+03	5.01E+02	1.62E+03	1.62E+03	1.62E+03	1.62E+03	1.62E+03	1.62E+03	1.62E+03	1.62E+03	1.62E+03	1.62E+03	1.62E+03	1.62E+03	1.62E+03	1.62E+03	1.62E+03	1.62E+03
Jun-60	1.98E+03	4.05E+01	4.68E+00	2.52E+01	7.09E+03	7.26E+02	3.72E+02	2.04E+03	2.04E+03	2.04E+03	2.04E+03	2.04E+03	2.04E+03	2.04E+03	2.04E+03	2.04E+03	2.04E+03	2.04E+03	2.04E+03	2.04E+03	2.04E+03	2.04E+03	2.04E+03
Jul-60	1.56E+03	4.01E+01	3.31E+00	2.29E+01	6.06E+03	5.95E+02	3.95E+02	1.36E+03	1.36E+03	1.36E+03	1.36E+03	1.36E+03	1.36E+03	1.36E+03	1.36E+03	1.36E+03	1.36E+03	1.36E+03	1.36E+03	1.36E+03	1.36E+03	1.36E+03	1.36E+03
Aug-60	2.02E+03	8.50E+01	3.23E+00	4.48E+01	7.04E+03	7.04E+03	5.34E+02	1.71E+03	1.71E+03	1.71E+03	1.71E+03	1.71E+03	1.71E+03	1.71E+03	1.71E+03	1.71E+03	1.71E+03	1.71E+03	1.71E+03	1.71E+03	1.71E+03	1.71E+03	1.71E+03
Sep-60	2.12E+03	3.26E+01	3.67E+02	2.48E+01	9.95E+03	5.87E+02	3.75E+02	1.29E+03	1.29E+03	1.29E+03	1.29E+03	1.29E+03	1.29E+03	1.29E+03	1.29E+03	1.29E+03	1.29E+03	1.29E+03	1.29E+03	1.29E+03	1.29E+03	1.29E+03	1.29E+03
Oct-60	2.06E+03	6.24E+01	3.35E+01	4.07E+01	8.64E+03	2.44E+03	5.31E+02	1.83E+03	1.83E+03	1.83E+03	1.83E+03	1.83E+03	1.83E+03	1.83E+03	1.83E+03	1.83E+03	1.83E+03	1.83E+03	1.83E+03	1.83E+03	1.83E+03	1.83E+03	1.83E+03
Nov-60	3.66E+03	7.85E+01	2.90E+01	4.87E+01	3.56E+04	2.61E+03	6.36E+02	1.53E+03	1.53E+03	1.53E+03	1.53E+03	1.53E+03	1.53E+03	1.53E+03	1.53E+03	1.53E+03	1.53E+03	1.53E+03	1.53E+03	1.53E+03	1.53E+03	1.53E+03	1.53E+03
Dec-60	4.14E+03	8.95E+01	3.21E+00	1.93E+01	3.81E+04	2.81E+03	7.40E+02	1.31E+03	1.31E+03	1.31E+03	1.31E+03	1.31E+03	1.31E+03	1.31E+03	1.31E+03	1.31E+03	1.31E+03	1.31E+03	1.31E+03	1.31E+03	1.31E+03	1.31E+03	1.31E+03
Jan-61	3.74E+03	8.09E+01	2.62E+00	7.43E+00	3.00E+04	2.26E+03	6.04E+02	1.27E+03	1.27E+03	1.27E+03	1.27E+03	1.27E+03	1.27E+03	1.27E+03	1.27E+03	1.27E+03	1.27E+03	1.27E+03	1.27E+03	1.27E+03	1.27E+03	1.27E+03	1.27E+03
Feb-61	4.10E+03	1.08E+02	2.62E+00	7.43E+00	3.00E+04	2.26E+03	6.04E+02	1.27E+03	1.27E+03	1.27E+03	1.27E+03	1.27E+03	1.27E+03	1.27E+03	1.27E+03	1.27E+03	1.27E+03	1.27E+03	1.27E+03	1.27E+03	1.27E+03	1.27E+03	1.27E+03
Mar-61	4.73E+03	8.69E+01	2.49E+00	1.83E+01	4.98E+04	3.51E+03	8.94E+02	1.32E+03	1.32E+03	1.32E+03	1.32E+03	1.32E+03	1.32E+03	1.32E+03	1.32E+03	1.32E+03	1.32E+03	1.32E+03	1.32E+03	1.32E+03	1.32E+03	1.32E+03	1.32E+03
Apr-61	3.82E+03	8.68E+01	2.49E+00	1.83E+01	5.97E+04	3.77E+03	8.81E+02	1.48E+03	1.48E+03	1.48E+03	1.48E+03	1.48E+03	1.48E+03	1.48E+03	1.48E+03	1.48E+03	1.48E+03	1.48E+03	1.48E+03	1.48E+03	1.48E+03	1.48E+03	1.48E+03
May-61	3.89E+03	7.71E+01	2.68E+00	4.05E+01	6.83E+04	4.05E+03	3.22E+04	1.32E+03	1.32E+03	1.32E+03	1.32E+03	1.32E+03	1.32E+03	1.32E+03	1.32E+03	1.32E+03	1.32E+03	1.32E+03	1.32E+03	1.32E+03	1.32E+03	1.32E+03	1.32E+03
Jun-61	5.83E+03	5.56E+01	2.68E+00	6.16E+01	2.53E+04	3.03E+03	2.57E+02	1.35E+03	1.35E+03	1.35E+03	1.35E+03	1.35E+03	1.35E+03	1.35E+03	1.35E+03	1.35E+03	1.35E+03	1.35E+03	1.35E+03	1.35E+03	1.35E+03	1.35E+03	1.35E+03
Jul-61	3.42E+03	3.76E+01	3.18E+00	4.70E+01	2.35E+04	2.00E+03	2.57E+02	1.19E+03	1.19E+03	1.19E+03	1.19E+03	1.19E+03	1.19E+03	1.19E+03	1.19E+03	1.19E+03	1.19E+03	1.19E+03	1.19E+03	1.19E+03	1.19E+03	1.19E+03	1.19E+03
Aug-61	2.45E+03	1.95E+01	3.18E+02	1.40E+00	1.62E+04	2.67E+03	2.48E+02	1.88E+03	1.88E+03	1.88E+03	1.88E+03	1.88E+03	1.88E+03	1.88E+03	1.88E+03	1.88E+03	1.88E+03	1.88E+03	1.88E+03	1.88E+03	1.88E+03	1.88E+03	1.88E+03
Sep-61	1.33E+03	2.83E+01	8.00E+01	1.30E+04	1.39E+04	1.19E+03	2.82E+02	2.01E+03	2.01E+03	2.01E+03	2.01E+03	2.01E+03	2.01E+03	2.01E+03	2.01E+03	2.01E+03	2.01E+03	2.01E+03	2.01E+03	2.01E+03	2.01E+03	2.01E+03	2.01E+03
Oct-61	2.21E+03	3.36E+01	8.00E+01	1.40E+04	1.40E+04	1.19E+03	2.82E+02	2.01E+03	2.01E+03	2.01E+03	2.01E+03	2.01E+03	2.01E+03	2.01E+03	2.01E+03	2.01E+03	2.01E+03	2.01E+03	2.01E+03	2.01E+03	2.01E+03	2.01E+03	2.01E+03
Nov-61	2.57E+03	3.67E+01	8.00E+01	1.57E+03	1.57E+03	1.19E+03	2.82E+02	2.01E+03	2.01E+03	2.01E+03	2.01E+03	2.01E+03	2.01E+03	2.01E+03	2.01E+03	2.01E+03	2.01E+03	2.01E+03	2.01E+03	2.01E+03	2.01E+03	2.01E+03	2.01E+03
Dec-61	2.71E+03	3.10E+01	2.14E+00	1.21E+04	1.21E+04	2.47E+03	2.98E+02	3.52E+03	3.52E+03	3.52E+03	3.52E+03	3.52E+03	3.52E+03	3.52E+03	3.52E+03	3.52E+03	3.52E+03	3.52E+03	3.52E+03	3.52E+03	3.52E+03	3.52E+03	3.52E+03
Jan-62	3.03E+03	3.45E+01	2.72E+00	1.75E+04	1.75E+04	4.35E+03	3.12E+02	2.98E+03	2.98E+03	2.98E+03	2.98E+03	2.98E+03	2.98E+03	2.98E+03	2.98E+03	2.98E+03	2.98E+03	2.98E+03	2.98E+03	2.98E+03	2.98E+03	2.98E+03	2.98E+03
Feb-62	3.50E+03	4.28E+01	1.98E+00	3.36E+04	3.36E+04	4.03E+03	4.71E+02	2.85E+03	2.85E+03	2.85E+03	2.85E+03	2.85E+03	2.85E+03	2.85E+03	2.85E+03	2.85E+03	2.85E+03	2.85E+03	2.85E+03	2.85E+03	2.85E+03	2.85E+03	2.85E+03
Mar-62	3.73E+03	5.30E+01	3.37E+00	1.28E+05	1.28E+05	6.83E+02	4.71E+02	4.50E+03	4.50E+03	4													

Jul-05	1.87E+01	3.00E+02	1.03E+03	2.51E+01	2.48E+02	219071	0.55
Aug-05	2.09E+01	3.61E+02	1.13E+03	2.18E+01	2.48E+02	129613	0.86
Sep-05	2.75E+01	4.07E+02	1.18E+03	2.35E+01	2.84E+02	76327	0.89
Oct-05	3.10E+01	5.95E+02	8.59E+02	1.11E+01	2.79E+02	64539	0.92
Nov-05	2.97E+01	4.77E+02	9.17E+02	1.75E+01	2.59E+02	70590	0.91
Dec-05	3.11E+01	4.38E+02	9.99E+02	2.89E+01	2.32E+02	74731	0.90
Jan-06	2.83E+01	2.84E+02	9.26E+02	2.20E+01	2.14E+02	68229	0.92
Feb-06	2.35E+01	2.48E+02	8.10E+02	2.07E+01	1.89E+02	81336	0.89
Mar-06	3.30E+01	3.63E+02	8.49E+02	2.87E+01	2.33E+02	77632	0.90
Apr-06	2.92E+01	3.05E+02	9.23E+02	3.39E+01	2.52E+02	76267	0.90
May-06	2.51E+01	2.63E+02	9.02E+02	5.12E+01	2.64E+02	163532	0.70
Jun-06	2.11E+01	2.72E+02	7.59E+02	2.20E+01	1.84E+02	273987	0.57
Jul-06	6.00E+00	7.40E+01	2.08E+02	6.40E+00	8.00E+01	227846	0.63
Aug-06	3.20E+00	4.56E+01	1.85E+02	5.30E+00	4.80E+01	110481	0.83
Sep-06	2.41E+01	2.08E+02	8.18E+02	3.47E+01	1.90E+02	73593	0.90
Oct-06	2.00E+01	2.08E+02	8.18E+02	4.52E+01	1.52E+02	66665	0.92
Nov-06	1.93E+01	1.64E+02	7.48E+02	3.14E+01	1.46E+02	65487	0.92
Dec-06	2.12E+01	2.10E+02	8.97E+02	3.73E+01	1.72E+02	73700	0.90
Jan-07	1.40E+03	2.88E+02	8.82E+02	3.86E+01	1.97E+02	75729	0.90
Feb-07	1.40E+03	1.90E+02	8.59E+02	5.16E+01	1.87E+02	78293	0.90
Mar-07	1.16E+03	2.37E+02	8.68E+02	6.27E+01	1.63E+02	69961	0.87
Apr-07	1.50E+03	4.09E+02	9.42E+02	7.09E+01	2.01E+02	90663	0.87
May-07	1.48E+03	3.17E+02	8.87E+02	4.20E+01	2.48E+02	139516	0.78
Jun-07	1.06E+03	3.80E+02	1.07E+03	4.98E+01	2.85E+02	472467	0.40
Jul-07	1.24E+03	2.17E+02	8.47E+02	4.34E+01	3.18E+02	289161	0.55
Aug-07	1.82E+03	2.47E+02	8.70E+02	2.85E+01	2.84E+02	126071	0.60
Sep-07	1.65E+03	1.80E+02	6.70E+02	3.45E+01	2.32E+02	82107	0.89
Oct-07	1.65E+03	2.64E+02	7.02E+02	2.40E+01	2.15E+02	73219	0.91
Nov-07	1.65E+03	2.05E+02	7.05E+02	3.17E+01	2.13E+02	75823	0.90
Dec-07	1.63E+03	2.83E+02	7.27E+02	2.89E+01	2.39E+02	89774	0.87
Jan-08	1.66E+03	3.20E+02	6.35E+02	2.00E+01	2.58E+02	78777	0.89
Feb-08	1.85E+03	2.33E+02	4.56E+02	2.38E+01	3.12E+02	74862	0.90
Mar-08	3.56E+01	3.68E+02	6.59E+02	3.55E+01	3.37E+02	109003	0.83
Apr-08	4.47E+01	3.21E+02	4.33E+02	3.89E+01	2.80E+02	100273	0.65
May-08	3.89E+01	1.80E+02	5.11E+02	3.02E+01	3.10E+02	127019	0.80
Jun-08	1.53E+01	1.37E+02	3.20E+02	2.01E+01	2.23E+02	271367	0.57
Jul-08	1.24E+01	1.30E+02	3.36E+02	2.28E+01	1.82E+02	226571	0.84
Aug-08	2.20E+01	1.58E+02	4.53E+02	1.49E+01	2.72E+02	114090	0.82
Sep-08	2.09E+01	1.35E+02	3.35E+02	1.49E+01	2.63E+02	77688	0.90
Oct-08	1.86E+01	2.08E+02	4.03E+02	1.57E+01	2.55E+02	78787	0.89
Nov-08	1.83E+01	1.84E+02	3.83E+02	1.92E+01	1.78E+02	82061	0.87
Dec-08	1.90E+01	1.98E+02	3.85E+02	1.78E+01	2.55E+02	104645	0.84
Jan-09	1.69E+01	1.60E+02	2.78E+02	2.09E+01	1.78E+02	104645	0.81
Feb-09	2.46E+01	1.98E+02	2.79E+02	2.78E+01	2.05E+02	119868	0.81
Mar-09	3.00E+01	2.82E+02	2.80E+02	2.91E+01	2.70E+02	109777	0.84
Apr-09	2.89E+01	3.53E+02	3.39E+02	3.08E+01	3.52E+02	166067	0.63
May-09	1.33E+01	2.45E+02	1.33E+01	1.97E+01	2.32E+02	232518	0.83
Jun-09	1.40E+01	2.10E+02	2.89E+02	1.75E+01	2.08E+02	234133	0.63
Jul-09	1.28E+01	1.44E+02	1.87E+02	1.07E+01	1.10E+02	187903	0.70
Aug-09	1.15E+01	1.32E+02	1.91E+02	1.65E+01	1.25E+02	101018	0.85
Sep-09	9.60E+00	1.24E+02	1.48E+02	1.03E+01	1.11E+02	75427	0.90
Oct-09	7.70E+00	1.38E+02	1.08E+02	1.18E+01	6.21E+01	82110	0.89
Nov-09	1.30E+01	1.13E+02	1.37E+02	1.18E+01	6.00E+01	89057	0.87
Dec-09	7.10E+00	1.41E+02	1.71E+02	1.89E+01	7.98E+01	86700	0.86
Jan-10	4.91E+00	8.72E+01	1.54E+02	2.21E+01	9.70E+01	87165	0.88
Feb-10	1.80E+00	0.00E+00				76688	0.90
Mar-10	1.07E+00	1.23E+01	1.39E+01	8.70E+00	8.30E+00	65216	0.86
Apr-10	5.45E+00	6.03E+01	6.13E+01	9.90E+00	4.82E+01	81763	0.87
May-10	1.95E+00	4.81E+01	5.77E+01	8.80E+00	5.33E+01	129590	0.80
Jun-10	1.14E+00	2.75E+01	7.05E+01	8.80E+00	8.66E+01	181667	0.71
Jul-10						123885	0.81
Aug-10						100703	0.85
Sep-10						74473	0.90
Oct-10						75177	0.90
Nov-10						74637	0.90
Dec-10						77116	0.90
Jan-11						70239	0.91

Effective Dose

(Ref: DOE/EH-0070)

22.8

20.1

2.08

4.78

0.347

28.2

6.56

6.52E-05

4.52

32.8

1.55E-03

0

0

1.05

18.8

1.89

(Z/Nb85)

