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Design Calculation or Analysis Cover Sheet

Complete only applicable items.

1. QA: QA
2. Page 1

3. System	4. Document Identifier
Monitored Geologic Repository	000-00C-MGR0-00900-000-00E

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Preclosure Consequence Analyses

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7. Document Status Designation

☐ Preliminary ☒ Committed ☐ Confirmed ☐ Cancelled/Superseded

8. Notes/Comments

Revision D is a complete rewrite and reorganization of Sections; thus, no revision bars are used.

Revision D Authors: Kathryn L. Ashley – All but GENII computations and Appendix III.
Jorge Schulz – All but Appendix III and Appendix V.
Wesley Wu – Appendix III and Appendix V.
Checkers: Dale Dexheimer – All but Appendix III and Appendix V.
John Wang – Appendix III.
Richard Smith – Appendix V
Sen-Sung Tsai – Text.

Revision E changed pages:
1 to 8, 11 to 13, 24, 26, 32, 55, 56, 59, 73, 78, 80, 97, 98, 103, 111, 112, 124 to 127, 131 to 133, 135 to 137, 139, 140, 148 to 154, 156, II-14, III-18, III-26, X-4 to X-7, X-12, X-13, X-18 to X-23.

Revision E does not update the uncertainty analysis in Appendix III because the increase in crud inventory for normal releases results in an increase in the external dose, thus reducing the uncertainty; therefore, the results from revision D are conservative.
Revision E checkers: Dale Dexheimer – text and tables; Wesley Wu – spreadsheets and GENII files.

Attachments	Total Number of Pages
Appendix I. E-Mail from Michael Frank to Mark Wisenburg (Reference 2.2.3)	2
Appendix II. End States for Event Sequences	26
Appendix III. Uncertainty Study	30
Appendix IV. Off-Normal Event – Low-level Liquid Waste Spill	8
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Appendix VI. Summary of Doses For Event Using Representative Inputs	2
Appendix VII. Expected Quantities of Failed Commercial SNF	4
Appendix VIII. Fire Engulfing a TAD	4
Appendix IX. E-Mail From Michael Frank to Dale Dexheimer (Reference 2.2.4)	2
Appendix X. Listing of Electronic Files Contained in Appendix XI	40
Appendix XI. CD	2 and 1 CD

RECORD OF REVISIONS

9. No.	10. Reason For Revision	11. Total # of Pgs.	12. Last Pg. #	13. Originator (Print/Sign/Date)	14. Checker (Print/Sign/Date)	15. EGS (Print/Sign/Date)	16. Approved/Accepted (Print/Sign/Date)
	See Page 2 for a complete Record of Revisions						
00E	Incorporates CACN001 and CACN002, updates crud source term for normal operation releases and event sequences 2-01, 2-13, and 2-14, and addresses CR11843.	284	XI-2	Jorge Schulz [signature] 3/10/2008	Dale T. Dexheimer [signature] 3/10/08 Wesley Wu [signature] 3/10/08	Sen-Sung Tsai [signature] 3/10/2008	Mark Wisenburg [signature] 3/10/2008

DISCLAIMER

The calculations contained in this document were developed by Bechtel SAIC Company, LLC (BSC) and are intended solely for the use of BSC in its work for the Yucca Mountain Project.

RECORD OF REVISIONS							
9. No.	10. Reason For Revision	11. Total # of Pgs.	12. Last Pg. #	13. Originator (Print/Sign/Date)	14. Checker (Print/Sign/Date)	15. EGS (Print/Sign/Date)	16. Approved/Accepted (Print/Sign/Date)
00A	Initial Issue	108	C-	Sen-Sung Tsai	R. P. McDonnell J A. Ziegler	N/A	Dennis C. Richardson
00B	Complete revision. Updated source terms and dose calculations for naval spent nuclear fuel and Hanford high-level radioactive waste. Deleted failed fuel oxidation from the Category 1 event sequence list. Included worker dose calculations for the Fuel Handling Facility and the spent nuclear fuel aging system. Updated references and revised to incorporate CR 3207 comments.	112 pages and 1 CD	C-2 of C-2	Sen-Sung Tsai	Kathryn L. Ashley	N/A	Dennis C. Richardson
00C	Major revision to include bounding source terms for Category 1 event sequences, direct radiation doses for Category 1 and Category 2 event sequences. Added dose evaluation with dose conversion factors from ICRP Publications 68 and 72. Revised to include updated event sequences involving other source terms. Incorporates CR 4920 comments	171 pages and 2 CDs	H-3 of H-3	Dale T. Dexheimer R. P. McDonnell Sen-Sung Tsai	Kathryn L. Ashley Jorge Schulz	N/A	Mark Wisenburg
00D	Complete Rewrite	280	XI-2	Kathryn L. Ashley Jorge Schulz Wesley Wu	Dale T. Dexheimer John Wang Sen-Sung Tsai Richard I. Smith	Sen-Sung Tsai	Mark Wisenburg

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FIGURES

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ACRONYMS

AED	aerodynamic equivalent diameter
ARF	airborne release fraction
BWR	boiling water reactor
CDE	committed dose equivalent
CEDE	committed effective dose equivalent
CRCF	Canister Receipt and Closure Facility
DAW	dry active waste
DDE	deep dose equivalent
DOE	U.S. Department of Energy
DPC	dual-purpose canister
EDE	effective dose equivalent
EPRI	Electric Power Research Institute
ESD	event sequence diagram
FRAMES	Framework for Risk Analysis in Multimedia Environmental Systems
GROA	geologic repository operations area
HEPA	high-efficiency particulate air [filter]
HIC	high-integrity container
HLW	high-level radioactive waste
HS	Hanford Site
HVAC	heating, ventilation, and air-conditioning
ICRP	International Commission on Radiological Protection
IHF	Initial Handling Facility
INL	Idaho National Laboratory
LDE	lens dose equivalent
LHS	Latin Hypercube sampling
LLLW	low-level liquid waste
LLW	low-level radioactive waste
LLWF	Low-Level Waste Facility
LPF	leak path factor
MAR	material at risk
MTHM	metric ton of heavy metal
MTU	metric ton of uranium
NRC	U.S. Nuclear Regulatory Commission
PWR	pressurized water reactor
RF	respirable fraction
SDD	software design document
SDE	shallow dose equivalent

