Consumers Energy

A CMS Energy Company

Big Rock Point Nuclear Plant
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10 CFR 20.2002

September 15, 2004

U.S. Nuclear Regulatory Commission
Document Control Desk
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**SUBJECT: DOCKETS 50-155 AND 72-043 - LICENSE DPR-6 - BIG ROCK POINT PLANT – REQUEST FOR APPROVAL OF PROPOSED DISPOSAL PROCEDURES IN ACCORDANCE WITH 10 CFR 20.2002**

References:
1. Letter from Big Rock Point to NRC dated March 14, 2001, Request for Approval of Proposed Disposal Procedures in Accordance with 10 CFR 20.2002
2. Letter from Big Rock Point to NRC dated May 18, 2001, Request for Approval of Proposed Disposal Procedures in Accordance with 10 CFR 20.2002
3. Letter from Big Rock Point to NRC dated June 20, 2001, Request for Approval of Proposed Disposal Procedures in Accordance with 10 CFR 20.2002
4. Letter from NRC to Big Rock Point dated February 5, 2002, Proposed Disposal Procedures in Accordance with 10 CFR 20.2002 (TAC No. MB1463)

The purpose of this letter is to submit a revision to the above references and request NRC continued approval of proposed procedures for disposal of demolition debris in accordance with the provisions of 10 CFR 20.2002. Attachment 1 to this letter contains a marked copy of the June 20, 2001 Request for Approval of Proposed Disposal Procedures Under 10 CFR 20.2002 Provisions (as approved in reference 4, above.) A vertical line in the right margin indicates proposed revisions. Attachment 2 is a copy of the proposed revisions without the marked, proposed revisions. Attachments 3, 4, and 5 are RESRAD assessments done to support the proposed revisions. The following items summarize the revisions included in this submittal:

1. This submittal revises the June 20, 2001 submittal in order to provide the latest available shipment parameters for demolition debris transported to the Michigan Type II landfill and for proposed shipment of PCB bulk product waste to the Environmental Quality Company (EQCo) landfill in Belleville, Michigan. Disposal of structural steel demolition debris, classified as PCB bulk product waste, does not fall within the bounds of the assumptions originally submitted in our referenced letters. The 10 CFR 20.2002 request stated that the demolition debris would be transferred to a State of Michigan licensed Type II landfill located approximately 60 miles from the Big Rock Point (BRP) Site. This letter justifies use of an alternate disposal site for PCB bulk product waste and requests an approval of the revision in accordance with 10 CFR 20.2002.
2. Big Rock Point now has more than a year of shipment experience on which to base more accurate shipment dose calculations. Calculations provided in the original submittal for dose to truck drivers utilized a conservatively high total quantity of shipped demolition debris by assuming a heavy shipment with a concentration of gamma

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emitters at 5.0 pCi/g, but a relatively low number of shipments. Lighter loads are being shipped than previously assumed, and shipments are now scheduled to occur over three years rather than one year as assumed in the original submittal. These factors serve to lower dose rates to the drivers, but increase the number of shipments required to reach the estimated total burial volume.

3. The total quantity of demolition debris for Michigan landfill disposal is estimated at 113 million pounds. This increase is due to a re-estimation of remaining quantities of waste, field experience, and non-impacted asphalt (15.5 million pounds) that has been added to the Big Rock Point site since decommissioning began, but was not included in the original submittal. Approximately 48.7 million pounds of demolition debris is considered to be potentially impacted.

4. Big Rock Point proposes to dispose of up to 3.05 million pounds of structural steel coated with PCB-contaminated paint, potentially including exterior steel from the containment building, classified by the EPA as PCB bulk product waste (40 CFR 761.3) at the EQCo Wayne Disposal Site #2 in Belleville, Michigan. Disposal of this PCB waste will be in accordance with the approved 10 CFR 20.2002 alternate disposal request dated February 5, 2002 and applicable Michigan disposal regulations. The EQCo site is located approximately 275 miles from Big Rock Point and is licensed as a PCB waste disposal facility by the State of Michigan and the U.S. Environmental Protection Agency. Landfill design and institutional controls for this facility are equal or more restrictive than the requirements placed on a State of Michigan licensed Type II landfill.

Dose effects to waste truck drivers, landfill workers and future resident farmer from the revisions outlined are considered minor, are consistent with the original submittal and are well below the public dose objective of 1 mrem/year. Changes as a result of revised assumptions and dose calculations are included in the proposed request. It is important to note that no credit is taken for reduction in landfill worker or resident farmer doses associated with the disposal of demolition debris in Type II landfill for PCB wastes material sent to the EQCo facility. However, if the entire estimated quantity of PCB bulk product waste were sent to the EQCo facility, doses associated with disposal at the licensed Type II landfill would be reduced for these individuals.

NRC approval of this revision is requested by January 1, 2005.

Kurt M. Haas
Site General Manager

cc: Administrator, Region III, USNRC
NRC Decommissioning Inspector - Big Rock Point
NRC NMSS Project Manager

Attachments

Attachment 1

Consumers Energy
BIG ROCK POINT
Docket Numbers 50-155 and 72-043

**Revision to the**
**Request for Approval of Proposed Disposal Procedures**
**in Accordance with 10 CFR 20.2002**
**Submitted March 14, 2001, May 18, 2001, and June 20, 2001**

**Marked Copy – Proposed Revisions**

September 15, 2004

27 Pages

For the reasons hereinafter set forth, it is requested that approval be granted to the Consumers Energy Big Rock Point Plant (BRP), as licensed by Facility Operating License DPR-6, Docket 50-155, issued on May 1, 1964, for procedures controlling the disposal of demolition debris in accordance with provisions of 10 CFR 20.2002. A description of the waste material for disposal that potentially contains licensed materials, including the physical and chemical properties important to risk evaluation, and the proposed manner and conditions of waste disposal is provided in the following sections. The content of this application follows the guidance of NUREG-1101, Volume 1, Onsite Disposal of Radioactive Waste – Guidance for Disposal by Subsurface Burial, March 1986 as applicable.

## I. PROPOSED ACTIVITIES

This request for approval of proposed disposal procedures in accordance with the provisions of 10 CFR 20.2002 allows Consumers Energy to dispose of demolition debris originating from decommissioning activities at BRP in a State of Michigan licensed Type II landfill or in a licensed PCB waste disposal facility where landfill design and institutional controls are equal to or more restrictive than the requirements placed on a State of Michigan licensed Type II landfill. The request is justified in the analysis discussed in the later sections of this document.

## II. BACKGROUND

By letters dated June 18, 1997, and June 26, 1997, Consumers Energy notified the NRC, pursuant to 10 CFR 50.82(a)(1)(i), that BRP would permanently cease operation on August 30, 1997. On August 29, 1997, the reactor was permanently shutdown, ending 35 years of electric power generation. On September 22, 1997, another letter was forwarded to the NRC certifying that the fuel had been removed from the reactor vessel and placed in the spent fuel pool for storage.

The BRP site is located on the northeast shore of Lake Michigan in Charlevoix County in the northern part of Michigan's Lower Peninsula. The site is approximately 60 miles northeast of Traverse City, Michigan, and about 4 miles north of the small town of Charlevoix along US Route 31.

The reactor at the BRP was of relatively small size (75 MWe) and contained a significantly small radioactive source term, only about 10 percent that of a standard boiling water reactor (BWR). Consumers Energy's goal is to dismantle BRP in a safe, environmentally conscious, and cost effective manner. This action will result in the timely removal of the existing nuclear plant in accordance with the DECON option found acceptable to the NRC in its Final Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities, NUREG-0586. Decommissioning activities started in June 1997, and ~~are~~ is

expected to be completed ~~culminate in~~in 2005~~after which its Part 50 license will be terminated~~.

As a part of the decommissioning process, Consumers Energy plans to dismantle the individual structures when they are empty and when they have been decontaminated and radiologically surveyed, as required. It is estimated that ~~a total~~ 97.5~~84.5~~ million pounds of predominately concrete debris will originate from the decommissioning project[1]. Approximately one half of this is non-impacted (*i.e.*, has never had the potential for neutron activation or to be exposed to licensed radioactive materials). The other half has a potential to contain residual surface activity and/or neutron activation products in a limited quantity. This submission deals with the disposition of demolition debris from the BRP decommissioning. Big Rock Point proposes to dispose of up to 3.05 million pounds at an alternate disposal facility licensed to accept PCB waste. This waste stream consists of painted structural steel in which non-liquid PCBs are contained within the dried paint matrix and is classified as PCB bulk product waste.

## III. JUSTIFICATION

10 CFR 20, Subpart K, §20.2001 requires that licensed radioactive material be disposed of only through (1) transfer to an authorized recipient, (2) decay in storage, (3) release in effluents within the limits in §20.1301, or (4) as authorized under §§20.2002, 20.2003, 20.2004, or §20.2005. This request for approval of proposed disposal procedures demonstrates compliance with 10 CFR 20.2001 requirements prior to disposal of demolition debris in a State of Michigan licensed landfill.

For demolition debris at BRP, three decommissioning options have been considered.

(1) License Termination with Structures Intact

This option would involve removal of licensed radioactive materials from the existing structures to residual radioactivity levels acceptable for termination of the license. Verification of achieving these residual radioactivity levels would require conducting a final status survey (FSS) for license termination on the remaining structures as well as the site environs. Specific disadvantages for application of this option at BRP include a delay in our management's environmental stewardship goal and commitment for restoration of the site to greenfield status. This option would also result in an increased expenditure of ratepayer decommissioning funds necessary to perform a much expanded FSS

[1] An additional 15.5 millions pounds of non-impacted asphalt will also be disposed of in accordance with this submittal; this asphalt was installed after decommissioning began in 1997 and was not included in the original waste estimate.

and demobilization followed by remobilization of the construction work force necessary for ultimate removal of site structures.

(2) Demolition Followed by License Termination

The initial process is similar to license termination with structures intact. Removal of licensed radioactive materials from existing structures to residual radioactivity levels acceptable for license termination with unrestricted access would still be performed. However, prior to performing the FSS, the remaining structures would be demolished and the concrete rubble left on site. The FSS would then be performed on the site environs. After license termination, the concrete rubble could be used as construction fill or disposed of in a State of Michigan licensed landfill facility. While this methodology appears to be able to meet all NRC requirements and public health and safety goals, the disadvantages are that the debris would be expensive to stabilize over the long-term context. Furthermore, redevelopment of the site after license termination for other uses may require that debris be removed at some later date and relocated to another location on-site or off-site.

This option could be performed with somewhat less expenditure of ratepayer decommissioning funds than Option (1).

(3) Demolition and Disposal Followed by License Termination

This option involves removal of licensed radioactive materials from the existing structures and installations. After decontamination of a work area, debris would be disposed of in a State of Michigan licensed landfill facility. After removal of all demolition debris, the FSS would then be performed on the site environs, the license terminated by the NRC and the site released for unrestricted future use. This option is the most cost-effective use of ratepayer decommissioning funds and will result in the most expedient environmental restoration of the site.

The option that is most attractive to Consumers Energy and the public stakeholders is the disposition of demolition debris in a landfill prior to license termination; therefore, BRP has selected Option (3) as the preferred option. The criterion used in the License Termination Rule (10 CFR 20, Subpart E) for termination of the site license for unrestricted use is a total effective dose equivalent (TEDE) of 25 mrem/year. In comparison, the TEDE of this ~~submission~~ submittal for Option (3) (demolition debris disposal in a State of Michigan licensed landfill) is 1 mrem/year. Therefore, selection of Option (3) is protective of the public health and safety, is consistent with As Low as Reasonably Achievable (ALARA), as well as being most cost-effective.

Consumers Energy is committed to conducting and completing decommissioning in a safe and cost efficient manner consistent with all regulatory requirements. Furthermore, Consumers Energy has determined that it is in the best interest to restore the site to greenfield conditions. Given the location of the site on the shore of Lake Michigan, the land is a valuable resource to the company and to the citizens of the area. The demolition debris that will originate from the demolition and removal of structures at BRP is included in this ~~submission~~submittal. This demolition debris includes flooring materials, concrete, rebar, roofing materials, structural steel, the soils associated with digging up foundations and concrete and/or asphalt pavement or other similar solid materials.

While Options (1) and (2) can be conducted under 10 CFR 20, Subpart E, Consumers Energy believes that Option (3) should be conducted under Subpart K. Although Subpart E allows small quantities of detectable licensed material to be left onsite for license termination, until the license is terminated, no amount of licensed material may be released from the site unless it is authorized under Subpart K. Consumers Energy does not intend to make this submittal for intentional disposal of radioactive waste. However; it is recognized that a potential will exist for trace quantities of licensed material to be present in the demolition debris at levels below instrument detection capabilities. Therefore, this submittal is being made in accordance with provisions of 10 CFR 20.2002 because of the potential presence of licensed material in the demolition debris.

## IV. DESCRIPTION OF WASTE

### A. Physical Properties

The demolition debris that will originate from the demolition and removal of structures and paved surfaces at BRP includes flooring materials, concrete, rebar, roofing materials, structural steel, soils associated with digging up foundations and concrete and/or asphalt pavement or other similar solid materials.

The physical form of this demolition debris will be that of bulk material with various screen sizes ranging from particles the size of sand up to occasional monoliths with a volume of several cubic feet. For the purpose of analyses performed for this application, the demolition debris is assumed to be a homogenous mixture with a density of ~~150~~94 pounds per cubic foot (~~2.4~~1.5 g/cm$^3$).

The demolition debris will exist as a dry solid waste containing no absorbents or chelating agents.

### B. Estimated Waste Volume and Burials Each Year

It is estimated that the mass of ~~both contaminated and non-contaminated~~potentially impacted demolition debris originating from the decommissioning of BRP will total

approximately ~~84.5~~48.7 -million pounds. With ~~an assumed average demolition debris~~landfill density of ~~150~~94 pounds per cubic foot, the estimated volume of potentially impacted demolition debris for disposal at a State of Michigan licensed landfill will be approximately ~~563,000~~518,000 cubic feet, and 1.2 million cubic feet of combined impacted and non-impacted demolition debris. This represents approximately ~~two~~four percent of the annual volume of waste disposed at the landfill most likely to receive most BRP demolition debris.

For the purpose of analyses performed for this application, completion of landfill disposal of demolition debris is assumed to occur within a ~~one~~three-year period of time, with disposal of 50% of the total volume to occur in one year. BRP demolition debris will not be isolated or dedicated to a single burial cell at the landfill. Rather, it will be co-mingled with other landfill materials that are available for disposal when the demolition debris is delivered to the landfill facility.

Institutional controls required at a State of Michigan licensed landfill are discussed in a later section of this application. However, one of these requirements is that materials deposited in a burial cell are required to be covered with an interim 6-inch layer of soil each day. Final closure of the burial cell will not occur until the burial cell has reached its design capacity. Institutional controls for the licensed PCB landfill are equal or more restrictive that those for a licensed Michigan Type II landfill.

Therefore, if a burial for purposes of this application is defined as final closure of the burial cell in which BRP demolition debris has been deposited, the number of burials per year will be dependent on the total volume of other landfill materials delivered to the landfill for disposal. However, it should be noted that each day that demolition debris is deposited in a burial cell, it would be covered with an interim 6-inch layer of soil.

C. Radiological Characterization of Structural Concrete

To date, over 200 core borings (2 inch diameter by 6 inch depth) have been taken from rooms or areas on the BRP site. Selection of the sampling location was biased toward areas expected to have the highest contamination potential. Each core has been analyzed onsite by gamma spectrometry and direct frisk to determine what types of radioactive material are present and how far the contaminants have penetrated into the concrete. The results of these onsite analyses ~~are~~were summarized in Enclosure 1 ~~to this~~of Big Rock Point's submittal dated June 20, 2001. In addition, portions of 14 core samples have been analyzed by an offsite laboratory (General Engineering Laboratories) at typical environmental monitoring lower limits of detection (LLD) using alpha and gamma

spectrometry as well as liquid scintillation to analyze for the presence of the following radionuclides:

| | | | | |
|---|---|---|---|---|
| Ac-227 | Ac-228 | Ag-108m | Ag-110m | Am-241 |
| C-14 | Cd-109 | Ce-144 | Cm-242 | Cm-243/244 |
| Co-60 | Cs-134 | Cs-135 | Cs-137 | Eu-152 |
| Eu-154 | Fe-55 | H-3 | I-129 | K-40 |
| Mn-54 | Ni-59 | Ni-63 | Nb-94 | Pb-214 |
| Pm-147 | Pu-241 | Pu-238 | Pu-239/240 | Ru-106 |
| Sb-125 | Sr-90 | Tc-99 | U-233/234 | U-235/236 |
| U-238 | Zn-65 | | | |

One-half inch thick, near surface wafers from 12 of the core samples were submitted to represent potential radioactive materials remaining after remediation of the structural surfaces. Laboratory analysis of these samples identified only Co-60, Cs-137, Fe-55 and H-3 at levels greater than the LLD values. K-40, Pb-214, U-233/234 and U-238 were also detected in these samples but at levels that were indistinguishable from naturally occurring background levels measured in plant concrete samples that were not contaminated by licensed radioactive materials. The results of these samples with concentration values representing the average concentration in the one-half inch thick wafer are detailed in Table 1. Copies of the General Engineering Laboratories Certificate of Analysis for these samples ~~are~~ were included as Enclosure 2 to ~~this~~ Big Rock Point's submittal dated June 20, 2001.

Table 1
Remediated Concrete Core Sample Results

| Sample Number | Radionuclide | | | |
|---|---|---|---|---|
| | Co-60 pCi/g | Cs-137 pCi/g | Fe-55 pCi/g | H-3 pCi/g |
| 19 | <LLD | <LLD | <LLD | <LLD |
| 31 | <LLD | <LLD | <LLD | <LLD |
| 83 | <LLD | 0.130 ± 0.088 | <LLD | <LLD |
| 104 | <LLD | 0.094 ± 0.054 | <LLD | <LLD |
| 112 | 0.084 ± 0.065 | <LLD | <LLD | 6.24 ± 2.51 |
| 123 | <LLD | <LLD | <LLD | 9.47 ± 2.88 |
| 128 | <LLD | 0.166 ± 0.062 | <LLD | <LLD |
| 7 | <LLD | <LLD | <LLD | <LLD |
| 90 | <LLD | <LLD | <LLD | <LLD |
| 149 | 0.458 ± 0.114 | <LLD | <LLD | <LLD |
| 117 | <LLD | <LLD | <LLD | <LLD |
| 100 | <LLD | <LLD | <LLD | <LLD |
| 119* | 2.47 ± 0.739 | <LLD | <LLD | <LLD |
| 153* | 0.292 ± 0.140 | 0.282 ± 0.128 | <LLD | <LLD |

*Remediated high surface contamination samples

The final two core samples listed above were taken from areas having a high potential for surface contamination and are average values of subsurface samples taken at various concrete depths. Laboratory analysis of these samples identified only Co-60, Cs-137 and H-3. K-40, Pb-214, U-233/234 and U-238 were also detected in these samples but at levels that were indistinguishable from naturally occurring background levels measured in plant concrete samples that were not contaminated by licensed radioactive materials.

D. Calculated Licensed Radioactive Material Content of Demolition Debris

Results of the radiological characterization of structural concrete and current remedial action contamination surveys were used to classify the surfaces as either uncontaminated, shallow surface contaminated or deep surface contaminated. Uncontaminated surfaces were defined as surfaces having no detectable

contamination as evidenced by historical records review, current remedial action contamination surveys and laboratory analysis of representative core samples.

Shallow surface contamination is defined as surfaces having no detectable contamination ($\geq$ 5,000 dpm/100 $cm^2$ total activity) as evidenced by contamination surveys performed after remedial action (if required) but detectable shallow subsurface contamination identified by laboratory analysis of representative core samples. Shallow subsurface contamination is assumed (based on core sample profiling) to penetrate to a depth of 1 inch after surface remediation.

Deep surface contamination is defined as highly contaminated surfaces prior to remediation with no detectable contamination as evidenced by contamination surveys performed after remedial action, but with some detectable deep subsurface contamination identified by laboratory analysis of representative core samples. This subsurface contamination is assumed to penetrate to a depth of 6 inches after surface remediation.

Based on the results of the radiological characterization of structural concrete on a room-by-room basis, a total surface area of 10,200 square feet have been calculated to have deep surface contamination. 51,835 square feet have been calculated to have shallow surface contamination and the remainder is considered to be uncontaminated. This results in a calculated 5,100 cubic feet of deep surface contaminated concrete and 4,320 cubic feet of shallow surface contaminated concrete.

Averaging the greater than LLD results from Table 1 and applying the resulting concentrations to the 4,320 cubic feet of shallow surface contaminated concrete and 5,100 cubic feet of deep surface contaminated concrete results in concentrations and total activity as reported in Table 2.

Table 2

Volumetric Contamination of Remediated Surface Contaminated Concrete

| Radionuclide | Concentration (pCi/g) | Total Activity (mCi) |
|---|---|---|
| Co-60 | 0.83 | ~~0.532~~0.613 |
| Cs-137 | 0.17 | ~~0.109~~0.126 |
| H-3 | 7.86 | ~~5.042~~5.806 |
| Total | 8.85 | ~~5.683~~6.544 |

All ~~42.25~~48.65 million pounds of impacted concrete will be treated as potentially contaminated. The volumes of 4,320 cubic feet of shallow and 5,100 cubic feet of deep contamination as calculated from structural characterization analyses, will not be separated from impacted concrete debris. Therefore, as a conservative estimate of activity potentially present, activity concentrations from Table 2 were applied to the impacted demolition debris mass of ~~42.25~~48.65 million pounds resulting in total activity as reported in Table 3.

Table 3

Impacted Demolition Debris Total Activity (~~42.25~~48.65 million pounds)

| Radionuclide | Concentration (pCi/g) | Total Activity (mCi) |
|---|---|---|
| Co-60 | 0.83 | ~~16.0~~18.4 |
| Cs-137 | 0.17 | ~~3.3~~3.8 |
| H-3 | 7.86 | ~~152~~175 |
| Total | 8.85 | ~~171~~197 |

E. Requested Limiting Demolition Debris Concentration

To allow operational flexibility and ensure monitoring capability, Consumers Energy requests a bounding principal gamma emitter concentration limit of 5 pCi/gm for licensed radioactive materials contained as trace contamination in demolition debris for disposal in a State of Michigan licensed Type II landfill or alternate landfill licensed for disposal of PCB wastes. Adjusting the total activity reported in Table 3 to a bounding principal gamma emitter concentration limit of 5 pCi/gm results in the bounding activity reported in Table 4.

Table 4

Impacted Demolition Debris Bounding Activity (~~42.25~~48.65 million pounds)

| Radionuclide | Concentration (pCi/g) | Total Activity (mCi) |
|---|---|---|
| Co-60 | 4.15 | ~~80.0~~92.1 |
| Cs-137 | 0.85 | ~~16.5~~19.0 |
| H-3 | 39.3 | ~~760~~875 |
| Total | 44.3 | 986~~856~~ |

To ensure that the 5 pCi/gm principal gamma emitter limit is not exceeded, structural surfaces will be surveyed prior to demolition to verify that surface contamination does not exceed 5,000 dpm/100 $cm^2$ averaged over areas appropriate for the detection system utilized and all demolition debris will be monitored by a bulk assay system with an alarm setpoint established at or below the 5 pCi/gm principal gamma emitter limit prior to disposal.

Establishment of this bounding concentration limit will ensure that any uncertainties in the content of licensed radioactive material in demolition debris sent to a State of Michigan licensed landfill or alternate landfill licensed for disposal of PCB wastes will not present a dose impact problem.

F. Dose Impacts

Dose impacts of the requested impacted demolition debris bounding activity were evaluated by performing calculations using the Table 4 radionuclide concentrations as source terms (reference Big Rock Point Engineering Analysis, EA-BRP-RAE-04-01, Disposal of Demolition Debris at Environmental Quality Company, Revision 0 and EA-BRP-RAE-04-02, Disposal of Demolition Debris at Environmental Quality Company: Alternative, Revision 0.) These calculations are bounding because release at a principal gamma emitter limit of 5 pCi/gm is assumed for all ~~42.25~~48.65 million pounds of impacted demolition debris. In practice, release surveys to a minimum detection limit of 5 pCi/gm of principal gamma emitters results in release of demolition debris from zero to 5 pCi/gm, or a mean of approximately 2.5 pCi/gm.

1. Transport Worker Dose Assessment

An evaluation of transport worker dose was performed using MicroShield, Version ~~5.03~~5.05, from Grove Engineering and site-specific assumptions

including bounding concentration values presented in Table 4. The transport system chosen for this evaluation was a roll-off container system with dimensions of 21.5 feet long, 8 feet wide and 3.5 feet high.