121512 cfs 179414 cfs 188893 cfs 236532 cfs	1.40E+03	7.70E+03	3.00E+03	5.60E+03	9.0E+04	4.30E+04	4.80E+03	1.30E+04	1.00E+02	1.40E+02	8.50E+05	1.20E+03	4.40E+03	1.00E+02	1.30E+03	8.70E+03	4.50E+03	5.80E+03	2.90E+03
(Ref: Walters et al Ch 3 u)	1.40E+03	7.70E+03	3.00E+03	5.60E+03	9.0E+04	4.30E+04	4.80E+03	1.30E+04	1.00E+02	1.40E+02	8.50E+05	1.20E+03	4.40E+03	1.00E+02	1.30E+03	8.70E+03	4.50E+03	5.80E+03	2.90E+03
(Ref: DOE/EH-0071)	1.40E+03	7.70E+03	3.00E+03	5.60E+03	9.0E+04	4.30E+04	4.80E+03	1.30E+04	1.00E+02	1.40E+02	8.50E+05	1.20E+03	4.40E+03	1.00E+02	1.30E+03	8.70E+03	4.50E+03	5.80E+03	2.90E+03
(Ref: DOE/EH-0071)	1.40E+03	7.70E+03	3.00E+03	5.60E+03	9.0E+04	4.30E+04	4.80E+03	1.30E+04	1.00E+02	1.40E+02	8.50E+05	1.20E+03	4.40E+03	1.00E+02	1.30E+03	8.70E+03	4.50E+03	5.80E+03	2.90E+03

External from ingestion (remuCi)

1.40E+03

7.70E+03

3.00E+03

5.60E+03

9.0E+04

4.30E+04

4.80E+03

1.30E+04

1.00E+02

1.40E+02

8.50E+05

1.20E+03

4.40E+03

1.00E+02

1.30E+03

8.70E+03

4.50E+03

5.80E+03

2.90E+03

External from swimming/boating (remuCi)

51.8

0

2.08E+10

2.08

4.78

0.347

28.2

6.56

6.52E-05

4.52

32.8

1.55E-03

0

0

1.05

18.8

1.89

(Z/Nb85)

Internal from ingestion (remuCi)

1.40E+03

7.70E+03

3.00E+03

5.60E+03

9.0E+04

4.30E+04

4.80E+03

1.30E+04

1.00E+02

1.40E+02

8.50E+05

1.20E+03

4.40E+03

1.00E+02

1.30E+03

8.70E+03

4.50E+03

5.80E+03

2.90E+03

Internal from ingestion (remuCi)

1.40E+03

7.70E+03

3.00E+03

5.60E+03

9.0E+04

4.30E+04

4.80E+03

1.30E+04

1.00E+02

1.40E+02

8.50E+05

1.20E+03

4.40E+03

1.00E+02

1.30E+03

8.70E+03

4.50E+03

5.80E+03

2.90E+03

Internal from ingestion (remuCi)

1.40E+03

7.70E+03

3.00E+03

5.60E+03

9.0E+04

4.30E+04

4.80E+03

1.30E+04

1.00E+02

1.40E+02

8.50E+05

1.20E+03

4.40E+03

1.00E+02

1.30E+03

8.70E+03

4.50E+03

5.80E+03

2.90E+03

Internal from ingestion (remuCi)

1.40E+03

7.70E+03

3.00E+03

5.60E+03

9.0E+04

4.30E+04

4.80E+03

1.30E+04

1.00E+02

1.40E+02

8.50E+05

1.20E+03

4.40E+03

1.00E+02

1.30E+03

8.70E+03

4.50E+03

5.80E+03

2.90E+03

Internal from ingestion (remuCi)

1.40E+03

7.70E+03

3.00E+03

5.60E+03

9.0E+04

4.30E+04

4.80E+03

1.30E+04

1.00E+02

1.40E+02

8.50E+05

1.20E+03

4.40E+03

1.00E+02

1.30E+03

8.70E+03

4.50E+03

5.80E+03

2.90E+03

Internal from ingestion (remuCi)

1.40E+03

7.70E+03

3.00E+03

5.60E+03

9.0E+04

4.30E+04

4.80E+03

1.30E+04

1.00E+02

1.40E+02

8.50E+05

1.20E+03

4.40E+03

1.00E+02

1.30E+03

8.70E+03

4.50E+03

5.80E+03

2.90E+03

Internal from ingestion (remuCi)

1.40E+03

7.70E+03

3.00E+03

5.60E+03

9.0E+04

4.30E+04

4.80E+03

1.30E+04

1.00E+02

1.40E+02

8.50E+05

1.20E+03

4.40E+03

1.00E+02

1.30E+03

8.70E+03

4.50E+03

5.80E+03

2.90E+03

Internal from ingestion (remuCi)

1.40E+03

7.70E+03

3.00E+03

5.60E+03

9.0E+04

4.30E+04

4.80E+03

1.30E+04

1.00E+02

1.40E+02

8.50E+05

1.20E+03

4.40E+03

1.00E+02

1.30E+03

8.70E+03

4.50E+03

5.80E+03

2.90E+03

Internal from ingestion (remuCi)

1.40E+03

7.70E+03

3.00E+03

5.60E+03

9.0E+04

4.30E+04

4.80E+03

1.30E+04

1.00E+02

1.40E+02

8.50E+05

1.20E+03

4.40E+03

1.00E+02

1.30E+03

8.70E+03

4.50E+03

5.80E+03

2.90E+03

Internal from ingestion (remuCi)

1.40E+03

7.70E+03

3.00E+03

5.60E+03

9.0E+04

4.30E+04

4.80E+03

1.30E+04

1.00E+02

1.40E+02

8.50E+05

1.20E+03

4.40E+03

1.00E+02

1.30E+03

8.70E+03

4.50E+03

5.80E+03

2.90E+03

Internal from ingestion (remuCi)

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3.00E+03

5.60E+03

9.0E+04

4.30E+04

4.80E+03

1.30E+04

1.00E+02

1.40E+02

8.50E+05

1.20E+03

4.40E+03

1.00E+02

1.30E+03

8.70E+03

4.50E+03

5.80E+03

2.90E+03

Internal from ingestion (remuCi)

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5.60E+03

9.0E+04

4.30E+04

4.80E+03

1.30E+04

1.00E+02

1.40E+02

8.50E+05

1.20E+03

4.40E+03

1.00E+02

1.30E+03

8.70E+03

4.50E+03

5.80E+03

2.90E+03

Internal from ingestion (remuCi)

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9.0E+04

4.30E+04

4.80E+03

1.30E+04

1.00E+02

1.40E+02

8.50E+05

1.20E+03

4.40E+03

1.00E+02

1.30E+03

8.70E+03

4.50E+03

5.80E+03

2.90E+03

Internal from ingestion (remuCi)

1.40E+03

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3.00E+03

5.60E+03

9.0E+04

4.30E+04

4.80E+03

1.30E+04

1.00E+02

1.40E+02

8.50E+05

1.20E+03

4.40E+03

1.00E+02

1.30E+03

8.70E+03

4.50E+03

5.80E+03

2.90E+03

Internal from ingestion (remuCi)

1.40E+03

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3.00E+03

5.60E+03

9.0E+04

4.30E+04

4.80E+03

1.30E+04

1.00E+02

1.40E+02

8.50E+05

1.20E+03

4.40E+03

1.00E+02

1.30E+03

8.70E+03

4.50E+03

5.80E+03

2.90E+03

Internal from ingestion (remuCi)

1.40E+03

7.70E+03

3.00E+03

5.60E+03

9.0E+04

4.30E+04

4.80E+03

1.30E+04

1.00E+02

1.40E+02

8.50E+05

1.20E+03

4.40E+03

1.00E+02

1.30E+03

8.70E+03

4.50E+03

5.80E+03

2.90E+03

Internal from ingestion (remuCi)

1.40E+03

7.70E+03

3.00E+03

5.60E+03

9.0E+04

4.30E+04

4.80E+03

1.30E+04

1.00E+02

1.40E+02

8.50E+05

1.20E+03

4.40E+03

1.00E+02

1.30E+03

8.70E+03

4.50E+03

5.80E+03

2.90E+03</

[illegible]

et dose

C. E

Aug 59	4 008 08	2 431 03	1 171 05	2 211 08	3 393 08	3 931 08	9 348 04	4 531 08	0 008 + 00	5 241 04	4 156 20	2 701 08	3 311 04	1 601 06	7 056 06	8 971 05	1 226 05	0 008 + 00	1 886 04	4 551 03
Sep 59	2 691 06	4 471 04	1 301 05	1 921 08	3 393 08	4 698 08	1 091 03	7 431 08	2 521 05	1 431 03	2 191 20	1 671 06	1 571 03	1 391 06	1 911 04	8 921 05	9 691 06	0 008 + 00	2 571 04	5 151 03
Oct 59	4 631 08	7 771 04	1 431 05	7 901 07	3 191 08	2 901 06	1 501 03	1 051 05	1 891 05	4 901 04	1 271 20	5 571 07	2 581 04	1 941 06	1 851 04	8 351 05	8 131 06	0 008 + 00	2 831 04	5 431 03
Nov 59	7 441 08	1 301 03	1 151 04	6 431 08	2 301 08	2 621 08	1 401 03	7 601 06	1 301 04	8 171 03	1 861 20	3 661 07	2 581 04	1 071 05	1 221 04	2 181 04	1 631 05	0 008 + 00	3 631 04	1 031 02
Dec 59	7 321 08	1 381 03	1 831 05	1 501 05	2 181 08	2 181 08	4 561 03	1 371 05	1 201 04	1 801 03	8 491 21	2 671 08	2 871 04	2 831 06	3 061 05	3 311 04	2 301 05	0 008 + 00	5 321 04	6 481 03
Jan 60	7 321 08	1 121 03	2 321 05	9 071 07	3 181 08	6 431 06	2 121 03	1 581 05	1 231 04	1 151 03	2 241 20	2 601 08	3 111 04	9 101 05	1 231 05	4 801 04	4 121 05	0 008 + 00	4 661 04	5 801 03
Feb 60	8 331 08	1 391 03	3 071 05	2 741 08	6 171 08	6 081 06	2 851 03	1 781 05	8 841 05	1 431 03	2 081 20	4 491 08	1 891 04	7 711 05	4 871 05	5 151 04	4 131 05	0 008 + 00	6 071 04	4 181 03
Mar 60	6 431 08	5 881 04	1 571 05	1 331 07	3 121 08	3 121 08	1 651 03	8 881 06	4 901 05	1 051 03	8 551 20	3 541 08	4 041 08	8 081 06	8 4341 08	1 671 04	4 341 05	0 008 + 00	2 691 04	3 081 03
Apr 60	4 021 08	4 301 04	2 021 05	1 231 08	7 571 08	3 381 08	1 171 03	7 111 08	6 731 05	8 481 04	8 351 20	1 011 05	4 481 05	1 751 08	8 171 08	1 371 05	1 581 05	0 008 + 00	1 381 04	1 771 03
May 60	2 291 08	2 421 04	1 371 05	1 371 08	8 921 08	1 991 08	6 871 04	6 281 06	7 891 05	8 651 04	6 381 19	3 541 08	4 781 05	1 541 08	1 651 08	8 371 05	9 381 08	0 008 + 00	1 381 04	1 901 03
Jun 60	2 021 08	2 661 04	7 531 08	1 451 08	7 491 08	7 471 08	6 931 04	4 861 08	7 891 05	7 541 04	1 211 19	3 181 08	5 251 06	1 711 08	3 371 08	1 721 04	1 851 05	0 008 + 00	2 381 04	4 481 03
Jul 60	4 251 08	1 141 03	2 151 05	9 221 05	4 301 08	4 901 08	1 831 04	4 831 08	7 001 05	7 181 04	5 271 21	3 181 08	2 271 04	6 251 06	8 791 08	4 831 04	2 201 05	0 008 + 00	4 681 04	9 721 03
Aug 60	6 591 08	7 121 04	3 891 03	5 001 08	6 421 08	3 821 08	1 971 03	1 481 05	0 008 + 00	1 481 03	9 721 22	8 851 08	1 771 03	8 841 08	8 551 08	4 841 04	2 891 05	0 008 + 00	4 401 04	1 111 02
Sep 60	7 001 08	6 311 04	2 801 03	8 891 08	4 731 08	9 081 07	3 101 03	2 431 05	0 008 + 00	1 481 03	1 131 21	8 491 08	1 101 03	4 931 06	5 891 08	3 581 04	4 291 05	0 008 + 00	8 221 04	1 331 02
Oct 60	2 041 05	1 511 03	4 031 04	8 381 06	1 601 07	1 721 05	4 321 03	3 621 05	0 008 + 00	4 801 03	2 681 21	8 161 08	1 101 03	8 271 06	5 891 05	8 791 04	4 871 05	0 008 + 00	8 421 04	1 381 02
Nov 60	1 491 05	2 211 03	4 081 04	1 271 08	2 001 07	2 101 05	5 991 03	2 241 05	0 008 + 00	2 831 03	4 511 21	2 431 05	1 131 03	1 031 05	8 891 05	1 641 03	1 721 04	0 008 + 00	1 241 03	1 831 02
Dec 60	1 691 05	2 491 03	4 121 05	4 591 08	2 101 07	2 091 05	7 291 03	4 811 05	0 008 + 00	4 241 03	1 091 20	2 481 05	1 071 03	1 891 05	8 151 04	6 081 05	0 008 + 00	7 351 04	8 801 03	
Jan 61	8 441 08	2 001 03	2 381 05	1 251 08	1 681 07	1 281 05	2 731 03	1 201 05	0 008 + 00	1 631 03	1 211 20	2 121 05	8 081 04	4 981 08	4 951 08	8 151 04	6 081 05	0 008 + 00	7 551 04	1 001 02
Feb 61	1 231 05	1 701 03	2 171 05	8 301 08	2 781 07	1 891 05	4 291 03	1 201 05	0 008 + 00	2 701 03	1 961 20	2 021 05	4 881 04	4 731 08	4 411 08	3 341 04	5 691 05	0 008 + 00	1 881 04	9 051 03
Mar 61	8 971 08	1 491 03	1 811 05	2 311 08	3 441 07	1 881 05	2 651 03	1 171 05	0 008 + 00	8 561 04	3 911 20	4 611 05	6 301 04	3 121 08	5 581 08	3 371 04	4 201 05	0 008 + 00	1 131 04	3 481 03
Apr 61	4 971 08	5 481 04	8 341 08	2 621 07	3 371 07	1 141 05	1 221 03	4 831 08	0 008 + 00	6 861 04	4 201 19	2 051 05	8 181 04	1 291 06	2 871 08	2 051 04	4 201 05	0 008 + 00	1 531 03	1 531 03
May 61	5 291 08	2 021 04	4 171 05	2 021 08	7 021 07	8 411 06	3 091 04	2 501 06	0 008 + 00	4 841 04	8 281 18	7 121 06	4 021 04	6 661 07	1 421 08	6 701 05	1 801 05	0 008 + 00	5 451 05	1 671 03
Jun 61	5 141 08	3 131 04	1 311 05	3 581 08	2 051 07	8 591 08	5 821 04	5 141 08	0 008 + 00	3 701 04	8 781 20	8 191 06	1 871 04	6 551 06	2 891 08	5 701 05	2 811 05	0 008 + 00	7 581 05	1 671 03
Jul 61	5 801 05	2 891 04	0 008 + 00	2 631 07	9 201 08	1 391 05	1 161 03	1 571 05	0 008 + 00	1 561 03	5 711 21	8 491 08	2 001 04	0 008 + 00	0 008 + 00	8 901 05	1 121 05	0 008 + 00	4 581 03	3 581 03
Aug 61	4 481 06	6 751 04	0 008 + 00	3 091 07	9 401 08	0 008 + 00	1 411 03	2 861 05	0 008 + 00	1 821 03	1 351 21	8 761 08	1 271 04	0 008 + 00	0 008 + 00	5 801 04	3 891 05	0 008 + 00	5 181 04	6 221 03
Sep 61	7 771 08	8 011 04	0 008 + 00	1 871 07	7 601 08	6 731 06	1 711 03	2 831 05	0 008 + 00	8 571 04	1 751 21	8 261 08	2 101 04	0 008 + 00	0 008 + 00	4 791 04	2 531 05	0 008 + 00	3 241 04	4 551 03
Oct 61	8 291 08	8 521 04	0 008 + 00	1 561 07	7 701 08	0 008 + 00	1 891 03	3 791 05	0 008 + 00	1 831 21	2 981 05	1 681 05	8 611 05	0 008 + 00	2 081 04	4 831 04	3 281 05	0 008 + 00	3 971 04	6 781 03
Nov 61	1 091 05	8 041 04	0 008 + 00	1 211 07	6 641 08	2 041 05	2 081 03	3 791 05	0 008 + 00	1 251 03	1 831 21	2 981 05	2 131 04	0 008 + 00	0 008 + 00	2 081 04	2 881 05	0 008 + 00	4 321 04	5 201 03
Dec 61	1 001 05	8 111 04	0 008 + 00	4 651 07	6 821 08	1 661 05	1 301 03	4 301 05	0 008 + 00	2 181 03	5 361 21	2 141 05	1 591 04	0 008 + 00	0 008 + 00	1 451 04	1 791 05	0 008 + 00	3 561 04	6 271 03
Jan 62	1 051 05	8 841 04	0 008 + 00	5 241 07	8 571 08	2 731 05	1 591 03	3 211 05	0 008 + 00	1 691 03	1 111 20	2 821 05	1 521 04	0 008 + 00	0 008 + 00	3 841 04	1 751 05	0 008 + 00	7 291 04	8 151 03
Feb 62	1 051 05	8 841 04	0 008 + 00	5 241 07	8 571 08	2 731 05	1 591 03	3 211 05	0 008 + 00	1 691 03	1 111 20	2 821 05	1 521 04	0 008 + 00	0 008 + 00	3 841 04	1 751 05	0 008 + 00	7 291 04	8 151 03
Mar 62	1 371 05	1 411 03	0 008 + 00	4 881 07	1 871 07	3 081 05	2 891 03	3 931 05	0 008 + 00	2 281 03	4 471 21	4 491 05	1 201 04	0 008 + 00	0 008 + 00	4 331 04	7 671 05	0 008 + 00	3 841 04	6 651 03
Apr 62	1 151 05	7 871 04	0 008 + 00	4 491 07	7 601 07	3 141 08	1 721 03	3 351 05	0 008 + 00	2 931 03	2 851 20	4 831 05	3 881 34	0 008 + 00	0 008 + 00	3 331 04	4 811 05	0 008 + 00	7 801 04	6 651 03
May 62	8 091 08	2 471 04	0 008 + 00	6 791 07	8 111 07	1 911 05	7 481 04	2 371 05	0 008 + 00	1 701 03	2 431 19	1 621 05	1 341 05	0 008 + 00	0 008 + 00	5 871 04	5 481 05	0 008 + 00	3 181 04	3 911 03
Jun 62	4 431 08	4 341 04	0 008 + 00	1 411 07	6 811 07	8 091 08	4 191 04	2 861 05	0 008 + 00	8 611 04	7 091 19	1 501 05	4 331 05	0 008 + 00	0 008 + 00	8 691 05	1 001 05	0 008 + 00	2 501 04	1 961 03
Jul 62	4 601 08	2 511 04	0 008 + 00	2 881 07	6 531 06	4 321 04	1 811 05	1 951 05	3 451 04	1 381 03	0 008 + 00	0 008 + 00	1 251 04	0 008 + 00	0 008 + 00	0 008 + 00	0 008 + 00	0 008 + 00	2 271 04	3 781 03
Aug 62	7 051 08	4 621 04	0 008 + 00	0 008 + 00	1 831 07	1 351 05	7 151 04	1 851 05	0 008 + 00	1 111 03	0 008 + 00	0 008 + 00	3 001 04	0 008 + 00	0 008 + 00	0 008 + 00	0 008 + 00	0 008 + 00	4 291 04	5 771 03
Sep 62	1 051 05	7 511 04	0 008 + 00	0 008 + 00	1 321 07	1 861 05	1 031 03	2 741 05	2 151 05	2 481 03	0 008 + 00	0 008 + 00	2 841 04	0 008 + 00	0 008 + 00	0 008 + 00	0 008 + 00	0 008 + 00	3 191 04	6 091 03
Oct 62	8 291 08	6 811 04	0 008 + 00	0 008 + 00	1 081 07	2 651 05	1 091 03	2 361 05	0 008 + 00	1 811 03	0 008 + 00	0 008 + 00	2 841 04	0 008 + 00	0 008 + 00	0 008 + 00	0 008 + 00	0 008 + 00	4 781 03	6 091 03
Nov 62	6 821 08	4 781 04	0 008 + 00	0 008 + 00	1 401 07	1 831 05	9 011 04	3 531 05	1 411 04	1 291 03	0 008 + 00	0 008 + 00	3 741 04	0 008 + 00	0 008 + 00	0 008 + 00	0 008 + 00	0 008 + 00	2 581 04	1 211 02
Dec 62	6 501 06	5 771 04	0 008 + 00	0 008 + 00	1 041 07	1 831 05	9 241 04	1 831 05	2 391 04	1 341 03	0 008 + 00	0 008 + 00	1 611 04	0 008 + 00	0 008 + 00	0 008 + 00	0 008 + 00	0 008 + 00	1 311 04	2 801 03
Jan 63	6 121 08	5 661 04	0 008 + 00	0 008 + 00	5 711 08	1 831 05	8 411 04	1 081 05	1 471 05	9 201 04	0 008 + 00	0 008 + 00	1 611 04	0 008 + 00	0 008 + 00	0 008 + 00	0 008 + 00	0 008 + 00	1 431 04	2 821 03
Feb 63	7 191 08	4 871 04	0 008 + 00	0 008 + 00	9 441 08	1 281 05	9 241 04	1 481 05	3 001 05	9 481 04	0 008 + 00	0 008 + 00	1 631 04	0 008 + 00	0 008 + 00	0 008 + 00	0 008 + 00	0 008 + 00	4 101 04	6 291 03
Mar 63	1 171 05	8 191 04	0 008 + 00	0 008 + 00	1 691 07	1 521 05	2 871 03	1 781 05	2 891 05	5 891 04	0 008 + 00	0 008 + 00	1 601 04	0 008 + 00	0 008 + 00	0 008 + 00	0 008 + 00	0 008 + 00	3 191 04	6 151 03
Apr 63	1 071 05	8 231 04	0 008 + 00	0 008 + 00	2 011 07	1 151 05	1 861 03	1 421 05	3 541 05	9 811 04	0 008 + 00	0 008 + 00	1 511							