SFA	spent fuel assembly
SNF	spent nuclear fuel
SRS	Savannah River Site
SUM^3	Sensitivity/Uncertainty Multimedia Modeling Module
TAD	transportation, aging, and disposal
TEDE	total effective dose equivalent
TODE	total organ dose equivalent
WHF	Wet Handling Facility
WVDP	West Valley Demonstration Project

UNITS OF MEASURE

Ci	curie
cm	centimeter
cm^2	square centimeter
cm^3	cubic centimeter
ft	feet
g	gram
gpm	gallons per minute
GWd	gigawatt days
hr	hour
in.	inch
m	meter
m^2	square meter
m^3	cubic meter
mrem	millirem
MTHM	metric tons of heavy metal
MTU	metric ton uranium
rem	roentgen equivalent man
s	second
Sv	Sievert
yr	year
µCi	microcurie
µm	micrometer

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1 PURPOSE

The purpose of this calculation is to demonstrate that the preclosure performance objectives specified in 10 CFR 63.111(a) and 10 CFR 63.111(b) (Reference 2.2.1) have been met for the proposed design and operations in the geologic repository operations area (GROA) during normal operations and Category 1 event sequences, and following Category 2 event sequences. Category 1 event sequences are those natural and human-induced event sequences that are expected to occur one or more times before permanent closure of the repository. Category 2 event sequences are other event sequences that have at least one chance in 10,000 of occurring before permanent closure of the repository (10 CFR 63.2) (Reference 2.2.1). Event sequences that have less than one chance in 10,000 of occurring before permanent closure of the repository are designated as beyond Category 2 event sequences and are not analyzed for dose consequences.

Preclosure performance objectives are discussed in Section 4.3 and are summarized in Table 1.

Table 1. Performance Objectives for Normal Operations and Category 1 Event Sequences, and for Category 2 Event Sequences

Event Sequence Type	Category of Individual	GROA[a] Restricted Areas	Site (Preclosure Controlled Area)	General Environment (Unrestricted Area)	Offsite, but not within the General Environment (Unrestricted Area)
Aggregate of Normal Operation and Category 1 Event Sequence Dose	Public	—	100 mrem/yr[b,c,d]	15 mrem/yr[f,g] 2 mrem in any one hour[e]	100 mrem/yr[b,c,d] 2 mrem in any one hour[e]
	Radiation Worker[j,k]	5 rem/yr[b,c,h] 50 rem/yr to any organ 15 rem/yr lens of eye 50 rem/yr skin	See note l	See note l	See note l
Single Category 2 Event Sequence Dose	Public	—	—	5 rem/event[i] 50 rem/event to any organ 15 rem/event lens of eye 50 rem/event skin	5 rem/event[i] 50 rem/event to any organ 15 rem/event lens of eye 50 rem/event skin

NOTES: [a]Other areas of the site may be identified as Restricted Areas as required by operations. Doses received by all individuals in restricted areas are occupational doses.
[b]10 CFR 63.111(a)(1) (Reference 2.2.1).
[c]10 CFR 63.111(b)(1) (Reference 2.2.1).
[d]10 CFR 20.1301(a)(1) (Reference 2.2.2).
[e]10 CFR 20.1301(a)(2) (Reference 2.2.2).
[f]10 CFR 63.111(a)(2) (Reference 2.2.1).
[g]10 CFR 63.204 (Reference 2.2.1).
[h]10 CFR 20.1201 (Reference 2.2.2).
[i]10 CFR 63.111(b)(2) (Reference 2.2.1).
[j]Individual with assigned duties involving exposure to radiation or to radioactive material.
[k]Occupational doses are those received during the course of those assigned duties.
[l]If receiving an occupational dose (see note k above) at this location, the GROA Restricted Areas Occupational dose limits apply; otherwise, the individual is considered a member of the public.
GROA = geologic repository operations area

Radiological consequences can result from exposure to airborne releases of radionuclides and from direct exposure to radioactive materials. Two categories of individuals, or receptors, are relevant for the application of performance objectives and operational dose constraints: (1) radiation workers, who are individuals receiving occupational doses, and (2) members of the public. Individuals who are assigned duties at the repository that involve exposure to radiation and/or to radioactive material are categorized as radiation workers. Personnel employed at the repository but do not receive an occupational dose in the performance of their duties are categorized as members of the public, for example, construction workers. Individuals present at the site but not employed at the repository are also considered as members of the public for dose consideration.

The members of the public are further divided into three categories: (1) members of the public in the general environment, (2) members of the public offsite but not in the general environment, and (3) onsite members of the public.

The general environment is defined in 10 CFR 63.202 (Reference 2.2.1) as everywhere outside the Yucca Mountain site, the Nellis Air Force Range (Nevada Test and Training Range), and the Nevada Test Site (Figure 1). Therefore, the members of the public in the general environment may be residing to the west and south of the site boundary. Members of the public not in the general environment are located to the east and north of the site boundary.