In addition to the above, the following assumptions were also applied to the analysis. In each case, the driver's seat is assumed to be 1 foot away from the cabin wall, which is conservatively assumed to be 0.12 inches thick, made of iron. The material hauler part of the truck is assumed to be made of iron with 0.25-inch thick sides, floor and tailgates. The distance between the hauler part and the driver's cabin is assumed to be 4 feet.

*a. Transportation to a Licensed Type II Landfill:*

It is assumed that three truck drivers will be used for the total duration of the project and that the number of loads transported will be divided equally between each driver. Given the anticipated volumes of the impacted demolition debris ~~(10,000 cubic yards)~~, combined with the assumptions of standard load volumes in tandem trailers, transport of ~~all~~50% ~~-~~of demolition debris within a one-year period and the driving time of 2 hours per load to the landfill, each truck driver will be potentially exposed to radiation from residual radioactivity for 324~~300~~ hours. Applying the above assumptions, results in a calculated dose rate to the driver of 9.87E-04 ~~1.22E-03~~ mrem/hour or an annual dose of ~~0.366~~ 0.320 mrem to each of the truck drivers.

*b. Transport to a Licensed PCB Landfill:*

Assume that two truck drivers will be used for transportation of PCB bulk product waste and that the number of loads transported will be divided equally between each driver. Given the maximum estimated 3.05 million pounds of PCB waste for disposal, combined with the assumptions of standard load volumes in tandem trailers, transport of all PCB waste within a one-year period and the driving time of 6 hours per load to the landfill, each truck driver will be potentially exposed to radiation from residual radioactivity for 180 hours. Applying the above assumptions, results in a calculated dose rate to the driver of 9.87E-04 mrem/hour or an annual dose of 0.178 mrem to each of the truck drivers.

Output from the MicroShield analysis is provided as ~~Enclosure~~ Attachment 3 to this submittal ~~and an electronic file (*Rolloff.ms5ROLL-3.MS5 and 2NDROLL.MS5*) of the analysis is included on the enclosed computer compact disk.~~

2. Landfill Worker Dose Assessment

An evaluation of landfill worker dose was performed using RESRAD, Version 6.0. For landfill operation, the landfill is assumed to close after placement of the demolition debris. Post-closure monitoring of the landfill is required by the State of Michigan for a 30-year period. Therefore, it is assumed that a member of the public, other than a landfill worker will not have access to a burial cell containing the demolition debris until 30 years after debris placement.

The following assumptions were made in the evaluation:

a. The most exposed individual at the landfill is a bulldozer operator, positioning and spreading the demolition debris and placing a soil cap on it at the end of the day.

b. The landfill most likely to receive BRP demolition debris currently has three bulldozer operators and, for purposes of this assessment, dose was assumed to be equally distributed between each bulldozer operator.

c. The ~~281,500~~522,200 cubic feet (~~7,930~~14,710 cubic meters) of impacted demolition debris are assumed to be deposited in a uniform ~~2~~3.71-meter thick, 3,965 square meter (0.98 acre) layer, assuming all demolition debris is buried in the licensed Type II landfill.

d. Based on the 0.98 acre surface area estimate of impacted demolition debris and a burial cell surface area of 8 acres, each landfill worker is assumed to spend 12.25 percent (0.98 acre/8 acres) of each worker's time working over or exposed to impacted demolition debris or 245 hours per occupational year of 2000 hours. This total of 245 hours equates to a RESRAD outdoor time fraction of 0.028.

e. A 0.15 m soil cover (which is a daily cover requirement) was assumed. No credit was taken for any other engineering controls required by the State of Michigan.

f. No credit was taken for shielding provided to the workers by the bulldozer.

g. The bounding concentration values presented in Table 4 were used as the impacted demolition debris source terms.

h. Doses will be distributed to workers at each landfill in proportion to the total quantity of radioactive material potentially present. Conservatively assuming a constant maximum level of 5.0 pCi/g, doses are proportionate to the weights shipped to each site.

Use of the above assumptions results in a calculated annual TEDE dose of ~~0.290~~ 0.291 mrem for each Type II landfill worker and a weight-proportionate dose of 0.0182 mrem for the PCB landfill worker. Output from the RESRAD analysis is provided as ~~Enclosure~~ Attachment 4 to this submittal ~~and an electronic file (*Worker.rad*) of the analysis is included on the enclosed computer compact disk~~.

3. Landfill Resident / Farmer Dose Assessment

An evaluation of dose to an individual member of the public was performed using RESRAD, Version 6.0. Post-closure monitoring of the landfill is required by the State of Michigan for a 30-year period. For purposes of this evaluation, it is assumed that a residence, including a basement to the residence and a vegetable garden, is established on the burial cell containing the demolition debris 30 years after debris disposal.

The following assumptions were made in the evaluation:

a. All RESRAD exposure pathways are active for the Resident / Farmer scenario except for the radon pathway (not regulated by the NRC).

b. The impacted demolition debris is assumed to be soil like material with the bounding concentration values presented in Table 4 even though its density is somewhat higher than most soils. Additionally, resuspension of demolition debris radioactivity is not expected to vary significantly from that for soil. Therefore, the RESRAD default soil parameters are considered appropriate for use in this analysis.

c. It is assumed that all licensed radioactive material in the impacted demolition debris is dispersed throughout the volume of impacted material originating at BRP and no dilution of the demolition debris occurs from other landfill materials deposited in the burial cell. This is very conservative since Michigan law requires a 6-inch soil cover over the debris at the end of each day and the demolition debris is expected to

be only two percent of the total waste volume processed at the landfill over a one-year period.

d. For the Resident / Farmer scenario, it is assumed that the resident spends 50 percent of the time indoors, 25 percent outdoors at the site, and 25 percent of the time away from the site. These assumptions are consistent with those suggested in the NRC Policy and Guidance Directive PG-8-08, Scenarios for Assessing Potential Doses Associated with Residual Radioactivity.

e. Fifty percent effectiveness is assumed for the leachate collection system required by the State of Michigan (resulting in a 50 percent reduction in calculated annual dose). Also, the required 18-inch infiltration layer, 24-inch erosion layer and 6-inch earthen material layer capable of sustaining native plant growth are considered to be intact at the end of the 30-year period.

f. No credit is taken for landfill material originating elsewhere which may be deposited on top of the demolition debris.

g. The 522,200~~281,500~~ cubic feet (14,710~~7,930~~ cubic meters) of impacted demolition debris are assumed to be deposited in a uniform ~~2~~3.71-meter thick, 3,965 square meter (0.98 acre) layer, assuming all demolition debris is buried in the licensed Type II landfill.

h. For the RESRAD model, root depth was extended from the default value of 0.9 m to a depth of 1.4 m. This was done to ensure communication between vegetation and the contaminated zone.

i. All other RESRAD parameters were set at their default values for this evaluation. An Engineering Analysis was performed on RESRAD parameter selections and concluded that, when applied to the northern Michigan climate and State of Michigan licensed Type II landfill requirements discussed in Section VIII, the use of default parameters will result in conservative dose estimates.

j. Doses will be distributed to residents at each landfill in proportion to the total quantity of radioactive material potentially present. Conservatively assuming a constant maximum level of 5.0 pCi/g, doses are proportionate to the weights buried at each site.

Applying the above assumptions results in a calculated maximum annual dose of 0.~~009~~178 mrem for a resident / farmer living at the Type II landfill site. This maximum annual dose occurs the first year of public access following the 30-year post-closure monitoring period. Using the assumption of weight proportionality, resident farmer living at the PCB landfill site would receive an annual dose of 0.001 mrem. Output from the RESRAD analysis is provided as ~~Enclosure~~ Attachment 5 to this submittal ~~and an electronic file (*Public.rad*) of the analysis is included on the enclosed computer compact disk.~~

4. Dose Impact Conclusions

Assuming that all impacted demolition debris would be released for State of Michigan licensed Type II landfill disposal at a bounding principal gamma emitter concentration limit of 5 pCi/gm as trace contamination in demolition debris would result in a maximum dose impact to an individual member of the public of ~~0.366~~0.320 mrem/year to each of three transport workers. Maximum dose to each landfill worker was calculated to be 0.29~~0~~1 mrem/year during impacted demolition debris disposal. Maximum calculated dose to a resident / farmer was calculated to be 0.0~~09~~18 mrem/year which would not occur until after completion of the required 30-year post-closure monitoring period. These maximum calculated doses are well below the public dose objective of 1 mrem/year. Annual doses associated with disposal of demolition debris classified as PCB bulk product waste at a licensed PCB waste facility with design and institutional controls equal or greater that the a Type II landfill are 0.178 mrem to each of the truck drivers, 0.018 mrem to a landfill worker and 0.001 mrem to a resident farmer. If the entire estimated quantity of PCB bulk product waste were sent to the alternate disposal facility, doses associated with disposal at the licensed Type II landfill would be reduced by the quantities above. However, only truck driver doses have been credited with reduced dose in this analysis.

Actual maximum dose impact to an individual member of the public is expected to be much less than these calculated values using a bounding principal gamma emitter concentration limit of 5 pCi/gm.

To ensure that the 5 pCi/gm principal gamma emitter limit is not exceeded, structural surfaces will be surveyed prior to demolition to verify that surface contamination does not exceed 5,000 dpm/100 $cm^2$ averaged over areas appropriate for the detection system utilized and all demolition debris will be monitored by a bulk assay system with an alarm setpoint established at or below the 5 pCi/gm principal gamma emitter limit prior to disposal.

G. Prohibition on Burial of Hazardous Waste

Hazardous waste as defined in the regulations of the Environmental Protection Agency (EPA), 40 CFR Parts 260 through 265, is not permitted to be included in the BRP demolition debris. Hazardous waste is required to be disposed of in a manner set out in EPA regulations and in accordance with applicable local and State laws and codes, and will not be disposed of in conjunction with the debris considered here.

V. PACKAGING OF WASTE

Big Rock Point demolition debris to be disposed of at a State of Michigan licensed Type II landfill or a licensed PCB landfill will not be packaged. Since the radiological survey process used to determine that the demolition debris is acceptable for landfill disposal will ensure that trace quantities of licensed material potentially present in the demolition debris are at levels below the requested bounding concentration limit, BRP demolition debris will be processed the same as debris generated from the demolition of any non-nuclear industrial facility.

The existing Radiation Protection Program, which is continually audited by the NRC, will ensure the radiological safety of BRP workers during generation and packaging of demolition debris. The dose evaluations discussed previously demonstrate that dose to members of the public from transportation and disposal of demolitions debris would not be measurable with state-of-the-art personnel monitoring instrumentation and is insignificant in comparison to the average annual dose received by individuals from natural sources (approximately 300 mrem per year).

Demolition debris will be transported from the BRP site to the landfill facility by truck transportation using either of three types of truck transport systems that are generally the common practice for carrying demolition debris. These transport systems include a roll-off container system, a dual-trailer mule system or a wide-bodied demolition hauler.

Roll-off container systems have the dimensions of 21.5 feet long by 8 feet wide by 3.5 feet high. Dual-trailer mule systems use two trailers, each having the dimensions of 50 feet long by 8 feet wide by 5 feet high. Wide-bodied demolition haulers have the dimensions of 30 feet long by 8 feet wide by 6 feet high.

Type II landfills licensed by the State of Michigan and PCB landfills licensed by the State of Michigan and the U.S. Environmental Protection Agency are required to implement controls to isolate the contents of burial cells from the environment. These controls will provide isolation of the BRP demolition debris from the environment over a reasonable period of time similar to the use waste packaging. The controls are discussed in Section VIII, Nature of the Burial Site.

## VI. BURIAL LOCATION

The State of Michigan licensed Type II landfill selected for burial of BRP demolition debris will be located within approximately 60 miles of the BRP site. The facility selected for disposal of PCB bulk products wastes is located approximately 275 miles from the BRP site.

The State of Michigan Solid Waste Management Act Administrative Rules Promulgated Pursuant To Part 115 Of the Natural Resources and Environmental Protection Act, 1994 Pa 451, As Amended contains restrictions on the location of Type II landfill facilities. Among these are restrictions on groundwater isolation, horizontal isolation distances, floodplains, wetlands, fault areas and seismic impact zones, and unstable areas. These restrictions are discussed in Section VIII, Nature of the Burial Site.

## VII. INSTITUTIONAL CONTROLS

Part 115 of the State of Michigan Administrative Rules contains institutional controls that restrict access to Type II licensed landfills. Licensing requirements for the landfill selected for disposal of PCB bulk products wastes are considered equal or more restrictive than those for licensed Type II landfills. The landfill operator is required to control public access to the landfill and prevent unauthorized vehicular traffic and illegal dumping of wastes by using artificial or natural barriers, or both, as appropriate.

After the final closure of a burial cell, the landfill operator is required to conduct post-closure care for not less than 30 years. This post-closure care includes:

- Maintaining the integrity and effectiveness of any final cover,
- Maintaining, operating, and monitoring the leachate collection system,
- Monitoring the groundwater,
- Monitoring all secondary collection systems and leak detection systems, and
- Maintaining and operating the gas monitoring and collection system.

## VIII. NATURE OF THE BURIAL SITE

The Type II landfill where the BRP demolition debris will be sent for disposal will meet State of Michigan Part 115 Administrative Rules that will limit migration of licensed radioactive material potentially mixed with the demolition debris in trace amounts. These requirements include but are not limited to:

- Location restrictions,
- A composite liner,
- Leachate collection and removal systems,

- Leak detection systems,
- Daily 6 inch interim soil covers,
- Explosive gas control and monitoring,
- Groundwater monitoring,
- Surface and Groundwater Performance,
- Run-On and Run-Off Control Systems, and
- Final cover composite liner designed to minimize infiltration and erosion.

A. Location Restrictions

The location of each burial cell will be isolated from groundwater sources. Permanent minimum clearances of ten feet to the natural groundwater level and 7 feet to a permanently depressed groundwater level is required to be maintained from the top of the primary liner.

The active work area at the landfill is required to not be located closer than 100 feet to adjacent property lines or road rights-of-way or closer than 300 feet to domiciles that exist at the time a landfill license is requested. It is also not allowed to be located within 400 feet of inland lakes and streams or within 2,000 feet of the Great Lakes. The active work area is also required to be a minimum of 2,000 feet from wells that serve Type I and Type IIa water supplies and a minimum distance of 800 feet from wells that serve Type IIb and Type III public water supplies.

If a landfill is located within a floodplain, the landfill operator is required to demonstrate that:

- The cell will not restrict the flow of the 100-year flood,
- The cell will not reduce the temporary water storage capacity of the floodplain,
- The cell will not result in washout of solid waste so as to pose a hazard to human health and the environment,
- The cell does not encroach upon the floodway and will not increase upstream or downstream flood stages,
- The cell has a natural or compacted soil base which is not less than 10 feet thick,
- The distance from the normal water line of the water body to the solid waste boundary of the landfill will not be less than 500 feet, and

- The design of the landfill will include a dike to preclude floodwater inundation with a top elevation that is not less than 5 feet above the 100-year flood elevation.

Landfills are not allowed to be located in wetlands unless extensive measures are taken for protection of the wetlands.

Landfill burial cells are not permitted to be located within 200 feet of a fault that has had displacement in holocene time, unless the landfill operator demonstrates that an alternative setback distance of less than 200 feet will prevent damage to the structural integrity of the cell and will be protective of human health and the environment. They are also not permitted to be located in seismic impact zones, unless the landfill operator demonstrates that all containment structures, including liners, leachate collection systems, and surface water control systems, are designed to resist the maximum horizontal acceleration in lithified earth material for the site.

B. Composite Liners

Burial cells are required to be constructed with a composite liner and a leachate collection system that is designed and constructed to maintain less than a 1-foot depth of leachate over the liner, excluding the sump.

Burial cells are required to be located, designed, and constructed so that the risks posed by leakage through the composite liner are minimized. To do so, a cell is required to be either a monitorable cell that is located over a natural soil barrier so as to restrict the migration of leakage from the unit or designed with a double liner system that is capable of detecting and collecting leakage through the primary composite liner.

C. Leachate Collection and Removal Systems

Each burial cell is required to have a leachate collection system that is designed and constructed to maintain less than a 1-foot depth of leachate over the primary liner. To do so, the system is required to be designed to do all of the following:

- Limit the head at any point in the system, excluding the sump, to not more than 1 foot,
- Extend across the entire bottom of the system,
- Be chemically resistant to the waste that is managed in the landfill and the leachate that is expected to be generated and be of sufficient strength and

thickness to prevent collapse under the pressures that are exerted by overlying wastes, waste cover materials, and equipment that is used at the landfill,

- Minimize clogging during the active life and postclosure care period,
- Drain leachate to sumps using pumps that are of a sufficient size to collect and remove liquids from the sump and prevent liquids from backing up into the drainage layer. The design of each sump and removal system provides a method for measuring and recording the volume of liquids removed and the depth of leachate in the sump.

A secondary collection system is required to be provided and be capable of detecting, collecting, and removing leaks of hazardous constituents at the earliest practicable time through all areas of the top liner that are likely to be exposed to waste or leachate during the active life and postclosure care period.

The landfill operator is required to remove leachate from a burial cell as frequently as necessary to ensure that the leachate depth on the liner, excluding the sump, is not more than 1 foot, except after a significant storm event. The leachate depth on the liner is not allowed to be more than 1 foot for more than seven days after a significant storm event. A significant storm event is a storm that generates 0.1 inches or more of rainfall in 24 hours.

D. Leak Detection Systems

Each burial cell is required to have a leak detection system. For unmonitorable units, the secondary collection system is also a leak detection system. A response flow rate is established in the operating license for each landfill to evaluate the performance of a leak detection system.

If the average daily flow rate removed from the sump of a leak detection system is more than the action flow rate for that burial cell, the landfill operator is required to evaluate the chemical characteristics of liquid in the leak detection system by sampling and analyzing the system and evaluating for the presence of a leak by a statistical test, a trend analysis, or other means. Before solid waste is placed in any new burial cell that has a leak detection system, the landfill operator may, at his discretion, establish a baseline concentration of constituents in the secondary collection system based on an analysis of representative samples from the system.

The landfill operator must conduct required response actions if monitoring of the leak detection system determines that both of the following apply to liquid that is removed from the system:

- The average daily flow rate is more than the response flow rate that is established for the unit and

- The liquid contains hazardous substances indicative of leachate from the unit.

A landfill operator who is required to conduct response actions is required to take all of the following actions:

- Within seven days of a determination that the response flow rate has been exceeded, notify the State of Michigan, in writing, that the response flow rate has been exceeded,

- Submit a preliminary written assessment to the State of Michigan within 14 days of a determination that the response flow rate has been exceeded. A preliminary written assessment is required to include all of the following information for the landfill cell in which the response flow rate was exceeded:

  - The amount of liquids removed from the leak detection system,

  - The likely sources of liquids, including the depth of leachate in the leachate collection system,

  - The possible location, size, and cause of any leaks, and

  - The short-term actions taken and planned.

- Determine, to the extent practicable, the location, size, and cause of any leak.

- Determine whether waste receipt should cease or be curtailed, whether any waste should be removed from the landfill cell for inspection, repairs, or controls, and whether or not the cell should be closed.

- Determine any other short-term and longer-term actions to be taken to mitigate or stop any leaks.

- After a determination that the response flow rate has been exceeded, and for as long as the flow rate in the system exceeds the response flow rate, the landfill operator is required to submit to the State of Michigan, within 30 days of the end of the calendar quarter, a report that summarizes the results of any remedial actions taken and planned.

- To make the leak or remediation determinations required, the landfill operator is required to do all of the following:

- Assess the source of liquids and amounts of liquids by source,
- Conduct a fingerprint, hazardous constituent, or other analysis of the liquids in the system to identify the source of liquids and possible location of any leaks and the hazard and mobility of the liquid, and
- Assess the seriousness of any leaks in terms of potential for escaping into the environment or document why the assessments are not needed.

E. Daily Six-Inch Soil Covers

The landfill operator is required to cover disposed of solid waste with 6 inches of earthen material at the end of each operating day or at more frequent intervals, if necessary, to control disease vectors, fires, odors, blowing litter, and scavenging. If clay or other low-permeability material is used as daily cover, then the operator is required to scrape back the previous day's cover to allow the free movement of liquids and gases through the landfill.

If an active burial cell will lie idle for a period of three months or more before additional lifts are constructed, the landfill operator is required to place 1 foot of compacted cover, which may include the 6-inch daily cover, on the surface to minimize nuisance conditions.

F. Explosive Gas Control and Monitoring

The landfill operator is required to ensure that the concentration of methane gas generated by the facility is not more than 25 percent of the lower explosive limit for methane in facility structures, excluding gas control or recovery system components, and the leachate collection system and that the concentration of methane gas is not more than the lower explosive limit at or beyond the facility property boundary. To demonstrate compliance with this requirement the landfill operator is required to implement a routine methane monitoring program.

G. Groundwater Monitoring

Detection monitoring is required at all required groundwater monitoring wells. At a minimum, a detection-monitoring program for a landfill is required to include monitoring for all of the following constituents:

- The listed primary indicators and pH, at least quarterly during the active life and semiannually during the postclosure period and

- The following constituents listed at least semiannually during the active life of the facility and the postclosure period:
  - Heavy metals that are listed,
  - Listed primary volatile organic constituents, and
  - Listed secondary organic constituents.

The landfill operator of a cell that contains a secondary collection system may conduct sampling and analysis for listed primary indicators in place of the heavy metals if all of the following conditions are met:

- Leachate monitoring shows that the concentration of all of the indicators in leachate is not less than ten times the concentration in groundwater and
- Secondary collection system monitoring shows all of the following:
  - That the allowable flow rate has not been exceeded,
  - That the concentration of two or more indicators in the system is not more than the following threshold values for two consecutive sampling events:
    - For chlorides, 250 mg/l,
    - For iron, 0.3 mg/l,
    - For sulfates, 250 mg/l,
    - For total inorganic nitrogen, 10 mg/l, and
    - For total dissolved solids, 500 mg/l.
  - That listed volatile organics have not been detected in the secondary collection system,
  - That the listed concentration of metals has not exceeded 1/10 the specified value,
- The unit is a monitorable unit, and
- The concentration of the indicators in groundwater is normally distributed.

Assessment monitoring is required at a landfill if a statistically significant increase over background has been detected for one or more of the listed constituents.

Within 90 days of the triggering of an assessment monitoring program, and annually thereafter, the landfill operator is required to sample and analyze the groundwater for all constituents listed in 40 CFR part 258, Appendix II. A minimum of one sample

from each downgradient well is required to be collected and analyzed during each sampling event. For any constituent that is detected in the downgradient wells as a result of the complete Appendix II constituent analysis, a minimum of four independent samples from each background and downgradient well are required to be collected and analyzed to establish background for the constituents.

H. Surface and Groundwater Performance

Operation of a State of Michigan licensed landfill is not allowed to cause a discharge of pollutants into waters of the United States, including wetlands, that is in violation of any of the requirements of the federal clean water act, including the national pollutant discharge elimination system (NPDES) requirements under Section 402 of the Federal Clean Water Act. Also, the landfill is not allowed to cause the discharge of a nonpoint source of pollution to waters of the United States, including wetlands, that is in violation of any of the requirements of an areawide or statewide water quality management plan that has been approved under Section 208 or 319 of the Federal Clean Water Act.

To demonstrate compliance with these requirements, the landfill operator is required to conduct a surface water-monitoring program approved by the State of Michigan for any surface water that may receive run-off from the active work area. Monitoring results are required to be submitted to the State of Michigan not more than 30 days after the end of the calendar quarter.

I. Run-On and Run-Off Control Systems

Two systems are required to control the flow of rainwater over burial cells. A run-on control system is required to prevent flow onto the active portion of the landfill during the peak discharge from a 25-year, 24-hour storm. Also, a run-off control system from the active portion of the landfill is required to collect and control at least the water volume that results from a 24-hour, 25-year storm.

J. Final Cover Composite Liner

A final cover system is required to be installed on each burial cell which is designed to minimize infiltration and erosion and which is comprised of an erosion layer underlain by an infiltration layer. The final cover system is required to be comprised of the following components:

- An infiltration layer that is comprised of either a minimum of 18 inches of earthen material that has a permeability which is less than or equal to $1.0 \times 10^{-5}$ cm/sec or a bentonite geocomposite liner which is underlain by not less than

18 inches of earthen material to protect the liner from waste and minimize the effect of settlement.