	External Drinking Fish Total %
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[illegible]

External exposure	Dose is calculated as water conc * hr/yr * Dose factor.																			Monthly sum	
	Water conc is calculated as release (Ci/d) / exp(farlands*transat)/flow (cfs)/m3/d (per cfs).																				
	1.66E-03	0.00E+00	1.43E-17	9.34E-08	4.09E-05	3.68E-05	6.78E-05	2.81E-05	3.09E-05	8.14E-18	4.85E-08	2.55E-04	6.18E-11	0.00E+00	0.00E+00	8.28E-08	4.32E-05	1.64E-07	2.38E-03		
Jan-61	1.66E-03	0.00E+00	1.43E-17	9.34E-08	4.09E-05	3.68E-05	6.78E-05	2.81E-05	3.09E-05	8.14E-18	4.85E-08	2.55E-04	6.18E-11	0.00E+00	0.00E+00	8.28E-08	4.32E-05	1.64E-07	2.38E-03		
Feb-61	9.35E-04	0.00E+00	8.27E-18	2.65E-08	2.53E-05	2.28E-05	2.53E-05	6.51E-08	1.17E-05	9.05E-18	4.15E-08	1.58E-04	2.90E-11	0.00E+00	0.00E+00	2.43E-08	2.55E-05	1.17E-07	1.37E-03		
Mar-61	1.26E-03	0.00E+00	7.54E-18	1.69E-05	3.41E-05	3.88E-05	3.88E-05	6.81E-08	1.97E-05	1.05E-18	4.04E-08	1.78E-04	2.83E-11	0.00E+00	0.00E+00	2.62E-08	1.29E-05	1.13E-07	1.87E-03		
Apr-61	8.93E-04	0.00E+00	6.63E-18	4.71E-08	6.81E-05	3.31E-05	2.46E-05	6.85E-08	2.91E-05	2.81E-17	9.03E-08	1.51E-04	1.87E-11	0.00E+00	0.00E+00	2.73E-08	6.53E-08	9.91E-08	1.32E-03		
May-61	5.51E-04	0.00E+00	3.24E-18	5.33E-07	6.56E-05	2.10E-05	1.14E-05	2.62E-06	4.78E-05	3.13E-18	4.01E-08	1.47E-04	7.88E-12	0.00E+00	0.00E+00	2.02E-08	3.91E-06	4.58E-08	8.13E-04		
Jun-61	5.89E-04	0.00E+00	1.45E-18	4.11E-08	1.37E-04	1.13E-05	2.87E-08	3.52E-08	6.37E-05	6.17E-15	1.39E-08	9.61E-05	3.98E-12	0.00E+00	0.00E+00	7.87E-07	1.89E-06	3.27E-08	8.42E-04		
Jul-61	5.63E-04	0.00E+00	4.54E-18	7.29E-08	3.90E-05	1.18E-05	6.50E-08	2.79E-06	2.69E-06	5.05E-17	1.80E-08	4.47E-05	3.31E-11	0.00E+00	0.00E+00	1.25E-08	2.63E-06	5.39E-08	6.82E-04		
Aug-61	8.81E-04	0.00E+00	0.00E+00	1.79E-05	1.78E-05	2.43E-05	1.08E-08	1.86E-08	1.14E-05	4.25E-18	1.69E-08	4.90E-05	0.00E+00	0.00E+00	0.00E+00	6.39E-07	6.29E-08	1.04E-07	7.81E-04		
Sep-61	4.84E-04	0.00E+00	0.00E+00	8.28E-07	1.63E-05	0.00E+00	1.31E-05	1.81E-05	1.32E-05	1.01E-18	1.71E-08	3.05E-05	0.00E+00	0.00E+00	0.00E+00	1.79E-08	1.60E-05	1.53E-07	6.07E-04		
Oct-61	8.81E-04	0.00E+00	0.00E+00	8.81E-05	1.49E-05	1.54E-05	1.54E-05	1.43E-05	6.97E-08	3.31E-18	1.82E-08	5.02E-05	0.00E+00	0.00E+00	0.00E+00	1.22E-08	1.12E-05	1.62E-07	9.92E-04		
Nov-61	1.03E-03	0.00E+00	0.00E+00	3.18E-07	1.50E-05	0.00E+00	1.81E-05	1.90E-05	9.40E-08	2.00E-18	3.28E-08	1.63E-05	0.00E+00	0.00E+00	0.00E+00	1.58E-08	1.38E-05	1.87E-07	1.13E-03		
Dec-61	1.16E-03	0.00E+00	0.00E+00	2.47E-07	1.29E-05	3.60E-05	1.91E-05	2.08E-05	1.31E-08	1.37E-18	5.83E-08	5.10E-05	0.00E+00	0.00E+00	0.00E+00	1.42E-08	1.50E-05	1.87E-07	1.37E-03		
Total	1.11E-02	0.00E+00	4.90E-17	3.63E-05	5.18E-04	2.45E-04	1.31E-04	1.53E-04	1.53E-04	6.81E-15	4.34E-05	1.26E-03	1.82E-10	0.00E+00	0.00E+00	2.86E-05	1.81E-04	1.39E-08	1.39E-02		
													0%	0%	0%	0%	1%	0%	100%		

Internal doses by radionuclide and month

Drinking water dose
Calculated as water conc. * DW Transmission factor * consumption * dose factor