This calculation determines the radiological consequence to the public from potential airborne releases during normal operations in surface and subsurface facilities and from Category 1 and Category 2 event sequences during the preclosure period. Radiological consequence to radiation and construction workers from direct radiation exposure and airborne releases during normal operations and Category 1 event sequences in surface and subsurface facilities are determined elsewhere, and presented in this calculation. The results of the worker dose calculations are summarized in this calculation and integrated with the results of the public dose calculations to show compliance with the performance objectives found in Table 1 (Section 7).

Airborne releases from normal surface repository operations are primarily from commercial spent nuclear fuel (SNF) radionuclides released during operations in the Wet Handling Facility (WHF) and contamination resuspension from canisters located on the aging pads. Subsurface releases from normal repository operations are from neutron activation of ventilated air and silica dust from host rock in the emplacement drifts and resuspension of waste package surface contamination. Potential surface and subsurface releases from normal operations are discussed in Section 4.4.1. Normal operations and event sequence categorization, and materials at risk (MAR) are discussed in Section 4.4. Public dose calculations are performed in Section 6.

Results of public and worker dose calculations for normal operational releases and Category 1 event sequences, as well as bounding Category 2 event sequences, are summarized in Sections 6.7 through 6.11, which include:

- Total effective dose equivalent (TEDE)
- The highest total organ dose equivalent (TODE)
- Shallow dose equivalent to skin (SDE)
- Lens dose equivalent (LDE).

The results of the worker dose calculations are used to perform worker dose aggregation in Section 6.9, as required by 10 CFR 63.111 (Reference 2.2.1). Aggregated dose results and compliance with performance objectives for both public and radiation workers are reported in Section 7.0.

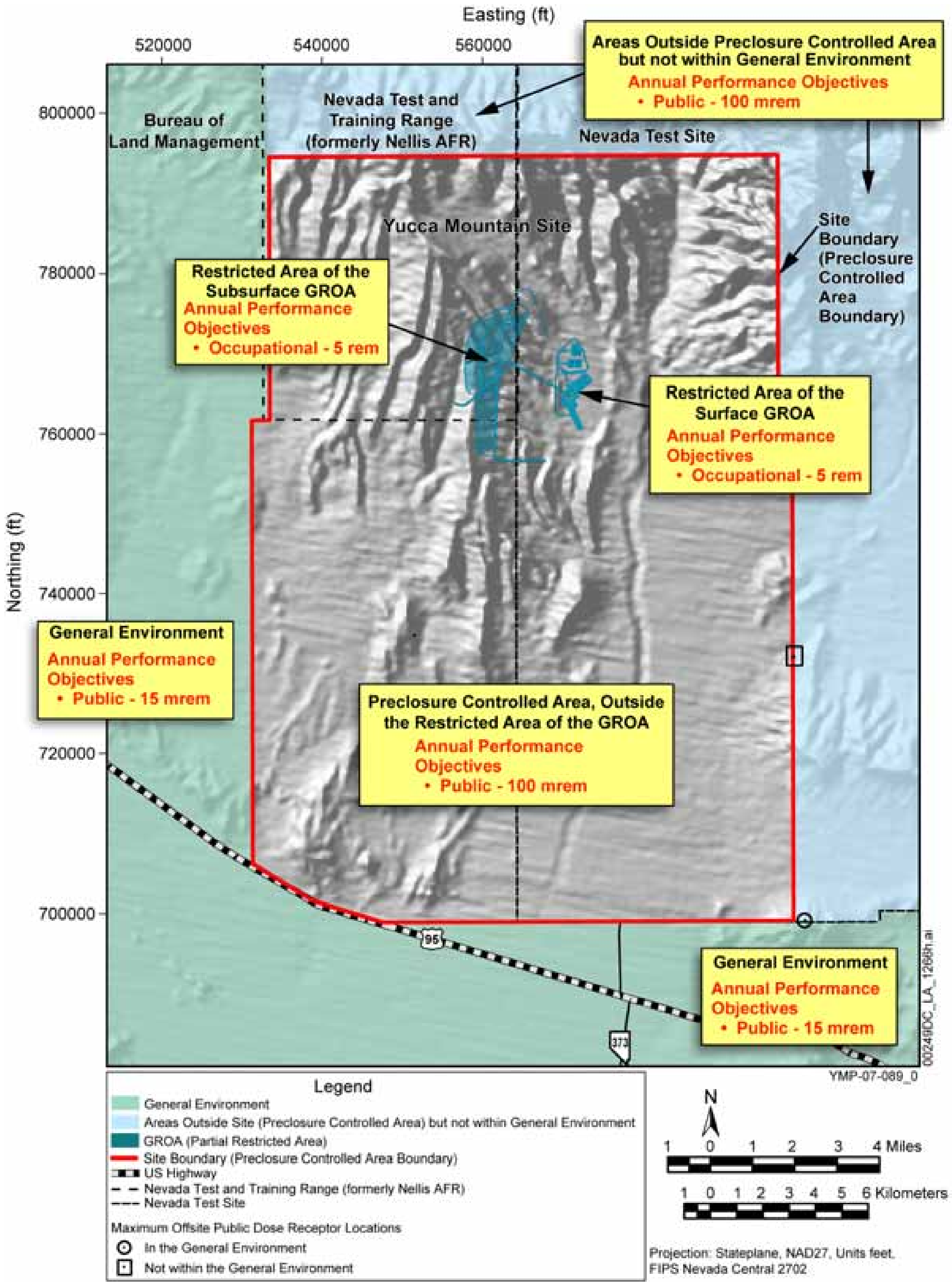

Figure 1. Performance Objectives for Normal Operations and Category 1 Event Sequences

2 REFERENCES

2.1 PROCEDURES/DIRECTIVES

2.1.1 BSC (Bechtel SAIC Company) 2007. *Quality Management Directive.* QA-DIR-10, Rev. 2. Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC. 20080103.0002.

