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Model Documentation

PATHRAE-EPA

Methodology and Users Manual

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Environmental Radiation Standards
for Management and Land Disposal
of Low-Level Radioactive Wastes

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PATHRAE-EPA: A Low-Level Radioactive Waste Environmental Transport and Risk Assessment Code

METHODOLOGY AND USERS MANUAL

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DISCLAIMER

PREFACE

This PATHRAE-EPA model documentation provides background information on the mathematical modeling used to generate the basic data for the Environmental Impact Statement (EIS) which is used to support EPA's rulemaking for generally applicable environmental standards for the management and disposal of low-level radioactive wastes. The model is used to assess the maximum annual dose to a critical population group (maximum CPG dose) resulting from the disposal of below regulatory concern (BRC) wastes. This model is considered a member of the PRESTO-EPA family of models. The model is expanded from the PRESTO-EPA-CPG and PRESTO-EPA-BRC models emphasizing two areas: (1) the addition of specific radionuclide exposure pathways pertaining to onsite workers during disposal operation, to offsite personnel after site closure, and to reclaimers and inadvertent intruders after site closure; and (2) the simplification of the sophisticated dynamic submodels to a quasi-steady state submodels so that the computation time can be greatly reduced and enable the model to be excuted on a personal computer.

Interested persons may apply this model, using appropriate and applicable input data, for assessing the maximum CPG dose from an unregulated sanitary landfill site.

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EXECUTIVE SUMMARY

The U.S. Environmental Protection Agency (EPA) is responsible for developing a generally applicable standard for the land disposal of low-level radioactive waste (LLW). The standard will support the U.S. Nuclear Regulatory Commission and the U.S. Department of Energy in developing a national radioactive waste management system. Technical support for the standard includes an estimation of the environmental impacts from the disposal of LLW in a wide variety of facilities ranging from a standard sanitary landfill to a deep geologic repository.

As an aid in developing the standard, a family of computer codes, entitled PRESTO-EPA-POP, PRESTO-EPA-DEEP, PRESTO-EPA-CPG, PRESTO-EPA-BRC and PATHRAE-EPA has been developed under EPA direction. The EPA uses the PRESTO-EPA code family to compare the potential health impacts of a broad number of LLW disposal alternatives to evaluate and support its decisions for the LLW standard.

This report documents the PATHRAE-EPA computer code used to calculate maximum annual doses to a critical population group (CPG). These doses may result from the disposal of candidate "below regulatory concern" (BRC) radioactive wastes at municipal dumps and sanitary landfills located in three representative and diverse hydrological, climatic, and demographic settings.

The PATHRAE-EPA code was developed by Rogers and Associates Engineering Corporation under EPA direction. The model for the code is based upon analytical solutions of the transport equation and both

radiation doses and health effects can be projected for any time period during or following the end of BRC waste disposal operations.

PATHRAE-EPA is a multiple transport pathway, annual dose assessment computer code. The code may be executed on a variety of computers including advanced personal computers (e.g., IBM-AT or IBM-XT). The multiple pathways modeled for radioactive nuclide transport include contaminated groundwater transport to rivers or wells, surface water contamination by erosion of contaminated soil, contamination of soil and water due to disposal facility overflow, atmospheric transport of airborne nuclides and inhalation by humans. Inhalation doses may be calculated to workers engaged in disposal operations and to an off-site population during operation and after site closure. Maximum annual doses to inadvertent intruders and residents at the site following site closure may be calculated. Annual doses may result from internal exposures due to inhalation or ingestion of contaminated materials or from external exposures arising from nuclides on or below the ground surface.

The Environmental Protection Agency wishes to warn potential users that, like any complex computer code, the PATHRAE-EPA code can be misused. Misuse could consist of using the code to examine a site where one or more critical modeling assumptions are invalid, or where values for significant input parameters are chosen that do not accurately reflect variables such as radionuclide inventory, site meteorology, surface and subsurface hydrology and geology, and future population demographics. Certain release and transport scenarios, such as major changes in meteorology or mining, are not considered in the PATHRAE-EPA model and code and significant changes to the existing code and the input data may be required to consider

such scenarios. The PATHRAE-EPA and PRESTO-EPA codes were developed to assess and compare alternative methods for managing and disposing of LLW at generic sites for general scenarios.

1. INTRODUCTION

The U.S. Environmental Protection Agency (EPA) is responsible for developing a generally applicable standard for the disposal of low-level radioactive waste (LLW) to support the U.S. Nuclear Regulatory Commission and the U.S. Department of Energy in developing a national radioactive waste management system. Technical support for the standard includes an estimation of the environmental impacts from the disposal of LLW in a wide variety of facilities, ranging from a standard sanitary landfill to a deep geologic repository.

As an aid in developing the standard, a family of computer codes, entitled PRESTO-EPA-POP, PRESTO-EPA-DEEP, PRESTO-EPA-CPG, PRESTO-EPA-BRC and PATHRAE-EPA has been developed under EPA direction. The PRESTO-EPA-POP code was the first code developed and served as the basis for the other PRESTO-EPA codes. The model is expanded and modified from the PRESTO-EPA-CPG and PRESTO-EPA-BRC models emphasizing two areas: (1) the addition of exposure pathways pertaining to onsite workers and to inadvertent intruders; and (2) the simplification of the sophisticated dynamic submodels to a quasi-steady state submodels which enables the model to be excuted on a personal computer. The EPA uses the PRESTO-EPA code family to compare the potential health impacts of a broad number of LLW disposal alternatives to evaluate and support its decisions for the LLW standard. Table 1-1 provides a brief description of each of the EPA codes. These codes, and how the EPA uses them, have been described in detail (Hu83, Ga84, Ro84a). Information on obtaining complete documentation and user's manuals for the PRESTO-EPA family of codes (EPA85a through EPA85g, Mey81, Mey84) is available from the EPA.

TABLE 1-1

PRESTO-EPA CODE FAMILY

PRESTO-EPA Code	Purpose
PRESTO-EPA-POP	Estimates cumulative population health effects to local and regional basin populations from land disposal of LLW by shallow methods; long-term analyses are modeled (generally 10,000 years).
PRESTO-EPA-DEEP	Estimates cumulative population health effects to local and regional basin populations from land disposal of LLW by deep methods.
PRESTO-EPA-CPG	Estimates maximum annual whole-body dose to a critical population group from land disposal of LLW by shallow or deep methods; dose in maximum year is determined.
PRESTO-EPA-BRC	Estimates cumulative population health effects to local and regional basin populations from less restrictive disposal of BRC wastes by sanitary landfill and incineration methods.
PATHRAE-EPA	Estimates annual whole-body doses to a critical population group from less restrictive disposal of BRC wastes by sanitary landfill and incineration methods.

1.1 BASIS FOR PATHRAE-EPA

The development of the standard for low-level waste (LLW) and below regulatory concern (BRC) waste disposal by EPA has led to the development of the performance assessment code PATHRAE-EPA. The PATHRAE-EPA code was developed by Rogers and Associates Engineering Corporation under EPA direction. The model for PATHRAE-EPA is based upon analytical solutions (Bu80) of the transport equation and both annual radiation doses and health effects can be projected for any time period during or following the end of BRC disposal operations.

The PATHRAE-EPA code may be used to provide estimates of the magnitude of health effects which could potentially occur if certain radioactive wastes were classified as BRC and disposed of in a sanitary landfill or municipal dump. PATHRAE-EPA has been used to calculate maximum annual effective whole body dose equivalents (doses)* to a critical population group (CPG) due to the disposal of candidate BRC wastes at municipal dumps and sanitary landfills located in three representative and diverse hydrogeologic, climatic, and demographic settings (EPA84). Maximum annual doses are calculated to workers during disposal operations, to off-site personnel after site closure, and to reclaimers and inadvertent intruders after site closure. A detailed description of the candidate BRC waste streams, the disposal facility characterizations and the resulting doses calculated by PATHRAE-EPA is given in the references (Ga84, EPA84).

The principal advantage of PATHRAE-EPA is its simplicity of operation and presentation while still allowing a comprehensive set of nuclides and

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* Throughout this report the term "dose" refers to the effective whole body dose equivalent.

pathways to be analyzed. PATHRAE-EPA can be installed and operated on a variety of computer systems including advanced personal computers such as the IBM-AT or IBM-XT. Site performance for radioactive waste disposal can be readily investigated with relatively few parameters needed to define the problem. Important parameters that limit site performance are also readily identified. For example, key site parameters are found generally to include:

- Depth to the aquifer
- Aquifer distance to accessible location
- Aquifer velocity
- Facility size
- Facility operating time
- Precipitation
- Soil retardation characteristics
- Depth of emplacement of waste
- Cover thickness and permeability

Of the many ways in which exposures to radiation from radioactive waste may occur, some have not been included in PATHRAE-EPA because they are either not restricting or are highly improbable. Only those reasonably probable pathways which are most significant and potentially restricting have been treated in the PATHRAE-EPA code. This does not mean that these exposure events will occur. Rather, it is the intent of the PATHRAE-EPA code to model a consistent set of events in such a manner as to estimate a range of probable impacts. The resulting range can be used as a basis for decision making among a variety of diverse alternatives.

The PATHRAE-EPA methodology models both off site and on site pathways through which humans may come in contact with radioactivity from the waste. The off site pathways include groundwater transport to a river and to a well, surface (wind or water) erosion, disposal facility overflow, and atmospheric transport. The on site pathways of concern arise principally from worker doses during operations and from post closure site reclamation or intruder activities such as living and growing edible vegetation on site and drilling wells for irrigation or drinking water.

For each of the pathways which have been included in PATHRAE-EPA, the dose from each nuclide is calculated as a function of time. Each of these doses is then summed to give the total effective dose for that pathway. The dose to the critical population group (CPG) from all pathways is then computed, assuming the entire nuclide inventory is accessible through each pathway. In addition to dose information, nuclide concentrations in river water are calculated for the river, erosion, and bathtub pathways, while well water concentrations are given for the well pathway.

1.3 OUTLINE OF DOCUMENTATION AND USERS MANUAL

This report contains the documentation necessary to understand and use the PATHRAE-EPA code. It is intended for those familiar with the operation of computer systems and who will be conducting PATHRAE-EPA type analyses. A basic familiarity with the pathway approach used in the PRESTO-EPA family of codes is also presumed (EPA87a-EPA87f).

In this chapter the background and use of the PATHRAE-EPA code are briefly described. A summary of the equations, calculational methods, and

general methodology used in PATHRAE-EPA is presented in Chapter 2 as well as a description of the program options that are available. Chapter 3 contains detailed card image input instructions which will allow the used to understand and construct the necessary data files to execute and fully utilize the capabilities of PATHRAE-EPA. Also a brief description of the code output is given. Finally, in Chapter 4 a sample problem is discussed and input data sets for running the problem are given. A source listing of PATHRAE-EPA given in Appendix A and a listing of the output for the sample problem is given in Appendix B.

2. PROBLEM DEFINITION

2.1 PROGRAM DESCRIPTION

The PATHRAE-EPA code has features which make it applicable to a wide range of nuclear waste disposal analyses. These features are briefly identified below.

2.1.1 Pathways

Up to ten pathways by which radioactivity may reach humans can be considered. As shown in Figure 2-1, the pathways are:

1. Groundwater migration with discharge to a river.
   This pathway consists of downward migration of waste components by advection or as a result of dissolution in percolating precipitation. The waste components move downward through the unsaturated zone to an aquifer beneath the disposal site. In the aquifer the waste components are transported by advection and dispersion to an outcrop location where the aquifer discharges to a surface stream.

2. Groundwater migration with discharge to a well.
   Groundwater transport to a well is similar to the pathway described above except that the contaminated aquifer water is withdrawn from a well.

3. Surface erosion of the cover material and waste and subsequent contamination of surface water.
   Erosion and movement to a surface stream involves the gradual removal of the cover over the disposed waste by erosion and, eventually, the slow removal of the waste itself. The time required for erosion of the total cover depth is calculated. Then erosion operates on the waste materials by removing a given amount (specific depth) from the top of the waste each year. A conservative assumption is made that the eroded waste components enter the surface stream in the same year they erode from the waste site.

4. Saturation of waste and facility overflow (bathtub effect).
   This pathway calculates the doses generated when a waste site becomes saturated with water and the contaminated water subsequently overflows the waste trench and enters a stream.

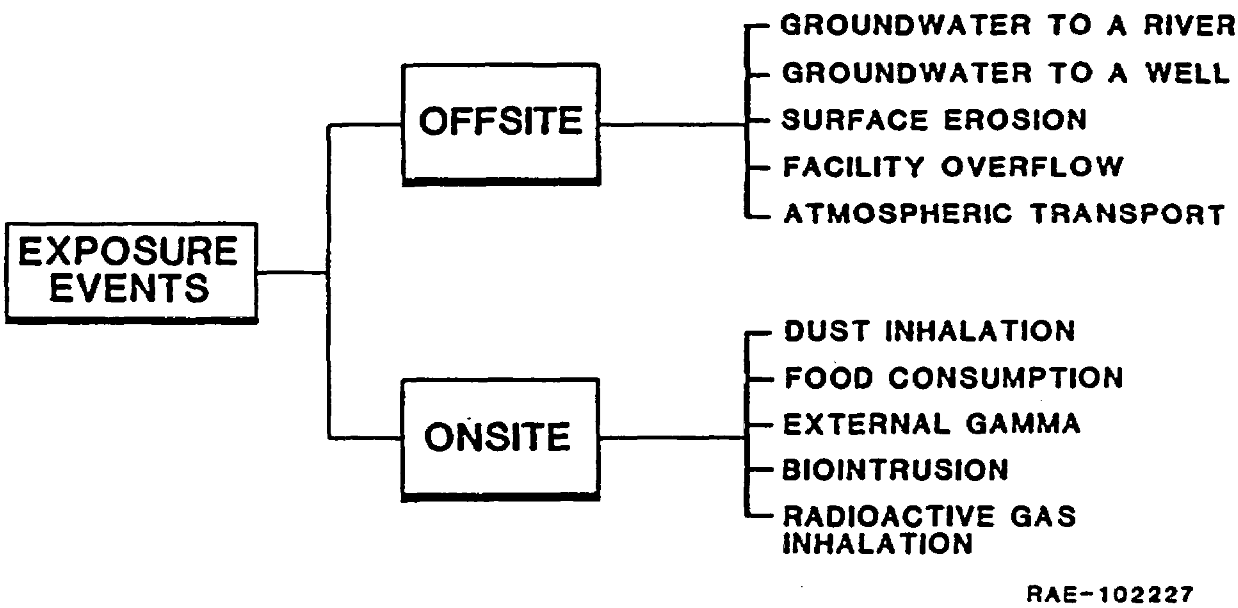

FIGURE 2-1. MAJOR PATHWAYS FOR PATHRAE-EPA.

5. Food grown on the waste site.

This pathway describes the consumption of food grown on reclaimed farm land and accounts for potential exposure of individuals to waste materials through the human food chain. A basic assumption in this pathway is that reclamation activities are required to cause exposure to waste materials. The means for disturbing the waste materials include drilling wells through the waste and excavating a basement for a house. The waste excavated by these activities is uniformly mixed with uncontaminated surface soil down to a specified depth. The soil mixture is then used to grow edible crops and forage for milk and meat producing animals. Individuals are assumed to get some fraction of their food needs from contaminated crops, meat, and milk. The total waste inventory at the site decreases with time to account for loss of contaminants by leaching to the groundwater pathways.

6. Biointrusion into the waste.

This pathway is similar to the food pathway described above, but involves the consumption of crops whose roots have penetrated into previously undisturbed subsurface waste materials. The crops are presumed to absorb waste constituents through root uptake after which the crops are directly consumed by humans. The difference between this pathway and the reclaimer farm pathway is that no excavation of waste material occurs.

7. Direct gamma exposure.

This exposure pathway calculates the external radiation dose to an individual standing directly over a waste site. The cover material over the waste is allowed to erode at a specified rate so the degree of shielding provided by the cover may decrease in time. For this pathway the conservative assumption is made that no loss of contaminants occurs by leaching to the groundwater pathways. The time dependence of the source term is described solely by radioactive decay.

8. Inhalation of radioactive dust on-site.

This pathway traces the effects of inhaling contaminated dust that is suspended during the excavation of a basement or well by a reclaimer and/or during the disposal operation by a operator.

9 Inhalation of radon gas and radon daughters on-site.

This pathway calculates the effects on a reclaimer of inhaling radon and radon daughters while inside a structure built over the waste.

10. Inhalation of radioactive particulates off-site (from an on-site incinerator, trench fire, or dust resuspension).

This pathway uses a Gaussian plume technique to trace the effects of site derived airborne contaminants on a representative off-site population.

2.1.2 Dose Rate Calculations and Environmental Foodchain Analysis

The annual doses are calculated at up to ten different times after site closure using factors contained in the input data. The equivalent whole body dose conversion factors for the sample problem given in Appendix B were obtained from PRESTO-EPA-CPG calculations using the DARTAB subroutines and RADRISK data file (Du80). The user may input other dose conversion factors if desired.

Complete environmental foodchain analysis is performed using the EPA methodology contained in the PRESTO-EPA codes (EPA87a-EPA87e). The foodchain calculations consider direct consumption of contaminated water, use of the water for animal consumption and irrigation of vegetation, consumption of the vegetation by humans and animals, and human consumption of contaminated milk and meat from the animals. The foodchain calculations also consider vegetation grown directly in contaminated soil, with consumption of the vegetation by humans and animals. The foodchain calculations include transfer factors to vegetation and animals as well as consumption rates for water, vegetation, meat, and milk. For convenience, the routines performing the foodchain calculations calculate equivalent uptake factors for use in similar model runs, such that the foodchain analysis need not be repeated each time.

The equivalent total uptake factors quantify, on a nuclide specific basis, the annual nuclide uptake by an individual from all potential sources. For inhalation, it is just the breathing rate. For ingestion, it is the total equivalent annual drinking water consumption in liters that would give the same annual nuclide uptake as would occur from the consumption of contaminated vegetation, meat, milk, seafood, and drinking

water. Since soil-to-plant transfer factors, and other related factors may be nuclide-dependent, the equivalent total uptake factors are nuclide-dependent.

As an example, suppose an individual uses contaminated well water for drinking, irrigating a vegetable garden, and watering a milk cow. If the individual consumes some of the vegetables and milk on a regular basis then the routes by which nuclides are ingested by humans are:

- water - human
- water - vegetables - human
- water - cow - milk - human

The uptake factor for each nuclide would then be the equivalent amount of water the individual would have to drink in order to ingest the same quantity of the nuclide as is ingested via the three pathways listed above. In this example the uptake factor depends on the amount of drinking water consumed by the individual and by the cow, and on the amounts of vegetables and milk consumed. Thus, the specific pathways by which contaminants are ingested and the quantities of contaminated foods ingested are built into the uptake factors.

For the pathways involving food grown over the waste site the uptake factors have a similar meaning. In this case, the uptake factor for a particular nuclide is the equivalent amount of waste material (kg/yr) an individual would have to directly consume in order to ingest the same amount of that nuclide as he ingests by eating contaminated foods.

2.1.3 Nuclide Inventory

The nuclide inventory for PATHRAE-EPA can contain up to 75 nuclides. This can be expanded easily by increasing the limits of appropriate parameters in the DIMENSION and COMMON statements. The inventory can either be specified at all of the designated times or calculated from an initial inventory. In addition, the decay of the nuclide inventory and the ingrowth of daughters can be calculated for the operational and post operational periods.

2.1.4 Groundwater Pathways

The transport of nuclides in the groundwater system can be calculated with or without longitudinal and transverse dispersion terms. The ingrowth of daughter nuclides during transport in the groundwater system can be included using any of seven three- or four-member decay chains. The decay chains are:

1. Cm-244 → Pu-240 → U-236
2. Pu-240 → U-236 → Th-232
3. Am-243 → Pu-239 → U-235
4. Pu-241 → Am-241 → Np-237
5. Pu-238 → U-234 → Th-230 → Ra-226
6. Pu-242 → U-238 → U-234
7. U-238 → Th-230 → Ra-226

Some of these chains are approximate representations of longer chains. For example, decay chain five is calculated assuming all of the Pu-238 decays to U-234 in a time period that is short compared to the nuclide transit time in the aquifer.

In most circumstances decay chain seven has the most significant impact on human nuclide doses and the other six chains can be ignored. However, the user should bear in mind that this is not always the case. The initial nuclide inventory should be carefully examined to assess the importance of the other chains.

When any of the decay chains are activated, PATHRAE-EPA requires that each nuclide in the chain be listed in the initial inventory. If it is desired to model a situation where a particular member of a decay chain is not present initially, the inventory for that nuclide should be input as a very small number, but not zero.

2.2 PATHWAY EQUATIONS

The equations used to calculate the doses for each of the ten pathways are presented in this section. References are given to aid the reader in understanding the assumptions on which the equations are based and, where appropriate, some discussion is given of the important features of the equations. In general, the equations can be grouped into three components representing the waste form or release rate, the transport pathway and environmental uptake. For simplicity, the results of the environmental foodchain analysis are represented in the equations by the symbol, U, called the equivalent uptake factor. Table 2-1 expresses the dose equations in terms of these three components.

Pathway One - Groundwater To A River

The annual whole body equivalent dose due to groundwater migration with discharge to a river is calculated from the following equation.

TABLE 2-1

DOSES AND THEIR COMPONENTS

PATHWAY	DOSE	WASTE FORM COMPONENT	PATHWAY COMPONENT	ENVIRONMENTAL UPTAKE COMPONENT
1. Groundwater	$\frac{Q\lambda_L f_o U_1(DF)}{q_w}$	$Q\lambda_L$	f_o	$\frac{U_1}{q_w}(DF)$
2. Well Water	$\frac{Q\lambda_L f_o U_2(DF)}{q_w}$	$Q\lambda_L$	f_o	$\frac{U_2}{q_w}(DF)$
3. Sheet Erosion	$\frac{Q f_e f_{dil} U_1(DF)}{q_w}$	Qf_e	f_{dil}	$\frac{U_1}{q_w}(DF)$
4. Overflow	$\frac{Q f_e f_{dil} U_1(DF)}{q_w}$	Qf_e	f_{dil}	$\frac{U_1}{q_w}(DF)$
5. Food Grown By Reclaimer	$\frac{Q f_d f_g U_3(DF)}{V d_s}$	$\frac{Q}{V}$	f_d	$\frac{f_g U_3}{d_s}(DF)$
6. Biointrusion	$\frac{Q f_{db} f_g U_3(DF)}{V d_s}$	$\frac{Q}{V}$	f_{db}	$\frac{f_g U_3}{d_s}(DF)$
7. Direct Gamma	$\frac{Q}{A}\frac{R_c R_w f_{exp}}{m_w T_w}(8760)(DFG)$*	$\frac{Q}{A}$	$R_c R_w$	$f_{exp}(8760)(DFG)$
8. Dust Inhalation	$\frac{Q f_d d_d f_{exp} U_i(DF)}{V d_w}$	$\frac{Q}{V}$	f_d	$\frac{d_d f_{exp} U_i}{d_w}(DF)$
9. Radon Inhalation	$\frac{Q E \sqrt{\lambda D_w} \tanh(b_w T_w)(e^{-b_c T_c}) U_i(DF)}{H\lambda_r V F}$	$\frac{QE}{V}$	$\frac{\sqrt{\lambda D_w} \tanh(b_w T_w) e^{-b_c T_c}}{H\lambda_r F}$	$U_i(DF)$
10. Atmospheric Transport	$\frac{Q}{V} r f_f f_v (\frac{X}{Q'}) U_i(DF)$	$\frac{Qf_v}{V}$	$r f_f(\frac{X}{Q'})$	$U_i(DF)$

* $R_c = B(m_c T_c) \exp(-m_c T_c)$

$R_w = 1 + \frac{3\sqrt{\pi}}{4 E_g} - B(m_w T_w) \exp(-m_w T_w)$

$$D = \frac{Q\lambda_L f_o U_1 (DF)}{q_w} \tag{2-1}$$

where

- D = annual whole body equivalent dose (mrem/yr)
- Q = inventory of the radioactive nuclide available in a given year (pCi)
- q_w = flow rate of the river (m^3/yr)
- f_o = fraction of inventory arriving at the river at time t from transport through the aquifer
- λ_L = fraction of each nuclide leached from the inventory in a year (yr^{-1})
- U_1 = annual equivalent uptake by an individual (m^3/yr)
- DF = dose conversion factor (mrem/pCi)

The components of the equation are:

$$\text{Release Rate} = Q\lambda_L$$

$$\text{Transport Pathway} = f_o$$

$$\text{Environmental Uptake} = \frac{U_1}{q_w}(DF)$$

The term f_o can be calculated for dispersive groundwater transport using two methods. For the first case a constant fraction leach model is used to obtain a non-dispersive solution, which is modified by the Hung Correction Factor (Hu86) to obtain a dispersive solution form for f_o given by:

$$f_o = \begin{cases} 0 & \text{for } t \le t_1 - t_0 \\ \dfrac{v_a F_h}{LR\lambda_L}\left\{1 - \exp\left[-\lambda_L(t-(t_1-t_0))\right]\right\} & \text{for } t_1 - t_0 < t < t_1 \\ \dfrac{v_a F_h}{LR\lambda_L}\exp\left[-\lambda_L(t-t_1)\right]\left[1-\exp(-\lambda_L t_0)\right] & \text{for } t_1 \le t \end{cases} \tag{2-2}$$

where

t = calendar time (yr)

t_0 = RL/v_a

t_1 = $R(L+x_r)/v_a$ (yr)

x_r = distance of groundwater flow from nearest edge of burial pits to the river (m)

v_a = interstitial horizontal aquifer velocity (m/yr)

F_h = Hung's correction factor for dispersion

L = length of waste site in direction parallel to aquifer flow (m)

R = retardation factor = $1 + \frac{d}{p} K_d$,

K_d = sorption coefficient in the aquifer (m^3/kg)

d = aquifer density (kg/m^3)

p = aquifer porosity

The term F_h is applicable to a time integration of the release and is given by (Hu86):

$$F_h = \exp\left[\frac{(L+0.5x_w)}{2D_a}(v_a+2v_d - \sqrt{4v_dv_a+v_a^2})\right], \qquad (2\text{-}3)$$

where

D_a = longitudinal dispersivity (m)

v_d = $R\lambda D_a$ (m/yr)

λ = radioactive decay constant for given nuclide (yr^{-1})

For dispersive groundwater transport a band release leaching model is used and f_o is given by (Ro82):

$$f_o = \frac{1}{N}\sum_{j=1}^{N}\left[F_j(t) - F_j(t-1/\lambda_L)\right] \qquad (2\text{-}4)$$

where

$F_j(t)$ = $0.5\ U(t)\ [\text{erfc}\ (z-) + \exp(d_j)\ \text{erfc}\ (z+)]$

erf(z) = error function of z

erfc(z) = complementary error function of z

U(t) = unit step function

$$z\pm = \frac{\sqrt{d_j}\ [1 \pm t/(Rt_{wj})]}{2\sqrt{t/(Rt_{wj})}}$$

d_j = distance from sector center to access location, divided by the dispersivity

t_{wj} = water travel time from sector center to access location (yr)

N = number of spatial integration mesh points over waste source

The numerical integration referred to above is a means by which the point source analytical solution for dispersive transport can be extended to approximate an area source. As shown in Figure 2-2, the disposal facility of length L is divided into N sectors of equal length. A point source of the appropriate magnitude is placed at the center of each sector. The distance, d_j, is proportional to the distance from the center of sector j to the access location. The point source analytical solutions are then summed over all sectors to approximate an area source.

When any of the decay chains are calculated in PATHRAE-EPA it is possible to get negative arguments for the square root function. This is due to the boundary conditions imposed on the solution. The problem arises only when the dispersivity is large and it affects only the calculation of concentrations for daughter nuclides in the decay chains. Like most dispersive transport solutions, the equations used in PATHRAE-EPA are, strictly speaking, only valid for low dispersivities. So, when the argument of a square root is less than zero, PATHRAE-EPA decreases the

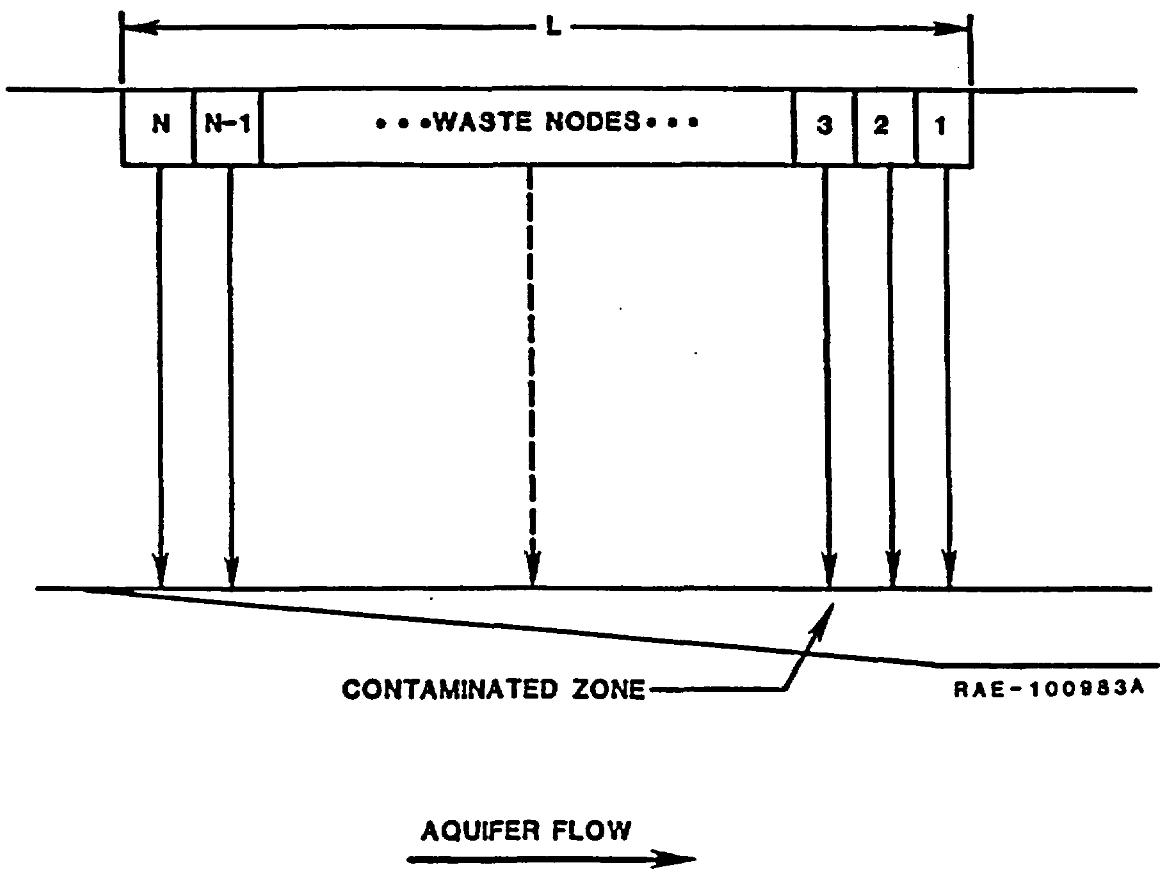

FIGURE 2-2. REPRESENTATION OF AREA SOURCE TERM FOR GROUNDWATER FLOW.

dispersivity by a factor of ten for the remainder of that decay chain calculation. After each chain calculation the dispersivity is restored to its original value. This procedure does not significantly alter the nuclide concentrations because the parent nuclides in the chains are not affected.

Pathway Two - Groundwater To A Well

Groundwater migration with discharge to a well is calculated from

$$D = \frac{Q\lambda_L f_o U_2 (DF)}{q_w} \tag{2-5}$$

where

U_2 = annual equivalent total uptake of well water by an individual (m^3/yr)

The aquifer dilution water flow rate q_w is given, in this case, by:

$$q_w = W\ L\ v_a\ P \tag{2-6}$$

where

W = width of waste pit perpendicular to aquifer flow (m)

L = Thickness of aquifer (m)

P = Porosity of the aquifer

Theoretically a stratified flow, having the leachate on top of the oncoming groundwater, will develop at the downstream end of a disposal site, Figure 2-2. However, in the case of a low yield aquifer normally occurring at a disposal site, a significant draw-down of the groundwater table will develop in the vicinity of the well. Therefore, the streamlines of the flow will be compressed and result in near-complete mixing at the well.

In addition to modeling the effects of longitudinal dispersion in the aquifer, the well pathway can account for any transverse dispersion that may occur. This reduces the conservatism when calculating nuclide doses for the well pathway. When modeling transverse dispersion the term f_o in Equation 2-5 is modified by an additional multiplicative term, f_t, given by:

$$f_t = \frac{1}{2}\,\mathrm{erf}\left[\frac{(y_w + W/2)\sqrt{R}}{2\sqrt{D_y\,t}}\right] - \frac{1}{2}\,\mathrm{erf}\left[\frac{(y_w - W/2)\sqrt{R}}{2\sqrt{D_y\,t}}\right] \qquad (2\text{-}7)$$

where

y_w = distance to well from center of waste area in the direction perpendicular to the aquifer flow (m)

D_y = transverse dispersion coefficient (m^2/yr)

For the limiting case in which D_y goes to zero f_t becomes equal to one. Therefore, the effects of transverse dispersion can be ignored by choosing D_y equal to zero.

The groundwater pathways to the river and the well can also accommodate transport in the vertical unsaturated zone between the waste and the aquifer. This is accomplished in the same manner as in the PRESTO-EPA-POP code (EPA87a). The vertical water velocity and retardation are given by:

$$V_v = P/(p_s S)$$

$$R = 1 + \frac{d_s}{p_s\,S} K_d \qquad (2\text{-}8)$$

where

p_s = effective soil porosity

S = fraction of saturation

d_s = bulk density of soil (g/cm^3)

The term S can either be input or calculated from the expression:

$$S = S_r + (1 - S_r) \left[\frac{P}{K_h}\right]^{SNO} \qquad (2\text{-}9)$$

where

S_r = residual saturation fraction

SNO = soil index

K_h = vertical zone saturated hydraulic conductivity (m/yr)

P = annual percolation (m/yr)

Pathway Three - Sheet Erosion and Transport To A River

In this pathway, the model calculates the doses due to surface transport of radionuclides and deposition in a river. The radionuclides originate either from operational spillage or from sheet erosion of the trench cover and waste. The dose for sheet erosion of cover material and waste and its subsequent deposition in a nearby river is given by:

$$D = \frac{Q f_e f_{dil}\ U_1(DF)}{q_w} \qquad (2\text{-}10)$$

where

f_e = fraction of waste eroded each year

f_{dil} = fraction of solids entering river that originated in waste trenches (calculated by the code)

The parameter f_e is calculated from the surface erosion rate, E_r, which is an input variable, according to the relation $f_e = E_r/T_w$, where T_w is the waste thickness (m) and E_r is expressed in m/yr.

In the initial year of the simulation it is assumed that surface runoff mobilizes radionuclides spilled during facility operations. These contaminants are subsequently deposited in a nearby river. The dose for this initial year of the erosion pathway is calculated using the same approach as that in the PRESTO-EPA codes (EPA85a-EPA85e) and is given by:

$$D = \frac{Q\ f_{spl}\ U_1\ (DF)}{q_w(r_p/d_{act} + K_d\ d_s + p)} \qquad (2\text{-}11)$$

where

f_{spl} = surface spillage fraction

d_{act} = active depth of soil in the surface-contaminated region (m)

r_p = annual runoff of precipitation (m)

Pathway Four - Disposal Facility Overflow

When precipitation and geologic conditions allow, the waste disposal facility may become filled with water and overflow across the ground surface. This "bathtub effect" is calculated as a modification to the erosion pathway. PATHRAE-EPA calculates the dose resulting from the bathtub effect by replacing the erosion rate E_r with the expression:

$$\frac{P}{K_d d_w + p} \exp\left[\frac{-P(t - t_f)}{(K_d d_w + p)t_w}\right] \qquad (2\text{-}12)$$

where

d_w = waste density (gm/cm3)

t_f = time at which trench overflow begins (yr)

Pathway Five - Food Grown On Site

The equation for the dose from ingestion of food grown over the disposal site is:

$$D = \frac{Q f_d f_g (DF)\ U_3}{V\ d_s} \tag{2-13}$$

where

f_d = dilution factor representing the dilution of waste in the soil

f_g = fraction of individual's diet consisting of food grown over the disposal site

U_3 = total equivalent uptake factor for food (kg/yr)

V = volume of waste (m^3)

Equation 2-13 assumes that at some future time a reclaimer moves onto the waste disposal site and builds a house. By excavating a basement for the house and by drilling a well on the property, some of the waste material is brought to the surface and is uniformly mixed with the surface soil to some depth (T_g). A representation of the parameters used to calculate f_d is shown in Figure 2-4. Using these assumptions, the factor f_d representing the dilution of waste in the surface soil is given by:

$$f_d = f_m \left[\frac{T_m - T_c}{T_g\left(\frac{A_1}{A_h} - 1\right)} + \frac{T_w}{T_g\left(\frac{A_1}{A_w} - 1\right)} \right] \tag{2-14}$$

where

f_m = dilution of waste in the trench before reclaimer activities occur

T_m = depth of maximum mechanical disturbance (m)

T_c = thickness of cover (m)

T_g = depth to which contaminants are mixed with surface soil (m)

T_w = thickness of the waste (m)

A_l = lot area (m^2)

A_h = house area (m^2)

A_w = cross sectional area of wells drilled (m^2)

The first term in the brackets of Equation 2-14 is the component due to the excavation of a basement. The second term is the well drilling component. A complete derivation of Equation 2-14 is given by Rogers (Ro82).

Pathway Six - Biointrusion

Biointrusion into the undisturbed waste is calculated in the program with Equation 2-13. It is assumed that plant roots penetrate into the waste and the plants are later consumed by humans. The main difference between this pathway and Pathway Five is that f_d is replaced by f_{db} which is computed differently. For this pathway:

$$f_{db} = \begin{cases} f_m \dfrac{T_w}{T_r} & \text{for } T_r \geq T_c + T_w \\ f_m \left(1 - \dfrac{T_c}{T_r}\right) & \text{for } T_c < T_r < T_c + T_w \\ 0 & \text{for } T_r \leq T_c \end{cases}$$

where

T_r = plant root depth (m)

Pathway Seven - Direct Gamma

The dose from direct gamma exposure to an intruder is calculated from:

$$D = \frac{Q}{A m_w t_w} B(m_c T_c) \exp(-m_c T_c)\left[1 + \frac{3\sqrt{\pi}}{4E_g} - B(m_w T_w) \exp(-m_w T_w)\right] f_{exp}\ (8760)(DFG) \quad (2\text{-}15)$$

where

$B(mT)$ = $1 + (mT)^{1.5}/E_g$ = buildup factor

m_w = gamma attenuation constant of the waste (1/m)

m_c = gamma attenuation constant of the cover (1/m)

f_{exp} = fraction of the year the individual is exposed to given pathway

A = plane area of the waste, the waste is assumed to be a circular horizontal plane with the exposed individual standing at the center (m^2)

E_g = weighted average gamma energy emitted by nuclide (MeV)

DFG = infinite ground plane dose conversion factor (mrem/hr per pCi/m^2)

The function B(mT) in Equation 2-15 is the gamma radiation buildup factor which is used to account for the effects of gamma ray scattering in the waste and in the cover. It is an empirical relation based on gamma scattering data at energies from 0.25 MeV to 1.0 MeV (Mo67). The term in brackets in Equation 2-15 accounts for self-shielding and buildup in the waste of gamma rays.

The weighted average gamma energy is computed by taking the average of all gamma energies emitted by a particular nuclide, each energy weighted by its probability of occurrence. For example, if decay of a nuclide produces a 1 MeV gamma ray 20 percent of the time, a 2 MeV gamma 80 percent of the time and a 2.1 MeV gamma 100 percent of the time, then the weighted average gamma energy would be:

$$E_g = \frac{(0.2 \times 1\ \text{MeV} + 0.8 \times 2\ \text{MeV} + 1.0 \times 2.1\ \text{MeV})}{(0.2 + 0.8 + 1.0)} = 1.95\ \text{MeV}$$

For the sample problem in Chapter 4, the gamma energy for Cs-137 was calculated from the Ba-137m gamma rays.

The infinite ground plane dose conversion factor is discussed in the references (NRC77). For the sample problem, DFG was obtained from PRESTO-EPA runs.

There are three alternatives available when calculating direct gamma doses using PATHRAE-EPA. The first alternative allows the calculation of the gamma dose from the undisturbed buried waste. The second alternative assumes that plant roots penetrate the waste and transport some nuclides to the surface. Each year the plants die and deposit their absorbed nuclides on the ground surface so there is continual transport of nuclides and deposition on the ground surface. The gamma dose is calculated from the nuclides deposited on the surface as well as the nuclides remaining in the original burial trenches. The third alternative assumes that a reclaimer builds a house and digs a well on the site as described for Pathway Five. This brings some of the waste material to the surface where it is mixed with the existing soil. The gamma dose is calculated from the waste on the surface and from the waste that remains underground. The three options in Pathway Seven are selected by the value of the PATHRAE-EPA variable IGAMMA which can have the value 0, 1, or 2.

Pathway Eight - On-Site Dust Inhalation

In this pathway, doses are calculated for a reclaimer excavating a disposal trench some time after site closure. Alternatively, doses to site

workers can be calculated for inhalation of suspended particulates during disposal operations. The dose for the inhalation of resuspended, contaminated dust by an inadvertent intruder is given by:

$$D = \frac{Q f_d d_d U_i f_{exp}(DF)}{V d_w} \quad (2\text{-}16)$$

where

f_d = dilution factor representing the dilution of waste in the soil

d_d = dust loading in the air breathed (kg/m^3)

d_w = waste density (kg/m^3)

U_i = volume of air breathed in a year (m^3/yr)

For the inadvertent intruder scenario, the assumptions for this pathway are similar to those for Pathway Five. That is, a reclaimer builds a house and drills a well over the waste site. The dose arises as a result of inhalation of contaminated dust during the excavation of the house's basement and the drilling of the well. As in Pathway Five, the dilution factor, f_d, is calculated using Equation 2-14. With a slight reinterpretation of the input values, Equation 2-16 is also used to calculate inhalation doses to disposal site workers.

Pathway Nine - Inhalation of Radon in Structures

The dose from inhalation of radon and radon daughters in a structure built over the waste is calculated from:

$$D = \frac{Q}{H \lambda_r V F} E \sqrt{\lambda D_w} \tanh(100\, b_w T_w) \exp(-100 b_1 T_1 - b_2 T_2)\, U_i (DF) \quad (2\text{-}17)$$

where

Q = inventory of Ra226 (pCi)

E = fraction of radon which can emanate upward from the waste

H = height of rooms in structure built over the waste (cm)

λ_r = air ventilation rate of the structure (air changes/sec)

λ = decay constant of radon (1/sec)

T_1 = thickness of earthen cover (m)

T_2 = thickness of concrete floor in reclaimer house (cm)

D_w = radon diffusion coefficient of the waste (cm^2/sec)

D_1 = radon diffusion coefficient of the cover (cm^2/sec)

D_2 = radon diffusion coefficient of concrete floor (cm^2/sec)

$$F = \frac{1}{2}[1 + \sqrt{a_w/a_c}\,\tanh(100 b_w T_w)] + \frac{1}{2}[1 - \sqrt{a_w/a_c}\,\tanh(100 b_w T_w)]\exp(-2(100\, b_1 T_1 + b_2 T_2))$$

$a_i = p_i^2 D_i [1 - (1-k)m]^2$ $(i = w, 1, 2)$

$b_i = \sqrt{\lambda/D_i}$ $(i = w, 1, 2)$

p_i = porosity $(i = w, 1, 2)$

$m_i = 0.01\, Md_i/p_i$ $(i = w, 1, 2)$

M = moisture content (dry weight percent)

k = 0.26 pCi/m^3 of radon in water per pCi/m^3 in air

A description of the theoretical basis of Equation 2-17 is given in the references (Ro82, Ro84b). For most problems, a_i can be set equal to unity with little loss of accuracy.