	Jan 01	Feb 01	Mar 01	Apr 01	May 01	Jun 01	Jul 01	Aug 01	Sep 01	Oct 01	Nov 01	Dec 01	Total DW						
Ca 45	4.78E-04	1.09E-04	3.74E-08	1.25E-05	8.93E-07	7.30E-05	6.34E-04	1.77E-04	4.81E-04	9.81E-18	5.14E-08	3.48E-04	1.28E-06	1.81E-08	4.71E-04	5.68E-05	7.32E-04	2.89E-05	3.38E-03
Co 60	2.40E-04	8.72E-05	2.17E-08	3.42E-08	5.47E-07	4.47E-05	2.37E-04	4.42E-05	1.73E-04	1.08E-17	4.40E-08	3.48E-04	6.92E-07	5.33E-07	1.01E-04	1.87E-05	2.18E-04	2.09E-05	1.74E-03
Co 60	3.50E-04	7.44E-05	1.97E-08	2.27E-05	9.17E-07	8.73E-05	3.73E-04	4.41E-05	3.06E-04	1.78E-17	4.29E-08	1.63E-04	5.78E-07	6.33E-07	5.51E-05	1.78E-05	2.18E-04	2.01E-05	1.70E-03
Co 60	2.55E-04	6.53E-05	1.74E-08	6.31E-08	1.14E-06	6.66E-05	2.30E-04	4.33E-05	4.07E-04	3.77E-17	9.67E-08	2.08E-04	3.80E-07	6.74E-07	5.58E-05	1.88E-05	1.11E-04	1.78E-05	1.48E-03
Co 60	1.41E-04	2.53E-05	8.48E-07	7.16E-07	1.11E-06	3.90E-05	1.08E-04	1.77E-05	7.45E-05	3.77E-18	4.25E-08	2.01E-04	1.68E-07	3.47E-07	3.39E-05	1.39E-05	6.63E-05	8.18E-06	7.28E-04
Co 60	1.50E-04	8.82E-06	3.79E-08	5.52E-08	2.32E-06	2.24E-05	2.88E-05	9.19E-06	5.49E-05	7.43E-15	1.48E-08	1.31E-04	8.11E-08	1.72E-07	8.63E-08	3.20E-05	4.23E-06	4.52E-04	4.23E-04
Co 60	1.48E-04	1.31E-05	1.19E-08	9.78E-08	6.77E-07	2.30E-05	1.54E-05	1.80E-05	4.70E-05	6.08E-17	1.81E-08	8.11E-05	8.75E-07	3.25E-07	9.42E-08	4.46E-05	8.59E-06	7.82E-04	7.82E-04
Co 60	1.68E-04	3.27E-05	0.00E+00	0.00E+00	3.10E-07	4.81E-05	1.01E-04	5.77E-05	1.77E-04	5.12E-18	1.78E-08	6.58E-05	0.00E+00	0.00E+00	1.63E-05	3.89E-08	1.07E-04	1.85E-05	1.85E-05
Co 60	1.27E-04	2.85E-05	0.00E+00	8.43E-07	2.51E-07	3.05E-05	1.22E-04	1.09E-04	2.08E-04	1.21E-18	1.82E-08	4.18E-05	0.00E+00	0.00E+00	9.75E-05	3.05E-04	3.05E-04	2.72E-05	1.05E-03
Co 60	2.21E-04	3.50E-05	0.00E+00	5.10E-07	2.51E-07	3.05E-05	1.48E-04	9.87E-05	1.90E-04	1.27E-18	1.71E-08	8.88E-05	0.00E+00	0.00E+00	7.91E-05	3.37E-08	1.90E-04	2.88E-05	9.88E-04
Co 60	2.83E-04	4.18E-05	0.00E+00	4.27E-07	2.54E-07	0.00E+00	1.70E-04	1.28E-04	2.08E-04	1.42E-18	3.40E-06	6.98E-05	0.00E+00	0.00E+00	7.97E-05	1.08E-05	2.33E-04	2.87E-05	1.16E-03
Co 60	3.06E-04	3.95E-05	0.00E+00	3.32E-07	2.18E-07	7.13E-05	1.79E-04	1.39E-04	1.42E-04	1.84E-18	6.19E-06	8.98E-05	0.00E+00	0.00E+00	3.46E-05	9.70E-06	2.54E-04	3.32E-05	1.25E-03
Co 60	2.84E-03	5.41E-04	1.20E-05	4.88E-05	8.74E-08	4.88E-04	2.38E-03	8.85E-04	2.38E-03	7.88E-15	4.60E-05	1.73E-03	3.72E-08	4.40E-08	8.41E-04	1.83E-04	2.72E-03	2.47E-04	1.51E-02
Co 60	2.84E-03	5.41E-04	1.20E-05	4.88E-05	8.74E-08	4.88E-04	2.38E-03	8.85E-04	2.38E-03	7.88E-15	4.60E-05	1.73E-03	3.72E-08	4.40E-08	8.41E-04	1.83E-04	2.72E-03	2.47E-04	1.51E-02
Co 60	2.84E-03	5.41E-04	1.20E-05	4.88E-05	8.74E-08	4.88E-04	2.38E-03	8.85E-04	2.38E-03	7.88E-15	4.60E-05	1.73E-03	3.72E-08	4.40E-08	8.41E-04	1.83E-04	2.72E-03	2.47E-04	1.51E-02
Co 60	2.84E-03	5.41E-04	1.20E-05	4.88E-05	8.74E-08	4.88E-04	2.38E-03	8.85E-04	2.38E-03	7.88E-15	4.60E-05	1.73E-03	3.72E-08	4.40E-08	8.41E-04	1.83E-04	2.72E-03	2.47E-04	1.51E-02
Co 60	2.84E-03	5.41E-04	1.20E-05	4.88E-05	8.74E-08	4.88E-04	2.38E-03	8.85E-04	2.38E-03	7.88E-15	4.60E-05	1.73E-03	3.72E-08	4.40E-08	8.41E-04	1.83E-04	2.72E-03	2.47E-04	1.51E-02
Co 60	2.84E-03	5.41E-04	1.20E-05	4.88E-05	8.74E-08	4.88E-04	2.38E-03	8.85E-04	2.38E-03	7.88E-15	4.60E-05	1.73E-03	3.72E-08	4.40E-08	8.41E-04	1.83E-04	2.72E-03	2.47E-04	1.51E-02
Co 60	2.84E-03	5.41E-04	1.20E-05	4.88E-05	8.74E-08	4.88E-04	2.38E-03	8.85E-04	2.38E-03	7.88E-15	4.60E-05	1.73E-03	3.72E-08	4.40E-08	8.41E-04	1.83E-04	2.72E-03	2.47E-04	1.51E-02
Co 60	2.84E-03	5.41E-04	1.20E-05	4.88E-05	8.74E-08	4.88E-04	2.38E-03	8.85E-04	2.38E-03	7.88E-15	4.60E-05	1.73E-03	3.72E-08	4.40E-08	8.41E-04	1.83E-04	2.72E-03	2.47E-04	1.51E-02
Co 60	2.84E-03	5.41E-04	1.20E-05	4.88E-05	8.74E-08	4.88E-04	2.38E-03	8.85E-04	2.38E-03	7.88E-15	4.60E-05	1.73E-03	3.72E-08	4.40E-08	8.41E-04	1.83E-04	2.72E-03	2.47E-04	1.51E-02
Co 60	2.84E-03	5.41E-04	1.20E-05	4.88E-05	8.74E-08	4.88E-04	2.38E-03	8.85E-04	2.38E-03	7.88E-15	4.60E-05	1.73E-03	3.72E-08	4.40E-08	8.41E-04	1.83E-04	2.72E-03	2.47E-04	1.51E-02
Co 60	2.84E-03	5.41E-04	1.20E-05	4.88E-05	8.74E-08	4.88E-04	2.38E-03	8.85E-04	2.38E-03	7.88E-15	4.60E-05	1.73E-03	3.72E-08	4.40E-08	8.41E-04	1.83E-04	2.72E-03	2.47E-04	1.51E-02
Co 60	2.84E-03	5.41E-04	1.20E-05	4.88E-05	8.74E-08	4.88E-04	2.38E-03	8.85E-04	2.38E-03	7.88E-15	4.60E-05	1.73E-03	3.72E-08	4.40E-08	8.41E-04	1.83E-04	2.72E-03	2.47E-04	1.51E-02
Co 60	2.84E-03	5.41E-04	1.20E-05	4.88E-05	8.74E-08	4.88E-04	2.38E-03	8.85E-04	2.38E-03	7.88E-15	4.60E-05	1.73E-03	3.72E-08	4.40E-08	8.41E-04	1.83E-04	2.72E-03	2.47E-04	1.51E-02
Co 60	2.84E-03	5.41E-04	1.20E-05	4.88E-05	8.74E-08	4.88E-04	2.38E-03	8.85E-04	2.38E-03	7.88E-15	4.60E-05	1.73E-03	3.72E-08	4.40E-08	8.41E-04	1.83E-04	2.72E-03	2.47E-04	1.51E-02
Co 60	2.84E-03	5.41E-04	1.20E-05	4.88E-05	8.74E-08	4.88E-04	2.38E-03	8.85E-04	2.38E-03	7.88E-15	4.60E-05	1.73E-03	3.72E-08	4.40E-08	8.41E-04	1.83E-04	2.72E-03	2.47E-04	1.51E-02
Co 60	2.84E-03	5.41E-04	1.20E-05	4.88E-05	8.74E-08	4.88E-04	2.38E-03	8.85E-04	2.38E-03	7.88E-15	4.60E-05	1.73E-03	3.72E-08	4.40E-08	8.41E-04	1.83E-04	2.72E-03	2.47E-04	1.51E-02
Co 60	2.84E-03	5.41E-04	1.20E-05	4.88E-05	8.74E-08	4.88E-04	2.38E-03	8.85E-04	2.38E-03	7.88E-15	4.60E-05	1.73E-03	3.72E-08	4.40E-08	8.41E-04	1.83E-04	2.72E-03	2.47E-04	1.51E-02
Co 60	2.84E-03	5.41E-04	1.20E-05	4.88E-05	8.74E-08	4.88E-04	2.38E-03	8.85E-04	2.38E-03	7.88E-15	4.60E-05	1.73E-03	3.72E-08	4.40E-08	8.41E-04	1.83E-04	2.72E-03	2.47E-04	1.51E-02
Co 60	2.84E-03	5.41E-04	1.20E-05	4.88E-05	8.74E-08	4.88E-04	2.38E-03	8.85E-04	2.38E-03	7.88E-15	4.60E-05	1.73E-03	3.72E-08	4.40E-08	8.41E-04	1.83E-04	2.72E-03	2.47E-04	1.51E-02
Co 60	2.84E-03	5.41E-04	1.20E-05	4.88E-05	8.74E-08	4.88E-04	2.38E-03	8.85E-04	2.38E-03	7.88E-15	4.60E-05	1.73E-03	3.72E-08	4.40E-08	8.41E-04	1.83E-04	2.72E-03	2.47E-04	1.51E-02
Co 60	2.84E-03	5.41E-04	1.20E-05	4.88E-05	8.74E-08	4.88E-04	2.38E-03	8.85E-04	2.38E-03	7.88E-15	4.60E-05	1.73E-03	3.72E-08	4.40E-08	8.41E-04	1.83E-04	2.72E-03	2.47E-04	1.51E-02
Co 60	2.84E-03	5.41E-04	1.20E-05	4.88E-05	8.74E-08	4.88E-04	2.38E-03	8.85E-04	2.38E-03	7.88E-15	4.60E-05	1.73E-03	3.72E-08	4.40E-08	8.41E-04	1.83E-04	2.72E-03	2.47E-04	1.51E-02
Co 60	2.84E-03	5.41E-04	1.20E-05	4.88E-05	8.74E-08	4.88E-04	2.38E-03	8.85E-04	2.38E-03	7.88E-15	4.60E-05	1.73E-03	3.72E-08	4.40E-08	8.41E-04	1.83E-04	2.72E-03	2.47E-04	1.51E-02
Co 60	2.84E-03	5.41E-04	1.20E-05	4.88E-05	8.74E-08	4.88E-04	2.38E-03	8.85E-04	2.38E-03	7.88E-15	4.60E-05	1.73E-03	3.72E-08	4.40E-08	8.41E-04	1.83E-04	2.72E-03	2.47E-04	1.51E-02
Co 60	2.84E-03	5.41E-04	1.20E-05	4.88E-05	8.74E-08	4.88E-04	2.38E-03	8.85E-04	2.38E-03	7.88E-15	4.60E-05	1.73E-03	3.72E-08	4.40E-08	8.41E-04	1.83E-04	2.72E-03	2.47E-04	1.51E-02
Co 60	2.84E-03	5.41E-04	1.20E-05	4.88E-05	8.74E-08	4.88E-04	2.38E-03	8.85E-04	2.38E-03	7.88E-15	4.60E-05	1.73E-03	3.72E-08	4.40E-08	8.41E-04	1.83E-04	2.72E-03	2.47E-04	1.51E-02
Co 60	2.84E-03	5.41E-04	1.20E-05	4.88E-05	8.74E-08	4.88E-04	2.38E-03	8.85E-04	2.38E-03	7.88E-15	4.60E-05	1.73E-03	3.72E-08	4.40E-08	8.41E-04	1.83E-04	2.72E-03	2.47E-04	1.51E-02
Co 60	2.84E-03	5.41E-04	1.20E-05	4.88E-05	8.74E-08	4.88E-04	2.38E-03	8.85E-04	2.38E-03	7.88E-15	4.60E-05	1.73E-03	3.72E-08	4.40E-08	8.41E-04	1.83E-04	2.72E-03	2.47E-04	1.51E-02
Co 60	2.84E-03	5.41E-04	1.20E-05	4.88E-05	8.74E-08	4.88E-04	2.38E-03	8.85E-04	2.38E-03	7.88E-15	4.60E-05	1.73E-03	3.72E-08	4.40E-08	8.41E-04	1.83E-04	2.72E-03	2.47E-04	1.51E-02
Co 60	2.84E-03	5.41E-04	1.20E-05	4.88E-05	8.74E-08	4.88E-04	2.38E-03	8.85E-04	2.38E-03	7.88E-15	4.60E-05	1.73E-03	3.72E-08	4.40E-08	8.41E-04	1.83E-04	2.72E-03	2.47E-04	1.51E-02
Co 60	2.84E-03	5.41E-04	1.20E-05	4.88E-05	8.74E-08	4.88E-04	2.38E-03	8.85E-04	2.38E-03	7.88E-15	4.60E-05	1.73E-03	3.72E-08	4.40E-08	8.41E-04	1.83E-04	2.72E-03	2.47E-04	1.51E-02
Co 60	2.84E-03	5.41E-04	1.20E-05	4.88E-05	8.74E-08	4.88E-04	2.38E-03	8.85E-04	2.38E-03	7.88E-15	4.60E-05	1.73E-03	3.72E-08	4.40E-08	8.41E-04	1.83E-04	2.72E-03	2.47E-04	1.51E-02
Co 60	2.84E-03	5.41E-04	1.20E-05	4.88E-05	8.74E-08	4.88E-04	2.38E-03	8.85E-04	2.38E-03	7.88E-15	4.60E-05	1.73E-03	3.72E-08	4.40E-08	8.41E-04	1.83E-04	2.72E-03	2.47E-04	1.51E-02
Co 60	2.84E-03	5.41E-04	1.20E-05	4.88E-05	8.74E-08	4.88E-04	2.38E-03	8.85E-04	2.38E-03	7.88E-15	4.60E-05	1.73E-03	3.72E-08	4.40E-08	8.41E-04	1.83E-04	2.72E-03	2.47E-04	1.51E-02
Co 60	2.84E-03	5.41E-04	1.20E-05	4.88E-05	8.74E-														

[illegible]

Calculated as water conc. • DW Transmission factor • consumption • dose factor.

Total D.W.	1.71E-03	3.26E-04	7.25E-06	2.89E-05	5.27E-08	2.83E-04	1.43E-03	5.33E-04	1.44E-03	4.70E-15	2.77E-05	1.04E-03	2.88E-08	6.07E-04	1.10E-04	1.04E-03	1.48E-04	8.11E-03
	0%	0%	0%	0%	0%	1%	18%	6%	18%	0%	0%	11%	0%	6%	1%	18%	2%	100%

Fish consumption dose
Calculated as water conc. * bioaccumulation * consumption * dose factor; 1-day holdup assumed.

[illegible]

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1961
Releases from all 8 reactors
DATE 1/2 (d) Ns-24 Cld P-32 Cld C-45 Cld Sc-48 Cld Mh-56 Cld Cu-64 Cld As-78 Cld Cr-51 Cld Zn-65 Cld Zn-69 Cld Zn-69m Cld Ga-72 Cld Sr-89 Cld Sr-90 Cld Y-90 Cld Y-83 Cld Np-239 Cld Columbia Flow Rate cfs Travel Time Days

Jan-61	4.70E+03	9.89E+01	3.21E+00	1.93E+01	3.91E+04	2.81E+03	1.19E+03	3.81E+03	2.21E+02	9.58E+01	1.54E+02	1.08E+03	1.89E+00	1.79E+01	5.03E+02	1.69E+03	1.40E+03	63708	5.01
Feb-61	3.14E+03	1.09E+02	2.82E+00	7.43E+00	3.00E+04	2.26E+03	8.04E+02	1.27E+03	1.12E+02	5.72E+01	1.74E+02	1.44E+03	1.25E+00	8.30E+02	2.81E+02	8.41E+02	1.15E+03	89879	4.52
Mar-61	4.73E+03	9.89E+01	2.49E+00	5.12E+01	4.99E+04	3.51E+03	9.04E+02	1.32E+03	2.08E+02	8.41E+02	1.74E+02	8.97E+02	1.27E+00	7.70E+02	1.48E+02	7.04E+02	8.03E+02	83413	4.45
Apr-61	3.82E+03	9.89E+01	2.49E+00	1.63E+01	5.97E+04	3.77E+03	8.81E+02	1.40E+03	3.12E+02	1.21E+02	4.31E+02	9.74E+02	9.53E+01	1.11E+01	1.89E+02	8.09E+02	3.48E+02	109483	4.22
May-61	3.69E+03	7.71E+01	2.89E+00	4.05E+00	3.22E+04	3.81E+03	6.09E+02	1.32E+03	1.28E+02	6.15E+01	3.29E+02	1.63E+03	8.81E+01	1.26E+01	2.14E+02	9.25E+02	4.28E+02	234488	2.63
Jun-61	5.83E+03	5.59E+01	2.36E+00	6.18E+01	2.53E+04	3.03E+03	2.57E+02	1.35E+03	1.83E+02	2.44E+01	1.64E+02	1.55E+03	8.79E+01	1.23E+01	7.74E+01	4.57E+02	3.79E+02	463067	1.01
Jul-61	3.42E+03	3.78E+01	3.18E+00	4.70E+01	2.35E+04	2.00E+03	2.57E+02	1.18E+03	6.01E+01	2.20E+01	1.32E+02	4.48E+02	3.15E+00	1.00E+01	5.11E+01	6.32E+02	2.48E+02	189703	2.82
Aug-61	2.45E+03	1.85E+01	1.77E+00	1.40E+00	1.62E+04	2.87E+03	2.88E+02	1.88E+03	1.02E+02	1.99E+01	7.68E+01	2.99E+02						101681	4.31
Sep-61	1.33E+03	2.83E+01	1.40E+00	1.40E+00	1.72E+04	2.45E+02	2.39E+03	1.30E+02	1.08E+01	1.08E+01	5.78E+01	1.39E+02						88587	4.92
Oct-61	2.21E+03	3.17E+01	8.00E+01	1.98E+04		1.18E+03	2.82E+02	2.01E+03	5.07E+01	1.50E+01	5.20E+01	2.18E+02						84774	4.99
Nov-61	2.57E+03	3.68E+01	6.50E+01	1.40E+04		3.14E+02	2.59E+03	9.44E+01	2.40E+01	1.03E+02	6.90E+01							82883	5.03
Dec-61	2.71E+03	3.10E+01	4.50E+01	1.18E+04		2.47E+03	2.98E+02	2.50E+03	5.73E+01	1.90E+01	1.88E+02	1.98E+02						56028	5.17

Columbia River Flow Multipliers
Umatilla Vancouver TriCities The Dalles
1.48 1.95 1 1.55
121512 cfs 178414 cfs 188983 cfs 236532 cfs
(Ref: Walters et al. Ch. 3.0)

Dose Conversion Factors by Radionuclide
External from swimming/boating (mSv/y per uCi/m3) Effective Dose (Ref: DOE/EH-0070) 2.08 4.79 0.347 8.56 6.52E-05 4.52 32.8 1.55E-03 0 0 1.05 1.89

Internal from ingestion (rem/uCi) (Ref: DOE/EH-0071) 1.40E-03 7.70E-03 3.00E-03 5.80E-03 9.50E-04 4.30E-04 4.80E-03 1.30E-04 1.40E-02 8.50E-05 1.20E-03 4.40E-03 8.70E-03 1.30E-01 1.00E-02 4.50E-03 2.90E-03

Resident fish bioaccumulation factors (L/kg) (Ref: Walters et al. p. 10.7; GENII BIOAC1.DAT) 1 1700 200 2 70 0.5 1 0.7 1 0.4 0.4 0.4 64 64 100 (1/10 equilibrium) 30 30 25 25 0.2 0.2 0.2 0.7
Drinking water transmission factors (Ref: GENII BIOAC1.DAT) 0.9 0.4 1 0.3 0.5 1 0.7 1 0.4 0.4 0.4 64 64 100 (1/10 equilibrium) 30 30 25 25 0.2 0.2 0.2 0.7
(Note: a minimal transit time in the distribution system of 12 hours is assumed.)

Individual exposure parameters
Boating 500 hr/yr
Swimming 100 hr/yr
Drinking 730 L/yr
Fish 40 kg/yr

External exposure	Dose is calculated as water conc * hr/yr * Dose factor.										Water conc is calculated as release (Ci/d) * exp(lambda*transit)/flow (cfs)/m3/d per cfs).										Monthly sum																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																											
	Jan-61	Feb-61	Mar-61	Apr-61	May-61	Jun-61	Jul-61	Aug-61	Sep-61	Oct-61	Nov-61	Dec-61	Ext. Total																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			

Calculated as water conc. • DW Transmission factor • consumption • dose factor.