2.1.2 EG-PRO-3DP-G04B-00037, Rev. 10. *Calculations and Analyses*. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071018.0001.

2.1.3 LS-PRO-0201, Rev. 5, *Preclosure Safety Analyses Process*. Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.20071010.0021.

2.1.4 PA-PRO-0301, Rev. 3. *Managing Technical Product Inputs*. Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.20070615.0003.

2.1.5 IT-PRO-0011, Rev. 7. *Software Management*. Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.20070905.0007.

2.2 DESIGN INPUTS

2.2.1 10 CFR 63. 2007. Energy: Disposal of High-Level Radioactive Wastes in a Geologic Repository at Yucca Mountain, Nevada. Internet Accessible. [DIRS 180319]

2.2.2 10 CFR 20. 2007. Energy: Standards for Protection Against Radiation. Internet Accessible. [DIRS 181962]

2.2.3 E-Mail from Michael Frank to Mark Wisenburg, *Preliminary Information on Event Sequence Diagrams and End States: Rev. 1. Please Disregard Previous Transmission*, 10/19/2007 12:58 (Presented in Appendix I).

2.2.4 E-Mail from Michael Frank to Dale Dexheimer, *Preliminary IHF Event Sequence results.* 01/11/2008 10:30 AM (Presented in Appendix IX).

2.2.5 BSC 2006. *Low-Level Waste Management Plan*. 000-30R-MW00-00100-000-000. Las Vegas, Nevada. Bechtel SAIC Company. ACC: ENG.20061218.0016.

2.2.6 Tooker, D.W. 2008. "Reference Information for Processing of the Spent Resin Material Generated in the Wet Handling Facility." Interoffice memorandum from D.W. Tooker (BSC) to Distribution, January 3, 2008, 0103082464. ACC: CCU.20080104.0002.

2.2.7 Tooker , D.W. 2008. "Reference Information for Processing of Pool Water Treatment System Spent Clean-Up Fliters and Spent Resin Generated in the Wet Handling Facility." Interoffice memorandum from D.W. Tooker (BSC) to Distribution, January 11, 2008, 0110082493. ACC: CCU.20080111.0011.

2.2.8 NRC (Nuclear Regulatory Commission) 2003. "Spent Fuel Project Office Interim Staff Guidance - 5, Revision 1. Confinement Evaluation." SFPO-ISG-5, Rev. 1. Washington, D.C.: U.S. Nuclear Regulatory Commission. Accessed January 24, 2003. ACC: MOL.20030124.0247. http://www.nrc.gov/reading-rm/doc-collections/isg/spent-fuel.html. [DIRS 160582]

2.2.9 NRC 2007. *Preclosure Safety Analysis - Dose Performance Objectives and Radiation Protection Program*. HLWRS-ISG-03. Washington, D.C.: Nuclear Regulatory Commission. Internet Accessible. [DIRS 182588]

2.2.10 BSC 2007. *Site-Specific Input Files for Use with GENII Version 2*. 000-00C-MGR0-02500-000-00A. Las Vegas, Nevada. Bechtel SAIC Company. ACC: ENG.20070328.0001.

2.2.11 Slade, D.H., ed. 1968. *Meteorology and Atomic Energy 1968*. TID-24190. Washington, D.C.: Air Resources Laboratories. TIC: 243832. [DIRS 107697]

2.2.12 GENII V2.05. 2007. Windows XP. STN: 11211-2.05-01. [DIRS 182388]

2.2.13 BSC 2007. *Shielding Requirements and Dose Rate Calculations for WHF and LLW*. 050-00C-WH00-00300-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071130.0017.

2.2.14 BSC 2007. *Basis of Design for the TAD Canister-Based Repository Design Concept*. 000-3DR-MGR0-00300-000-002. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG. 20080229.0007.

2.2.15 DOE (U.S. Department of Energy) 2007. *Software Validation Report for: GENII Version 2.05*. Document ID: 11211-SVR-2.05-02-WinXP. Las Vegas, Nevada: U.S. Department of Energy, Office of Repository Development. ACC: MOL.20071009.0112. [DIRS 183404]

2.2.16 40 CFR 191. 2006. Protection of Environment: Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes. Internet Accessible. [DIRS 182411]

2.2.17 NRC 2003. *Use of the Effective Dose Equivalent in Place of the Deep Dose Equivalent in Dose Assessments*. RIS 2003-04. Washington, D.C.: U.S. Nuclear Regulatory Commission. TIC: 254200. [DIRS 163018]

2.2.18 Napier, B.A. 2007. *GENII Version 2 Users' Guide*. PNNL-14583, Rev. 2. Richland, Washington: Pacific Northwest National Laboratory. ACC: MOL.20070314.0029. [DIRS 179907]

2.2.19 NRC 2000. *Standard Review Plan for Spent Fuel Dry Storage Facilities*. NUREG-1567. Washington, D.C.: U.S. Nuclear Regulatory Commission. TIC: 247929. [DIRS 149756]

2.2.20 Napier, B.A.; Strenge, D.L.; Ramsdell, J.V., Jr.; Eslinger, P.W.; and Fosmire, C. 2007. *GENII Version 2 Software Design Document*. PNNL-14584, Rev. 2. Richland, Washington: Pacific Northwest National Laboratory. ACC: MOL.20070314.0030. [DIRS 179908]

2.2.21 DOE 1994. *Analysis of Experimental Data*. Volume 1 of *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities*. DOE-HDBK-3010-94. Washington, DC: U.S. Department of Energy. TIC: 233366. [DIRS 103756]

2.2.22 BSC 2007. *Leak Path Factors for Radionuclide Releases from Breached Confinement Barriers and Confinement Areas*. 000-00C-MGR0-01500-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071018.0002.