- An erosion layer that consists of both a soil layer which is not less than 2 feet thick, which is immediately above the composite cover liner, and which is designed to do all of the following:
  - Provide for the lateral drainage of precipitation off the cover of the landfill,
  - Minimize frost penetration into the infiltration layer, and
  - Protect the flexible membrane liner from root penetration, ultraviolet light, and other deleterious effects.

A minimum of 6 inches of earthen material capable of sustaining native plant growth is required to be placed over the final cover system. To prevent the ponding of water on completed fill surfaces, the grading contours are required to be sufficient to prevent the development of local depressions due to post construction settlement. Slopes of the final cover are required to be not less than four percent at any location.

## IX. BURIAL PROCEDURES

Please refer to Section VIII, Nature of the Burial Site regarding the burial of BRP demolition debris at ~~a~~ State of Michigan licensed landfill facilitiesy~~.~~

## X. RADIATION SAFETY PROCEDURES

BRP is currently conducting decommissioning activities under a Radiation Protection Program and implementing procedures that comply with NRC regulatory requirements contained in 10 CFR 20, Standards for Protection Against Radiation. The Radiation Protection Program and implementing procedures are a requirement of the BRP Defueled Technical Specifications 6.6.1 and 6.6.2. The NRC Region III Office routinely reviews the Radiation Protection Program and implementing procedures and their implementation.

Disposal of BRP demolition debris will be performed in accordance with the Radiation Protection Program and implementing procedures as applicable.

## XI. RECORDKEEPING

Recordkeeping requirements for landfill disposal of demolition debris are specified in BRP procedures.

As a minimum, these records will include:

- Surface contamination monitoring reports and
- Bulk container assay records for each container which will include but not be limited to:
  - Date and time the assay was performed,
  - Source of the demolition debris,
  - Mass, volume and composition of the demolition debris,
  - Landfill destination for the demolition debris, and
  - Assay results.

## XII. ANALYSIS OF NO SIGNIFICANT ENVIRONMENTAL IMPACTS EVALUATION

Consumers Energy finds, in compliance with 10 CFR 50.82(a)(6)(ii), that activities associated with this application involve no significant environmental impacts. The following evaluation in conjunction with the foregoing discussion supports that finding.

A. Will the proposed activity result in significant environmental impacts not previously reviewed?

No significant environmental impacts are expected from the disposal of demolition debris with trace concentrations of licensed radioactive materials in a State of Michigan licensed landfill or alternate licensed PCB landfill. Total volume of landfill waste projected for BRP decommissioning is ~~635,100~~1.34 million cubic feet including ~~72,100~~142,000 cubic feet of radioactive waste and ~~563,000~~1.2 million cubic feet of demolition debris. In comparison, NUREG-0586, "Final Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities," (FGEIS) lists a radioactive waste volume for the reference boiling water reactor (BWR) of 18,975 cubic meters (670,096 cubic feet), including disposable containers.

~~Although the GEIS evaluation of waste disposal volumes did not address the removal and disposal of non-radioactive structures and materials beyond that necessary to terminate the NRC license, the volume of waste evaluated in the GEIS (670,096 cubic feet) exceeds the total waste volume (including demolition debris and radioactive waste) projected for BRP decommissioning of 635,100 cubic feet.~~The BRP potentially impacted waste volume of 518,000 cubic feet and the total other radwaste volume of 142,000 cubic feet (total of approximately 660,000 cubic feet) compares with the FGEIS reference BWR.

Non-radiological environmental impacts evaluated in the GEIS included:

- Demography and human activities in the area,
- Hydrology,
- Aquatic resources/ecosystems in the area surrounding the plant site,
- Terrestrial resources,
- Endangered and threatened species,
- Land use,
- Air pollution control requirements,
- Water pollution control requirements,
- Hazardous materials and waste control,
- Occupational safety, and
- Public safety.

Radiological environmental impacts evaluated in the GEIS included:

- Occupational radiation exposure,
- Radiation exposure to the public,
- Radioactive waste management systems,
- Liquid radioactive effluents, and
- Airborne radioactive effluents.

The FGEIS concludes that the major environmental impact of decommissioning is the commitment of small amounts of land for waste burial in exchange for reuse of the facility and site for other purposes. Since in many instances, such as at a reactor facility, the land is a valuable resource, return of this land to the commercial or public sector is highly desirable. Therefore, the FGEIS evaluation bounds disposal of all BRP demolition debris including disposal of the demolition debris containing trace concentrations of licensed radioactive materials requested by this application.

Attachment 2

Consumers Energy
BIG ROCK POINT
Docket Numbers 50-155 and 72-043

**Proposed Revision to the**
**Request for Approval of Proposed Disposal Procedures**
**in Accordance with 10 CFR 20.2002**
**Submitted March 14, 2001, May 18, 2001, and June 20, 2001**

September 15, 2004

27 Pages

For the reasons hereinafter set forth, it is requested that approval be granted to the Consumers Energy Big Rock Point Plant (BRP), as licensed by Facility Operating License DPR-6, Docket 50-155, issued on May 1, 1964, for procedures controlling the disposal of demolition debris in accordance with provisions of 10 CFR 20.2002. A description of the waste material for disposal that potentially contains licensed materials, including the physical and chemical properties important to risk evaluation, and the proposed manner and conditions of waste disposal is provided in the following sections. The content of this application follows the guidance of NUREG-1101, Volume 1, Onsite Disposal of Radioactive Waste – Guidance for Disposal by Subsurface Burial, March 1986 as applicable.

## I. PROPOSED ACTIVITIES

This request for approval of proposed disposal procedures in accordance with the provisions of 10 CFR 20.2002 allows Consumers Energy to dispose of demolition debris originating from decommissioning activities at BRP in a State of Michigan licensed Type II landfill or in a licensed PCB waste disposal facility where landfill design and institutional controls are equal to or more restrictive than the requirements placed on a State of Michigan licensed Type II landfill. The request is justified in the analysis discussed in the later sections of this document.

## II. BACKGROUND

By letters dated June 18, 1997, and June 26, 1997, Consumers Energy notified the NRC, pursuant to 10 CFR 50.82(a)(1)(i), that BRP would permanently cease operation on August 30, 1997. On August 29, 1997, the reactor was permanently shutdown, ending 35 years of electric power generation. On September 22, 1997, another letter was forwarded to the NRC certifying that the fuel had been removed from the reactor vessel and placed in the spent fuel pool for storage.

The BRP site is located on the northeast shore of Lake Michigan in Charlevoix County in the northern part of Michigan's Lower Peninsula. The site is approximately 60 miles northeast of Traverse City, Michigan, and about 4 miles north of the small town of Charlevoix along US Route 31.

The reactor at the BRP was of relatively small size (75 MWe) and contained a significantly small radioactive source term, only about 10 percent that of a standard boiling water reactor (BWR). Consumers Energy's goal is to dismantle BRP in a safe, environmentally conscious, and cost effective manner. This action will result in the timely removal of the existing nuclear plant in accordance with the DECON option found acceptable to the NRC in its Final Generic Environmental Impact Statement on Decommissioning of Nuclear

Facilities, NUREG-0586. Decommissioning activities started in June 1997, and is expected to be completed in 2005.

As a part of the decommissioning process, Consumers Energy plans to dismantle the individual structures when they are empty and when they have been decontaminated and radiologically surveyed, as required. It is estimated that 97.5 million pounds of predominately concrete debris will originate from the decommissioning project[1]. Approximately one half of this is non-impacted (i.e., has never had the potential for neutron activation or to be exposed to licensed radioactive materials). The other half has a potential to contain residual surface activity and/or neutron activation products in a limited quantity. This submission deals with the disposition of demolition debris from the BRP decommissioning. Big Rock Point proposes to dispose of up to 3.05 million pounds at an alternate disposal facility licensed to accept PCB waste. This waste stream consists of painted structural steel in which non-liquid PCBs are contained within the dried paint matrix and is classified as PCB bulk product waste.

## III. JUSTIFICATION

10 CFR 20, Subpart K, §20.2001 requires that licensed radioactive material be disposed of only through (1) transfer to an authorized recipient, (2) decay in storage, (3) release in effluents within the limits in §20.1301, or (4) as authorized under §§20.2002, 20.2003, 20.2004, or §20.2005. This request for approval of proposed disposal procedures demonstrates compliance with 10 CFR 20.2001 requirements prior to disposal of demolition debris in a State of Michigan licensed landfill.

For demolition debris at BRP, three decommissioning options have been considered.

(1) License Termination with Structures Intact

This option would involve removal of licensed radioactive materials from the existing structures to residual radioactivity levels acceptable for termination of the license. Verification of achieving these residual radioactivity levels would require conducting a final status survey (FSS) for license termination on the remaining structures as well as the site environs. Specific disadvantages for application of this option at BRP include a delay in our management's environmental stewardship goal and commitment for restoration of the site to greenfield status. This option would also result in an increased expenditure of ratepayer decommissioning funds necessary to perform a much expanded FSS

[1] An additional 15.5 millions pounds of non-impacted asphalt will also be disposed of in accordance with this submittal; this asphalt was installed after decommissioning began in 1997 and was not included in the original waste estimate.

and demobilization followed by remobilization of the construction work force necessary for ultimate removal of site structures.

(2) Demolition Followed by License Termination

The initial process is similar to license termination with structures intact. Removal of licensed radioactive materials from existing structures to residual radioactivity levels acceptable for license termination with unrestricted access would still be performed. However, prior to performing the FSS, the remaining structures would be demolished and the concrete rubble left on site. The FSS would then be performed on the site environs. After license termination, the concrete rubble could be used as construction fill or disposed of in a State of Michigan licensed landfill facility. While this methodology appears to be able to meet all NRC requirements and public health and safety goals, the disadvantages are that the debris would be expensive to stabilize over the long-term context. Furthermore, redevelopment of the site after license termination for other uses may require that debris be removed at some later date and relocated to another location on-site or off-site.

This option could be performed with somewhat less expenditure of ratepayer decommissioning funds than Option (1).

(3) Demolition and Disposal Followed by License Termination

This option involves removal of licensed radioactive materials from the existing structures and installations. After decontamination of a work area, debris would be disposed of in a State of Michigan licensed landfill facility. After removal of all demolition debris, the FSS would then be performed on the site environs, the license terminated by the NRC and the site released for unrestricted future use. This option is the most cost-effective use of ratepayer decommissioning funds and will result in the most expedient environmental restoration of the site.

The option that is most attractive to Consumers Energy and the public stakeholders is the disposition of demolition debris in a landfill prior to license termination; therefore, BRP has selected Option (3) as the preferred option. The criterion used in the License Termination Rule (10 CFR 20, Subpart E) for termination of the site license for unrestricted use is a total effective dose equivalent (TEDE) of 25 mrem/year. In comparison, the TEDE of this submittal for Option (3) (demolition debris disposal in a State of Michigan licensed landfill) is 1 mrem/year. Therefore, selection of Option (3) is

protective of the public health and safety, is consistent with As Low as Reasonably Achievable (ALARA), as well as being most cost-effective.

Consumers Energy is committed to conducting and completing decommissioning in a safe and cost efficient manner consistent with all regulatory requirements. Furthermore, Consumers Energy has determined that it is in the best interest to restore the site to greenfield conditions. Given the location of the site on the shore of Lake Michigan, the land is a valuable resource to the company and to the citizens of the area. The demolition debris that will originate from the demolition and removal of structures at BRP is included in this submittal. This demolition debris includes flooring materials, concrete, rebar, roofing materials, structural steel, the soils associated with digging up foundations and concrete and/or asphalt pavement or other similar solid materials.

While Options (1) and (2) can be conducted under 10 CFR 20, Subpart E, Consumers Energy believes that Option (3) should be conducted under Subpart K. Although Subpart E allows small quantities of detectable licensed material to be left onsite for license termination, until the license is terminated, no amount of licensed material may be released from the site unless it is authorized under Subpart K. Consumers Energy does not intend to make this submittal for intentional disposal of radioactive waste. However; it is recognized that a potential will exist for trace quantities of licensed material to be present in the demolition debris at levels below instrument detection capabilities. Therefore, this submittal is being made in accordance with provisions of 10 CFR 20.2002 because of the potential presence of licensed material in the demolition debris.

IV. Description of Waste

A. Physical Properties

The demolition debris that will originate from the demolition and removal of structures and paved surfaces at BRP includes flooring materials, concrete, rebar, roofing materials, structural steel, soils associated with digging up foundations and concrete and/or asphalt pavement or other similar solid materials.

The physical form of this demolition debris will be that of bulk material with various screen sizes ranging from particles the size of sand up to occasional monoliths with a volume of several cubic feet. For the purpose of analyses performed for this application, the demolition debris is assumed to be a homogenous mixture with a density of 94 pounds per cubic foot (1.5 g/cm$^3$).

The demolition debris will exist as a dry solid waste containing no absorbents or chelating agents.

B. Estimated Waste Volume and Burials Each Year

It is estimated that the mass of potentially impacted demolition debris originating from the decommissioning of BRP will total approximately 48.7 million pounds. With landfill density of 94 pounds per cubic foot, the estimated volume of potentially impacted demolition debris for disposal at a State of Michigan licensed landfill will be approximately 518,000 cubic feet, and 1.2 million cubic feet of combined impacted and non-impacted demolition debris. This represents approximately two percent of the annual volume of waste disposed at the landfill most likely to receive most BRP demolition debris.

For the purpose of analyses performed for this application, completion of landfill disposal of demolition debris is assumed to occur within a three-year period of time, with disposal of 50% of the total volume to occur in one year. BRP demolition debris will not be isolated or dedicated to a single burial cell at the landfill. Rather, it will be co-mingled with other landfill materials that are available for disposal when the demolition debris is delivered to the landfill facility.

Institutional controls required at a State of Michigan licensed landfill are discussed in a later section of this application. However, one of these requirements is that materials deposited in a burial cell are required to be covered with an interim 6-inch layer of soil each day. Final closure of the burial cell will not occur until the burial cell has reached its design capacity. Institutional controls for the licensed PCB landfill are equal or more restrictive that those for a licensed Michigan Type II landfill.

Therefore, if a burial for purposes of this application is defined as final closure of the burial cell in which BRP demolition debris has been deposited, the number of burials per year will be dependent on the total volume of other landfill materials delivered to the landfill for disposal. However, it should be noted that each day that demolition debris is deposited in a burial cell, it would be covered with an interim 6-inch layer of soil.

C. Radiological Characterization of Structural Concrete

To date, over 200 core borings (2 inch diameter by 6 inch depth) have been taken from rooms or areas on the BRP site. Selection of the sampling location was biased toward areas expected to have the highest contamination potential. Each core has been analyzed onsite by gamma spectrometry and direct frisk to determine what types of radioactive material are present and how far the contaminants have penetrated into the concrete. The results of these onsite analyses are summarized in

Enclosure 1 to Big Rock Point's submittal dated June 20, 2001. In addition, portions of 14 core samples have been analyzed by an offsite laboratory (General Engineering Laboratories) at typical environmental monitoring lower limits of detection (LLD) using alpha and gamma spectrometry as well as liquid scintillation to analyze for the presence of the following radionuclides:

| | | | | |
|---|---|---|---|---|
| Ac-227 | Ac-228 | Ag-108m | Ag-110m | Am-241 |
| C-14 | Cd-109 | Ce-144 | Cm-242 | Cm-243/244 |
| Co-60 | Cs-134 | Cs-135 | Cs-137 | Eu-152 |
| Eu-154 | Fe-55 | H-3 | I-129 | K-40 |
| Mn-54 | Ni-59 | Ni-63 | Nb-94 | Pb-214 |
| Pm-147 | Pu-241 | Pu-238 | Pu-239/240 | Ru-106 |
| Sb-125 | Sr-90 | Tc-99 | U-233/234 | U-235/236 |
| U-238 | Zn-65 | | | |

One-half inch thick, near surface wafers from 12 of the core samples were submitted to represent potential radioactive materials remaining after remediation of the structural surfaces. Laboratory analysis of these samples identified only Co-60, Cs-137, Fe-55 and H-3 at levels greater than the LLD values. K-40, Pb-214, U-233/234 and U-238 were also detected in these samples but at levels that were indistinguishable from naturally occurring background levels measured in plant concrete samples that were not contaminated by licensed radioactive materials. The results of these samples with concentration values representing the average concentration in the one-half inch thick wafer are detailed in Table 1. Copies of the General Engineering Laboratories Certificate of Analysis for these samples were included as Enclosure 2 to Big Rock Point's submittal dated June 20, 2001.

Table 1
Remediated Concrete Core Sample Results

| Sample Number | Radionuclide | | | |
|---|---|---|---|---|
| | Co-60 pCi/g | Cs-137 pCi/g | Fe-55 pCi/g | H-3 pCi/g |
| 19 | <LLD | <LLD | <LLD | <LLD |
| 31 | <LLD | <LLD | <LLD | <LLD |
| 83 | <LLD | 0.130 ± 0.088 | <LLD | <LLD |
| 104 | <LLD | 0.094 ± 0.054 | <LLD | <LLD |
| 112 | 0.084 ± 0.065 | <LLD | <LLD | 6.24 ± 2.51 |
| 123 | <LLD | <LLD | <LLD | 9.47 ± 2.88 |
| 128 | <LLD | 0.166 ± 0.062 | <LLD | <LLD |
| 7 | <LLD | <LLD | <LLD | <LLD |
| 90 | <LLD | <LLD | <LLD | <LLD |
| 149 | 0.458 ± 0.114 | <LLD | <LLD | <LLD |
| 117 | <LLD | <LLD | <LLD | <LLD |
| 100 | <LLD | <LLD | <LLD | <LLD |
| 119* | 2.47 ± 0.739 | <LLD | <LLD | <LLD |
| 153* | 0.292 ± 0.140 | 0.282 ± 0.128 | <LLD | <LLD |

*Remediated high surface contamination samples

The final two core samples listed above were taken from areas having a high potential for surface contamination and are average values of subsurface samples taken at various concrete depths. Laboratory analysis of these samples identified only Co-60, Cs-137 and H-3. K-40, Pb-214, U-233/234 and U-238 were also detected in these samples but at levels that were indistinguishable from naturally occurring background levels measured in plant concrete samples that were not contaminated by licensed radioactive materials.

D. Calculated Licensed Radioactive Material Content of Demolition Debris

Results of the radiological characterization of structural concrete and current remedial action contamination surveys were used to classify the surfaces as either uncontaminated, shallow surface contaminated or deep surface contaminated.

Uncontaminated surfaces were defined as surfaces having no detectable contamination as evidenced by historical records review, current remedial action contamination surveys and laboratory analysis of representative core samples.

Shallow surface contamination is defined as surfaces having no detectable contamination ($\geq$ 5,000 dpm/100 $cm^2$ total activity) as evidenced by contamination surveys performed after remedial action (if required) but detectable shallow subsurface contamination identified by laboratory analysis of representative core samples. Shallow subsurface contamination is assumed (based on core sample profiling) to penetrate to a depth of 1 inch after surface remediation.

Deep surface contamination is defined as highly contaminated surfaces prior to remediation with no detectable contamination as evidenced by contamination surveys performed after remedial action, but with some detectable deep subsurface contamination identified by laboratory analysis of representative core samples. This subsurface contamination is assumed to penetrate to a depth of 6 inches after surface remediation.

Based on the results of the radiological characterization of structural concrete on a room-by-room basis, a total surface area of 10,200 square feet have been calculated to have deep surface contamination. 51,835 square feet have been calculated to have shallow surface contamination and the remainder is considered to be uncontaminated. This results in a calculated 5,100 cubic feet of deep surface contaminated concrete and 4,320 cubic feet of shallow surface contaminated concrete.

Averaging the greater than LLD results from Table 1 and applying the resulting concentrations to the 4,320 cubic feet of shallow surface contaminated concrete and 5,100 cubic feet of deep surface contaminated concrete results in concentrations and total activity as reported in Table 2.

Table 2

Volumetric Contamination of Remediated Surface Contaminated Concrete

| Radionuclide | Concentration (pCi/g) | Total Activity (mCi) |
|---|---|---|
| Co-60 | 0.83 | 0.613 |
| Cs-137 | 0.17 | 0.126 |
| H-3 | 7.86 | 5.806 |
| Total | 8.85 | 6.544 |

All 48.65 million pounds of impacted concrete will be treated as potentially contaminated. The volumes of 4,320 cubic feet of shallow and 5,100 cubic feet of deep contamination as calculated from structural characterization analyses, will not be separated from impacted concrete debris. Therefore, as a conservative estimate of activity potentially present, activity concentrations from Table 2 were applied to the impacted demolition debris mass of 48.65 million pounds resulting in total activity as reported in Table 3.

Table 3

Impacted Demolition Debris Total Activity (48.65 million pounds)

| Radionuclide | Concentration (pCi/g) | Total Activity (mCi) |
|---|---|---|
| Co-60 | 0.83 | 18.4 |
| Cs-137 | 0.17 | 3.8 |
| H-3 | 7.86 | 175 |
| Total | 8.85 | 197 |

E. Requested Limiting Demolition Debris Concentration

To allow operational flexibility and ensure monitoring capability, Consumers Energy requests a bounding principal gamma emitter concentration limit of 5 pCi/gm for licensed radioactive materials contained as trace contamination in demolition debris for disposal in a State of Michigan licensed Type II landfill or alternate landfill licensed for disposal of PCB wastes. Adjusting the total activity reported in Table 3 to a bounding principal gamma emitter concentration limit of 5 pCi/gm results in the bounding activity reported in Table 4.

Table 4

Impacted Demolition Debris Bounding Activity (48.65 million pounds)

| Radionuclide | Concentration (pCi/g) | Total Activity (mCi) |
|---|---|---|
| Co-60 | 4.15 | 92.1 |
| Cs-137 | 0.85 | 19.0 |
| H-3 | 39.3 | 875 |
| Total | 44.3 | 986 |

To ensure that the 5 pCi/gm principal gamma emitter limit is not exceeded, structural surfaces will be surveyed prior to demolition to verify that surface contamination does not exceed 5,000 dpm/100 $cm^2$ averaged over areas appropriate for the detection system utilized and all demolition debris will be monitored by a bulk assay system with an alarm setpoint established at or below the 5 pCi/gm principal gamma emitter limit prior to disposal.

Establishment of this bounding concentration limit will ensure that any uncertainties in the content of licensed radioactive material in demolition debris sent to a State of Michigan licensed landfill or alternate landfill licensed for disposal of PCB wastes will not present a dose impact problem.

F. Dose Impacts

Dose impacts of the requested impacted demolition debris bounding activity were evaluated by performing calculations using the Table 4 radionuclide concentrations as source terms (reference Big Rock Point Engineering Analysis, EA-BRP-RAE-04-01, Disposal of Demolition Debris at Environmental Quality Company, Revision 0 and EA-BRP-RAE-04-02, Disposal of Demolition Debris at Environmental Quality Company: Alternative, Revision 0.) These calculations are bounding because release at a principal gamma emitter limit of 5 pCi/gm is assumed for all 48.65 million pounds of impacted demolition debris. In practice, release surveys to a minimum detection limit of 5 pCi/gm of principal gamma emitters results in release of demolition debris from zero to 5 pCi/gm, or a mean of approximately 2.5 pCi/gm.

1. Transport Worker Dose Assessment

An evaluation of transport worker dose was performed using MicroShield, Version 5.05, from Grove Engineering and site-specific assumptions including

bounding concentration values presented in Table 4. The transport system chosen for this evaluation was a roll-off container system with dimensions of 21.5 feet long, 8 feet wide and 3.5 feet high.

In addition to the above, the following assumptions were also applied to the analysis. In each case, the driver's seat is assumed to be 1 foot away from the cabin wall, which is conservatively assumed to be 0.12 inches thick, made of iron. The material hauler part of the truck is assumed to be made of iron with 0.25-inch thick sides, floor and tailgates. The distance between the hauler part and the driver's cabin is assumed to be 4 feet.

a. *Transportation to a Licensed Type II Landfill:*

It is assumed that three truck drivers will be used for the total duration of the project and that the number of loads transported will be divided equally between each driver. Given the anticipated volumes of the impacted demolition debris, combined with the assumptions of standard load volumes in tandem trailers, transport of 50% of demolition debris within a one-year period and the driving time of 2 hours per load to the landfill, each truck driver will be potentially exposed to radiation from residual radioactivity for 324 hours. Applying the above assumptions, results in a calculated dose rate to the driver of 9.87E-04 mrem/hour or an annual dose of 0.320 mrem to each of the truck drivers.

b. *Transport to a Licensed PCB Landfill:*

Assume that two truck drivers will be used for transportation of PCB bulk product waste and that the number of loads transported will be divided equally between each driver. Given the maximum estimated 3.05 million pounds of PCB waste for disposal, combined with the assumptions of standard load volumes in tandem trailers, transport of all PCB waste within a one-year period and the driving time of 6 hours per load to the landfill, each truck driver will be potentially exposed to radiation from residual radioactivity for 180 hours. Applying the above assumptions, results in a calculated dose rate to the driver of 9.87E-04 mrem/hour or an annual dose of 0.178 mrem to each of the truck drivers.