	Jan-61	Feb-61	Mar-61	Apr-61	May-61	Jun-61	Jul-61	Aug-61	Sep-61	Oct-61	Nov-61	Dec-61	Total D.W.				
3.48E-08	6.03E-05	2.48E-08	8.19E-08	2.33E-07	3.26E-05	1.08E-04	3.21E-04	9.05E-50	2.48E-08	1.89E-08	8.30E-07	1.22E-08	4.60E-08	2.86E-05	4.90E-08	1.49E-04	7.53E-04
2.84E-08	4.94E-05	1.41E-08	2.08E-17	2.55E-07	1.61E-05	2.73E-05	1.18E-04	2.76E-48	3.62E-08	3.18E-08	8.03E-07	4.04E-07	2.66E-05	2.80E-08	2.80E-08	1.00E-04	3.46E-04
4.43E-08	4.23E-05	1.31E-08	4.19E-05	1.55E-07	2.63E-05	2.72E-05	2.05E-04	9.09E-44	3.78E-08	1.60E-08	3.71E-07	3.90E-07	1.47E-05	3.30E-08	3.30E-08	1.54E-05	3.90E-04
4.03E-08	3.74E-05	4.15E-08	4.15E-08	4.15E-07	1.84E-05	2.67E-05	2.72E-04	9.59E-44	1.08E-07	2.58E-08	2.45E-07	4.55E-07	1.56E-05	4.83E-08	4.83E-08	2.77E-05	4.11E-04
4.15E-05	1.16E-08	5.68E-07	4.70E-07	2.22E-08	2.16E-05	1.14E-05	6.00E-05	3.40E-31	2.89E-07	1.43E-05	1.03E-07	2.35E-07	1.40E-05	4.08E-07	4.08E-07	2.68E-05	1.87E-04
1.55E-05	5.78E-06	1.08E-08	3.29E-12	3.29E-12	6.49E-08	1.21E-05	3.70E-05	4.69E-20	4.57E-07	4.15E-05	5.43E-08	1.19E-07	3.70E-08	1.23E-08	1.23E-08	1.76E-05	1.82E-04
4.97E-05	5.78E-06	6.55E-07	4.84E-08	6.49E-08	2.54E-07	1.20E-05	2.82E-05	1.35E-34	8.56E-08	2.92E-08	4.42E-07	2.20E-07	3.56E-08	1.45E-07	1.45E-07	8.89E-05	8.99E-05
8.20E-08	8.30E-08	7.95E-07	8.49E-08	2.25E-13	7.75E-07	3.58E-05	1.19E-04	3.77E-45	1.82E-08	7.47E-07	0.00E+00	0.00E+00	0.00E+00	2.33E-05	2.33E-05	2.61E-05	2.04E-04
2.47E-08	7.48E-06	0.00E+00	4.72E-07	3.50E-07	6.72E-05	3.58E-05	1.39E-04	5.28E-50	9.73E-09	2.50E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.86E-05	3.19E-04
1.01E-06	1.64E-05	0.00E+00	5.51E-07	1.17E-18	0.00E+00	6.65E-05	1.39E-04	5.28E-50	8.46E-09	3.91E-07	0.00E+00	0.00E+00	0.00E+00	1.88E-05	1.88E-05	3.90E-05	2.18E-04
1.64E-08	1.84E-05	0.00E+00	3.33E-07	6.14E-19	9.98E-08	7.73E-06	7.25E-05	2.05E-50	1.65E-08	1.19E-07	0.00E+00	0.00E+00	0.00E+00	8.85E-08	8.85E-08	4.73E-05	3.17E-04
1.88E-08	2.30E-05	0.00E+00	2.78E-07	4.90E-19	0.00E+00	8.66E-08	7.84E-05	1.71E-50	1.65E-08	1.19E-07	0.00E+00	0.00E+00	0.00E+00	6.30E-08	6.30E-08	4.98E-05	2.70E-04
1.91E-08	2.18E-05	0.00E+00	2.16E-07	1.92E-19	1.90E-07	8.45E-08	8.47E-05	1.23E-51	2.52E-08	3.21E-07	0.00E+00	0.00E+00	0.00E+00	7.90E-06	7.90E-06	4.98E-05	2.70E-04
9.31E-05	3.08E-04	8.02E-08	3.19E-05	2.40E-08	1.16E-05	1.75E-04	1.59E-03	4.80E-20	1.11E-08	8.89E-05	2.40E-08	3.01E-08	2.14E-04	1.98E-08	1.98E-08	6.13E-04	3.67E-03
9.31E-05	3.08E-04	8.02E-08	3.19E-05	2.40E-08	1.16E-05	1.75E-04	1.59E-03	4.80E-20	1.11E-08	8.89E-05	2.40E-08	3.01E-08	2.14E-04	1.98E-08	1.98E-08	6.13E-04	3.67E-03
9.31E-05	3.08E-04	8.02E-08	3.19E-05	2.40E-08	1.16E-05	1.75E-04	1.59E-03	4.80E-20	1.11E-08	8.89E-05	2.40E-08	3.01E-08	2.14E-04	1.98E-08	1.98E-08	6.13E-04	3.67E-03

Fish consumption dose

Fish consumption dose
Calculated as water conc. • bioaccumulation • consumption • dose factor; 1-day holdup assumed.

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Calculated for The Dalles																					
1961 releases from all 8 reactors	Ne-24		P-32	Cs-45	Sr-90	Mn-56	Cu-64	As-76	Cr-51	Zn-65	Zn-69	Zn-89m	Gd-72	Sr-89	Sr-90	Y-90	Y-93	Np-238	Columbia Flow Rate	TravelTime	
DATE 1/2 (d)	6.25E-01	1.43E+01	C/d	C/d	8.39E+02	1.63E+02	5.29E-01	1.10E+00	2.77E+01	2.44E+02	3.86E-02	5.73E-01	5.87E-01	5.06E+01	1.04E+04	2.87E+00	4.21E-01	2.36E+00	C/d	cfs	-3.90E-06 5.51549
Jan-61	4.70E+03	9.89E+01	3.21E+00	1.93E+01	3.81E+04	3.81E+04	2.81E+03	1.19E+03	3.61E+03	2.21E+02	9.56E+01	1.54E+02	1.09E+03	1.89E+00	1.79E-01	5.03E+02	1.89E+03	1.40E+03	63708	8.08	
Feb-61	3.14E+03	1.09E+02	2.62E+00	7.43E+00	3.00E+04	2.26E+03	2.26E+03	6.04E+02	1.27E+03	1.12E+02	5.72E+01	1.74E+02	1.44E+03	1.25E+00	8.30E-02	2.81E+02	6.41E+02	1.15E+03	99879	7.30	
Mar-61	4.73E+03	9.69E+01	2.48E+00	5.12E+01	4.98E+04	3.51E+03	3.51E+03	9.84E+02	1.32E+03	2.06E+02	8.41E+01	1.74E+02	8.97E+02	1.27E+00	7.70E-02	1.49E+02	7.04E+02	6.03E+02	92413	7.19	
Apr-61	3.92E+03	9.89E+01	2.68E+00	1.63E+01	5.97E+04	3.77E+03	3.81E+03	9.81E+02	1.46E+03	3.12E+02	1.21E+02	4.31E+02	9.74E+02	9.53E-01	1.11E-01	1.69E+02	8.09E+02	3.46E+02	106493	6.84	
May-61	3.68E+03	7.71E+01	2.68E+00	4.05E+00	6.35E+04	3.81E+03	3.81E+03	6.06E+02	1.32E+03	1.26E+02	6.15E+01	3.26E+02	1.63E+03	8.81E-01	1.28E-01	2.14E+02	9.25E+02	4.28E+02	234468	4.15	
Jun-61	5.93E+03	5.56E+01	2.36E+00	6.18E-01	2.35E+04	3.03E+03	2.57E+02	1.35E+03	1.35E+03	1.63E+02	2.44E+01	1.64E+02	1.55E+03	8.78E-01	1.23E-01	7.74E+01	4.57E+02	3.79E+02	483087	1.70	
Jul-61	3.42E+03	3.95E+01	3.18E+00	4.70E-01	2.35E+04	2.00E+03	2.00E+03	2.57E+02	1.19E+03	8.01E+01	1.20E+01	1.32E+02	4.46E+02	3.15E+00	1.00E-01	5.11E+01	5.32E+02	2.48E+02	189703	4.77	
Aug-61	2.45E+03	2.83E+01	1.40E+00	1.77E+00	1.82E+04	2.87E+03	2.87E+03	2.88E+02	1.88E+03	1.30E+02	1.89E+01	7.66E+01	2.99E+02			4.72E+01	1.54E+02	6.27E+02	101681	6.97	
Sep-61	1.33E+03	2.93E+01	1.40E+00	1.33E+01	1.39E+04	1.19E+03	1.19E+03	2.82E+02	2.01E+03	5.07E+01	1.50E+01	5.78E+01	1.39E+02			1.94E+02	3.80E+02	6.27E+02	69567	7.93	
Oct-61	2.21E+03	3.17E+01	6.50E-01	6.50E-01	1.40E+04	1.19E+03	1.19E+03	2.82E+02	2.01E+03	5.07E+01	1.50E+01	5.78E+01	1.39E+02			1.49E+02	2.52E+02	3.71E+02	64774	8.04	
Nov-61	2.57E+03	3.66E+01	4.50E-01	4.50E-01	1.19E+04	2.47E+03	2.47E+03	2.98E+02	2.50E+03	5.73E+01	1.90E+01	1.66E+02	1.90E+02			1.48E+02	3.19E+02	4.42E+02	82983	8.10	
Dec-61	2.71E+03	3.10E+01														5.88E+01	2.63E+02	4.30E+02	56026	8.32	

Columbia River Flow Multipliers																					
The Dalles	Unattila	TriCities	Vancouver																		
1.55	1.48	1	1.95																		
121512 cfs	179414 cfs	188893 cfs	236532 cfs																		
(Ref: Walters et al. Ch 3.0)																					

Dose Conversion Factors by Radionuclide																					
Effective Dose																					
External from swimming/boating (Intensity per uCi/m3)																					
51.6	0	2.06E-10	22.8	2.08	4.79	0.347	6.56	6.52E-05	4.52	32.8	1.55E-03	0	0	1.05	1.89						

Internal from Ingestion (Inten/MCI)																					
1.40E-03	7.70E-03	3.00E-03	5.80E-03	8.50E-04	4.30E-04	4.80E-03	1.30E-04	1.40E-02	8.50E-05	1.20E-03	4.40E-03	8.70E-03	1.30E-01	1.00E-02	4.50E-03	2.80E-03					

Resident fish bioaccumulation factors (LAq)																					
1	1700	200	2	70	10	200	5	64	64	64	100	30	25	25	25	25					
10x Solidat																					
(Ref: Walters et al. p. 10-7; GENII BIOAC1.DAT)																					
Drinking water transmission factors																					
0.9	0.4	1	0.3	0.5	1	0.7	1	0.4	0.4	0.4	1	0.2	0.2	0.2	0.2	0.7					
(Note: a minimal transit time in the distribution system of 12 hours is assumed)																					

Individual exposure parameters																					
Boating	Swimming	Drinking	Fish	500 h/yr	100 h/yr	730 L/yr	40 kg/yr														

[illegible]

Internal doses by radionuclide and month		Calculated as water conc * DW Transmutation factor * consumption		* dose factor		Monthly sum	
Drinking water dose		Calculated as water conc * bioaccumulation * consumption		* dose factor, 1-day holdup assumed		Monthly totals	
Jan-81	1.11E-07	4.98E-08	2.34E-08	7.62E-08	3.43E-27	4.02E-08	5.78E-05
Feb-81	1.24E-07	4.12E-08	1.36E-08	2.09E-08	2.95E-25	6.37E-08	4.22E-05
Mar-81	2.02E-07	3.53E-08	1.24E-08	1.38E-08	9.34E-25	1.09E-08	2.74E-05
Apr-81	2.13E-07	3.15E-08	1.08E-08	3.88E-08	8.95E-24	1.84E-08	2.19E-05
May-81	1.82E-08	1.30E-08	5.39E-08	4.48E-07	8.74E-17	2.54E-07	1.23E-05
Jun-81	2.22E-08	5.24E-08	2.43E-07	3.52E-08	2.68E-10	6.97E-08	1.52E-05
Jul-81	1.01E-06	7.24E-08	7.53E-07	6.10E-08	1.35E-18	1.03E-08	1.40E-05
Aug-81	1.24E-07	6.29E-08	0.00E+00	4.41E-07	1.22E-24	1.03E-08	8.85E-08
Sep-81	3.44E-08	1.39E-08	0.00E+00	5.13E-07	3.84E-27	0.00E+00	1.01E-05
Oct-81	5.31E-08	1.60E-08	0.00E+00	3.10E-07	1.52E-27	1.79E-08	1.14E-05
Nov-81	6.95E-08	1.90E-08	0.00E+00	2.59E-07	1.08E-27	0.00E+00	8.60E-08
Dec-81	5.52E-08	1.79E-08	0.00E+00	2.01E-07	2.46E-28	2.81E-09	1.01E-05
Total D.W.	2.60E-05	2.56E-04	7.57E-06	2.97E-05	2.88E-10	2.90E-08	2.74E-03
	1%	9%	0%	1%	0%	0%	10%
							100%
Fish consumption dose							
Calculated as water conc. * bioaccumulation * consumption * dose factor, 1-day holdup assumed							
Jan-81	3.01E-05	1.14E-02	2.56E-05	2.79E-08	1.04E-27	1.15E-09	9.83E-05
Feb-81	1.43E-05	9.43E-03	1.50E-05	7.87E-07	8.84E-26	1.82E-09	8.31E-10
Mar-81	2.07E-05	6.08E-03	1.37E-05	5.08E-08	2.83E-25	3.12E-09	7.18E-05
Apr-81	1.47E-05	7.20E-03	1.20E-05	1.42E-08	3.01E-24	4.70E-09	1.04E-09
May-81	8.41E-08	2.97E-03	5.93E-08	1.84E-07	2.85E-17	7.27E-08	2.94E-08
Jun-81	5.14E-08	1.22E-03	2.87E-08	1.29E-08	8.11E-11	7.22E-07	1.89E-08
Jul-81	7.03E-08	1.66E-03	8.29E-08	2.24E-08	4.08E-19	2.00E-08	3.90E-08
Aug-81	9.85E-08	1.43E-03	0.00E+00	1.82E-07	3.88E-25	2.84E-08	5.31E-05
Sep-81	7.93E-08	3.10E-03	0.00E+00	1.98E-07	1.16E-27	0.00E+00	1.15E-08
Oct-81	1.39E-05	3.68E-03	0.00E+00	1.14E-07	4.81E-28	5.01E-10	2.00E+00
Nov-81	1.67E-05	4.34E-03	0.00E+00	9.50E-08	3.26E-28	0.00E+00	0.00E+00
Dec-81	1.98E-05	4.08E-03	0.00E+00	7.37E-08	7.45E-29	8.34E-10	0.00E+00
Fish Total	1.67E-04	5.85E-02	8.33E-05	1.09E-05	8.11E-11	8.30E-07	1.89E-05
	0%	79%	0%	0%	0%	0%	0%
							1%
							100%
External							
Jan-81	1.01E-04	0.00E+00	2.89E-17	2.22E-05	1.58E-08	1.48E-08	6.04E-08
Feb-81	2.60E-05	2.56E-04	7.57E-08	2.97E-05	2.88E-10	2.90E-08	1.54E-05
Mar-81	1.67E-04	6.85E-02	8.33E-05	1.09E-05	8.11E-11	8.30E-07	2.81E-07
Apr-81	2.84E-04	6.88E-02	9.09E-05	8.29E-05	1.62E-08	5.19E-08	4.19E-07
May-81	0%	78%	0%	0%	0%	0%	6.04E-04
Jun-81	0%	78%	0%	0%	0%	0%	1.20E-08
Jul-81	0%	78%	0%	0%	0%	0%	4.44E-04
Aug-81	0%	78%	0%	0%	0%	0%	7.38E-02
Sep-81	0%	78%	0%	0%	0%	0%	7.20E-04
Oct-81	0%	78%	0%	0%	0%	0%	1.73E-08
Nov-81	0%	78%	0%	0%	0%	0%	0%
Dec-81	0%	78%	0%	0%	0%	0%	0%
Total	0%	78%	0%	0%	0%	0%	1%
							100%
							100%

1961									
Releases from all 8 reactors									
DATE	Na 24	P-32	Ca-45	Sc-46	Min-56	Cu-64	As-76	Ci-51	Zn-65
T 1/2 (d)	Cld	Cld	Cld	Cld	Cld	Cld	Cld	Cld	Cld
Jan-61	4.70E+03	6.98E+01	3.21E+00	1.93E+01	3.91E+04	2.81E+03	1.19E+03	3.61E+03	2.21E+02
Feb-61	3.14E+03	1.08E+02	2.62E+00	7.43E+00	3.00E+04	2.28E+03	6.04E+02	1.27E+03	1.12E+02
Mar-61	4.73E+03	9.69E+01	2.49E+00	5.12E+01	4.96E+04	3.51E+03	9.84E+02	1.32E+03	2.08E+02
Apr-61	3.82E+03	9.68E+01	2.49E+00	1.63E+01	5.97E+04	3.77E+03	8.81E+02	1.48E+03	3.12E+02
May-61	3.69E+03	7.71E+01	2.89E+00	4.05E+00	3.22E+04	3.81E+03	6.06E+02	1.32E+03	1.29E+02
Jun-61	5.69E+03	5.56E+01	2.36E+00	6.18E+01	2.53E+04	3.03E+03	2.57E+02	1.35E+03	1.83E+02
Jul-61	3.42E+03	3.78E+01	3.18E+00	4.70E+01	2.35E+04	2.00E+03	2.57E+02	1.19E+03	6.01E+01
Aug-61	2.45E+03	1.85E+01		1.77E+00	1.82E+04	2.67E+03	2.88E+02	1.88E+03	1.30E+02
Sep-61	1.39E+03	2.83E+01		1.40E+00	1.72E+04	2.45E+03	2.39E+02	1.02E+03	1.09E+01
Oct-61	2.21E+03	3.17E+01		8.00E-01	1.38E+04	1.19E+03	2.82E+02	2.01E+03	5.07E+01
Nov-61	2.57E+03	3.68E+01		6.50E-01	1.40E+04	3.14E+03	3.14E+02	2.58E+03	9.44E+01
Dec-61	2.71E+03	3.10E+01		4.50E-01	1.18E+04	2.47E+03	2.98E+02	2.50E+03	5.73E+01

Columbia River Flow Multipliers
 Vancouver: Unsettled 1.48
 TriCities: 1.55
 121512 cfs 179414 cfs 189983 cfs 236532 cfs
 (Ref: Waters et al. Ch 3.0)

Dose Conversion Factors by Radionuclide Effective Dose (Ref: DOE/EH-0070)
 External from swimming/boating (mrem/y per uCi/m³)
 51.8 0 2.09E-10 22.8 20.1 2.06 4.79 0.347 6.58 8.52E-05 4.52 32.8 1.55E-03 0 0 1.05 1.89

Internal from ingestion (mrem/uCi) (Ref: DOE/EH-0071)
 1.40E-03 7.70E-03 3.00E-03 5.60E-03 9.50E-04 4.30E-04 4.80E-03 1.30E-04 1.40E-02 8.60E-05 1.20E-03 4.40E-03 8.70E-03 1.30E-01 1.00E-02 4.50E-03 2.90E-03

Resident fish bioaccumulation factors (L/kg) (Ref: Waters et al. p. 10.7; GENII BIOACT.DAT)
 1 1700 200 2 70 10 200 5 64 64 64 100 30 25 25 25 25
 10x Saldad (1110 equilibrium)

Drinking water transmission factors (Ref: GENII BIOACT.DAT)
 0.9 0.4 1 0.3 0.5 1 0.7 1 0.5
 (Note: a minimal transit time in the distribution system of 12 hours is assumed.)