Pathway Ten - Atmospheric Transport of Contaminants

The dose from the inhalation of airborne contaminants from dust resuspension, incineration, or a trench fire is given by:

$$D = \frac{Q}{V} r f_f f_v \left(\frac{X}{Q'}\right) U_i \text{ (DF)} \tag{2-18}$$

where

r = dust resuspension rate or burn rate of incinerator or trench fire (m^3/sec)

f_f = deposition velocity for resuspended dust (m/sec) or fraction of the year the burning occurs for incinerator and trench fire

f_v = nuclide specific volatility factor for incineration or trench fire (fraction of nuclide released to atmosphere)

X = downwind atmospheric concentration (pCi/m^3)

Q' = atmospheric source release rate (pCi/sec)

PATHRAE-EPA uses Gaussian plume (S168, EPA85a) expressions for X/Q':

$$\frac{X}{Q'} = \sqrt{\frac{2}{\pi}} \frac{f_w}{s_z u} \frac{n}{2\pi x} \exp\left(-h^2/2s_z^2\right) \tag{2-19}$$

where

f_w = fraction of time wind blows in direction of interest

s_z = standard deviation of plume concentration in vertical direction (m)

u = average wind speed (m/sec)

n = number of sectors or wind directions (usually 16 sectors)

x = distance from source to receptor (m)

h = effective release height including momentum and thermal plume rise effects (m)

Plume depletion effects from deposition are represented by a reduced source release rate calculated within the code (EPA87a). The actual release height is modified to account for momentum and thermal plume rise effects by the following equation (S168):

$$h = h_s + \frac{1.5\ v_s\ D_s}{u} + \frac{1.6(3.7E\text{-}5\ \ x^2\ Q_H)^{0.333}}{u} \qquad (2\text{-}20)$$

where

h_s = actual release height (m)

v_s = stack gas velocity (m/sec)

D_s = stack inside diameter (m)

Q_H = heat emission rate from stack (cal/sec)

Equation 2-20 is valid as long as the distance to the receptor location is less than ten times the stack height. For greater distances the receptor distance, x, is replaced with 10 h_s.

If some parameters are unknown or poorly characterized, a default option, based on the location of the maximum plume concentration, is used. In this case:

$$\frac{X}{Q'} = \frac{2}{\pi h^2 eu} \qquad (2\text{-}21)$$

where

e = base of the natural logarithm (2.71828)

Equations 2-19 and 2-21 (S168) are expressions for point sources. For the trench fire scenario it is assumed that the fire involves a relatively small amount of waste (for example, the amount received by the facility in one day). For an incinerator the only source is a single incinerator stack. Since the extent of the source is small in these cases, the use of the point source expression is justified.

If an area source is desired it can be represented by the virtual point source approximation, where x is replaced by x', given by (EPA84)

$$x' = x + 2.5137\, y$$

where

y = width of the facility (m)

The s_z in Equation 2-19 is calculated in PATHRAE-EPA using Briggs' approximations (S168). This necessitates specifying one of the six Pasquill atmospheric stability classes. If no stability class is specified in the input data set, the moderately stable Class D is used. The stability class should be chosen to represent an annual average stability. The wind speed, u, is the annual average wind speed from the source to the receptor.

2.3 SUMMARY OF EQUATIONS

Table 2-1 summarizes the dose equations for each of the ten pathways. The table also shows how the equations can be broken into groups of terms representing the waste form, the transport pathway, and nuclide uptake by humans. An examination of the components of the dose equations reveals the similiarities among the various pathways. In addition to providing a comparison of all the pathways, the table gives insight regarding the relative importance of certain environmental and facility parameters. By studying the relationships among key parameters the most effective means of limiting the doses can be more easily identified.

2.4 FOOD CHAIN CALCULATIONS

Mean concentrations of radionuclides in air, river water, and well water are calculated by the equations listed in Table 2-1. This section describes how radionuclides in those and other environmental media are used to calculate human intake/exposure of radionuclides using PRESTO-EPA foodchain analysis (EPA87a).

Radionuclides in water may impact humans by internal exposure, directly from use of drinking water or indirectly from use of irrigation water for crops. External doses may result from exposure to contaminated soil surfaces. Internal doses may result from inhalation of contaminated air or ingestion of contaminated water and food products, including drinking water, beef, milk, fish, and produce.

The deposition rate onto food surfaces or soil that is used in subsequent calculation of radionuclide content in the food chain, comes from spray irrigation and is:

$$I_r = C_w W_I \tag{2-22}$$

where

I_r = radionuclide application rate (pCi/m^2 - hr)

C_w = radionuclide concentration in irrigation water (pCi/l)

W_I = irrigation rate (l/m^2-hr)

The concentration in water, C_w, is either the well or river water, dependent upon the pathway under consideration.

The following equation estimates the concentration C_v of a given nuclide in and on vegetation at the location of deposition (except for tritium and carbon-14):

$$C_v = \left\{ \frac{I_r f_R [1-\exp(-\lambda_e t_w)]}{Y_v \lambda_e} + \frac{B_c \cdot CSP\ f_I}{d_{ss}} \right\} \exp(-\lambda t_h) \qquad (2\text{-}23)$$

where

C_v = radionuclide concentration in vegetation (pCi/kg)

f_R = fraction of deposited activity retained on crops (unitless)

λ_e = removal rate constant for physical loss by weathering

t_w = time period for irrigation (hr)

Y_v = agricultural productivity yield (kg(wet weight)/m^2)

B_c = radionuclide concentration factor for uptake from soil by edible parts of crops (pCi/kg (wet weight)/pCi/kg (dry soil))

CSP = time average value of soil radionuclide concentration assuming a steady rate of deposition (pCi/m^2).

d_{ss} = effective "surface density" for soil (kg of dry soil)/m^2)

f_I = fraction of the year that irrigation occurs

t_h = time interval between harvest and consumption of the food (hr)

The term CSP is given by:

$$CSP = \frac{8760\ I_r f_I}{t'(\lambda_s - \lambda)} \left\{ \frac{1}{\lambda_s} [1-\exp(-\lambda_s t')] - \frac{1}{\lambda} [1-\exp(-\lambda t')] \right\} \qquad (2\text{-}24)$$

where

t' = min $[1/\lambda_L, (t_{max} - t_o)]$

t_{max} = maximum input time for calculation

The rate constant for contaminant removal from the soil, λ_s, is estimated using:

$$\lambda_s = \frac{r_s}{(0.15)(8760)R} \quad (2\text{-}25)$$

where

λ_s = soil nuclide removal rate coefficient (hr^{-1})

r_s = watershed infiltration (m/yr)

0.15 = depth of contaminated soil layer(m)

8760 = h/yr

If farming is performed on the trench site, then CSP is set equal to d_{ss} in Equation 2-23, giving a soil concentration of 1 pCi/kg.

Equation 2-23 is used to estimate radionuclide concentrations in produce and leafy vegetables consumed by humans and in forage (pasture grass or stored feed) consumed by dairy cows, beef cattle, or goats.

The concentration of each radionuclide in animal forage is calculated by use of the equation:

$$C_f = f_p f_s C_p + (1 - f_p f_s) C_s \quad (2\text{-}26)$$

where

C_f = radionuclide concentration in animal feed (pCi/kg)

C_p = radionuclide concentration on pasture grass (pCi/kg)

C_s = radionuclide concentration in stored feeds in (pCi/kg)

f_p = fraction of the year that animals graze on pasture

f_s = fraction of daily feed that is pasture grass when the animals graze on pasture

The concentration of each radionuclide in milk is estimated as:

$$C_m = (F_m C_f Q_f + C_w Q_w) \exp(-\lambda t_f) \quad (2\text{-}27)$$

where

C_m = radionuclide concentration in milk (pCi/l)

F_m = average fraction of the animal's daily intake of a given radionuclide which appears in each liter of milk (d/l)

Q_f = amount of feed consumed by the animal per day (wet kg/d)

t_f = average transport time of the activity from the feed into the milk and to the receptor (hr)

Q_w = amount of water consumed by the animal (l/d)

The radionuclide concentration in meat depends, as with milk, on the amount of feed consumed and its level of contamination. The radionuclide concentration in meat is estimated using:

$$C_F = F_f(C_f Q_f + C_w Q_w) \exp(-\lambda t_s) \tag{2-28}$$

where

C_F = nuclide concentration in animal flesh (pCi/kg)

F_f = fraction of the animal's daily intake of a given radionuclide which appears in each kilogram of flesh (d/kg)

t_s = average time from slaughter to consumption (hr)

Once radionuclide concentrations in all the various foodstuffs are calculated, the annual human ingestion rate for each radionuclide is estimated by:

$$Q_{ing} = Q_v + Q_{milk} + Q_{meat} + Q_w \tag{2-29}$$

where the variables represent individual annual intakes of a given radionuclide via total ingestion (Q_{ing}), and ingestion of vegetation (Q_v), milk (Qmilk), meat (Qmeat), and drinking water (Q_w), respectively, in pCi/yr. The annual intakes via each type of food, Q_v for instance, are calculated as:

$$Q_v = C_v U_v \tag{2-30}$$

where

Q_v = annual radionuclide intake from vegetation (pCi/yr)

C_v = radionculide concentration in vegetation (pCi/kg)

U_v = individual annual intake of vegetation (kg/yr)

As mentioned earlier, Equations 2-22 through 2-29 do not apply directly to calculations of concentrations of H-3 or C-14 in foodstuffs. For the application of tritium in irrigation water, it is assumed that the concentration in all vegetation, C_v, is the same as the tritium concentration in drinking water; therefore:

$$C_v = C_w \tag{2-31}$$

where C_v and C_w are in pCi/kg and pCi/l, respectively. The concentration of H-3 in animal's feed, C_f, is therefore also equal to C_w. Then, the concentration of tritium in animal's milk and flesh can be written as:

$$C_m = F_m C_w (Q_f + Q_w) \tag{2-32}$$

$$C_f = F_f C_w (Q_f + Q_w) \tag{2-33}$$

where

C_m = concentration of tritium in milk (pCi/l)

F_m = fraction of the animal's daily intake of H-3 that appears in each liter of milk (d/l)

C_w = H-3 concentration in animal's drinking water (pCi/l)

C_F = concentration of tritium in animal's flesh (pCi/kg)

F_f = fraction of the animal's daily intake of H-3 that appears in each kg of flesh (d/kg)

The exponential term is neglected due to the relatively long radioactive half life of tritium compared to transit times through the food chain. The root uptake of C-14 from irrigation water is considered negligible and has been set equal to zero.

3. APPLICATION INFORMATION

This chapter contains the detailed information necessary to construct data sets and perform PATHRAE-EPA analyses. Section 3.1 describes the data files and the organization of the PATHRAE-EPA main program and subroutines. The program options are described in Section 3.2. Detailed input instructions are given in Section 3.3 and the output is discussed in Section 3.4.

3.1 INPUT DATA AND PROGRAM ORGANIZATION

The input data for PATHRAE-EPA are read from four (five, if food pathway option is used) data files. Figure 3-1 shows the general types of information read from these files. The dose conversion factors and equivalent uptake factors, if appropriate, are read from the first file and are usually the same for all PATHRAE-EPA runs. The second file contains site parameters such as dimensions of the facility, cover thickness, volume of waste, etc. This file also contains pathway parameters such as distance to the river and well, aquifer dispersivity, radon diffusion coefficients, and meteorological data. The third data set, labeled "variable site parameters", contains parameters which are likely to be varied when conducting sensitivity analyses. For example, this data set includes nuclide leach rates, groundwater velocities, and trench infiltration rates. These parameters have been placed in a separate data set to minimize the unnecessary duplication of data when performing multiple PATHRAE-EPA runs. The fourth data set contains nuclide specific data such as inventories,

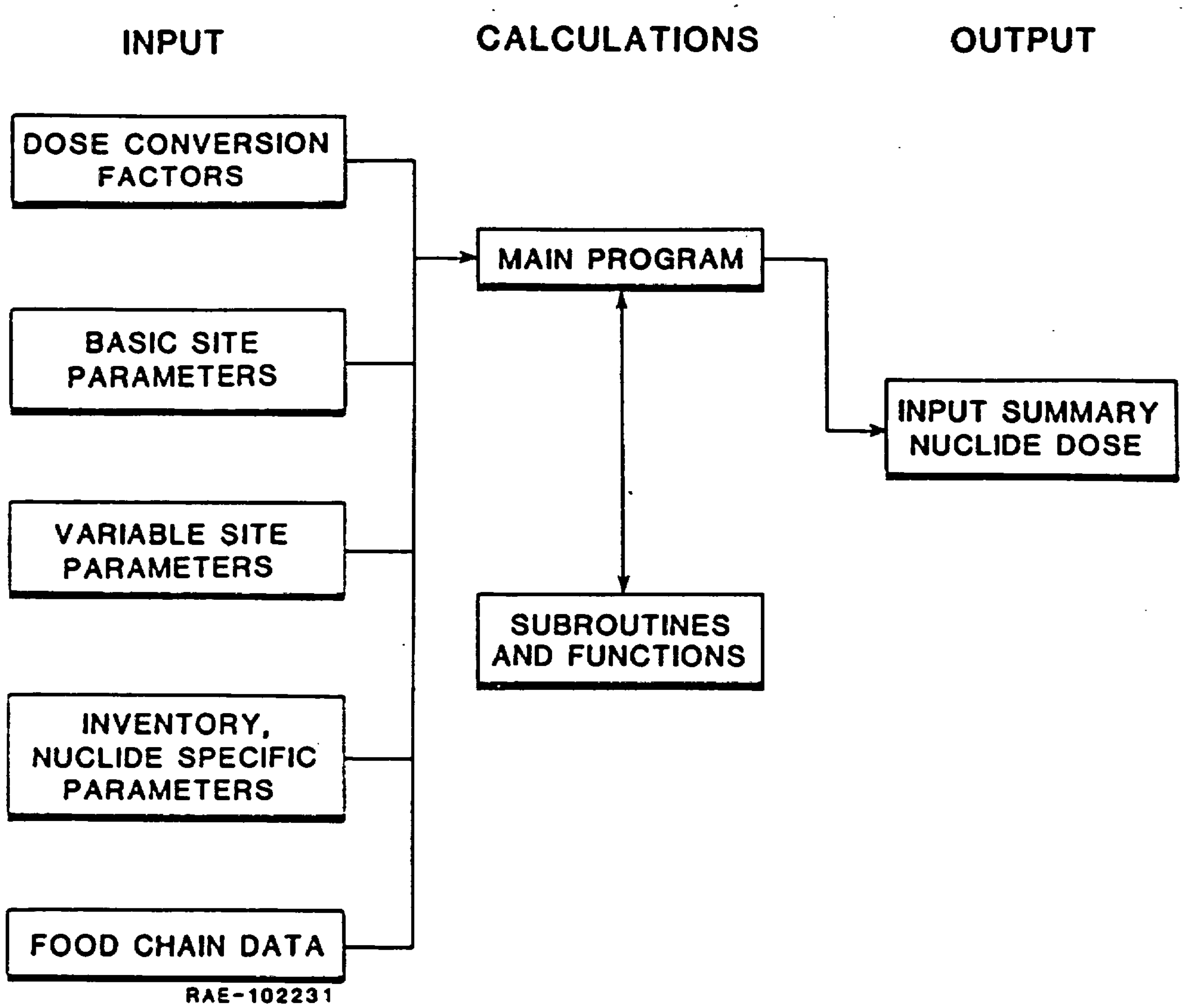

FIGURE 3-1. INPUT AND OUTPUT DATA FLOW FOR PATHRAE-EPA.

half-lives, gamma energies, and volatility factors. The fifth data set is read only if the equivalent uptake factors in the first file are entered as zero. File five contains the element and nuclide specific data such as bioconcentration factors, irrigation rate, food consumption rates, and animal retention factors.

PATHRAE-EPA and its subroutines use double precision arithmetic to accommodate the requirements of the groundwater calculations. The minimum memory requirement to run PATHRAE-EPA is approximately 72K bytes.

In addition to the MAIN program, PATHRAE-EPA uses 15 subroutines and 6 functions. Figure 3-2 shows the subroutine hierarchy and Table 3-1 gives a brief description of the function performed by each program module. The logic flow of PATHRAE-EPA and its subroutines is illustrated in Figure 3-3.

3.2 PROGRAM OPTIONS

The PATHRAE-EPA code has several options which increase its flexibility and allow it to perform a variety of functions. The available options and the input required to activate the options are discussed here.

During the operational period of a waste facility, waste arrives at a relatively uniform rate and is emplaced in the burial trenches. For short-lived nuclides the loss due to decay during facility operations can be significant. PATHRAE-EPA has the option of adjusting the nuclide inventory for decay during operations through the use of the variable TIMOP. To ignore decay during operations set TIMOP equal to zero. Otherwise, TIMOP should equal the number of years of facility operation.

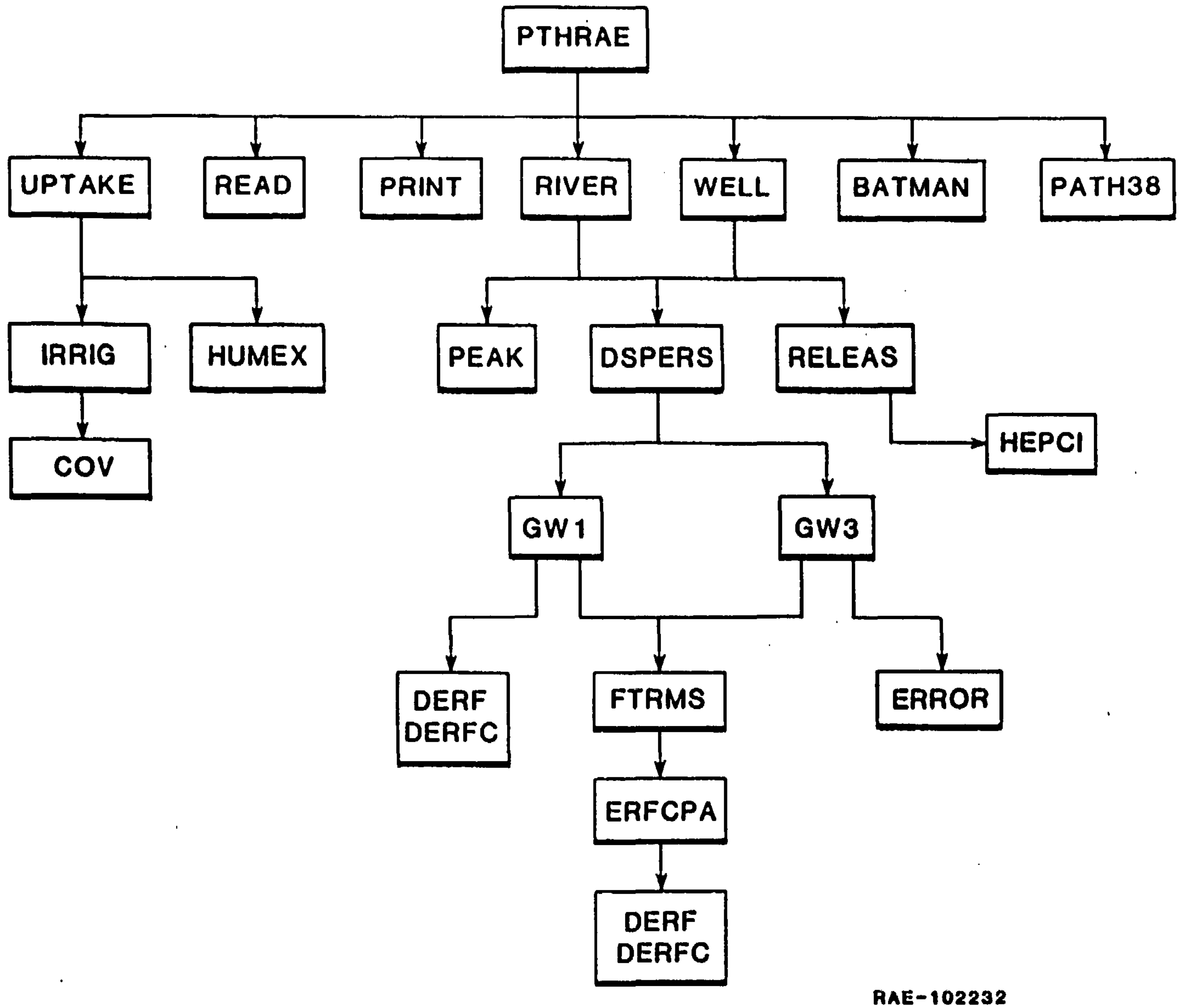

FIGURE 3-2. PATHRAE-EPA SUBROUTINE HIERARCHY.

TABLE 3-1

DESCRIPTIONS OF PATHRAE-EPA SUBROUTINES

Sub-routine	Purpose
PTHRAE	Main program. Coordinates subroutine calls and prints summary dose information.
UPTAKE	Computes total equivalent uptake factors for food and water ingestion.
IRRIG	Calculates nuclide concentrations in vegetation, milk, meat, and fish.
COV	Aids in the calculations performed by subroutine IRRIG.
HUMEX	Calculates amount of each nuclide ingested by humans.
READ	Reads the four input data files and performs preliminary calculations.
PRINT	Prints summary of input data.
BATMAN	Performs Bateman calculations for nuclide ingrowth and decay as a function of time.
RIVER	Calculates doses for groundwater to river pathway.
WELL	Calculates doses for groundwater to well pathway.
PATH38	Calculates doses for all non-groundwater pathways.
PEAK	Calculates maximum dose and time of maximum dose for groundwater pathways with dispersion.
RELEAS	Calculates total curies released in a given time period for groundwater pathways.
HEPCI	Converts total curies released to health effects.
DSPERS	Coordinates groundwater transport subroutines GW1 and GW3.
GW1	Calculates nuclide concentrations for groundwater pathways with dispersion.
GW3	Calculates nuclide concentrations for daughter nuclides in decay chains.
ERROR	Adjusts dispersivity to avoid negative square root arguments in GW3 (see Section 2.2).
FTRMS	Evaluates dispersive groundwater transport expressions in GW1 and GW3.
ERFCPA	Evaluates the natural logarithm of the complementary Gaussian error function.
DERF	Evaluates the Gaussian error function.
DERFC	Evaluates the complementary Gaussian error function.
HUNG	Calculates dispersion correction factor for non-dispersive groundwater pathways.

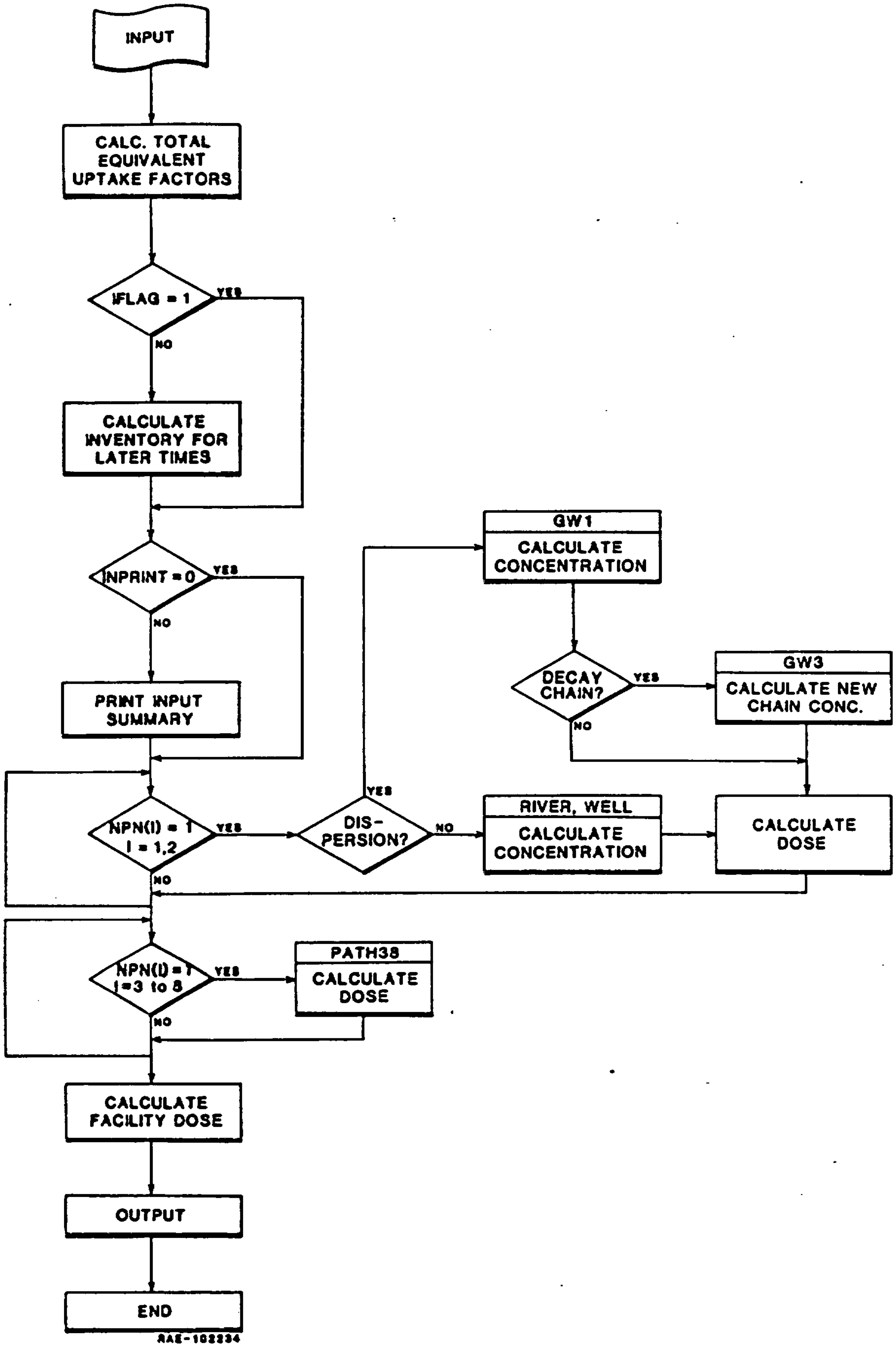

FIGURE 3-3. LOGIC FLOW OF PATHRAE-EPA.

One factor that can affect the dose through the groundwater pathways is the method by which waste is placed in the trench. A value of zero for the variable IFILL refers to placement of waste in the trench beginning at the upstream end of the site, relative to the aquifer. A value of one pertains to placement of waste beginning at the downstream side of the site.

PATHRAE-EPA allows two methods of obtaining the nuclide inventory at times beyond the time of facility closure. The most direct method is to input the nuclide inventory at each of the future times at which doses are to be calculated. A much simpler method is to input the initial inventory and let PATHRAE-EPA compute the inventory at all future times. This option is controlled by the input variable IFLAG. To calculate the future inventories from the initial inventory set IFLAG to zero. If the future inventories are to be read from the input data, set IFLAG equal to one.

When calculating the groundwater pathways, PATHRAE-EPA can use a dispersive solution or a non-dispersive solution with application of a dispersion correction factor. The variable ALDIS, the longitudinal dispersivity in the aquifer, controls this option. For no dispersion use ALDIS equal to zero. Otherwise, enter a positive value for the dispersivity.

PATHRAE-EPA can also model transverse dispersion in the aquifer. This is only important for the well pathway. To ignore transverse dispersion set the transverse dispersion coefficient, DY, equal to zero.

During dispersive transport in the aquifer the decay and ingrowth of nuclides can often have significant impact on the doses from the

groundwater pathways. This can be modeled by using any of the seven decay chains discussed in Section 2.1.4. To implement any of the decay chains it is important to set the transverse dispersion coefficient, DY, equal to zero, since the decay chain expressions are valid only when this is the case. The longitudinal dispersivity, ALDIS, however, must not be zero. To activate decay chain J, set IFL(J) equal to one. To ignore the chain set IFL(J) equal to zero. When considering any of the chains the user must be sure that all of the chain members are present in the initial inventory. The amounts of each nuclide can be arbitrarily small but they must all be greater than zero. Also, the equations for the decay chain calculations require that the sorption coefficients (XKD(I)) for all members of a particular chain be different. However, the sorption coefficients can be almost identical if desired.

PATHRAE-EPA will also locate the position of the maximum dose for each individual nuclide as well as the time at which the maximum dose occurs. To select this option set the variable IOPT equal to one. By using this peak finding option the user can get a general idea of what nuclides are most important and at what times they contribute most to the total dose. Subsequent runs without the peak finding option can then be made to further explore the time dependence of the dose near critical times.

Sometimes it is important to know the total release of each nuclide to the environment during a given time interval. PATHRAE-EPA will calculate the releases if the variable IOPT is equal to two. Like the peak finding option, this only applies to the groundwater pathways with dispersion. The time period for the release is defined by variables T(1) and T(2). Also,

for this option only, the variable NTIME must be greater than or equal to two. Both the peak finding option and the total release option can be turned off by setting IOPT equal to zero.

The atmospheric transport pathway has the option of calculating doses at off-site locations due to dust resuspension, incineration of the waste, or a trench fire. This is controlled by the variable IVFAC. For dust resuspension use IVFAC equal to zero. For incineration use IVFAC equal to one and for a trench fire enter a value of two. When calculating the doses due to dust resuspension, the variable BURN is the resuspension rate (m^3/s) and FFIRE is the deposition velocity (m/s). The volatility factors are not used when doing dust resuspension. For an incinerator or trench fire, BURN is the rate at which the waste is burned (m^3/s) and FFIRE is the fraction of the year the burning occurs.

The atmospheric transport pathway also has an option for calculating X/Q when specific atmospheric and meteorological data are unavailable. To activate this option, which is based on the position of maximum plume concentration, enter the source to receptor distance, XRECEP, equal to zero. When using this default option it is unnecessary to enter data for the atmospheric stability class or fraction of time the wind blows. To bypass this option enter a positive value for XRECEP.

The final option to be described here is a solubility limit on the leach fraction. If the solubility of a nuclide is low enough that it becomes the limiting factor in the release process, PATHRAE-EPA will adjust the leach fraction so that the amount of nuclide leached is the maximum amount that is soluble in the available leachant. To use this option

enter the nuclide solubility (Ci/m^3) as variable SOL. To ignore solubility effects, enter zero.

If the complete foodchain analysis is required for the annual ingestion of contaminant, then set the equivalent uptake factors equal to zero in data file one and enter the data as file 5. Table 3-2 contains a summary of the options and the input data required to control each of them.

3.3 INPUT DATA

All of the input data for PATHRAE-EPA are read from files on the computer. Normally there are four input files required for each run unless a complete foodchain analysis is performed, which requires a fifth input file. The four data files have the specific file names BRCDCF.DAT, ABCDEF.DAT, RQSITE.DAT, and INVNTRY.DAT. The fifth data file is named UPTAKE.DAT. The data in all files may be entered in free format separated by commas or entered with the format specified. The following is a detailed description of the input data for each of the five files. Included are the units of the variable, the applicable pathway number (one through ten) to which the variable is relevant, and the name of the variable as it is referred to in Chapter 2.

TABLE 3-2

SUMMARY OF PATHRAE PROGRAM OPTIONS

Option	Instructions For Use	
Nuclide decay during operations	on: TIMOP > 0	off: TIMOP = 0
Direction in which trenches are filled	To start at end of trench farthest upstream on the aquifer, IFILL = 0	To start at downstream end, IFILL = 1
Bateman calculations for nuclide decay and ingrowth	on: IFLAG = 0	off: IFLAG = 1
Longitudinal dispersion for groundwater pathways	on: ALDIS > 0	off: ALDIS = 0
Transverse dispersion for well pathway*	on: DY > 0 ALDIS > 0 IFL(J) all zero	off: DY = 0
Decay chains for aquifer transport	to activate Jth chain: IFL(J) = 1 ALDIS > 0 DY = 0	to ignore Jth chain: IFL(J) = 0
Peak finder for groundwater pathways	on: IOPT = 1 ALDIS > 0	off: IOPT = 0
Calculate total curies released for groundwater pathways	on: IOPT = 2 NTIME ≥ 2 T(1) = beginning of relese period T(2) = end of release period ALDIS > 0	off: IOPT = 0
Gamma pathway options	Gamma dose from undisturbed waste: IGAMMA = 0 Gamma dose for biointrusion scenario: IGAMMA = 1 Gamma dose for reclaimer farm scenario: IGAMMA = 2	
Atmospheric pathway calculation	Dust resuspension: IVFAC = 0 Incineration: IVFAC = 1 Trench fire: IVFAC = 2	
Atmospheric pathway X/Q default calculation	on: XRECEP = 0	off: XRECEP > 0
Solubility limit on leaching	on: SOL > 0	off: SOL = 0
Perform complete foodchain analysis	on: U1 = 0	off: U1 > 0

* Where multiple conditions are given to activate an option, all conditions must be met simultaneously.

3.3.1 Data File One - BRCDCF.DAT

Card	Variable	Description	Pathway	Text Name
1		Radionuclide Data (I6,2F12.6)		
	NDOSE	Number of isotopes in dose factor library. This is the number of nuclides for which dose conversion factors are provided in the file BRCDCF.DAT.		
	TCUT	Maximum nuclide half-life (yr) considered for analysis. The inventory of any nuclide with a half-life greater than TCUT is set equal to SINV (usually zero). In this way the doses due to short-lived nuclides can be evaluated independently of the long-lived nuclides. To consider all nuclides set TCUT equal to zero and no adjustments will be made.	All	
	SINV	Nuclide inventory (Ci). See TCUT above.	All	
2		Dose Calculations (I6,10F12.6)		
	NTIME	Number of times for which dose calculations will be made (up to 10).	All	
	T(M)	Times (yr) at which the doses are to be calculated. M = 1, 2,..., NTIME. Time T(1) corresponds to the end of facility operations and must be entered as 1. If the food pathway is being run, the time T(4) must correspond to the time at which institutional control of the site ceases.	All	t
3		Dose Factors (I4,A8,9E12.4)		
	KK	Nuclide library number.		

Card	Variable	Description	Pathway	Text Name
	XNAME2(KK)	Nuclide name (e.g., Pu-239). The name is read as an eight character alphanumeric variable. For example, Pu-239 would be input as 'Pu-239---'.		
	DOSE(1,KK)	Dose factor (mrem/pCi) for ingestion.	1-6	DF
	DOSE(2,KK)	Dose factor (mrem/pCi) for	8,10	DF
	DOSE(3,KK)	Dose factor (mrem-m^2/pCi-hr) for direct gamma exposure.	7	DFG
	UT(KK,1)	Total equivalent uptake factor (l/yr) for river water usage.	1	U_1
	UT(KK,2)	Total equivalent uptake factor (l/yr) for well water usage.	2	U_2
	UT(KK,3)	Total equivalent uptake factor (l/yr) for erosion pathway water usage.	3	U_1
	UT(KK,4)	Total equivalent uptake factor (l/yr) for bathtub pathway water usage.	4	U_1
	UT(KK,5)	Total equivalent uptake factor (l/yr) for erosion or bathtub pathways with surface spillage.	3,4	U_1
	UT(KK,6)	Total equivalent uptake factor (kg/yr) for food pathway.	5,6	U_3

Note: Card 3 is repeated for each nuclide in the dose library. If the uptake factors are entered as zeros, they are calculated internally using input data in data file five.

3.3.2 Data File Two - ABCDEF.DAT

Card	Variable	Description	Pathway	Text Name
1		Run Identification (10A8)		
	A(I)	Title of run. Up to 80 characters allowed.		
2		Nuclide Inventory (3I6)		
	NISO	Number of isotopes in inventory.	All	
	IFLAG	Flag indicating whether or not to calculate the inventory for the designated times. If IFLAG = 0 the inventory for all designated future times is calculated from the initial inventory, taking into account the ingrowth of daughter products where appropriate. If IFLAG = 1 the calculation is skipped and the inventory is read from the input data for all future times. If IFLAG = 2 the inventory for all designated future times is calculated from the initial inventory. No account is made for the ingrowth of daughter products.	All	
	NNP	Number of pathways to be considered.		
3		Pathway Data (20I6)		
	NPN(J)	Index indicating a particular pathway. NPN = 1 groundwater to river NPN = 2 groundwater to well NPN = 3 surface erosion and deposition in river NPN = 4 bathtub effect and runoff of water to river NPN = 5 food grown on waste site NPN = 6 biointrusion into waste and consumption of plants by humans		

Card	Variable	Description	Pathway	Text Name
		NPN = 7 direct gamma exposure NPN = 8 dust inhalation on site NPN = 9 radon inhalation NPN = 10 offsite atmospheric transport (incinerator, trench fire, dust resuspension)		
	JUF(J)	Index indicating type of use for ingestion uptake factors. JUF = 0 no water use JUF = 1 all types of water use JUF = 2 all types of water use except fish JUF = 3 drinking water only For the water pathways JUF should be equal to 1, 2, or 3. For the food pathways and pathways not involving ingestion of water use JUF = 0.		

Note: NPN(J) and JUF(J) are repeated on Card 3 for each of the NNP pathways considered.

Card	Variable	Description	Pathway	Text Name
4		Site Description (6F12.6)		
	TIMOP	Time (yr) of active operation of facility. If TIMOP is different than zero, the nuclide inventory is adjusted to account for decay during site operation. If TIMOP is set equal to zero, this correction is omitted.		
	XLP	Length (m) of trench in direction of aquifer flow.		L
	WIDTH	Width (m) of trench.		W
	RFR	River flow rate (m^3/yr)	1,3,4	q_w
	XR	Distance (m) from nearest edge of waste trench to river.	1,3,4	x_r
	SPILL	Surface spillage fraction.	3	f_{spl}

Card	Variable	Description	Pathway	Text Name
5		Transport Data (8F12.6)		
	ARHO	Density (kg/m^3) of aquifer.	1,2	d
	ALDIS	Longitudinal dispersivity (m) of the aquifer.	1,2	D
	DY	Transverse dispersion coefficient (m^2/yr) in aquifer.	2	D_y
	DZ	Not used.		
	SS	Fraction of saturation, if zero, it is calculated internally.	1,2	S
	SR	Residual saturation fraction.		S_r
	PV	Saturated hydraulic conductivity (m/yr) of vertical zone.	1,2	K_h
	SNO	Soil index.	1,2	SNO
6		Gamma Radiation Data (5I6)		
	NM	Number of mesh points for area source integration.	1,2	N
	IGAMMA	Flag for gamma pathway options. IGAMMA = 0 Calculate gamma dose from undisturbed buried waste. IGAMMA = 1 Calculate gamma dose for natural biointrusion scenario. IGAMMA = 2 Calculate gamma dose for farming scenario.	7	
	IVFAC	Flag indicating off-site atmospheric pathway. For dust resuspension enter zero, for incineration enter one, for trench fire enter two. For incineration the dose for all other pathways is adjusted to		

Card	Variable	Description	Pathway	Text Name
		account for the loss of nuclides by incineration before being placed in the trench.		
7		Waste Properties (10F12.6)		
	XCT	Thickness (m) of cover over waste.	3-9	T_c
	XWT	Thickness (m) of waste.	3-9	T_w
	TWV	Volume (m^3) of waste disposed.	All	V
	XW	Distance (m) to well from nearest edge of waste along direction of aquifer flow.	2	x_w
	YW	Distance (m) to well from center line of disposal facility in direction perpendicular to aquifer flow.	2	y_w
	RHO	Density (kg/m^3) of waste.	4,8,9	d_w
	FG	Fraction of food eaten which is grown over waste site.	5,6	f_g
	FEXT	Fraction of year spent in direct radiation field.	7	f_{exp}
	XROOT	Depth (m) of plant root zone.	6,7	T_r
	PLANT	Surface density (kg/m^2) of living plants.	7	
8		Exposure Data (3F12.6)		
	ADL	Average dust loading (kg/m^3) in air.	8	d_d
	UBR	Adult breathing rate (m^3/yr).	8-10	U_i
	FTX	Fraction of year exposed to dust.	8	f_{exp}
	CANLIF	Waste container lifetime (yr)	1,2	
	FIXINV	Inventory scaling factor. (The inventory on file is multiplied by FIXINV before calculations begin.)	All	

Card	Variable	Description	Pathway	Text Name
9		Residency Data (7F12.6)		
	XH	Height of room (cm) in dwellings built over the site.	9	H
	ACR	Air change rate (changes/s) in dwelling.	9	λ_r
	EPW	Radon emanating power of the waste. (Fraction of radon produced which enters pore spaces.)	9	E
	DIFW	Diffusion coefficient (cm^2/sec) for radon in waste.	9	D_w
	DIFCON	Diffusion coefficient (cm^2/sec) for radon in concrete.	9	D_2
	TCON	Thickness (cm) of concrete floor.	9	T_2
	DIFCOV	Diffusion coefficient (cm^2/s) for radon in the cover material.	9	D_1
10		Atmosphere Data (10F12.6)		
	ISTAB	Pasquill atmospheric stability class. Enter an integer 0 through 6. A value of 1 signifies stability class A, a value of 6 signifies stability class F. If zero is entered, a default value of 4 is used.	10	
	VWIND	Average annual wind speed (m/s) in direction from source to receptor.	10	u
	FWIND	Fraction of time wind blows toward receptor location.	10	f_w
	XRECEP	Distance (m) from atmospheric release source to receptor location. To exercise default option on X/Q calculation, enter zero and set HSTACK = unity.	10	x

Card	Variable	Description	Pathway	Text Name
	BURN	Dust resuspension rate (m^3/s) or burn rate (m^3/s) of incinerator or trench fire.	10	r
	FFIRE	Fraction of year incinerator or trench fire burns,	10	f_f
		or		
		Deposition velocity (m/s) for dust resuspension.	10	f_f
	HSTACK	Height (m) of incinerator stack. For trench fire scenario enter zero.	10	h_s
	DSTACK	Stack inside diameter (m).	10	D_s
	VSTACK	Stack gas velocity (m/s).	10	v_s
	QH	Heat emission rate (cal/s) of incinerator stack.	10	Q_H
11		<u>Flag Options (20I6)</u>		
	IFL(I)	Flags indicating which decay chains will be considered for the dispersion calculations.	1,2	

If IFL(I) = 1, then decay chain I is computed.
If IFL(I) = 0, it is skipped. The values of I refer to the following chains:

I = 1 Cm-244 → Pu-240 → U-236
I = 2 Pu-240 → U-236 → Th-232
I = 3 Am-243 → Pu-239 → U-235
I = 4 Pu-241 → Am-241 → Np-237
I = 5 Pu-238 → U-234 → Th-230 → Ra-226
I = 6 Pu-242 → U-238 → U-234
I = 7 U-238 → Th-230 → Ra-226

If a particular decay chain is used, all of the nuclides in the chain should be present in the initial inventory. The equations used for calculating decay chains are not valid unless all members of the chain have different sorption coefficients.

Card	Variable	Description	Pathway	Text Name
12		Printout Control (4I6)		
	INPRNT	Flag for printout of input summary. If INPRNT = 0, no input summary is printed. If INPRNT = 1, the summary is printed.		
	IDSRPT	Not used.		
	IFILL	Flag indicating how the waste trenches are filled. If IFILL = 0, the trench is filled beginning at the side farthest upstream of the aquifer. If IFILL = 1, the trench is filled beginning at the downstream side.	1,2	
	IOPT	Flag for selecting groundwater pathway options. To use the peak finding option set IOPT = 1. To calculate the total curies released during a given time period set IOPT = 2. If neither of these two options are required use IOPT = 0. See Table 3-2 for more information on the use of these options.	1,2	

3.3.3 Data File Three - RQSITE.DAT

Card	Variable	Description	Pathway	Text Name
1		Site Water Data (9F12.6)		
	XPERC	Amount of water (m^3/m^2-yr) which percolates through the waste annually per unit area.	2	P
	VA	Horizontal velocity (m/yr) of aquifer.	1,2	v_a
	XPOR	Porosity of aquifer.	1,2	p

Card	Variable	Description	Pathway	Text Name
	XAQD	Distance (m) from trench bottom to aquifer.	1,2	
	XVV	Vertical velocity (m/yr) of the water in the soil between the waste and the aquifer. Calculated internally if entered as zero.	1,2	v_d
	XLC	Length (m) of perforated well casing set equal to aqufer thickness.	2	L
	XALE	Surface erosion rate (m/yr)	3,4	E_r
	FLCH	Scaling factor for leach constant.	1,2	
	RUNF	Annual runoff of precipitation (m).	3	
2		<u>Transport Characteristics (I4,3E12.4)</u>		
	KK	An integer library index specifying the nuclide.		
	XLL(KK)	The leach constant (1/yr). In the band release model used in the dispersive calculation, it is the fraction of the initial inventory which is leached from the waste each year. For the exponential release model used in the nondispersive calculations, this constant is the fraction of current inventory leached each year.	1,2	λ_L
	XKD(KK)	The sorption coefficient (cm^3/g). This is used to obtain the retardation coefficient in the aquifer.	1,2,4	K_d
	RVERTI(KK)	Sorption coefficient (cm^3/g) for vertical transport of the nuclide from the trench to the aquifer.	1,2	K_d

Note: Card 2 is repeated for each nuclide in the inventory.