Output from the MicroShield analysis is provided as Attachment 3 to this submittal.

2. Landfill Worker Dose Assessment

An evaluation of landfill worker dose was performed using RESRAD, Version 6.0. For landfill operation, the landfill is assumed to close after placement of the demolition debris. Post-closure monitoring of the landfill is required by the State of Michigan for a 30-year period. Therefore, it is assumed that a member of the public, other than a landfill worker will not have access to a burial cell containing the demolition debris until 30 years after debris placement.

The following assumptions were made in the evaluation:

a. The most exposed individual at the landfill is a bulldozer operator, positioning and spreading the demolition debris and placing a soil cap on it at the end of the day.

b. The landfill most likely to receive BRP demolition debris currently has three bulldozer operators and, for purposes of this assessment, dose was assumed to be equally distributed between each bulldozer operator.

c. The 522,200 cubic feet (14,710 cubic meters) of impacted demolition debris are assumed to be deposited in a uniform 3.71-meter thick, 3,965 square meter (0.98 acre) layer, assuming all demolition debris is in the licensed Type II landfill.

d. Based on the 0.98 acre surface area estimate of impacted demolition debris and a burial cell surface area of 8 acres, each landfill worker is assumed to spend 12.25 percent (0.98 acre/8 acres) of each worker's time working over or exposed to impacted demolition debris or 245 hours per occupational year of 2000 hours. This total of 245 hours equates to a RESRAD outdoor time fraction of 0.028.

e. A 0.15 m soil cover (which is a daily cover requirement) was assumed. No credit was taken for any other engineering controls required by the State of Michigan.

f. No credit was taken for shielding provided to the workers by the bulldozer.

g. The bounding concentration values presented in Table 4 were used as the impacted demolition debris source terms.

h. Doses will be distributed to workers at each landfill in proportion to the total quantity of radioactive material potentially present. Conservatively assuming a constant maximum level of 5.0 pCi/g, doses are proportionate to the weights shipped to each site.

Use of the above assumptions results in a calculated annual TEDE dose of 0.291 mrem for each Type II landfill worker and a weight-proportionate dose of 0.0182 mrem for the PCB landfill worker. Output from the RESRAD analysis is provided as Attachment 4.

3. Landfill Resident / Farmer Dose Assessment

An evaluation of dose to an individual member of the public was performed using RESRAD, Version 6.0. Post-closure monitoring of the landfill is required by the State of Michigan for a 30-year period. For purposes of this evaluation, it is assumed that a residence, including a basement to the residence and a vegetable garden, is established on the burial cell containing the demolition debris 30 years after debris disposal.

The following assumptions were made in the evaluation:

a. RESRAD exposure pathways are active for the Resident / Farmer scenario except for the radon pathway (not regulated by the NRC).

b. The impacted demolition debris is assumed to be soil like material with the bounding concentration values presented in Table 4 even though its density is somewhat higher than most soils. Additionally, resuspension of demolition debris radioactivity is not expected to vary significantly from that for soil. Therefore, the RESRAD default soil parameters are considered appropriate for use in this analysis.

c. It is assumed that all licensed radioactive material in the impacted demolition debris is dispersed throughout the volume of impacted material originating at BRP and no dilution of the demolition debris occurs from other landfill materials deposited in the burial cell. This is very conservative since Michigan law requires a 6-inch soil cover over the debris at the end of each day and the demolition debris is expected to be only two percent of the total waste volume processed at the landfill over a one-year period.

d. For the Resident / Farmer scenario, it is assumed that the resident spends 50 percent of the time indoors, 25 percent outdoors at the site, and 25

percent of the time away from the site. These assumptions are consistent with those suggested in the NRC Policy and Guidance Directive PG-8-08, Scenarios for Assessing Potential Doses Associated with Residual Radioactivity.

e. Fifty percent effectiveness is assumed for the leachate collection system required by the State of Michigan (resulting in a 50 percent reduction in calculated annual dose). Also, the required 18-inch infiltration layer, 24-inch erosion layer and 6-inch earthen material layer capable of sustaining native plant growth are considered to be intact at the end of the 30-year period.

f. No credit is taken for landfill material originating elsewhere which may be deposited on top of the demolition debris.

g. The 522,200 cubic feet (14,710 cubic meters) of impacted demolition debris are assumed to be deposited in a uniform 3.71-meter thick, 3,965 square meter (0.98 acre) layer, assuming all demolition debris is buried in the licensed Type II landfill.

h. For the RESRAD model, root depth was extended from the default value of 0.9 m to a depth of 1.4 m. This was done to ensure communication between vegetation and the contaminated zone.

i. All other RESRAD parameters were set at their default values for this evaluation. An Engineering Analysis was performed on RESRAD parameter selections and concluded that, when applied to the northern Michigan climate and State of Michigan licensed Type II landfill requirements discussed in Section VIII, the use of default parameters will result in conservative dose estimates.

j. Doses will be distributed to residents at each landfill in proportion to the total quantity of radioactive material potentially present. Conservatively assuming a constant maximum level of 5.0 pCi/g, doses are proportionate to the weights buried at each site.

Applying the above assumptions results in a calculated maximum annual dose of 0.0178 mrem for a resident / farmer living at the Type II landfill site. This maximum annual dose occurs the first year of public access following the 30-year post-closure monitoring period. Using the assumption of weight proportionality, resident farmer living at the PCB landfill site would receive an

annual dose of 0.001 mrem. Output from the RESRAD analysis is provided as Attachment 5 to this submittal.

4. Dose Impact Conclusions

Assuming that all impacted demolition debris would be released for State of Michigan licensed Type II landfill disposal at a bounding principal gamma emitter concentration limit of 5 pCi/gm as trace contamination in demolition debris would result in a maximum dose impact to an individual member of the public of 0.320 mrem/year to each of three transport workers. Maximum dose to each landfill worker was calculated to be 0.291 mrem/year during impacted demolition debris disposal. Maximum calculated dose to a resident / farmer was calculated to be 0.018 mrem/year which would not occur until after completion of the required 30-year post-closure monitoring period. These maximum calculated doses are well below the public dose objective of 1 mrem/year. Annual doses associated with disposal of demolition debris classified as PCB bulk product waste at a licensed PCB waste facility with design and institutional controls equal or greater that the a Type II landfill are 0.178 mrem to each of the truck drivers, 0.018 mrem to a landfill worker and 0.001 mrem to a resident farmer. If the entire estimated quantity of PCB bulk product waste were sent to the alternate disposal facility, doses associated with disposal at the licensed Type II landfill would be reduced by the quantities above.

Actual maximum dose impact to an individual member of the public is expected to be much less than these calculated values using a bounding principal gamma emitter concentration limit of 5 pCi/gm.

To ensure that the 5 pCi/gm principal gamma emitter limit is not exceeded, structural surfaces will be surveyed prior to demolition to verify that surface contamination does not exceed 5,000 dpm/100 $cm^2$ averaged over areas appropriate for the detection system utilized and all demolition debris will be monitored by a bulk assay system with an alarm setpoint established at or below the 5 pCi/gm principal gamma emitter limit prior to disposal.

G. Prohibition on Burial of Hazardous Waste

Hazardous waste as defined in the regulations of the Environmental Protection Agency (EPA), 40 CFR Parts 260 through 265, is not permitted to be included in the BRP demolition debris. Hazardous waste is required to be disposed of in a manner set out in EPA regulations and in accordance with applicable local and State laws

and codes, and will not be disposed of in conjunction with the debris considered here.

## V. PACKAGING OF WASTE

Big Rock Point demolition debris to be disposed of at a State of Michigan licensed Type II landfill or a licensed PCB landfill will not be packaged. Since the radiological survey process used to determine that the demolition debris is acceptable for landfill disposal will ensure that trace quantities of licensed material potentially present in the demolition debris are at levels below the requested bounding concentration limit, BRP demolition debris will be processed the same as debris generated from the demolition of any non-nuclear industrial facility.

The existing Radiation Protection Program, which is continually audited by the NRC, will ensure the radiological safety of BRP workers during generation and packaging of demolition debris. The dose evaluations discussed previously demonstrate that dose to members of the public from transportation and disposal of demolitions debris would not be measurable with state-of-the-art personnel monitoring instrumentation and is insignificant in comparison to the average annual dose received by individuals from natural sources (approximately 300 mrem per year).

Demolition debris will be transported from the BRP site to the landfill facility by truck transportation using either of three types of truck transport systems that are generally the common practice for carrying demolition debris. These transport systems include a roll-off container system, a dual-trailer mule system or a wide-bodied demolition hauler. Big Rock Point currently utilizes a dual-trailer mule (tandem trailer) system.

Roll-off container systems have the dimensions of 21.5 feet long by 8 feet wide by 3.5 feet high. Dual-trailer mule systems use two trailers, each having the dimensions of 50 feet long by 8 feet wide by 5 feet high. Wide-bodied demolition haulers have the dimensions of 30 feet long by 8 feet wide by 6 feet high.

Type II landfills licensed by the State of Michigan and PCB landfills licensed by the State of Michigan and the U.S. Environmental Protection Agency are required to implement controls to isolate the contents of burial cells from the environment. These controls will provide isolation of the BRP demolition debris from the environment over a reasonable period of time similar to the use waste packaging. The controls are discussed in Section VIII, Nature of the Burial Site.

## VI. BURIAL LOCATION

The State of Michigan licensed Type II landfill selected for burial of BRP demolition debris will be located within approximately 60 miles of the BRP site. The facility selected for disposal of PCB bulk products wastes is located approximately 275 miles from the BRP site.

The State of Michigan Solid Waste Management Act Administrative Rules Promulgated Pursuant To Part 115 Of the Natural Resources and Environmental Protection Act, 1994 Pa 451, As Amended contains restrictions on the location of Type II landfill facilities. Among these are restrictions on groundwater isolation, horizontal isolation distances, floodplains, wetlands, fault areas and seismic impact zones, and unstable areas. These restrictions are discussed in Section VIII, Nature of the Burial Site.

## VII. INSTITUTIONAL CONTROLS

Part 115 of the State of Michigan Administrative Rules contains institutional controls that restrict access to Type II licensed landfills. Licensing requirements for the landfill selected for disposal of PCB bulk products wastes are considered equal or more restrictive than those for licensed Type II landfills. The landfill operator is required to control public access to the landfill and prevent unauthorized vehicular traffic and illegal dumping of wastes by using artificial or natural barriers, or both, as appropriate.

After the final closure of a burial cell, the landfill operator is required to conduct post-closure care for not less than 30 years. This post-closure care includes:

- Maintaining the integrity and effectiveness of any final cover,
- Maintaining, operating, and monitoring the leachate collection system,
- Monitoring the groundwater,
- Monitoring all secondary collection systems and leak detection systems, and
- Maintaining and operating the gas monitoring and collection system.

## VIII. NATURE OF THE BURIAL SITE

The Type II landfill where the BRP demolition debris will be sent for disposal will meet State of Michigan Part 115 Administrative Rules that will limit migration of licensed radioactive material potentially mixed with the demolition debris in trace amounts. These requirements include but are not limited to:

- Location restrictions,
- A composite liner,

- Leachate collection and removal systems,
- Leak detection systems,
- Daily 6 inch interim soil covers,
- Explosive gas control and monitoring,
- Groundwater monitoring,
- Surface and Groundwater Performance,
- Run-On and Run-Off Control Systems, and
- Final cover composite liner designed to minimize infiltration and erosion.

A. Location Restrictions

The location of each burial cell will be isolated from groundwater sources. Permanent minimum clearances of ten feet to the natural groundwater level and 7 feet to a permanently depressed groundwater level is required to be maintained from the top of the primary liner.

The active work area at the landfill is required to not be located closer than 100 feet to adjacent property lines or road rights-of-way or closer than 300 feet to domiciles that exist at the time a landfill license is requested. It is also not allowed to be located within 400 feet of inland lakes and streams or within 2,000 feet of the Great Lakes. The active work area is also required to be a minimum of 2,000 feet from wells that serve Type I and Type IIa water supplies and a minimum distance of 800 feet from wells that serve Type IIb and Type III public water supplies.

If a landfill is located within a floodplain, the landfill operator is required to demonstrate that:

- The cell will not restrict the flow of the 100-year flood,
- The cell will not reduce the temporary water storage capacity of the floodplain,
- The cell will not result in washout of solid waste so as to pose a hazard to human health and the environment,
- The cell does not encroach upon the floodway and will not increase upstream or downstream flood stages,
- The cell has a natural or compacted soil base which is not less than 10 feet thick,
- The distance from the normal water line of the water body to the solid waste boundary of the landfill will not be less than 500 feet, and

- The design of the landfill will include a dike to preclude floodwater inundation with a top elevation that is not less than 5 feet above the 100-year flood elevation.

Landfills are not allowed to be located in wetlands unless extensive measures are taken for protection of the wetlands.

Landfill burial cells are not permitted to be located within 200 feet of a fault that has had displacement in holocene time, unless the landfill operator demonstrates that an alternative setback distance of less than 200 feet will prevent damage to the structural integrity of the cell and will be protective of human health and the environment. They are also not permitted to be located in seismic impact zones, unless the landfill operator demonstrates that all containment structures, including liners, leachate collection systems, and surface water control systems, are designed to resist the maximum horizontal acceleration in lithified earth material for the site.

B. Composite Liners

Burial cells are required to be constructed with a composite liner and a leachate collection system that is designed and constructed to maintain less than a 1-foot depth of leachate over the liner, excluding the sump.

Burial cells are required to be located, designed, and constructed so that the risks posed by leakage through the composite liner are minimized. To do so, a cell is required to be either a monitorable cell that is located over a natural soil barrier so as to restrict the migration of leakage from the unit or designed with a double liner system that is capable of detecting and collecting leakage through the primary composite liner.

C. Leachate Collection and Removal Systems

Each burial cell is required to have a leachate collection system that is designed and constructed to maintain less than a 1-foot depth of leachate over the primary liner. To do so, the system is required to be designed to do all of the following:

- Limit the head at any point in the system, excluding the sump, to not more than 1 foot,
- Extend across the entire bottom of the system,
- Be chemically resistant to the waste that is managed in the landfill and the leachate that is expected to be generated and be of sufficient strength and

thickness to prevent collapse under the pressures that are exerted by overlying wastes, waste cover materials, and equipment that is used at the landfill,

- Minimize clogging during the active life and postclosure care period,
- Drain leachate to sumps using pumps that are of a sufficient size to collect and remove liquids from the sump and prevent liquids from backing up into the drainage layer. The design of each sump and removal system provides a method for measuring and recording the volume of liquids removed and the depth of leachate in the sump.

A secondary collection system is required to be provided and be capable of detecting, collecting, and removing leaks of hazardous constituents at the earliest practicable time through all areas of the top liner that are likely to be exposed to waste or leachate during the active life and postclosure care period.

The landfill operator is required to remove leachate from a burial cell as frequently as necessary to ensure that the leachate depth on the liner, excluding the sump, is not more than 1 foot, except after a significant storm event. The leachate depth on the liner is not allowed to be more than 1 foot for more than seven days after a significant storm event. A significant storm event is a storm that generates 0.1 inches or more of rainfall in 24 hours.

D. Leak Detection Systems

Each burial cell is required to have a leak detection system. For unmonitorable units, the secondary collection system is also a leak detection system. A response flow rate is established in the operating license for each landfill to evaluate the performance of a leak detection system.

If the average daily flow rate removed from the sump of a leak detection system is more than the action flow rate for that burial cell, the landfill operator is required to evaluate the chemical characteristics of liquid in the leak detection system by sampling and analyzing the system and evaluating for the presence of a leak by a statistical test, a trend analysis, or other means. Before solid waste is placed in any new burial cell that has a leak detection system, the landfill operator may, at his discretion, establish a baseline concentration of constituents in the secondary collection system based on an analysis of representative samples from the system.

The landfill operator must conduct required response actions if monitoring of the leak detection system determines that both of the following apply to liquid that is removed from the system:

- The average daily flow rate is more than the response flow rate that is established for the unit and
- The liquid contains hazardous substances indicative of leachate from the unit.

A landfill operator who is required to conduct response actions is required to take all of the following actions:

- Within seven days of a determination that the response flow rate has been exceeded, notify the State of Michigan, in writing, that the response flow rate has been exceeded,
- Submit a preliminary written assessment to the State of Michigan within 14 days of a determination that the response flow rate has been exceeded. A preliminary written assessment is required to include all of the following information for the landfill cell in which the response flow rate was exceeded:
    - The amount of liquids removed from the leak detection system,
    - The likely sources of liquids, including the depth of leachate in the leachate collection system,
    - The possible location, size, and cause of any leaks, and
    - The short-term actions taken and planned.
- Determine, to the extent practicable, the location, size, and cause of any leak.
- Determine whether waste receipt should cease or be curtailed, whether any waste should be removed from the landfill cell for inspection, repairs, or controls, and whether or not the cell should be closed.
- Determine any other short-term and longer-term actions to be taken to mitigate or stop any leaks.
- After a determination that the response flow rate has been exceeded, and for as long as the flow rate in the system exceeds the response flow rate, the landfill operator is required to submit to the State of Michigan, within 30 days of the end of the calendar quarter, a report that summarizes the results of any remedial actions taken and planned.

- To make the leak or remediation determinations required, the landfill operator is required to do all of the following:
  - Assess the source of liquids and amounts of liquids by source,
  - Conduct a fingerprint, hazardous constituent, or other analysis of the liquids in the system to identify the source of liquids and possible location of any leaks and the hazard and mobility of the liquid, and
  - Assess the seriousness of any leaks in terms of potential for escaping into the environment or document why the assessments are not needed.

E. Daily Six-Inch Soil Covers

The landfill operator is required to cover disposed of solid waste with 6 inches of earthen material at the end of each operating day or at more frequent intervals, if necessary, to control disease vectors, fires, odors, blowing litter, and scavenging. If clay or other low-permeability material is used as daily cover, then the operator is required to scrape back the previous day's cover to allow the free movement of liquids and gases through the landfill.

If an active burial cell will lie idle for a period of three months or more before additional lifts are constructed, the landfill operator is required to place 1 foot of compacted cover, which may include the 6-inch daily cover, on the surface to minimize nuisance conditions.

F. Explosive Gas Control and Monitoring

The landfill operator is required to ensure that the concentration of methane gas generated by the facility is not more than 25 percent of the lower explosive limit for methane in facility structures, excluding gas control or recovery system components, and the leachate collection system and that the concentration of methane gas is not more than the lower explosive limit at or beyond the facility property boundary. To demonstrate compliance with this requirement the landfill operator is required to implement a routine methane monitoring program.

G. Groundwater Monitoring

Detection monitoring is required at all required groundwater monitoring wells. At a minimum, a detection-monitoring program for a landfill is required to include monitoring for all of the following constituents:

- The listed primary indicators and pH, at least quarterly during the active life and semiannually during the postclosure period and
- The following constituents listed at least semiannually during the active life of the facility and the postclosure period:
  - Heavy metals that are listed,
  - Listed primary volatile organic constituents, and
  - Listed secondary organic constituents.

The landfill operator of a cell that contains a secondary collection system may conduct sampling and analysis for listed primary indicators in place of the heavy metals if all of the following conditions are met:

- Leachate monitoring shows that the concentration of all of the indicators in leachate is not less than ten times the concentration in groundwater and
- Secondary collection system monitoring shows all of the following:
  - That the allowable flow rate has not been exceeded,
  - That the concentration of two or more indicators in the system is not more than the following threshold values for two consecutive sampling events:
    - For chlorides, 250 mg/l,
    - For iron, 0.3 mg/l,
    - For sulfates, 250 mg/l,
    - For total inorganic nitrogen, 10 mg/l, and
    - For total dissolved solids, 500 mg/l.
  - That listed volatile organics have not been detected in the secondary collection system,
  - That the listed concentration of metals has not exceeded 1/10 the specified value,
- The unit is a monitorable unit, and
- The concentration of the indicators in groundwater is normally distributed.

Assessment monitoring is required at a landfill if a statistically significant increase over background has been detected for one or more of the listed constituents.

Within 90 days of the triggering of an assessment monitoring program, and annually thereafter, the landfill operator is required to sample and analyze the groundwater for all constituents listed in 40 CFR part 258, Appendix II. A minimum of one sample from each downgradient well is required to be collected and analyzed during each sampling event. For any constituent that is detected in the downgradient wells as a result of the complete Appendix II constituent analysis, a minimum of four independent samples from each background and downgradient well are required to be collected and analyzed to establish background for the constituents.

H. Surface and Groundwater Performance

Operation of a State of Michigan licensed landfill is not allowed to cause a discharge of pollutants into waters of the United States, including wetlands, that is in violation of any of the requirements of the federal clean water act, including the national pollutant discharge elimination system (NPDES) requirements under Section 402 of the Federal Clean Water Act. Also, the landfill is not allowed to cause the discharge of a nonpoint source of pollution to waters of the United States, including wetlands, that is in violation of any of the requirements of an areawide or statewide water quality management plan that has been approved under Section 208 or 319 of the Federal Clean Water Act.

To demonstrate compliance with these requirements, the landfill operator is required to conduct a surface water-monitoring program approved by the State of Michigan for any surface water that may receive run-off from the active work area. Monitoring results are required to be submitted to the State of Michigan not more than 30 days after the end of the calendar quarter.

I. Run-On and Run-Off Control Systems

Two systems are required to control the flow of rainwater over burial cells. A run-on control system is required to prevent flow onto the active portion of the landfill during the peak discharge from a 25-year, 24-hour storm. Also, a run-off control system from the active portion of the landfill is required to collect and control at least the water volume that results from a 24-hour, 25-year storm.

J. Final Cover Composite Liner

A final cover system is required to be installed on each burial cell which is designed to minimize infiltration and erosion and which is comprised of an erosion layer

underlain by an infiltration layer. The final cover system is required to be comprised of the following components:

- An infiltration layer that is comprised of either a minimum of 18 inches of earthen material that has a permeability which is less than or equal to $1.0 \times 10^{-5}$ cm/sec or a bentonite geocomposite liner which is underlain by not less than 18 inches of earthen material to protect the liner from waste and minimize the effect of settlement.

- An erosion layer that consists of both a soil layer which is not less than 2 feet thick, which is immediately above the composite cover liner, and which is designed to do all of the following:

  - Provide for the lateral drainage of precipitation off the cover of the landfill,

  - Minimize frost penetration into the infiltration layer, and

  - Protect the flexible membrane liner from root penetration, ultraviolet light, and other deleterious effects.

A minimum of 6 inches of earthen material capable of sustaining native plant growth is required to be placed over the final cover system. To prevent the ponding of water on completed fill surfaces, the grading contours are required to be sufficient to prevent the development of local depressions due to post construction settlement. Slopes of the final cover are required to be not less than four percent at any location.

## IX. BURIAL PROCEDURES

Please refer to Section VIII, Nature of the Burial Site regarding the burial of BRP demolition debris at State of Michigan licensed landfill facilities.

## X. RADIATION SAFETY PROCEDURES

BRP is currently conducting decommissioning activities under a Radiation Protection Program and implementing procedures that comply with NRC regulatory requirements contained in 10 CFR 20, Standards for Protection Against Radiation. The Radiation Protection Program and implementing procedures are a requirement of the BRP Defueled Technical Specifications 6.6.1 and 6.6.2. The NRC Region III Office routinely reviews the Radiation Protection Program and implementing procedures and their implementation.

Disposal of BRP demolition debris will be performed in accordance with the Radiation Protection Program and implementing procedures as applicable.

## XI. RECORDKEEPING

Recordkeeping requirements for landfill disposal of demolition debris are specified in BRP procedures.

As a minimum, these records will include:

- Surface contamination monitoring reports and
- Bulk container assay records for each container which will include but not be limited to:
  - Date and time the assay was performed,
  - Source of the demolition debris,
  - Mass, volume and composition of the demolition debris,
  - Landfill destination for the demolition debris, and
  - Assay results.

## XII. ANALYSIS OF NO SIGNIFICANT ENVIRONMENTAL IMPACTS EVALUATION

Consumers Energy finds, in compliance with 10 CFR 50.82(a)(6)(ii), that activities associated with this application involve no significant environmental impacts. The following evaluation in conjunction with the foregoing discussion supports that finding.