Individual exposure parameters
 Boating 500 hr/yr
 Swimming 100 hr/yr
 Drinking 730 L/y
 Fish 40 kg/yr

External exposure									
Dose is calculated as water conc * hr/yr * Dose factor.									
Water conc is calculated as release (Ci/d) * exp(rembda**transitflow) (cis/m ³ /d per cfa).									
Jan-61	2.77E-09	0.00E+00	6.98E-18	4.36E-08	9.67E-38	5.44E-12	2.49E-08	1.01E-05	1.53E-05
Feb-61	4.98E-09	0.00E+00	4.06E-18	1.20E-08	1.25E-34	1.48E-11	1.31E-08	2.58E-08	5.53E-08
Mar-61	8.58E-09	0.00E+00	3.70E-18	7.98E-08	5.72E-34	2.75E-11	3.31E-08	2.58E-08	9.79E-08
Apr-61	1.12E-08	0.00E+00	3.27E-18	2.23E-08	2.12E-32	5.32E-11	2.84E-08	2.58E-08	1.30E-05
May-61	4.77E-07	0.00E+00	1.82E-18	2.61E-07	2.16E-21	5.47E-09	1.55E-07	1.16E-08	2.41E-08
Jun-61	2.48E-05	0.00E+00	7.34E-19	2.07E-08	3.35E-11	3.05E-07	3.57E-07	6.59E-07	1.79E-08
Jul-61	1.81E-07	0.00E+00	2.26E-18	3.54E-08	3.82E-24	9.68E-10	4.25E-08	1.21E-08	9.48E-33
Aug-61	6.02E-09	0.00E+00	0.00E+00	2.53E-07	1.65E-33	3.04E-11	1.11E-08	3.42E-08	1.36E-08
Sep-61	9.44E-10	0.00E+00	0.00E+00	2.94E-07	1.84E-37	0.00E+00	5.52E-08	8.22E-08	5.68E-08
Oct-61	1.36E-09	0.00E+00	0.00E+00	1.77E-07	4.82E-38	2.42E-12	8.00E-09	5.51E-08	3.48E-08
Nov-61	1.47E-09	0.00E+00	0.00E+00	1.48E-07	2.77E-38	0.00E+00	8.50E-08	7.30E-08	6.83E-08
Dec-61	1.20E-09	0.00E+00	0.00E+00	1.15E-07	2.96E-39	3.31E-12	5.80E-08	7.85E-08	4.51E-08
Ext. Total	2.56E-05	0.00E+00	2.28E-17	1.71E-05	3.35E-11	3.11E-07	8.84E-07	5.11E-05	7.61E-05
	14%	0%	0%	10%	0%	0%	0%	29%	43%
Monthly sum	3.08E-05	7.57E-07	2.58E-14	4.95E-08	8.20E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1976-06	9.97E-06	6.25E-07	4.95E-14	8.82E-07	1.85E-07	1.95E-07	1.85E-07	1.85E-07	1.85E-07
1980-05	1.80E-05	3.30E-07	8.82E-14	1.70E-13	1.95E-07	7.92E-11	3.70E-07	5.01E-07	3.20E-05
1983-08	4.83E-06	5.01E-07	9.73E-09	1.12E-11	1.81E-07	1.81E-07	1.81E-07	1.81E-07	1.81E-07
1986-08	8.56E-06	1.78E-07	2.44E-14	7.88E-15	3.38E-07	2.44E-14	1.78E-07	1.78E-07	1.78E-07
1989-05	1.34E-05	3.38E-07	4.08E-15	4.08E-15	2.00E-07	7.88E-15	3.38E-07	2.00E-07	2.00E-07
1993-06	1.43E-05	2.38E-07	4.59E-15	4.59E-15	2.38E-07	4.59E-15	2.38E-07	2.38E-07	2.38E-07
1997-05	1.27E-05	2.38E-07	2.43E-15	2.43E-15	2.38E-07	2.43E-15	2.38E-07	2.38E-07	2.38E-07
2000-05	1.79E-04	4.18E-08	9.82E-09	0%	0%	0%	0%	0%	0%
2002-05	100%	2%	0%	0%	0%	0%	0%	0%	0%

Internal doses by radionuclide and month																		
Drinking water dose																		
Calculated as water conc * DW Transmission factor * consumption * dose factor.																		
	Jan-61	Feb-61	Mar-61	Apr-61	May-61	Jun-61	Jul-61	Aug-61	Sep-61	Oct-61	Nov-61	Dec-61	Monthly sum					
	7.10E-10	3.18E-05	1.83E-08	5.85E-08	1.64E-39	1.08E-11	2.33E-07	6.90E-05	2.39E-04	1.18E-107	2.41E-12	2.28E-10	5.50E-07	9.26E-07	7.04E-08	1.78E-13	1.28E-05	3.88E-04
	1.27E-09	2.71E-05	1.08E-08	1.81E-08	2.12E-38	2.85E-11	1.79E-07	1.76E-05	8.83E-05	1.05E-98	8.23E-12	8.77E-10	2.83E-07	3.07E-07	2.73E-07	3.64E-08	1.48E-04	1.48E-04
	2.20E-09	2.33E-05	9.70E-07	1.07E-05	9.70E-38	5.45E-11	3.10E-07	1.75E-05	1.53E-04	2.74E-97	9.68E-12	4.84E-10	2.57E-07	2.73E-07	2.00E-08	4.89E-13	5.60E-08	2.14E-04
	2.87E-09	2.09E-05	8.55E-07	2.99E-08	3.59E-34	1.05E-10	2.68E-07	1.73E-05	2.03E-04	6.73E-83	4.07E-11	1.18E-09	1.71E-07	3.45E-07	2.32E-08	1.17E-12	3.31E-08	2.51E-04
	1.22E-07	8.25E-08	4.24E-07	3.50E-07	3.66E-23	1.09E-08	1.45E-08	7.88E-08	3.78E-05	2.50E-81	2.06E-09	1.15E-07	7.42E-08	1.78E-07	3.80E-08	5.45E-10	6.27E-08	8.76E-05
	6.38E-08	4.08E-08	1.92E-07	2.78E-08	5.87E-13	8.04E-07	3.34E-08	4.45E-08	2.80E-05	1.14E-32	5.00E-08	4.75E-08	4.03E-08	8.81E-08	1.80E-08	8.70E-08	8.49E-09	8.24E-05
	1.54E-09	4.85E-08	5.08E-08	5.92E-07	4.75E-08	8.47E-28	1.82E-08	3.98E-07	2.11E-05	3.76E-69	3.11E-10	1.21E-08	3.18E-07	1.87E-07	8.58E-07	7.87E-11	3.24E-08	4.01E-05
	2.42E-10	8.77E-08	0.00E+00	3.04E-07	3.11E-39	9.00E+00	1.04E-07	2.31E-05	8.85E-05	3.20E-85	5.95E-12	2.95E-10	0.00E+00	0.00E+00	8.45E-07	1.68E-13	3.02E-08	1.20E-04
	3.48E-10	1.03E-05	0.00E+00	2.38E-07	8.17E-40	8.82E-08	5.82E-08	4.21E-05	1.02E-04	4.87E-107	1.12E-12	3.54E-11	0.00E+00	0.00E+00	2.88E-08	5.41E-14	5.70E-08	1.82E-04
	3.77E-10	1.22E-05	0.00E+00	1.89E-07	4.70E-40	0.00E+00	6.08E-08	4.94E-05	1.03E-04	4.52E-108	1.56E-12	1.39E-11	0.00E+00	0.00E+00	2.08E-08	2.81E-14	3.39E-08	1.07E-04
	3.07E-10	1.14E-05	0.00E+00	1.54E-07	5.00E-41	8.58E-12	5.82E-08	5.31E-05	7.03E-05	2.89E-111	1.88E-12	2.88E-11	0.00E+00	0.00E+00	8.17E-07	1.68E-14	4.05E-08	1.71E-04
	3.07E-10	1.14E-05	0.00E+00	1.54E-07	5.00E-41	8.58E-12	5.82E-08	5.31E-05	7.03E-05	2.89E-111	1.88E-12	2.88E-11	0.00E+00	0.00E+00	8.17E-07	1.68E-14	4.00E-08	1.40E-04
	6.56E-06	1.88E-04	5.92E-06	2.28E-05	5.67E-13	8.17E-07	6.50E-08	3.48E-04	1.19E-03	1.14E-32	5.25E-08	4.88E-08	1.67E-08	2.28E-08	2.88E-05	8.78E-08	7.05E-05	1.86E-03
Total D.W.																		

Fish consumption dose
Calculated as water conc * bioaccumulation * consumption * dose factor ; 1 day holdup assumed.

	Jan-61	Feb-61	Mar-61	Apr-61	May-61	Jun-61	Jul-61	Aug-61	Sep-61	Oct-61	Nov-61	Dec-61	Fish Total	Monthly totals				
	2.50E-11	7.31E-03	2.01E-05	2.14E-06	4.98E-40	3.09E-12	2.68E-08	1.85E-05	2.10E-03	1.30E-110	1.16E-11	8.97E-10	4.52E-08	7.88E-08	4.28E-05	5.34E-13	2.18E-05	9.54E-03
	4.48E-11	6.20E-03	1.17E-05	5.90E-07	8.43E-37	8.48E-12	2.08E-06	4.77E-06	7.60E-04	1.17E-101	3.97E-11	2.68E-09	2.18E-08	2.54E-08	2.15E-05	1.03E-12	1.80E-05	7.02E-03
	7.75E-11	5.33E-03	1.07E-05	3.91E-08	2.94E-36	1.56E-11	3.58E-06	4.77E-06	1.35E-03	3.05E-100	4.85E-11	1.51E-08	2.11E-08	2.28E-08	1.21E-05	1.42E-12	9.52E-08	8.72E-03
	1.01E-10	4.78E-03	9.41E-06	1.09E-08	1.09E-34	3.02E-11	3.06E-06	4.71E-06	1.79E-03	7.50E-96	1.96E-10	3.54E-09	1.40E-08	2.88E-08	1.40E-05	3.54E-12	5.84E-08	8.02E-03
	4.31E-09	2.12E-03	4.67E-08	1.28E-07	1.11E-23	3.11E-09	1.67E-05	2.15E-08	3.31E-04	2.78E-84	9.95E-08	3.53E-07	6.08E-07	1.47E-08	2.38E-05	1.85E-09	1.07E-05	2.51E-03
	2.25E-07	9.28E-04	2.12E-08	1.02E-08	1.72E-13	1.73E-07	3.84E-05	1.21E-08	2.48E-04	1.27E-35	2.41E-07	1.45E-05	3.31E-07	7.29E-07	1.15E-05	2.03E-07	1.44E-05	1.28E-03
	1.84E-09	1.16E-03	6.52E-08	1.74E-08	1.86E-28	1.68E-08	5.50E-10	4.57E-08	1.88E-04	4.20E-72	1.50E-09	3.89E-08	2.60E-08	1.38E-08	6.20E-08	2.32E-10	5.56E-06	1.38E-03
	6.44E-11	9.50E-04	0.00E+00	1.25E-07	8.46E-36	1.73E-11	1.19E-08	6.30E-06	7.80E-04	3.57E-88	2.87E-11	9.04E-10	0.00E+00	0.00E+00	3.81E-08	5.08E-13	5.14E-08	1.75E-03
	8.52E-12	2.01E-03	0.00E+00	1.44E-07	9.42E-40	0.00E+00	5.95E-07	1.15E-05	9.03E-04	8.78E-110	5.39E-11	1.08E-10	0.00E+00	0.00E+00	1.82E-05	1.84E-13	9.70E-08	2.96E-03
	1.23E-11	2.38E-03	0.00E+00	8.71E-08	2.48E-40	1.38E-12	6.48E-07	1.01E-05	4.75E-04	5.04E-111	4.12E-12	1.45E-10	0.00E+00	0.00E+00	1.26E-05	8.52E-14	5.78E-08	2.88E-03
	1.33E-11	2.78E-03	0.00E+00	7.28E-08	1.42E-40	0.00E+00	7.00E-07	1.34E-05	9.11E-04	1.81E-111	7.52E-12	4.28E-11	0.00E+00	0.00E+00	1.24E-05	9.58E-14	8.88E-08	3.74E-03
	1.08E-11	2.61E-03	0.00E+00	5.85E-08	1.51E-41	1.88E-12	6.02E-07	1.45E-05	8.20E-04	3.32E-114	9.04E-12	9.11E-11	0.00E+00	0.00E+00	4.84E-08	5.07E-14	8.81E-08	3.28E-03
	2.31E-07	3.85E-02	8.52E-05	8.38E-08	1.72E-13	1.77E-07	7.48E-05	9.42E-05	1.04E-02	1.27E-35	2.53E-07	1.48E-05	1.37E-05	1.88E-05	1.81E-04	2.05E-07	1.20E-04	4.98E-02
	Na-24	P-32	Ca-45	Sc-46	Mn-56	Cu-64	As-76	Cr-51	Zn-65	Zn-69	Zn-68m	Ga-72	Si-89	Si-90	Y-90	Y-83	Np-239	
External	2.56E-05	0.00E+00	2.28E-17	1.71E-05	3.35E-11	3.11E-07	6.84E-07	5.11E-05	7.61E-05	9.48E-33	4.95E-08	3.57E-08	8.20E-11	0.00E+00	0.00E+00	9.82E-08	4.18E-08	1.78E-04
Drinking	6.56E-08	1.68E-04	5.92E-08	2.29E-05	5.67E-13	8.17E-07	8.50E-08	3.46E-04	1.19E-03	1.14E-32	6.25E-08	4.88E-08	1.67E-08	2.28E-05	2.88E-05	8.78E-08	7.05E-05	1.86E-03
Fish	2.31E-07	3.85E-02	6.52E-05	8.38E-08	1.72E-13	1.77E-07	7.48E-05	9.42E-05	1.04E-02	1.27E-35	2.53E-07	1.48E-05	1.37E-05	1.88E-05	1.81E-04	2.05E-07	1.20E-04	4.98E-02
Total	3.24E-05	3.87E-02	7.11E-05	4.83E-05	3.42E-11	1.10E-08	8.19E-05	4.91E-04	1.17E-02	2.08E-32	3.55E-07	2.34E-05	1.54E-05	2.12E-05	2.10E-04	2.82E-07	1.85E-04	5.18E-02
%	0%	75%	0%	0%	0%	0%	0%	1%	23%	0%	0%	0%	0%	0%	0%	0%	0%	100%
	Na-24	P-32	Ca-45	Sc-46	Mn-56	Cu-64	As-76	Cr-51	Zn-65	Zn-69	Zn-68m	Ga-72	Si-89	Si-90	Y-90	Y-83	Np-239	