2.2.23 BSC 2007. *General Public Atmospheric Dispersion Factors*. 000-00C-MGR0-02800-000-00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070813.0003.

2.2.24 BSC 2007. *GROA External Dose Rate Calculation*. 000-PSA-MGR0-01300-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071023.0003.

2.2.25 DOE 2004. *General Description of Database Information Version 5.0.1*. DOE/SNF/REP-094, Rev. 0. Idaho Falls, Idaho: U.S. Department of Energy, Idaho Operations Office. ACC: MOL.20040812.0117. [DIRS 171271]

2.2.26 BSC 2007. *Low-Level Waste Facility General Arrangement Ground Floor Plan*. 160-P10-LW00-00102-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070924.0026.

2.2.27 BSC 2006. *Dose Consequences from Site-Generated Low-Level Radioactive Waste*. 100-30R-WHS0-00700-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20060329.0017.

2.2.28 BSC 2007. *Site-Generated Low-Level Radioactive Waste Source Terms*. 000-PSA-LW00-00100-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070601.0021.

2.2.29 BSC 2007. *Wet Handling Facility and Low Level Waste Facility Worker Dose Assessment.* 050-00C-WH00-00200-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071017.0002.

2.2.30 BSC 2008. *WHF Solid Low-Level Waste Collection and Disposal.* 050-M0A-MWS0-00100-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080123.0024.

2.2.31 BSC 2007. *Characteristics for the Representative Commercial Spent Fuel Assembly for Preclosure Normal Operations*. 000-PSA-MGR0-00700-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070521.0008.

2.2.32 BSC 2007. *Release Fractions for Spent Nuclear Fuel and High-Level Waste*. 000-00C-MGR0-03400-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071105.0010.

2.2.33 BSC 2007. *Source Terms for HLW Glass Canisters*. 000-00C-MGR0-03500-000-00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080130.0002.

2.2.34 BSC 2005. *Normal Operation Airborne Release Calculation*. 000-HSC-WHS0-00200-000-00C. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20050615.0018; ENG.20050801.0007.

2.2.35 Baum, E.M.; Knox, H.D.; and Miller, T.R. 2002. *Nuclides and Isotopes*. 16th edition. [Schenectady, New York]: Knolls Atomic Power Laboratory. TIC: 255130. [DIRS 175238]

2.2.36 BSC 2007. *GROA Airborne Release Dose Calculation*. 000-PSA-MGR0-01200-000-00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071217.0023.

2.2.37 BSC 2004. *PWR Source Term Generation and Evaluation.* 000-00C-MGR0-00100-000-00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20040524.0007; ENG.20050815.0020; ENG.20050822.0006; ENG.20070905.0007.

2.2.38 BSC 2003. *BWR Source Term Generation and Evaluation.* 000-00C-MGR0-00200-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20030723.0001; ENG.20050815.0024.

2.2.39 BSC 2007. *GROA Worker Dose Calculation*. 000-PSA-MGR0-01400-000-00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071218.0027.

2.2.40 BSC 2007. *Geologic Repository Operations Area North Portal Site Plan*. 100-C00-MGR0-00501-000-00E. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071116.0004.

2.2.41 BSC 2007. *Aging Facility General Arrangement Aging Pad Area Plan*. 170-P10-AP00-00101-000-00C. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071126.0018.

2.2.42 Regulatory Guide 1.183. 2000. *Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors*. Washington, D.C.: U.S. Nuclear Regulatory Commission. ACC: MOL.20050518.0242. [DIRS 173584]

2.2.43 ICRP (International Commission on Radiological Protection) 1996. *Age-Dependent Doses to Members of the Public from Intake of Radionuclides: Part 5 Compilation of Ingestion and Inhalation Dose Coefficients*. Volume 26, No. 1 of Annals of the ICRP. Smith, H., ed. ICRP Publication 72. New York, New York: Pergamon Press. TIC: 235870. [DIRS 152446]

2.2.44 EPA (U.S. Environmental Protection Agency) 2000. *Cancer Risk Coefficients for Environmental Exposure to Radionuclides*. EPA 402-C-99-001. Federal Guidance Report No. 13. CD Supplement. [Washington, D.C.]: U.S. Environmental Protection Agency. TIC: 249372. [DIRS 153733]

2.2.45 ICRP 1991. "1990 Recommendations of the International Commission on Radiological Protection." Volume 21, No. 1-3 of *Annals of the ICRP*. ICRP Publication 60. New York, New York: Pergamon Press. TIC: 235864. [DIRS 101836]

2.2.46 BSC 2001. *Significant Radionuclides Determination*. CAL-WHS-SE-000002 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010905.0143. [DIRS 156955]

2.2.47 DOE 2004. *Source Term Estimates for DOE Spent Nuclear Fuels*. DOE/SNF/REP-078, Rev. 1. Three volumes. Idaho Falls, Idaho: U.S. Department of Energy, Idaho Operations Office. ACC: MOL.20040524.0451. [DIRS 169354]

2.2.48 BSC 2007. *Receipt Facility Worker Dose Assessment*. 200-00C-RF00-00100-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070730.0004.