A. Will the proposed activity result in significant environmental impacts not previously reviewed?

No significant environmental impacts are expected from the disposal of demolition debris with trace concentrations of licensed radioactive materials in a State of Michigan licensed landfill or alternate licensed PCB landfill. Total volume of landfill waste projected for BRP decommissioning is 1.34 million cubic feet including 142,000 cubic feet of radioactive waste and 1.2 million cubic feet of demolition debris. In comparison, NUREG-0586, "Final Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities, " (FGEIS) lists a radioactive waste volume for the reference boiling water reactor (BWR) of 18,975 cubic meters (670,096 cubic feet), including disposable containers.

The BRP potentially impacted waste volume of 518,000 cubic feet and the total other radwaste volume of 142,000 cubic feet (total of approximately 660,000 cubic feet) compares with the FGEIS reference BWR .

Non-radiological environmental impacts evaluated in the GEIS included:

- Demography and human activities in the area,
- Hydrology,
- Aquatic resources/ecosystems in the area surrounding the plant site,
- Terrestrial resources,
- Endangered and threatened species,
- Land use,
- Air pollution control requirements,
- Water pollution control requirements,
- Hazardous materials and waste control,
- Occupational safety, and
- Public safety.

Radiological environmental impacts evaluated in the GEIS included:

- Occupational radiation exposure,
- Radiation exposure to the public,
- Radioactive waste management systems,
- Liquid radioactive effluents, and
- Airborne radioactive effluents.

The FGEIS concludes that the major environmental impact of decommissioning is the commitment of small amounts of land for waste burial in exchange for reuse of the facility and site for other purposes. Since in many instances, such as at a reactor facility, the land is a valuable resource, return of this land to the commercial or public sector is highly desirable. Therefore, the FGEIS evaluation bounds disposal of all BRP demolition debris including disposal of the demolition debris containing trace concentrations of licensed radioactive materials requested by this application.

Attachment 3

Consumers Energy
BIG ROCK POINT
Docket Numbers 50-155 and 72-043

**MICROSHIELD ASSESSMENT OF TRANSPORTATION WORKER (ROLL_3.MS5 and 2NDROLL.MS5)**

September 15, 2004

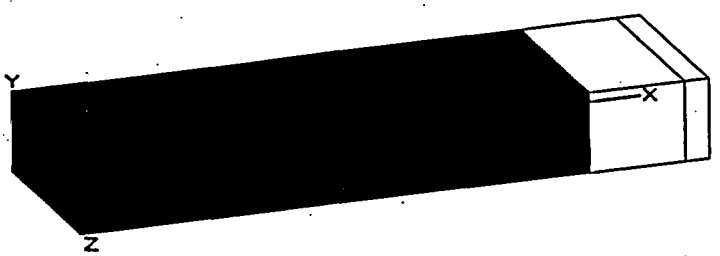
4 Pages

MicroShield v5.05 (5.05-00326)
CONSUMERS ENERGY COMPANY

Page : 1
DOS File: ROLL_3.MS5
Run Date: July 21, 2004
Run Time: 8:26:26 AM
Duration: 00:00:02

File Ref: _____
Date: _____
By: _____
Checked: _____

**Case Title: Rolloff Recalc**
**Description: Density 0.667 (25,000 lbs)**
**Geometry: 13 - Rectangular Volume**




**Source Dimensions**

| | | |
|---|---|---|
| Length | 655.32 cm | 21 ft 6.0 in |
| Width | 243.84 cm | 8 ft |
| Height | 106.68 cm | 3 ft 6.0 in |

**Dose Points**

| | X | Y | Z |
|---|---|---|---|
| # 1 | 808.672 cm | 53.34 cm | 121.72 cm |
| | 26 ft 6.4 in | 1 ft 9.0 in | 3 ft 11.9 in |

**Shields**

| Shield Name | Dimension | Material | Density |
|---|---|---|---|
| Source | 1.70e+07 cm | NBS Concrete | 0.667 |
| Shield 1 | .64 cm | Iron | 7.86 |
| Shield 2 | 121.92 cm | Air | 0.00122 |
| Shield 3 | .305 cm | Iron | 7.86 |
| Shield 4 | 30.48 cm | Air | 0.00122 |
| Air Gap | | Air | 0.00122 |

**Source Input**
**Grouping Method : Actual Photon Energies**

| Nuclide | curies | becquerels | µCi/cm³ | Bq/cm³ |
|---|---|---|---|---|
| Ba-137m | 9.1919e-006 | 3.4010e+005 | 5.3922e-007 | 1.9951e-002 |
| Co-60 | 4.7219e-005 | 1.7471e+006 | 2.7700e-006 | 1.0249e-001 |
| Cs-137 | 9.7166e-006 | 3.5952e+005 | 5.7000e-007 | 2.1090e-002 |
| Fe-55 | | | | |
| H-3 | 4.4662e-004 | 1.6525e+007 | 2.6200e-005 | 9.6940e-001 |

**Buildup**
**The material reference is : Source**

**Integration Parameters**

| | |
|---|---|
| X Direction | 10 |
| Y Direction | 20 |
| Z Direction | 20 |

**Results**

| Energy MeV | Activity photons/sec | Fluence Rate MeV/cm²/sec No Buildup | Fluence Rate MeV/cm²/sec With Buildup | Exposure Rate mR/hr No Buildup | Exposure Rate mR/hr With Buildup |
|---|---|---|---|---|---|
| 0.0318 | 7.041e+03 | 2.190e-30 | 1.063e-29 | 1.824e-32 | 8.854e-32 |
| 0.0322 | 1.299e+04 | 2.602e-29 | 9.640e-29 | 2.094e-31 | 7.758e-31 |
| 0.0364 | 4.727e+03 | 9.538e-23 | 4.974e-22 | 5.419e-25 | 2.826e-24 |
| 0.6616 | 3.060e+05 | 7.134e-03 | 2.187e-02 | 1.383e-05 | 4.240e-05 |
| 0.6938 | 2.850e+02 | 7.193e-06 | 2.152e-05 | 1.389e-08 | 4.156e-08 |

DOS File: ROLL_3.MS5
Run Date: July 21, 2004
Run Time: 8:26:26 AM
Duration: 00:00:02

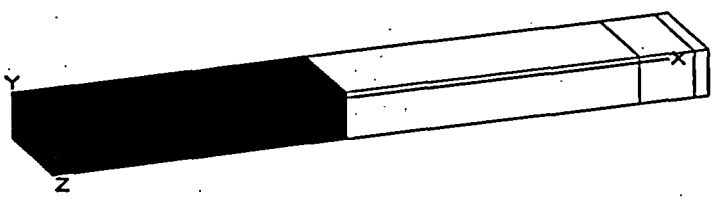
| Energy MeV | Activity photons/sec | Fluence Rate MeV/cm²/sec No Buildup | Fluence Rate MeV/cm²/sec With Buildup | Exposure Rate mR/hr No Buildup | Exposure Rate mR/hr With Buildup |
|---|---|---|---|---|---|
| 1.1732 | 1.747e+06 | 1.057e-01 | 2.474e-01 | 1.888e-04 | 4.421e-04 |
| 1.3325 | 1.747e+06 | 1.303e-01 | 2.897e-01 | 2.260e-04 | 5.026e-04 |
| TOTALS: | 3.825e+06 | 2.431e-01 | 5.590e-01 | 4.287e-04 | 9.871e-04 |

MicroShield v5.05 (5.05-00326)
CONSUMERS ENERGY COMPANY

Page : 1
DOS File: 2NDROLL.MS5
Run Date: July 21, 2004
Run Time: 11:37:56 AM
Duration: 00:00:02

File Ref: _____
Date: _____
By: _____
Checked: _____

**Case Title: Rolloff Recalc**
**Description: Density 0.667 (25,000 lbs)**
**Geometry: 13 - Rectangular Volume**




**Source Dimensions**

| | | |
|---|---|---|
| Length | 655.32 cm | 21 ft 6.0 in |
| Width | 243.84 cm | 8 ft |
| Height | 106.68 cm | 3 ft 6.0 in |

**Dose Points**

| | X | Y | Z |
|---|---|---|---|
| # 1 | 1466 cm | 53.34 cm | 121.72 cm |
| | 48 ft 1.2 in | 1 ft 9.0 in | 3 ft 11.9 in |

**Shields**

| Shield Name | Dimension | Material | Density |
|---|---|---|---|
| Source | 1.70e+07 cm | NBS Concrete | 0.667 |
| Shield 1 | 1.921 cm | Iron | 7.86 |
| Shield 2 | 655.32 cm | NBS Concrete | 0.667 |
| Shield 3 | .64 cm | Iron | 7.86 |
| Shield 4 | 121.92 cm | Air | 0.00122 |
| Shield 5 | .305 cm | Iron | 7.86 |
| Shield 6 | 30.48 cm | Air | 0.00122 |
| Air Gap | | Air | 0.00122 |

**Source Input**
**Grouping Method : Actual Photon Energies**

| Nuclide | curies | becquerels | µCi/cm³ | Bq/cm³ |
|---|---|---|---|---|
| Ba-137m | 9.1919e-006 | 3.4010e+005 | 5.3922e-007 | 1.9951e-002 |
| Co-60 | 4.7219e-005 | 1.7471e+006 | 2.7700e-006 | 1.0249e-001 |
| Cs-137 | 9.7166e-006 | 3.5952e+005 | 5.7000e-007 | 2.1090e-002 |
| Fe-55 | | | | |
| H-3 | 4.4662e-004 | 1.6525e+007 | 2.6200e-005 | 9.6940e-001 |

**Buildup**
**The material reference is : Shield 1**

**Integration Parameters**

| | |
|---|---|
| X Direction | 10 |
| Y Direction | 20 |
| Z Direction | 20 |

**Results**

| Energy MeV | Activity photons/sec | Fluence Rate MeV/cm²/sec No Buildup | Fluence Rate MeV/cm²/sec With Buildup | Exposure Rate mR/hr No Buildup | Exposure Rate mR/hr With Buildup |
|---|---|---|---|---|---|
| 0.0318 | 7.041e+03 | 1.164e-261 | 1.442e-31 | 9.696e-264 | 1.201e-33 |
| 0.0322 | 1.299e+04 | 1.230e-253 | 2.704e-31 | 9.901e-256 | 2.176e-33 |
| 0.0364 | 4.727e+03 | 1.624e-187 | 1.185e-31 | 9.229e-190 | 6.733e-34 |
| 0.6616 | 3.060e+05 | 2.437e-19 | 3.461e-17 | 4.725e-22 | 6.710e-20 |

DOS File: 2NDROLL.MS5
Run Date: July 21, 2004
Run Time: 11:37:56 AM
Duration: 00:00:02

| Energy MeV | Activity photons/sec | Fluence Rate MeV/cm²/sec No Buildup | Fluence Rate MeV/cm²/sec With Buildup | Exposure Rate mR/hr No Buildup | Exposure Rate mR/hr With Buildup |
|---|---|---|---|---|---|
| 0.6938 | 2.850e+02 | 5.163e-22 | 6.894e-20 | 9.969e-25 | 1.331e-22 |
| 1.1732 | 1.747e+06 | 1.585e-14 | 9.146e-13 | 2.832e-17 | 1.634e-15 |
| 1.3325 | 1.747e+06 | 1.044e-13 | 4.904e-12 | 1.811e-16 | 8.507e-15 |
| TOTALS: | 3.825e+06 | 1.202e-13 | 5.818e-12 | 2.094e-16 | 1.014e-14 |

Attachment 4

Consumers Energy
BIG ROCK POINT
Docket Numbers 50-155 and 72-043

**RESRAD ASSESSMENT OF LANDFILL WORKER DOSE**
**(Worker.rad)**

September 15, 2004

18 Pages

Landfill Worker
0.291 mrem/y t=0

Table of Contents

Part I: Mixture Sums and Single Radionuclide Guidelines

Dose Conversion Factor (and Related) Parameter Summary
File: FGR 13 Morbidity

| Menu | Parameter | Current Value | Default | Parameter Name |
|---|---|---|---|---|
| B-1 | Dose conversion factors for inhalation, mrem/pCi: | | | |
| B-1 | Co-60 | 2.190E-04 | 2.190E-04 | DCF2( 1) |
| B-1 | Cs-137+D | 3.190E-05 | 3.190E-05 | DCF2( 2) |
| B-1 | H-3 | 6.400E-08 | 6.400E-08 | DCF2( 3) |
| | | | | |
| D-1 | Dose conversion factors for ingestion, mrem/pCi: | | | |
| D-1 | Co-60 | 2.690E-05 | 2.690E-05 | DCF3( 1) |
| D-1 | Cs-137+D | 5.000E-05 | 5.000E-05 | DCF3( 2) |
| D-1 | H-3 | 6.400E-08 | 6.400E-08 | DCF3( 3) |
| | | | | |
| D-34 | Food transfer factors: | | | |
| D-34 | Co-60 , plant/soil concentration ratio, dimensionless | 8.000E-02 | 8.000E-02 | RTF( 1,1) |
| D-34 | Co-60 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d) | 2.000E-02 | 2.000E-02 | RTF( 1,2) |
| D-34 | Co-60 , milk/livestock-intake ratio, (pCi/L)/(pCi/d) | 2.000E-03 | 2.000E-03 | RTF( 1,3) |
| D-34 | | | | |
| D-34 | Cs-137+D , plant/soil concentration ratio, dimensionless | 4.000E-02 | 4.000E-02 | RTF( 2,1) |
| D-34 | Cs-137+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d) | 3.000E-02 | 3.000E-02 | RTF( 2,2) |
| D-34 | Cs-137+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d) | 8.000E-03 | 8.000E-03 | RTF( 2,3) |
| D-34 | | | | |
| D-34 | H-3 , plant/soil concentration ratio, dimensionless | 4.800E+00 | 4.800E+00 | RTF( 3,1) |
| D-34 | H-3 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d) | 1.200E-02 | 1.200E-02 | RTF( 3,2) |
| D-34 | H-3 , milk/livestock-intake ratio, (pCi/L)/(pCi/d) | 1.000E-02 | 1.000E-02 | RTF( 3,3) |
| | | | | |
| D-5 | Bioaccumulation factors, fresh water, L/kg: | | | |
| D-5 | Co-60 , fish | 3.000E+02 | 3.000E+02 | BIOFAC( 1,1) |
| D-5 | Co-60 , crustacea and mollusks | 2.000E+02 | 2.000E+02 | BIOFAC( 1,2) |
| D-5 | | | | |
| D-5 | Cs-137+D , fish | 2.000E+03 | 2.000E+03 | BIOFAC( 2,1) |
| D-5 | Cs-137+D , crustacea and mollusks | 1.000E+02 | 1.000E+02 | BIOFAC( 2,2) |
| D-5 | | | | |
| D-5 | H-3 , fish | 1.000E+00 | 1.000E+00 | BIOFAC( 3,1) |
| D-5 | H-3 , crustacea and mollusks | 1.000E+00 | 1.000E+00 | BIOFAC( 3,2) |

Site-Specific Parameter Summary

| Menu | Parameter | User Input | Default | Used by RESRAD (If different from user input) | Parameter Name |
|---|---|---|---|---|---|
| R011 | Area of contaminated zone (m**2) | 3.965E+03 | 1.000E+04 | --- | AREA |
| R011 | Thickness of contaminated zone (m) | 3.710E+00 | 2.000E+00 | --- | THICK0 |
| R011 | Length parallel to aquifer flow (m) | not used | 1.000E+02 | --- | LCZPAQ |
| R011 | Basic radiation dose limit (mrem/yr) | 2.500E+01 | 2.500E+01 | --- | BRDL |
| R011 | Time since placement of material (yr) | 0.000E+00 | 0.000E+00 | --- | TI |
| R011 | Times for calculations (yr) | 1.000E+00 | 1.000E+00 | --- | T( 2) |
| R011 | Times for calculations (yr) | 3.000E+00 | 3.000E+00 | --- | T( 3) |
| R011 | Times for calculations (yr) | 1.000E+01 | 1.000E+01 | --- | T( 4) |
| R011 | Times for calculations (yr) | 3.000E+01 | 3.000E+01 | --- | T( 5) |
| R011 | Times for calculations (yr) | 1.000E+02 | 1.000E+02 | --- | T( 6) |
| R011 | Times for calculations (yr) | 3.000E+02 | 3.000E+02 | --- | T( 7) |
| R011 | Times for calculations (yr) | 1.000E+03 | 1.000E+03 | --- | T( 8) |
| R011 | Times for calculations (yr) | not used | 0.000E+00 | --- | T( 9) |
| R011 | Times for calculations (yr) | not used | 0.000E+00 | --- | T(10) |
| | | | | | |
| R012 | Initial principal radionuclide (pCi/g): Co-60 | 4.150E+00 | 0.000E+00 | --- | S1( 1) |
| R012 | Initial principal radionuclide (pCi/g): Cs-137 | 8.500E-01 | 0.000E+00 | --- | S1( 2) |
| R012 | Initial principal radionuclide (pCi/g): H-3 | 3.930E+01 | 0.000E+00 | --- | S1( 3) |
| R012 | Concentration in groundwater (pCi/L): Co-60 | not used | 0.000E+00 | --- | W1( 1) |
| R012 | Concentration in groundwater (pCi/L): Cs-137 | not used | 0.000E+00 | --- | W1( 2) |
| R012 | Concentration in groundwater (pCi/L): H-3 | not used | 0.000E+00 | --- | W1( 3) |
| | | | | | |
| R013 | Cover depth (m) | 1.500E-01 | 0.000E+00 | --- | COVER0 |
| R013 | Density of cover material (g/cm**3) | 1.500E+00 | 1.500E+00 | --- | DENSCV |
| R013 | Cover depth erosion rate (m/yr) | 1.000E-03 | 1.000E-03 | --- | VCV |
| R013 | Density of contaminated zone (g/cm**3) | 1.500E+00 | 1.500E+00 | --- | DENSCZ |
| R013 | Contaminated zone erosion rate (m/yr) | 1.000E-03 | 1.000E-03 | --- | VCZ |
| R013 | Contaminated zone total porosity | 4.000E-01 | 4.000E-01 | --- | TPCZ |
| R013 | Contaminated zone field capacity | 2.000E-01 | 2.000E-01 | --- | FCCZ |
| R013 | Contaminated zone hydraulic conductivity (m/yr) | 1.000E+01 | 1.000E+01 | --- | HCCZ |
| R013 | Contaminated zone b parameter | 5.300E+00 | 5.300E+00 | --- | BCZ |
| R013 | Average annual wind speed (m/sec) | 2.000E+00 | 2.000E+00 | --- | WIND |
| R013 | Humidity in air (g/m**3) | 8.000E+00 | 8.000E+00 | --- | HUMID |
| R013 | Evapotranspiration coefficient | 5.000E-01 | 5.000E-01 | --- | EVAPTR |
| R013 | Precipitation (m/yr) | 1.000E+00 | 1.000E+00 | --- | PRECIP |
| R013 | Irrigation (m/yr) | 2.000E-01 | 2.000E-01 | --- | RI |
| R013 | Irrigation mode | overhead | overhead | --- | IDITCH |
| R013 | Runoff coefficient | 2.000E-01 | 2.000E-01 | --- | RUNOFF |
| R013 | Watershed area for nearby stream or pond (m**2) | not used | 1.000E+06 | --- | WAREA |
| R013 | Accuracy for water/soil computations | not used | 1.000E-03 | --- | EPS |
| | | | | | |
| R014 | Density of saturated zone (g/cm**3) | not used | 1.500E+00 | --- | DENSAQ |
| R014 | Saturated zone total porosity | not used | 4.000E-01 | --- | TPSZ |
| R014 | Saturated zone effective porosity | not used | 2.000E-01 | --- | EPSZ |
| R014 | Saturated zone field capacity | not used | 2.000E-01 | --- | FCSZ |
| R014 | Saturated zone hydraulic conductivity (m/yr) | not used | 1.000E+02 | --- | HCSZ |
| R014 | Saturated zone hydraulic gradient | not used | 2.000E-02 | --- | HGWT |
| R014 | Saturated zone b parameter | not used | 5.300E+00 | --- | BSZ |
| R014 | Water table drop rate (m/yr) | not used | 1.000E-03 | --- | VWT |
| R014 | Well pump intake depth (m below water table) | not used | 1.000E+01 | --- | DWIBWT |
| R014 | Model: Nondispersion (ND) or Mass-Balance (MB) | not used | ND | --- | MODEL |

Site-Specific Parameter Summary (continued)

| Menu | Parameter | User Input | Default | Used by RESRAD (If different from user input) | Parameter Name |
|---|---|---|---|---|---|
| R014 | Well pumping rate (m**3/yr) | not used | 2.500E+02 | --- | UW |
| | | | | | |
| R015 | Number of unsaturated zone strata | not used | 1 | --- | NS |
| R015 | Unsat. zone 1, thickness (m) | not used | 4.000E+00 | --- | H(1) |
| R015 | Unsat. zone 1, soil density (g/cm**3) | not used | 1.500E+00 | --- | DENSUZ(1) |
| R015 | Unsat. zone 1, total porosity | not used | 4.000E-01 | --- | TPUZ(1) |
| R015 | Unsat. zone 1, effective porosity | not used | 2.000E-01 | --- | EPUZ(1) |
| R015 | Unsat. zone 1, field capacity | not used | 2.000E-01 | --- | FCUZ(1) |
| R015 | Unsat. zone 1, soil-specific b parameter | not used | 5.300E+00 | --- | BUZ(1) |
| R015 | Unsat. zone 1, hydraulic conductivity (m/yr) | not used | 1.000E+01 | --- | HCUZ(1) |
| | | | | | |
| R016 | Distribution coefficients for Co-60 | | | | |
| R016 | Contaminated zone (cm**3/g) | 1.000E+03 | 1.000E+03 | --- | DCNUCC( 1) |
| R016 | Unsaturated zone 1 (cm**3/g) | not used | 1.000E+03 | --- | DCNUCU( 1,1) |
| R016 | Saturated zone (cm**3/g) | not used | 1.000E+03 | --- | DCNUCS( 1) |
| R016 | Leach rate (/yr) | 0.000E+00 | 0.000E+00 | 8.983E-05 | ALEACH( 1) |
| R016 | Solubility constant | 0.000E+00 | 0.000E+00 | not used | SOLUBK( 1) |
| | | | | | |
| R016 | Distribution coefficients for Cs-137 | | | | |
| R016 | Contaminated zone (cm**3/g) | 1.000E+03 | 1.000E+03 | --- | DCNUCC( 2) |
| R016 | Unsaturated zone 1 (cm**3/g) | not used | 1.000E+03 | --- | DCNUCU( 2,1) |
| R016 | Saturated zone (cm**3/g) | not used | 1.000E+03 | --- | DCNUCS( 2) |
| R016 | Leach rate (/yr) | 0.000E+00 | 0.000E+00 | 8.983E-05 | ALEACH( 2) |
| R016 | Solubility constant | 0.000E+00 | 0.000E+00 | not used | SOLUBK( 2) |
| | | | | | |
| R016 | Distribution coefficients for H-3 | | | | |
| R016 | Contaminated zone (cm**3/g) | 0.000E+00 | 0.000E+00 | --- | DCNUCC( 3) |
| R016 | Unsaturated zone 1 (cm**3/g) | not used | 0.000E+00 | --- | DCNUCU( 3,1) |
| R016 | Saturated zone (cm**3/g) | not used | 0.000E+00 | --- | DCNUCS( 3) |
| R016 | Leach rate (/yr) | 0.000E+00 | 0.000E+00 | 4.200E-01 | ALEACH( 3) |
| R016 | Solubility constant | 0.000E+00 | 0.000E+00 | not used | SOLUBK( 3) |
| | | | | | |
| R017 | Inhalation rate (m**3/yr) | 8.400E+03 | 8.400E+03 | --- | INHALR |
| R017 | Mass loading for inhalation (g/m**3) | 1.000E-04 | 1.000E-04 | --- | MLINH |
| R017 | Exposure duration | 3.000E+01 | 3.000E+01 | --- | ED |
| R017 | Shielding factor, inhalation | 4.000E-01 | 4.000E-01 | --- | SHF3 |
| R017 | Shielding factor, external gamma | 7.000E-01 | 7.000E-01 | --- | SHF1 |
| R017 | Fraction of time spent indoors | 0.000E+00 | 5.000E-01 | --- | FIND |
| R017 | Fraction of time spent outdoors (on site) | 2.800E-02 | 2.500E-01 | --- | FOTD |
| R017 | Shape factor flag, external gamma | 1.000E+00 | 1.000E+00 | >0 shows circular AREA. | FS |