1984 Helicases from all 9 reactors DATE	Calculated for Tricities				"Maximum" Individual Parameters										Travel Time						
	Na-24 1 1/2 (d)	P-32 Cld	Ca-45 Cld	Sc-46 Cld	Min-56 Cld	Cu-64 Cld	As-76 Cld	Cr-51 Cld	Zn-65 Cld	Zn-69 Cld	Zn-69m Cld	Ga-72 Cld	Si-69 Cld	Si-90 Cld	Y-90 Cld	Y-93 Cld	Np-239 Cld	Est. 1-131 Flow Rate cfs	Columbia Flow Rate cfs	Travel Time days	
Jan-64	2.96E+03	4.03E+01			1.74E+04	2.39E+03	3.76E+02	1.82E+03	3.30E+01	3.82E+02	5.73E+01	2.94E+02	2.92E+02	5.54E+02	4.00E+00	5.5071	5.47E+02	4.00E+00	72703	0.94	
Feb-64	4.40E+01				1.70E+04	2.71E+03	3.82E+02	1.78E+03	4.57E+01	3.62E+02	5.73E+01	2.92E+02	2.92E+02	5.35E+02	4.00E+00	61223	5.35E+02	4.00E+00	81223	0.83	
Mar-64	2.50E+03	5.00E+01			1.82E+04	2.31E+03	3.60E+02	1.59E+03	7.11E+01	3.58E+02	5.73E+01	3.10E+02	3.10E+02	6.30E+02	4.00E+00	63107	7.70E+02	4.00E+00	187619	0.73	
Apr-64	4.55E+01						4.21E+02	1.59E+03	6.11E+01	4.02E+02	1.70E+03	5.79E+01	5.79E+01	6.70E+02	4.00E+00	388287	6.70E+02	4.00E+00	294323	0.44	
May-64	4.87E+01				3.38E+01		2.57E+02	1.01E+03	3.01E+01	2.82E+02	1.28E+03	3.03E+01	3.03E+01	3.40E+02	4.00E+00	130229	3.50E+02	4.00E+00	74573	0.54	
Jun-64	3.38E+01						3.29E+02	1.42E+03	2.80E+01	3.17E+02	1.23E+03	2.80E+01	2.80E+01	3.70E+02	4.00E+00	88819	3.70E+02	4.00E+00	70837	0.79	
Jul-64	2.25E+01				1.71E+01		3.40E+02	1.54E+03	3.90E+01	3.40E+02	1.88E+03	4.00E+01	4.00E+01	4.44E+02	4.00E+00	88819	4.44E+02	4.00E+00	70837	0.87	
Aug-64	2.04E+01				2.21E+01																0.91
Sep-64																					0.91
Oct-64																					0.91
Nov-64																					0.91
Dec-64																					0.91

Columbia River Flow Multipliers
 Tricities Umatilla The Dalles Vancouver
 1.00 1.48 1.55 1.86
 121512 cfs 178414 cfs 188983 cfs 236532 cfs
 (Ref: Walters et al. Ch 3.0)

Dose Conversion Factors by Radionuclide
 External from swimming/boating (Incm/yr per uCi/m3)
 51.6 0 2.09E-10

Internal from ingestion (Incm/yr)
 1.40E-03 7.70E-03 3.00E-03 5.60E-03 9.50E-04 4.30E-04

Resident fish bioaccumulation factors (L/kg)
 1 1700 200 200 200 200
 10x Solid

Drinking water transmission factors
 0.9 0.3 0.5 1 0.7 0.5
 (Note: z minimal transit time in the distribution system of 12 hours is assumed.)

Individual exposure parameters
 Boating 500 h/yr
 Swimming 100 h/yr
 Drinking 730 L/yr
 Fish 40 kg/yr

External exposure
 Dose is calculated as water conc * h/yr * Dose factor.
 Water conc is calculated as release (Cld) * exp(-lambda * transit)/flow (cfs)/m3/d (per cfs).

	Jan-61	Feb-61	Mar-61	Apr-61	May-61	Jun-61	Jul-61	Aug-61	Sep-61	Oct-61	Nov-61	Dec-61	Ext. Total	Monthly sum
Boating	1.32E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.22E-03	1.52E-03
Swimming	8.73E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.88E-07
Drinking	1.02E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.20E-03
Fish	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.82E-06
														2.75E-06
														1.24E-05
														2.00E-05
														3.52E-05
														2.98E-05
														4.48E-05
														4.58E-05
														4.06E-03
														100%

Calculated as water conc * DW Transmission factor * consumption * dose factor.

**Total D.W. 8.26E-04
12%**

Calculated

21

3%
Na-24

1964 Releases from all 8 reactors DATE T 1/2 (d)	Calculated for InCites				Average Individual Parameters										Travel Time			
	Na-24 6.25E-01 Cld	P-32 1.43E+01 Cld	Ca-45 1.63E+02 Cld	Sc-46 8.39E+01 Cld	Mn-56 1.07E-01 Cld	Cu-64 5.29E-01 Cld	Az-78 1.10E+00 Cld	Cr-51 2.77E+01 Cld	Zn-65 2.44E+02 Cld	Zn-69 3.86E-02 Cld	Zn-69m 5.73E-01 Cld	Ga-72 5.87E-01 Cld	Si-89 5.06E+01 Cld	Y-90 2.67E+00 Cld	Y-93 4.21E-01 Cld	Np-239 2.39E+00 Cld	Est. I-131 8.05 cfs	Columbia Flow Rate cfs
Jan-64	2.98E+03	4.03E+01	1.74E+04	2.38E+03	3.78E+02	1.82E+03	3.30E+01	2.44E+02	3.30E+01	3.86E-02	5.73E-01	2.94E+02	5.47E+02	4.00E+00	55071	0.84		
Feb-64	2.47E+03	4.00E+01	1.70E+04	2.71E+03	3.82E+02	1.78E+03	4.57E+01	2.89E+02	4.57E+01	3.86E-02	5.73E-01	2.92E+02	5.47E+02	4.00E+00	72703	0.91		
Mar-64	2.50E+03	5.00E+01	1.82E+04	2.31E+03	3.80E+02	1.55E+03	4.58E+01	3.59E+02	4.58E+01	3.86E-02	5.73E-01	3.10E+02	5.35E+02	4.00E+00	61223	0.83		
Apr-64	4.55E+01	4.55E+01	1.82E+04	2.31E+03	3.58E+02	1.10E+03	7.11E+01	4.21E+02	6.11E+01	3.86E-02	5.73E-01	3.10E+02	7.70E+02	4.00E+00	63107	0.73		
May-64	4.87E+01	4.87E+01	1.82E+04	2.31E+03	4.21E+02	1.59E+03	6.11E+01	4.02E+02	5.79E+01	3.86E-02	5.73E-01	3.10E+02	6.70E+02	4.00E+00	187819	0.44		
Jun-64	3.38E+01	3.38E+01	1.70E+04	2.31E+03	4.02E+02	1.70E+03	5.79E+01	2.57E+02	1.01E+03	3.01E+01	3.01E+01	3.40E+02	4.00E+00	4.00E+00	294323	0.54		
Jul-64	2.25E+01	2.25E+01	1.71E+04	2.31E+03	2.82E+02	1.28E+03	3.03E+01	2.82E+02	1.28E+03	3.86E+01	3.86E+01	3.50E+02	4.00E+00	4.00E+00	130229	0.79		
Aug-64	2.04E+01	2.04E+01	1.71E+04	2.31E+03	3.28E+02	1.42E+03	3.86E+01	3.28E+02	1.42E+03	3.86E+01	3.86E+01	3.70E+02	4.00E+00	4.00E+00	74573	0.87		
Sep-64	2.21E+01	2.21E+01	1.71E+04	2.31E+03	3.17E+02	1.23E+03	2.60E+01	3.17E+02	1.23E+03	2.60E+01	2.60E+01	3.23E+02	4.00E+00	4.00E+00	88819	0.87		
Oct-64	3.52E+01	3.52E+01	1.71E+04	2.31E+03	3.40E+02	1.54E+03	3.90E+01	3.40E+02	1.54E+03	3.90E+01	3.90E+01	4.44E+02	4.00E+00	4.00E+00	70837	0.91		
Nov-64	3.52E+01	3.52E+01	1.71E+04	2.31E+03	3.40E+02	1.54E+03	3.90E+01	3.40E+02	1.54E+03	3.90E+01	3.90E+01	3.97E+02	4.00E+00	4.00E+00	89488	0.91		
Dec-64	3.52E+01	3.52E+01	1.71E+04	2.31E+03	3.40E+02	1.54E+03	3.90E+01	3.40E+02	1.54E+03	3.90E+01	3.90E+01	3.97E+02	4.00E+00	4.00E+00	89488	0.91		

Columbia River Flow Multipliers
TriCities Unattila The Dalles Vancouver
1.00 1.48 1.55 1.95
121512 cfs 179414 cfs 189893 cfs 238532 cfs
(Ref: Walters et al. Ch 3.0)

Dose Conversion Factors by Radionuclide		Effective Dose	
External from swimming/boating (mrem/yr per uCi/m3)	51.6	22.8	20.1
Internal from ingestion (rem/uCi)	1.40E-03	7.70E-03	3.00E-03
External from swimming/boating (mrem/yr per uCi/m3)	51.6	22.8	20.1
Internal from ingestion (rem/uCi)	1.40E-03	7.70E-03	3.00E-03

Resident fish bioaccumulation factors (L/kg)		Effective Dose	
10x Solidat	200	2	20.1
10x Solidat	200	2	20.1

Drinking water transmission factors		Effective Dose	
0.9	0.4	1	0.3
0.9	0.4	1	0.3

Individual exposure parameters		Effective Dose	
Boating	5 hr/yr	1	0.3
Swimming	10 hr/yr	1	0.3
Drinking	440 L/yr	1	0.3
Fish	2 kg/yr	1	0.3

Dose is calculated as water conc * hr/yr * Dose factor.		Effective Dose	
Water conc is calculated as release (Ci/d) * exp(-lambda*t) / (transit/flow) (cfs/m3/d per cfs)	200	2	20.1
Water conc is calculated as release (Ci/d) * exp(-lambda*t) / (transit/flow) (cfs/m3/d per cfs)	200	2	20.1

External exposure		Effective Dose	
Dose is calculated as water conc * hr/yr * Dose factor.	200	2	20.1
Dose is calculated as water conc * hr/yr * Dose factor.	200	2	20.1

Monthly sum		Effective Dose	
Jan-81	4.73E-05	0.00E+00	0.00E+00
Feb-81	3.12E-05	0.00E+00	0.00E+00
Mar-81	3.85E-05	0.00E+00	0.00E+00
Apr-81	0.00E+00	0.00E+00	0.00E+00
May-81	0.00E+00	0.00E+00	0.00E+00
Jun-81	0.00E+00	0.00E+00	0.00E+00
Jul-81	0.00E+00	0.00E+00	0.00E+00
Aug-81	0.00E+00	0.00E+00	0.00E+00
Sep-81	0.00E+00	0.00E+00	0.00E+00
Oct-81	0.00E+00	0.00E+00	0.00E+00
Nov-81	0.00E+00	0.00E+00	0.00E+00
Dec-81	0.00E+00	0.00E+00	0.00E+00
Ext Total	1.15E-04	0.00E+00	0.00E+00

Monthly sum		Effective Dose	
Jan-81	4.73E-05	0.00E+00	0.00E+00
Feb-81	3.12E-05	0.00E+00	0.00E+00
Mar-81	3.85E-05	0.00E+00	0.00E+00
Apr-81	0.00E+00	0.00E+00	0.00E+00
May-81	0.00E+00	0.00E+00	0.00E+00
Jun-81	0.00E+00	0.00E+00	0.00E+00
Jul-81	0.00E+00	0.00E+00	0.00E+00
Aug-81	0.00E+00	0.00E+00	0.00E+00
Sep-81	0.00E+00	0.00E+00	0.00E+00
Oct-81	0.00E+00	0.00E+00	0.00E+00
Nov-81	0.00E+00	0.00E+00	0.00E+00
Dec-81	0.00E+00	0.00E+00	0.00E+00
Ext Total	1.15E-04	0.00E+00	0.00E+00

Monthly sum		Effective Dose	
Jan-81	4.73E-05	0.00E+00	0.00E+00
Feb-81	3.12E-05	0.00E+00	0.00E+00
Mar-81	3.85E-05	0.00E+00	0.00E+00
Apr-81	0.00E+00	0.00E+00	0.00E+00
May-81	0.00E+00	0.00E+00	0.00E+00
Jun-81	0.00E+00	0.00E+00	0.00E+00
Jul-81	0.00E+00	0.00E+00	0.00E+00
Aug-81	0.00E+00	0.00E+00	0.00E+00
Sep-81	0.00E+00	0.00E+00	0.00E+00
Oct-81	0.00E+00	0.00E+00	0.00E+00
Nov-81	0.00E+00	0.00E+00	0.00E+00
Dec-81	0.00E+00	0.00E+00	0.00E+00
Ext Total	1.15E-04	0.00E+00	0.00E+00

Monthly sum		Effective Dose	
Jan-81	4.73E-05	0.00E+00	0.00E+00
Feb-81	3.12E-05	0.00E+00	0.00E+00
Mar-81	3.85E-05	0.00E+00	0.00E+00
Apr-81	0.00E+00	0.00E+00	0.00E+00
May-81	0.00E+00	0.00E+00	0.00E+00
Jun-81	0.00E+00	0.00E+00	0.00E+00
Jul-81	0.00E+00	0.00E+00	0.00E+00
Aug-81	0.00E+00	0.00E+00	0.00E+00
Sep-81	0.00E+00	0.00E+00	0.00E+00
Oct-81	0.00E+00	0.00E+00	0.00E+00
Nov-81	0.00E+00	0.00E+00	0.00E+00
Dec-81	0.00E+00	0.00E+00	0.00E+00
Ext Total	1.15E-04	0.00E+00	0.00E+00

Monthly sum		Effective Dose	
Jan-81	4.73E-05	0.00E+00	0.00E+00
Feb-81	3.12E-05	0.00E+00	0.00E+00
Mar-81	3.85E-05	0.00E+00	0.00E+00
Apr-81	0.00E+00	0.00E+00	0.00E+00
May-81	0.00E+00	0.00E+00	0.00E+00
Jun-81	0.00E+00	0.00E+00	0.00E+00
Jul-81	0.00E+00	0.00E+00	0.00E+00
Aug-81	0.00E+00	0.00E+00	0.00E+00
Sep-81	0.00E+00	0.00E+00	0.00E+00
Oct-81	0.00E+00	0.00E+00	0.00E+00
Nov-81	0.00E+00	0.00E+00	0.00E+00
Dec-81	0.00E+00	0.00E+00	0.00E+00
Ext Total	1.15E-04	0.00E+00	0.00E+00

Internal doses by radionuclide and month		Calculated as water conc * DW Transmission factor * consumption * dose factor.																				Monthly sum		
Drinking water dose																								
Jan-81	2.05E-04	3.15E-05	0.00E+00	0.00E+00	1.95E-07	4.20E-05	1.38E-04	8.21E-05	5.01E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.40E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.00E-04	4.00E-05	7.84E-04
Feb-81	1.35E-04	2.81E-05	0.00E+00	0.00E+00	1.84E-07	3.81E-05	1.03E-04	4.64E-05	6.25E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.51E-04	3.04E-05	6.03E-04
Mar-81	1.58E-04	3.52E-05	0.00E+00	0.00E+00	2.00E-07	3.73E-05	1.20E-04	4.76E-05	8.25E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.17E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.75E-04	3.60E-05	6.97E-04
Apr-81	0.00E+00	3.11E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.18E-04	3.28E-05	9.42E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.00E-04	3.50E-05	4.74E-04
May-81	0.00E+00	1.28E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.83E-05	1.79E-05	3.05E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.75E-05	1.34E-05	2.17E-04
Jun-81	0.00E+00	3.82E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.89E-05	8.33E-08	1.25E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.98E-05	6.93E-06	8.34E-05
Jul-81	0.00E+00	3.38E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.28E-05	6.31E-08	8.58E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.59E-05	7.75E-08	8.71E-05
Aug-81	0.00E+00	5.89E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.48E-05	1.83E-05	1.95E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.69E-05	1.71E-05	1.44E-04
Sep-81	0.00E+00	1.18E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.17E-05	3.59E-05	4.13E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E-04	2.98E-05	2.81E-04
Oct-81	0.00E+00	1.07E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.97E-05	2.81E-05	2.45E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.39E-05	2.50E-05	2.11E-04
Nov-81	0.00E+00	2.14E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.93E-05	4.08E-05	4.80E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.28E-04	3.11E-05	3.33E-04
Dec-81	0.00E+00	2.27E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.03E-04	4.59E-05	4.81E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.15E-04	3.18E-05	3.34E-04
Total D.W.	4.89E-04	2.16E-04	0.00E+00	0.00E+00	5.90E-07	1.17E-04	1.00E-03	3.88E-04	4.90E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.76E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.36E-03	3.03E-04	4.25E-03
	12%	5%	0%	0%	0%	3%	24%	9%	12%	0%	0%	0%	0%	4%	0%	0%	0%	0%	0%	0%	32%	7%	100%	

Fish consumption dose
Calculated as water conc * bioaccumulation * consumption * dose factor ; 1 -ay holdup assumed.