2.2.49 Till, J.E. and Meyer, H.R. 1983. *Radiological Assessment, A Textbook on Environmental Dose Analysis*. NUREG/CR-3332. Washington, D.C.: U.S. Nuclear Regulatory Commission. ACC: NNA.19900212.0010 – NNA.19900212.0024. TIC: 223809. [DIRS 101895]

2.2.50 BSC 2006. *A Study of Uncertainty and Sensitivity Analysis Techniques for GENII Version 2*. 000-PSA-WHS0-00300-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20061129.0001.

2.2.51 Iman, R.L. and Conover, W.J. 1982. *Sensitivity Analysis Techniques: Self-Teaching Curriculum*. NUREG/CR-2350. Washington, D.C.: U.S. Nuclear Regulatory Commission. ACC: HQS.19880517.2724. [DIRS 165064]

2.2.52 Steel, R.G.D. and Torrie, J.H. 1980. *Principles and Procedures of Statistics: A Biometrical Approach.* 2nd Edition. New York, New York: McGraw Hill. TIC: 6322. [DIRS 150857]

2.2.53 SNL (Sandia National Laboratories) 2007. *Biosphere Model Report.* MDL-MGR-MD-000001 REV 02. Las Vegas, Nevada: Sandia National Laboratories. ACC: DOC.20070830.0007. [DIRS 177399]

2.2.54 Wing, James 1979. *Toxic Vapor Concentrations in the Control Room Following a Postulated Accidental Release*. NUREG-0570. Washington, DC: U.S. Nuclear Regulatory Commission. ACC: MOL.20071009.0058. [DIRS 183202]

2.2.55 ICRP (International Commission on Radiological Protection) 1995. *Dose Coefficients for Intakes of Radionuclides by Workers, Replacement of ICRP Publication 61*. Volume 24, No. 4 of *Annals of the ICRP*. ICRP Publication 68. Tarrytown, New York: Pergamon. TIC: 235867. [DIRS 172721]

2.2.56 ICRP 2001. *The ICRP Database of Dose Coefficients: Workers and Members of the Public*. ICRP Publications 68. [New York, New York]: Elsevier. TIC: 255638. [DIRS 172979]

2.2.57 BSC 2007. *Shielding Requirements and Dose Rate Calculations for WHF and LLW.* 050-00C-WH00-00300-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20030723.0001; ENG.20071130.0017.

2.2.58 BSC 2007. *Low-Level Waste Facility General Arrangement Sections A, B, & C*. 160-P10-LW00-00105-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070924.0029.

2.2.59 NRC (U.S. Nuclear Regulatory Commission) 2002. *Interim Staff Guidance 1. Damaged Fuel.* ISG-1, Rev. 1. Washington, D.C.: U.S. Nuclear Regulatory Commission. ACC: MOL.20061121.0044. [DIRS 164018]

2.2.60 EIA (Energy Information Administration) 2004. "Spent Nuclear Fuel Data, Detailed United States as of December 31, 2002." [Washington, D.C.]: U.S. Department of Energy, Energy Information Administration. Accessed March 8, 2005. ACC: MOL.20050306.0374.
URL: http://www.eia.doe.gov/cneaf/nuclear/spent_fuel/ussnfdata.html [DIRS 172860]

2.2.61 Bailey, W.J. and Wu, S. 1990. *Fuel Performance Annual Report for 1988.* NUREG/CR-3950. Washington, D.C.: U.S. Nuclear Regulatory Commission. TIC: 245644. [DIRS 109192]

2.2.62 Potts, G.A. and Proebstle, R.A. 1994. "Recent GE BWR Fuel Experience." *Proceedings of the 1994 International Topical Meeting on Light Water Reactor Fuel Performance, West Palm Beach, Florida, April 17-21, 1994.* Pages 87-95. La Grange Park, Illinois: American Nuclear Society. TIC: 243043. [DIRS 107774]

2.2.63 Yang, R.L. 1997. "Meeting the Challenge of Managing Nuclear Fuel in a Competitive Environment." *Proceedings of the 1997 International Topical Meeting on LWR Fuel Performance, Portland, Oregon, March 2-6, 1997.* Pages 3-10. La Grange Park, Illinois: American Nuclear Society. TIC: 232556. [DIRS 102049]

2.2.64 Yang, R; Ozer, O.; Edsinger, K.; Cheng, B.; and Deshon, J. 2004. "An Integrated Approach to Maximizing Fuel Reliability." *2004 International Meeting on LWR Fuel Performance, Orlando, Florida, September 19-22, 2004. Paper 1119,* 11-17. La Grange Park, Illinois: American Nuclear Society. TIC: 256786. [DIRS 172866]

2.2.65 Yang, R.L.; Ozer, O.; and Klepfer, H.H. 1991. *Fuel Performance Evaluation for EPRI Program Planning.* Volume 1 of *International Topical Meeting on LWR Fuel Performance, Avignon (France), April 21-24, 1991, Proceedings, Fuel for the 90's.* Pages 258-271. La Grange Park, Illinois: American Nuclear Society. TIC: 243519. [DIRS 125302]

2.2.66 McDonald, S.G. and Kaiser, R.S. 1985. "The Impact of Metallic Debris on Fuel Performance - A Case History." *Proceedings, American Nuclear Society Topical Meeting on Light Water Reactor Fuel Performance, Orlando, Florida, April 21-24, 1985.* DOE/NE/34130-1. Volume 1. La Grange Park, Illinois: American Nuclear Society. TIC: 226810. [DIRS 101725]

2.2.67 EPRI (Electric Power Research Institute) 1997. *The Technical Basis for the Classification of Failed Fuel in the Back-End of the Fuel Cycle.* EPRI TR-108237. Palo Alto, California: Electric Power Research Institute. TIC: 236839. [DIRS 100444]

2.2.68 DOE (U.S. Department of Energy) 2007. *Transportation, Aging and Disposal Canister System Performance Specification.* WMO-TADCS-000001, Rev. 0. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: DOC.20070614.0007. [DIRS 181403]

2.2.69 Sprung, J.L.; Ammerman, D.J.; Breivik, N.L.; Dukart, R.J.; Kanipe, F.L.; Koski, J.A.; Mills, G.S.; Neuhauser, K.S.; Radloff, H.D.; Weiner, R.F.; and Yoshimura, H.R. 2000. *Reexamination of Spent Fuel Shipment Risk Estimates.* NUREG/CR-6672. Two volumes. Washington, D.C.: U.S. Nuclear Regulatory Commission. ACC: MOL.20001010.0217. [DIRS 152476]

2.3 DESIGN CONSTRAINTS

There are no design constraints.