Site-Specific Parameter Summary (continued)

| Menu | Parameter | User Input | Default | Used by RESRAD (If different from user input) | Parameter Name |
|---|---|---|---|---|---|
| R017 | Radii of shape factor array (used if FS = -1): | | | | |
| R017 | Outer annular radius (m), ring 1: | not used | 5.000E+01 | --- | RAD_SHAPE( 1) |
| R017 | Outer annular radius (m), ring 2: | not used | 7.071E+01 | --- | RAD_SHAPE( 2) |
| R017 | Outer annular radius (m), ring 3: | not used | 0.000E+00 | --- | RAD_SHAPE( 3) |
| R017 | Outer annular radius (m), ring 4: | not used | 0.000E+00 | --- | RAD_SHAPE( 4) |
| R017 | Outer annular radius (m), ring 5: | not used | 0.000E+00 | --- | RAD_SHAPE( 5) |
| R017 | Outer annular radius (m), ring 6: | not used | 0.000E+00 | --- | RAD_SHAPE( 6) |
| R017 | Outer annular radius (m), ring 7: | not used | 0.000E+00 | --- | RAD_SHAPE( 7) |
| R017 | Outer annular radius (m), ring 8: | not used | 0.000E+00 | --- | RAD_SHAPE( 8) |
| R017 | Outer annular radius (m), ring 9: | not used | 0.000E+00 | --- | RAD_SHAPE( 9) |
| R017 | Outer annular radius (m), ring 10: | not used | 0.000E+00 | --- | RAD_SHAPE(10) |
| R017 | Outer annular radius (m), ring 11: | not used | 0.000E+00 | --- | RAD_SHAPE(11) |
| R017 | Outer annular radius (m), ring 12: | not used | 0.000E+00 | --- | RAD_SHAPE(12) |
| | | | | | |
| R017 | Fractions of annular areas within AREA: | | | | |
| R017 | Ring 1 | not used | 1.000E+00 | --- | FRACA( 1) |
| R017 | Ring 2 | not used | 2.732E-01 | --- | FRACA( 2) |
| R017 | Ring 3 | not used | 0.000E+00 | --- | FRACA( 3) |
| R017 | Ring 4 | not used | 0.000E+00 | --- | FRACA( 4) |
| R017 | Ring 5 | not used | 0.000E+00 | --- | FRACA( 5) |
| R017 | Ring 6 | not used | 0.000E+00 | --- | FRACA( 6) |
| R017 | Ring 7 | not used | 0.000E+00 | --- | FRACA( 7) |
| R017 | Ring 8 | not used | 0.000E+00 | --- | FRACA( 8) |
| R017 | Ring 9 | not used | 0.000E+00 | --- | FRACA( 9) |
| R017 | Ring 10 | not used | 0.000E+00 | --- | FRACA(10) |
| R017 | Ring 11 | not used | 0.000E+00 | --- | FRACA(11) |
| R017 | Ring 12 | not used | 0.000E+00 | --- | FRACA(12) |
| | | | | | |
| R018 | Fruits, vegetables and grain consumption (kg/yr) | not used | 1.600E+02 | --- | DIET(1) |
| R018 | Leafy vegetable consumption (kg/yr) | not used | 1.400E+01 | --- | DIET(2) |
| R018 | Milk consumption (L/yr) | not used | 9.200E+01 | --- | DIET(3) |
| R018 | Meat and poultry consumption (kg/yr) | not used | 6.300E+01 | --- | DIET(4) |
| R018 | Fish consumption (kg/yr) | not used | 5.400E+00 | --- | DIET(5) |
| R018 | Other seafood consumption (kg/yr) | not used | 9.000E-01 | --- | DIET(6) |
| R018 | Soil ingestion rate (g/yr) | not used | 3.650E+01 | --- | SOIL |
| R018 | Drinking water intake (L/yr) | not used | 5.100E+02 | --- | DWI |
| R018 | Contamination fraction of drinking water | not used | 1.000E+00 | --- | FDW |
| R018 | Contamination fraction of household water | not used | 1.000E+00 | --- | FHHW |
| R018 | Contamination fraction of livestock water | not used | 1.000E+00 | --- | FLW |
| R018 | Contamination fraction of irrigation water | not used | 1.000E+00 | --- | FIRW |
| R018 | Contamination fraction of aquatic food | not used | 5.000E-01 | --- | FR9 |
| R018 | Contamination fraction of plant food | not used | -1 | --- | FPLANT |
| R018 | Contamination fraction of meat | not used | -1 | --- | FMEAT |
| R018 | Contamination fraction of milk | not used | -1 | --- | FMILK |
| | | | | | |
| R019 | Livestock fodder intake for meat (kg/day) | not used | 6.800E+01 | --- | LFI5 |
| R019 | Livestock fodder intake for milk (kg/day) | not used | 5.500E+01 | --- | LFI6 |
| R019 | Livestock water intake for meat (L/day) | not used | 5.000E+01 | --- | LWI5 |
| R019 | Livestock water intake for milk (L/day) | not used | 1.600E+02 | --- | LWI6 |
| R019 | Livestock soil intake (kg/day) | not used | 5.000E-01 | --- | LSI |
| R019 | Mass loading for foliar deposition (g/m**3) | not used | 1.000E-04 | --- | MLFD |

Site-Specific Parameter Summary (continued)

| Menu | Parameter | User Input | Default | Used by RESRAD (If different from user input) | Parameter Name |
|---|---|---|---|---|---|
| R019 | Depth of soil mixing layer (m) | 1.500E-01 | 1.500E-01 | --- | DM |
| R019 | Depth of roots (m) | not used | 9.000E-01 | --- | DROOT |
| R019 | Drinking water fraction from ground water | not used | 1.000E+00 | --- | FGWDW |
| R019 | Household water fraction from ground water | not used | 1.000E+00 | --- | FGWHH |
| R019 | Livestock water fraction from ground water | not used | 1.000E+00 | --- | FGWLW |
| R019 | Irrigation fraction from ground water | not used | 1.000E+00 | --- | FGWIR |
| | | | | | |
| R19B | Wet weight crop yield for Non-Leafy (kg/m**2) | not used | 7.000E-01 | --- | YV(1) |
| R19B | Wet weight crop yield for Leafy (kg/m**2) | not used | 1.500E+00 | --- | YV(2) |
| R19B | Wet weight crop yield for Fodder (kg/m**2) | not used | 1.100E+00 | --- | YV(3) |
| R19B | Growing Season for Non-Leafy (years) | not used | 1.700E-01 | --- | TE(1) |
| R19B | Growing Season for Leafy (years) | not used | 2.500E-01 | --- | TE(2) |
| R19B | Growing Season for Fodder (years) | not used | 8.000E-02 | --- | TE(3) |
| R19B | Translocation Factor for Non-Leafy | not used | 1.000E-01 | --- | TIV(1) |
| R19B | Translocation Factor for Leafy | not used | 1.000E+00 | --- | TIV(2) |
| R19B | Translocation Factor for Fodder | not used | 1.000E+00 | --- | TIV(3) |
| R19B | Dry Foliar Interception Fraction for Non-Leafy | not used | 2.500E-01 | --- | RDRY(1) |
| R19B | Dry Foliar Interception Fraction for Leafy | not used | 2.500E-01 | --- | RDRY(2) |
| R19B | Dry Foliar Interception Fraction for Fodder | not used | 2.500E-01 | --- | RDRY(3) |
| R19B | Wet Foliar Interception Fraction for Non-Leafy | not used | 2.500E-01 | --- | RWET(1) |
| R19B | Wet Foliar Interception Fraction for Leafy | not used | 2.500E-01 | --- | RWET(2) |
| R19B | Wet Foliar Interception Fraction for Fodder | not used | 2.500E-01 | --- | RWET(3) |
| R19B | Weathering Removal Constant for Vegetation | not used | 2.000E+01 | --- | WLAM |
| | | | | | |
| C14 | C-12 concentration in water (g/cm**3) | not used | 2.000E-05 | --- | C12WTR |
| C14 | C-12 concentration in contaminated soil (g/g) | not used | 3.000E-02 | --- | C12CZ |
| C14 | Fraction of vegetation carbon from soil | not used | 2.000E-02 | --- | CSOIL |
| C14 | Fraction of vegetation carbon from air | not used | 9.800E-01 | --- | CAIR |
| C14 | C-14 evasion layer thickness in soil (m) | not used | 3.000E-01 | --- | DMC |
| C14 | C-14 evasion flux rate from soil (1/sec) | not used | 7.000E-07 | --- | EVSN |
| C14 | C-12 evasion flux rate from soil (1/sec) | not used | 1.000E-10 | --- | REVSN |
| C14 | Fraction of grain in beef cattle feed | not used | 8.000E-01 | --- | AVFG4 |
| C14 | Fraction of grain in milk cow feed | not used | 2.000E-01 | --- | AVFG5 |
| C14 | DCF correction factor for gaseous forms of C14 | not used | 8.894E+01 | --- | CO2F |
| | | | | | |
| STOR | Storage times of contaminated foodstuffs (days): | | | | |
| STOR | Fruits, non-leafy vegetables, and grain | 1.400E+01 | 1.400E+01 | --- | STOR_T(1) |
| STOR | Leafy vegetables | 1.000E+00 | 1.000E+00 | --- | STOR_T(2) |
| STOR | Milk | 1.000E+00 | 1.000E+00 | --- | STOR_T(3) |
| STOR | Meat and poultry | 2.000E+01 | 2.000E+01 | --- | STOR_T(4) |
| STOR | Fish | 7.000E+00 | 7.000E+00 | --- | STOR_T(5) |
| STOR | Crustacea and mollusks | 7.000E+00 | 7.000E+00 | --- | STOR_T(6) |
| STOR | Well water | 1.000E+00 | 1.000E+00 | --- | STOR_T(7) |
| STOR | Surface water | 1.000E+00 | 1.000E+00 | --- | STOR_T(8) |
| STOR | Livestock fodder | 4.500E+01 | 4.500E+01 | --- | STOR_T(9) |
| | | | | | |
| R021 | Thickness of building foundation (m) | not used | 1.500E-01 | --- | FLOOR1 |
| R021 | Bulk density of building foundation (g/cm**3) | not used | 2.400E+00 | --- | DENSFL |
| R021 | Total porosity of the cover material | not used | 4.000E-01 | --- | TPCV |
| R021 | Total porosity of the building foundation | not used | 1.000E-01 | --- | TPFL |
| R021 | Volumetric water content of the cover material | not used | 5.000E-02 | --- | PH2OCV |

Site-Specific Parameter Summary (continued)

| Menu | Parameter | User Input | Default | Used by RESRAD (If different from user input) | Parameter Name |
|---|---|---|---|---|---|
| R021 | Volumetric water content of the foundation | not used | 3.000E-02 | --- | PH2OFL |
| R021 | Diffusion coefficient for radon gas (m/sec): | | | | |
| R021 | in cover material | not used | 2.000E-06 | --- | DIFCV |
| R021 | in foundation material | not used | 3.000E-07 | --- | DIFFL |
| R021 | in contaminated zone soil | not used | 2.000E-06 | --- | DIFCZ |
| R021 | Radon vertical dimension of mixing (m) | not used | 2.000E+00 | --- | HMIX |
| R021 | Average building air exchange rate (1/hr) | not used | 5.000E-01 | --- | REXG |
| R021 | Height of the building (room) (m) | not used | 2.500E+00 | --- | HRM |
| R021 | Building interior area factor | not used | 0.000E+00 | --- | FAI |
| R021 | Building depth below ground surface (m) | not used | -1.000E+00 | --- | DMFL |
| R021 | Emanating power of Rn-222 gas | not used | 2.500E-01 | --- | EMANA(1) |
| R021 | Emanating power of Rn-220 gas | not used | 1.500E-01 | --- | EMANA(2) |
| | | | | | |
| TITL | Number of graphical time points | 32 | --- | --- | NPTS |
| TITL | Maximum number of integration points for dose | 17 | --- | --- | LYMAX |
| TITL | Maximum number of integration points for risk | 257 | --- | --- | KYMAX |

Summary of Pathway Selections

| Pathway | User Selection |
|---|---|
| 1 -- external gamma | active |
| 2 -- inhalation (w/o radon) | active |
| 3 -- plant ingestion | suppressed |
| 4 -- meat ingestion | suppressed |
| 5 -- milk ingestion | suppressed |
| 6 -- aquatic foods | suppressed |
| 7 -- drinking water | suppressed |
| 8 -- soil ingestion | suppressed |
| 9 -- radon | suppressed |
| Find peak pathway doses | active |

| Contaminated Zone Dimensions | | Initial Soil Concentrations, pCi/g | |
|---|---|---|---|
| Area: | 3965.00 square meters | Co-60 | 4.150E+00 |
| Thickness: | 3.71 meters | Cs-137 | 8.500E-01 |
| Cover Depth: | 0.15 meters | H-3 | 3.930E+01 |

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 2.500E+01 mrem/yr
Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)

| t (years): | 0.000E+00 | 1.000E+00 | 3.000E+00 | 1.000E+01 | 3.000E+01 | 1.000E+02 | 3.000E+02 | 1.000E+03 |
|---|---|---|---|---|---|---|---|---|
| TDOSE(t): | 2.906E-01 | 2.586E-01 | 2.051E-01 | 9.301E-02 | 1.449E-02 | 3.617E-03 | 6.972E-05 | 6.195E-12 |
| M(t): | 1.162E-02 | 1.034E-02 | 8.205E-03 | 3.720E-03 | 5.796E-04 | 1.447E-04 | 2.789E-06 | 2.478E-13 |

Maximum TDOSE(t): 2.906E-01 mrem/yr at t = 0.000E+00 years

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

| Radio- | Ground | | Inhalation | | Radon | | Plant | | Meat | | Milk | | Soil | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nuclide | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. |
| Co-60 | 2.815E-01 | 0.9689 | 1.005E-08 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Cs-137 | 8.844E-03 | 0.0304 | 3.222E-10 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| H-3 | 0.000E+00 | 0.0000 | 1.877E-04 | 0.0006 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Total | 2.904E-01 | 0.9994 | 1.877E-04 | 0.0006 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years

Water Dependent Pathways

| Radio- | Water | | Fish | | Radon | | Plant | | Meat | | Milk | | All Pathways* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nuclide | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. |
| Co-60 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.815E-01 | 0.9689 |
| Cs-137 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 8.844E-03 | 0.0304 |
| H-3 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.877E-04 | 0.0006 |
| Total | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.906E-01 | 1.0000 |

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

| Radio- | Ground | | Inhalation | | Radon | | Plant | | Meat | | Milk | | Soil | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nuclide | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. |
| Co-60 | 2.497E-01 | 0.9657 | 2.683E-08 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Cs-137 | 8.765E-03 | 0.0339 | 9.468E-10 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| H-3 | 0.000E+00 | 0.0000 | 9.484E-05 | 0.0004 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Total | 2.585E-01 | 0.9996 | 9.487E-05 | 0.0004 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Dependent Pathways

| Radio- | Water | | Fish | | Radon | | Plant | | Meat | | Milk | | All Pathways* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nuclide | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. |
| Co-60 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.497E-01 | 0.9657 |
| Cs-137 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 8.765E-03 | 0.0339 |
| H-3 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 9.484E-05 | 0.0004 |
| Total | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.586E-01 | 1.0000 |

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

| Radio- | Ground | | Inhalation | | Radon | | Plant | | Meat | | Milk | | Soil | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nuclide | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. |
| Co-60 | 1.965E-01 | 0.9579 | 4.832E-08 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Cs-137 | 8.610E-03 | 0.0420 | 2.111E-09 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| H-3 | 0.000E+00 | 0.0000 | 2.402E-05 | 0.0001 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Total | 2.051E-01 | 0.9999 | 2.407E-05 | 0.0001 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years

Water Dependent Pathways

| Radio- | Water | | Fish | | Radon | | Plant | | Meat | | Milk | | All Pathways* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nuclide | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. |
| Co-60 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.965E-01 | 0.9579 |
| Cs-137 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 8.610E-03 | 0.0420 |
| H-3 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.402E-05 | 0.0001 |
| Total | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.051E-01 | 1.0000 |

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

Water Independent Pathways (Inhalation excludes radon)

| Radio- | Ground | | Inhalation | | Radon | | Plant | | Meat | | Milk | | Soil | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nuclide | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. |
| Co-60 | 8.492E-02 | 0.9130 | 5.782E-08 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Cs-137 | 8.087E-03 | 0.0869 | 5.385E-09 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| H-3 | 0.000E+00 | 0.0000 | 1.795E-07 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Total | 9.301E-02 | 1.0000 | 2.427E-07 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

Water Dependent Pathways

| Radio- | Water | | Fish | | Radon | | Plant | | Meat | | Milk | | All Pathways* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nuclide | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. |
| Co-60 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 8.492E-02 | 0.9130 |
| Cs-137 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 8.087E-03 | 0.0869 |
| H-3 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.795E-07 | 0.0000 |
| Total | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 9.301E-02 | 1.0000 |

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years

Water Independent Pathways (Inhalation excludes radon)

| Radio- | Ground | | Inhalation | | Radon | | Plant | | Meat | | Milk | | Soil | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nuclide | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. |
| Co-60 | 7.728E-03 | 0.5333 | 1.209E-08 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Cs-137 | 6.762E-03 | 0.4667 | 9.838E-09 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| H-3 | 0.000E+00 | 0.0000 | 6.998E-14 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Total | 1.449E-02 | 1.0000 | 2.193E-08 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years

Water Dependent Pathways

| Radio- | Water | | Fish | | Radon | | Plant | | Meat | | Milk | | All Pathways* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nuclide | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. |
| Co-60 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 7.728E-03 | 0.5333 |
| Cs-137 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 6.762E-03 | 0.4667 |
| H-3 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 6.998E-14 | 0.0000 |
| Total | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.449E-02 | 1.0000 |

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years

Water Independent Pathways (Inhalation excludes radon)

| adio- | Ground | | Inhalation | | Radon | | Plant | | Meat | | Milk | | Soil | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| uclide | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. |
| o-60 | 1.756E-06 | 0.0005 | 3.981E-12 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| s-137 | 3.615E-03 | 0.9995 | 6.392E-09 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| -3 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| otal | 3.617E-03 | 1.0000 | 6.396E-09 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years

Water Dependent Pathways

| adio- | Water | | Fish | | Radon | | Plant | | Meat | | Milk | | All Pathways* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| uclide | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. |
| o-60 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.756E-06 | 0.0005 |
| s-137 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 3.615E-03 | 0.9995 |
| -3 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| otal | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 3.617E-03 | 1.0000 |

Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years

Water Independent Pathways (Inhalation excludes radon)

| Radio- | Ground | | Inhalation | | Radon | | Plant | | Meat | | Milk | | Soil | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nuclide | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. |
| Co-60 | 1.163E-17 | 0.0000 | 2.208E-23 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Cs-137 | 6.972E-05 | 1.0000 | 9.224E-11 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| H-3 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Total | 6.972E-05 | 1.0000 | 9.224E-11 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years

Water Dependent Pathways

| Radio- | Water | | Fish | | Radon | | Plant | | Meat | | Milk | | All Pathways* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nuclide | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. |
| Co-60 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.163E-17 | 0.0000 |
| Cs-137 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 6.972E-05 | 1.0000 |
| H-3 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Total | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 6.972E-05 | 1.0000 |

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

Water Independent Pathways (Inhalation excludes radon)

| Radio- | Ground | | Inhalation | | Radon | | Plant | | Meat | | Milk | | Soil | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nuclide | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. |
| Co-60 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Cs-137 | 6.195E-12 | 1.0000 | 8.195E-18 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| H-3 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Total | 6.195E-12 | 1.0000 | 8.195E-18 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

Water Dependent Pathways

| Radio- | Water | | Fish | | Radon | | Plant | | Meat | | Milk | | All Pathways* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nuclide | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. |
| Co-60 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Cs-137 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 6.195E-12 | 1.0000 |
| H-3 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Total | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 6.195E-12 | 1.0000 |

*Sum of all water independent and dependent pathways.

Dose/Source Ratios Summed Over All Pathways
Parent and Progeny Principal Radionuclide Contributions Indicated

| Parent (i) | Product (j) | Branch Fraction* | DSR(j,t) (mrem/yr)/(pCi/g) t= 0.000E+00 | 1.000E+00 | 3.000E+00 | 1.000E+01 | 3.000E+01 | 1.000E+02 | 3.000E+02 | 1.000E+03 |
|---|---|---|---|---|---|---|---|---|---|---|
| Co-60 | Co-60 | 1.000E+00 | 6.784E-02 | 6.017E-02 | 4.735E-02 | 2.046E-02 | 1.862E-03 | 4.232E-07 | 2.803E-18 | 0.000E+00 |
| Cs-137 | Cs-137 | 1.000E+00 | 1.040E-02 | 1.031E-02 | 1.013E-02 | 9.514E-03 | 7.956E-03 | 4.254E-03 | 8.203E-05 | 7.288E-12 |
| H-3 | H-3 | 1.000E+00 | 4.775E-06 | 2.413E-06 | 6.111E-07 | 4.567E-09 | 1.781E-15 | 8.855E-42 | 0.000E+00 | 0.000E+00 |

*Branch Fraction is the cumulative factor for the j't principal radionuclide daughter: CUMBRF(j) = BRF(1)*BRF(2)* ... BRF(j).
The DSR includes contributions from associated (half-life ≤ 0.5 yr) daughters.

Single Radionuclide Soil Guidelines G(i,t) in pCi/g
Basic Radiation Dose Limit = 2.500E+01 mrem/yr

| Nuclide (i) | t= 0.000E+00 | 1.000E+00 | 3.000E+00 | 1.000E+01 | 3.000E+01 | 1.000E+02 | 3.000E+02 | 1.000E+03 |
|---|---|---|---|---|---|---|---|---|
| Co-60 | 3.685E+02 | 4.155E+02 | 5.280E+02 | 1.222E+03 | 1.343E+04 | 5.907E+07 | *1.131E+15 | *1.131E+15 |
| Cs-137 | 2.403E+03 | 2.424E+03 | 2.468E+03 | 2.628E+03 | 3.142E+03 | 5.877E+03 | 3.048E+05 | 3.430E+12 |
| H-3 | 5.235E+06 | 1.036E+07 | 4.091E+07 | 5.475E+09 | *9.594E+15 | *9.594E+15 | *9.594E+15 | *9.594E+15 |

*At specific activity limit

Summed Dose/Source Ratios DSR(i,t) in (mrem/yr)/(pCi/g)
and Single Radionuclide Soil Guidelines G(i,t) in pCi/g
at tmin = time of minimum single radionuclide soil guideline
and at tmax = time of maximum total dose = 0.000E+00 years

| Nuclide (i) | Initial (pCi/g) | tmin (years) | DSR(i,tmin) | G(i,tmin) (pCi/g) | DSR(i,tmax) | G(i,tmax) (pCi/g) |
|---|---|---|---|---|---|---|
| Co-60 | 4.150E+00 | 0.000E+00 | 6.784E-02 | 3.685E+02 | 6.784E-02 | 3.685E+02 |
| Cs-137 | 8.500E-01 | 0.000E+00 | 1.040E-02 | 2.403E+03 | 1.040E-02 | 2.403E+03 |
| H-3 | 3.930E+01 | 0.000E+00 | 4.775E-06 | 5.235E+06 | 4.775E-06 | 5.235E+06 |

Individual Nuclide Dose Summed Over All Pathways
Parent Nuclide and Branch Fraction Indicated

| Nuclide (j) | Parent (i) | BRF(i) | DOSE(j,t), mrem/yr t= 0.000E+00 | 1.000E+00 | 3.000E+00 | 1.000E+01 | 3.000E+01 | 1.000E+02 | 3.000E+02 | 1.000E+03 |
|---|---|---|---|---|---|---|---|---|---|---|
| Co-60 | Co-60 | 1.000E+00 | 2.815E-01 | 2.497E-01 | 1.965E-01 | 8.492E-02 | 7.728E-03 | 1.756E-06 | 1.163E-17 | 0.000E+00 |
| Cs-137 | Cs-137 | 1.000E+00 | 8.844E-03 | 8.765E-03 | 8.610E-03 | 8.087E-03 | 6.762E-03 | 3.615E-03 | 6.972E-05 | 6.195E-12 |
| H-3 | H-3 | 1.000E+00 | 1.877E-04 | 9.484E-05 | 2.402E-05 | 1.795E-07 | 6.998E-14 | 0.000E+00 | 0.000E+00 | 0.000E+00 |

BRF(i) is the branch fraction of the parent nuclide.