3.3.4 Data File Four - INVNTRY.DAT

Card	Variable	Description	Pathway	Text Name
1		Nuclide Data (I4,7E12.4)		
	KK	An integer library index specifying the nuclide.		
	HLIFE(KK)	Nuclide halflife (yr).		$Ln2/\lambda$
	Q(KK,M)	The amount of nuclide present (Ci) at each of the times T(M) for M = 1,2,...,NTIME. If IFLAG is entered as zero, then only the inventory at time T(1) needs to be entered and the inventory at all subsequent times will be calculated. See Section 3.2 for a description of the use of IFLAG.		Q
	XXMU(KK)	Gamma attenuation coefficient (1/m). These are derived from empirical data on gamma attenuation by soil for various gamma energies. For nuclides which are not gamma emitters, enter zero.* Must be nonzero if EGAMMA and Q are nonzero.	7	m_w, m_c
	EGAMMA(KK)	Weighted average gamma ray energy (MeV) emitted by nuclide. The averaging method is described in Section 2.2. For nuclides which are not gamma emitters, enter zero.*	7	E_g
	BIV(KK)	The nuclide specific soil to plant transfer factor. It is the ratio of the nuclide concentration (Ci/kg) in plants to the nuclide concentration (Ci/kg) in the soil.	7	

* Cs-137 is considered as if it is a gamma emitter, even though the gamma rays are emitted by its decay product, Ba-137m.

Card	Variable	Description	Pathway	Text Name
	SOL(KK)	Solubility (Ci/m^3) of the nuclide in the aquifer. To omit the effects of solubility limitations, enter zero.	1,2	
	VOLATL(KK)	Volatility factor for incineration. It is the fraction of the inventory of a nuclide which is lost to the atmosphere as a result of incineration. This variable is not used when pathway 10 calculates dust resuspension.	10	f_v

Note: Card 1 is repeated for each nuclide in the inventory.

3.3.5 Data File Five - UPTAKE.DAT (All data for food chain calculations)

Card	Variable	Description	Text Name
1		Site Soil Data (3F12.6)	
	SINFL	Infiltration rate (m/yr)	I_n
	PORS	Porosity of surface soil.	p_s
	BDENS	Bulk density (g/cm^3) of soil.	d_s
2		Vegetation Data (5F12.6)	
	Y1	Agriculture productivity (kg/m^2) for pasture grass.	Y_v
	Y2	Agriculture productivity (kg/m^2) for other vegetation.	Y_v
	XAMBWE	Weathering removal constant (hv^{-1}) from vegetation.	λe
	TE1	Hours for irrigation of pasture grass.	t_w
	TE2	Hours for irrigation of other vegetation.	t_w

Card	Variable	Description	Text Name
3		Pasture Data (6F12.6)	
	TH1 - TH4	Delay time (hr) between harvest and consumption of pasture grass, stored feed, leavy vegetables, and produce.	t_h
	FP	Fraction of the year animals graze on pasture grass.	f_p
	FS	Fraction of animal feed that is pasture grass.	f_s
4		Animal Uptake (5F12.6)	
	QFC	Amount of feed consumed daily (kg/d) by cattle.	Q_f
	QFG	Amount of feed consumed daily (kg/d) by goats.	Q_f
	TF1	Transport time (hr) for annual feed into milk.	t_f
	TS	Delay time (hr) between animal slaughter and meat consumption.	t_s
	TFIS	Delay time (hr) between catching and consumption of fish.	
5		Water Consumption (5F12.6)	
	FI	Fraction of the year the crops are irrigated.	f_I
	WIRATE	Irrigation rate (l/m^2-hr).	W_I
	QCW	Amount of water consumed (l/d) by milk cows.	Q_w
	QGW	Amount of water consumed (l/d) by goats.	Q_w
	QBW	Amount of water consumed (l/d) by beef cattle.	Q_w
6		Human Uptake (7F12.6)	
	ULEAFY	Human uptake (kg/yr) of leafy vegetation.	U_v

Card	Variable	Description	Text Name
	UPROD	Human uptake (kg/yr) of produce.	U_p
	UCMILK	Human uptake (l/yr) of cow milk.	U_c
	UGMILK	Human uptake (l/yr) of goats milk.	U_g
	UMEAT	Human uptake (kg/yr) of meat.	U_m
	UWAT	Human uptake (l/yr) of contaminated drinking water.	U_w
	UFISH	Human uptake (kg/yr) of fish.	U_f
7+		Transfer and Retention Data (A8,6F12.6)	
	NUCLID(KK)	Nuclide identification no.	
	RW(KK)	Radionuclide retention factor.	R
	BR(KK)	Soil-to-plant uptake factor for grain.	B_c
	FMC(KK)	Forage to milk transfer factor for cows.	F_m
	FMG(KK)	Forage to milk transfer for goats.	F_m
	FF(KK)	Forage to beef transfer factor.	F_f
	FIS(KK)	Radionuclide water-to-fish transfer factor.	F_S

3.4 OUTPUT DATA

A typical output for the PATHRAE code for a LLW inventory of about 25 nuclides, is approximately 12 pages in length. The output begins by listing a complete summary of the input data. The site parameters, dose conversion factors, and equivalent uptake factors are included. This is followed by tables of nuclide doses for each nuclide and pathway considered. For the two groundwater pathways, the erosion pathway, and the facility overflow pathway, tables giving nuclide concentrations in water at various times are generated.

Following the outputs for the individual pathways, values for the cumulative risks and doses are given for the entire facility. The output also contains a table of the nuclide inventory at each of the times considered. A final summary of the maximum annual dose, health risk, year of the maximum health impact and dominant nuclide are given for each pathway.

4. SAMPLE PROBLEM

4.1 PROBLEM DEFINITION

A PATHRAE-EPA sample problem is considered in this chapter. The facility evaluated in this sample problem is a 350,000 square meter municipal dump with a capacity of one million cubic meters of BRC waste as illustrated in Figure 4-1. The facility has a 20 year operating lifetime during which the radioactive wastes are received at a constant rate. The waste is placed in disposal pits to a depth of six meters and is covered by a 0.6 meter thick cover. An aquifer with a water velocity of 28 meters per year is located 7.7 meters below the waste. The annual infiltration into the waste is 0.45 cubic meters of water per square meter of trench area. A well is located 50 meters from the edge of the waste trenches. For the groundwater calculations the waste area is represented by a 20-point mesh spacing grid. Values of pertinent site parameters and radiation exposure data required by PATHRAE-EPA are listed in Table 4-1. The initial inventory of 29 nuclides is given in Table 4-2.

4.2 RESULTS

A summary of the doses as functions of time and the pathway summary are contained in Table 4-3. The total dose falls from a maximum value of 95 mrem/yr in year zero to about 1.8 mrem/yr at 15 years and 0.18 mrem/yr in 100 years. The external exposure pathway, primarily from Co-60, dominates the early doses with the well pathway becoming dominant after 100 years primarily from C-14. Cobalt-60, cesium-137, carbon-14, and americium-241 are the dominant nuclides.

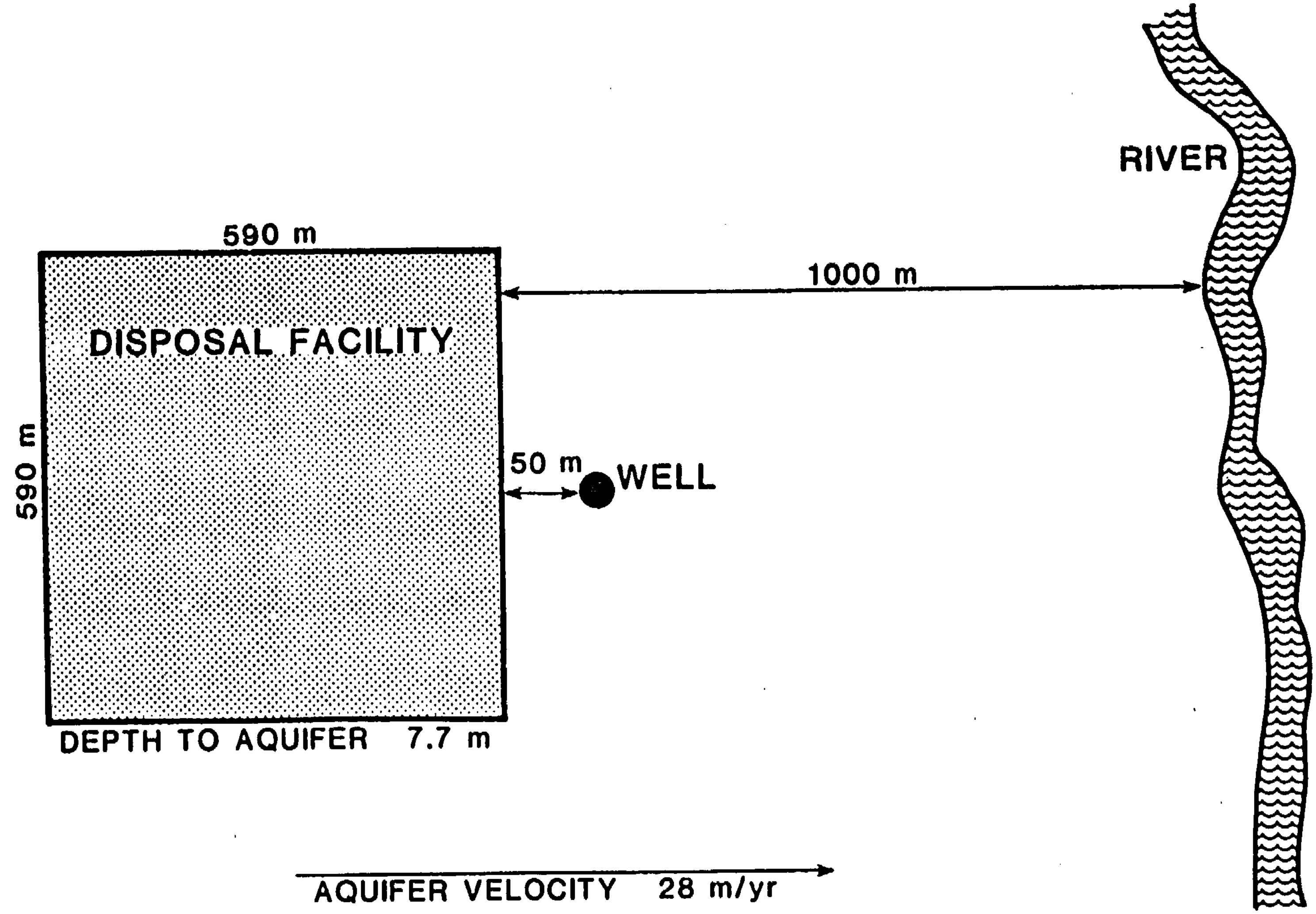

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FIGURE 4-1. REPRESENTATION OF SAMPLE PROBLEM.

TABLE 4-1

SITE PARAMETERS USED IN SAMPLE PROBLEM

Total area of Disposal Trenches	3.48E+5 m^2
Length of Trenches Parallel to Aquifer Flow	590 m
Velocity of Aquifer	27.8 m/yr
Porosity of Aquifer	0.39
Trench Infiltration	0.45 m^3/m^2
Total Surface Erosion Rate	1.96E-4 m/yr
Cover Thickness Over Waste	0.6 m
Waste Thickness in Pits	6.0 m
Total Waste Volume	1.0E+6 m^3
Distance From Waste Pits to Well	50 m
Length of Perforated Casing in Well (aquifer thickness)	10 m
Average Dust Loading During Excavation	5.0E-7 kg/m^3
Annual Adult Breathing Rate	8E+3 m^3/yr
Fraction of Time Spent in Excavation	0.228
Average Wind Speed	2.01 m/s
Downwind distance to receptor location	345 m

TABLE 4-2

NUCLIDE INVENTORY

Nuclide	Halflife (yr)	Initial Inventory (Ci)
H-3	1.23E+1	1.31E+02
C-14	5.73E+3	7.43E+00
Fe-55	2.70E+0	1.20E+02
Co-60	5.25E+0	2.46E+02
Ni-59	8.00E+4	1.43E-01
Ni-63	1.10E+2	4.41E+01
Sr-90	2.86E+1	3.40E+00
Nb-94	2.00E+4	4.54E-03
Tc-99	2.13E+5	1.90E-03
Ru-106	1.01E+0	5.04E-02
Sb-125	2.77E+0	1.85E+00
I-129	1.70E+7	5.26E-3
Cs-134	2.06E+0	5.04E+01
Cs-135	2.30E+6	1.80E-3
Cs-137	3.01E+1	5.70E+01
Ba-137m	3.01E+1*	5.70E+01
Eu-154	8.50E+0	1.86E-01
U-234	2.45E+5	4.27E-03
U-235	7.04E+8	6.85E-05
U-238	4.47E+9	1.25E-03
Np-237	2.10E+6	9.68E-06
Pu-238	8.77E+1	1.20E-01
Pu-239	2.42E+4	1.12E-01
Pu-241	1.32E+1	4.85E+00
Pu-242	3.79E+5	2.43E-04
Am-241	4.59E+2	2.31E-01
Am-243	7.37E+3	5.41E-05
Cm-243	3.19E+1	5.52E-05
Cm-244	1.76E+1	5.26E-02

* Assumed to be in equilibrium with Cs-137.

TABLE 4-3

FACILITY DOSE RATES FOR VARIOUS TIMES FOR SAMPLE PROBLEM

Parameter	Time (yr) 0	1	15	50	100	200	350	500	750	1000
Dose (mrem/yr)	9.46	8.33E+0	1.78E+0	3.83E-1	1.84E-1	8.63E-2	5.51E-2	4.03E-2	2.56E-2	1.88E-2

PATHWAY SUMMARY

	Pathway Dust	Atmospheric	Gamma	Well	Food
Maximum Annual Dose (mrem/yr)	2.2E-2	2.6E-6	8.8E+0	1.1E-1	4.8E-1
Year of Maximum Dose	0	0	0	50	1
Dominant Nuclide	Am-241	Am-241	Co-60	C-14	Cs-137

A complete listing of the five data sets required to execute the sample problem and the output for the sample problem are given in Appendix B. A complete source listing of PATHRAE-EPA code is given in Appendix A.

Finally, it should be noted that the sample problem described in Section 4.1 merely illustrates the application of PATHRAE-EPA and is not intended as a basis for arriving at any general conclusions regarding specific disposal alternatives.

4.3 PATHRAE-EPA COMPUTER COMPATIBILITY

The PATHRAE-EPA code is sufficiently compact and calculationally efficient that it can be executed on a variety of computer systems including advanced personal computers. For example, the PATHRAE-EPA code has been implemented and operated within reasonable execution times on an IBM-AT Personal Computer.

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APPENDIX A

SOURCE LISTING FOR PATHRAE-EPA CODE

```
      PROGRAM PTHRAE
C     PEI MODIFIED VERSION OF PATHRAE ON THE IBM-AT
      IMPLICIT REAL*8 (A-H,O-Z)
      REAL*4 C,Q,UT
      CHARACTER*8 VNUCL,XNAME2
      COMMON/XECR/NREC
      COMMON/BLK1/ALDIS,C(100,10),CANLIF,DILFAC,DOSV(5),DY,DZ,NM,NMY,
     &       NMZ,NTIME,Q(100,10),RVERT(100),T(10),TTIME(5),VA,VNUCL(5),
     &       WIDTH,WSLABL(10),XAQD,XL,XLD(100),XLL(100),XLP,XRC(100),
     &       XVV,YW,ZR
      COMMON/BLK2/ACR,ADL,AMIN,ARHO,BIV(100),BURN,CUMDOS(10),DIFCON,
     &       DIFCOV,DIFW,DOSE(3,100),DSTACK,EGAMMA(100),EPW,FEXT,FFIRE,
     &       FG,FIXINV,FTX,FWIND,HLIFE(100),HSTACK,IDSRPT,IFL(7),IFLAG,
     &       IGAMMA,INPRNT,IOPT,ISTAB,IUP,IVFAC,JUF(10),NDOSE,NISO,NNP,
     &       NP,NPN(10),PLANT,PV,QH,RFR,RHO,RUNF,SINV,SNO,SPILL,SR,SS,
     &       TBEG,TCON,TCUT,TEND,TIMOP,TIMOP1,TWV,UBR,UT(100,6),
     &       VOLATL(100),VSTACK,VWIND,XALE,XCT,XH,XKD(100),XLC,
     &       XNAME2(100),XPERC,XPOR,XR,XRECEP,XROOT,XW,XWT,XXMU(100)
      COMMON/BLK3/IFILL
      DIMENSION XLLI(100),RVERTI(100)
C     COMPUTER SPECIFIC TO RAECO SYSTEM TO CATCH 'ZERO' ERRORS
C      CALL ERRSET(63,.TRUE.,.FALSE.,.FALSE.,.FALSE.,50)
C      CALL ERRSET(73,.TRUE.,.FALSE.,.FALSE.,.TRUE.,50)
      OPEN(UNIT=6,FILE='OUTPUT.FIL',STATUS='NEW')
      CALL ZERO
C
C     CALL SUBROUTINE WHICH READS INPUT
C
      CALL READ(XLLI,RVERTI)
C
C     CALCULATE TOTAL EQUIVALENT UPTAKE FACTORS
C
      IF(IUP .NE. 0) CALL UPTAKE
C
C     CALL SUBROUTINE WHICH PRINTS INPUT SUMMARY
C
      CALL PRINT(XLLI,RVERTI)
      IF(IFLAG.EQ.1) GO TO 200
      DO 100 K=1,NDOSE
      IF(Q(K,1).EQ.0.) GO TO 100
      DO 50 M=2,NTIME
      ARG=XLD(K)*T(M)
      Q(K,M)=0.
      IF(ARG.LE.85.) Q(K,M)=Q(K,1)*DEXP(-ARG)
   50 CONTINUE
  100 CONTINUE
C
C     CALL SUBROUTINE TO DO BATEMAN CALCULATIONS
C
      IF(IFLAG.EQ.0) CALL BATMAN
  200 DISY=DY
      DO 300 K=1,NNP
      KK=K
      DY=DISY
      IF(NPN(K).EQ.1) CALL RIVER
      IF(NPN(K).EQ.2) CALL WELL
      IF(NPN(K).EQ.3) CALL PATH38(3)
      IF(NPN(K).EQ.4) CALL PATH38(4)
      IF(NPN(K).EQ.5) CALL PATH38(5)
      IF(NPN(K).EQ.6) CALL PATH38(6)
```

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      IF(NPN(K).EQ.7) CALL PATH38(7)
      IF(NPN(K).EQ.8) CALL PATH38(8)
      IF(NPN(K).EQ.9) CALL PATH38(9)
      IF(NPN(K).EQ.10) CALL PATH38(10)
  300 CONTINUE
      IF(IOPT.NE.0) GO TO 1000
      WRITE(6,10) 'DOSES'
   10 FORMAT(1H1,' AAAAAAAAAA CUMULATIVE TOTAL ',A5,' PER YEAR FOR ',
     & 'GIVEN TIMES AAAAAAAAAA',//)
      WRITE(6,20) NP,(CUMDOS(M),M=1,NTIME)
      WRITE(6,11) 'RISKS'
      WRITE(6,20) NP,(CUMDOS(M)A2.8E-4,M=1,NTIME)
   11 FORMAT(///,' AAAAAAAAAA CUMULATIVE TOTAL ',A5,' PER YEAR FOR ',
     & 'GIVEN TIMES AAAAAAAAAA',//)
   19 FORMAT(1X,I2,1X,A8,11(1PE10.2))
   20 FORMAT(4X,I3,9X,1P10E10.2)
C
C     PRINT INVENTORY
C
   30 IVR=0
      WRITE(6,31) (T(M),M=1,NTIME)
   31 FORMAT(1H1,8X,'NUCLIDE HALFLIFE AND INVENTORY (CI) ',
     & 'ASSUMING NO TRANSPORT FROM THE FACILITY',///,
     & ' (TIME IN YR) HALFLIFE',10F10.0)
   32 IF(IVR .GT. 0) WRITE(6,33) (T(M),M=1,NTIME)
   33 FORMAT(1H1,8X,'NUCLIDE HALFLIFE AND INVENTORY (CI) ',
     & 'REMAINING IN THE FACILITY',///,' (TIME IN YR) HALFLIFE',
     & 10F10.0)
      DO 500 K=1,NDOSE
      IF(Q(K,1).GT.0.)
     &  WRITE(6,19) K,XNAME2(K),HLIFE(K),(Q(K,M),M=1,NTIME)
  500 CONTINUE
      IF(IVR .GT. 0) GO TO 508
      DO 505 M=2,NTIME
      DO 505 K=1,NDOSE
      ARG=XLL(K)AT(M)
  505 Q(K,M)=Q(K,M)ADEXP(-ARG)
      IVR=1
      GO TO 32
  508 DO 510 ICHECK=1,5
      IF(DOSV(ICHECK).EQ.0.) TTIME(ICHECK)=0.
  510 CONTINUE
C
C     WRITE SUMMARY FILES
C
      WRITE(6,3505) WSLABL,(DOSV(I),I=1,5)
      WRITE(6,3507) (IDINT(TTIME(I)),I=1,5)
      WRITE(6,3506) (VNUCL(I),I=1,5)
 3505 FORMAT(1H1,11('A'),' MAXIMUM DOSES & DOMINANT NUCLIDES BY ',
     & 'PATHWAY ',10('A'),//,8X,'NAME OF RUN',3X,10A8,/,12X,'PATHWAY',
     & 7X,'DUST',9X,'ATMOSPHERIC',9X,'GAMMA',13X,'WELL',13X,'FOOD',/,
     & 8X,'ANNUAL DOSE',4X,1PE9.2,4(8X,E9.2))
 3506 FORMAT(3X,'DOMINANT NUCLIDE',6X,A8,4(9X,A8))
 3507 FORMAT(15X,'YEAR',1X,I8,4(9X,I8))
      OPEN(UNIT=3,FILE='BRC.DAT',STATUS='NEW')
      WRITE(3,3505) WSLABL,(DOSV(I),I=1,5)
      WRITE(3,3506) (VNUCL(I),I=1,5)
      WRITE(3,3507) (IDINT(TTIME(I)),I=1,5)
      CLOSE(UNIT=3)
 1000 CLOSE(UNIT=6)
```

```
C     WRITE(4,1987,REC=1) NREC
 1987 FORMAT(I5)
C     CLOSE(4)
      END
      SUBROUTINE BATMAN
C     THIS SUBROUTINE PERFORMS THE BATEMAN
C      CALCULATIONS FOR NUCLIDE INGROWTH.
      IMPLICIT REAL*8 (A-H,O-Z)
      CHARACTER*8 VNUCL
      REAL*4 C,Q
      COMMON/BLK1/ALDIS,C(100,10),CANLIF,DILFAC,DOSV(5),DY,DZ,NM,NMY,
     &       NMZ,NTIME,Q(100,10),RVERT(100),T(10),TTIME(5),VA,VNUCL(5),
     &       WIDTH,WSLABL(10),XAQD,XL,XLD(100),XLL(100),XLP,XRC(100),
     &       XVV,YW,ZB
C
C     INDICES IN THIS SUBROUTINE REFER TO THE FOLLOWING NUCLIDES:
C          8  SR- 90       23  TH-230       28  U -238       33  PU-241
C          9  Y - 90       24  TH-232       29  NP-237       34  PU-242
C         18  CE-144       25  U -234       30  PU-238       35  AM-241
C         19  PR-144       26  U -235       31  PU-239       36  AM-243
C         22  RA-226       27  U -236       32  PU-240       38  CM-244
C
      DO 100 M=2,NTIME
      Q(9,M)=Q(8,M)
      Q(19,M)=Q(18,M)
      IF(Q(24,1).EQ.0.) GO TO 1000
      Q(24,M)=.74*XLD(24)/(XLD(24)-XLD(27))*(XLD(27)*.76/(XLD(27)-XLD(32
     &))*(XLD(32)*(XLD(24)-XLD(27))/(XLD(24)-XLD(38))*(Q(38,M)*(XLD(27)-
     &XLD(32))/((XLD(27)-XLD(38))*(XLD(32)-XLD(38)))+Q(38,1)*((XLD(38)-
     &XLD(24))*DEXP(-XLD(32)*T(M))/((XLD(24)-XLD(32))*(XLD(32)-XLD(38)))
     &+(XLD(24)-XLD(38))*DEXP(-XLD(27)*T(M))/((XLD(27)-XLD(38))*(XLD(24)
     &-XLD(27)))+(XLD(32)-XLD(27))*DEXP(-XLD(24)*T(M))/((XLD(24)-XLD(27)
     &)*(XLD(24)-XLD(32)))))+(XLD(24)-XLD(27))*Q(32,M)/(XLD(24)-XLD(32))
     &+Q(32,1)*(-DEXP(-XLD(27)*T(M))+(XLD(27)-XLD(32))*DEXP(-XLD(24)*
     &T(M))/(XLD(24)-XLD(32))))+Q(27,M)-Q(27,1)*DEXP(-XLD(24)*T(M)))+
     &Q(24,M)
 1000 IF(Q(27,1).EQ.0.) GO TO 1010
      Q(27,M)=.76*XLD(27)/(XLD(27)-XLD(32))*(XLD(32)*(Q(38,M)*(XLD(27)-
     &XLD(32))/((XLD(27)-XLD(38))*(XLD(32)-XLD(38)))+Q(38,1)*(DEXP(-XLD(
     &27)*T(M))/(XLD(27)-XLD(38))+DEXP(-XLD(32)*T(M))/(XLD(38)-XLD(32)))
     &)+Q(32,M)-Q(32,1)*DEXP(-XLD(27)*T(M)))+Q(27,M)
 1010 IF(Q(32,1).EQ.0.) GO TO 1020
      Q(32,M)=XLD(32)*(Q(38,M)-Q(38,1)*DEXP(-XLD(32)*T(M)))
     &/(XLD(32)-XLD(38))+Q(32,M)
 1020 IF(Q(26,1).EQ.0.) GO TO 1030
      Q(26,M)=.73*XLD(26)/(XLD(26)-XLD(31))*(XLD(31)*(Q(36,M)*(XLD(26)-
     &XLD(31))/((XLD(26)-XLD(36))*(XLD(31)-XLD(36)))+Q(36,1)*(DEXP(-XLD(
     &26)*T(M))/(XLD(26)-XLD(36))+DEXP(-XLD(31)*T(M))/(XLD(36)-XLD(31)))
     &)+Q(31,M)-Q(31,1)*DEXP(-XLD(26)*T(M)))+Q(26,M)
 1030 IF(Q(31,1).EQ.0.) GO TO 1040
      Q(31,M)=XLD(31)*(Q(36,M)-Q(36,1)*DEXP(-XLD(31)*T(M)))
     &/(XLD(31)-XLD(36))+Q(31,M)
 1040 IF(Q(29,1).EQ.0.) GO TO 1050
      Q(29,M)=XLD(35)*XLD(29)*(Q(33,M)/((XLD(33)-XLD(35))*(XLD(33)-XLD(
     &29)))+Q(33,1)*DEXP(-XLD(35)*T(M))/((XLD(33)-XLD(35))*(XLD(29)-XLD(
     &35)))+Q(33,1)*DEXP(-XLD(29)*T(M))/((XLD(33)-XLD(29))*(XLD(35)-XLD(
     &29))))+XLD(29)*(Q(35,M)-Q(35,1)*DEXP(-XLD(29)*T(M)))/(XLD(29)-XLD(
     &35))+Q(29,M)
 1050 IF(Q(35,1).EQ.0.) GO TO 1060
      Q(35,M)=XLD(35)*(Q(33,M)-Q(33,1)*DEXP(-XLD(35)*T(M)))
```

```
     &/(XLD(35)-XLD(33))+Q(35,M)
1060 IF((XLD(28)-XLD(34)).EQ.0.) GO TO 1070
     E13=(DEXP(-XLD(34)*T(M))-DEXP(-XLD(28)*T(M)))/(XLD(28)-XLD(34))
1070 IF((XLD(25)-XLD(30)).EQ.0.) GO TO 1080
     E24=(DEXP(-XLD(30)*T(M))-DEXP(-XLD(25)*T(M)))/(XLD(25)-XLD(30))
1080 IF((XLD(25)-XLD(28)).EQ.0.) GO TO 1090
     E34=(DEXP(-XLD(28)*T(M))-DEXP(-XLD(25)*T(M)))/(XLD(25)-XLD(28))
1090 IF((XLD(23)-XLD(25)).EQ.0.) GO TO 1100
     E45=(DEXP(-XLD(25)*T(M))-DEXP(-XLD(23)*T(M)))/(XLD(23)-XLD(25))
1100 IF((XLD(22)-XLD(23)).EQ.0.) GO TO 1110
     E56=(DEXP(-XLD(23)*T(M))-DEXP(-XLD(22)*T(M)))/(XLD(22)-XLD(23))
1110 IF((XLD(25)-XLD(34)).EQ.0.) GO TO 1120
     E134=(E13-E34)/(XLD(25)-XLD(34))
1120 IF((XLD(23)-XLD(30)).EQ.0.) GO TO 1130
     E245=(E24-E45)/(XLD(23)-XLD(30))
1130 IF((XLD(23)-XLD(28)).EQ.0.) GO TO 1140
     E345=(E34-E45)/(XLD(23)-XLD(28))
1140 IF((XLD(22)-XLD(25)).EQ.0.) GO TO 1150
     E456=(E45-E56)/(XLD(22)-XLD(25))
1150 IF((XLD(23)-XLD(34)).EQ.0.) GO TO 1160
     E1345=(E134-E345)/(XLD(23)-XLD(34))
1160 IF((XLD(22)-XLD(30)).EQ.0.) GO TO 1170
     E2456=(E245-E456)/(XLD(22)-XLD(30))
1170 IF((XLD(22)-XLD(28)).EQ.0.) GO TO 1180
     E3456=(E345-E456)/(XLD(22)-XLD(28))
1180 IF((XLD(22)-XLD(34)).EQ.0.) GO TO 1190
     E13456=(E1345-E3456)/(XLD(22)-XLD(34))
1190 CONTINUE
     Q(22,M)=(((Q(34,1)*XLD(28)*E13456*.77+Q(30,1)*E2456*.72+Q(28,1)*
    &E3456*.77)*XLD(25)+Q(25,1)*E456)*XLD(23)+Q(23,1)*E56)*XLD(22)+
    &Q(22,M)
     Q(23,M)=((Q(34,1)*XLD(28)*E1345*.77+Q(30,1)*E245*.72+Q(28,1)*
    &E345*.77)*XLD(25)+Q(25,1)*E45)*XLD(23)+Q(23,M)
     Q(25,M)=(Q(34,1)*XLD(28)*E134*.77+Q(30,1)*E24*.72+Q(28,1)*E34
    &*.77)*XLD(25)+Q(25,M)
     Q(28,M)=Q(34,1)*XLD(28)*E13+Q(28,M)
 100 CONTINUE
     RETURN
     END
     SUBROUTINE WELL
     IMPLICIT REAL*8 (A-H,O-Z)
     CHARACTER*8 VNUCL,XNAME2
     REAL*4 C,Q,UT,NDPKW
     COMMON/XEER/NREC
     COMMON/BLK1/ALDIS,C(100,10),CANLIF,DILFAC,DOSV(5),DY,DZ,NM,NMY,
    &        NMZ,NTIME,Q(100,10),RVERT(100),T(10),TTIME(5),VA,VNUCL(5),
    &        WIDTH,WSLABL(10),XAQD,XL,XLD(100),XLL(100),XLP,XRC(100),
    &        XVV,YW,ZB
     COMMON/BLK2/ACR,ADL,AMIN,ARHO,BIV(100),BURN,CUMDOS(10),DIECON,
    &        DIECOV,DIEW,DOSE(3,100),DSTACK,EGAMMA(100),EPW,EEXT,EFIRE,
    &        EG,EIXINV,EIX,EWIND,HLIFE(100),HSTACK,IDSRPT,IEL(7),IFLAG,
    &        IGAMMA,INPRNT,IOPT,ISTAB,IUP,IVFAC,JUE(10),NDOSE,NISO,NNP,
    &        NP,NPN(10),PLANT,PV,QH,RER,RHO,RUNE,SINV,SNO,SPILL,SR,SS,
    &        TBEG,TCON,TCUT,TEND,TIMOP,TIMOP1,TWV,UBR,UT(100,6),
    &        VOLATL(100),VSTACK,VWIND,XALE,XCT,XH,XKD(100),XLC,
    &        XNAME2(100),XPERC,XPOR,XR,XRECEP,XROOT,XW,XWT,XXMU(100)
     COMMON/BLK3/IFILL
     DIMENSION EDOSE(10),IVMD(10),SUMDOS(10),VMXDOS(10),HMT(100),
    &HVT(100),NDPKW(50)
     CHARACTER*8 BLAN
```

```
      DATA VMXDOS /10A0.DO/
      DATA BLAN/'         '/
C
C     CALCULATIONS FOR GROUNDWATER DISCHARGE TO A WELL
C
 3000 DO 3088 K=1,NTIME
 3088 SUMDOS(K)=0.
 3005 TO=XLP/VA
      TW=XW/VA+XAQD/XVV
      TT=TO+TW
      XLSAV=XLP
      TIMOP1=TIMOP
      HW=XPERCAXLP/(XPORAVA)
      CORFAC=1.
      ED=XPERCAXLPAWIDTH
      IF(XPERC.LE.0.) ED=WIDTHAXLCAVAAXPOR
      IF(HW.GT.0.) CORFAC=XLC/HW
      IF(HW.GT.0..AND.HW.LT.XLC) ED=EDACORFAC
      IF(HW.GT.XLC) XLP=XLPACORFAC
        IF (HW.GT.XLC) TIMOP1 = TIMOPACORFAC
 3008 DILFAC=ED
      ED=EDAXLSAV/VA
      ZB=XW
      XL=ZB+0.5AXLP
      IF(IOPT.EQ.0) GO TO 3010
      IF(IOPT.NE.1) GO TO 2011
      IF(ALDIS.GT.0.) CALL PEAK(2)
      IF(ALDIS.GT.0.) GO TO 3500
      NTIME=1
      GO TO 3010
 2011 CONTINUE
      IF(IOPT.EQ.1) CALL PEAK(2)
      IF(IOPT.EQ.2) CALL RELEAS(2)
      GO TO 3500
 3010 IF(ALDIS.GT.0.) CALL DSPERS
      WRITE(6,31)
   31 FORMAT(1H1,56X,'PATHWAY  2',/,52X,'GROUNDWATER TO WELL',//,
     & 'AAAAAAAAA NUCLIDE DOSES FOR GIVEN TIMES AAAAAAAA',/)
 1031 FORMAT(56X,'PATHWAY  2   GROUNDWATER TO WELL')
      IF(IOPT.EQ.1) WRITE(6,12)
      IF(IOPT.NE.1) WRITE(6,11) (T(M),M=1,NTIME)
   11 FORMAT(/,'  NUCLIDE/TIME  ',10F10.0)
   12 FORMAT(/,'   NUCLIDE',11X,'DOSE',/)
      DO 3015 K=1,NDOSE
      IF(Q(K,1).EQ.0.) GO TO 3015
      TW=XW/VA+XAQDA(RVERT(K)/XRC(K))/XVV
      TT=TO+TW
      IF(IOPT.EQ.1) T(1)=XRC(K)ATW+DLOG(XLL(K)/XLD(K)+1.)/XLL(K)
      IF(IOPT.EQ.1.AND.T(1).GE.XRC(K)ATT) T(1)=TTAXRC(K)
      IF(IOPT.EQ.1) NDPKW(K)=T(1)
      QSAVE=Q(K,1)
      IF(IOPT.EQ.1) Q(K,1)=Q(K,1)ADEXP(-XLD(K)AT(1))
      CONST1=1.E9ADOSE(1,K)AUT(K,2)
      IF(ALDIS.GT.0.) GOTO 13
      UUV=XLD(K)ARVERT(K)
      UUH=XLD(K)AXRC(K)
      HVT(K)=HUNG(UUV,XAQD,XVV)
      HHT(K)=HUNG(UUH,XL,VA)
      HUNF=HVT(K)AHHT(K)
   13 CONTINUE
```

```
      XZ=-XLL(K)*XRC(K)*TO
      IF(XZ.LT.-85.) XZ=-85.
      DO 3016 M=1,NTIME
      IF(ALOIS.GT.0.) GO TO 3333
      XX=-XLL(K)*(T(M)-XRC(K)*TW)
      XY=-XLL(K)*(T(M)-XRC(K)*TT)
      IF(XX.GT.85.) XX=85.
      IF(XY.GT.85.) XY=85.
      XY=DEXP(XY)*(1.-DEXP(XZ))/XRC(K)
      XX=(1.-DEXP(XX))/XRC(K)
      IF(T(M).LT.XRC(K)*TW) C(K,M)=0.
      IF(T(M).GE.XRC(K)*TW) C(K,M)=XX*Q(K,M)*HUNF/ED
      IF(T(M).GE.XRC(K)*TT) C(K,M)=XY*Q(K,M)*HUNF/ED
 3333 IF(C(K,M).LT.1.D-35.AND.C(K,M).NE.0.) C(K,M)=1.D-35
      EDOSE(M)=CONST1*C(K,M)
       IF(IVFAC.EQ.1) EDOSE(M)=EDOSE(M)*(1.-VOLATL(K))
      SUMDOS(M)=SUMDOS(M)+EDOSE(M)
      IF(EDOSE(M).GT.VMXDOS(M)) IVMD(M)=K
      IF(EDOSE(M).GT.VMXDOS(M)) VMXDOS(M)=EDOSE(M)
 3016 CONTINUE
      WRITE(6,19) K,XNAME2(K),(EDOSE(M),M=1,NTIME)
      Q(K,1)=QSAVE
 3015 CONTINUE
   19 FORMAT(1X,I3,2X,A8,2X,11(1PE10.2))
      DOSV(4)=0.
      DO 3020 K=1,10
      IF(SUMDOS(K).GT.DOSV(4)) M=K
      IF(SUMDOS(K).GT.DOSV(4)) DOSV(4)=SUMDOS(K)
 3020 CONTINUE
      TTIME(4) = T(M)
      VNUCL(4)=XNAME2(IVMD(M))
      IF(DOSV(4).EQ.0.) VNUCL(4)=BLAN
      NP=NP+1
      DO 3100 M=1,NTIME
 3100 CUMDOS(M)=CUMDOS(M)+SUMDOS(M)
      WRITE(6,32) 'DOSES'
      WRITE(6,20) NISO,(SUMDOS(M),M=1,NTIME)
      WRITE(6,32) 'RISKS'
      WRITE(6,20) NISO,(SUMDOS(M)*2.8E-4,M=1,NTIME)
   20 FORMAT(4X,I3,9X,11(1PE10.2))
   32 FORMAT(///,'******* SUM OF NUCLIDE ',A5,' FOR GIVEN TIMES ******')
      WRITE(6,35)
   35 FORMAT(1H1,'******* DISPERSION CORRECTION FACTOR ******',//,5X,
     & 'NUCLIDE',8X,'VERTICAL FACTOR',8X,'HORIZONTAL FACTOR',8X,
     & 'TOTAL FACTOR',//)
      DO 36 K=1,NDOSE
      IF(Q(K,1).EQ.0.) GOTO 36
      WRITE(6,37) K,XNAME2(K),HVT(K),HHT(K),HVT(K)*HHT(K)
   37 FORMAT(1X,I3,2X,A8,9X,1PE10.2,14X,1PE10.2,12X,1PE10.2)
   36 CONTINUE
      WRITE(6,3401)
      IF(IOPT.EQ.1) WRITE(6,21)
   21 FORMAT(/,'   NUCLIDE',11X,'CONC',4X,'PEAK TIME',/)
 3401 FORMAT(1H1,' CONCENTRATION ARRAY',8X,'CONCENTRATIONS IN CI/M**3')
      IF(IOPT.NE.1) WRITE(6,11) (T(M),M=1,NTIME)
      DO 3400 K=1,NDOSE
      IF(Q(K,1) .EQ. 0.) GO TO 3400
      IF(IOPT.EQ.1) WRITE(6,19) K,XNAME2(K),C(K,1),NDPKW(K)
      IF(IOPT.NE.1) WRITE(6,19) K,XNAME2(K),(C(K,M),M=1,NTIME)
 3400 CONTINUE
```