2.4 DESIGN OUTPUTS

This calculation does not support a specific engineering drawing, specification, or design list.

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3 ASSUMPTIONS

3.1 ASSUMPTIONS REQUIRING VERIFICATION

3.1.1 Event Sequences

The event sequence categorization process is performed and documented by facility and separately for seismic initiating events. Facilities include the Initial Handling Facility (IHF), Canister Receipt and Closure Facility (CRCF), Receipt Facility (RF), Wet Handling Facility (WHF), Intra-site Operation (which include the Aging Facility and the Low-level Waste Facility) and Balance of Plant facilities, and Subsurface Operations facilities. Phase one of the process is a qualitative analysis by facility to identify and develop potential event sequences. Phase two is a quantitative analysis of event sequences for the purpose of categorization in accordance with the definitions of Category 1 and Category 2 event sequences.

The first phase includes the development of master logic diagrams, event sequence diagrams (ESD) and event trees. For each facility, the preliminary end states of the event trees and the material involved in the event are provided by Reference 2.2.3 and identified in Appendix II. The end states exclude any end states associated with seismic event sequences.

Reference 2.2.3 also provides preliminary expectations concerning the end states, which include:

- No Category 1 event sequences are expected
- A breach of canister confinement following a fire event is expected to be a beyond Category 2 event
- Event sequences resulting in direct exposure are expected to be Category 2 or beyond Category 2 events
- Event sequences involving the breach of canister confinement involving DOE SNF are expected to be beyond Category 2 events
- A breach of a waste package due to event sequences involving Subsurface emplacement operations are expected to be categorized as beyond Category 2
- Airborne radionuclides released as a result of Category 2 event sequences are expected to be released to the environment through high-efficiency particulate air (HEPA) filters, with the exception of releases from events that occur in the IHF or the Low-Level Waste Facility (LLWF) and seismic events. The Category 2 event sequences in the IHF can affect high-level waste (HLW) glass.

In addition, Reference 2.2.4 indicates that event sequences involving the breach of a naval SNF canister are beyond Category 2 events.

Rationale: The referenced E-mails provide preliminary categorization of event sequences. This is the best available information and is suitable for use in this calculation.

3.1.2 Low-Level Waste Management

The management of low-level waste (LLW) generated by the surface facilities is evolving. An initial study (Reference 2.2.5) estimated the amount of LLW that will be generated at each facility and the requirements for handling this waste. Subsequently, as discussed in References 2.2.6 and 2.2.7, the following changes to the LLW waste management have been initiated:

- Spent resins generated at the WHF will be received, de-watered into a high-integrity container (HIC) that may be subsequently transported to an approved disposal location or to the LLWF. It is expected that one HIC will be required annually to dispose of the spent resins (Reference 2.2.7).

- Spent fuel pool filters will be placed in a HIC at the WHF and transported to the LLWF when the HIC is full. It is expected that three HICs will be required annually to dispose of the pool filters (Reference 2.2.7).

Rationale: The referenced Interoffice Memoranda provide preliminary LLW management information. This is the best available information and is suitable for use in this calculation.

3.2 ASSUMPTIONS NOT REQUIRING VERIFICATION

3.2.1 Damage Ratio

The damage ratio is the fraction of the material at risk (MAR) actually affected by a normal operation process or an event sequence. For normal operations involving commercial SNF and event sequences involving commercial SNF but not resulting in cladding damage, the damage ratio is equal to the fuel rod breakage percentage of 1%. Thus, the damage ratio is 0.01. Because crud releases can occur from all fuel rods, not just those with rod damage, the damage ratio for crud is 1.0.

For Category 1 and 2 event sequences resulting in cladding damage, such as drops or collisions, it is assumed that 100% of the MAR involved in the event is affected. Therefore, the damage ratio is 1.0 for these Category 1 and 2 event sequences.

Rationale: The 1% fuel rod breakage percentage is from Interim Safety Guide-5 (Reference 2.2.8, Attachment, p. 7) for normal operations and is applied to event sequences involving commercial SNF but not resulting in cladding damage. This value bounds the failed fuel experience of the nuclear industry as discussed in Appendix VII. For event sequences, it is bounding to assume that all of the material involved in the event is affected by that event.

3.2.2 Drop Event/Burst Release Duration of Exposure

Following a waste form drop event and cladding burst release, the radionuclides are assumed to be released in a one hour period and the receptor is exposed to the plume for the entire one hour period.

Rationale: This is a modeling assumption that exposes the receptor to the entire released source term. Equation 2 and Equation 6, discussed in Section 4.3.1, show that the source term is released over a duration period (Δt) and then multiplied by the exposure period (T). Thus, regardless of the duration of the release and plume passage, the receptor is exposed to the same source term. Assuming a short release and exposure duration minimizes the radioactive decay and thus maximizes the dose.