Individual Nuclide Soil Concentration
Parent Nuclide and Branch Fraction Indicated

| Nuclide (j) | Parent (i) | BRF(i) | S(j,t), pCi/g t= 0.000E+00 | 1.000E+00 | 3.000E+00 | 1.000E+01 | 3.000E+01 | 1.000E+02 | 3.000E+02 | 1.000E+03 |
|---|---|---|---|---|---|---|---|---|---|---|
| Co-60 | Co-60 | 1.000E+00 | 4.150E+00 | 3.638E+00 | 2.796E+00 | 1.113E+00 | 8.009E-02 | 8.000E-06 | 2.973E-17 | 0.000E+00 |
| Cs-137 | Cs-137 | 1.000E+00 | 8.500E-01 | 8.305E-01 | 7.929E-01 | 6.740E-01 | 4.239E-01 | 8.358E-02 | 8.080E-04 | 7.179E-11 |
| H-3 | H-3 | 1.000E+00 | 3.930E+01 | 1.976E+01 | 4.950E+00 | 3.568E-02 | 1.268E-08 | 4.942E-35 | 0.000E+00 | 0.000E+00 |

BRF(i) is the branch fraction of the parent nuclide.

RESCALC.EXE execution time = 0.71 seconds

Attachment 5

Consumers Energy
BIG ROCK POINT
Docket Numbers 50-155 and 72-043

**RESRAD ASSESSMENT OF PUBLIC RESIDENT / FARMER DOSE**
**(Public.rad)**

September 15, 2004

18 Pages

Land fill Farmer

0.0178 mrem/y @ 30y

Table of Contents

Part I: Mixture Sums and Single Radionuclide Guidelines

Dose Conversion Factor (and Related) Parameter Summary
File: FGR 13 Morbidity

| Menu | Parameter | Current Value | Default | Parameter Name |
|---|---|---|---|---|
| B-1 | Dose conversion factors for inhalation, mrem/pCi: | | | |
| B-1 | Co-60 | 2.190E-04 | 2.190E-04 | DCF2( 1) |
| B-1 | Cs-137+D | 3.190E-05 | 3.190E-05 | DCF2( 2) |
| B-1 | H-3 | 6.400E-08 | 6.400E-08 | DCF2( 3) |
| | | | | |
| D-1 | Dose conversion factors for ingestion, mrem/pCi: | | | |
| D-1 | Co-60 | 2.690E-05 | 2.690E-05 | DCF3( 1) |
| D-1 | Cs-137+D | 5.000E-05 | 5.000E-05 | DCF3( 2) |
| D-1 | H-3 | 6.400E-08 | 6.400E-08 | DCF3( 3) |
| | | | | |
| D-34 | Food transfer factors: | | | |
| D-34 | Co-60 , plant/soil concentration ratio, dimensionless | 8.000E-02 | 8.000E-02 | RTF( 1,1) |
| D-34 | Co-60 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d) | 2.000E-02 | 2.000E-02 | RTF( 1,2) |
| D-34 | Co-60 , milk/livestock-intake ratio, (pCi/L)/(pCi/d) | 2.000E-03 | 2.000E-03 | RTF( 1,3) |
| D-34 | | | | |
| D-34 | Cs-137+D , plant/soil concentration ratio, dimensionless | 4.000E-02 | 4.000E-02 | RTF( 2,1) |
| D-34 | Cs-137+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d) | 3.000E-02 | 3.000E-02 | RTF( 2,2) |
| D-34 | Cs-137+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d) | 8.000E-03 | 8.000E-03 | RTF( 2,3) |
| D-34 | | | | |
| D-34 | H-3 , plant/soil concentration ratio, dimensionless | 4.800E+00 | 4.800E+00 | RTF( 3,1) |
| D-34 | H-3 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d) | 1.200E-02 | 1.200E-02 | RTF( 3,2) |
| D-34 | H-3 , milk/livestock-intake ratio, (pCi/L)/(pCi/d) | 1.000E-02 | 1.000E-02 | RTF( 3,3) |
| | | | | |
| D-5 | Bioaccumulation factors, fresh water, L/kg: | | | |
| D-5 | Co-60 , fish | 3.000E+02 | 3.000E+02 | BIOFAC( 1,1) |
| D-5 | Co-60 , crustacea and mollusks | 2.000E+02 | 2.000E+02 | BIOFAC( 1,2) |
| D-5 | | | | |
| D-5 | Cs-137+D , fish | 2.000E+03 | 2.000E+03 | BIOFAC( 2,1) |
| D-5 | Cs-137+D , crustacea and mollusks | 1.000E+02 | 1.000E+02 | BIOFAC( 2,2) |
| D-5 | | | | |
| D-5 | H-3 , fish | 1.000E+00 | 1.000E+00 | BIOFAC( 3,1) |
| D-5 | H-3 , crustacea and mollusks | 1.000E+00 | 1.000E+00 | BIOFAC( 3,2) |

Site-Specific Parameter Summary

| Menu | Parameter | User Input | Default | Used by RESRAD (If different from user input) | Parameter Name |
|---|---|---|---|---|---|
| R011 | Area of contaminated zone (m**2) | 3.965E+03 | 1.000E+04 | --- | AREA |
| R011 | Thickness of contaminated zone (m) | 3.710E+00 | 2.000E+00 | --- | THICK0 |
| R011 | Length parallel to aquifer flow (m) | 1.000E+02 | 1.000E+02 | --- | LCZPAQ |
| R011 | Basic radiation dose limit (mrem/yr) | 2.500E+01 | 2.500E+01 | --- | BRDL |
| R011 | Time since placement of material (yr) | 0.000E+00 | 0.000E+00 | --- | TI |
| R011 | Times for calculations (yr) | 1.000E+00 | 1.000E+00 | --- | T( 2) |
| R011 | Times for calculations (yr) | 3.000E+00 | 3.000E+00 | --- | T( 3) |
| R011 | Times for calculations (yr) | 1.000E+01 | 1.000E+01 | --- | T( 4) |
| R011 | Times for calculations (yr) | 3.000E+01 | 3.000E+01 | --- | T( 5) |
| R011 | Times for calculations (yr) | 5.000E+01 | 1.000E+02 | --- | T( 6) |
| R011 | Times for calculations (yr) | 3.000E+02 | 3.000E+02 | --- | T( 7) |
| R011 | Times for calculations (yr) | 1.000E+03 | 1.000E+03 | --- | T( 8) |
| R011 | Times for calculations (yr) | not used | 0.000E+00 | --- | T( 9) |
| R011 | Times for calculations (yr) | not used | 0.000E+00 | --- | T(10) |
| | | | | | |
| R012 | Initial principal radionuclide (pCi/g): Co-60 | 4.150E+00 | 0.000E+00 | --- | S1( 1) |
| R012 | Initial principal radionuclide (pCi/g): Cs-137 | 8.500E-01 | 0.000E+00 | --- | S1( 2) |
| R012 | Initial principal radionuclide (pCi/g): H-3 | 3.930E+01 | 0.000E+00 | --- | S1( 3) |
| R012 | Concentration in groundwater (pCi/L): Co-60 | not used | 0.000E+00 | --- | W1( 1) |
| R012 | Concentration in groundwater (pCi/L): Cs-137 | not used | 0.000E+00 | --- | W1( 2) |
| R012 | Concentration in groundwater (pCi/L): H-3 | not used | 0.000E+00 | --- | W1( 3) |
| | | | | | |
| R013 | Cover depth (m) | 1.220E+00 | 0.000E+00 | --- | COVER0 |
| R013 | Density of cover material (g/cm**3) | 1.500E+00 | 1.500E+00 | --- | DENSCV |
| R013 | Cover depth erosion rate (m/yr) | 1.000E-03 | 1.000E-03 | --- | VCV |
| R013 | Density of contaminated zone (g/cm**3) | 1.500E+00 | 1.500E+00 | --- | DENSCZ |
| R013 | Contaminated zone erosion rate (m/yr) | 1.000E-03 | 1.000E-03 | --- | VCZ |
| R013 | Contaminated zone total porosity | 4.000E-01 | 4.000E-01 | --- | TPCZ |
| R013 | Contaminated zone field capacity | 2.000E-01 | 2.000E-01 | --- | FCCZ |
| R013 | Contaminated zone hydraulic conductivity (m/yr) | 1.000E+01 | 1.000E+01 | --- | HCCZ |
| R013 | Contaminated zone b parameter | 5.300E+00 | 5.300E+00 | --- | BCZ |
| R013 | Average annual wind speed (m/sec) | 2.000E+00 | 2.000E+00 | --- | WIND |
| R013 | Humidity in air (g/m**3) | 8.000E+00 | 8.000E+00 | --- | HUMID |
| R013 | Evapotranspiration coefficient | 5.000E-01 | 5.000E-01 | --- | EVAPTR |
| R013 | Precipitation (m/yr) | 1.000E+00 | 1.000E+00 | --- | PRECIP |
| R013 | Irrigation (m/yr) | 2.000E-01 | 2.000E-01 | --- | RI |
| R013 | Irrigation mode | overhead | overhead | --- | IDITCH |
| R013 | Runoff coefficient | 2.000E-01 | 2.000E-01 | --- | RUNOFF |
| R013 | Watershed area for nearby stream or pond (m**2) | 1.000E+06 | 1.000E+06 | --- | WAREA |
| R013 | Accuracy for water/soil computations | 1.000E-03 | 1.000E-03 | --- | EPS |
| | | | | | |
| R014 | Density of saturated zone (g/cm**3) | 1.500E+00 | 1.500E+00 | --- | DENSAQ |
| R014 | Saturated zone total porosity | 4.000E-01 | 4.000E-01 | --- | TPSZ |
| R014 | Saturated zone effective porosity | 2.000E-01 | 2.000E-01 | --- | EPSZ |
| R014 | Saturated zone field capacity | 2.000E-01 | 2.000E-01 | --- | FCSZ |
| R014 | Saturated zone hydraulic conductivity (m/yr) | 1.000E+02 | 1.000E+02 | --- | HCSZ |
| R014 | Saturated zone hydraulic gradient | 2.000E-02 | 2.000E-02 | --- | HGWT |
| R014 | Saturated zone b parameter | 5.300E+00 | 5.300E+00 | --- | BSZ |
| R014 | Water table drop rate (m/yr) | 1.000E-03 | 1.000E-03 | --- | VWT |
| R014 | Well pump intake depth (m below water table) | 1.000E+01 | 1.000E+01 | --- | DWIBWT |
| R014 | Model: Nondispersion (ND) or Mass-Balance (MB) | ND | ND | --- | MODEL |

Site-Specific Parameter Summary (continued)

| Menu | Parameter | User Input | Default | Used by RESRAD (If different from user input) | Parameter Name |
|---|---|---|---|---|---|
| R014 | Well pumping rate (m**3/yr) | 2.500E+02 | 2.500E+02 | --- | UW |
| | | | | | |
| R015 | Number of unsaturated zone strata | 1 | 1 | --- | NS |
| R015 | Unsat. zone 1, thickness (m) | 4.000E+00 | 4.000E+00 | --- | H(1) |
| R015 | Unsat. zone 1, soil density (g/cm**3) | 1.500E+00 | 1.500E+00 | --- | DENSUZ(1) |
| R015 | Unsat. zone 1, total porosity | 4.000E-01 | 4.000E-01 | --- | TPUZ(1) |
| R015 | Unsat. zone 1, effective porosity | 2.000E-01 | 2.000E-01 | --- | EPUZ(1) |
| R015 | Unsat. zone 1, field capacity | 2.000E-01 | 2.000E-01 | --- | FCUZ(1) |
| R015 | Unsat. zone 1, soil-specific b parameter | 5.300E+00 | 5.300E+00 | --- | BUZ(1) |
| R015 | Unsat. zone 1, hydraulic conductivity (m/yr) | 1.000E+01 | 1.000E+01 | --- | HCUZ(1) |
| | | | | | |
| R016 | Distribution coefficients for Co-60 | | | | |
| R016 | Contaminated zone (cm**3/g) | 1.000E+03 | 1.000E+03 | --- | DCNUCC( 1) |
| R016 | Unsaturated zone 1 (cm**3/g) | 1.000E+03 | 1.000E+03 | --- | DCNUCU( 1,1) |
| R016 | Saturated zone (cm**3/g) | 1.000E+03 | 1.000E+03 | --- | DCNUCS( 1) |
| R016 | Leach rate (/yr) | 0.000E+00 | 0.000E+00 | 8.983E-05 | ALEACH( 1) |
| R016 | Solubility constant | 0.000E+00 | 0.000E+00 | not used | SOLUBK( 1) |
| | | | | | |
| R016 | Distribution coefficients for Cs-137 | | | | |
| R016 | Contaminated zone (cm**3/g) | 1.000E+03 | 1.000E+03 | --- | DCNUCC( 2) |
| R016 | Unsaturated zone 1 (cm**3/g) | 1.000E+03 | 1.000E+03 | --- | DCNUCU( 2,1) |
| R016 | Saturated zone (cm**3/g) | 1.000E+03 | 1.000E+03 | --- | DCNUCS( 2) |
| R016 | Leach rate (/yr) | 0.000E+00 | 0.000E+00 | 8.983E-05 | ALEACH( 2) |
| R016 | Solubility constant | 0.000E+00 | 0.000E+00 | not used | SOLUBK( 2) |
| | | | | | |
| R016 | Distribution coefficients for H-3 | | | | |
| R016 | Contaminated zone (cm**3/g) | 0.000E+00 | 0.000E+00 | --- | DCNUCC( 3) |
| R016 | Unsaturated zone 1 (cm**3/g) | 0.000E+00 | 0.000E+00 | --- | DCNUCU( 3,1) |
| R016 | Saturated zone (cm**3/g) | 0.000E+00 | 0.000E+00 | --- | DCNUCS( 3) |
| R016 | Leach rate (/yr) | 0.000E+00 | 0.000E+00 | 4.200E-01 | ALEACH( 3) |
| R016 | Solubility constant | 0.000E+00 | 0.000E+00 | not used | SOLUBK( 3) |
| | | | | | |
| R017 | Inhalation rate (m**3/yr) | 8.400E+03 | 8.400E+03 | --- | INHALR |
| R017 | Mass loading for inhalation (g/m**3) | 1.000E-04 | 1.000E-04 | --- | MLINH |
| R017 | Exposure duration | 3.000E+01 | 3.000E+01 | --- | ED |
| R017 | Shielding factor, inhalation | 4.000E-01 | 4.000E-01 | --- | SHF3 |
| R017 | Shielding factor, external gamma | 7.000E-01 | 7.000E-01 | --- | SHF1 |
| R017 | Fraction of time spent indoors | 5.000E-01 | 5.000E-01 | --- | FIND |
| R017 | Fraction of time spent outdoors (on site) | 2.580E-01 | 2.500E-01 | --- | FOTD |
| R017 | Shape factor flag, external gamma | 1.000E+00 | 1.000E+00 | >0 shows circular AREA. | FS |

Site-Specific Parameter Summary (continued)

| Menu | Parameter | User Input | Default | Used by RESRAD (If different from user input) | Parameter Name |
|---|---|---|---|---|---|
| R017 | Radii of shape factor array (used if FS = -1): | | | | |
| R017 | Outer annular radius (m), ring 1: | not used | 5.000E+01 | --- | RAD_SHAPE( 1) |
| R017 | Outer annular radius (m), ring 2: | not used | 7.071E+01 | --- | RAD_SHAPE( 2) |
| R017 | Outer annular radius (m), ring 3: | not used | 0.000E+00 | --- | RAD_SHAPE( 3) |
| R017 | Outer annular radius (m), ring 4: | not used | 0.000E+00 | --- | RAD_SHAPE( 4) |
| R017 | Outer annular radius (m), ring 5: | not used | 0.000E+00 | --- | RAD_SHAPE( 5) |
| R017 | Outer annular radius (m), ring 6: | not used | 0.000E+00 | --- | RAD_SHAPE( 6) |
| R017 | Outer annular radius (m), ring 7: | not used | 0.000E+00 | --- | RAD_SHAPE( 7) |
| R017 | Outer annular radius (m), ring 8: | not used | 0.000E+00 | --- | RAD_SHAPE( 8) |
| R017 | Outer annular radius (m), ring 9: | not used | 0.000E+00 | --- | RAD_SHAPE( 9) |
| R017 | Outer annular radius (m), ring 10: | not used | 0.000E+00 | --- | RAD_SHAPE(10) |
| R017 | Outer annular radius (m), ring 11: | not used | 0.000E+00 | --- | RAD_SHAPE(11) |
| R017 | Outer annular radius (m), ring 12: | not used | 0.000E+00 | --- | RAD_SHAPE(12) |
| | | | | | |
| R017 | Fractions of annular areas within AREA: | | | | |
| R017 | Ring 1 | not used | 1.000E+00 | --- | FRACA( 1) |
| R017 | Ring 2 | not used | 2.732E-01 | --- | FRACA( 2) |
| R017 | Ring 3 | not used | 0.000E+00 | --- | FRACA( 3) |
| R017 | Ring 4 | not used | 0.000E+00 | --- | FRACA( 4) |
| R017 | Ring 5 | not used | 0.000E+00 | --- | FRACA( 5) |
| R017 | Ring 6 | not used | 0.000E+00 | --- | FRACA( 6) |
| R017 | Ring 7 | not used | 0.000E+00 | --- | FRACA( 7) |
| R017 | Ring 8 | not used | 0.000E+00 | --- | FRACA( 8) |
| R017 | Ring 9 | not used | 0.000E+00 | --- | FRACA( 9) |
| R017 | Ring 10 | not used | 0.000E+00 | --- | FRACA(10) |
| R017 | Ring 11 | not used | 0.000E+00 | --- | FRACA(11) |
| R017 | Ring 12 | not used | 0.000E+00 | --- | FRACA(12) |
| | | | | | |
| R018 | Fruits, vegetables and grain consumption (kg/yr) | 1.600E+02 | 1.600E+02 | --- | DIET(1) |
| R018 | Leafy vegetable consumption (kg/yr) | 1.400E+01 | 1.400E+01 | --- | DIET(2) |
| R018 | Milk consumption (L/yr) | 9.200E+01 | 9.200E+01 | --- | DIET(3) |
| R018 | Meat and poultry consumption (kg/yr) | 6.300E+01 | 6.300E+01 | --- | DIET(4) |
| R018 | Fish consumption (kg/yr) | 5.400E+00 | 5.400E+00 | --- | DIET(5) |
| R018 | Other seafood consumption (kg/yr) | 9.000E-01 | 9.000E-01 | --- | DIET(6) |
| R018 | Soil ingestion rate (g/yr) | 3.650E+01 | 3.650E+01 | --- | SOIL |
| R018 | Drinking water intake (L/yr) | 5.100E+02 | 5.100E+02 | --- | DWI |
| R018 | Contamination fraction of drinking water | 1.000E+00 | 1.000E+00 | --- | FDW |
| R018 | Contamination fraction of household water | not used | 1.000E+00 | --- | FHHW |
| R018 | Contamination fraction of livestock water | 1.000E+00 | 1.000E+00 | --- | FLW |
| R018 | Contamination fraction of irrigation water | 1.000E+00 | 1.000E+00 | --- | FIRW |
| R018 | Contamination fraction of aquatic food | 5.000E-01 | 5.000E-01 | --- | FR9 |
| R018 | Contamination fraction of plant food | -1 | -1 | 0.500E+00 | FPLANT |
| R018 | Contamination fraction of meat | -1 | -1 | 0.198E+00 | FMEAT |
| R018 | Contamination fraction of milk | -1 | -1 | 0.198E+00 | FMILK |
| | | | | | |
| R019 | Livestock fodder intake for meat (kg/day) | 6.800E+01 | 6.800E+01 | --- | LFI5 |
| R019 | Livestock fodder intake for milk (kg/day) | 5.500E+01 | 5.500E+01 | --- | LFI6 |
| R019 | Livestock water intake for meat (L/day) | 5.000E+01 | 5.000E+01 | --- | LWI5 |
| R019 | Livestock water intake for milk (L/day) | 1.600E+02 | 1.600E+02 | --- | LWI6 |
| R019 | Livestock soil intake (kg/day) | 5.000E-01 | 5.000E-01 | --- | LSI |
| R019 | Mass loading for foliar deposition (g/m**3) | 1.000E-04 | 1.000E-04 | --- | MLFD |

Site-Specific Parameter Summary (continued)

| Menu | Parameter | User Input | Default | Used by RESRAD (If different from user input) | Parameter Name |
|---|---|---|---|---|---|
| R019 | Depth of soil mixing layer (m) | 1.500E-01 | 1.500E-01 | --- | DM |
| R019 | Depth of roots (m) | 1.400E+00 | 9.000E-01 | --- | DROOT |
| R019 | Drinking water fraction from ground water | 1.000E+00 | 1.000E+00 | --- | FGWDW |
| R019 | Household water fraction from ground water | not used | 1.000E+00 | --- | FGWHH |
| R019 | Livestock water fraction from ground water | 1.000E+00 | 1.000E+00 | --- | FGWLW |
| R019 | Irrigation fraction from ground water | 1.000E+00 | 1.000E+00 | --- | FGWIR |
| | | | | | |
| R19B | Wet weight crop yield for Non-Leafy (kg/m**2) | 7.000E-01 | 7.000E-01 | --- | YV(1) |
| R19B | Wet weight crop yield for Leafy (kg/m**2) | 1.500E+00 | 1.500E+00 | --- | YV(2) |
| R19B | Wet weight crop yield for Fodder (kg/m**2) | 1.100E+00 | 1.100E+00 | --- | YV(3) |
| R19B | Growing Season for Non-Leafy (years) | 1.700E-01 | 1.700E-01 | --- | TE(1) |
| R19B | Growing Season for Leafy (years) | 2.500E-01 | 2.500E-01 | --- | TE(2) |
| R19B | Growing Season for Fodder (years) | 8.000E-02 | 8.000E-02 | --- | TE(3) |
| R19B | Translocation Factor for Non-Leafy | 1.000E-01 | 1.000E-01 | --- | TIV(1) |
| R19B | Translocation Factor for Leafy | 1.000E+00 | 1.000E+00 | --- | TIV(2) |
| R19B | Translocation Factor for Fodder | 1.000E+00 | 1.000E+00 | --- | TIV(3) |
| R19B | Dry Foliar Interception Fraction for Non-Leafy | 2.500E-01 | 2.500E-01 | --- | RDRY(1) |
| R19B | Dry Foliar Interception Fraction for Leafy | 2.500E-01 | 2.500E-01 | --- | RDRY(2) |
| R19B | Dry Foliar Interception Fraction for Fodder | 2.500E-01 | 2.500E-01 | --- | RDRY(3) |
| R19B | Wet Foliar Interception Fraction for Non-Leafy | 2.500E-01 | 2.500E-01 | --- | RWET(1) |
| R19B | Wet Foliar Interception Fraction for Leafy | 2.500E-01 | 2.500E-01 | --- | RWET(2) |
| R19B | Wet Foliar Interception Fraction for Fodder | 2.500E-01 | 2.500E-01 | --- | RWET(3) |
| R19B | Weathering Removal Constant for Vegetation | 2.000E+01 | 2.000E+01 | --- | WLAM |
| | | | | | |
| C14 | C-12 concentration in water (g/cm**3) | not used | 2.000E-05 | --- | C12WTR |
| C14 | C-12 concentration in contaminated soil (g/g) | not used | 3.000E-02 | --- | C12CZ |
| C14 | Fraction of vegetation carbon from soil | not used | 2.000E-02 | --- | CSOIL |
| C14 | Fraction of vegetation carbon from air | not used | 9.800E-01 | --- | CAIR |
| C14 | C-14 evasion layer thickness in soil (m) | not used | 3.000E-01 | --- | DMC |
| C14 | C-14 evasion flux rate from soil (1/sec) | not used | 7.000E-07 | --- | EVSN |
| C14 | C-12 evasion flux rate from soil (1/sec) | not used | 1.000E-10 | --- | REVSN |
| C14 | Fraction of grain in beef cattle feed | not used | 8.000E-01 | --- | AVFG4 |
| C14 | Fraction of grain in milk cow feed | not used | 2.000E-01 | --- | AVFG5 |
| C14 | DCF correction factor for gaseous forms of C14 | not used | 8.894E+01 | --- | CO2F |
| | | | | | |
| STOR | Storage times of contaminated foodstuffs (days): | | | | |
| STOR | Fruits, non-leafy vegetables, and grain | 1.400E+01 | 1.400E+01 | --- | STOR_T(1) |
| STOR | Leafy vegetables | 1.000E+00 | 1.000E+00 | --- | STOR_T(2) |
| STOR | Milk | 1.000E+00 | 1.000E+00 | --- | STOR_T(3) |
| STOR | Meat and poultry | 2.000E+01 | 2.000E+01 | --- | STOR_T(4) |
| STOR | Fish | 7.000E+00 | 7.000E+00 | --- | STOR_T(5) |
| STOR | Crustacea and mollusks | 7.000E+00 | 7.000E+00 | --- | STOR_T(6) |
| STOR | Well water | 1.000E+00 | 1.000E+00 | --- | STOR_T(7) |
| STOR | Surface water | 1.000E+00 | 1.000E+00 | --- | STOR_T(8) |
| STOR | Livestock fodder | 4.500E+01 | 4.500E+01 | --- | STOR_T(9) |
| | | | | | |
| R021 | Thickness of building foundation (m) | not used | 1.500E-01 | --- | FLOOR1 |
| R021 | Bulk density of building foundation (g/cm**3) | not used | 2.400E+00 | --- | DENSFL |
| R021 | Total porosity of the cover material | not used | 4.000E-01 | --- | TPCV |
| R021 | Total porosity of the building foundation | not used | 1.000E-01 | --- | TPFL |
| R021 | Volumetric water content of the cover material | not used | 5.000E-02 | --- | PH2OCV |