```
 3500 XLP=XLSAV
      RETURN
      END
      SUBROUTINE PATH38(NPATH)
      IMPLICIT REAL*8 (A-H,O-Z)
      CHARACTER*8 VNUCL,XNAME2,XN1
      REAL*4 C,Q,UT
      COMMON/XFER/NREC
      COMMON/BLK1/ALDIS,C(100,10),CANLIF,DILFAC,DOSV(5),DY,DZ,NM,NMY,
     &        NMZ,NTIME,Q(100,10),RVERT(100),T(10),TTIME(5),VA,VNUCL(5),
     &        WIDTH,WSLABL(10),XAQD,XL,XLD(100),XLL(100),XLP,XRC(100),
     &        XVV,YW,ZB
      COMMON/BLK2/ACR,ADL,AMIN,ARHO,BIV(100),DURN,CUMDOS(10),DIFCON,
     &        DIFCOV,DIFW,DOSE(3,100),DSTACK,EGAMMA(100),EPW,FEXT,FFIRE,
     &        FG,FIXINV,FTX,FWIND,HLIFE(100),HSTACK,IDSRPT,IFL(7),IFLAG,
     &        IGAMMA,INPRNT,IOPT,ISTAB,IUP,IVFAC,JUF(10),NDOSE,NISO,NNP,
     &        NP,NPN(10),PLANT,PV,QH,RFR,RHO,RUNF,SINV,SNO,SPILL,SR,SS,
     &        TBEG,TCON,TCUT,TEND,TIMOP,TIMOP1,TWV,UBR,UT(100,6),
     &        VOLATL(100),VSTACK,VWIND,XALE,XCT,XH,XKD(100),XLC,
     &        XNAME2(100),XPERC,XPOR,XR,XRECEP,XROOT,XW,XWT,XXMU(100)
      DIMENSION BRIGGS(6,3),EDOSE(10),IVMD(10),SUMDOS(10),VMXDOS(10)
      CHARACTER*8 BLAN
      DATA AHOUSE,ALOT,TG/1.D2,2.3D3,0.91D0/
      DATA BLAN/'        '/
      DATA BRIGGS/0.200D0, 0.120D0, 0.080D0, 0.060D0, 0.030D0, 0.016D0,
     &            0.000D0, 0.000D0, 2.00D-4, 1.50D-3, 3.00D-4, 3.00D-4,
     &            0.000D0, 0.000D0, -0.50D0, -0.50D0, -1.00D0, -1.00D0/
      DATA VMXDOS /10*0.D0/
      IF(IOPT.NE.0) GO TO 9000
      IF(NPATH.EQ.3) GO TO 3000
      IF(NPATH.EQ.4) GO TO 3000
      IF(NPATH.EQ.5) GO TO 4000
      IF(NPATH.EQ.6) GO TO 4000
      IF(NPATH.EQ.7) GO TO 5000
      IF(NPATH.EQ.8) GO TO 6000
      IF(NPATH.EQ.9) GO TO 7000
      IF(NPATH.EQ.10) GO TO 8000
C
C     CALCULATIONS FOR EROSION & BATHTUB PATHWAYS
C
 3000 FD=TWV/(XLP*WIDTH*XWT)
      DO 3088 K=1,NTIME
 3088 SUMDOS(K)=0.
      FQ=1.
      TZ1=XCT/XALE
      TZ2=TZ1+XWT/XALE
      TZ3=(XWT+XCT)/(XPERC/XPOR*XALE)
      FE=XALE/XWT
      IF(NPATH .EQ. 3) WRITE(6,3005)
      IF(NPATH .EQ. 4) WRITE(6,3006)
 3005 FORMAT(1H1,56X,'PATHWAY  3',/,57X,'EROSION',//,
     & '********* NUCLIDE DOSES FOR GIVEN TIMES ********',/)
13005 FORMAT(56X,'PATHWAY  3   EROSION')
 3006 FORMAT(1H1,56X,'PATHWAY  4',/,54X,'BATHTUB EFFECT',//,
     & '********* NUCLIDE DOSES FOR GIVEN TIMES ********',/)
13006 FORMAT(56X,'PATHWAY  4   BATHTUB EFFECT')
      IF(SPILL .GT. 0..AND.NPATH.EQ.3) WRITE(6,3008) SPILL
 3008 FORMAT(' DOSE AT YEAR 1 IS DUE TO SPILLAGE FRACTION OF ',1PE9.2)
      WRITE(6,11) (T(M),M=1,NTIME)
   11 FORMAT(//,'  NUCLIDE/TIME  ',10F10.0)
```

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      CONST1=.001*ED/RFR
      DO 3015 K=1,NDOSE
      IF(Q(K,1).EQ.0.) GO TO 3015
      UPTK=UT(K,3)
      IF(NPATH .EQ. 4) UPTK=UT(K,4)
      IF(SPILL .GT. 0.) UPTK=UT(K,5)
      CONST2=UPTK*DOSE(1,K)*CONST1
      IF(NPATH.EQ.3) GO TO 3010
      XALE1=XPERC/(XKD(K)*.001*RHO+XPOR)
      FE=XALE1/XWT
 3010 DO 3016 M=1,NTIME
      IF(NPATH.EQ.4) FQ=DEXP(-XALE1*(T(M)-TZ3)/XWT)
      TF=XCT-XALE*T(M)
      EDOSE(M)=1.E12*Q(K,M)*FE*CONST2*FQ
      C(K,M)=Q(K,M)*FE*ED/RFR*FQ
        IF(IVFAC.EQ.1) EDOSE(M)=EDOSE(M)*(1.-VOLATL(K))
      IF (IVFAC.EQ.1) C(K,M)=C(K,M)*(1.-VOLATL(K))
      IF(NPATH.EQ.3 .AND. TF.GE.0.) EDOSE(M)=0.
      IF(NPATH.EQ.3 .AND. TF.GE.0.) C(K,M)=0.
      IF(NPATH.EQ.4 .AND. T(M).LE.TZ3) EDOSE(M)=0.
      IF(NPATH.EQ.4 .AND. T(M).LE.TZ3) C(K,M)=0.
      IF(TF.LT.-XWT) EDOSE(M)=0.
      IF(TF.LT.-XWT) C(K,M)=0.
      IF(M.GT.1 .OR. SPILL.LE.0.) GO TO 3014
      IF(NPATH.EQ.4) GO TO 3014
        EDOSE(1)=1.E12*Q(K,1)*CONST2*SPILL/
     &  (FD*(10.*RUNE+XKD(K)*.001*RHO+XPOR))
      C(K,1)=Q(K,1)*ED/RFR*SPILL/(FD*(10.*RUNE+XKD(K)*.001*RHO+XPOR))
        IF(IVFAC .EQ. 1) EDOSE(1)=EDOSE(1)*(1.-VOLATL(K))
      IF(IVFAC.EQ.1) C(K,1)=C(K,1)*(1.-VOLATL(K))
 3014 SUMDOS(M)=SUMDOS(M)+EDOSE(M)
 3016 CONTINUE
      WRITE(6,19) K,XNAME2(K),(EDOSE(M),M=1,NTIME)
 3015 CONTINUE
   19 FORMAT(1X,I3,2X,A8,2X,11(1PE10.2))
   20 FORMAT(4X,I3,9X,11(1PE10.2))
      NP=NP+1
      DO 3100 M=1,NTIME
 3100 CUMDOS(M)=CUMDOS(M)+SUMDOS(M)
      WRITE(6,32) 'DOSES'
      WRITE(6,20) NISO,(SUMDOS(M),M=1,NTIME)
      WRITE(6,32) 'RISKS'
      WRITE(6,20) NISO,(SUMDOS(M)*2.8E-7,M=1,NTIME)
   32 FORMAT(///,'******* SUM OF NUCLIDE ',A5,' FOR GIVEN TIMES ******')
      WRITE(6,28) TZ1,TZ2
   28 FORMAT(///,' ******* EROSION OF WASTE STARTS AFTER ',F10.1,' YEARS
     &  AND ENDS AFTER WASTE IS ALL ERODED IN ',F10.1,' YEARS.')
      IF(NPATH.EQ.4) WRITE(6,3110) TZ3
 3110 FORMAT(9X,'FACILITY OVERFLOW BEGINS AT YEAR ',F10.1)
      WRITE(6,3401)
 3401 FORMAT(1H1,' CONCENTRATION ARRAY',8X,'CONCENTRATIONS IN CI/M**3')
      WRITE(6,11) (T(M),M=1,NTIME)
      DO 3400 K=1,NDOSE
      IF(Q(K,1).GT.0.) WRITE(6,19) K,XNAME2(K),(C(K,M),M=1,NTIME)
 3400 CONTINUE
      GO TO 9000
C
C     CALCULATIONS FOR FOOD & BIOINTRUSION PATHWAYS
C
 4000 FD=TWV/(XLP*WIDTH*XWT)
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      DOSV(5)=0.
      DO 4088 K=1,NTIME
 4088 SUMDOS(K)=0.
      IF(NPATH .EQ. 5) WRITE(6,4005)
      IF(NPATH .EQ. 6) WRITE(6,4006)
 4005 FORMAT(1H1,56X,'PATHWAY  5',/,52X,'FOOD GROWN ON SITE',//,
     & '********* NUCLIDE DOSES FOR GIVEN TIMES ********',/)
14005 FORMAT(56X,'PATHWAY  5   FOOD GROWN ON SITE')
 4006 FORMAT(1H1,56X,'PATHWAY  6',/,51X,'NATURAL BIOINTRUSION',//,
     & '********* NUCLIDE DOSES FOR GIVEN TIMES ********',/)
14006 FORMAT(56X,'PATHWAY  6   NATURAL BIOINTRUSION')
      WRITE(6,11) (T(M),M=1,NTIME)
      CONST1=XWT
      IF(3.-XCT .LT. XWT) CONST1=3.-XCT
      FM=CONST1/((ALOT/AHOUSE-1.)*TG)
      IF(XCT.GT.3.) FM=0.
      FM=FM+4.6E-6*XWT
      CONST1=FD*FG/(TWV*RHO)
      IF(NPATH.EQ.5) GO TO 4010
      FM=1.-XCT/XROOT
      IF(XROOT .GT. XCT+XWT) FM=XWT/XROOT
      IF(XROOT .LE. XCT) FM=0.
 4010 DO 4015 K=1,NDOSE
      IF(Q(K,1).EQ.0.) GO TO 4015
      CONST2=DOSE(1,K)*UT(K,6)*CONST1
      DO 4016 M=1,NTIME
      EDOSE(M)=1.E12*Q(K,M)*FM*CONST2
        IF(IVFAC.EQ.1) EDOSE(M)=EDOSE(M)*(1.-VOLATL(K))
      SUMDOS(M)=SUMDOS(M)+EDOSE(M)
 4016 CONTINUE
      WRITE(6,19) K,XNAME2(K),(EDOSE(M),M=1,NTIME)
      IF(EDOSE(2).GT.DOSV(5)) KKN=K
      IF(EDOSE(2).GT.DOSV(5)) DOSV(5)=EDOSE(2)
 4015 CONTINUE
      TTIME(5)=T(2)
      NP=NP+1
      DO 4100 M=1,NTIME
 4100 CUMDOS(M)=CUMDOS(M)+SUMDOS(M)
      WRITE(6,32) 'DOSES'
      WRITE(6,20) NISO,(SUMDOS(M),M=1,NTIME)
      WRITE(6,32) 'RISKS'
      WRITE(6,20) NISO,(SUMDOS(M)*2.8E-7,M=1,NTIME)
      DOSV(5)=SUMDOS(2)
      VNUCL(5)=XNAME2(KKN)
      IF(DOSV(5).EQ.0.) VNUCL(5)=BLAN
      WRITE(6,4300) FD
 4300 FORMAT(//,' FRACTIONAL MIXING OF WASTE IN SOIL IN TRENCH IS ',
     & F5.3)
      WRITE(6,4301) FG
 4301 FORMAT(' FRACTION OF FOOD CONSUMED WHICH IS GROWN AT THE WASTE ',
     & 'SITE (FG) IS ',F6.3)
      IF(NPATH .EQ. 5) WRITE(6,4303) FM
 4303 FORMAT(' FRACTIONAL MIXING OF TRENCH MATERIAL IN SURFACE SOIL IS '
     & ,F5.3)
      GO TO 9000
C
C     CALCULATIONS FOR DIRECT GAMMA EXPOSURE
C
 5000 DO 5088 K=1,NTIME
 5088 SUMDOS(K)=0.
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      WRITE(6,5090)
 5090 FORMAT(1H1,56X,'PATHWAY  7',/,55X,'DIRECT GAMMA',//,
     & '********* NUCLIDE DOSES FOR GIVEN TIMES ********',/)
15090 FORMAT(56X,'PATHWAY  7   DIRECT GAMMA')
      WRITE(6,11) (T(M),M=1,NTIME)
      T21=XCT/XALE
      CONST1=8.76E15/AMIN
      CONST2=2.*XLP*WIDTH/(FEXT*AMIN)
      IF(IGAMMA.NE.1) GO TO 5100
      T1=(XROOT-XCT-XWT)/(PLANT/RHO-XALE)
      T2=(XROOT-XCT)/(PLANT/RHO-XALE)
      IF(T1.LT.0.) T1=0.
      IF(T2.LT.0.) T2=0.
      GO TO 5110
 5100 IF(IGAMMA.NE.2) GO TO 5110
      FM=(1.-XCT)/((ALOT/AHOUSE-1.)*TG)
      IF(XCT.GT.3.) FM=0.
      FM=FM+4.6E-6*XWT
C      FM=FM+2.3E-5
      CONST4=FM*TG*(ALOT-AHOUSE)/(XLP*WIDTH*XWT)
 5110 CONTINUE
      DO 5015 K=1,NDOSE
      IF(Q(K,1).EQ.0.0.OR.EGAMMA(K).EQ.0.) GO TO 5015
      IF(XXMU(K) .LE. 0.) GO TO 5112
      CONST3=XXMU(K)*XWT
      EXPO=0.
      IF(CONST3.LE.85.) EXPO=DEXP(-CONST3)
      CONST3=CONST3/(1.+1.32934/EGAMMA(K)-(1.+CONST3**1.5/EGAMMA(K))
     &*EXPO)
 5112 IF(IGAMMA.NE.1) GO TO 5120
      CONST5=PLANT*BIV(K)/(XWT*RHO)
      QUNDR1=Q(K,1)*DEXP(-(XLD(K)+CONST5*XWT/XROOT)*T1)
      QUNDR2=QUNDR1*DEXP(-(XLD(K)+CONST5*(1.-XCT/XROOT))*(T2-T1)+CONST5*
     &        (PLANT/RHO-XALE)*(T2*T2-T1*T1)/(2.*XROOT))
 5120 DO 5016 M=1,NTIME
      IF(IGAMMA.NE.0) GO TO 5010
      IF(XXMU(K) .GT. 0.) GO TO 5122
        PQ=1.
        RQ=Q(K,M)*EGAMMA(K)*DOSE(3,K)*FEXT/(XLP*WIDTH*XWT)
        GO TO 5014
 5122 RQ=CONST1*Q(K,M)*DOSE(3,K)
      TMU=XXMU(K)*(XCT-XALE*T(M))
      IF(TMU.LT.0.) TMU=0.
      IF(TMU.GT.85.) TMU=85.
      BU=1.+TMU**1.5/EGAMMA(K)
      IF(EGAMMA(K) .LT. 0.25) BU=1.+2.*TMU
      BU=BU*DEXP(-TMU)
      IF(BU .GT. 1.) BU=1.
      PQ=CONST2*CONST3/BU
      GO TO 5014
 5010 IF(IGAMMA.NE.1) GO TO 5012
      IF(T(M).LE.T1) QUNDR=Q(K,1)*DEXP(-(XLD(K)+CONST5*XWT/XROOT)*T(M))
      IF(T1.LT.T(M).AND.T(M).LT.T2) QUNDR=QUNDR1*DEXP(-(XLD(K)+CONST5*
     &(1.-XCT/XROOT))*(T(M)-T1)+CONST5*(PLANT/RHO-XALE)*(T(M)*T(M)
     &-T1*T1)/(2.*XROOT))
      IF(T(M).GE.T2) QUNDR=QUNDR2*DEXP(-XLD(K)*(T(M)-T2))
      QSURF=Q(K,1)*DEXP(-XLD(K)*T(M))-QUNDR
      QSURF=QSURF*(1.-RHO*XALE/PLANT)
      IF(QSURF.LT.0.) QSURF=0.
      IF(XXMU(K) .GT. 0.) GO TO 5011
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```
        PQ=1.
        RQ=QSURF*EGAMMA(K)*DOSE(3,K)*FEXT/(XLP*WIDTH*XWT)
        GO TO 5014
 5011 RQUNDR=CONST1*QUNDR*DOSE(3,K)
      RQSURF=CONST1*QSURF*DOSE(3,K)
      TMU=XXMU(K)*(PLANT/RHO-XALE)*T(M)
      EXPO=DEXP(-TMU)
      IF(TMU.GT.35.) EXPO=0.
      PQSURF=1.D35
      IF(TMU.GT.0.) PQSURF=CONST2*TMU/(1.+1.32934/EGAMMA(K)-(1.+TMU**
     &1.5/EGAMMA(K))*EXPO)
      TMU=TMU+XXMU(K)*XCT
      IF(TMU.LT.0.) TMU=0.
      IF(TMU.GT.85.) TMU=85.
      BU=1.+TMU**1.5/EGAMMA(K)
      IF(EGAMMA(K) .LT. 0.25) BU=1.+2.*TMU
      BU=BU*DEXP(-TMU)
      IF(BU .GT. 1.) BU=1.
      PQUNDR=CONST2*CONST3/BU
      RQ=RQUNDR+RQSURF
      PQ=RQ/(RQUNDR/PQUNDR+RQSURF/PQSURF)
      GO TO 5014
 5012 IF(XXMU(K) .GT. 0.) GO TO 5013
        PQ=1.
        RQ=Q(K,M)*EGAMMA(K)*DOSE(3,K)*FEXT*FM/(XLP*WIDTH*XWT)
        GO TO 5014
 5013 QSURF=Q(K,M)*CONST4
      QUNDR=Q(K,M)-QSURF
      QSURF=QSURF*(1.-XALE*T(M)/TG)
      IF(QSURF.LT.0.) QSURF=0.
      RQSURF=CONST1*QSURF*DOSE(3,K)
      RQUNDR=CONST1*QUNDR*DOSE(3,K)
      TMU=XXMU(K)*(TG-XALE*T(M))
      EXPO=0.
      IF(DABS(TMU).LE.85.) EXPO=DEXP(-TMU)
      PQSURF=1.D35
      IF(TMU.GT.0.) PQSURF=2.*TMU*(ALOT-AHOUSE)/(FEXT*AMIN*(1.+1.32934/
     &EGAMMA(K)-(1.+TMU**1.5/EGAMMA(K))*EXPO))
      TMU=XXMU(K)*(XCT-XALE*T(M))
      IF(TMU.LT.0.) TMU=0.
      IF(TMU.GT.85.) TMU=85.
      BU=1.+TMU**1.5/EGAMMA(K)
      IF(EGAMMA(K) .LT. 0.25) BU=1.+2.*TMU
      BU=BU*DEXP(-TMU)
      IF(BU .GT. 1.) BU=1.
      PQUNDR=CONST2*CONST3/BU
      RQ=RQUNDR+RQSURF
      PQ=RQ/(RQUNDR/PQUNDR+RQSURF/PQSURF)
 5014 EDOSE(M)=RQ/PQ
        IF(IVFAC.EQ.1) EDOSE(M)=EDOSE(M)*(1.-VOLATL(K))
      SUMDOS(M)=SUMDOS(M)+EDOSE(M)
      IF(EDOSE(M).GT.VMXDOS(M)) IVMD(M)=K
      IF(EDOSE(M).GT.VMXDOS(M)) VMXDOS(M)=EDOSE(M)
 5016 CONTINUE
      WRITE(6,19) K,XNAME2(K),(EDOSE(M),M=1,NTIME)
 5015 CONTINUE
      NP=NP+1
      DO 5200 M=1,NTIME
 5200 CUMDOS(M)=CUMDOS(M)+SUMDOS(M)
      DOSV(3)=0.
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```
      DO 5210 K=1,10
      IF(SUMDOS(K).GT.DOSV(3)) M=K
      IF(SUMDOS(K).GT.DOSV(3)) DOSV(3)=SUMDOS(K)
 5210 CONTINUE
      TTIME(3) = T(M)
      VNUCL(3)=XNAME2(IVMD(M))
      IF(DOSV(3).EQ.0.) VNUCL(3)=BLAN
      WRITE(6,32) 'DOSES'
      WRITE(6,20) NISO,(SUMDOS(M),M=1,NTIME)
      WRITE(6,32) 'RISKS'
      WRITE(6,20) NISO,(SUMDOS(M)*2.8E-7,M=1,NTIME)
      IF(IGAMMA.EQ.1) TZ1=XCT/(XALE-PLANT/RHO)
      IF(TZ1.GT.0.) WRITE(6,29) TZ1
   29 FORMAT(///,' ******* EROSION STOPS AFTER COVER IS ALL ERODED IN ',
     &F10.1,' YEARS *******')
      GO TO 9000
C
C     CALCULATIONS FOR DUST INHALATION PATHWAY
C
 6000 DO 6088 K=1,NTIME
 6088 SUMDOS(K)=0.
      DOSV(1)=0.
      FM=(3.-XCT)/((ALOT/AHOUSE-1.)*TG)
      IF(XCT.GT.3.) FM=0.
      FM=FM+4.6E-6*XWT
      WRITE(6,6010)
 6010 FORMAT(1H1,56X,'PATHWAY  8',/,54X,'DUST INHALATION',//,
     & '********* NUCLIDE DOSES FOR GIVEN TIMES ********',/)
16010 FORMAT(56X,'PATHWAY  8   DUST INHALATION')
      WRITE(6,11) (T(M),M=1,NTIME)
      CONST1=1.E12*FM*ADLAU*BR*FTX/(XLPA*WIDTH*XWT*RHO)
      DO 6015 K=1,NDOSE
      IF(Q(K,1).EQ.0.) GO TO 6015
      DO 6016 M=1,NTIME
      EDOSE(M)=Q(K,M)*DOSE(2,K)*CONST1
        IF(IVFAC.EQ.1) EDOSE(M)=EDOSE(M)*(1.-VOLATL(K))
      SUMDOS(M)=SUMDOS(M)+EDOSE(M)
 6016 CONTINUE
      WRITE(6,19) K,XNAME2(K),(EDOSE(M),M=1,NTIME)
      IF(EDOSE(1).GT.DOSV(1)) KKN=K
      IF(EDOSE(1).GT.DOSV(1)) DOSV(1)=EDOSE(1)
 6015 CONTINUE
      TTIME(1)=T(1)
      NP=NP+1
      DO 6100 M=1,NTIME
 6100 CUMDOS(M)=CUMDOS(M)+SUMDOS(M)
      WRITE(6,32) 'DOSES'
      WRITE(6,20) NISO,(SUMDOS(M),M=1,NTIME)
      WRITE(6,32) 'RISKS'
      WRITE(6,20) NISO,(SUMDOS(M)*2.8E-7,M=1,NTIME)
      DOSV(1)=SUMDOS(1)
      VNUCL(1)=XNAME2(KKN)
      IF(DOSV(1).EQ.0.)VNUCL(1)=BLAN
      GO TO 9000
C
C     CALCULATIONS FOR RADON INHALATION PATHWAY
C
 7000 DO 7088 K=1,NTIME
 7088 SUMDOS(K)=0.
      WRITE(6,7010)
```

```
 7010 FORMAT(1H1,56X,'PATHWAY  9',/,53X,'RADON INHALATION',//,
     & '********* NUCLIDE DOSES FOR GIVEN TIMES ********',/)
17010 FORMAT(56X,'PATHWAY  9   RADON INHALATION')
      WRITE(6,11) (T(M),M=1,NTIME)
      K=21
      XN1='RN222
      XLRN=2.1D-6
      BT=DSQRT(XLRN/DIFW)*XWT*100.
      EPLUS=DEXP(BT)
      EMINUS=1./EPLUS
      TANH=(EPLUS-EMINUS)/(EPLUS+EMINUS)
      BT=DSQRT(XLRN/DIFCOV)*XCT*100. + DSQRT(XLRN/DIFCON)*TCON
      EPLUS=DEXP(BT)
      EMINUS=1./EPLUS
      FF=0.5*((1.+TANH)*EPLUS + (1.-TANH)*EMINUS)
      CONST1=6.5544D8*EPW*DSQRT(XLRN*DIFW)*TANH*UBR/(XH*ACRATW*FF)
      DO 7016 M=1,NTIME
      EDOSE(M)=CONST1*Q(22,M)
        IF(IVFAC.EQ.1) EDOSE(M)=EDOSE(M)*(1.-VOLATL(22))
      SUMDOS(M)=SUMDOS(M)+EDOSE(M)
 7016 CONTINUE
      WRITE(6,19) K,XN1,(EDOSE(M),M=1,NTIME)
      NP=NP+1
      DO 7100 M=1,NTIME
 7100 CUMDOS(M)=CUMDOS(M)+SUMDOS(M)
      WRITE(6,32) 'DOSES'
      WRITE(6,20) NISO,(SUMDOS(M),M=1,NTIME)
      WRITE(6,32) 'RISKS'
      WRITE(6,20) NISO,(SUMDOS(M)*2.8E-7,M=1,NTIME)
      GO TO 9000
C
C     CALCULATIONS FOR OFF-SITE ATMOSPHERIC TRANSPORT
C
 8000 DO 8088 K=1,NTIME
 8088 SUMDOS(K)=0.
      DOSV(2)=0.
      WRITE(6,8005)
 8005 FORMAT(1H1,56X,'PATHWAY 10',/,51X,'ATMOSPHERIC TRANSPORT',//,
     & '********* NUCLIDE DOSES FOR GIVEN TIMES ********',/)
18005 FORMAT(56X,'PATHWAY 10   ATMOSPHERIC TRANSPORT')
      WRITE(6,8010)
 8010 FORMAT(/,' ANNUAL DOSE TO AN INDIVIDUAL DUE TO OFF-SITE ',
     & 'ATMOSPHERIC TRANSPORT')
      CONST1=10.*HSTACK
       IF(XRECEP .LT. CONST1) CONST1=XRECEP
      HEFF=HSTACK + (1.5*VSTACK*DSTACK +
     &   1.6*(3.7E-5*CONST1*CONST1*QH)**0.3333)/VWIND
       IF(ISTAB.LE.0) ISTAB=4
      SIGMAZ=BRIGGS(ISTAB,1)*XRECEP*(1.+BRIGGS(ISTAB,2)*XRECEP)**
     &  BRIGGS(ISTAB,3)
       IF(XRECEP.LE.0.) CHIQ=2./(3.14159*HEFF*HEFF*VWIND*2.71828)
       IF(XRECEP.GT.0.) CHIQ=2.032*FWIND*DEXP(-0.5*(HEFF/SIGMAZ)**2.)/
     &  (SIGMAZ*VWIND*XRECEP)
      ARG=-0.79788*FFIRE/(VWIND*BRIGGS(ISTAB,1))
       IF(IVFAC.EQ.0 .AND. XRECEP.GT.0.) FFIRE=XRECEP**ARG
      DENOM=TWV
       IF(IVFAC .EQ. 0) DENOM=XLP*WIDTH*(XWT+XCT)
      CONST1=1.E12*BURN*FFIRE*CHIQ*UBR/DENOM
      DO 8015 K=1,NDOSE
       IF(Q(K,1).EQ.0.) GO TO 8015
```

```
      ARG=1.
      IF(IVIAL .GT. 0) ARG=VOLATL(K)
      EDOSE(1)=Q(K,1)*CONST1*ARG*DOSE(2,K)
      SUMDOS(1)=SUMDOS(1)+EDOSE(1)
      WRITE(6,19) K,XNAME2(K),EDOSE(1)
      IF(EDOSE(1).LE.DOSV(2)) GO TO 8015
      KKN=K
      DOSV(2)=EDOSE(1)
 8015 CONTINUE
      TTIME(2)=T(1)
      NP=NP+1
      DO 8100 M=1,NTIME
 8100 CUMDOS(M)=CUMDOS(M)+SUMDOS(M)
      WRITE(6,32) 'DOSES'
      WRITE(6,20) NISO,SUMDOS(1)
      WRITE(6,32) 'RISKS'
      WRITE(6,20) NISO,SUMDOS(1)*2.8E-7
      IF(XRECEP .GT. 0.) WRITE(6,8110) XRECEP,CHIQ
 8110 FORMAT(//,' DISTANCE TO RECEPTOR IS ',F7.1,' METERS',/,
     & ' CHI/Q  IS ',1PE9.2,' CI/M**3 PER CI/SEC',//)
      IF(XRECEP .LE. 0.) WRITE(6,8120) CHIQ
 8120 FORMAT(//,' CHI/Q IS ',1PE9.2,' CI/M**3 PER CI/SEC',//)
      DOSV(2)=SUMDOS(1)
      VNUCL(2)=XNAME2(KKN)
      IF(DOSV(2).EQ.0.) VNUCL(2)=BLAN
 9000 RETURN
      END
C     PE1 ZERO SUBROUTINE: INITIALIZES ALL COMMON BLOCK VARIABLES
      SUBROUTINE ZERO
      IMPLICIT REAL*8 (A-H,O-Z)
      CHARACTER*8 NUCLID,VNUCL,XNAME2
      REAL*4 C,Q,UT
      COMMON/BLK1/ALDIS,C(100,10),CANLIF,DILFAC,DOSV(5),DY,DZ,NM,NMY,
     &        NMZ,NTIME,Q(100,10),RVERT(100),T(10),TTIME(5),VA,VNUCL(5),
     &        WIDTH,WSLABL(10),XAQD,XL,XLD(100),XLL(100),XLP,XRC(100),
     &        XVV,YW,ZB
      COMMON/BLK2/ACK,ADL,AMIN,ARHO,BIV(100),BURN,CUMDOS(10),DIFCON,
     &        DIFCOV,DIFW,DOSE(3,100),DSTACK,EGAMMA(100),EPW,FEXT,FFIRE,
     &        FG,FIXINV,FIX,FWIND,HLIFE(100),HSTACK,IDSRPT,IEL(7),IFLAG,
     &        IGAMMA,INPRNT,IOPT,ISTAB,IUP,IVEAC,JUF(10),NDOSE,NISO,NNP,
     &        NP,NPN(10),PLANT,PV,QH,RFR,RHO,RUNE,SINV,SNO,SPILL,SR,SS,
     &        TBEG,TCON,TCUT,TEND,TIMOP,TIMOP1,TWV,UBR,UT(100,6),
     &        VOLATL(100),VSTACK,VWIND,XALE,XCT,XH,XKD(100),XLC,
     &        XNAME2(100),XPERC,XPOR,XR,XRECEP,XROOT,XW,XWT,XXMU(100)
      COMMON/BLK3/IFILL
      COMMON/UPTAK/BDENS,BR,COL1,COP1,COCMI1,COFISH,COGMI1,COMEAT,CWAT,
     &        DECA,FE,FI,FIS,FMC,FMG,FP,FS,INTAKE(5),KK,NUCLID,PORS,PP,
     &        QBW,QCW,QFC,QFG,QGW,RW,SINFL,TE1,TE2,TFIS,TF1,TH1,TH2,TH3,
     &        TH4,TIMAV,TS,UCMILK,UFISH,UGMILK,ULEAFY,UMEAT,UPROD,UWAT,
     &        WIRATE,XAMBWE,Y1,Y2
C
C     COMMON BLK1
C
      DO 10 I=1,100
         RVERT(I)=0.
         XLD(I)=0.
         XLL(I)=0.
         XRC(I)=0.
   10 CONTINUE
      DO 20 I=1,10
```