		Calculated as water conc * bioaccumulation * consumption * dose factor ; 1 -ay holdup assumed.																				Monthly totals		
Jan-81	1.70E-08	6.26E-04	0.00E+00	0.00E+00	2.22E-08	3.44E-08	2.39E-04	1.44E-08	3.87E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.95E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.73E-05	3.57E-08	9.88E-04
Feb-81	1.08E-08	5.18E-04	0.00E+00	0.00E+00	1.64E-08	2.87E-08	1.75E-04	1.07E-08	3.85E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.72E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.78E-05	2.70E-08	8.03E-04
Mar-81	1.29E-08	6.99E-04	0.00E+00	0.00E+00	2.09E-08	3.00E-08	2.06E-04	1.10E-08	4.59E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.89E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.24E-05	3.11E-08	1.04E-03
Apr-81	0.00E+00	8.17E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.89E-04	7.58E-07	6.90E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.70E-05	3.11E-08	9.22E-04
May-81	0.00E+00	2.49E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.81E-05	4.12E-07	2.23E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.70E-05	1.17E-08	3.76E-04
Jun-81	0.00E+00	7.40E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.83E-05	1.90E-07	9.14E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.40E-08	5.06E-07	1.28E-04
Jul-81	0.00E+00	8.54E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.05E-05	1.49E-07	6.27E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.28E-08	6.87E-07	1.07E-04
Aug-81	0.00E+00	1.12E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.55E-04	4.21E-07	1.43E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.89E-08	1.51E-08	2.07E-04
Sep-81	0.00E+00	2.34E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.05E-05	8.28E-07	3.02E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.84E-05	2.83E-08	4.38E-04
Oct-81	0.00E+00	2.13E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.25E-04	6.02E-07	1.79E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.35E-05	2.21E-08	3.70E-04
Nov-81	0.00E+00	4.24E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.68E-04	9.44E-07	3.37E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.32E-05	2.77E-08	6.50E-04
Dec-81	0.00E+00	4.51E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.75E-04	1.08E-08	3.53E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.12E-05	2.63E-08	8.83E-04
Fish Total	4.07E-08	4.28E-03	0.00E+00	0.00E+00	5.95E-08	9.41E-08	1.67E-03	9.97E-06	3.59E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.34E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.48E-04	2.68E-05	8.72E-03
	0%	64%	0%	0%	0%	0%	25%	0%	5%	0%	0%	0%	0%	2%	0%	0%	0%	0%	0%	0%	4%	0%	100%	
Na-24	1.15E-04	0.00E+00	0.00E+00	0.00E+00	2.03E-08	3.51E-08	8.35E-08	3.40E-08	1.88E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.63E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.75E-08	1.03E-07	1.44E-04
External	4.98E-04	2.16E-04	0.00E+00	0.00E+00	5.90E-07	1.17E-04	1.00E-03	3.88E-04	4.90E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.76E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.36E-03	3.03E-04	4.25E-03
Drinking	4.07E-06	4.28E-03	0.00E+00	0.00E+00	5.95E-08	9.41E-08	1.67E-03	9.97E-06	3.59E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.34E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.48E-04	2.68E-05	8.72E-03
Fish	6.17E-04	4.50E-03	0.00E+00	0.00E+00	8.55E-08	1.30E-04	2.68E-03	4.01E-04	8.51E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.17E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.81E-03	3.30E-04	1.11E-02
Total	6%	40%	0%	0%	0%	1%	24%	4%	8%	0%	0%	0%	0%	3%	0%	0%	0%	0%	0%	0%	15%	3%	100%	
%	Na-24	P-32	Ca-45	Sc-48	Mn-58	Cu-64	As-76	Cr-51	Zn-65	Zn-68	Zn-69	Zn-89	Sr-90	Ga-72	Sr-89	Sr-90	Y-90	Y-93	Np-239	I-131	Sub-Total			

GI Tract Comparison w/ 1964 Annual Rpt.

Maximum Individual Parameters																				
Calculated for Tricities				Calculated for Tricities															Travel Time	
1964	Releases from all 8 reactors				Releases from all 8 reactors															days
DATE	Na-24	P-32	Cs-45	Sc-46	Mn-56	Cu-64	As-78	Cr-51	Zn-65	Zn-69m	Ga-72	Si-89	Si-90	Y-83	Np-239	Est. 1-131	Columbia	Flow Rate		
1/12 (d)	Enhanced	Enhanced	Enhanced	Enhanced	Enhanced	Enhanced	Enhanced	Enhanced	Enhanced	Enhanced	Enhanced	Enhanced	Enhanced	Enhanced	Enhanced	Enhanced	Enhanced	Enhanced		
Jan-64	2.96E+03	4.03E+01			1.74E+04	2.38E+03	3.78E+02	1.82E+03	3.30E+01		2.94E+02				5.54E+02	4.00E+00		55071		
Feb-64	2.47E+03	4.40E+01			1.70E+04	2.71E+03	3.62E+02	1.79E+03	4.57E+01		2.92E+02				5.47E+02	4.00E+00		72703		
Mar-64	2.50E+03	5.00E+01			1.82E+04	2.31E+03	3.80E+02	1.55E+03	4.58E+01		3.10E+02				5.35E+02	4.00E+00		61223		
Apr-64	2.50E+03	4.55E+01			1.82E+04	2.31E+03	3.68E+02	1.10E+03	7.11E+01		3.10E+02				6.90E+02	4.00E+00		63107		
May-64	2.50E+03	4.87E+01			1.82E+04	2.31E+03	4.21E+02	1.59E+03	6.11E+01		3.10E+02				7.70E+02	4.00E+00		187819		
Jun-64	2.50E+03	3.26E+01			1.82E+04	2.31E+03	4.02E+02	1.70E+03	5.79E+01		3.10E+02				6.70E+02	4.00E+00		388287		
Jul-64	2.50E+03	2.25E+01			1.82E+04	2.31E+03	2.67E+02	1.01E+03	3.01E+01		3.10E+02				3.40E+02	4.00E+00		294323		
Aug-64	2.50E+03	1.71E+01			1.82E+04	2.31E+03	2.82E+02	1.28E+03	3.03E+01		3.10E+02				3.50E+02	4.00E+00		130229		
Sep-64	2.50E+03	2.04E+01			1.82E+04	2.31E+03	3.29E+02	1.42E+03	3.68E+01		3.10E+02				3.70E+02	4.00E+00		74573		
Oct-64	2.50E+03	2.21E+01			1.82E+04	2.31E+03	3.17E+02	1.23E+03	2.80E+01		3.10E+02				3.23E+02	4.00E+00		68819		
Nov-64	2.50E+03	3.52E+01			1.82E+04	2.31E+03	3.40E+02	1.54E+03	3.90E+01		3.10E+02				4.44E+02	4.00E+00		70837		
															3.97E+02	4.00E+00		68468		

Columbia River Flow Multipliers
 TriCities Unattila Vancouver
 1.00 1.48 1.55
 121512 cfs 179414 cfs 188993 cfs 238532 cfs
 (Ref: Walters et al. Ch.3.0)

Dose Conversion Factors by Radionuclide
 External from swimming/boating (mrem/yr per uCi/m3)
 51.6 0 2.08E-10

Internal from ingestion (rem/uCi)
 6.20E-03 2.17E-02 0.00E+00

Resident fish bioaccumulation factors (L/kg)
 1 1700 200
 10x Solid

Drinking water transmission factors
 0.7 0.1 0.3
 (Note: a min.-J transit time in th distribution system of 12 hours is assumed.)

Individual exposure parameters
 Boating 500 h/yr
 Swimming 100 h/yr
 Drinking 440 L/yr
 Fish 40 kg/yr

Drinking water dose
 Calculated as water conc * DW Transmission factor * consumption * dose factor.

1964	Na-24	P-32	Ce-45	Sc-46	Mn-56	Cu-64	As-78	Cu-51	Zn-65	Zn-68m	Ga-72	Si-89	Si-90	Y-83	Y-90	Est. 1-131	Columbia	Flow Rate	Travel Time
DATE	Enhanced	Enhanced	Enhanced	Enhanced	Enhanced	Enhanced	Enhanced	Enhanced	Enhanced	Enhanced	Enhanced	Enhanced	Enhanced	Enhanced	Enhanced	Enhanced	Enhanced	Enhanced	days
Jan-61	7.05E-04	2.22E-05	0.00E+00	0.00E+00	7.55E-07	1.35E-04	9.52E-04	4.01E-04	1.72E-05	0.00E+00	6.40E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.29E-03	1.21E-06	3.58E-03	
Feb-61	4.65E-04	1.34E-05	0.00E+00	0.00E+00	7.12E-07	1.22E-04	7.11E-04	3.00E-04	1.80E-05	0.00E+00	5.04E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.77E-04	9.18E-07	2.86E-03	
Mar-61	5.44E-04	2.48E-05	0.00E+00	0.00E+00	7.74E-07	1.70E-04	8.27E-04	3.07E-04	2.14E-05	0.00E+00	6.17E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.13E-03	1.08E-06	3.03E-03	
Apr-61	5.30E-04	2.19E-05	0.00E+00	0.00E+00	7.71E-07	1.17E-04	8.90E-04	2.12E-04	3.23E-05	0.00E+00	6.01E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.28E-03	1.08E-06	3.08E-03	
May-61	2.48E-04	8.90E-06	0.00E+00	0.00E+00	1.05E-06	6.70E-05	4.01E-04	1.18E-04	1.05E-05	0.00E+00	2.88E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.28E-04	4.04E-07	1.50E-03	
Jun-61	1.48E-04	2.89E-06	0.00E+00	0.00E+00	2.95E-06	3.60E-05	1.98E-04	5.38E-05	4.78E-06	0.00E+00	1.74E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.57E-04	1.79E-07	7.21E-04	
Jul-61	1.74E-04	2.36E-06	0.00E+00	0.00E+00	1.98E-06	4.13E-05	1.57E-04	4.21E-05	2.93E-06	0.00E+00	2.02E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.87E-04	2.34E-07	6.08E-04	
Aug-61	2.87E-04	4.01E-06	0.00E+00	0.00E+00	8.81E-07	6.74E-05	3.08E-04	1.18E-04	6.87E-06	0.00E+00	3.41E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.81E-04	5.17E-07	1.20E-03	
Sep-61	4.81E-04	8.31E-06	0.00E+00	0.00E+00	7.82E-07	1.02E-04	6.31E-04	2.31E-04	1.41E-05	0.00E+00	6.24E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.45E-04	8.95E-07	2.15E-03	
Oct-61	3.89E-04	7.57E-06	0.00E+00	0.00E+00	7.73E-07	8.90E-05	5.20E-04	1.68E-04	8.38E-06	0.00E+00	5.45E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.77E-04	7.53E-07	1.72E-03	
Nov-61	4.80E-04	1.51E-05	0.00E+00	0.00E+00	7.83E-07	1.06E-04	6.63E-04	2.84E-04	1.58E-05	0.00E+00	5.48E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.17E-04	9.40E-07	2.43E-03	
Dec-61	4.89E-04	1.80E-05	0.00E+00	0.00E+00	7.84E-07	1.06E-04	7.08E-04	2.88E-04	1.55E-05	0.00E+00	5.55E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.41E-04	9.80E-07	2.43E-03	
Total D.W	4.84E-03	1.52E-04	0.00E+00	0.00E+00	1.28E-05	1.10E-03	6.90E-03	2.51E-03	1.68E-04	0.00E+00	5.44E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.77E-03	9.15E-06	2.51E-02	
Na-24	20%	P-32	1%	0%	0%	0%	27%	10%	1%	0%	2%	0%	0%	0%	0%	35%	0%	100%	
							As-78	Cu-64	Zn-65	Zn-68m	Ga-72	Si-89	Si-90	Y-83	Y-90	Np-239	Est. 1-131		

Calculated for Tricities										Non-Target Duck Ingestion, Users										Travel Time									
Increase from all 8 reactions																													
DATE	Na 24	P 32	Ca 45	Sc 48	Mn 56	Cu 64	As 76	Cd 51	Zn 85	Zn 89	Zn 89m	Ga 72	Si 89	Si 90	Y 90	Y 83	Np 239	Columbia	Flow Rate										
1 1/2 days	Cld	Cld	Cld	Cld	Cld	Cld	Cld	Cld	Cld	Cld	Cld	Cld	Cld	Cld	Cld	Cld	Cld	Cld	Cld										
Jan 81	4 70E+03	9 69E+01	3 21E+00	1 93E+01	3 81E+04	2 81E+03	1 38E+03	3 01E+03	2 21E+02	9 58E+01	1 54E+02	1 09E+03	1 89E+00	1 78E+01	5 03E+02	1 69E+03	1 40E+03	63706	0.83										
Feb 81	3 14E+03	1 09E+02	2 62E+00	7 43E+00	3 00E+04	2 28E+03	6 04E+02	1 27E+03	1 12E+02	5 72E+01	1 74E+02	1 44E+03	1 75E+00	8 30E+02	2 81E+02	6 41E+02	1 15E+03	88679	0.87										
Mar 81	4 71E+03	9 89E+01	2 49E+00	5 17E+01	4 88E+04	3 51E+03	9 84E+02	1 32E+03	2 08E+02	8 41E+01	1 74E+02	8 97E+02	1 27E+00	7 70E+02	1 48E+02	7 04E+02	6 03E+02	83413	0.86										
Apr 81	3 82E+03	9 68E+01	2 49E+00	1 63E+01	5 97E+04	3 77E+03	8 81E+02	1 48E+03	3 12E+02	1 21E+02	4 31E+02	9 74E+02	9 53E+01	1 11E+01	1 89E+02	8 09E+02	3 48E+02	106483	0.84										
May 81	3 88E+03	7 71E+01	2 98E+00	4 05E+00	4 05E+00	3 22E+04	3 81E+03	8 06E+02	1 32E+03	7 98E+02	3 29E+02	1 63E+03	6 78E+01	1 25E+01	2 14E+02	8 75E+02	4 78E+02	234468	0.82										
Jun 81	5 83E+02	5 68E+01	2 30E+00	6 18E+01	2 53E+04	3 03E+03	2 57E+02	1 35E+03	1 83E+02	2 44E+01	1 64E+02	1 65E+03	8 78E+01	1 72E+01	7 74E+01	4 57E+02	3 79E+02	463087	0.37										
Jul 81	3 47E+03	3 78E+01	3 18E+00	1 77E+00	2 35E+04	2 90E+03	2 57E+02	1 19E+03	6 01E+01	2 20E+01	1 32E+02	4 48E+02	3 75E+00	1 00E+01	5 11E+01	6 32E+02	2 48E+02	180703	0.86										
Aug 81	2 45E+03	1 85E+01		1 77E+00	1 62E+04	2 97E+03	2 88E+02	1 88E+03	1 30E+02	1 89E+01	7 68E+01	2 89E+02			4 72E+01	1 54E+02	3 19E+02	101861	0.86										
Sep 81	1 33E+03	2 83E+01		9 00E+01	1 38E+04	1 18E+03	2 87E+02	2 39E+03	1 02E+02	1 06E+01	6 78E+01	1 19E+02			1 49E+02	3 80E+02	6 27E+02	88687	0.81										
Oct 81	2 21E+03	3 17E+01		8 00E+01	1 38E+04	1 18E+03	2 87E+02	2 39E+03	1 02E+02	1 06E+01	6 78E+01	1 19E+02			1 49E+02	3 80E+02	6 27E+02	88687	0.81										
Nov 81	2 57E+03	3 66E+01		8 54E+01	1 40E+04	1 40E+03	3 14E+02	2 59E+03	9 44E+01	2 40E+01	1 03E+02	6 90E+01			1 49E+02	3 19E+02	4 42E+02	82683	0.83										
Dec 81	2 71E+03	3 10E+01		4 50E+01	1 18E+04	2 47E+03	2 98E+02	2 50E+03	6 73E+01	1 90E+01	1 69E+02	1 98E+02			5 89E+01	2 83E+02	4 30E+02	58026	0.84										

Calculate River Flow Multipliers

facilities

1 Cu

(127, 312 cfs)

(Ref: Walters et al Ch. 3.0)

Dose Conversion Factors by Radionuclide

External from swimmers (mSv/yr per uCi/mCi)

51.6

22.8

2.0

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$\text{dose} \times \text{concentration} \times \text{transmission factor} \times \text{consumption} \times \text{dose factor}$

Internal dose from eating ducks

Internal dose from eating ducks

fish consumption dose

C.26

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