Site-Specific Parameter Summary (continued)

| Menu | Parameter | User Input | Default | Used by RESRAD (If different from user input) | Parameter Name |
|---|---|---|---|---|---|
| R021 | Volumetric water content of the foundation | not used | 3.000E-02 | --- | PH2OFL |
| R021 | Diffusion coefficient for radon gas (m/sec): | | | | |
| R021 | in cover material | not used | 2.000E-06 | --- | DIFCV |
| R021 | in foundation material | not used | 3.000E-07 | --- | DIFFL |
| R021 | in contaminated zone soil | not used | 2.000E-06 | --- | DIFCZ |
| R021 | Radon vertical dimension of mixing (m) | not used | 2.000E+00 | --- | HMIX |
| R021 | Average building air exchange rate (1/hr) | not used | 5.000E-01 | --- | REXG |
| R021 | Height of the building (room) (m) | not used | 2.500E+00 | --- | HRM |
| R021 | Building interior area factor | not used | 0.000E+00 | --- | FAI |
| R021 | Building depth below ground surface (m) | not used | -1.000E+00 | --- | DMFL |
| R021 | Emanating power of Rn-222 gas | not used | 2.500E-01 | --- | EMANA(1) |
| R021 | Emanating power of Rn-220 gas | not used | 1.500E-01 | --- | EMANA(2) |
| | | | | | |
| TITL | Number of graphical time points | 32 | --- | --- | NPTS |
| TITL | Maximum number of integration points for dose | 17 | --- | --- | LYMAX |
| TITL | Maximum number of integration points for risk | 257 | --- | --- | KYMAX |

Summary of Pathway Selections

| Pathway | User Selection |
|---|---|
| 1 -- external gamma | active |
| 2 -- inhalation (w/o radon) | active |
| 3 -- plant ingestion | active |
| 4 -- meat ingestion | active |
| 5 -- milk ingestion | active |
| 6 -- aquatic foods | active |
| 7 -- drinking water | active |
| 8 -- soil ingestion | active |
| 9 -- radon | suppressed |
| Find peak pathway doses | active |

| Contaminated Zone Dimensions | | Initial Soil Concentrations, pCi/g | |
|---|---|---|---|
| Area: | 3965.00 square meters | Co-60 | 4.150E+00 |
| Thickness: | 3.71 meters | Cs-137 | 8.500E-01 |
| Cover Depth: | 1.22 meters | H-3 | 3.930E+01 |

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 2.500E+01 mrem/yr
Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)

| t (years): | 0.000E+00 | 1.000E+00 | 3.000E+00 | 1.000E+01 | 3.000E+01 | 5.000E+01 | 3.000E+02 | 1.000E+03 |
|---|---|---|---|---|---|---|---|---|
| TDOSE(t): | 2.348E-01 | 5.370E-01 | 2.122E+00 | 2.619E-01 | 1.777E-02 | 1.065E-02 | 6.606E-05 | 2.040E-11 |
| M(t): | 9.391E-03 | 2.148E-02 | 8.488E-02 | 1.048E-02 | 7.106E-04 | 4.262E-04 | 2.642E-06 | 8.161E-13 |

Maximum TDOSE(t): 2.485E+00 mrem/yr at t = 4.529 ± 0.009 years

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 4.529E+00 years

Water Independent Pathways (Inhalation excludes radon)

| Radio-Nuclide | Ground | | Inhalation | | Radon | | Plant | | Meat | | Milk | | Soil | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nuclide | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. |
| Co-60 | 1.238E-05 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 5.301E-02 | 0.0213 | 1.034E-02 | 0.0042 | 1.222E-03 | 0.0005 | 0.000E+00 | 0.0000 |
| Cs-137 | 4.404E-08 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.739E-02 | 0.0070 | 5.090E-03 | 0.0020 | 1.604E-03 | 0.0006 | 0.000E+00 | 0.0000 |
| H-3 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.010E-02 | 0.0041 | 6.004E-04 | 0.0002 | 5.212E-04 | 0.0002 | 0.000E+00 | 0.0000 |
| Total | 1.242E-05 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 8.050E-02 | 0.0324 | 1.603E-02 | 0.0065 | 3.347E-03 | 0.0013 | 0.000E+00 | 0.0000 |

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 4.529E+00 years

Water Dependent Pathways

| Radio-Nuclide | Water | | Fish | | Radon | | Plant | | Meat | | Milk | | All Pathways* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nuclide | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. |
| Co-60 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 6.458E-02 | 0.0260 |
| Cs-137 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.409E-02 | 0.0097 |
| H-3 | 2.106E+00 | 0.8476 | 5.152E-05 | 0.0000 | 0.000E+00 | 0.0000 | 2.023E-01 | 0.0814 | 1.994E-02 | 0.0080 | 5.657E-02 | 0.0228 | 2.396E+00 | 0.9643 |
| Total | 2.106E+00 | 0.8476 | 5.152E-05 | 0.0000 | 0.000E+00 | 0.0000 | 2.023E-01 | 0.0814 | 1.994E-02 | 0.0080 | 5.657E-02 | 0.0228 | 2.485E+00 | 1.0000 |

*Sum of all water independent and dependent pathways.

Summary : 3.71m Landfill Farm File: 02_3.71Fmr.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

| Radio- | Ground | | Inhalation | | Radon | | Plant | | Meat | | Milk | | Soil | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nuclide | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. |
| Co-60 | 2.130E-05 | 0.0001 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 9.384E-02 | 0.3997 | 1.831E-02 | 0.0780 | 2.163E-03 | 0.0092 | 0.000E+00 | 0.0000 |
| Cs-137 | 4.586E-08 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.885E-02 | 0.0803 | 5.515E-03 | 0.0235 | 1.738E-03 | 0.0074 | 0.000E+00 | 0.0000 |
| H-3 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 8.495E-02 | 0.3618 | 5.021E-03 | 0.0214 | 4.368E-03 | 0.0186 | 0.000E+00 | 0.0000 |
| Total | 2.135E-05 | 0.0001 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.976E-01 | 0.8418 | 2.884E-02 | 0.1229 | 8.268E-03 | 0.0352 | 0.000E+00 | 0.0000 |

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years

Water Dependent Pathways

| Radio- | Water | | Fish | | Radon | | Plant | | Meat | | Milk | | All Pathways* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nuclide | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. |
| Co-60 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.143E-01 | 0.4870 |
| Cs-137 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.610E-02 | 0.1112 |
| H-3 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 9.433E-02 | 0.4018 |
| Total | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.348E-01 | 1.0000 |

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

| Radio- | Ground | | Inhalation | | Radon | | Plant | | Meat | | Milk | | Soil | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nuclide | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. |
| Co-60 | 1.890E-05 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 8.273E-02 | 0.1540 | 1.614E-02 | 0.0301 | 1.907E-03 | 0.0036 | 0.000E+00 | 0.0000 |
| Cs-137 | 4.546E-08 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.852E-02 | 0.0345 | 5.418E-03 | 0.0101 | 1.707E-03 | 0.0032 | 0.000E+00 | 0.0000 |
| H-3 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 5.314E-02 | 0.0990 | 3.160E-03 | 0.0059 | 2.743E-03 | 0.0051 | 0.000E+00 | 0.0000 |
| Total | 1.894E-05 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.544E-01 | 0.2875 | 2.472E-02 | 0.0460 | 6.357E-03 | 0.0118 | 0.000E+00 | 0.0000 |

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Dependent Pathways

| Radio- | Water | | Fish | | Radon | | Plant | | Meat | | Milk | | All Pathways* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nuclide | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. |
| Co-60 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.008E-01 | 0.1877 |
| Cs-137 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.564E-02 | 0.0477 |
| H-3 | 3.136E-01 | 0.5839 | 7.347E-06 | 0.0000 | 0.000E+00 | 0.0000 | 2.747E-02 | 0.0512 | 2.341E-03 | 0.0044 | 8.158E-03 | 0.0152 | 4.106E-01 | 0.7646 |
| Total | 3.136E-01 | 0.5839 | 7.347E-06 | 0.0000 | 0.000E+00 | 0.0000 | 2.747E-02 | 0.0512 | 2.341E-03 | 0.0044 | 8.158E-03 | 0.0152 | 5.370E-01 | 1.0000 |

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

| Radio- | Ground | | Inhalation | | Radon | | Plant | | Meat | | Milk | | Soil | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nuclide | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. |
| Co-60 | 1.487E-05 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 6.428E-02 | 0.0303 | 1.254E-02 | 0.0059 | 1.482E-03 | 0.0007 | 0.000E+00 | 0.0000 |
| Cs-137 | 4.465E-08 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.787E-02 | 0.0084 | 5.230E-03 | 0.0025 | 1.648E-03 | 0.0008 | 0.000E+00 | 0.0000 |
| H-3 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.073E-02 | 0.0098 | 1.233E-03 | 0.0006 | 1.070E-03 | 0.0005 | 0.000E+00 | 0.0000 |
| Total | 1.491E-05 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.029E-01 | 0.0485 | 1.900E-02 | 0.0090 | 4.199E-03 | 0.0020 | 0.000E+00 | 0.0000 |

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years

Water Dependent Pathways

| Radio- | Water | | Fish | | Radon | | Plant | | Meat | | Milk | | All Pathways* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nuclide | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. |
| Co-60 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 7.832E-02 | 0.0369 |
| Cs-137 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.475E-02 | 0.0117 |
| H-3 | 1.764E+00 | 0.8313 | 4.300E-05 | 0.0000 | 0.000E+00 | 0.0000 | 1.682E-01 | 0.0793 | 1.639E-02 | 0.0077 | 4.726E-02 | 0.0223 | 2.019E+00 | 0.9514 |
| Total | 1.764E+00 | 0.8313 | 4.300E-05 | 0.0000 | 0.000E+00 | 0.0000 | 1.682E-01 | 0.0793 | 1.639E-02 | 0.0077 | 4.726E-02 | 0.0223 | 2.122E+00 | 1.0000 |

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

Water Independent Pathways (Inhalation excludes radon)

| Radio- | Ground | | Inhalation | | Radon | | Plant | | Meat | | Milk | | Soil | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nuclide | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. |
| Co-60 | 6.426E-06 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.657E-02 | 0.1014 | 5.183E-03 | 0.0198 | 6.123E-04 | 0.0023 | 0.000E+00 | 0.0000 |
| Cs-137 | 4.194E-08 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.577E-02 | 0.0602 | 4.616E-03 | 0.0176 | 1.454E-03 | 0.0056 | 0.000E+00 | 0.0000 |
| H-3 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 7.685E-04 | 0.0029 | 4.569E-05 | 0.0002 | 3.966E-05 | 0.0002 | 0.000E+00 | 0.0000 |
| Total | 6.468E-06 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 4.311E-02 | 0.1646 | 9.844E-03 | 0.0376 | 2.106E-03 | 0.0080 | 0.000E+00 | 0.0000 |

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

Water Dependent Pathways

| Radio- | Water | | Fish | | Radon | | Plant | | Meat | | Milk | | All Pathways* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nuclide | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. |
| Co-60 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 3.237E-02 | 0.1236 |
| Cs-137 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.184E-02 | 0.0834 |
| H-3 | 1.823E-01 | 0.6961 | 4.496E-06 | 0.0000 | 0.000E+00 | 0.0000 | 1.781E-02 | 0.0680 | 1.802E-03 | 0.0069 | 4.929E-03 | 0.0188 | 2.077E-01 | 0.7930 |
| Total | 1.823E-01 | 0.6961 | 4.496E-06 | 0.0000 | 0.000E+00 | 0.0000 | 1.781E-02 | 0.0680 | 1.802E-03 | 0.0069 | 4.929E-03 | 0.0188 | 2.619E-01 | 1.0000 |

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years

Water Independent Pathways (Inhalation excludes radon)

| Radio- | Ground | | Inhalation | | Radon | | Plant | | Meat | | Milk | | Soil | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nuclide | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. |
| Co-60 | 5.847E-07 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.112E-03 | 0.1189 | 4.121E-04 | 0.0232 | 4.868E-05 | 0.0027 | 0.000E+00 | 0.0000 |
| Cs-137 | 3.507E-08 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.096E-02 | 0.6169 | 3.207E-03 | 0.1805 | 1.011E-03 | 0.0569 | 0.000E+00 | 0.0000 |
| H-3 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 6.221E-08 | 0.0000 | 3.699E-09 | 0.0000 | 3.211E-09 | 0.0000 | 0.000E+00 | 0.0000 |
| Total | 6.198E-07 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.307E-02 | 0.7358 | 3.620E-03 | 0.2037 | 1.059E-03 | 0.0596 | 0.000E+00 | 0.0000 |

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years

Water Dependent Pathways

| Radio- | Water | | Fish | | Radon | | Plant | | Meat | | Milk | | All Pathways* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nuclide | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. |
| Co-60 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.573E-03 | 0.1448 |
| Cs-137 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.518E-02 | 0.8543 |
| H-3 | 1.339E-05 | 0.0008 | 3.301E-10 | 0.0000 | 0.000E+00 | 0.0000 | 1.307E-06 | 0.0001 | 1.323E-07 | 0.0000 | 3.619E-07 | 0.0000 | 1.526E-05 | 0.0009 |
| Total | 1.339E-05 | 0.0008 | 3.301E-10 | 0.0000 | 0.000E+00 | 0.0000 | 1.307E-06 | 0.0001 | 1.323E-07 | 0.0000 | 3.619E-07 | 0.0000 | 1.777E-02 | 1.0000 |

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 5.000E+01 years

Water Independent Pathways (Inhalation excludes radon)

| Radio- | Ground | | Inhalation | | Radon | | Plant | | Meat | | Milk | | Soil | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nuclide | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. |
| Co-60 | 5.321E-08 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.664E-04 | 0.0156 | 3.247E-05 | 0.0030 | 3.836E-06 | 0.0004 | 0.000E+00 | 0.0000 |
| Cs-137 | 2.933E-08 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 7.547E-03 | 0.7083 | 2.209E-03 | 0.2073 | 6.958E-04 | 0.0653 | 0.000E+00 | 0.0000 |
| H-3 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 4.991E-12 | 0.0000 | 2.968E-13 | 0.0000 | 2.576E-13 | 0.0000 | 0.000E+00 | 0.0000 |
| Total | 8.253E-08 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 7.713E-03 | 0.7240 | 2.241E-03 | 0.2104 | 6.997E-04 | 0.0657 | 0.000E+00 | 0.0000 |

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 5.000E+01 years

Water Dependent Pathways

| Radio- | Water | | Fish | | Radon | | Plant | | Meat | | Milk | | All Pathways* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nuclide | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. |
| Co-60 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.027E-04 | 0.0190 |
| Cs-137 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.045E-02 | 0.9810 |
| H-3 | 9.828E-10 | 0.0000 | 2.424E-14 | 0.0000 | 0.000E+00 | 0.0000 | 9.599E-11 | 0.0000 | 9.715E-12 | 0.0000 | 2.657E-11 | 0.0000 | 1.121E-09 | 0.0000 |
| Total | 9.828E-10 | 0.0000 | 2.424E-14 | 0.0000 | 0.000E+00 | 0.0000 | 9.599E-11 | 0.0000 | 9.715E-12 | 0.0000 | 2.657E-11 | 0.0000 | 1.065E-02 | 1.0000 |

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years

Water Independent Pathways (Inhalation excludes radon)

| Radio- | Ground | | Inhalation | | Radon | | Plant | | Meat | | Milk | | Soil | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nuclide | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. |
| Co-60 | 5.173E-21 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.790E-18 | 0.0000 | 3.493E-19 | 0.0000 | 4.127E-20 | 0.0000 | 0.000E+00 | 0.0000 |
| Cs-137 | 3.134E-09 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 4.769E-05 | 0.7220 | 1.396E-05 | 0.2114 | 4.399E-06 | 0.0666 | 0.000E+00 | 0.0000 |
| H-3 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Total | 3.134E-09 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 4.769E-05 | 0.7220 | 1.396E-05 | 0.2114 | 4.399E-06 | 0.0666 | 0.000E+00 | 0.0000 |

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years

Water Dependent Pathways

| Radio- | Water | | Fish | | Radon | | Plant | | Meat | | Milk | | All Pathways* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nuclide | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. |
| Co-60 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.186E-18 | 0.0000 |
| Cs-137 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 6.606E-05 | 1.0000 |
| H-3 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Total | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 6.606E-05 | 1.0000 |

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

Water Independent Pathways (Inhalation excludes radon)

| Radio- | Ground | | Inhalation | | Radon | | Plant | | Meat | | Milk | | Soil | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nuclide | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. |
| Co-60 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Cs-137 | 5.982E-12 | 0.2932 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.041E-11 | 0.5103 | 3.049E-12 | 0.1494 | 9.603E-13 | 0.0471 | 0.000E+00 | 0.0000 |
| H-3 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Total | 5.982E-12 | 0.2932 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 1.041E-11 | 0.5103 | 3.049E-12 | 0.1494 | 9.603E-13 | 0.0471 | 0.000E+00 | 0.0000 |

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

Water Dependent Pathways

| Radio- | Water | | Fish | | Radon | | Plant | | Meat | | Milk | | All Pathways* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nuclide | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. | mrem/yr | fract. |
| Co-60 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Cs-137 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.040E-11 | 1.0000 |
| H-3 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 |
| Total | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 0.000E+00 | 0.0000 | 2.040E-11 | 1.0000 |

*Sum of all water independent and dependent pathways.

Dose/Source Ratios Summed Over All Pathways
Parent and Progeny Principal Radionuclide Contributions Indicated

| Parent (i) | Product (j) | Branch Fraction* | DSR(j,t) (mrem/yr)/(pCi/g) t= 0.000E+00 | 1.000E+00 | 3.000E+00 | 1.000E+01 | 3.000E+01 | 5.000E+01 | 3.000E+02 | 1.000E+03 |
|---|---|---|---|---|---|---|---|---|---|---|
| Co-60 | Co-60 | 1.000E+00 | 2.755E-02 | 2.429E-02 | 1.887E-02 | 7.799E-03 | 6.201E-04 | 4.885E-05 | 5.266E-19 | 0.000E+00 |
| Cs-137 | Cs-137 | 1.000E+00 | 3.070E-02 | 3.017E-02 | 2.912E-02 | 2.570E-02 | 1.786E-02 | 1.230E-02 | 7.772E-05 | 2.400E-11 |
| H-3 | H-3 | 1.000E+00 | 2.400E-03 | 1.045E-02 | 5.137E-02 | 5.285E-03 | 3.882E-07 | 2.851E-11 | 0.000E+00 | 0.000E+00 |

*Branch Fraction is the cumulative factor for the j't principal radionuclide daughter: CUMBRF(j) = BRF(1)*BRF(2)* ... BRF(j).
The DSR includes contributions from associated (half-life ≤ 0.5 yr) daughters.

Single Radionuclide Soil Guidelines G(i,t) in pCi/g
Basic Radiation Dose Limit = 2.500E+01 mrem/yr

| Nuclide (i) | t= 0.000E+00 | 1.000E+00 | 3.000E+00 | 1.000E+01 | 3.000E+01 | 5.000E+01 | 3.000E+02 | 1.000E+03 |
|---|---|---|---|---|---|---|---|---|
| Co-60 | 9.074E+02 | 1.029E+03 | 1.325E+03 | 3.205E+03 | 4.032E+04 | 5.117E+05 | *1.131E+15 | *1.131E+15 |
| Cs-137 | 8.142E+02 | 8.288E+02 | 8.587E+02 | 9.729E+02 | 1.400E+03 | 2.033E+03 | 3.217E+05 | 1.042E+12 |
| H-3 | 1.042E+04 | 2.393E+03 | 4.866E+02 | 4.730E+03 | 6.440E+07 | 8.767E+11 | *9.594E+15 | *9.594E+15 |

*At specific activity limit

Summed Dose/Source Ratios DSR(i,t) in (mrem/yr)/(pCi/g)
and Single Radionuclide Soil Guidelines G(i,t) in pCi/g
at tmin = time of minimum single radionuclide soil guideline
and at tmax = time of maximum total dose = 4.529 ± 0.009 years

| Nuclide (i) | Initial (pCi/g) | tmin (years) | DSR(i,tmin) | G(i,tmin) (pCi/g) | DSR(i,tmax) | G(i,tmax) (pCi/g) |
|---|---|---|---|---|---|---|
| Co-60 | 4.150E+00 | 0.000E+00 | 2.755E-02 | 9.074E+02 | 1.556E-02 | 1.606E+03 |
| Cs-137 | 8.500E-01 | 0.000E+00 | 3.070E-02 | 8.142E+02 | 2.834E-02 | 8.823E+02 |
| H-3 | 3.930E+01 | 4.537 ± 0.009 | 6.096E-02 | 4.101E+02 | 6.097E-02 | 4.100E+02 |

Individual Nuclide Dose Summed Over All Pathways
Parent Nuclide and Branch Fraction Indicated

| Nuclide (j) | Parent (i) | BRF(i) | DOSE(j,t), mrem/yr t= 0.000E+00 | 1.000E+00 | 3.000E+00 | 1.000E+01 | 3.000E+01 | 5.000E+01 | 3.000E+02 | 1.000E+03 |
|---|---|---|---|---|---|---|---|---|---|---|
| Co-60 | Co-60 | 1.000E+00 | 1.143E-01 | 1.008E-01 | 7.832E-02 | 3.237E-02 | 2.573E-03 | 2.027E-04 | 2.186E-18 | 0.000E+00 |
| Cs-137 | Cs-137 | 1.000E+00 | 2.610E-02 | 2.564E-02 | 2.475E-02 | 2.184E-02 | 1.518E-02 | 1.045E-02 | 6.606E-05 | 2.040E-11 |
| H-3 | H-3 | 1.000E+00 | 9.433E-02 | 4.106E-01 | 2.019E+00 | 2.077E-01 | 1.526E-05 | 1.121E-09 | 0.000E+00 | 0.000E+00 |

BRF(i) is the branch fraction of the parent nuclide.

Individual Nuclide Soil Concentration
Parent Nuclide and Branch Fraction Indicated

| Nuclide (j) | Parent (i) | BRF(i) | S(j,t), pCi/g t= 0.000E+00 | 1.000E+00 | 3.000E+00 | 1.000E+01 | 3.000E+01 | 5.000E+01 | 3.000E+02 | 1.000E+03 |
|---|---|---|---|---|---|---|---|---|---|---|
| Co-60 | Co-60 | 1.000E+00 | 4.150E+00 | 3.638E+00 | 2.796E+00 | 1.113E+00 | 8.009E-02 | 5.762E-03 | 2.973E-17 | 0.000E+00 |
| Cs-137 | Cs-137 | 1.000E+00 | 8.500E-01 | 8.305E-01 | 7.929E-01 | 6.740E-01 | 4.239E-01 | 2.665E-01 | 8.080E-04 | 7.179E-11 |
| H-3 | H-3 | 1.000E+00 | 3.930E+01 | 2.441E+01 | 9.421E+00 | 3.364E-01 | 2.464E-05 | 1.805E-09 | 0.000E+00 | 0.000E+00 |

BRF(i) is the branch fraction of the parent nuclide.

RESCALC.EXE execution time = 0.89 seconds