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      DO 30 J=1,100
        C(J,I)=0.
        Q(J,I)=0.
 30   CONTINUE
      T(I)=0.
 20 CONTINUE
    DO 40 I=1,5
      DOSV(I)=0.
      TTIME(I)=0.
      VNUCL(I)='
 40 CONTINUE
C
C   COMMON BLK2
C
    DO 100 I=1,100
      BIV(I)=0.
      EGAMMA(I)=0.
      HLIFE(I)=0.
      VOLATL(I)=0.
      XKD(I)=0.
      XXMU(I)=0.
      XNAME2(I)='
      DO 110 J=1,3
        DOSE(J,I)=0.
110   CONTINUE
      DO 120 J=1,6
        UT(I,J)=0.
120   CONTINUE
100 CONTINUE
    DO 130 I=1,10
      CUMDOS(I)=0.
      JUF(I)=0
      NPN(I)=0
130 CONTINUE
    DO 140 I=1,7
      IFL(I)=0
140 CONTINUE
C
C   COMMON UPTAK
C
    DO 200 I=1,5
      INTAKE(I)=0
200 CONTINUE
C
    RETURN
    END
    SUBROUTINE RIVER
    IMPLICIT REALA8 (A-H,O-Z)
    CHARACTERA8 VNUCL,XNAME2
    REALA4 C,Q,UT,NDPKR
    COMMON/XFER/NREC
    COMMON/BLK1/ALDIS,C(100,10),CANLIF,DILFAC,DOSV(5),DY,DZ,NM,NMY,
  &      NMZ,NTIME,Q(100,10),RVERT(100),T(10),TTIME(5),VA,VNUCL(5),
  &      WIDTH,WSLABL(10),XAQD,XL,XLD(100),XLL(100),XLP,XRC(100),
  &      XVV,YW,ZB
    COMMON/BLK2/ACK,ADL,AMIN,AKHO,BIV(100),BURN,CUMDOS(10),DIFCON,
  &      DIFCOV,DIFW,DOSE(3,100),DSTACK,EGAMMA(100),EPW,EEXT,FFIRE,
  &      FG,FIXINV,FTX,FWIND,HLIFE(100),HSTACK,IDSRPT,IFL(7),IFLAG,
  &      IGAMMA,INPRNT,IOPT,ISTAB,IUP,IVFAC,JUF(10),NDOSE,NISO,NNP,
  &      NP,NPN(10),PLANT,PV,QH,RER,RHO,RUNE,SINV,SHO,SPILL,SR,SS,
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     &         TBEG,TCON,TCUT,TEND,TIMOP,TIMOP1,TWV,UBR,UI(100,6),
     &         VOLATL(100),VSTACK,VWIND,XALE,XCT,XH,XKD(100),XLC,
     &         XNAME2(100),XPERC,XPOR,XR,XRECEP,XROOT,XW,XWT,XXMU(100)
      COMMON/BLK3/IFILL
      DIMENSION EDOSE(10),SUMDOS(10),HHT(100),HVT(100),NDPKR(50)
      DY=0.
C
C     CALCULATIONS FOR GROUNDWATER DISCHARGE TO A RIVER
C
 2000 DO 2008 K=1,NTIME
 2008 SUMDOS(K)=0.
 2005 TO=XLP/VA
      TR=XR/VA+XAQD/XVV
      TT=TO+TR
      ED=XLPAKER/VA
      DILFAC=RFR
      ZB=XR
      XL=ZB+0.5AXLP
      TIMOP1=TIMOP
      IF(IOPT.EQ.0) GO TO 2010
      IF(IOPT.NE.1) GO TO 2011
      IF(ALDIS.GT.0.) CALL PEAK(1)
      IF(ALDIS.GT.0.) GO TO 2500
      NTIME=1
      GO TO 2010
 2011 CONTINUE
      IF(IOPT.EQ.2) CALL RELEAS(1)
      GO TO 2500
 2010 IF(ALDIS.GT.0.) CALL DSPERS
      WRITE(6,31)
   31 FORMAT(1H1,56X,'PATHWAY  1',/,51X,'GROUNDWATER TO RIVER',//,
     & 'AAAAAAAAA NUCLIDE DOSES FOR GIVEN TIMES AAAAAAAA',/)
 1031 FORMAT(56X,'PATHWAY  1   GROUNDWATER TO RIVER')
      IF(IOPT.EQ.1) WRITE (6,12)
      IF(IOPT.NE.1) WRITE(6,11) (T(M),M=1,NTIME)
   11 FORMAT(/,'  NUCLIDE/TIME  ',10E10.0)
   12 FORMAT(/,'  NUCLIDE',11X,'DOSE',/)
      DO 2015 K=1,NDOSE
      IF(Q(K,1).EQ.0.) GO TO 2015
      TR=XR/VA+XAQDA(RVERT(K)/XRC(K))/XVV
      TT=TO+TR
      CONST1=1.E9ADOSE(1,K)AUT(K,1)
      IF(IOPT.EQ.1) T(1)=XRC(K)ATR+DLOG(XLL(K)/XLD(K)+1.)/XLL(K)
      IF(IOPT.EQ.1.AND.T(1).GE.TTAXRC(K)) T(1)=TTAXRC(K)
      IF(IOPT.EQ.1) NDPKR(K)=T(1)
      QSAVE=Q(K,1)
      IF (IOPT.EQ.1) Q(K,1)=Q(K,1)ADEXP(-XLD(K)AT(1))
      IF(ALDIS.GT.0.) GOTO 13
      UUV=XLD(K)ARVERT(K)
      UUH=XLD(K)AXRC(K)
      HVT(K)=HUNG(UUV,XAQD,XVV)
      HHT(K)=HUNG(UUH,XL,VA)
      HUNE=HVT(K)AHHT(K)
   13 CONTINUE
      XZ=-XLL(K)AXRC(K)ATO
      IF(XZ.LT.-85.) XZ=-85.
      DO 2016 M=1,NTIME
      IF(ALDIS.GT.0.) GO TO 2222
      XX=-XLL(K)A(T(M)-XRC(K)ATR)
      XY=-XLL(K)A(T(M)-XRC(K)ATT)
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      IF(XX.GT.85.) XX=85.
      IF(XY.GT.85.) XY=85.
      XY=DEXP(XY)*(1.-DEXP(XZ))/XRC(K)
      XX=(1.-DEXP(XX))/XRC(K)
      IF(T(M).LT.XRC(K)*TR) C(K,M)=0.
      IF(T(M).GE.XRC(K)*TR) C(K,M)=XX*Q(K,M)*HUNE/ED
      IF(T(M).GE.XRC(K)*TT) C(K,M)=XY*Q(K,M)*HUNE/ED
 2222 IF(C(K,M).LT.1.D-35.AND.C(K,M).NE.0.) C(K,M)=1.D-35
      EDOSE(M)=CONST1*C(K,M)
        IF(IVFAC.EQ.1) EDOSE(M)=EDOSE(M)*(1.-VOLATL(K))
      SUMDOS(M)=SUMDOS(M)+EDOSE(M)
C     IF(EDOSE(M) .LT. 0.) ADI(K,M)=ADI(K,M)-EDOSE(M)
 2016 CONTINUE
      WRITE(6,19) K,XNAME2(K),(EDOSE(M),M=1,NTIME)
      Q(K,1)=QSAVE
 2015 CONTINUE
   19 FORMAT(1X,I3,2X,A8,2X,11(1PE10.2))
      NP=NP+1
      DO 2100 M=1,NTIME
 2100 CUMDOS(M)=CUMDOS(M)+SUMDOS(M)
      WRITE(6,32) 'DOSES'
      WRITE(6,20) NISO,(SUMDOS(M),M=1,NTIME)
      WRITE(6,32) 'RISKS'
      WRITE(6,20) NISO,(SUMDOS(M)*2.8E-7,M=1,NTIME)
   20 FORMAT(4X,I3,9X,11(1PE10.2))
   32 FORMAT(///,'******* SUM OF NUCLIDE ',A5,' FOR GIVEN TIMES ******')
      WRITE(6,35)
   35 FORMAT(///,'******* DISPERSION CORRECTION FACTOR ******',//,5X,
     & 'NUCLIDE',8X,'VERTICAL FACTOR',8X,'HORIZONTAL FACTOR',8X,
     & 'TOTAL FACTOR',//)
      DO 36 K=1,NDOSE
      IF(Q(K,1).EQ.0.) GOTO 36
      WRITE(6,37) K,XNAME2(K),HVT(K),HHT(K),HVT(K)*HHT(K)
   37 FORMAT(1X,I3,2X,A8,9X,1PE10.2,14X,1PE10.2,12X,1PE10.2)
   36 CONTINUE
      WRITE(6,2401)
      IF(IOPT.EQ.1) WRITE (6,21)
      IF(IOPT.NE.1) WRITE(6,11) (T(M),M=1,NTIME)
   21 FORMAT(/,'    NUCLIDE',11X,'CONC',4X,'PEAK TIME',/)
 2401 FORMAT(///,' CONCENTRATION ARRAY',8X,'CONCENTRATIONS IN CI/M**3')
      DO 2400 K=1,NDOSE
      IF(Q(K,1).EQ.0.) GO TO 2400
      IF(IOPT.EQ.1) WRITE(6,19) K,XNAME2(K),C(K,1),NDPKR(K)
      IF(IOPT.NE.1) WRITE(6,19) K,XNAME2(K),(C(K,M),M=1,NTIME)
 2400 CONTINUE
 2500 RETURN
      END
      SUBROUTINE PRINT(XLLI,RVERTI)
      IMPLICIT REAL*8 (A-H,O-Z)
      CHARACTER*8 VNUCL,XNAME2
      REAL*4 C,Q,UT
      COMMON/BLK1/ALDIS,C(100,10),CANLIF,DILFAC,DOSV(5),DY,DZ,NH,NHY,
     &        NHZ,NTIME,Q(100,10),RVERT(100),T(10),TTIME(5),VA,VNUCL(5),
     &        WIDTH,WSLABL(10),XAQD,XL,XLD(100),XLL(100),XLP,XRC(100),
     &        XVV,YW,ZB
      COMMON/BLK2/ACK,ADL,AMIN,ARHO,BIV(100),BURN,CUMDOS(10),DIFCON,
     &        DIFCOV,DIFW,DOSE(3,100),DSTACK,EGAMMA(100),EPW,FEXT,FFIRE,
     &        FG,FIXINV,FTX,FWIND,HLIFE(100),HSTACK,IDSRPT,IFL(7),IFLAG,
     &        IGAMMA,INPRNT,IOPT,ISTAB,IUP,IVFAC,JUF(10),NDOSE,NISO,NNP,
     &        NP,NPN(10),PLANT,PO,QH,RFR,RHO,RUNE,SINV,SNO,SPILL,SR,SS,
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     &      TREG,TCON,TCUT,TEND,TIMOP,TIMOP1,TWV,UBR,UI(100,6),
     &      VOLATL(100),VSTACK,VWIND,XALE,XCT,XH,XKD(100),XLC,
     &      XNAME2(100),XPERC,XPOR,XR,XRECEP,XROOT,XW,XWT,XXMU(100)
      COMMON/BLK3/IFILL
      DIMENSION PTHNAM(3,10),XLLI(100),RVERTI(100)
      CHARACTER*8 PTHNAM
      DATA PTHNAM/'GROUNDWA','TER TO R','IVER    ',
     &'GROUNDWA','TER TO W','ELL     ','EROSION ','        ','        ',
     &'BATHTUB ','EFFECT  ','        ','FOOD GRO','WN ON SI','TE      ',
     &'NATURAL ','BIOINTRU','SION    ','DIRECT G','AMMA    ','        ',
     &'DUST INH','ALATION ','        ','RADON IN','HALATION','        ',
     &'ATMOSPHE','RIC TRAN','SPORT   '/
      IF(INPRNT.EQ.0) GO TO 1000
  100 FORMAT(1H1,' **********  PATHRAE INPUT SUMMARY  **********')
  107 FORMAT(' LENGTH OF REPOSITORY (METERS)',31X,F8.0)
  108 FORMAT(' WIDTH OF REPOSITORY (METERS)',32X,F8.0)
  109 FORMAT(' HORIZONTAL VELOCITY OF AQUIFER (METERS/YR)',21X,F8.3)
  110 FORMAT(' ',/,' POROSITY OF AQUIFER',45X,F6.2)
  111 FORMAT(' DISTANCE TO RIVER (METERS)',34X,F8.0)
  112 FORMAT(' FLOW RATE OF RIVER (CUBIC METERS/YEAR)',25X,1PE11.2)
  113 FORMAT(' DISTANCE TO WELL -- X COORDINATE (METERS)',19X,F8.0)
  114 FORMAT(' MIXING THICKNESS OF AQUIFER (METERS)',28X,F7.3)
  115 FORMAT(' DISTANCE TO WELL -- Y COORDINATE (METERS)',19X,F8.0)
  116 FORMAT(' CANISTER LIFETIME (YEARS)',37X,F6.0)
  121 FORMAT(' DISTANCE FROM AQUIFER TO WASTE (METERS)',23X,F7.1)
  122 FORMAT(' AVERAGE VERTICAL GROUNDWATER VELOCITY (M/YR)',17X,F10.3)
  123 FORMAT(' ',/,' DENSITY OF AQUIFER (KG/CUBIC METER)',25X,F8.0)
  124 FORMAT(' LONGITUDINAL DISPERSIVITY (M)',34X,1PE11.2)
  125 FORMAT(' NUMBER OF MESH POINTS FOR DISPERSION CALCULATION',15X,
     &I4)
  127 FORMAT(' ',/,' TIME OF OPERATION OF WASTE FACILITY IN YEARS',
     &16X,F8.0)
  128 FORMAT(' ',/,
     &' AMOUNT OF WATER PERCOLATING THROUGH WASTE ANNUALLY (M)',
     & 10X,F7.3,/,' DEGREE OF SOIL SATURATION',40X,F6.3,/,
     & ' RESIDUAL SOIL SATURATION',41X,F6.3,/,
     & ' PERMEABILITY OF VERTICAL ZONE (M/YR)',27X,F7.2,/,
     & ' SOIL NUMBER',54X,F6.3)
  129 FORMAT(' LATERAL DISPERSION COEFFICIENT -- Y AXIS (M**2/YR)',13X,
     & 1PE11.2)
  131 FORMAT(' COVER THICKNESS OVER WASTE (METERS)',25X,F10.2)
  132 FORMAT(' THICKNESS OF WASTE IN PITS (METERS)',25X,F10.2)
  202 FORMAT(' ',/,
     &' THERE ARE',I3,' ISOTOPES IN THE DOSE FACTOR LIBRARY',/,
     & ' THE CUTOFF VALUE FOR NUCLIDE HALF LIVES IS',F7.1,' YEARS',/,
     & ' DEFAULT INVENTORY VALUE FOR CUTOFF NUCLIDES IS',1PE9.2,' CI')
  204 FORMAT(' NUMBER OF TIMES FOR CALCULATION IS',I3,/,' YEARS TO BE',
     & ' CALCULATED ARE ...',//,(1X,5E9.2))
  206 FORMAT(' ',/,' THERE ARE',I4,' ISOTOPES IN THE INVENTORY FILE',/,
     & ' THE VALUE OF IFLAG IS ',I3,/,' NUMBER OF PATHWAYS IS ',I3)
  208 FORMAT(/,12X,'PATHWAY',11X,'TYPE OF USAGE',/,28X,'FOR UPTAKE ',
     & 'FACTORS',/,(3X,I2,2X,3A8,4X,I2))
  212 FORMAT(' ',/,' FLAG FOR GAMMA PATHWAY OPTIONS',34X,I3,/,
     & ' FLAG FOR ATMOSPHERIC PATHWAY',36X,I3)
  216 FORMAT(' INVENTORY SCALING FACTOR',41X,1PE9.2)
  218 FORMAT(' RADON EMANATING POWER OF THE WASTE',31X,1PE9.2,/,
     & ' DIFFUSION COEFF. OF RADON IN WASTE (CM**2/SEC)',19X,E9.2,/,
     & ' DIFFUSION COEFF. OF RN IN CONCRETE (CM**2/SEC)',19X,E9.2)
  220 FORMAT(' ',/,' DIFFUSION COEFF. OF RADON IN COVER (CM**2/SEC)',
     & 19X,1PE9.2)
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222 FORMAT(' ',/,' DECAY CHAIN FLAGS',19X,7I4)
224 FORMAT(' FLAG FOR INPUT SUMMARY PRINTOUT',33X,I3,/,
   & ' FLAG FOR DIRECTION OF TRENCH FILLING',28X,I3,/,
   & ' FLAG FOR GROUNDWATER PATHWAY OPTIONS',28X,I3)
510 FORMAT(' RECEPTOR DISTANCE FOR ATMOSPHERIC PATHWAY (M)',17X,F7.1)
511 FORMAT(' STACK HEIGHT (M)',48X,F5.1,/' STACK INSIDE DIAMETER (M)',
   & 40X,F5.2,/,' STACK GAS VELOCITY (M/S)',40X,F5.1)
512 FORMAT(' HEAT EMISSION RATE FROM BURNING (CAL/S)',26X,1PE9.2)
513 FORMAT(' ',/,
   &' DUST RESUSPENSION RATE FOR OFFSITE TRANSPORT (M**3/S)',
   & 12X,1PE9.2,/,' DEPOSITION VELOCITY (M/S)',41X,0PF6.4)
514 FORMAT(' ',/,' INCINERATOR OR TRENCH FIRE BURN RATE (M**3/S)',20X,
   & 1PE9.2,/,' FRACTION OF YEAR FIRE BURNS',39X,0PF6.4)
515 FORMAT(' ATMOSPHERIC STABILITY CLASS',38X,I2,/,
   & ' AVERAGE WIND SPEED (M/S)',41X,F5.2,/,
   & ' FRACTION OF TIME WIND BLOWS TOWARD RECEPTOR',23X,F6.4)
516 FORMAT(' SURFACE EROSION RATE (M/YR)',36X,1PE12.3,/,
   & ' ANNUAL RUNOFF OF PRECIPITATION (M)',31X,E9.2)
517 FORMAT(' ',/,' TOTAL  WASTE VOLUME (M**3)',38X,1PE12.3)
519 FORMAT(' DENSITY OF WASTE   (KG/M**3)',34X,F8.0)
520 FORMAT(' FRACTION OF FOOD CONSUMED THAT IS GROWN ON SITE',17X,
   &F7.3)
521 FORMAT(' DEPTH OF PLANT ROOT ZONE (METERS)',32X,F6.3)
522 FORMAT(' ',/,
   &' FRACTION OF YEAR SPENT IN DIRECT RADIATION FIELD',15X,F8.3)
524 FORMAT(' AVERAGE DUST LOADING IN AIR (KG/M**3)',26X,1PE11.2)
525 FORMAT(' ',/,' ANNUAL ADULT BREATHING RATE (M**3/YR)',23X,F8.0)
526 FORMAT(' FRACTION OF YEAR EXPOSED TO DUST',31X,F8.3)
527 FORMAT(' AREAL DENSITY OF PLANTS (KG/M**2)',32X,F6.3)
529 FORMAT(' HEIGHT OF ROOMS IN RECLAIMER HOUSE (CM)',21X,F8.0)
530 FORMAT(1H1,/,' AIR CHANGE RATE IN RECLAIMER HOUSE (CHANGES/SEC)',
   &15X,1PE11.2)
531 FORMAT(' THICKNESS OF CONCRETE SLAB FLOOR (CM)',24X,F8.1)
    WRITE(6,100)
    WRITE(6,202) NDOSE,TCUT,SINV
    WRITE(6,204) NTIME,(T(I),I=1,NTIME)
    WRITE(6,206) NISO,IFLAG,NNP
    WRITE(6,208) (NPN(J),(PTHNAM(I,NPN(J)),I=1,3),JUF(J),J=1,NNP)
    WRITE(6,127) TIMOP
    WRITE(6,107) XLP
    WRITE(6,108) WIDTH
    WRITE(6,112) RER
    WRITE(6,111) XR
    WRITE(6,123) ARHO
    WRITE(6,124) ALDIS
    WRITE(6,129) DY
    WRITE(6,125) NM
    WRITE(6,212) IGAMMA,IVEAC
    WRITE(6,131) XCT
    WRITE(6,132) XWT
    WRITE(6,517) TWV
    WRITE(6,113) XW
    WRITE(6,115) YW
    WRITE(6,519) RHO
    WRITE(6,520) FG
    WRITE(6,522) FEXT
    WRITE(6,521) XROOT
    WRITE(6,527) PLANT
    WRITE(6,524) ADL
    WRITE(6,525) UBR
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      WRITE(6,526) FTX
      WRITE(6,116) CANLIF
      WRITE(6,216) FIXINV
      WRITE(6,529) XH
      WRITE(6,530) ACR
      WRITE(6,218) EPW,DIFW,DIFCON
      WRITE(6,531) TCON
      WRITE(6,220) DIFCOV
      WRITE(6,515) ISTAB,VWIND,FWIND
      WRITE(6,510) XRECEP
      IF(IVFAC.EQ.0) WRITE(6,513) BURN,FFIRE
      IF(IVFAC.GT.0) WRITE(6,514) BURN,FFIRE
      WRITE(6,511) HSTACK,DSTACK,VSTACK
      WRITE(6,512) OH
      IF(ALDIS.NE.0.) WRITE(6,222) (IFL(I),I=1,7)
      WRITE(6,224) INPRNT,IFILL,IOPT
      WRITE(6,128) XPERC,SS,SR,PV,SNO
      WRITE(6,110) XPOR
      WRITE(6,121) XAQD
      WRITE(6,122) XVV
      VAQ=VA
  225 WRITE(6,109) VAQ
      WRITE(6,114) XLC
      WRITE(6,516) XALE,RUNF
      WRITE(6,300)
  300 FORMAT(1H1,3X,'NUCLIDE',12X,'INGESTION',6X,'INHALATION',5X,
     & 'DIRECT GAMMA',5X,'VOLATILITY',/,' NUMBER   NAME',2X,
     & 3(4X,'DOSE FACTORS'),7X,'FACTOR',/,15X,2(6X,'(MREM/PCI)'),
     & 2X,'(MREM-MAA2/PCI-HR)',2X,'(FRACTION)',/)
      DO 310 K=1,NDOSE
      IF(Q(K,1).EQ.0.) GO TO 310
      WRITE(6,360) K,XNAME2(K),DOSE(1,K),DOSE(2,K),
     & DOSE(3,K),VOLATL(K)
  310 CONTINUE
      WRITE(6,340)
  340 FORMAT(1H1,3X,'NUCLIDE',20X,'EQUIVALENT UPTAKE FACTORS',17X,
     & 'GAMMA',/,' NUMBER',3X,'NAME',6X,'RIVER USEAGE   WELL WATER USE',
     & '  FOOD CONSUMPTION',5X,'ENERGY',/,23X,'(L/YR)',10X,'(L/YR)',10X,
     & '(KG/YR)',10X,'(MEV)',/)
      DO 350 K=1,NDOSE
      IF(Q(K,1) .GT. 0.) WRITE(6,360) K,XNAME2(K),UT(K,1),
     & UT(K,2),UT(K,6),EGAMMA(K)
  350 CONTINUE
      WRITE(6,320)
  320 FORMAT(1H1,3X,'NUCLIDE',11X,'INPUT LEACH',5X,
     & 'FINAL LEACH',8X,'GAMMA'/' NUMBER',3X,'NAME',5X,
     & 'CONSTANT(1/YR)',2X,'CONSTANT(1/YR)  ATTENUATION(1/M)'/)
      DO 330 K=1,NDOSE
      IF(Q(K,1) .GT. 0.) WRITE(6,360) K,XNAME2(K),XLLI(K),XLL(K),XXMU(K)
  330 CONTINUE
      WRITE (6,227)
  227 FORMAT(1H1,3X,'NUCLIDE',13X,'AQUIFER',9X,'AQUIFER',9X,'VERTICAL',
     & 8X,'VERTICAL',/,' NUMBER',3X,'NAME',8X,'SORPTION',7X,
     & 'RETARDATION',7X,'SORPTION',6X,'RETARDATION',/)
      DO 354 K=1,NDOSE
      IF(Q(K,1).GT.0.) WRITE(6,360) K,XNAME2(K),XKD(K),XRC(K),
     & RVERTI(K),RVERT(K)
  354 CONTINUE
      WRITE(6,228)
  228 FORMAT(1H1,3X,'NUCLIDE',10X,'SOIL TO PLANT',7X,'HALF',11X,
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      & 'INITIAL',/,' NUMBER   NAME',7X,'CONVERSION',6X,
      & 'LIFE (YR)',7X,'INVENTORY (CI)',/)
       DO 355 K=1,NDOSE
       IF(Q(K,1).GT.0.) WRITE(6,360) K,XNAME2(K),BIV(K),
      &  HLIFE(K),Q(K,1)
  355  CONTINUE
  360  FORMAT(1X,I4,2X,A8,8(4X,1PE12.3))
 1000  RETURN
       END
       SUBROUTINE UPTAKE
C      THIS PROGRAM GENERATES TOTAL EQUIVALENT UPTAKE FACTORS FOR USE IN
C      THE PATHRAE CODE. THE METHOD USED TO CALCULATE THESE NUMBERS IS
C      THAT USED IN THE PRESTO CODES. THE EQUATIONS COME FROM PRESTO
C      SUBROUTINES IRRIG AND HUMEX.
       IMPLICIT REAL*8 (A-H,O-Z)
       CHARACTER*8 VNUCL,XNAME2
       CHARACTER*8 NUCLID
       REAL*4 C,Q,UT
       COMMON/BLK1/ALDIS,C(100,10),CANLIF,DILFAC,DOSV(5),DY,DZ,NM,NMY,
      &       NMZ,NTIME,Q(100,10),RVERT(100),T(10),TTIME(5),VA,VNUCL(5),
      &       WIDTH,WSLABL(10),XAQD,XL,XLD(100),XLL(100),XLP,XRC(100),
      &       XVV,YW,ZB
       COMMON/BLK2/ACK,ADL,AMIN,ARHO,BIV(100),BURN,CUMDOS(10),DIFCON,
      &       DIFCOV,DIFW,DOSE(3,100),DSTACK,EGAMMA(100),EPW,FEXT,FFIRE,
      &       FG,FIXINV,FTX,FWIND,HLIFE(100),HSTACK,IDSRPT,IFL(7),IFLAG,
      &       IGAMMA,INPRNT,IOPT,ISTAB,IUP,IVFAC,JUF(10),NDOSE,NISO,NNP,
      &       NP,NPN(10),PLANT,PV,QH,RFR,RHO,RUNF,SINV,SNO,SPILL,SR,SS,
      &       TBEG,TCON,TCUT,TEND,TIMOP,TIMOP1,TWV,UBR,UT(100,6),
      &       VOLATL(100),VSTACK,VWIND,XALE,XCT,XH,XKD(100),XLC,
      &       XNAME2(100),XPERC,XPOR,XR,XRECEP,XROOT,XW,XWT,XXMU(100)
       COMMON/UPTAK/BDENS,BR,COL1,COP1,COCMI1,COFISH,COGMI1,COMEAT,CWAT,
      &       DECA,FF,FI,FIS,FMC,FMG,FP,FS,INTAKE(5),KK,NUCLID,PORS,PP,
      &       QBW,QCW,QFC,QFG,QGW,RW,SINFL,TE1,TE2,TFIS,TF1,TH1,TH2,TH3,
      &       TH4,TIMAV,TS,UCMILK,UFISH,UGMILK,ULEAFY,UMEAT,UPROD,UWAT,
      &       WIRATE,XAMBWE,Y1,Y2
C
C      READ INPUT DATA
C
C
       OPEN(UNIT=3,FILE='UPTAKE.DAT',STATUS='OLD')
       READ(3,100) SINFL,PORS,BDENS
       READ(3,100) Y1,Y2,XAMBWE,TE1,TE2
       READ(3,100) TH1,TH2,TH3,TH4,FP,FS
       READ(3,100) QFC,QFG,TF1,TS,TFIS
       READ(3,100) FI,WIRATE,QCW,QGW,QBW
       READ(3,100) ULEAFY,UPROD,UCMILK,UGMILK,UMEAT,UWAT,UFISH
  100  FORMAT(7F12.6)
       DO 110 I=1,4
       DO 110 J=1,NNP
       IF(NPN(J) .EQ. I) INTAKE(I)=JUF(J)
  110  CONTINUE
       INTAKE(5)=INTAKE(3)
       PP=1000.*BDENS*0.15
C
C
  120  READ(3,130,END=300) NUCLID,RW,BR,FMC,FMG,FF,FIS
  130  FORMAT(A8,6F12.6)
       DO 140 J=1,NDOSE
       IF(NUCLID .EQ. XNAME2(J)) GO TO 200
  140  CONTINUE
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      GO TO 120
C
C     CALCULATE TOTAL EQUIVALENT UPTAKE FACTORS FOR WATER USAGE
C
  200 IF(Q(J,1) .LE. 0.) GO TO 120
      DECA=XLD(J)/8760.
      CWAT=1.
      DO 280 KK=1,5
        DIST=XR
        GO TO (220,210,230,240,250) KK
C       CALCULATE TIME OVER WHICH SOIL CONCENTRATION WILL BE AVERAGED
  210   DIST=XW
  220   TIMAV=1./XLL(J)
        RET=1.+ARHO*XKD(J)/XPOR
        ARG=T(NTIME)-RET*(DIST+0.5*XLP)/VA
        IF(TIMAV .GT. ARG) TIMAV=ARG
        GO TO 260
  230   TIMAV=XWT/XALE
        ARG=T(NTIME)-XCT/XALE
        IF(TIMAV .GT. ARG) TIMAV=ARG
        GO TO 260
  240   TIMAV=(XWT+XCT)/XALE
        IF(TIMAV .GT. T(NTIME)) TIMAV=T(NTIME)
        TIMAV=TIMAV-(XWT+XCT)/(XPERC/XPOR+XALE)
        GO TO 260
  250   TIMAV=0.15/XALE
  260   IF(TIMAV .LT. 1.) TIMAV=1.
        CALL IRRIG(J)
        CALL HUMEX(J)
  280 CONTINUE
C
C     CALCULATE TOTAL EQUIVALENT UPTAKE FACTORS FOR FOOD
C
      CWAT=0.
      KK=6
      CALL IRRIG(J)
      CALL HUMEX(J)
      GO TO 120
C
C     PRINT UPTAKE FACTORS
C
  300 CLOSE(UNIT=3)
      WRITE(6,310) (I,I=1,6)
  310 FORMAT(//,23X,'TOTAL EQUIVALENT UPTAKE FACTORS FOR PATHRAE',//,
     &  13X,6(3X,'UT(J,',I1,')'),/,17X,'RIVER',5X,'WELL',5X,'EROSION',
     &  3X,'BATHTUB  SPILLAGE    FOOD',/,' NUCLIDE',3X,
     &  5(6X,'L/YR'),6X,'KG/YR',/)
      DO 320 I=1,NDOSE
      IF(Q(I,1) .GT. 0.) WRITE(6,330) XNAME2(I),(UT(I,J),J=1,6)
  320 CONTINUE
  330 FORMAT(3X,A8,3X,1P6E10.3)
      RETURN
      END
      SUBROUTINE DSPERS
      IMPLICIT REAL*8 (A-H,O-Z)
      CHARACTER*8 VNUCL,XNAME2
      REAL*4 C,Q,UT
      COMMON/BLK1/ALDIS,C(100,10),CANLIF,DILFAC,DOSV(5),DY,DZ,NM,NMY,
     &            NMZ,NTIME,Q(100,10),RVERT(100),T(10),TTIME(5),VA,VNUCL(5),
     &            WIDTH,WSLABL(10),XAQD,XL,XLD(100),XLL(100),XLP,XRC(100),
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&         XVV,YW,ZB
      COMMON/BLK2/ACK,ADL,AMIN,ARHO,BIV(100),BURN,CUMDOS(10),DIFCON,
&         DIFCOV,DIFW,DOSE(3,100),DSTACK,EGAMMA(100),EPW,FEXT,FFIRE,
&         FG,FIXINV,FTX,FWIND,HLIFE(100),HSTACK,IDSRPT,IFL(7),IFLAG,
&         IGAMMA,INPRNT,IOPT,ISTAB,IUP,IVFAC,JUF(10),NDOSE,NISO,NNP,
&         NP,NPN(10),PLANT,PV,QH,RFR,RHO,RUNF,SINV,SNO,SPILL,SR,SS,
&         TBEG,TCON,TCUT,TEND,TIMOP,TIMOP1,TWV,UBR,UT(100,6),
&         VOLATL(100),VSTACK,VWIND,XALE,XCT,XH,XKD(100),XLC,
&         XNAME2(100),XPERC,XPOR,XR,XRECEP,XROOT,XW,XWT,XXMU(100)
      COMMON/BLK3/IFILL
      DO 100 K=1,NDOSE
      KK=K
      IF(Q(K,1).GT.0.) CALL GW1(KK)
  100 CONTINUE
C
C     DECAY CHAIN CALCULATIONS
C
      IF(IFL(1).EQ.1) CALL GW3(38,32,27)
      IF(IFL(2).EQ.1) CALL GW3(32,27,24)
      IF(IFL(3).EQ.1) CALL GW3(36,31,26)
      IF(IFL(4).EQ.1) CALL GW3(33,35,29)
      IF(IFL(5).EQ.1) CALL GW3(30,23,22)
      IF(IFL(6).EQ.1) CALL GW3(34,28,25)
      IF(IFL(7).EQ.1) CALL GW3(28,23,22)
      RETURN
      END
      SUBROUTINE IRRIG(J)
C     CALCULATION OF RADIONUCLIDE CONCENTRATION IN VEGETABLES, MILK,
C     AND MEAT CONSUMED BY MAN RESULTING FROM WATER IRRIGATION.
C     CONCENTRATION IN FISH ALSO CALCULATED.
C     COFISH = NUCLIDE CONC IN FISH
C     COPAST = NUCLIDE CONC IN PASTURE GRASS CONSUMED BY ANIMALS
C     COSTO  = NUCLIDE CONC IN STORED FEED CONSUMED BY ANIMALS
C     COFEED = NUCLIDE CONC IN ANIMAL FEED
C     COL1   = NUCLIDE CONC IN LEAFY VEGETABLES CONSUMED BY MAN
C     COP1   = NUCLIDE CONC IN PRODUCE CONSUMED BY MAN
C     COCMI1 = NUCLIDE CONC IN COW'S MILK
C     COGMI1 = NUCLIDE CONC IN GOAT'S MILK
C     COMEAT = NUCLIDE CONC IN BEEF CATTLE
      IMPLICIT REAL*8 (A-H,O-Z)
      CHARACTER*8 NUCLID,VNUCL,XNAME2
      REAL*4 C,Q,UT
      COMMON/BLK1/ALDIS,C(100,10),CANLIF,DILFAC,DOSV(5),DY,DZ,NM,NMY,
&         NMZ,NTIME,Q(100,10),RVERT(100),T(10),TTIME(5),VA,VNUCL(5),
&         WIDTH,WSLABL(10),XADD,XL,XLD(100),XLL(100),XLP,XRC(100),
&         XVV,YW,ZB
      COMMON/BLK2/ACK,ADL,AMIN,ARHO,BIV(100),BURN,CUMDOS(10),DIFCON,
&         DIFCOV,DIFW,DOSE(3,100),DSTACK,EGAMMA(100),EPW,FEXT,FFIRE,
&         FG,FIXINV,FTX,FWIND,HLIFE(100),HSTACK,IDSRPT,IFL(7),IFLAG,
&         IGAMMA,INPRNT,IOPT,ISTAB,IUP,IVFAC,JUF(10),NDOSE,NISO,NNP,
&         NP,NPN(10),PLANT,PV,QH,RFR,RHO,RUNF,SINV,SNO,SPILL,SR,SS,
&         TBEG,TCON,TCUT,TEND,TIMOP,TIMOP1,TWV,UBR,UT(100,6),
&         VOLATL(100),VSTACK,VWIND,XALE,XCT,XH,XKD(100),XLC,
&         XNAME2(100),XPERC,XPOR,XR,XRECEP,XROOT,XW,XWT,XXMU(100)
      COMMON/UPTAK/BDENS,BR,COL1,COP1,COCMI1,COFISH,COGMI1,COMEAT,CWAT,
&         DECA,FF,FI,FIS,FMC,FMG,FP,FS,INTAKE(5),KK,NUCLID,PORS,PP,
&         QBW,QCW,QFC,QFG,QGW,RW,SINFL,TE1,TE2,TFIS,TF1,TH1,TH2,TH3,
&         TH4,TIMAV,TS,UCMILK,UFISH,UGMILK,ULEAFY,UMEAT,UPROD,UWAT,
&         WIRATE,XAMBWE,Y1,Y2
C
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      COFISH = FIS * CWAT * DEXP(-DECA*TFIS)
      IF(NUCLID .EQ. 'H-3     ') GO TO 200
      IF(NUCLID .EQ. 'C-14    ') GO TO 300
      B = 0.243*BIV(J)
      TV=1.
      COPAST=COV(J,Y1,TE1,TH1,B,TV)
      B = 0.68 * (0.378*BR + 0.622*BIV(J))
      TV=.1
      COSTO=COV(J,Y1,TE1,TH2,B,TV)
      COFEED=FPAFS*COPAST + (1.-FPAFS)*COSTO
      B = 0.066*BIV(J)
      TV=1.
      COL1=COV(J,Y2,TE2,TH3,B,TV)
      B = 0.187*BR
      TV=.1
      COP1=COV(J,Y2,TE2,TH4,B,TV)
      COCM11 = FMC * (COFEED*QFC+CWAT*QCW) * DEXP(-DECA*TF1)
      COGM11 = FMG * (COFEED*QFG+CWAT*QGW) * DEXP(-DECA*TF1)
      COMEAT = FF  * (COFEED*QFC+CWAT*QBW) * DEXP(-DECA*TS)
C
C
      RETURN
C
C     CALCULATION FOR TRITIUM
C
  200 COL1=CWAT
      COP1=CWAT
      COCM11 = FMC * CWAT * (QFC+QCW) * DEXP(-DECA*TF1)
      COGM11 = FMG * CWAT * (QFG+QGW) * DEXP(-DECA*TF1)
      COMEAT = FF  * CWAT * (QFC+QCW) * DEXP(-DECA*TS)
C
C
      RETURN
C
C     CALCULATION FOR C-14
C
  300 CO14=0.
      COL1=CO14
      COP1=CO14
      COCM11 = FMC * (CO14*QFC+CWAT*QCW) * DEXP(-DECA*TF1)
      COGM11 = FMG * (CO14*QFG+CWAT*QGW) * DEXP(-DECA*TF1)
      COMEAT = FF  * (CO14*QFC+CWAT*QBW) * DEXP(-DECA*TS)
C
C
      RETURN
      END
      SUBROUTINE HUMEX(J)
      IMPLICIT REAL*8 (A-H,O-Z)
      CHARACTER*8 NUCLID,VNUCL,XNAME2
      REAL*4 UT
      COMMON/BLK2/ACR,ADL,AMIN,ARHO,BIV(100),BURN,CUMDOS(10),DIFCON,
     &      DIFCOV,DIFW,DOSE(3,100),DSTACK,EGAMMA(100),EPW,FEXT,FFIRE,
     &      FG,FIXINV,FTX,FWIND,HLIFE(100),HSTACK,IDSRPT,IFL(7),IFLAG,
     &      IGAMMA,INPRNT,IOPT,ISTAB,IUP,IVFAC,JUF(10),NDOSE,NISO,NNP,
     &      NP,NPN(10),PLANT,PO,QH,RFR,RHO,RUNE,SINV,SNO,SPILL,SR,SS,
     &      TBEG,TCON,TCUT,TEND,TIMOP,TIMOP1,TWO,UBR,UT(100,6),
     &      VOLATL(100),VSTACK,VWIND,XALE,XCT,XH,XKD(100),XLC,
     &      XNAME2(100),XPERC,XPOR,XR,XRECEP,XROOT,XW,XWT,XXMU(100)
      COMMON/UPTAK/BDENS,BR,COL1,COP1,COCM11,COFISH,COGM11,COMEAT,CWAT,
     &      DECA,FF,FI,FIS,FMC,FMG,FP,FS,INTAKE(5),KK,NUCLID,PORS,PP,
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     &        QBW,QCW,QFC,QFG,QGW,KW,SINFL,TE1,TE2,TFIS,TF1,TH1,TH2,TH3,
     &        TH4,TIMAV,TS,UCMILK,UFISH,UGMILK,ULEAFY,UMEAT,UPROD,UWAT,
     &        WIRATE,XAMBWE,Y1,Y2
C
C     CALCULATION OF RADIONUCLIDE INTAKE BY CONSUMPTION
C     OF VEGETATION, MILK, MEAT, FISH, AND DRINKING WATER
C
      QVEG = COL1*ULEAFY + COP1*UPROD
      QMILK = COCMI1*UCMILK + COGMI1*UGMILK
      QMEAT = COMEAT*UMEAT
      QFISH = COFISH*UFISH
      QWAT = CWAT*UWAT
C
C
      IF(KK .LT. 6) GO TO 100
        UT(J,6) = QVEG+QMILK+QMEAT
        GO TO 200
  100 QING = QWAT
      IF(INTAKE(KK) .LE. 2) QING=QING+QVEG+QMILK+QMEAT
      IF(INTAKE(KK) .EQ. 1) QING=QING+QFISH
      UT(J,KK) = QING/CWAT
  200 RETURN
      END
      SUBROUTINE READ(XLLI,RVERTI)
      IMPLICIT REAL*8 (A-H,O-Z)
      CHARACTER*8 VNUCL,XNAME2,XN
      REAL*4 C,Q,UT
      COMMON/XFER/NREC
      COMMON/BLK1/ALDIS,C(100,10),CANLIF,DILFAC,DOSV(5),DY,DZ,NM,NMY,
     &        NMZ,NTIME,Q(100,10),RVERT(100),T(10),TTIME(5),VA,VNUCL(5),
     &        WIDTH,WSLABL(10),XAQD,XL,XLD(100),XLL(100),XLP,XRC(100),
     &        XVV,YW,ZB
      COMMON/BLK2/ACR,ADL,AMIN,ARHO,BIV(100),BURN,CUMDOS(10),DIFCON,
     &        DIFCOV,DIFW,DOSE(3,100),DSTACK,EGAMMA(100),EPW,FEXT,FFIRE,
     &        FG,FIXINV,FTX,FWIND,HLIFE(100),HSTACK,IDSRPT,IFL(7),IFLAG,
     &        IGAMMA,INPRNT,IOPT,ISTAB,IUP,IVFAC,JUF(10),NDOSE,NISO,NNP,
     &        NP,NPN(10),PLANT,PV,QH,RFR,RHO,RUNF,SINV,SNO,SPILL,SR,SS,
     &        TBEG,TCON,TCUT,TEND,TIMOP,TIMOP1,TWV,UBR,UT(100,6),
     &        VOLATL(100),VSTACK,VWIND,XALE,XCT,XH,XKD(100),XLC,
     &        XNAME2(100),XPERC,XPOR,XR,XRECEP,XROOT,XW,XWT,XXMU(100)
      COMMON/BLK3/IFILL
      DIMENSION A(10),DUM(9),XLLI(100),RVERTI(100)
C
      OPEN(UNIT=3,FILE='RKCDCF.DAT',STATUS='OLD')
      READ(3,108) NDOSE,TCUT,SINV
      READ(3,108) NTIME,(T(M),M=1,NTIME)
      IUP=1
      DO 1000 J=1,NDOSE
      READ(3,114,END=1001) KK,XN,(DUM(I),I=1,9)
      IF(KK.LE.0 .OR. KK.GT.100) GO TO 1000
      XNAME2(KK)=XN
      DOSE(1,KK)=DUM(1)
      DOSE(2,KK)=DUM(2)
      DOSE(3,KK)=DUM(3)
      DO 101 I=1,6
  101 UT(KK,I)=DUM(I+3)
       IF(UT(KK,1) .NE. 0) IUP=0
 1000 CONTINUE
  114 FORMAT(I4,A8,9E12.4)
 1001 CLOSE(UNIT=3)
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C
      OPEN(UNIT=3,FILE='ABCDEF.DAT',STATUS='OLD')
      READ(3,102) (A(I),I=1,10)
C     NREC=NREC+1
C     WRITE(4,102,REC=NREC) (A(I),I=1,10)
  102 FORMAT(10A8)
      READ(3,103) NISO,IFLAG,NNP
      READ(3,103) (NPN(J),JUF(J),J=1,NNP)
  103 FORMAT(20I6)
  104 FORMAT(10F12.6)
      READ(3,104) TIMOP,XLP,WIDTH,RFR,XR,SPILL
      READ(3,104) ARHO,ALDIS,DY,DZ,SS,SR,PV,SNO
      READ(3,103) NM,IGAMMA,IVFAC,NMY,NMZ
      READ(3,104) XCT,XWT,TWV,XW,YW,RHO,FG,FEXT,XROOT,PLANT
      READ(3,104) ADL,UBR,FTX,CANLIF,FIXINV
      READ(3,104) XH,ACR,EPW,DIFW,DIFCON,TCON,DIFCOV
      READ(3,108) ISTAB,VWIND,FWIND,XRECEP,BURN,FFIRE,HSTACK,DSTACK,
     &            VSTACK,QH
      READ(3,103) (IFL(I),I=1,7)
      READ(3,103) INPRNT,IDSRPT,IFILL,IOPT
      CLOSE(UNIT=3)
  108 FORMAT(I6,(10F12.6))
      AMIN=1.6D4
      TBEG=T(1)
      TEND=T(2)
      DO 120 I=1,7
      IF(IFL(I).NE.0) GO TO 121
  120 CONTINUE
      GO TO 123
  121 IF(DY.NE.0.) WRITE(6,122)
  122 FORMAT(/,' WARNING: WITH THE PRESENT MODEL, LATERAL DISPERSION ',
     & 'CANNOT BE',/,10X,'CALCULATED FOR DECAY CHAINS. FOR DECAY ',
     & 'CHAINS USE DY=0.',/)
  123 MTIME=NTIME
      IF(IFLAG.EQ.0) MTIME=1
      DECFAC=1.
C
      OPEN(UNIT=3,FILE='ROSITE.DAT',STATUS='OLD')
      READ(3,104) XPERC,VA,XPOR,XAQD,XVV,XLC,XALE,FLCH,RUNF
      DO 332 K=1,NDOSE
      READ(3,109,END=340) KK,(DUM(I),I=1,3)
  109 FORMAT(I4,3E12.4)
      IF(KK.LE.0 .OR. KK.GT.100) GO TO 332
      XLL(KK)=DUM(1)
      XKD(KK)=DUM(2)
      RVERTI(KK)=DUM(3)
  332 CONTINUE
  340 CLOSE(UNIT=3)
      DO 350 K=1,NDOSE
      XLLI(K)=XLL(K)
  350 XLL(K)=XLL(K)*FLCH
C
      OPEN(UNIT=3,FILE='INVNTRY.DAT',STATUS='OLD')
      VOL=XLP*WIDTH*XPERC
      IF(SS .EQ. 0.) SS=SR+(1.-SR)*(XPERC/PV)**SNO
      IF(SS .GT. 1.) SS=1.
      IF(XVV .LE. 0.) XVV=XPERC/(XPOR*SS)
      DO 15 K=1,NISO
      READ(3,111,END=4) KK,HLIFE(KK),(Q(KK,JJ),JJ=1,MTIME),
     &  XXMU(KK),EGAMMA(KK),BIV(KK),SOL,VOLATL(KK)
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111 FORMAT(I4,7E12.4)
      IF(SOL.EQ.0.) GO TO 125
      SOL=SOL*VOL/Q(KK,1)
      IF(XLL(KK).GT.SOL) XLL(KK)=SOL
  125 XLD(KK)=.69314718/HLIFE(KK)
      XRC(KK)=XKD(KK)*.001*RHO/XPOR+1.
      RVERT(KK)=RVERTI(KK)*.001*RHO/XPOR+1.
      RVERT(KK)=1.+(RVERT(KK)-1.)/SS
      IF(TIMOP.NE.0.) DECFAC=(1.-DEXP(-XLD(KK)*TIMOP))/(XLD(KK)*TIMOP)
      IF(TCUT.GT.0.01 .AND. HLIFE(KK).GT.TCUT) Q(KK,1)=SINV
      DO 15 M=1,NTIME
      Q(KK,M)=Q(KK,M)*FIXINV*DECFAC
   15 CONTINUE
      GO TO 5
    4 NISO=K-1
    5 CLOSE(UNIT=3)
C
      IF(Q(26,1).LE.0. .OR. Q(31,1).LE.0. .OR. Q(36,1).LE.0.) IFL(3)=0
      IF(Q(29,1).LE.0. .OR. Q(33,1).LE.0. .OR. Q(35,1).LE.0.) IFL(4)=0
      WRITE(6,3) (A(I),I=1,10)
    3 FORMAT('1',10A8,///)
      DO 100 IWING=1,10
         WSLABL(IWING)=A(IWING)
  100 CONTINUE
      RETURN
      END
      SUBROUTINE RELEAS(NPATH)
      IMPLICIT REAL*8 (A-H,O-Z)
      CHARACTER*8 VNUCL,XNAME2
      REAL*4 C,Q,UT
      COMMON/BLK1/ALDIS,C(100,10),CANLIF,DILFAC,DOSV(5),DY,DZ,NM,NMY,
     &        NMZ,NTIME,Q(100,10),RVERT(100),T(10),TTIME(5),VA,VNUCL(5),
     &        WIDTH,WSLABL(10),XAQD,XL,XLD(100),XLL(100),XLP,XRC(100),
     &        XVV,YW,ZB
      COMMON/BLK2/ACK,AUL,AMIN,ARHO,BIV(100),BURN,CUMDOS(10),DIFCON,
     &        DIFCOV,DIFW,DOSE(3,100),DSTACK,EGAMMA(100),EPW,FEXT,FFIRE,
     &        FG,FIXINV,FTX,FWIND,HLIFE(100),HSTACK,IDSRPT,IFL(7),IFLAG,
     &        IGAMMA,INPRNT,IOPT,ISTAB,IUP,IVFAC,JUF(10),NDOSE,NISO,NNP,
     &        NP,NPN(10),PLANT,PV,QH,RFR,RHO,RUNF,SINV,SNO,SPILL,SR,SS,
     &        TBEG,TCON,TCUT,TEND,TIMOP,TIMOP1,TWV,UBR,UT(100,6),
     &        VOLATL(100),VSTACK,VWIND,XALE,XCT,XH,XKD(100),XLC,
     &        XNAME2(100),XPERC,XPOR,XR,XRECEP,XROOT,XW,XWT,XXMU(100)
      COMMON/BLK3/IFILL
      WRITE(6,50) TBEG,TEND,NPATH
   50 FORMAT(/////,' ***** TOTAL CURIES RELEASED AND HEALTH EFFECTS FROM
     & YEAR ',F8.0,' TO YEAR ',F8.0,' *****',4X,'PATHWAY ',I2,///,4X,
     &'NUCLIDE',12X,'CURIES RELEASED',4X,'HEALTH EFFECTS',/,
     &' NUMBER   NAME',/)
      DO 500 K=1,NDOSE
      IF(Q(K,1).EQ.0.) GO TO 500
      KK=K
      SUM=0.
      NTIME=10
      TAU=(ZB+0.5*XLP/NM)*XRC(K)/VA+XAQD*RVERT(K)/XVV+CANLIF
      DELT=0.1/XLL(K)
      IF(DELT.GT.0.5*HLIFE(K)) DELT=0.5*HLIFE(K)
      IF(TAU.GT.TEND) GO TO 201
      T(10)=TAU-DELT
  100 T(1)=T(10)+DELT
      IF(T(1).LT.TEND) GO TO 110
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      T(1)=TEND
      DELT1=TEND-T(10)
      NTIME=1
      I=1
      GO TO 130
  110 IF(T(1).LT.TBEG) T(1)=TBEG
      DO 120 I=2,10
      T(I)=T(I-1)+DELT
      IF(T(I).LT.TEND) GO TO 120
      T(I)=TEND
      DELT1=TEND-T(I-1)
      NTIME=I
      GO TO 130
  120 CONTINUE
  130 CALL GW1(KK)
      IF(IFL(1).EQ.1.AND.(KK.EQ.32.OR.KK.EQ.27)) CALL GW3(38,32,27)
      IF(IFL(2).EQ.1.AND.(KK.EQ.27.OR.KK.EQ.24)) CALL GW3(32,27,24)
      IF(IFL(3).EQ.1.AND.(KK.EQ.31.OR.KK.EQ.26)) CALL GW3(36,31,26)
      IF(IFL(4).EQ.1.AND.(KK.EQ.35.OR.KK.EQ.29)) CALL GW3(33,35,29)
      IF(IFL(5).EQ.1.AND.(KK.EQ.23.OR.KK.EQ.22)) CALL GW3(30,23,22)
      IF(IFL(6).EQ.1.AND.(KK.EQ.28.OR.KK.EQ.25)) CALL GW3(34,28,25)
      IF(IFL(7).EQ.1.AND.(KK.EQ.23.OR.KK.EQ.22)) CALL GW3(28,23,22)
      IF(T(1).EQ.TAU.OR.T(1).EQ.TBEG) C(K,1)=0.5*C(K,1)
      IF(I.EQ.11) GO TO 140
      C(K,I)=0.5*C(K,I)*DELT1/DELT
      J=I-1
      IF(J.GT.0) C(K,J)=0.5*C(K,J)*(1.+DELT1/DELT)
      GO TO 150
  140 I=10
  150 CSUM=0.
      DO 160 J=1,I
  160 CSUM=CSUM+C(K,J)
      IF(I.EQ.1) CSUM=CSUM+0.5*C(K,10)*(DELT1/DELT-1.)
      SUM=SUM+CSUM
      IF(I.EQ.10.AND.T(10).LT.TEND.AND.CSUM.GT.SUM*.0001) GO TO 100
      IF(TAU.LT.TBEG) GO TO 300
      NTIME=10
  201 T(10)=TAU+DELT
  200 T(1)=T(10)-DELT
      IF(T(1).GT.TBEG) GO TO 210
      T(1)=TBEG
      DELT1=T(10)-TBEG
      NTIME=1
      I=1
      GO TO 230
  210 IF(T(1).GT.TEND) T(1)=TEND
      DO 220 I=2,10
      T(I)=T(I-1)-DELT
      IF(T(I).GT.TBEG) GO TO 220
      T(I)=TBEG
      DELT1=T(I-1)-TBEG
      NTIME=I
      GO TO 230
  220 CONTINUE
  230 CALL GW1(KK)
      IF(IFL(1).EQ.1.AND.(KK.EQ.32.OR.KK.EQ.27)) CALL GW3(38,32,27)
      IF(IFL(2).EQ.1.AND.(KK.EQ.27.OR.KK.EQ.24)) CALL GW3(32,27,24)
      IF(IFL(3).EQ.1.AND.(KK.EQ.31.OR.KK.EQ.26)) CALL GW3(36,31,26)
      IF(IFL(4).EQ.1.AND.(KK.EQ.35.OR.KK.EQ.29)) CALL GW3(33,35,29)
      IF(IFL(5).EQ.1.AND.(KK.EQ.23.OR.KK.EQ.22)) CALL GW3(30,23,22)
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      IF(IFL(6).EQ.1.AND.(KK.EQ.28.OR.KK.EQ.25)) CALL GW3(34,28,25)
      IF(IFL(7).EQ.1.AND.(KK.EQ.23.OR.KK.EQ.22)) CALL GW3(28,23,22)
      IF(T(1).EQ.TAU.OR.T(1).EQ.TEND) C(K,1)=0.5*C(K,1)
      IF(I.EQ.11) GO TO 240
      C(K,I)=0.5*C(K,I)*DELT1/DELT
      J=I-1
      IF(J.GT.0) C(K,J)=0.5*C(K,J)*(1.+DELT1/DELT)
      GO TO 250
  240 I=10
  250 CSUM=0.
      DO 260 J=1,I
  260 CSUM=CSUM+C(K,J)
      IF(I.EQ.1) CSUM=CSUM+0.5*C(K,10)*(DELT1/DELT-1.)
      SUM=SUM+CSUM
      IF(I.EQ.10.AND.T(10).GT.TBEG.AND.CSUM.GT.SUM*.0001) GO TO 200
  300 SUM=SUM*DELT*DILFAC
      WRITE(6,350) K,XNAME2(K),SUM,HEPCI(KK,SUM,NPATH)
  350 FORMAT(2X,I3,3X,A8,9X,1PE10.2,10X,E8.2)
  500 CONTINUE
      RETURN
      END
      SUBROUTINE GW1(K)
      IMPLICIT REAL*8 (A-H,O-Z)
      CHARACTER*8 VNUCL,XNAME2
      REAL*4 C,Q,UT
      COMMON/BLK1/ALDIS,C(100,10),CANLIF,DILFAC,DOSV(5),DY,DZ,NM,NMY,
     &        NMZ,NTIME,Q(100,10),RVERT(100),T(10),TTIME(5),VA,VNUCL(5),
     &        WIDTH,WSLABL(10),XAQD,XL,XLD(100),XLL(100),XLP,XRC(100),
     &        XVV,YW,ZB
      COMMON/BLK2/ACK,ADL,AMIN,ARHO,BIV(100),BURN,CUMDOS(10),DIFCON,
     &        DIFCOV,DIFW,DOSE(3,100),DSTACK,EGAMMA(100),EPW,FEXT,FFIRE,
     &        FG,FIXINV,FTX,FWIND,HLIFE(100),HSTACK,IDSRPT,IFL(7),IFLAG,
     &        IGAMMA,INPRNT,IOPT,ISTAB,IUP,IVFAC,JUF(10),NDOSE,NISO,NNP,
     &        NP,NPN(10),PLANT,PV,QH,RFR,RHO,RUNE,SINV,SNO,SPILL,SR,SS,
     &        TBEG,TCON,TCUT,TEND,TIMOP,TIMOP1,TWV,UBR,UT(100,6),
     &        VOLATL(100),VSTACK,VWIND,XALE,XCT,XH,XKD(100),XLC,
     &        XNAME2(100),XPERC,XPOR,XR,XRECEP,XROOT,XW,XWT,XXMU(100)
      COMMON/BLK3/IFILL
C
      TL=1./XLL(K)
      TDELAY=XAQD*RVERT(K)/XVV+CANLIF
      P=XL/ALDIS
      QK1=Q(K,1)
C     REMOVE OPERATIONS DECAY FACTOR AND USE UNDECAYED INITIAL INVENTORY
      IF(TIMOP .GT. 0.) QK1=QK1*XLD(K)*TIMOP/(1.-DEXP(-XLD(K)*TIMOP))
      QDECAY=QK1*DEXP(-XLD(K)*TDELAY)
      F1=QDECAY/(DILFAC*TL)
        DTOP = TIMOP1*VA/(NM*XL)
         IF(IFILL .EQ. 0) GO TO 50
           LB = 0
           IUB = 1-NM
           ISTEP = -1
           GO TO 70
   50      LB = 1
           IUB = NM
           ISTEP = 1
   70    CONTINUE
      DO 200 M=1,NTIME
        TCORR = DTOP/2.
        TIMSAV = T(M)
```

```
      T(M) = T(M) + TIMOP
      THTA=(T(M)-TDELAY)*VA/XL
      THTA2=THTA-TL*VA/XL
     SC=0.
     DO 100 JJ=LB,IUB,ISTEP
      T(M) = TIMSAV + TIMOP - TCORR*XL/VA
      THETA = THTA - TCORR
      IF (THETA .LE. 0.) GO TO 195
      THETA2 = THTA2 - TCORR
     ETA=(ZB+XLP*(1.-IFILL+(0.5-JJ)/NM))/XL
     A1=-XLD(K)*(T(M)-TDELAY)
     A23M=0.5*ETA*DSQRT(XRC(K)*P/THETA)-DSQRT(P*THETA/(4.*XRC(K)))
     A24M=0.
     IF(THETA2.GT.0.)
    & A24M=0.5*ETA*DSQRT(XRC(K)*P/THETA2)-DSQRT(P*THETA2/(4.*XRC(K)))
     A4=A1+ETA*P
     A23P=0.5*ETA*DSQRT(XRC(K)*P/THETA)+DSQRT(P*THETA/(4.*XRC(K)))
     A24P=0.
     IF(THETA2.GT.0.)
    & A24P=0.5*ETA*DSQRT(XRC(K)*P/THETA2)+DSQRT(P*THETA2/(4.*XRC(K)))
     SC=SC+FTRMS(A1,A23M,A24M,A4,A23P,A24P,THETA2)
     TCORR = TCORR + DTOP
 100 CONTINUE
 195 T(M) = TIMSAV
     IF(SC.LT.0.) SC=-SC
     YCONC=1.
     IF(DY .LE. 0.) GO TO 198
     IF(T(M) .LE. TDELAY) GO TO 198
     THETA=(ZB+0.5*XLP)*XRC(K)/VA
     TAQ=T(M)-TDELAY
     IF(TAQ .GT. THETA) TAQ=THETA
     YCONC=2.*DSQRT(DY*TAQ/XRC(K))
     YCONC=0.5*(DERF((YW+0.5*WIDTH)/YCONC)-DERF((YW-0.5*WIDTH)/YCONC))
 198 C(K,M)=0.5*F1*SC*YCONC/NM
 200 CONTINUE
     RETURN
     END
     SUBROUTINE GW3(IDC,JDC,KDC)
     IMPLICIT REAL*8 (A-H,O-Z)
     CHARACTER*8 VNUCL,XNAME2
     REAL*4 C,Q,UT
C    THIS SUBROUTINE EVALUATES BURKHOLDER'S SOLUTION FOR GROUNDWATER
C      MIGRATION EQUATIONS. FOUND IN NUC. TECH. VOL. 49, JUNE 1980
C                     (THREE MEMBER CHAINS WITH DISPERSION)
     COMMON/BLK1/ALDIS,C(100,10),CANLIF,DILFAC,DOSV(5),DY,DZ,NM,NMY,
    &        NMZ,NTIME,Q(100,10),RVERT(100),T(10),TTIME(5),VA,VNUCL(5),
    &        WIDTH,WSLABL(10),XAQD,XL,XLD(100),XLL(100),XLP,XRC(100),
    &        XVV,YW,ZB
     COMMON/BLK2/ACR,ADL,AMIN,ARHO,BIV(100),BURN,CUMDOS(10),DIFCON,
    &        DIFCOV,DIFW,DOSE(3,100),DSTACK,EGAMMA(100),EPW,FEXT,FFIRE,
    &        FG,FIXINV,FTX,FWIND,HLIFE(100),HSTACK,IDSRPT,IEL(7),IFLAG,
    &        IGAMMA,INPRNT,IOPT,ISTAB,IUP,IVFAC,JUF(10),NDOSE,NISO,NNP,
    &        NP,NPN(10),PLANT,PV,QH,RFR,RHO,RUNF,SINV,SNO,SPILL,SR,SS,
    &        TBEG,TCON,TCUT,TEND,TIMOP,TIMOP1,TWV,UBR,UT(100,6),
    &        VOLATL(100),VSTACK,VWIND,XALE,XCT,XH,XKD(100),XLC,
    &        XNAME2(100),XPERC,XPOR,XR,XRECEP,XROOT,XW,XWT,XXMU(100)
     COMMON/BLK3/IFILL
     DIMENSION F1(3),R(3),XK(3)
C
     TL=1./XLL(IDC)
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      TDELAY=XAQD*RVERT(IDC)/XVV+CANLIF
      XK(1)=XRC(IDC)
      XK(2)=XRC(JDC)
      XK(3)=XRC(KDC)
      PSAVE=XL/ALDIS
C     RECOVER UNDECAYED INITIAL INVENTORIES OF EACH CHAIN MEMBER
        QI1=Q(IDC,1)
        QJ1=Q(JDC,1)
        QK1=Q(KDC,1)
      IF(TIMOP .EQ. 0.) GO TO 40
        QI1=QI1*XLD(IDC)*TIMOP/(1.-DEXP(-XLD(IDC)*TIMOP))
        QJ1=QJ1*XLD(JDC)*TIMOP/(1.-DEXP(-XLD(JDC)*TIMOP))
        QK1=QK1*XLD(KDC)*TIMOP/(1.-DEXP(-XLD(KDC)*TIMOP))
   40 QDECAY=QI1*DEXP(-XLD(IDC)*TDELAY)
      F1(1)=QDECAY/(DILFAC*TL)
      QDECAY=(QJ1-XLD(IDC)*QI1/(XLD(JDC)-XLD(IDC)))*
     &       DEXP(-XLD(JDC)*TDELAY)+XLD(IDC)*QI1*DEXP(-XLD(IDC)*
     &       TDELAY)/(XLD(JDC)-XLD(IDC))
      F1(2)=QDECAY/(DILFAC*TL)
      QDECAY=(QK1+XLD(JDC)/(XLD(KDC)-XLD(JDC))*(XLD(IDC)*QI1
     &       /(XLD(KDC)-XLD(IDC))-QJ1))*DEXP(-XLD(KDC)*TDELAY)+
     &       XLD(JDC)/(XLD(KDC)-XLD(JDC))*(QJ1-XLD(IDC)*QI1/
     &       (XLD(JDC)-XLD(IDC)))*DEXP(-XLD(JDC)*TDELAY)+XLD(IDC)*
     &       XLD(JDC)*QI1*DEXP(-XLD(IDC)*TDELAY)/((XLD(JDC)-
     &       XLD(IDC))*(XLD(KDC)-XLD(IDC)))
      F1(3)=QDECAY/(DILFAC*TL)
        DTOP = TIMOP1*VA/(NM*XL)
      IF(IFILL .EQ. 0) GO TO 50
        LB=0
        IUB=1-NM
        ISTEP=-1
        GO TO 70
   50   LB=1
        IUB=NM
        ISTEP=1
   70 CONTINUE
      R(1)=XLD(IDC)*XL/VA
      R(2)=XLD(JDC)*XL/VA
      R(3)=XLD(KDC)*XL/VA
      F221=F1(2)+F1(1)*R(1)/(R(1)-R(2))
      F232=F1(3)+F1(2)*R(2)/(R(2)-R(3))
      F312=F1(1)*R(1)*XK(1)/((R(2)-R(1))*XK(2))
      F323=F1(2)*R(2)*XK(2)/((R(3)-R(2))*XK(3))
      F412=F1(1)*R(1)*(1.-XK(1)/XK(2))/(R(2)-R(1))
      F423=F1(2)*R(2)*(1.-XK(2)/XK(3))/(R(3)-R(2))
      F5=F1(1)*R(1)*R(2)/((R(1)-R(3))*(R(2)-R(3)))
      F61=F1(1)*R(1)*R(2)*XK(2)/((R(1)-R(2))*(R(2)-R(3))*XK(3))
      F62=F1(1)*R(1)*R(2)*XK(1)/((R(1)-R(2))*(R(1)-R(3))*XK(3))
      F71=F61*(XK(3)/XK(2)-1.)
      F72=F62*(XK(3)/XK(1)-1.)
      F8=F1(1)*XK(2)*R(1)*R(2)/((R(2)-R(1))*(XK(2)*(R(2)-R(1))-XK(3)*
     &(R(3)-R(1))))
      F9=F8*(1.-XK(1)/XK(2))
      F10=F1(1)*XK(1)*XK(2)*R(1)*R(2)*(XK(2)-XK(3))/((XK(2)*(R(2)-R(1))
     &-XK(3)*(R(3)-R(1)))*(XK(1)*XK(3)*(R(1)-R(3))+XK(2)*XK(3)*(R(3)-
     &R(2))+XK(1)*XK(2)*(R(2)-R(1))))
      F11=F10*(1.-XK(1)/XK(3))*(XK(2)*(R(2)-R(1))-XK(3)*(R(3)-R(1)))/
     &((XK(2)-XK(3))*(R(3)-R(1)))
      F12=F11*(R(3)-R(1))*(XK(1)-XK(2))/((R(2)-R(1))*XK(2)*(1.-XK(1)/
     &XK(3)))
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      DO 2000 M=1,NTIME
        TCORR = DTOP/2.
        TIMSAV = T(M)
        T(M) = T(M) + TIMOP
      THTA=(T(M)-TDELAY)*VA/XL
      IF(THTA.LE.0.) GO TO 1990
      THTA2=THTA-TL*VA/XL
      SC2=0.
      SC3=0.
      DO 1000 JJ=IB,IUB,ISTEP
        T(M) = TIMSAV + TIMOP - TCORR*XL/VA
        THETA = THTA - TCORR
        IF (THETA .LE. 0.0) GO TO 1990
        THETA2 = THTA2 - TCORR
      ETA=(ZB+XLP*(1.-IFILL+(0.5-JJ)/NM))/XL
C
C     COMPUTE CONCENTRATION OF SECOND CHAIN MEMBER
C
      P=PSAVE
      A1=-R(2)*THETA
      A2=0.5*ETA*DSQRT(XK(2)*P/THETA)-DSQRT(P*THETA/(4.*XK(2)))
      A3=0.
      IF(THETA2.GT.0.) A3=0.5*ETA*DSQRT(XK(2)*P/THETA2)-
     $DSQRT(P*THETA2/(4.*XK(2)))
      A4=A1+ETA*P
      A5=0.5*ETA*DSQRT(XK(2)*P/THETA)+DSQRT(P*THETA/(4.*XK(2)))
      A6=0.
      IF(THETA2.GT.0.) A6=0.5*ETA*DSQRT(XK(2)*P/THETA2)+
     $DSQRT(P*THETA2/(4.*XK(2)))
      SC2=SC2+F221*FTRMS(A1,A2,A3,A4,A5,A6,THETA2)
      A1=-R(1)*THETA
      A4=A1+ETA*P
      A2=0.5*ETA*DSQRT(XK(1)*P/THETA)
      A5=DSQRT(P*THETA/(4.*XK(1)))
      A2=A2-A5
      A5=A2+2.*A5
      IF(THETA2.LE.0.) GO TO 100
      A3=0.5*ETA*DSQRT(XK(1)*P/THETA2)
      A6=DSQRT(P*THETA2/(4.*XK(1)))
      A3=A3-A6
      A6=A3+2.*A6
  100 SC2=SC2+F312*FTRMS(A1,A2,A3,A4,A5,A6,THETA2)
    1 A1=1.+4.*XK(2)*(R(2)-R(1))/P
      IF(A1.LT.0.) CALL ERROR(1,A1,P)
      IF(A1.LT.0.) GO TO 1
      A1=DSQRT(A1)
      A4=-R(1)*THETA+0.5*ETA*P*(1.+A1)
      A1=-R(1)*THETA+0.5*ETA*P*(1.-A1)
      A2=0.5*ETA*DSQRT(XK(2)*P/THETA)
      A5=(P/(4.*XK(2))+R(2)-R(1))*THETA
      IF(A5.LT.0.) CALL ERROR(2,A5,P)
      IF(A5.LT.0.) GO TO 1
      A5=DSQRT(A5)
      A2=A2-A5
      A5=A2+2.*A5
      IF(THETA2.LE.0.) GO TO 110
      A3=0.5*ETA*DSQRT(XK(2)*P/THETA2)
      A6=(P/(4.*XK(2))+R(2)-R(1))*THETA2
      IF(A6.LT.0.) CALL ERROR(3,A6,P)
      IF(A6.LT.0.) GO TO 1
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      A6=DSQRT(A6)
      A3=A3-A6
      A6=A3+2.*A6
  110 SC2=SC2+F412*FTRMS(A1,A2,A3,A4,A5,A6,THETA2)
    2 XTM=(XK(2)*R(2)-XK(1)*R(1))*THETA/(XK(1)-XK(2))
      A1=1.+4.*XK(1)*XK(2)*(R(2)-R(1))/(P*(XK(1)-XK(2)))
      IF(A1.LT.0.) CALL ERROR(4,A1,P)
      IF(A1.LT.0.) GO TO 2
      A1=DSQRT(A1)
      A4=XTM+0.5*ETA*P*(1.+A1)
      A1=XTM+0.5*ETA*P*(1.-A1)
      A2=0.5*ETA*DSQRT(XK(2)*P/THETA)
      A5=(P/(4.*XK(2))+XK(1)*(R(2)-R(1))/(XK(1)-XK(2)))*THETA
      IF(A5.LT.0.) CALL ERROR(5.A5,P)
      IF(A5.LT.0.) GO TO 2
      A5=DSQRT(A5)
      A2=A2-A5
      A5=A2+2.*A5
      A3=0.5*ETA*DSQRT(XK(1)*P/THETA)
      A6=(P/(4.*XK(1))+XK(2)*(R(2)-R(1))/(XK(1)-XK(2)))*THETA
      IF(A6.LT.0.) CALL ERROR(6.A6,P)
      IF(A6.LT.0.) GO TO 2
      A6=DSQRT(A6)
      A3=A3-A6
      A6=A3+2.*A6
      SC2=SC2+F312*FTRMS(A1,A2,A3,A4,A5,A6,1D0)
      IF(THETA2.LE.0.) GO TO 120
    3 XTM=(XK(2)*R(2)-XK(1)*R(1))*THETA/(XK(1)-XK(2))-(R(1)+(XK(2)*R(2)-
     &XK(1)*R(1))/(XK(1)-XK(2)))*TLAVA/XL
      A1=1.+4.*XK(1)*XK(2)*(R(2)-R(1))/(P*(XK(1)-XK(2)))
      IF(A1.LT.0.) CALL ERROR(7,A1,P)
      IF(A1.LT.0.) GO TO 3
      A1=DSQRT(A1)
      A4=XTM+0.5*ETA*P*(1.+A1)
      A1=XTM+0.5*ETA*P*(1.-A1)
      A2=0.5*ETA*DSQRT(XK(2)*P/THETA2)
      A5=(P/(4.*XK(2))+XK(1)*(R(2)-R(1))/(XK(1)-XK(2)))*THETA2
      IF(A5.LT.0.) CALL ERROR(8,A5,P)
      IF(A5.LT.0.) GO TO 3
      A5=DSQRT(A5)
      A2=A2-A5
      A5=A2+2.*A5
      A3=0.5*ETA*DSQRT(XK(1)*P/THETA2)
      A6=(P/(4.*XK(1))+XK(2)*(R(2)-R(1))/(XK(1)-XK(2)))*THETA2
      IF(A6.LT.0.) CALL ERROR(9.A6,P)
      IF(A6.LT.0.) GO TO 3
      A6=DSQRT(A6)
      A3=A3-A6
      A6=A3+2.*A6
      SC2=SC2-F312*FTRMS(A1,A2,A3,A4,A5,A6,1D0)
  120 CONTINUE
C
C     NOW COMPUTE CONCENTRATION OF THIRD CHAIN MEMBER
C
      P=PSAVE
      A1=-R(3)*THETA
      A4=A1+ETA*P
      A2=0.5*ETA*DSQRT(XK(3)*P/THETA)
      A5=DSQRT(P*THETA/(4.*XK(3)))
      A2=A2-A5
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      A5=A2+2.*A5
      IF(THETA2.LE.0.) GO TO 130
      A3=0.5*ETA*DSQRT(XK(3)*P/THETA2)
      A6=DSQRT(P*THETA2/(4.*XK(3)))
      A3=A3-A6
      A6=A3+2.*A6
  130 SC3=SC3+(E232+E5)*FTRMS(A1,A2,A3,A4,A5,A6,THETA2)
    4 XTM=-R(2)*THETA
      A1=1.+4.*XK(3)*(R(3)-R(2))/P
      IF(A1.LT.0.) CALL ERROR(10,A1,P)
      IF(A1.LT.0.) GO TO 4
      A1=DSQRT(A1)
      A4=XTM+0.5*ETA*P*(1.+A1)
      A1=XTM+0.5*ETA*P*(1.-A1)
      A2=0.5*ETA*DSQRT(XK(3)*P/THETA)
      A5=(P/(4.*XK(3))+R(3)-R(2))*THETA
      IF(A5.LT.0.) CALL ERROR(11,A5,P)
      IF(A5.LT.0.) GO  TO 4
      A5=DSQRT(A5)
      A2=A2-A5
      A5=A2+2.*A5
      IF(THETA2.LE.0.) GO TO 140
      A3=0.5*ETA*DSQRT(XK(3)*P/THETA2)
      A6=(P/(4.*XK(3))+R(3)-R(2))*THETA2
      IF(A6.LT.0.) CALL ERROR(12,A6,P)
      IF(A6.LT.0.) GO TO 4
      A6=DSQRT(A6)
      A3=A3-A6
      A6=A3+2.*A6
  140 SC3=SC3+(E423-E71)*FTRMS(A1,A2,A3,A4,A5,A6,THETA2)
    5 XTM=-R(1)*THETA
      A1=1.+4.*XK(3)*(R(3)-R(1))/P
      IF(A1.LT.0.) CALL ERROR(13,A1,P)
      IF(A1.LT.0.) GO TO 5
      A1=DSQRT(A1)
      A4=XTM+0.5*ETA*P*(1.+A1)
      A1=XTM+0.5*ETA*P*(1.-A1)
      A2=0.5*ETA*DSQRT(XK(3)*P/THETA)
      A5=(P/(4.*XK(3))+R(3)-R(1))*THETA
      IF(A5.LT.0.) CALL ERROR(14,A5,P)
      IF(A5.LT.0.) GO TO 5
      A5=DSQRT(A5)
      A2=A2-A5
      A5=A2+2.*A5
      IF(THETA2.LE.0.) GO TO 150
      A3=0.5*ETA*DSQRT(XK(3)*P/THETA2)
      A6=(P/(4.*XK(3))+R(3)-R(1))*THETA2
      IF(A6.LT.0.) CALL ERROR(15,A6,P)
      IF(A6.LT.0.) GO TO 5
      A6=DSQRT(A6)
      A3=A3-A6
      A6=A3+2.*A6
  150 SC3=SC3+(E72+E9)*FTRMS(A1,A2,A3,A4,A5,A6,THETA2)
      A1=-R(2)*THETA
      A4=A1+ETA*P
      A2=0.5*ETA*DSQRT(XK(2)*P/THETA)
      A5=DSQRT(P*THETA/(4.*XK(2)))
      A2=A2-A5
      A5=A2+2.*A5
      IF(THETA2.LE.0.) GO TO 160
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      A3=0.5*ETA*DSQRT(XK(2)*P/THETA2)
      A6=DSQRT(P*THETA2/(4.*XK(2)))
      A3=A3-A6
      A6=A3+2.*A6
  160 SC3=SC3+(F323-F61)*FTRMS(A1,A2,A3,A4,A5,A6,THETA2)
    6 XTM=-R(1)*THETA
      A1=1.+4.*XK(2)*(R(2)-R(1))/P
      IF(A1.LT.0.) CALL ERROR(16,A1,P)
      IF(A1.LT.0.) GO TO 6
      A1=DSQRT(A1)
      A4=XTM+0.5*ETA*P*(1.+A1)
      A1=XTM+0.5*ETA*P*(1.-A1)
      A2=0.5*ETA*DSQRT(XK(2)*P/THETA)
      A5=(P/(4.*XK(2))+R(2)-R(1))*THETA
      IF(A5.LT.0.) CALL ERROR(17,A5,P)
      IF(A5.LT.0.) GO TO 6
      A5=DSQRT(A5)
      A2=A2-A5
      A5=A2+2.*A5
      IF(THETA2.LE.0.) GO TO 170
      A3=0.5*ETA*DSQRT(XK(2)*P/THETA2)
      A6=(P/(4.*XK(2))+R(2)-R(1))*THETA2
      IF(A6.LT.0.) CALL ERROR(18,A6,P)
      IF(A6.LT.0.) GO TO 6
      A6=DSQRT(A6)
      A3=A3-A6
      A6=A3+2.*A6
  170 SC3=SC3-F9*FTRMS(A1,A2,A3,A4,A5,A6,THETA2)
      A1=-R(1)*THETA
      A4=A1+ETA*P
      A2=0.5*ETA*DSQRT(XK(1)*P/THETA)
      A5=DSQRT(P*THETA/(4.*XK(1)))
      A2=A2-A5
      A5=A2+2.*A5
      IF(THETA2.LE.0.) GO TO 180
      A3=0.5*ETA*DSQRT(XK(1)*P/THETA2)
      A6=DSQRT(P*THETA2/(4.*XK(1)))
      A3=A3-A6
      A6=A3+2.*A6
  180 SC3=SC3+F62*FTRMS(A1,A2,A3,A4,A5,A6,THETA2)
    7 XTM=(XK(3)*R(3)-XK(2)*R(2))*THETA/(XK(2)-XK(3))
      A1=1.+4.*XK(2)*XK(3)*(R(3)-R(2))/(P*(XK(2)-XK(3)))
      IF(A1.LT.0.) CALL ERROR(19,A1,P)
      IF(A1.LT.0.) GO TO 7
      A1=DSQRT(A1)
      A4=XTM+0.5*ETA*P*(1.+A1)
      A1=XTM+0.5*ETA*P*(1.-A1)
      A2=0.5*ETA*DSQRT(XK(3)*P/THETA)
      A5=(P/(4.*XK(3))+XK(2)*(R(3)-R(2))/(XK(2)-XK(3)))*THETA
      IF(A5.LT.0.) CALL ERROR(20,A5,P)
      IF(A5.LT.0.) GO TO 7
      A5=DSQRT(A5)
      A2=A2-A5
      A5=A2+2.*A5
      A3=0.5*ETA*DSQRT(XK(2)*P/THETA)
      A6=(P/(4.*XK(2))+XK(3)*(R(3)-R(2))/(XK(2)-XK(3)))*THETA
      IF(A6.LT.0.) CALL ERROR(21,A6,P)
      IF(A6.LT.0.) GO TO 7
      A6=DSQRT(A6)
      A3=A3-A6
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      A6=A3+2.AA6
      SC3=SC3+(F323-F61-F8+F10)AFTRMS(A1,A2,A3,A4,A5,A6,1D0)
      IF(THETA2.LE.0.) GO TO 190
    8 XTM=(XK(3)AR(3)-XK(2)AR(2))ATHETA/(XK(2)-XK(3))-(R(2)+(XK(3)A
     &R(3)-XK(2)AR(2))/(XK(2)-XK(3)))ATLAVA/XL
      A1=1.+4.AXK(2)AXK(3)A(R(3)-R(2))/(PA(XK(2)-XK(3)))
      IF(A1.LT.0.) CALL ERROR(22,A1,P)
      IF(A1.LT.0.) GO TO 8
      A1=DSQRT(A1)
      A4=XTM+0.5AETAAPA(1.+A1)
      A1=XTM+0.5AETAAPA(1.-A1)
      A2=0.5AETAADSQRT(XK(3)AP/THETA2)
      A5=(P/(4.AXK(3))+XK(2)A(R(3)-R(2))/(XK(2)-XK(3)))ATHETA2
      IF(A5.LT.0.) CALL ERROR(23,A5,P)
      IF(A5.LT.0.) GO TO 8
      A5=DSQRT(A5)
      A2=A2-A5
      A5=A2+2.AA5
      A3=0.5AETAADSQRT(XK(2)AP/THETA2)
      A6=(P/(4.AXK(2))+XK(3)A(R(3)-R(2))/(XK(2)-XK(3)))ATHETA2
      IF(A6.LT.0.) CALL ERROR(24,A6,P)
      IF(A6.LT.0.) GO TO 8
      A6=DSQRT(A6)
      A3=A3-A6
      A6=A3+2.AA6
      SC3=SC3+(F61-F323)AETRMS(A1,A2,A3,A4,A5,A6,1D0)
    9 XTM=(XK(3)AR(3)-XK(2)AR(2))ATHETA/(XK(2)-XK(3))-(R(1)+(XK(3)A
     &R(3)-XK(2)AR(2))/(XK(2)-XK(3)))ATLAVA/XL
      A1=1.+4.AXK(2)AXK(3)A(R(3)-R(2))/(PA(XK(2)-XK(3)))
      IF(A1.LT.0.) CALL ERROR(25,A1,P)
      IF(A1.LT.0.) GO TO 9
      A1=DSQRT(A1)
      A4=XTM+0.5AETAAPA(1.+A1)
      A1=XTM+0.5AETAAPA(1.-A1)
      SC3=SC3+(F8-F10)AETRMS(A1,A2,A3,A4,A5,A6,1D0)
  190 XTM=(XK(3)AR(3)-XK(1)AR(1))ATHETA/(XK(1)-XK(3))
      A1=1.+4.AXK(1)AXK(3)A(R(3)-R(1))/(PA(XK(1)-XK(3)))
      IF(A1.LT.0.) CALL ERROR(26,A1,P)
      IF(A1.LT.0.) GO TO 190
      A1=DSQRT(A1)
      A4=XTM+0.5AETAAPA(1.+A1)
      A1=XTM+0.5AETAAPA(1.-A1)
      A2=0.5AETAADSQRT(XK(3)AP/THETA)
      A5=(P/(4.AXK(3))+XK(1)A(R(3)-R(1))/(XK(1)-XK(3)))ATHETA
      IF(A5.LT.0.) CALL ERROR(27,A5,P)
      IF(A5.LT.0.) GO TO 190
      A5=DSQRT(A5)
      A2=A2-A5
      A5=A2+2.AA5
      A3=0.5AETAADSQRT(XK(1)AP/THETA)
      A6=(P/(4.AXK(1))+XK(3)A(R(3)-R(1))/(XK(1)-XK(3)))ATHETA
      IF(A6.LT.0.) CALL ERROR(28,A6,P)
      IF(A6.LT.0.) GO TO 190
      A6=DSQRT(A6)
      A3=A3-A6
      A6=A3+2.AA6
      SC3=SC3-F11AETRMS(A1,A2,A3,A4,A5,A6,1D0)
      IF(THETA2.LE.0.) GO TO 200
   10 XTM=(XK(3)AR(3)-XK(1)AR(1))ATHETA/(XK(1)-XK(3))-(R(1)+(XK(3)A
     &R(3)-XK(1)AR(1))/(XK(1)-XK(3)))ATLAVA/XL
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      A1=1.+4.*XK(1)*XK(3)*(R(3)-R(1))/(P*(XK(1)-XK(3)))
      IF(A1.LT.0.) CALL ERROR(29,A1,P)
      IF(A1.LT.0.) GO TO 10
      A1=DSQRT(A1)
      A4=XTM+0.5*ETA*P*(1.+A1)
      A1=XTM+0.5*ETA*P*(1.-A1)
      A2=0.5*ETA*DSQRT(XK(3)*P/THETA2)
      A5=(P/(4.*XK(3))+XK(1)*(R(3)-R(1))/(XK(1)-XK(3)))*THETA2
      IF(A5.LT.0.) CALL ERROR(30,A5,P)
      IF(A5.LT.0.) GO TO 10
      A5=DSQRT(A5)
      A2=A2-A5
      A5=A2+2.*A5
      A3=0.5*ETA*DSQRT(XK(1)*P/THETA2)
      A6=(P/(4.*XK(1))+XK(3)*(R(3)-R(1))/(XK(1)-XK(3)))*THETA2
      IF(A6.LT.0.) CALL ERROR(31,A6,P)
      IF(A6.LT.0.) GO TO 10
      A6=DSQRT(A6)
      A3=A3-A6
      A6=A3+2.*A6
      SC3=SC3+F11*FTRMS(A1,A2,A3,A4,A5,A6,1D0)
  200 XTM=(XK(2)*R(2)-XK(1)*R(1))*THETA/(XK(1)-XK(2))
      A1=1.+4.*XK(1)*XK(2)*(R(2)-R(1))/(P*(XK(1)-XK(2)))
      IF(A1.LT.0.) CALL ERROR(32,A1,P)
      IF(A1.LT.0.) GO TO 200
      A1=DSQRT(A1)
      A4=XTM+0.5*ETA*P*(1.+A1)
      A1=XTM+0.5*ETA*P*(1.-A1)
      A2=0.5*ETA*DSQRT(XK(2)*P/THETA)
      A5=(P/(4.*XK(2))+XK(1)*(R(2)-R(1))/(XK(1)-XK(2)))*THETA
      IF(A5.LT.0.) CALL ERROR(33,A5,P)
      IF(A5.LT.0.) GO TO 200
      A5=DSQRT(A5)
      A2=A2-A5
      A5=A2+2.*A5
      A3=0.5*ETA*DSQRT(XK(1)*P/THETA)
      A6=(P/(4.*XK(1))+XK(2)*(R(2)-R(1))/(XK(1)-XK(2)))*THETA
      IF(A6.LT.0.) CALL ERROR(34,A6,P)
      IF(A6.LT.0.) GO TO 200
      A6=DSQRT(A6)
      A3=A3-A6
      A6=A3+2.*A6
      SC3=SC3-F12*FTRMS(A1,A2,A3,A4,A5,A6,1D0)
      IF(THETA2.LE.0.) GO TO 210
   11 XTM=(XK(2)*R(2)-XK(1)*R(1))*THETA/(XK(1)-XK(2))-(R(1)+(XK(2)*
     &R(2)-XK(1)*R(1))/(XK(1)-XK(2)))*TLAVA/XL
      A1=1.+4.*XK(1)*XK(2)*(R(2)-R(1))/(P*(XK(1)-XK(2)))
      IF(A1.LT.0.) CALL ERROR(35,A1,P)
      IF(A1.LT.0.) GO TO 11
      A1=DSQRT(A1)
      A4=XTM+0.5*ETA*P*(1.+A1)
      A1=XTM+0.5*ETA*P*(1.-A1)
      A2=0.5*ETA*DSQRT(XK(2)*P/THETA2)
      A5=(P/(4.*XK(2))+XK(1)*(R(2)-R(1))/(XK(1)-XK(2)))*THETA2
      IF(A5.LT.0.) CALL ERROR(36,A5,P)
      IF(A5.LT.0.) GO TO 11
      A5=DSQRT(A5)
      A2=A2-A5
      A5=A2+2.*A5
      A3=0.5*ETA*DSQRT(XK(1)*P/THETA2)
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      A6=(P/(4.*XK(1))+XK(2)*(R(2)-R(1))/(XK(1)-XK(2)))*THETA2
      IF(A6.LT.0.) CALL ERROR(37,A6,P)
      IF(A6.LT.0.) GO TO 11
      A6=DSQRT(A6)
      A3=A3-A6
      A6=A3+2.*A6
      SC3=SC3+F12*ETRMS(A1,A2,A3,A4,A5,A6,1D0)
  210 CONTINUE
      TCORR=TCORR+DTOP
 1000 CONTINUE
 1990 T(M) = TIMSAV
      IF(SC2.LT.0.) SC2=-SC2
      IF(SC3.LT.0.) SC3=-SC3
      C(JDC,M)=0.5*SC2/NM
      C(KDC,M)=0.5*SC3/NM
 2000 CONTINUE
      RETURN
      END
      FUNCTION HEPCI(K,CURIES,NPATH)
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION HECON(100)
C     EPA DATA
      DATA HECON/3.16D-3,4.58D-2,-1.00D0,-1.00D0,6.80D-4,1.81D-3,
     &   -1.00D0,1.21D-1,6.10D-3,6.94D-2,-1.00D0,2.86D-4,-1.00D0,
     &   1.20D-1,1.09D-2,3.83D-3,1.98D-2,-1.00D0,-1.00D0,9.50D-1,
     &   3.17D00,3.17D00,1.06D00,1.06D00,1.33D00,1.06D00,1.33D00,
     &   1.06D00,5.98D-1,2.29D-2,6.93D-2,6.54D-2,1.12D-3,6.77D-2,
     &   7.31D-1,2.77D00,-1.00D0,-1.00D0,-1.00D0,-1.00D0,-1.00D0,
     &   -1.00D0,-1.00D0,-1.00D0,-1.00D0,-1.00D0,-1.00D0,-1.00D0,
     &   -1.00D0,-1.00D0,50*0.00D0/
C     RAE DATA
C     DATA HECON/-1.00D0,1.52D-4,-1.00D0,-1.00D0,2.08D-5,-1.00D0,
C    &   -1.00D0,7.69D-3,-1.00D0,-1.00D0,-1.00D0,3.33D-6,-1.00D0,
C    &   2.04D-4,1.33D-4,6.67D-5,3.45D-4,-1.00D0,-1.00D0,-1.00D0,
C    &   -1.00D0,2.63D-1,-1.00D0,-1.00D0,8.33D-3,-1.00D0,-1.00D0,
C    &   -1.00D0,6.67D-3,1.52D-4,2.86D-3,8.33D-4,-1.00D0,7.69D-4,
C    &   4.35D-3,7.69D-3,-1.00D0,-1.00D0,-1.00D0,-1.00D0,-1.00D0,
C    &   -1.00D0,-1.00D0,-1.00D0,-1.00D0,-1.00D0,-1.00D0,-1.00D0,
C    &   -1.00D0,-1.00D0/
      HEPCI=CURIES*HECON(K)
      IF(NPATH.NE.1) HEPCI=-1.
      RETURN
      END
      SUBROUTINE PEAK(NPATH)
      IMPLICIT REAL*8 (A-H,O-Z)
      CHARACTER*8 VNUCL,XNAME2
      REAL*4 C,Q,UT
      COMMON/BLK1/ALDIS,C(100,10),CANLIF,DILFAC,DOSV(5),DY,DZ,NM,NMY,
     &       NMZ,NTIME,Q(100,10),RVERT(100),T(10),TTIME(5),VA,VNUCL(5),
     &       WIDTH,WSLABL(10),XAOD,XL,XLD(100),XLL(100),XLP,XRC(100),
     &       XVV,YW,ZB
      COMMON/BLK2/ACR,ADL,AMIN,ARHO,BIV(100),BURN,CUMDOS(10),DIFCON,
     &       DIFCOV,DIFW,DOSE(3,100),DSTACK,EGAMMA(100),EPW,FEXT,FFIRE,
     &       FG,FIXINV,FIX,FWIND,HLIFE(100),HSTACK,IDSRPT,IFL(7),IFLAG,
     &       IGAMMA,INPRNT,IOPT,ISTAB,IUP,IVFAC,JUE(10),NDOSE,NISO,NNP,
     &       NP,NPN(10),PLANT,PO,QH,RFR,RAO,RUNE,SINV,SNO,SPILL,SR,SS,
     &       TBEG,TCON,TCUT,TEND,TIMOP,TIMOP1,TWV,UBR,UT(100,6),
     &       VOLATL(100),VSTACK,VWIND,XALE,XCT,XH,XKD(100),XLC,
     &       XNAME2(100),XPERC,XPOR,XR,XRECEP,XROOT,XW,XWT,XXMU(100)
      COMMON/BLK3/IFILL
```

```
      WRITE(6,100) NPATH
  100 FORMAT(/////,' ***** PEAK CONCENTRATIONS AND TIMES FOR PATHWAY ',
     & I2,' *****',///,4X,'NUCLIDE',9X,'PEAK CONCENTRATION',5X,
     & 'PEAK TIME',9X,'AVERAGE DOSE',/,' NUMBER   NAME',10X,'(CI/M**3)',
     & 12X,'(YR)',12X,'AT PEAK TIME',/,62X,'(MREM/YR)',/)
      DO 300 K=1,NDOSE
      IF(Q(K,1).EQ.0.) GO TO 300
      WRITE(5,10) K
   10 FORMAT(' K = ',I2)
      KK=K
      NTIME=5
      IPASS=0
      CMAX1=0.
      TMAX1=0.
      TBREAK=(ZB+0.5*XLP/NM)*XRC(K)/VA+XAQD*RVERT(K)/XVV+CANLIF
      TMESH=XLP*XRC(K)/(NM*VA)
      DELT=.15/XLL(K)
      IF(DELT.GT.HLIFE(K)) DELT=HLIFE(K)
      IF(DELT.GT.0.5*TBREAK) DELT=0.5*TBREAK
      DO 110 I=1,5
  110 T(I)=TBREAK+(I-3)*DELT
      TBREAK=TBREAK+TMESH
  120 CALL GW1(KK)
      IF(IFL(1).EQ.1.AND.(KK.EQ.32.OR.KK.EQ.27)) CALL GW3(38,32,27)
      IF(IFL(2).EQ.1.AND.(KK.EQ.27.OR.KK.EQ.24)) CALL GW3(32,27,24)
      IF(IFL(3).EQ.1.AND.(KK.EQ.31.OR.KK.EQ.26)) CALL GW3(36,31,26)
      IF(IFL(4).EQ.1.AND.(KK.EQ.35.OR.KK.EQ.29)) CALL GW3(33,35,29)
      IF(IFL(5).EQ.1.AND.(KK.EQ.23.OR.KK.EQ.22)) CALL GW3(30,23,22)
      IF(IFL(6).EQ.1.AND.(KK.EQ.28.OR.KK.EQ.25)) CALL GW3(34,28,25)
      IF(IFL(7).EQ.1.AND.(KK.EQ.23.OR.KK.EQ.22)) CALL GW3(28,23,22)
  130 CMIN=C(K,1)
      CMAX=CMIN
      IMAX=1
      TMAX=T(1)
      DO 140 I=2,5
      IF(C(K,I).LT.CMIN) CMIN=C(K,I)
      IF(C(K,I).LE.CMAX) GO TO 140
      CMAX=C(K,I)
      IMAX=I
      TMAX=T(I)
  140 CONTINUE
      IF(NM.EQ.1.OR.IPASS.EQ.1) GO TO 149
      IF(T(5).GT.TBREAK.AND.CMAX.LE.CMAX1) GO TO 147
      IF(CMAX.LE.CMAX1) GO TO 145
          CMAX1=CMAX
          TMAX1=TMAX
  145 CONTINUE
      IF(TBREAK-T(5).GT.10.*HLIFE(K)) GO TO 147
      IF(TMESH.GT.20./XLL(K)) GO TO 147
      IF(T(5).GT.TBREAK) TBREAK=TBREAK+TMESH
      T(1)=T(5)+DELT
      DO 146 I=2,5
  146 T(I)=T(I-1)+DELT
      GO TO 120
  147 IPASS=1
      DO 148 I=1,5
  148 T(I)=TMAX1+(I-3)*DELT
      GO TO 120
  149 IF(CMAX.EQ.0.) GO TO 300
      NTIME=1
```

```
      GO TO (150,210,210,210,180) IMAX
  150 DO 160 I=1,5
  160 T(I)=T(I)-DELT
      DO 170 I=5,2,-1
  170 C(K,I)=C(K,I-1)
      GO TO 120
  180 T(1)=T(5)+DELT
      CALL GW1(KK)
      IF(IFL(1).EQ.1.AND.(KK.EQ.32.OR.KK.EQ.27)) CALL GW3(38,32,27)
      IF(IFL(2).EQ.1.AND.(KK.EQ.27.OR.KK.EQ.24)) CALL GW3(32,27,24)
      IF(IFL(3).EQ.1.AND.(KK.EQ.31.OR.KK.EQ.26)) CALL GW3(36,31,26)
      IF(IFL(4).EQ.1.AND.(KK.EQ.35.OR.KK.EQ.29)) CALL GW3(33,35,29)
      IF(IFL(5).EQ.1.AND.(KK.EQ.23.OR.KK.EQ.22)) CALL GW3(30,23,22)
      IF(IFL(6).EQ.1.AND.(KK.EQ.28.OR.KK.EQ.25)) CALL GW3(34,28,25)
      IF(IFL(7).EQ.1.AND.(KK.EQ.23.OR.KK.EQ.22)) CALL GW3(28,23,22)
      CSAVE=C(K,1)
      DO 190 I=1,4
  190 C(K,I)=C(K,I+1)
      C(K,5)=CSAVE
      T(5)=T(1)
      DO 200 I=4,1,-1
  200 T(I)=T(I+1)-DELT
      GO TO 130
  210 NTIME=2
  220 T(3)=TMAX-DELT
      T(4)=TMAX
      T(5)=TMAX+DELT
      DELT=0.5*DELT
      T(1)=TMAX-DELT
      T(2)=TMAX+DELT
      CALL GW1(KK)
      IF(IFL(1).EQ.1.AND.(KK.EQ.32.OR.KK.EQ.27)) CALL GW3(38,32,27)
      IF(IFL(2).EQ.1.AND.(KK.EQ.27.OR.KK.EQ.24)) CALL GW3(32,27,24)
      IF(IFL(3).EQ.1.AND.(KK.EQ.31.OR.KK.EQ.26)) CALL GW3(36,31,26)
      IF(IFL(4).EQ.1.AND.(KK.EQ.35.OR.KK.EQ.29)) CALL GW3(33,35,29)
      IF(IFL(5).EQ.1.AND.(KK.EQ.23.OR.KK.EQ.22)) CALL GW3(30,23,22)
      IF(IFL(6).EQ.1.AND.(KK.EQ.28.OR.KK.EQ.25)) CALL GW3(34,28,25)
      IF(IFL(7).EQ.1.AND.(KK.EQ.23.OR.KK.EQ.22)) CALL GW3(28,23,22)
      CMIN=CMAX
      DO 230 I=1,2
      IF(C(K,I).LT.CMIN) CMIN=C(K,I)
      IF(C(K,I).LE.CMAX) GO TO 230
      CMAX=C(K,I)
      TMAX=T(I)
  230 CONTINUE
      IF((CMAX-CMIN)/CMAX.GT.0.02) GO TO 220
      PEKDOS=1.E9*DOSE(1,K)*UT(K,1)*CMAX
      IF(NPATH.EQ.2) PEKDOS=1.E9*DOSE(1,K)*UT(K,2)*CMAX
      WRITE(6,240) K,XNAME2(K),CMAX,TMAX,PEKDOS
  300 CONTINUE
  240 FORMAT(2X,I3,3X,A8,7X,1PE10.2,9X,E10.2,9X,E10.2)
      RETURN
      END
      FUNCTION HUNG(UU,DL,VV)
C     CALCULATIONS FOR DISPERSION CONCENTRATION FACTOR - HUNG(X,Y,Z)
      IMPLICIT REAL*8 (A-H,O-Z)
C     DD IS THE DISPERSION COEFFICIENT FOR HUNG FUNCTION
      DD=0.3
      XDL=DL/(DD*2.)
      XUU=UU*DD/VV
```

```
      T2R=DSQRT(4.*XUU*VV+VV*VV)
      ARG=XDL*(VV+2.*XUU-T2R)
      IF(ARG.GT.6.93) GOTO 3939
      IF(ARG.LT.0.) GOTO 3940
      HUNG=DEXP(ARG)
      RETURN
 3939 HUNG=1000.
      RETURN
 3940 HUNG=1.
      RETURN
      END
      FUNCTION COV(J,Y,TE,TH,B,TV)
C     CALCULATION OF NUCLIDE CONC IN FORAGE, PRODUCE, & VEGETABLES
      IMPLICIT REAL*8 (A-H,O-Z)
      CHARACTER*3 NUCLID,VNUCL
      REAL*4 C,Q
      COMMON/BLK1/ALDIS,C(100,10),CANLIF,DILFAC,DOSV(5),DY,DZ,NH,NMY,
     &        NMZ,NTIME,Q(100,10),RVERT(100),T(10),TTIME(5),VA,VNUCL(5),
     &        WIDTH,WSLABL(10),XAQD,XL,XLD(100),XLL(100),XLP,XRC(100),
     &        XVV,YW,ZB
      COMMON/UPTAK/BDENS,BR,COL1,COP1,COCMI1,COFISH,COGMI1,COMEAT,CWAT,
     &        DECA,FF,FI,FIS,FMC,FMG,FP,FS,INTAKE(5),KK,NUCLID,PORS,PP,
     &        QBW,QCW,QFC,QFG,QGW,RW,SINFL,TE1,TE2,TFIS,TF1,TH1,TH2,TH3,
     &        TH4,TIMAV,TS,UCMILK,UFISH,UGMILK,ULEAFY,UMEAT,UPROD,UWAT,
     &        WIRATE,XAMBWE,Y1,Y2
C     CSPO/PP = SOIL CONCENTRATION IN PCI/KG
      XAMBEF=DECA+XAMBWE
      TERM1=WIRATE*CWAT*TV*RW*(1.-DEXP(-XAMBEF*TE))/(Y*XAMBEF)
      CSPO=PP
      IF(KK .EQ. 6) GO TO 100
        RET=1.+BDENS*RVERT(J)/PORS
        TDEC=XLD(J)+SINFL/(0.15*RET)
        EXP1=0.
        EXP2=0.
        IF(XLD(J)*TIMAV .LE. 85.) EXP1=DEXP(-XLD(J)*TIMAV)
        IF(TDEC*TIMAV .LE. 85.) EXP2=DEXP(-TDEC*TIMAV)
        ARG = (1.-EXP1)/XLD(J) - (1.-EXP2)/TDEC
        IF(SINFL .EQ. 0.) ARG=(1.-(1.+XLD(J)*TIMAV)*DEXP(-XLD(J)
     & *TIMAV))/(XLD(J)**2*TIMAV)
        IF(SINFL .GT. 0.) ARG = ARG/(TIMAV*(TDEC-XLD(J)))
        CSPO = CWAT*WIRATE*8/60.*FI*ARG
  100 TERM2=CSPO*B/PP
      COV=(TERM1+TERM2)*DEXP(-DECA*TH)
      RETURN
      END

      FUNCTION FTRMS(A1,A2,A3,A4,A5,A6,T)
      IMPLICIT REAL*8 (A-H,O-Z)
C     THIS FUNCTION COMPUTES:
C      EXP(A1)*(ERFC(A2)-U(T)*ERFC(A3))+EXP(A4)*(ERFC(A5)-U(T)*ERFC(A6))
C          U(T) = UNIT STEP FUNCTION  ( IF(T.LE.0) U=0, IF(T.GT.0) U=1 )
      FTRMS=0.
      SIGN=1.
      IF(A2.LT.0.0.AND.T.GT.0.) SIGN=-1.
      ARG=A1+ERFCPA(A2*SIGN)
      IF(ARG.GT.85.) ARG=85.
      IF(ARG.LT.-85.) GO TO 10
      FTRMS=SIGN*DEXP(ARG)
   10 IF(T.LE.0.) GO TO 20
      ARG=A1+ERFCPA(A3*SIGN)
```

```
      IF(ARG.GT.85.) ARG=85.
      IF(ARG.LT.-85.) GO TO 20
      FTRMS=FTRMS-SIGN*DEXP(ARG)
   20 ARG=A4+ERFCPA(A5)
      IF(ARG.GT.85.) ARG=85.
      IF(ARG.LT.-85.) GO TO 30
      FTRMS=FTRMS+DEXP(ARG)
   30 IF(T.LE.0.) GO TO 40
      ARG=A4+ERFCPA(A6)
      IF(ARG.GT.85.) ARG=85.
      IF(ARG.LT.-85.) GO TO 40
      FTRMS=FTRMS-DEXP(ARG)
   40 RETURN
      END
      FUNCTION DERF(Z)
      IMPLICIT REAL*8 (A-H,O-Z)
C     SERIES EXPANSION FOR ERF Z FOUND IN ABRAMOWITZ & STEGUN #7.1.5
      IF(DABS(Z).LT.2.) GO TO 10
      DERF=1.-DERFC(Z)
      GO TO 50
   10 SUM=0.
      IF(Z.EQ.0.) GO TO 40
      Z2=Z*Z
      ZPOWR=Z
      FAC=1.
      N2P1=1
      TERM=Z
      DO 20 I=1,30
      SUM=SUM+TERM
      ZPOWR=-ZPOWR*Z2
      FAC=FAC*I
      N2P1=N2P1+2
      TERM=ZPOWR/(FAC*N2P1)
      IF(DABS(TERM/SUM).LT.1.E-15) GO TO 30
   20 CONTINUE
   30 SUM=SUM+TERM
   40 DERF=1.128379167095513*SUM
   50 RETURN
      END
      SUBROUTINE ERROR(I,X,P)
      IMPLICIT REAL*8 (A-H,O-Z)
C     THIS SUBROUTINE TESTS AND CORRECTS ARGUMENTS OF
C        SQUARE ROOT OPERATIONS THAT ARE NEGATIVE.
C
      X=0.
      P=P*10.
C     WRITE(5,100) I
C 100 FORMAT(' SQUARE ROOT HAS NEGATIVE ARGUMENT AT LOCATION ',I2,
C    &' IN SUBROUTINE GW3')
      RETURN
      END
      FUNCTION DERFC(Z)
      IMPLICIT REAL*8 (A-H,O-Z)
C     BASED ON CONTINUED FRACTION FROM ABRAMOWITZ & STEGUN #7.1.14
      IF(DABS(Z).GE.2.) GO TO 10
      DERFC=1.-DERF(Z)
      GO TO 30
   10 XNUM=20.
      ZAB=DABS(Z)
      FRAC=ZAB
      DO 20 I=1,40
```

```
      FRAC=ZAB+XNUM/FRAC
   20 XNUM=XNUM-0.5
      DERFC=0.
      IF(ZAB.LE.9.3) DERFC=DEXP(-ZAB*ZAB)/(FRAC*1.772453850905516)
      IF(Z.LT.0.) DERFC=2.-DERFC
   30 RETURN
      END
      FUNCTION ERFCPA(Z)
      IMPLICIT REAL*8 (A-H,O-Z)
C     ERFCPA IS NATURAL LOG OF COMPLEMENTARY ERROR FUNCTION
C     BASED ON CONTINUED FRACTION FROM ABRAMOWITZ & STEGUN #7.1.14
      IF(Z.GE.2.) GO TO 10
      ERFCPA=DLOG(DERFC(Z))
      GO TO 30
   10 XNUM=20.
      FRAC=Z
      DO 20 I=1,40
      FRAC=Z+XNUM/FRAC
   20 XNUM=XNUM-0.5
      ERFCPA=-(Z*Z+DLOG(FRAC*1.772453850905516))
   30 RETURN
      END
```

APPENDIX B

DATA FILES AND OUTPUT FROM PATHRAE-EPA FOR SAMPLE PROBLEM

APPENDIX B

DATA FILES AND OUTPUT FROM PATHRAE-EPA FOR SAMPLE PROBLEM

The five data sets used for the sample problem described in Chapter 4 are presented here. Each data set is displayed in two forms. First, the Fortran variables are given in the order in which they are read (load form). Then the data set is given in the form read by PATHRAE-EPA.

B.1 DATA SET ONE - BRCDCF.DAT

```
NDOSE, TCUT, SINV
NTIME, (T(M), M=1, NTIME)
KK, XNAME2(KK), (DOSE(I,KK), I=1,3),(UT1(I,KK), UT2(I,KK), I = 1,3)
```

Note: The last line is repeated for each nuclide in the dose library.

```
80,0.,0.
10,0.,1.,15.,50.,100.,200.,350.,500.,750.,1000.
41,H-3      8.6E-8,  1.2E-7,  0.,0.,0.,0.,0.,0.,0.
42,C-14     1.5E-6,  1.1E-8,  0.,0.,0.,0.,0.,0.,0.
43,Fe-55    4.7E-7,  1.9E-6,  9.6E-13,0.,0.,0.,0.,0.,0.
44,Co-60    5.8E-6,  4.0E-4,  1.2E-08,0.,0.,0.,0.,0.,0.
45,Ni-59    1.5E-7,  1.7E-6,  1.8E-12,0.,0.,0.,0.,0.,0.
46,Ni-63    3.7E-7,  4.4E-6,  0.,0.,0.,0.,0.,0.,0.
47,Sr-90    5.6E-6,  2.0E-4,  0.,0.,0.,0.,0.,0.,0.
48,Nb-94    2.7E-6,  5.8E-4,  8.0E-09,0.,0.,0.,0.,0.,0.
49,Tc-99    1.9E-6,  2.2E-5,  2.9E-15,0.,0.,0.,0.,0.,0.
50,I-129    8.6E-4,  5.7E-4,  8.1E-11,0.,0.,0.,0.,0.,0.
51,Cs-135   6.5E-6,  4.5E-6,  0.,0.,0.,0.,0.,0.,0.
52,Ba137m   0.0E+0,  1.4E-9,  3.1E-09,0.,0.,0.,0.,0.,0.
53,Cs-137   4.4E-5,  3.0E-5,  0.,0.,0.,0.,0.,0.,0.
54,Ra-226   7.4E-4,  2.1E-2,  3.7E-11,0.,0.,0.,0.,0.,0.
55,Th-232   2.2E-4,  2.5E-1,  2.8E-12,0.,0.,0.,0.,0.,0.
56,U-234    8.4E-6,  1.9E-1,  3.3E-12,0.,0.,0.,0.,0.,0.
57,U-235    8.6E-6,  1.8E-1,  8.3E-10,0.,0.,0.,0.,0.,0.
58,U-238    7.9E-6,  1.7E-1,  2.6E-12,0.,0.,0.,0.,0.,0.
59,Np-237   3.1E-3,  4.0E-1,  1.4E-10,0.,0.,0.,0.,0.,0.
60,Pu-238   2.9E-3,  3.6E-1,  3.4E-12,0.,0.,0.,0.,0.,0.
61,Pu-239   3.4E-4,  3.7E-1,  1.6E-12,0.,0.,0.,0.,0.,0.
62,Pu-241   7.6E-5,  4.4E-3,  0.,0.,0.,0.,0.,0.,0.
```

```
63,Pu-242   3.3E-4,  3.5E-1,  2.7E-12,0.,0.,0.,0.,0.,0.
64,Am-241   3.4E-3,  4.4E-1,  1.3E-10,0.,0.,0.,0.,0.,0.
65,Am-243   3.5E-3,  4.4E-1,  2.9E-10,0.,0.,0.,0.,0.,0.
66,Cm-243   2.0E-3,  2.7E-1,  7.0E-10,0.,0.,0.,0.,0.,0.
67,Cm-244   1.6E-3,  2.1E-1,  3.2E-12,0.,0.,0.,0.,0.,0.
68,Ru-106   1.1E-5,  1.2E-3,  0.,0.,0.,0.,0.,0.,0.
69,Sb-125   0.0E+0,  2.8E-5,  2.2E-09,0.,0.,0.,0.,0.,0.
70,Cs-134   6.6E-5,  4.5E-5,  8.0E-09,0.,0.,0.,0.,0.,0.
71,Eu-154   0.0E+0,  3.4E-4,  6.1E-09,0.,0.,0.,0.,0.,0.
72,Pb-214   3.8E-7,  7.8E-7,  1.3E-09,0.,0.,0.,0.,0.,0.
73,Bi-214   3.0E-7,  2.4E-7,  7.2E-09,0.,0.,0.,0.,0.,0.
74,Pb-210   3.8E-4,  9.8E-3,  1.2E-11,0.,0.,0.,0.,0.,0.
75,Po-210   6.4E-4,  1.7E-2,  4.4E-14,0.,0.,0.,0.,0.,0.
76,Ra-228   0.0E+0,  4.5E-5,  4.6E-09,0.,0.,0.,0.,0.,0.
77,Ac-228   4.7E-4,  4.0E-3,  2.9E-18,0.,0.,0.,0.,0.,0.
78,Th-228   7.7E-5,  5.5E-1,  1.3E-11,0.,0.,0.,0.,0.,0.
79,Pb-212   2.4E-5,  2.8E-4,  8.0E-10,0.,0.,0.,0.,0.,0.
80,Tl-208   0.0E+0,  0.0E+0,  1.6E-08,0.,0.,0.,0.,0.,0.
```

B.2 DATA SET TWO - ABCDEF.DAT

```
(A(I), I = 1,10)
NISO, IFLAG, NNP
(NPN(J), JUF(J), J=1, NNP)
TIMOP, XLP, WIDTH, RFR, XR, SPILL
ARHO, ALDIS, DY, DZ, SS, SR, PV, SNO
NM, IGAMMA, IVFAC
XCT, XWT, TWV, XW, YW, RHO, FG, FEXT, XROOT, PLANT
ADL, UBR, FTX, CANLIF, FIXINV
XH, ACR, EPW, DIFW, DIFCON, TCON, DIFCOV
ISTAB, VWIND, FWIND, XRECEP, BURN, FFIRE, HSTACK, DSTACK, VSTACK, QH
(IFL(I), I = 1,7)
INPRNT, IDSRPT, IFILL, IOPT
```

```
******** 6  PWRHU - MD     SE     3/86            ********
29,0,7
2,2, 3,1, 5,1, 6,1, 7,0, 8,0, 10,0
20.,590.,590.,3.57E5,50.,0.0
1600.,0.,0.,0.,.801,0.,0.,0.
20,0,2
0.6,6.,2.10E6,50.,0.,590.,0.22,0.228,1.,0.
5.E-7,8035.,0.228,0.,1.
240.0,5.56E-04,0.2,2.00E-02,6.00E-05,20.0,1.14E-02
4,2.01,0.093,345.,2.51E-5,0.00274,1.0,0.,0.,0.
0,0,0,0,0,0,0
1,0,0,0
```

B.3 DATA SET THREE - RQSITE.DAT

XPERC, VA, XPOR, XAQD, XVV, XLC, XALE, FLCH, RUNF
KK, XLL(KK), XKD(KK), RVERTI(KK)

Note: The last line is repeated for each nuclide in the inventory.

```
.454,27.8,.39,7.7,1.11,10.,1.96E-4,1.0,.322
41,3.48E-3, .01, .01
42,3.48E-3, .01, .01
43,2.99E-5,6000.,6000.
44,2.99E-5,55., 55.
45,2.99E-5,150.,150.
46,2.99E-5,150.,150.
47,4.96E-5,20.,150.
48,2.14E-5,350.,350.
49,1.63E-3, .5, .5
50,4.40E-4, 3., 3.
51,1.50E-5,500.,1000.
52,1.50E-5,500.,1000.
53,1.50E-5,500.,1000.
54,6.84E-6,2.20E+2,2.20E+2
55,2.51E-8,6.00E+4,6.00E+4
56,2.01E-6,7.50E+2,7.50E+2
57,2.01E-6,750.,750.
58,2.01E-6,7.50E+2,7.50E+2
59,2.78E-4, 5., 5.
60,2.15E-6,3500.,3500.
61,2.15E-6,3500.,3500.
62,2.15E-6,3500.,3500.
63,2.15E-6,3500.,3500.
64,1.87E-5,80000.,80000.
65,1.87E-5,80000.,80000.
66,2.15E-6,3300.,3300.
67,2.15E-6,3300.,3300.
68,2.14E-5,220.,220.
69,3.32E-5, 45.,45.
70,1.50E-5,500.,1000.
71,7.54E-7,4000.,4000.
72,6.84E-6,2.20E+2,2.20E+2
73,6.84E-6,2.20E+2,2.20E+2
74,6.84E-6,2.20E+2,2.20E+2
75,6.84E-6,2.20E+2,2.20E+2
76,6.84E-6,2.20E+2,2.20E+2
77,6.84E-6,2.20E+2,2.20E+2
78,2.51E-8,6.00E+4,6.00E+4
79,2.51E-8,6.00E+4,6.00E+4
80,2.51E-8,6.00E+4,6.00E+4
```

B.4 DATA SET FOUR - INVNTRY.DAT

KK, HLIFE(KK), Q(KK,M), XXMU(KK), EGAMMA(KK), BIV(KK), SOL(KK), VOLATL(KK)

Note: This line is repeated for each nuclide in the inventory.

```
41,1.23E+01,1.31E+02,0.00E-01,0.00E-01,0.00E+00,0.,0.9
42,5.73E+03,7.43E+00,0.00E-01,0.00E-01,0.00E+00,0.,0.75
43,2.70E+00,1.20E+02,0.00E+00,0.00E+00,4.00E-03,0.,0.0025
44,5.25E+00,2.46E+02,8.30E+00,1.25E+00,2.00E-02,0.,0.0025
45,8.00E+04,1.43E-01,0.00E-01,0.00E-01,6.00E-02,0.,0.0025
46,9.20E+01,4.41E+01,0.00E-01,0.00E-01,6.00E-02,0.,0.0025
47,2.86E+01,3.40E+00,2.00E+01,3.39E-01,2.50E+00,0.,0.0025
48,2.00E+04,4.54E-03,1.15E+01,7.87E-01,2.00E-02,0.,0.0025
49,2.13E+05,1.90E-03,0.00E-01,0.00E-01,9.50E+00,0.,0.01
50,1.70E+07,5.61E-03,9.70E+01,3.96E-02,1.50E-01,0.,0.01
51,3.01E+06,1.90E-03,0.00E-01,0.00E-01,8.00E-02,0.,0.0025
52,3.00E+01,5.70E+01,1.30E+01,6.62E-01,1.50E-01,0.,0.0025
53,3.00E+01,5.70E+01,1.30E+01,6.62E-01,8.00E-02,0.,0.0025
56,4.47E+09,4.27E-03,5.00E+01,1.20E-01,8.50E-03,0.,0.0025
57,7.04E+08,6.85E-05,2.90E+01,1.77E-01,8.50E-03,0.,0.0025
58,4.47E+09,1.25E-03,6.30E+01,4.80E-02,8.50E-03,0.,0.0025
59,2.10E+06,9.68E-06,5.00E+01,6.02E-02,1.00E-01,0.,0.0025
60,8.77E+01,1.20E-01,5.00E+01,5.62E-02,4.50E-04,0.,0.0025
61,2.42E+04,1.12E-01,5.00E+01,1.37E-01,4.50E-04,0.,0.0025
62,1.32E+01,4.85E+00,5.00E+01,1.32E-01,4.50E-04,0.,0.0025
63,3.79E+05,2.43E-04,5.00E+01,0.00E-01,4.50E-04,0.,0.0025
64,4.59E+02,2.31E-01,5.00E+01,5.74E-02,5.50E-03,0.,0.0025
65,7.37E+03,5.41E-05,5.00E+01,7.29E-02,5.50E-03,0.,0.0025
66,3.19E+01,5.52E-05,1.80E+01,2.24E-01,8.50E-04,0.,0.0025
67,1.76E+01,5.26E-02,5.00E+01,6.66E-02,8.50E-04,0.,0.0025
68,1.01E+00,5.04E-02,1.40E+01,6.00E-01,7.50E-02,0.,0.01
69,2.77E+00,1.85E+00,1.70E+01,4.60E-01,2.00E-01,0.,0.0025
70,2.06E+00,5.04E+01,1.20E+01,7.00E-01,8.00E-02,0.,0.0025
71,8.50E+00,1.86E-01,1.00E+01,1.00E+00,1.00E-02,0.,0.0025
```

B.5 DATA SET FIVE - UPTAKE.DAT

```
SINFL, PORS, BDENS
Y1, Y2, XAMBWE, TE1, TE2
TH1, TH2, TH3, TH4, FP, FS
QFC, QFG, TF1, TS, TFIS
FI, WIRATE, QCW, QGW, QBW
ULEAFY, UPROD, UCMILK, UMEAT, UWAT, UFISH
NUCLID(K), RW(K), BR(K), FMC(K), FMG(K), FF(K), FIS(K)
```

Note: The last line is repeated for each nuclide in the inventory.

```
0.43, 0.39, 1.60
0.67, 0.65, 2.1E-3, 720., 1440.
 0.0,2160.,  24.,  1440.,  1.0, 0.83
 50.,   6.,  48.,   480.,  0.
0.40, .015,  60.,     8.,   50.
 14., 88.5, 89.4,     0., 62.8, 481.6, 0.
H-3      .25,       0.,       0.,       0.,       0., 9.0E-1
C-14     .25,       0.,       0.,       0.,       0., 4.6E3
Fe-55    .25,     .001, 2.5E-4, 1.3E-4, 2.0E-2, 1.0E2
Co-60    .25,     .007, 2.0E-3, 1.0E-3, 2.0E-2, 5.0E1
Ni-59    .25,      .06, 1.0E-3, 6.7E-3, 6.0E-3, 1.0E2
Ni-63    .25,      .06, 1.0E-3, 6.7E-3, 6.0E-3, 1.0E2
Sr-90    .25,      .25, 1.5E-3, 1.4E-2, 3.0E-4, 3.0E1
Nb-94    .25,     .005, 2.0E-2, 2.5E-3, 2.5E-1, 3.0E4
Tc-99    .25,      1.5, 1.0E-2, 2.5E-2, 8.5E-3, 1.5E1
I-129    .25,     0.05, 1.0E-2, 3.0E-1, 7.0E-3, 1.5E1
Cs-135   .25,      .03, 7.0E-3, 3.0E-1, 2.0E-2, 2.0E3
Ba-137M  .25, 1.5E-2, 3.5E-4, 3.0E-1, 1.5E-4,     0.
Cs-137   .25,      .03, 7.0E-3, 3.0E-1, 2.0E-2, 2.0E3
Ra-226   .25, 1.5E-3, 4.5E-4, 5.0E-6, 2.5E-4, 5.0E1
Th-232   .25, 8.5E-5, 5.0E-6,     0.,   6.0E-6, 3.0E1
U-234    .25, 4.0E-3, 6.0E-4, 5.0E-4, 2.0E-4, 2.0E0
U-235    .25, 4.0E-3, 6.0E-4, 5.0E-4, 2.0E-4, 2.0E0
U-238    .25, 4.0E-3, 6.0E-4, 5.0E-4, 2.0E-4, 2.0E0
Np-237   .25, 1.0E-2, 5.0E-6, 5.0E-6, 5.5E-5, 1.0E1
Pu-238   .25, 4.5E-5, 1.0E-7, 1.5E-6, 5.0E-7, 3.5E0
Pu-239   .25, 4.5E-5, 1.0E-7, 1.5E-6, 5.0E-7, 3.5E0
Pu-241   .25, 4.5E-5, 1.0E-7, 1.5E-6, 5.0E-7, 3.5E0
Pu-242   .25, 4.5E-5, 1.0E-7, 1.5E-6, 5.0E-7, 3.5E0
Am-241   .25, 2.5E-4, 4.0E-7,     0.,   3.5E-6, 2.5E1
Am-243   .25, 2.5E-4, 4.0E-7,     0.,   3.5E-6, 2.5E1
Cm-243   .25, 1.5E-5, 2.0E-5,     0.,   3.5E-6, 2.5E1
Cm-244   .25, 1.5E-5, 2.0E-5,     0.,   3.5E-6, 2.5E1
Ru-106   .25,      .02, 6.0E-7, 1.3E-4, 2.0E-3, 1.0E1
Sb-125   .25,      .03, 1.0E-4, 1.5E-3, 1.0E-3, 1.0E0
Cs-134   .25,      .03, 7.0E-3, 3.0E-1, 2.0E-2, 2.0E3
Eu-154   .25, 4.0E-3, 2.0E-5, 2.0E-5, 5.0E-3, 2.5E1
Pb-214   .25, 9.0E-3, 5.0E-4,       0., 4.0E-4,     0.
Bi-214   .25, 9.0E-3, 5.0E-4,       0., 4.0E-4,     0.
Pb-210   .25, 9.0E-3, 5.0E-4,       0., 4.0E-4, 1.0E2
Po-210   .25, 9.0E-3, 5.0E-4,       0., 4.0E-4, 5.0E2
Ra-228   .25, 1.5E-3, 4.5E-4, 5.0E-6, 2.5E-4, 5.0E1
Ac-228   .25, 3.5E-4, 2.0E-5,       0., 2.5E-5,     0.
Th-228   .25, 8.5E-5, 5.0E-6,       0., 6.0E-6, 3.0E1
Pb-212   .25, 9.0E-3, 2.0E-3,       0., 4.0E-2,     0.
Tl-208   .25, 9.0E-3, 2.0E-3,       0., 4.0E-2,     0.
```

B.6 OUTPUT FROM PATHRAE-EPA

The following is the output from the PATHRAE-EPA computer code for the sample problem generated by the five data sets defined in Sections B.1 through B.5, and described in detail in Chapter 4.

TOTAL EQUIVALENT UPTAKE FACTORS FOR PATHRAE

NUCLIDE	UT(J,1) RIVER L/YR	UT(J,2) WELL L/YR	UT(J,3) EROSION L/YR	UT(J,4) BATHTUB L/YR	UT(J,5) SPILLAGE L/YR	UT(J,6) FOOD KG/YR
H-3	5.841E+02	5.841E+02	5.841E+02	5.841E+02	5.841E+02	0.000E-01
C-14	4.816E+02	4.816E+02	4.816E+02	4.816E+02	4.816E+02	0.000E-01
Fe-55	7.128E+02	7.128E+02	7.128E+02	7.128E+02	7.128E+02	9.002E-02
Co-60	7.384E+02	7.384E+02	7.384E+02	7.384E+02	7.384E+02	5.397E-01
Ni-59	6.067E+02	6.067E+02	6.067E+02	7.287E+02	7.066E+02	1.492E+00
Ni-63	6.066E+02	6.066E+02	6.066E+02	6.116E+02	6.131E+02	1.490E+00
Sr-90	5.649E+02	5.649E+02	5.649E+02	5.678E+02	5.691E+02	1.173E+01
Nb-94	2.973E+03	2.973E+03	2.973E+03	3.449E+03	3.352E+03	5.077E+00
Tc-99	7.704E+02	7.704E+02	7.704E+02	1.012E+03	1.012E+03	2.238E+02
I-129	7.347E+02	7.347E+02	7.347E+02	7.538E+02	7.537E+02	3.848E+00
Cs-135	8.075E+02	8.075E+02	8.075E+02	1.094E+03	1.030E+03	2.753E+00
Ba137m	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01
Cs-137	8.070E+02	8.070E+02	8.070E+02	8.079E+02	8.082E+02	2.746E+00
U-234	5.510E+02	5.510E+02	5.510E+02	5.594E+02	5.576E+02	8.233E-02
U-235	5.510E+02	5.510E+02	5.510E+02	5.594E+02	5.576E+02	8.233E-02
U-238	5.510E+02	5.510E+02	5.510E+02	5.594E+02	5.576E+02	8.233E-02
Np-237	5.419E+02	5.419E+02	5.419E+02	5.440E+02	5.440E+02	2.633E-01
Pu-238	5.413E+02	5.413E+02	5.413E+02	5.413E+02	5.413E+02	1.160E-03
Pu-239	5.413E+02	5.413E+02	5.413E+02	5.415E+02	5.414E+02	1.161E-03
Pu-241	5.410E+02	5.410E+02	5.410E+02	5.410E+02	5.410E+02	1.154E-03
Pu-242	5.413E+02	5.413E+02	5.413E+02	5.415E+02	5.414E+02	1.161E-03
Am-241	5.414E+02	5.414E+02	5.414E+02	5.417E+02	5.417E+02	9.238E-03
Am-243	5.414E+02	5.414E+02	5.414E+02	5.423E+02	5.421E+02	9.239E-03
Cm-243	5.415E+02	5.415E+02	5.415E+02	5.415E+02	5.415E+02	1.056E-03
Cm-244	5.414E+02	5.414E+02	5.414E+02	5.414E+02	5.414E+02	1.055E-03
Ru-106	5.535E+02	5.535E+02	5.535E+02	5.535E+02	5.535E+02	4.884E-01
Sb-125	5.496E+02	5.496E+02	5.496E+02	5.495E+02	5.495E+02	8.564E-01
Cs-134	8.000E+02	8.000E+02	8.000E+02	7.998E+02	7.998E+02	2.646E+00
Eu-154	5.841E+02	5.841E+02	5.841E+02	5.841E+02	5.841E+02	1.200E-01

AAAAAAAAAA PATHRAE INPUT SUMMARY AAAAAAAAAA

THERE ARE 80 ISOTOPES IN THE DOSE FACTOR LIBRARY
THE CUTOFF VALUE FOR NUCLIDE HALF LIVES IS 0.0 YEARS
DEFAULT INVENTORY VALUE FOR CUTOFF NUCLIDES IS 0.00E-01 CI
NUMBER OF TIMES FOR CALCULATION IS 10
YEARS TO BE CALCULATED ARE ...

0.00	1.00	15.00	50.00	100.00
200.00	350.00	500.00	750.00	1000.00

THERE ARE 29 ISOTOPES IN THE INVENTORY FILE
THE VALUE OF IFLAG IS 0
NUMBER OF PATHWAYS IS 7

PATHWAY	TYPE OF USAGE FOR UPTAKE FACTORS
2 GROUNDWATER TO WELL	2

3 EROSION	1
5 FOOD GROWN ON SITE	1
6 NATURAL BIOINTRUSION	1
7 DIRECT GAMMA	0
8 DUST INHALATION	0
10 ATMOSPHERIC TRANSPORT	0

TIME OF OPERATION OF WASTE FACILITY IN YEARS	20.
LENGTH OF REPOSITORY (METERS)	590.
WIDTH OF REPOSITORY (METERS)	590.
FLOW RATE OF RIVER (CUBIC METERS/YEAR)	3.57E+05
DISTANCE TO RIVER (METERS)	50.
DENSITY OF AQUIFER (KG/CUBIC METER)	1600.
LONGITUDINAL DISPERSIVITY (M)	0.00E-01
LATERAL DISPERSION COEFFICIENT -- Y AXIS (MAA2/YR)	0.00E-01
NUMBER OF MESH POINTS FOR DISPERSION CALCULATION	20
FLAG FOR GAMMA PATHWAY OPTIONS	0
FLAG FOR ATMOSPHERIC PATHWAY	1
COVER THICKNESS OVER WASTE (METERS)	0.60
THICKNESS OF WASTE IN PITS (METERS)	6.00
TOTAL WASTE VOLUME (MAA3)	2.100E+06
DISTANCE TO WELL -- X COORDINATE (METERS)	50.
DISTANCE TO WELL -- Y COORDINATE (METERS)	0.
DENSITY OF WASTE (KG/MAA3)	590.
FRACTION OF FOOD CONSUMED THAT IS GROWN ON SITE	0.220
FRACTION OF YEAR SPENT IN DIRECT RADIATION FIELD	0.228
DEPTH OF PLANT ROOT ZONE (METERS)	1.000
AREAL DENSITY OF PLANTS (KG/MAA2)	0.000
AVERAGE DUST LOADING IN AIR (KG/MAA3)	5.00E-07
ANNUAL ADULT BREATHING RATE (MAA3/YR)	8035.
FRACTION OF YEAR EXPOSED TO DUST	0.228
CANISTER LIFETIME (YEARS)	0.
INVENTORY SCALING FACTOR	1.00E+00
HEIGHT OF ROOMS IN RECLAIMER HOUSE (CM)	240.
AIR CHANGE RATE IN RECLAIMER HOUSE (CHANGES/SEC)	5.56E-04
RADON EMANATING POWER OF THE WASTE	3.00E-01
DIFFUSION COEFF. OF RADON IN WASTE (CMAA2/SEC)	2.00E-02
DIFFUSION COEFF. OF RN IN CONCRETE (CMAA2/SEC)	6.00E-05
THICKNESS OF CONCRETE SLAB FLOOR (CM)	20.0
DIFFUSION COEFF. OF RADON IN COVER (CMAA2/SEC)	1.14E-02
ATMOSPHERIC STABILITY CLASS	4
AVERAGE WIND SPEED (M/S)	2.01
FRACTION OF TIME WIND BLOWS TOWARD RECEPTOR	0.0930
RECEPTOR DISTANCE FOR ATMOSPHERIC PATHWAY (M)	345.0
INCINERATOR OR TRENCH FIRE BURN RATE (MAA3/S)	2.51E-05
FRACTION OF YEAR FIRE BURNS	0.0027
STACK HEIGHT (M)	1.0
STACK INSIDE DIAMETER (M)	0.00
STACK GAS VELOCITY (M/S)	0.0
HEAT EMISSION RATE FROM BURNING (CAL/S)	0.00E-01
FLAG FOR INPUT SUMMARY PRINTOUT	1
FLAG FOR DIRECTION OF TRENCH FILLING	0

FLAG FOR GROUNDWATER PATHWAY OPTIONS	0
AMOUNT OF WATER PERCOLATING THROUGH WASTE ANNUALLY (M)	0.454
DEGREE OF SOIL SATURATION	0.801
RESIDUAL SOIL SATURATION	0.000
PERMEABILITY OF VERTICAL ZONE (M/YR)	0.00
SOIL NUMBER	0.000
POROSITY OF AQUIFER	0.39
DISTANCE FROM AQUIFER TO WASTE (METERS)	7.7
AVERAGE VERTICAL GROUNDWATER VELOCITY (M/YR)	1.[illegible]
HORIZONTAL VELOCITY OF AQUIFER (METERS/YR)	27.800
MIXING THICKNESS OF AQUIFER (METERS)	10.000
SURFACE EROSION RATE (M/YR)	1.960E-04
ANNUAL RUNOFF OF PRECIPITATION (M)	3.22E-01

NUCLIDE NUMBER	NUCLIDE NAME	INGESTION DOSE FACTORS (MREM/PCI)	INHALATION DOSE FACTORS (MREM/PCI)	DIRECT GAMMA DOSE FACTORS (MREM-MAA2/PCI-HR)	VOLATILITY FACTOR (FRACTION)
41	H-3	8.600E-08	1.200E-07	0.000E-01	9.000E-01
42	C-14	1.500E-06	1.100E-08	0.000E-01	7.500E-01
43	Fe-55	4.700E-07	1.900E-06	9.600E-13	2.500E-03
44	Co-60	5.800E-06	4.000E-04	1.200E-08	2.500E-03
45	Ni-59	1.500E-07	1.700E-06	1.800E-12	2.500E-03
46	Ni-63	3.700E-07	4.400E-06	0.000E-01	2.500E-03
47	Sr-90	5.600E-06	2.000E-04	0.000E-01	2.500E-03
48	Nb-94	2.700E-06	5.800E-04	8.000E-09	2.500E-03
49	Tc-99	1.900E-06	2.200E-05	2.900E-15	1.000E-02
50	I-129	8.600E-04	5.700E-04	8.100E-11	1.000E-02
51	Cs-135	6.500E-06	4.500E-06	0.000E-01	2.500E-03
52	Ba137m	0.000E-01	1.400E-09	3.100E-09	2.500E-03
53	Cs-137	4.400E-05	3.000E-05	0.000E-01	2.500E-03
56	U-234	8.400E-06	1.900E-01	3.300E-12	2.500E-03
57	U-235	8.600E-06	1.800E-01	8.300E-10	2.500E-03
58	U-238	7.900E-06	1.700E-01	2.600E-12	2.500E-03
59	Np-237	3.100E-03	4.000E-01	1.400E-10	2.500E-03
60	Pu-238	2.900E-03	3.600E-01	3.400E-12	2.500E-03
61	Pu-239	3.400E-04	3.700E-01	1.600E-12	2.500E-03
62	Pu-241	7.600E-05	4.400E-03	0.000E-01	2.500E-03
63	Pu-242	3.300E-04	3.500E-01	2.700E-12	2.500E-03
64	Am-241	3.400E-03	4.400E-01	1.300E-10	2.500E-03
65	Am-243	3.500E-03	4.400E-01	2.900E-10	2.500E-03
66	Cm-243	2.000E-03	2.700E-01	7.000E-10	2.500E-03
67	Cm-244	1.600E-03	2.100E-01	3.200E-12	2.500E-03
68	Ru-106	1.100E-05	1.200E-03	0.000E-01	1.000E-02
69	Sb-125	0.000E-01	2.800E-05	2.200E-09	2.500E-03
70	Cs-134	6.600E-05	4.500E-05	8.000E-09	2.500E-03
71	Eu-154	0.000E-01	3.400E-04	6.100E-09	2.500E-03

NUCLIDE NUMBER	NUCLIDE NAME	EQUIVALENT UPTAKE FACTORS: RIVER USEAGE (L/YR)	WELL WATER USE (L/YR)	FOOD CONSUMPTION (KG/YR)	GAMMA ENERGY (MEV)
41	H-3	5.841E+02	5.841E+02	0.000E-01	0.000E-01
42	C-14	4.816E+02	4.816E+02	0.000E-01	0.000E-01
43	Fe-55	7.128E+02	7.128E+02	9.002E-02	0.000E-01
44	Co-60	7.384E+02	7.384E+02	5.397E-01	1.250E+00
45	Ni-59	6.067E+02	6.067E+02	1.492E+00	0.000E-01
46	Ni-63	6.066E+02	6.066E+02	1.490E+00	0.000E-01
47	Sr-90	5.649E+02	5.649E+02	1.173E+01	3.390E-01
48	Nb-94	2.973E+03	2.973E+03	5.077E+00	7.870E-01

49	Tc-99	7.704E+02	7.704E+02	2.238E+02	0.000E-01
50	I-129	7.347E+02	7.347E+02	3.848E+00	3.960E-02
51	Cs-135	8.075E+02	8.075E+02	2.753E+00	0.000E-01
52	Ba137m	0.000E-01	0.000E-01	0.000E-01	6.620E-01
53	Cs-137	8.070E+02	8.070E+02	2.746E+00	6.620E-01
56	U-234	5.510E+02	5.510E+02	8.233E-02	1.200E-01
57	U-235	5.510E+02	5.510E+02	8.233E-02	1.770E-01
58	U-238	5.510E+02	5.510E+02	3.233E-02	4.300E-02
59	Np-237	5.419E+02	5.419E+02	2.633E-01	6.020E-02
60	Pu-238	5.413E+02	5.413E+02	1.160E-03	5.620E-02
61	Pu-239	5.413E+02	5.413E+02	1.161E-03	1.370E-01
62	Pu-241	5.410E+02	5.410E+02	1.154E-03	1.320E-01
63	Pu-242	5.413E+02	5.413E+02	1.161E-03	0.000E-01
64	Am-241	5.414E+02	5.414E+02	9.238E-03	5.740E-02
65	Am-243	5.414E+02	5.414E+02	9.239E-03	7.290E-02
66	Cm-243	5.415E-02	5.415E+02	1.056E-03	3.240E-01
67	Cm-244	5.414E+02	5.414E+02	1.055E-03	6.660E-02
68	Ru-106	5.535E+02	5.535E+02	4.884E-01	6.000E-01
69	Sb-125	5.496E+02	5.496E+02	8.564E-01	4.600E-01
70	Cs-134	8.000E+02	9.000E+02	2.646E+00	7.000E-01
71	Eu-154	5.841E+02	5.841E+02	1.200E-01	1.000E+00

NUCLIDE NUMBER	NAME	INPUT LEACH CONSTANT(1/YR)	FINAL LEACH CONSTANT(1/YR)	GAMMA ATTENUATION(1/M)
41	H-3	3.480E-03	3.480E-03	0.000E-01
42	C-14	3.480E-03	3.480E-03	0.000E-01
43	Fe-55	2.990E-05	2.990E-05	0.000E-01
44	Co-60	2.990E-05	2.990E-05	8.300E+00
45	Ni-59	2.990E-05	2.990E-05	0.000E-01
46	Ni-63	2.990E-05	2.990E-05	0.000E-01
47	Sr-90	4.960E-05	4.960E-05	2.000E+01
48	Nb-94	2.140E-05	2.140E-05	1.150E+01
49	Tc-99	1.630E-03	1.630E-03	0.000E-01
50	I-129	4.400E-04	4.400E-04	9.700E+01
51	Cs-135	1.500E-05	1.500E-05	0.000E-01
52	Ba137m	1.500E-05	1.500E-05	1.300E+01
53	Cs-137	1.500E-05	1.500E-05	1.300E+01
56	U-234	2.010E-06	2.010E-06	5.000E+01
57	U-235	2.010E-06	2.010E-06	2.900E+01
58	U-238	2.010E-06	2.010E-06	6.300E+01
59	Np-237	2.780E-04	2.780E-04	5.000E+01
60	Pu-238	2.150E-06	2.150E-06	5.000E+01
61	Pu-239	2.150E-06	2.150E-06	5.000E+01
62	Pu-241	2.150E-06	2.150E-06	5.000E+01
63	Pu-242	2.150E-06	2.150E-06	5.000E+01
64	Am-241	1.870E-05	1.870E-05	5.000E+01
65	Am-243	1.870E-05	1.870E-05	5.000E+01
66	Cm-243	2.150E-06	2.150E-06	1.800E+01
67	Cm-244	2.150E-06	2.150E-06	5.000E+01
68	Ru-106	2.140E-05	2.140E-05	1.400E+01
69	Sb-125	3.320E-05	3.320E-05	1.700E+01
70	Cs-134	1.500E-05	1.500E-05	1.200E+01
71	Eu-154	7.540E-07	7.540E-07	1.000E+01

NUCLIDE NUMBER	NAME	AQUIFER SORPTION	AQUIFER RETARDATION	VERTICAL SORPTION	VERTICAL RETARDATION
41	H-3	1.000E-02	1.041E+00	1.000E-02	1.051E+00
42	C-14	1.000E-02	1.041E+00	1.000E-02	1.051E+00
43	Fe-55	6.000E+03	2.462E+04	6.000E+03	3.073E+04
44	Co-60	5.500E+01	2.266E+02	5.500E+01	2.827E+02

45	Ni-59	1.500E+02	6.164E+02	1.500E+02	7.693E+02
46	Ni-63	1.500E+02	6.164E+02	1.500E+02	7.693E+02
47	Sr-90	2.000E+01	8.305E+01	1.500E+02	7.693E+02
48	Nb-94	3.500E+02	1.437E+03	3.500E+02	1.794E+03
49	Tc-99	5.000E-01	3.051E+00	5.000E-01	3.561E+00
50	I-129	3.000E+00	1.331E-01	3.000E+00	1.637E+01
51	Cs-135	5.000E+02	2.052E+03	1.000E+03	5.123E+03
52	Ba137m	5.000E+02	2.052E+03	1.000E+03	5.123E+03
53	Cs-137	5.000E+02	2.052E+03	1.000E+03	5.123E+03
56	U-234	7.500E+02	3.078E+03	7.500E+02	3.842E+03
57	U-235	7.500E+02	3.078E+03	7.500E+02	3.842E+03
58	U-238	7.500E+02	3.078E+03	7.500E+02	3.842E+03
59	Np-237	5.000E+00	2.151E+01	5.000E+00	2.661E+01
60	Pu-238	3.500E+03	1.436E+04	3.500E+03	1.793E+04
61	Pu-239	3.500E+03	1.436E+04	3.500E+03	1.793E+04
62	Pu-241	3.500E+03	1.436E+04	3.500E+03	1.793E+04
63	Pu-242	3.500E+03	1.436E+04	3.500E+03	1.793E+04
64	Am-241	8.000E+04	3.282E+05	8.000E+04	4.097E+05
65	Am-243	8.000E+04	3.282E+05	8.000E+04	4.097E+05
66	Cm-243	3.300E+03	1.354E+04	3.300E+03	1.690E+04
67	Cm-244	3.300E+03	1.354E+04	3.300E+03	1.690E+04
68	Ru-106	2.200E+02	9.036E+02	2.200E+02	1.128E+03
69	Sb-125	4.500E+01	1.856E+02	4.500E+01	2.315E+02
70	Cs-134	5.000E+02	2.052E+03	1.000E+03	5.123E+03
71	Eu-154	4.000E+03	1.641E+04	4.000E+03	2.049E+04

NUCLIDE NUMBER	NAME	SOIL TO PLANT CONVERSION	HALF LIFE (YR)	INITIAL INVENTORY (CI)
41	H-3	0.000E-01	1.230E+01	7.857E+01
42	C-14	0.000E-01	5.730E+03	7.421E+00
43	Fe-55	4.000E-03	2.700E+00	2.323E+01
44	Co-60	2.000E-02	5.250E+00	8.652E+01
45	Ni-59	6.000E-02	8.000E+04	1.430E-01
46	Ni-63	6.000E-02	9.200E+01	4.094E+01
47	Sr-90	2.500E+00	2.860E+01	2.694E+00
48	Nb-94	2.000E-02	2.000E+04	4.538E-03
49	Tc-99	9.500E+00	2.130E+05	1.900E-03
50	I-129	1.500E-01	1.700E+07	5.610E-03
51	Cs-135	8.000E-02	3.010E+06	1.900E-03
52	Ba137m	1.500E-01	3.000E+01	4.564E+01
53	Cs-137	8.000E-02	3.000E+01	4.564E+01
56	U-234	8.500E-03	4.470E+09	4.270E-03
57	U-235	8.500E-03	7.040E+08	6.850E-05
58	U-238	8.500E-03	4.470E+09	1.250E-03
59	Np-237	1.000E-01	2.100E+06	9.680E-06
60	Pu-238	4.500E-04	8.770E+01	1.110E-01
61	Pu-239	4.500E-04	2.420E+04	1.120E-01
62	Pu-241	4.500E-04	1.320E+01	3.002E+00
63	Pu-242	4.500E-04	3.790E+05	2.430E-04
64	Am-241	5.500E-03	4.590E+02	2.275E-01
65	Am-243	5.500E-03	7.370E+03	5.405E-05
66	Cm-243	8.500E-04	3.190E+01	4.477E-05
67	Cm-244	8.500E-04	1.760E+01	3.640E-02
68	Ru-106	7.500E-02	1.010E+00	3.672E-03
69	Sb-125	2.000E-01	2.770E+00	3.672E-01
70	Cs-134	8.000E-02	2.060E+00	7.480E+00
71	Eu-154	1.000E-02	8.500E+00	9.172E-02

PATHWAY 2
GROUNDWATER TO WELL

AAAAAAAA NUCLIDE DOSES FOR GIVEN TIMES AAAAAAAA

NUCLIDE/TIME		0.	1.	15.	50.	100.	200.	350.	500.	750.	1000.
41	H-3	0.00E-01	0.00E-01	9.81E-03	4.71E-03	2.36E-04	5.96E-07	7.54E-11	9.54E-15	3.04E-21	9.70E-28
42	C-14	0.00E-01	0.00E-01	3.08E-02	1.06E-01	8.84E-02	6.17E-02	3.59E-02	2.09E-02	8.51E-03	3.46E-03
43	Fe-55	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
44	Co-60	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
45	Ni-59	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
46	Ni-63	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
47	Sr-90	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
48	Nb-94	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
49	Tc-99	0.00E-01	0.00E-01	0.00E-01	8.63E-06	2.70E-05	2.29E-05	1.79E-05	1.40E-05	9.34E-06	5.21E-06
50	I-129	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	2.16E-03	7.09E-03	8.96E-03	8.03E-03	7.19E-03
51	Cs-135	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
52	Ba137m	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
53	Cs-137	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
56	U-234	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
57	U-235	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
58	U-238	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
59	Np-237	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	7.80E-06	1.67E-05	2.63E-05	2.46E-05
60	Pu-238	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
61	Pu-239	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
62	Pu-241	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
63	Pu-242	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
64	Am-241	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
65	Am-243	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
66	Cm-243	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
67	Cm-244	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
68	Ru-106	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
69	Sb-125	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
70	Cs-134	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
71	Eu-154	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01

AAAAAA SUM OF NUCLIDE DOSES FOR GIVEN TIMES AAAAAA

29	0.00E-01	0.00E-01	4.06E-02	1.11E-01	8.86E-02	6.38E-02	4.30E-02	2.99E-02	1.66E-02	1.07E-02

AAAAAA SUM OF NUCLIDE RISKS FOR GIVEN TIMES AAAAAA

29	0.00E-01	0.00E-01	1.14E-05	3.09E-05	2.48E-05	1.79E-05	1.21E-05	8.38E-06	4.64E-06	2.99E-06

AAAAAAA DISPERSION CORRECTION FACTOR AAAAAA

NUCLIDE		VERTICAL FACTOR	HORIZONTAL FACTOR	TOTAL FACTOR
41	H-3	1.01E+00	1.00E+00	1.01E+00
42	C-14	1.00E+00	1.00E+00	1.00E+00
43	Fe-55	1.00E+03	1.00E+03	1.00E+06
44	Co-60	1.00E+03	7.93E+00	7.93E+03
45	Ni-59	1.00E+00	1.00E+00	1.00E+00
46	Ni-63	1.00E+03	1.05E+00	1.05E+03
47	Sr-90	1.00E+03	1.01E+00	1.01E+03
48	Nb-94	1.01E+00	1.00E+00	1.01E+00
49	Tc-99	1.00E+00	1.00E+00	1.00E+00
50	I-129	1.00E+00	1.00E+00	1.00E+00
51	Cs-135	1.00E+00	1.00E+00	1.00E+00
52	Ba137m	1.00E+03	1.69E+02	1.69E+05

53	Cs-137	1.00E+03	1.69E+02	1.69E+05
56	U-234	1.00E+00	1.70E+00	1.00E+00
57	U-235	1.00E+00	1.00E+00	1.00E+00
58	U-238	1.00E+00	1.00E+00	1.00E+00
59	Np-237	1.00E+00	1.00E+00	1.00E+00
60	Pu-238	1.00E+03	1.00E+03	1.00E+06
61	Pu-239	1.43E+00	1.00E+00	1.43E+00
62	Pu-241	1.00E+03	1.00E+03	1.00E+06
63	Pu-242	1.00E+00	1.00E+00	1.00E+00
64	Am-241	1.00E+03	1.00E+03	1.00E+06
65	Am-243	1.00E+03	9.04E+00	9.04E+03
66	Cm-243	1.00E+03	1.00E+03	1.00E+06
67	Cm-244	1.00E+03	1.00E+03	1.00E+06
68	Ru-106	1.00E+03	1.00E+03	1.00E+06
69	Sb-125	1.00E+03	1.38E+02	1.38E+05
70	Cs-134	1.00E+03	1.00E+03	1.00E+06
71	Eu-154	1.00E+03	1.00E+03	1.00E+06

CONCENTRATION ARRAY CONCENTRATIONS IN CI/M**3

NUCLIDE/TIME		0.	1.	15.	50.	100.	200.	350.	500.	750.	1000.
41	H-3	0.00E-01	0.00E-01	1.95E-07	9.38E-08	4.71E-09	1.19E-11	1.50E-15	1.90E-19	6.06E-26	1.93E-32
42	C-14	0.00E-01	0.00E-01	4.26E-08	1.46E-07	1.22E-07	8.53E-08	4.97E-08	2.90E-08	1.13E-08	4.79E-09
43	Fe-55	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
44	Co-60	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
45	Ni-59	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
46	Ni-63	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
47	Sr-90	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
48	Nb-94	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
49	Tc-99	0.00E-01	0.00E-01	0.00E-01	5.90E-12	1.84E-11	1.57E-11	1.23E-11	9.59E-12	6.38E-12	4.24E-12
50	I-129	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	3.41E-12	1.12E-11	1.42E-11	1.27E-11	[illegible]
51	Cs-135	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
52	Ba137m	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
53	Cs-137	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
56	U-234	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
57	U-235	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
58	U-238	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
59	Np-237	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	4.64E-15	9.93E-15	1.57E-14	1.46E-14
60	Pu-238	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
61	Pu-239	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
62	Pu-241	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
63	Pu-242	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
[illegible]	[illegible]-241	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
65	Am-243	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
66	Cm-243	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
67	Cm-244	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
68	Ru-106	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
69	Sb-125	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
70	Cs-134	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
71	Eu-154	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01

PATHWAY 3
EROSION

******** NUCLIDE DOSES FOR GIVEN TIMES ********

NUCLIDE/TIME		0.	1.	15.	50.	100.	200.	350.	500.	750.	1000.
41	H-3	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
42	C-14	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
43	Fe-55	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01

44	Co-60	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
45	Ni-59	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
46	Ni-63	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
47	Sr-90	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
48	Nb-94	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
49	Tc-99	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
50	I-129	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
51	Cs-135	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
52	Ba137m	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
53	Cs-137	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
56	U-234	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
57	U-235	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
58	U-238	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
59	Np-237	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
60	Pu-238	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
61	Pu-239	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
62	Pu-241	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
63	Pu-242	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
64	Am-241	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
65	Am-243	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
66	Cm-243	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
67	Cm-244	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
68	Ru-106	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
69	Sb-125	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
70	Cs-134	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
71	Eu-154	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01

AAAAAA SUM OF NUCLIDE DOSES FOR GIVEN TIMES AAAAAA

29	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01

AAAAAA SUM OF NUCLIDE RISKS FOR GIVEN TIMES AAAAAA

29	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01

AAAAAAA EROSION OF WASTE STARTS AFTER 3061.2 YEARS AND ENDS AFTER WASTE IS ALL ERODED IN 33673.5 YEARS.

CONCENTRATION ARRAY CONCENTRATIONS IN CI/MAA3

NUCLIDE/TIME		0.	1.	15.	50.	100.	200.	350.	500.	750.	1000.
41	H-3	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
42	C-14	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
43	Fe-55	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
44	Co-60	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
45	Ni-59	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
46	Ni-63	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
47	Sr-90	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
48	Nb-94	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
49	Tc-99	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
50	I-129	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
51	Cs-135	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
52	Ba137m	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
53	Cs-137	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
56	U-234	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
57	U-235	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
58	U-238	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01

59	Np-237	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
60	Pu-238	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
61	Pu-239	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
62	Pu-241	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
63	Pu-242	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
64	Am-241	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
65	Am-243	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
66	Cm-243	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
67	Cm-244	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
68	Ru-106	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
69	Sb-125	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
70	Cs-134	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
71	Eu-154	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01

PATHWAY 5

FOOD GROWN ON SITE

******** NUCLIDE DOSES FOR GIVEN TIMES ********

NUCLIDE/TIME		0.	1.	15.	50.	100.	200.	350.	500.	750.	1000.
41	H-3	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
42	C-14	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
43	Fe-55	2.10E-05	1.63E-05	4.47E-07	5.60E-11	1.49E-16	1.06E-27	0.00E-01	0.00E-01	0.00E-01	0.00E-01
44	Co-60	5.90E-03	5.09E-03	8.00E-04	7.98E-06	1.07E-08	1.97E-14	4.95E-23	1.24E-31	0.00E-01	0.00E-01
45	Ni-59	6.85E-07	6.85E-07	6.85E-07	6.85E-07	6.85E-07	6.84E-07	6.83E-07	6.82E-07	6.81E-07	6.79E-07
46	Ni-63	4.93E-04	4.90E-04	4.32E-04	3.32E-04	2.29E-04	1.07E-04	3.46E-05	1.12E-05	1.70E-06	2.53E-07
47	Sr-90	3.79E-03	3.70E-03	2.64E-03	1.13E-03	3.36E-04	2.98E-05	7.85E-07	2.07E-08	4.84E-11	1.13E-13
48	Nb-94	1.33E-06	1.33E-06	1.33E-06	1.33E-06	1.33E-06	1.32E-06	1.32E-06	1.31E-06	1.30E-06	1.29E-06
49	Tc-99	1.73E-05	1.73E-05	1.73E-05	1.73E-05	1.73E-05	1.73E-05	1.73E-05	1.73E-05	1.73E-05	1.73E-05
50	I-129	3.97E-04	3.97E-04	3.97E-04	3.97E-04	3.97E-04	3.97E-04	3.97E-04	3.97E-04	3.97E-04	3.97E-04
51	Cs-135	7.28E-07	7.28E-07	7.28E-07	7.28E-07	7.28E-07	7.28E-07	7.28E-07	7.28E-07	7.28E-07	7.28E-07
52	Ba137m	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
53	Cs-137	1.18E-01	1.15E-01	8.35E-02	3.72E-02	1.17E-02	1.16E-03	3.63E-05	1.13E-06	3.52E-09	1.09E-11
56	U-234	6.32E-08	6.32E-08	6.32E-08	6.32E-08	6.32E-08	6.32E-08	6.32E-08	6.32E-08	6.32E-08	6.32E-03
57	U-235	1.04E-09	1.04E-09	1.04E-09	1.04E-09	1.04E-09	1.04E-09	1.04E-09	1.04E-09	1.04E-09	1.04E-09
58	U-238	1.74E-08	1.74E-08	1.74E-08	1.74E-08	1.74E-08	1.74E-08	1.74E-08	1.74E-08	1.74E-08	1.74E-08
59	Np-237	1.69E-07	1.69E-07	1.69E-07	1.69E-07	1.69E-07	1.69E-07	1.69E-07	1.69E-07	1.69E-07	1.69E-07
60	Pu-238	7.99E-06	7.93E-06	7.10E-06	5.38E-06	3.63E-06	1.64E-06	5.03E-07	1.54E-07	2.13E-08	3.95E-09
61	Pu-239	9.46E-07	9.46E-07	9.46E-07	9.45E-07	9.43E-07	9.41E-07	9.37E-07	9.33E-07	9.26E-07	9.19E-07
62	Pu-241	5.64E-06	5.35E-06	2.57E-06	4.08E-07	2.96E-08	1.55E-10	5.88E-14	2.23E-17	4.44E-23	3.83E-29
63	Pu-242	1.99E-09	1.99E-09	1.99E-09	1.99E-09	1.99E-09	1.99E-09	1.99E-09	1.99E-09	1.99E-09	1.99E-09
64	Am-241	1.53E-04	1.53E-04	1.50E-04	1.42E-04	1.32E-04	1.13E-04	9.02E-05	7.19E-05	4.93E-05	3.38E-05
65	Am-243	3.74E-08	3.74E-08	3.74E-08	3.72E-08	3.71E-08	3.67E-08	3.62E-08	3.57E-08	3.49E-08	3.41E-08
66	Cm-243	2.02E-09	1.98E-09	1.46E-09	6.83E-10	2.30E-10	2.62E-11	1.01E-13	3.87E-14	1.69E-16	7.41E-19
67	Cm-244	1.32E-06	1.26E-06	7.29E-07	1.84E-07	2.56E-08	4.99E-10	1.36E-12	3.69E-15	1.96E-19	1.04E-23
68	Ru-106	4.22E-07	2.13E-07	1.43E-11	5.29E-22	6.62E-37	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
69	Sb-125	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
70	Cs-134	2.80E-02	2.00E-02	1.80E-04	1.38E-09	6.82E-17	1.66E-31	0.00E-01	0.00E-01	0.00E-01	0.00E-01
71	Eu-154	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01

****** SUM OF NUCLIDE DOSES FOR GIVEN TIMES ******

29	1.57E-01	1.45E-01	8.81E-02	3.92E-02	1.28E-02	1.83E-03	5.81E-04	5.03E-04	4.70E-04	4.53E-04

****** SUM OF NUCLIDE RISKS FOR GIVEN TIMES ******

29	4.39E-08	4.07E-08	2.47E-08	1.10E-08	3.59E-09	5.13E-10	1.63E-10	1.41E-10	1.31E-10	1.27E-10

FRACTIONAL MIXING OF WASTE IN SOIL IN TRENCH IS 1.005
FRACTION OF FOOD CONSUMED WHICH IS GROWN AT THE WASTE SITE (FG) IS 0.220
FRACTIONAL MIXING OF TRENCH MATERIAL IN SURFACE SOIL IS 0.120

PATHWAY 6
NATURAL BIOINTRUSION

AAAAAAAA NUCLIDE DOSES FOR GIVEN TIMES AAAAAAAA

NUCLIDE/TIME		0.	1.	15.	50.	100.	200.	350.	500.	750.	1000.
41	H-3	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
42	C-14	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
43	Fe-55	7.02E-05	5.43E-05	1.49E-06	1.87E-10	4.98E-16	3.53E-27	0.00E-01	0.00E-01	0.00E-01	0.00E-01
44	Co-60	1.93E-02	1.69E-02	2.67E-03	2.63E-05	3.57E-08	6.59E-14	1.65E-22	4.14E-31	0.00E-01	0.00E-01
45	Ni-59	2.29E-06	2.29E-06	2.29E-06	2.28E-06	2.28E-06	2.28E-06	2.28E-06	2.28E-06	2.27E-06	2.27E-06
46	Ni-63	1.61E-03	1.60E-03	1.44E-03	1.11E-03	7.59E-04	3.57E-04	1.15E-04	3.73E-05	5.67E-06	8.62E-07
47	Sr-90	1.26E-02	1.23E-02	8.79E-03	3.76E-03	1.12E-03	9.93E-05	2.62E-06	6.90E-08	1.61E-10	3.77E-13
48	Nb-94	4.44E-06	4.44E-06	4.44E-06	4.43E-06	4.43E-06	4.41E-06	4.39E-06	4.37E-06	4.33E-06	4.29E-06
49	Tc-99	5.77E-05	5.77E-05	5.77E-05	5.77E-05	5.77E-05	5.77E-05	5.76E-05	5.76E-05	5.76E-05	5.75E-05
50	I-129	1.33E-03	1.33E-03	1.33E-03	1.33E-03	1.33E-03	1.33E-03	1.33E-03	1.33E-03	1.33E-03	1.33E-03
51	Cs-135	2.43E-06	2.43E-06	2.43E-06	2.43E-06	2.43E-06	2.43E-06	2.43E-06	2.43E-06	2.43E-06	2.43E-06
52	Ba137m	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
53	Cs-137	3.94E-01	3.85E-01	2.78E-01	1.24E-01	3.91E-02	3.88E-03	1.21E-04	3.79E-06	1.17E-08	3.64E-11
56	U-234	2.11E-07	2.11E-07	2.11E-07	2.11E-07	2.11E-07	2.11E-07	2.11E-07	2.11E-07	2.11E-07	2.11E-07
57	U-235	3.46E-09	3.46E-09	3.46E-09	3.46E-09	3.46E-09	3.46E-09	3.46E-09	3.46E-09	3.46E-09	3.46E-09
58	U-238	5.81E-08	5.81E-08	5.81E-08	5.81E-08	5.81E-08	5.81E-08	5.81E-08	5.81E-08	5.81E-08	5.81E-08
59	Np-237	5.64E-07	5.64E-07	5.64E-07	5.64E-07	5.64E-07	5.64E-07	5.64E-07	5.64E-07	5.64E-07	5.64E-07
60	Pu-238	2.67E-05	2.65E-05	2.37E-05	1.30E-05	1.21E-05	5.49E-06	1.68E-06	5.12E-07	7.10E-08	9.35E-09
61	Pu-239	3.16E-06	3.16E-06	3.15E-06	3.15E-06	3.15E-06	3.14E-06	3.12E-06	3.11E-06	3.09E-06	3.07E-06
62	Pu-241	1.88E-05	1.78E-05	8.56E-06	1.36E-06	9.86E-08	5.17E-10	1.96E-13	7.44E-17	1.48E-22	2.94E-23
63	Pu-242	6.65E-09	6.65E-09	6.65E-09	6.65E-09	6.65E-09	6.64E-09	6.64E-09	6.64E-09	6.64E-09	6.64E-09
64	Am-241	5.10E-04	5.10E-04	4.99E-04	4.73E-04	4.39E-04	3.77E-04	3.01E-04	2.40E-04	1.64E-04	1.13E-04
65	Am-243	1.25E-07	1.25E-07	1.25E-07	1.24E-07	1.24E-07	1.22E-07	1.21E-07	1.19E-07	1.16E-07	1.14E-07
66	Cm-243	6.75E-09	6.61E-09	4.87E-09	2.28E-09	7.69E-10	8.75E-11	3.36E-12	1.29E-13	5.65E-16	3.47E-18
67	Cm-244	4.39E-06	4.22E-06	2.43E-06	6.13E-07	8.55E-08	1.67E-09	4.53E-12	1.23E-14	6.52E-19	3.45E-23
68	Ru-106	1.41E-06	7.09E-07	4.77E-11	1.76E-21	2.21E-36	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
69	Sb-125	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
70	Cs-134	9.33E-02	6.66E-02	6.00E-04	4.61E-09	2.27E-16	5.54E-31	0.00E-01	0.00E-01	0.00E-01	0.00E-01
71	Eu-154	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01

AAAAAA SUM OF NUCLIDE DOSES FOR GIVEN TIMES AAAAAA

	0.	1.	15.	50.	100.	200.	350.	500.	750.	1000.
29	5.23E-01	4.84E-01	2.94E-01	1.31E-01	4.28E-02	6.11E-03	1.94E-03	1.68E-03	1.57E-03	1.51E-03

AAAAAA SUM OF NUCLIDE RISKS FOR GIVEN TIMES AAAAAA

	0.	1.	15.	50.	100.	200.	350.	500.	750.	1000.
29	1.46E-07	1.36E-07	8.23E-08	3.66E-08	1.20E-08	1.71E-09	5.43E-10	4.70E-10	4.39E-10	4.23E-10

FRACTIONAL MIXING OF WASTE IN SOIL IN TRENCH IS 1.005
FRACTION OF FOOD CONSUMED WHICH IS GROWN AT THE WASTE SITE (FG) IS 0.220

PATHWAY 7
DIRECT GAMMA

AAAAAAAA NUCLIDE DOSES FOR GIVEN TIMES AAAAAAAA

NUCLIDE/TIME		0.	1.	15.	50.	100.	200.	350.	500.	750.	1000.
44	Co-60	8.39E+00	7.36E+00	1.18E+00	1.21E-02	1.74E-05	3.61E-11	1.08E-19	3.20E-28	0.00E-01	0.00E-01
47	Sr-90	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
48	Nb-94	9.83E-05	9.85E-05	1.01E-04	1.07E-04	1.17E-04	1.39E-04	1.80E-04	2.31E-04	3.48E-04	5.17E-04
50	I-129	4.82E-28	4.91E-28	6.37E-28	1.23E-27	3.12E-27	2.02E-26	3.31E-25	5.42E-24	5.68E-22	5.39E-20
52	Ba137m	2.17E-01	2.13E-01	1.59E-01	7.60E-02	2.65E-02	3.23E-03	1.37E-04	5.77E-06	2.92E-08	1.45E-10
53	Cs-137	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
56	U-234	9.29E-18	9.38E-18	1.07E-17	1.49E-17	2.40E-17	6.17E-17	2.55E-16	1.05E-15	1.10E-14	1.14E-13
57	U-235	7.93E-12	7.97E-12	9.59E-12	1.04E-11	1.35E-11	2.31E-11	5.15E-11	1.14E-10	4.29E-10	1.59E-09
58	U-238	2.08E-21	2.10E-21	2.49E-21	3.79E-21	6.92E-21	2.30E-20	1.39E-19	8.37E-19	1.66E-17	3.25E-16
59	Np-237	1.71E-18	1.72E-18	1.97E-18	2.74E-18	4.40E-18	1.13E-17	4.68E-17	1.92E-16	2.02E-15	2.09E-14
60	Pu-238	5.08E-16	5.09E-16	5.20E-16	5.49E-16	5.94E-16	6.94E-16	8.75E-16	1.10E-15	1.60E-15	2.30E-15
61	Pu-239	1.05E-16	1.06E-16	1.21E-16	1.68E-16	2.69E-16	6.91E-16	2.84E-15	1.16E-14	1.21E-13	1.24E-12
62	Pu-241	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
64	Am-241	3.90E-14	3.93E-14	4.40E-14	5.81E-14	8.65E-14	1.92E-13	6.30E-13	2.07E-12	1.48E-11	1.05E-10
65	Am-243	1.65E-17	1.66E-17	1.89E-17	2.63E-17	4.20E-17	1.07E-16	4.36E-16	1.77E-15	1.81E-14	1.83E-13
66	Cm-243	2.66E-09	2.61E-09	2.02E-09	1.05E-09	4.18E-10	6.55E-11	4.06E-12	2.51E-13	2.40E-15	2.28E-17
67	Cm-244	1.33E-16	1.29E-16	8.51E-17	2.99E-17	6.70E-18	3.36E-19	3.77E-21	4.21E-23	2.34E-26	1.28E-29
68	Ru-106	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
69	Sb-125	2.36E-04	1.84E-04	5.77E-06	1.00E-09	4.25E-15	7.65E-26	0.00E-01	0.00E-01	0.00E-01	0.00E-01
70	Cs-134	1.48E-01	1.06E-01	9.76E-04	8.00E-09	4.34E-16	1.27E-30	0.00E-01	0.00E-01	0.00E-01	0.00E-01
71	Eu-154	2.42E-03	2.24E-03	7.30E-04	4.43E-05	8.09E-07	2.70E-10	1.64E-15	9.88E-21	1.96E-29	3.84E-38

****** SUM OF NUCLIDE DOSES FOR GIVEN TIMES ******

29	3.76E+00	7.68E+00	1.34E+00	8.82E-02	2.67E-02	3.37E-03	3.16E-04	2.37E-04	3.48E-04	5.17E-04

****** SUM OF NUCLIDE RISKS FOR GIVEN TIMES ******

29	2.45E-06	2.15E-06	3.75E-07	2.47E-08	7.47E-09	9.43E-10	8.86E-11	6.63E-11	9.75E-11	1.45E-10

******* EROSION STOPS AFTER COVER IS ALL ERODED IN 3061.2 YEARS *******

PATHWAY 8

DUST INHALATION

******** NUCLIDE DOSES FOR GIVEN TIMES ********

NUCLIDE/TIME		0.	1.	15.	50.	100.	200.	350.	500.	750.	1000.
41	H-3	8.40E-07	7.94E-07	3.61E-07	5.02E-08	3.00E-09	1.07E-11	2.28E-15	4.87E-19	3.71E-25	2.82E-31
42	C-14	7.28E-09	7.28E-09	7.26E-09	7.23E-09	7.19E-09	7.10E-09	6.97E-09	6.85E-09	6.64E-09	6.45E-09
43	Fe-55	3.93E-06	3.04E-06	8.37E-08	1.05E-11	2.79E-17	1.98E-28	0.00E-01	0.00E-01	0.00E-01	0.00E-01
44	Co-60	3.08E-03	2.70E-03	4.26E-04	4.19E-06	5.69E-09	1.05E-14	2.63E-23	6.60E-32	0.00E-01	0.00E-01
45	Ni-59	2.17E-08	2.17E-08	2.17E-08	2.17E-08	2.16E-08	2.16E-08	2.16E-08	2.16E-08	2.15E-08	2.15E-08
46	Ni-63	1.61E-05	1.59E-05	1.43E-05	1.10E-05	7.56E-06	3.56E-06	1.15E-06	3.71E-07	5.64E-08	8.58E-09
47	Sr-90	4.80E-05	4.69E-05	3.34E-05	1.43E-05	4.26E-06	3.77E-07	9.94E-09	2.62E-10	6.13E-13	1.43E-15
48	Nb-94	2.35E-07	2.35E-07	2.34E-07	2.34E-07	2.34E-07	2.33E-07	2.32E-07	2.31E-07	2.29E-07	2.27E-07
49	Tc-99	3.73E-09	3.73E-09	3.73E-09	3.72E-09	3.72E-09	3.72E-09	3.72E-09	3.72E-09	3.72E-09	3.71E-09
50	I-129	2.85E-07	2.85E-07	2.85E-07	2.85E-07	2.85E-07	2.85E-07	2.85E-07	2.85E-07	2.85E-07	2.85E-07
51	Cs-135	7.62E-10	7.62E-10	7.62E-10	7.62E-10	7.62E-10	7.62E-10	7.62E-10	7.62E-10	7.62E-10	7.62E-10
52	Ba137m	5.70E-09	5.57E-09	4.03E-09	1.79E-09	5.65E-10	5.61E-11	1.75E-12	5.47E-14	1.70E-16	5.26E-19
53	Cs-137	1.22E-04	1.19E-04	8.63E-05	3.84E-05	1.21E-05	1.20E-06	3.75E-08	1.17E-09	3.64E-12	1.13E-14

56	U-234	7.23E-05	7.23E-05	7.23E-05	7.23E-05	7.23E-05	7.23E-05	7.23E-05	7.23E-05	7.23E-05	7.23E-05
57	U-235	1.10E-06	1.10E-06	1.10E-06	1.10E-06	1.10E-06	1.10E-06	1.10E-06	1.10E-06	1.10E-06	1.10E-06
58	U-238	1.89E-05	1.89E-05	1.89E-05	1.89E-05	1.89E-05	1.89E-05	1.89E-05	1.89E-05	1.89E-05	1.89E-05
59	Np-237	3.45E-07	3.45E-07	3.45E-07	3.45E-07	3.45E-07	3.45E-07	3.45E-07	3.45E-07	3.45E-07	3.45E-07
60	Pu-238	3.56E-03	3.53E-03	3.16E-03	2.40E-03	1.62E-03	7.33E-04	2.24E-04	6.85E-05	9.49E-06	1.32E-06
61	Pu-239	3.69E-03	3.69E-03	3.69E-03	3.69E-03	3.68E-03	3.67E-03	3.66E-03	3.64E-03	3.61E-03	3.59E-03
62	Pu-241	1.19E-03	1.12E-03	5.36E-04	8.52E-05	6.17E-06	3.24E-08	1.23E-11	4.66E-15	9.27E-21	1.34E-26
63	Pu-242	7.58E-06	7.58E-06	7.58E-06	7.58E-06	7.58E-06	7.58E-06	7.58E-06	7.57E-06	7.57E-06	7.57E-06
64	Am-241	8.92E-03	8.91E-03	8.72E-03	8.27E-03	7.67E-03	6.60E-03	5.26E-03	4.19E-03	2.93E-03	1.97E-03
65	Am-243	2.12E-06	2.12E-06	2.12E-06	2.11E-06	2.10E-06	2.08E-06	2.05E-06	2.02E-06	1.98E-06	1.93E-06
66	Cm-243	1.08E-06	1.05E-06	7.78E-07	3.64E-07	1.23E-07	1.40E-08	5.36E-10	2.06E-11	9.01E-14	3.94E-16
67	Cm-244	6.61E-04	6.55E-04	3.77E-04	9.51E-05	1.33E-05	2.59E-07	7.03E-10	1.91E-12	1.01E-16	5.36E-21
68	Ru-106	3.93E-07	1.98E-07	1.33E-11	4.92E-22	6.15E-37	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
69	Sb-125	9.16E-07	7.13E-07	2.15E-08	3.38E-12	1.24E-17	1.69E-28	0.00E-01	0.00E-01	0.00E-01	0.00E-01
70	Cs-134	3.00E-05	2.14E-05	1.93E-07	1.48E-12	7.31E-20	1.79E-34	0.00E-01	0.00E-01	0.00E-01	0.00E-01
71	Eu-154	2.78E-06	2.56E-06	8.18E-07	4.71E-08	7.99E-10	2.30E-13	1.12E-18	5.45E-24	7.63E-33	1.07E-41

AAAAAA SUM OF NUCLIDE DOSES FOR GIVEN TIMES AAAAAA

29	2.15E-02	2.09E-02	1.72E-02	1.47E-02	1.31E-02	1.11E-02	9.24E-03	8.01E-03	6.60E-03	5.66E-03

AAAAAA SUM OF NUCLIDE RISKS FOR GIVEN TIMES AAAAAA

29	6.01E-09	5.86E-09	4.80E-09	4.12E-09	3.67E-09	3.11E-09	2.59E-09	2.24E-09	1.85E-09	1.59E-09

PATHWAY 10
ATMOSPHERIC TRANSPORT

AAAAAAAA NUCLIDE DOSES FOR GIVEN TIMES AAAAAAAA

ANNUAL DOSE TO AN INDIVIDUAL DUE TO OFF-SITE ATMOSPHERIC TRANSPORT

41	H-3	3.62E-08
42	C-14	2.61E-10
43	Fe-55	4.70E-10
44	Co-60	3.69E-07
45	Ni-59	2.59E-12
46	Ni-63	1.92E-09
47	Sr-90	5.74E-09
48	Nb-94	2.80E-11
49	Tc-99	1.78E-12
50	[illegible]	[illegible]
51	Cs-135	9.[illegible]E-14
52	Ba137m	6.81E-13
53	Cs-137	1.46E-08
56	U-234	8.64E-09
57	U-235	1.31E-10
58	U-238	2.26E-09
59	Np-237	4.12E-11
60	Pu-238	4.26E-07
61	Pu-239	4.41E-07
62	Pu-241	1.41E-07
63	Pu-242	9.06E-10
64	Am-241	1.07E-06
65	Am-243	2.53E-10
66	Cm-243	1.29E-10
67	Cm-244	8.14E-08
68	Ru-106	1.88E-10
69	Sb-125	1.09E-10

```
70  Cs-134      3.58E-09
71  Eu-154      3.32E-10
```

****** SUM OF NUCLIDE DOSES FOR GIVEN TIMES ******

```
   29          2.60E-06
```

****** SUM OF NUCLIDE RISKS FOR GIVEN TIMES ******

```
   29          7.28E-13
```

DISTANCE TO RECEPTOR IS 345.0 METERS
CHI/Q IS 1.62E-05 CI/M**3 PER CI/SEC

********** CUMULATIVE TOTAL DOSES PER YEAR FOR GIVEN TIMES **********

```
    7          9.46E+00  8.33E+00  1.78E+00  3.83E-01  1.84E-01  8.63E-02  5.51E-02  4.03E-02  2.56E-02  1.88E-02
```

********** CUMULATIVE TOTAL RISKS PER YEAR FOR GIVEN TIMES **********

```
    7          2.65E-03  2.33E-03  4.98E-04  1.07E-04  5.15E-05  2.42E-05  1.54E-05  1.13E-05  7.16E-06  5.27E-06
```

NUCLIDE HALFLIFE AND INVENTORY (CI) ASSUMING NO TRANSPORT FROM THE FACILITY

(TIME IN YR)	HALFLIFE	0.	1.	15.	50.	100.	200.	350.	500.	750.	1000.
41 H-3	1.23E+01	7.86E+01	7.43E+01	3.37E+01	4.69E+00	2.80E-01	1.00E-03	2.13E-07	4.55E-11	3.47E-17	2.64E-23
42 C-14	5.73E+03	7.42E+00	7.42E+00	7.41E+00	7.38E+00	7.33E+00	7.24E+00	7.11E+00	6.99E+00	6.78E+00	6.58E+00
43 Fe-55	2.70E+00	2.32E+01	1.30E+01	4.94E-01	6.19E-05	1.65E-10	1.17E-21	0.00E-01	0.00E-01	0.00E-01	0.00E-01
44 Co-60	5.25E+00	8.65E+01	7.58E+01	1.19E+01	1.18E-01	1.60E-04	2.95E-10	7.39E-19	1.85E-27	0.00E-01	0.00E-01
45 Ni-59	8.00E+04	1.43E-01	1.43E-01	1.43E-01	1.43E-01	1.43E-01	1.43E-01	1.43E-01	1.42E-01	1.42E-01	1.42E-01
46 Ni-63	9.20E+01	4.09E+01	4.06E+01	3.66E+01	2.81E+01	1.93E+01	9.07E+00	2.93E+00	9.46E-01	1.44E-01	2.19E-02
47 Sr-90	2.86E+01	2.69E+00	2.63E+00	1.87E+00	8.02E-01	2.39E-01	2.12E-02	5.58E-04	1.47E-05	3.44E-08	8.03E-11
48 Nb-94	2.00E+04	4.54E-03	4.54E-03	4.54E-03	4.53E-03	4.52E-03	4.51E-03	4.48E-03	4.46E-03	4.42E-03	4.38E-03
49 [illegible]	[illegible]	1.90E-03	1.90E-03	1.90E-03	1.90E-03	1.90E-03	1.90E-03	1.90E-03	1.90E-03	1.90E-03	1.39E-03
50 I-129	1.70E+07	5.61E-03	5.61E-03	5.61E-03	5.61E-03	5.61E-03	5.61E-03	5.61E-03	5.61E-03	5.61E-03	5.61E-03
51 Cs-135	3.01E+06	1.90E-03	1.90E-03	1.90E-03	1.90E-03	1.90E-03	1.90E-03	1.90E-03	1.90E-03	1.90E-03	1.90E-03
52 Ba137m	3.00E+01	4.56E+01	4.46E+01	3.23E+01	1.44E+01	4.53E+00	4.49E-01	1.40E-02	4.39E-04	1.36E-06	4.22E-09
53 Cs-137	3.00E+01	4.56E+01	4.46E+01	3.23E+01	1.44E+01	4.53E+00	4.49E-01	1.40E-02	4.39E-04	1.36E-06	4.22E-09
56 U-234	4.47E+09	4.27E-03	4.27E-03	4.27E-03	4.27E-03	4.27E-03	4.27E-03	4.27E-03	4.27E-03	4.27E-03	4.27E-03
57 U-235	7.04E+08	6.85E-05	6.85E-05	6.85E-05	6.85E-05	6.85E-05	6.85E-05	6.85E-05	6.35E-05	6.85E-05	6.85E-05
58 U-238	4.47E+09	1.25E-03	1.25E-03	1.25E-03	1.25E-03	1.25E-03	1.25E-03	1.25E-03	1.25E-03	1.25E-03	1.25E-03
59 Np-237	2.10E+06	9.68E-06	9.68E-06	9.68E-06	9.68E-06	9.68E-06	9.68E-06	9.68E-06	9.68E-06	9.68E-06	9.68E-06
60 Pu-238	8.77E+01	1.11E-01	1.10E-01	9.86E-02	7.48E-02	5.04E-02	2.28E-02	6.98E-03	2.13E-03	2.96E-04	4.10E-05
61 Pu-239	2.42E+04	1.12E-01	1.12E-01	1.12E-01	1.12E-01	1.12E-01	1.11E-01	1.11E-01	1.10E-01	1.10E-01	1.09E-01
62 Pu-241	1.32E+01	3.00E+00	2.85E+00	1.37E+00	2.17E-01	1.57E-02	8.25E-05	3.13E-08	1.19E-11	2.36E-17	4.70E-23
63 Pu-242	[illegible]	[illegible]	2.43E-04	2.43E-04	2.43E-04	2.43E-04	2.43E-04	2.43E-04	2.43E-04	2.43E-04	2.43E-04
64 Am-241	4.58E+02	2.28E-01	2.27E-01	2.22E-01	2.11E-01	1.96E-01	1.68E-01	1.34E-01	1.07E-01	7.33E-02	5.03E-02
65 Am-243	7.37E+03	5.40E-05	5.40E-05	5.40E-05	5.38E-05	5.35E-05	5.30E-05	5.23E-05	5.16E-05	5.04E-05	4.92E-05
66 Cm-243	3.19E+01	4.48E-05	4.38E-05	3.23E-05	1.51E-05	5.10E-06	5.80E-07	2.23E-08	8.56E-10	3.75E-12	1.64E-14
67 Cm-244	1.76E+01	3.64E-02	3.50E-02	2.02E-02	5.08E-03	7.09E-04	1.38E-05	3.76E-08	1.02E-10	5.41E-15	2.87E-19
68 Ru-106	1.01E+00	3.67E-03	1.85E-03	1.24E-07	4.60E-18	5.75E-33	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
69 Sb-125	2.77E+00	3.67E-01	2.86E-01	8.60E-03	1.35E-06	4.98E-12	6.76E-23	0.00E-01	0.00E-01	0.00E-01	0.00E-01

70 Cs-134	2.06E+00	7.48E+00	5.34E+00	4.81E-02	3.69E-07	1.82E-14	4.44E-29	0.00E-01	0.00E-01	0.00E-01	0.00E-01
71 Eu-154	8.50E+00	9.17E-02	3.45E-02	2.70E-02	1.55E-03	2.64E-05	7.58E-09	3.69E-14	1.80E-19	2.52E-28	3.53E-37

NUCLIDE HALFLIFE AND INVENTORY (CI) REMAINING IN THE FACILITY

(TIME IN YR)	HALFLIFE	0.	1.	15.	50.	100.	200.	350.	500.	750.	1000.
41 H-3	1.23E+01	7.86E+01	7.40E+01	3.20E+01	3.94E+00	1.98E-01	4.99E-04	6.32E-08	7.99E-12	2.55E-18	8.13E-25
42 C-14	5.73E+03	7.42E+00	7.39E+00	7.03E+00	6.20E+00	5.13E+00	3.61E+00	2.10E+00	1.23E+00	4.98E-01	2.03E-01
43 Fe-55	2.70E+00	2.32E+01	1.80E+01	4.94E-01	6.18E-05	1.64E-10	1.16E-21	0.00E-01	0.00E-01	0.00E-01	0.00E-01
44 Co-60	5.25E+00	8.65E+01	7.53E+01	1.19E+01	1.17E-01	1.59E-04	2.92E-10	7.31E-19	1.92E-27	0.00E-01	0.00E-01
45 Ni-59	8.00E+04	1.43E-01	1.43E-01	1.43E-01	1.43E-01	1.42E-01	1.42E-01	1.41E-01	1.40E-01	1.39E-01	1.38E-01
46 Ni-63	9.20E+01	4.09E+01	4.06E+01	3.65E+01	2.30E+01	1.92E+01	9.02E+00	2.90E+00	9.32E-01	1.4[illegible]E-01	2.12E-02
47 Sr-90	2.86E+01	2.69E+00	2.63E+00	1.87E+00	8.00E-01	2.38E-01	2.09E-02	5.48E-04	1.44E-05	3.31E-08	7.65E-11
48 Nb-94	2.00E+04	4.54E-03	4.54E-03	4.53E-03	4.53E-03	4.51E-03	4.49E-03	4.45E-03	4.41E-03	4.35E-03	4.29E-03
49 Tc-99	2.13E+05	1.90E-03	1.90E-03	1.85E-03	1.75E-03	1.61E-03	1.37E-03	1.07E-03	8.40E-04	5.58E-04	3.71E-04
50 I-129	1.70E+07	5.61E-03	5.61E-03	5.57E-03	5.49E-03	5.37E-03	5.14E-03	4.81E-03	4.50E-03	4.03E-03	3.61E-03
51 Cs-135	3.01E+06	1.90E-03	1.90E-03	1.90E-03	1.90E-03	1.90E-03	1.89E-03	1.89E-03	1.89E-03	1.88E-03	1.87E-03
52 Ba137m	3.00E+01	4.56E+01	4.46E+01	3.23E+01	1.44E+01	4.52E+00	4.48E-01	1.40E-02	4.35E-04	1.35E-06	4.15E-09
53 Cs-137	3.00E+01	4.56E+01	4.46E+01	3.23E+01	1.44E+01	4.52E+00	4.48E-01	1.40E-02	4.35E-04	1.35E-06	4.15E-09
56 U-234	4.47E+05	4.27E-03	4.27E-03	4.27E-03	4.27E-03	4.27E-03	4.27E-03	4.27E-03	4.27E-03	4.26E-03	4.26E-03
57 U-235	7.04E+08	6.85E-05	6.85E-05	6.85E-05	6.85E-05	6.85E-05	6.85E-05	6.85E-05	6.84E-05	6.84E-05	6.84E-05
58 U-238	4.47E+09	1.25E-03	1.25E-03	1.25E-03	1.25E-03	1.25E-03	1.25E-03	1.25E-03	1.25E-03	1.25E-03	1.25E-03
59 Np-237	2.10E+06	9.68E-06	9.68E-06	9.64E-06	9.55E-06	9.41E-06	9.16E-06	8.78E-06	8.42E-06	7.86E-06	7.33E-06
60 Pu-238	8.77E+01	1.11E-01	1.10E-01	9.86E-02	7.48E-02	5.03E-02	2.28E-02	6.98E-03	2.13E-03	2.95E-04	4.09E-05
61 Pu-239	2.42E+04	1.12E-01	1.12E-01	1.12E-01	1.12E-01	1.12E-01	1.11E-01	1.11E-01	1.10E-01	1.09E-01	1.09E-01
62 Pu-241	1.32E+01	3.00E+00	2.85E+00	1.37E+00	2.17E-01	1.57E-02	8.25E-05	3.13E-08	1.19E-11	2.36E-17	4.69E-23
63 Pu-242	3.79E+05	2.43E-04	2.43E-04	2.43E-04	2.43E-04	2.43E-04	2.43E-04	2.43E-04	2.43E-04	2.42E-04	2.42E-04
64 Am-241	4.59E+02	2.23E-01	2.27E-01	2.22E-01	2.11E-01	1.95E-01	1.68E-01	1.33E-01	1.06E-01	7.23E-02	4.93E-02
65 Am-243	7.37E+03	5.40E-05	5.40E-05	5.40E-05	5.37E-05	5.34E-05	5.28E-05	5.20E-05	5.11E-05	4.97E-05	4.83E-05
66 Cm-243	3.19E+01	4.48E-05	4.38E-05	3.23E-05	1.51E-05	5.10E-06	5.80E-07	2.23E-08	8.55E-10	3.74E-12	1.63E-14
67 Cm-244	1.76E+01	3.64E-02	3.50E-02	2.02E-02	5.08E-03	7.09E-04	1.38E-05	3.75E-08	1.02E-10	5.40E-15	2.86E-19
68 Ru-106	1.01E+00	3.67E-03	1.85E-03	1.24E-07	4.59E-18	5.74E-33	0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01
69 Sb-125	2.77E+00	3.67E-01	2.86E-01	8.60E-03	1.35E-06	4.97E-12	6.71E-23	0.00E-01	0.00E-01	0.00E-01	0.00E-01
70 Cs-134	2.06E+00	7.48E+00	5.34E+00	4.81E-02	3.69E-07	1.82E-14	4.43E-29	0.00E-01	0.00E-01	0.00E-01	0.00E-01
71 Eu-154	8.50E+00	9.17E-02	8.45E-02	2.70E-02	1.55E-03	2.64E-05	7.57E-09	3.69E-14	1.80E-19	2.52E-28	3.52E-37

*********** MAXIMUM DOSES & DOMINANT NUCLIDES BY PATHWAY **********

NAME OF RUN ******** 6 PWRHU - MD SE 3/86 ********

PATHWAY	DUST	ATMOSPHERIC	GAMMA	WELL	FOOD
ANNUAL DOSE	2.15E-02	2.60E-06	8.76E+00	1.11E-01	4.84E-01
YEAR	0	0	0	50	1
DOMINANT NUCLIDE	Am-241	Am-241	Co-60	C-14	Cs-137

*U.S. Government Printing Office : 1988 - 516-002/80051