3.2.3 Category 2 Event Sequence Duration of Exposure

It is conservatively assumed that the exposure time following a Category 2 event sequence is the duration of the event up to a maximum of 30 days. For purposes of determining the fraction of fuel oxidized after an event sequence, it is assumed that oxidation begins immediately following the event and continues for the entire 30 days (720 hours) after the event.

Rationale: If a canister containing commercial SNF is breached as a result of a Category 2 event sequence, spent fuel can be exposed to air and, if the cladding has failed, begin to oxidize. It is conservatively assumed that fuel oxidation begins immediately and continues unabated for 30 days, although recovery actions can realistically be taken much quicker to limit oxidation (e.g., cooling, confinement, etc.) and small cladding defects could restrict the availability of oxygen, thereby limiting the progress of the oxidation process. A 30-day exposure time is consistent with guidance provided in HLWRS-ISG-03, *Preclosure Safety Analysis – Dose Performance Objectives and Radiation Protection Program* (Reference 2.2.9, p. 4).

3.2.4 Category 1 Event Sequence Duration of Exposure

The exposure time following a Category 1 event sequence is the duration of the event for air submersion and inhalation dose pathways and one year for ground shine, ingestion, and resuspension inhalation dose pathways.

Rationale: Category 1 event sequences are considered terminated when elevated exposure conditions to persons have ended (e.g., by evacuation of personnel or physical mitigation), and when the affected systems are no longer reasonably vulnerable to additional failure progression or additional failures related to the event sequence (Reference 2.2.9, p. 3). Air submersion and inhalation in the plume can only occur during the period of time that the release occurs. Exposures to ground shine, ingestion, and resuspension inhalation may continue following the event. It is conservative to assume that the duration for these pathways is one year following the event.

3.2.5 Normal Operations Duration of Exposure

For normal operations, the offsite public in the general environment is assumed to receive doses from the inhalation, resuspension inhalation, air submersion, groundshine, and ingestion pathways for a period of 365 days per year. Both the offsite public not in the general environment and the onsite public and workers are assumed to receive doses from inhalation, resuspension inhalation, air submersion, and groundshine pathways for a period of 250 days per year.

Rationale: For offsite public in the general environment, it is bounding to assume a continuous full-time residential occupancy of 365 days per year. Because no one can live onsite, or offsite not in the general environment (i.e. in the Nevada Test Site or in the Nevada Test and Training

Range), a normal work year of 8 hours per day for 50 weeks, which is equivalent to 250 days, is appropriate (Reference 2.2.10, Section 7.5.2).

3.2.6 Facility Leak Path Factor

For normal operations and event sequences, the facility leak path factor $(LPF)_{fac}$ is 1.0. The LPF is the fraction of airborne MAR that leaves a confinement barrier after the action of depletion mechanisms such as precipitation, gravitational settling of the released particulate material, filtration, or agglomeration, through the confinement barrier. The $(LPF)_{fac}$ is the fraction of the airborne MAR that reaches the ventilation system after local deposition, consisting of plate-out and gravitational settling.

Rationale: A LPF of 1.0 means that all of the airborne MAR reaches the ventilation system or is released to the environment. This is a bounding assumption because no credit is taken for local deposition of particulates within a surface facility or deposition on heating, ventilation and air-conditioning (HVAC) ducting.

3.2.7 Commercial Spent Nuclear Fuel Cladding Leak Path Factor

For normal operations and event sequences, the commercial SNF cladding $(LPF)_{clad}$ is 1.0. The $(LPF)_{clad}$ is the fraction of the airborne MAR that is released from the fuel cladding.

Rationale: A LPF of 1.0 means that all of the airborne MAR available for release is released. This is a bounding assumption because no credit is taken for agglomeration of particulates or holdup within the cladding as the particulates and fuel fines are released.

3.2.8 Respirable Fractions Following High-Efficiency Particulate Air Filtration

All particles that pass through HEPA filters are of respirable size. Therefore, for airborne releases that are released through HEPA filtration, the respirable fraction is 1.0.

Rationale: This is a bounding assumption that accounts for the reduction in average particle size following HEPA filtration.

3.2.9 Particle Size Distribution for Public Dose Calculations

Only the respirable fraction (RF), particles less than 10 μm aerodynamic equivalent diameter (AED), of the total airborne released radionuclides is considered for doses to the offsite public.

Rationale: Only particles less than 10 μm AED are considered for offsite atmospheric dispersion because the nearest members of the offsite public are located at distances greater than 6 km (Reference 2.2.23 Tables 7 and 9) from the release point that these larger particles have settled out before reaching them. Particles greater than 10 μm AED have much larger settling and deposition velocities than particles less than 10 μm. The deposition velocities of particles larger than 0.5 μm AED are determined by their gravitational settling velocity, v_g, which is directly proportional to the square of the particle diameter (Reference 2.2.11, Equation 5.36). Thus, a particle of 100 μm AED has a settling velocity 100 times that of a particle of 10 μm AED. With their larger settling velocity, larger particles deposit on the ground surface within a relatively short distance from the release location and are depleted from the atmosphere much faster than smaller particles.

The depletion of a release can be quantified by its depletion fraction that is the ratio of its depleted concentration at a down wind distance to its initial concentration. The relationship between depletion fractions at two different settling velocities at the same distance and same atmospheric condition is provided in *Meteorology and Atomic Energy 1968* (Reference 2.2.11, Equation 5.49). Applying that relationship to the site boundary distances, the depletion fraction, and therefore concentration, of particles of 100 μm AED are orders of magnitude less than those for particles of 10 μm AED. Therefore, larger particles are not significant offsite public dose contributors and can be excluded without a loss of conservatism.

The fraction of total airborne particles released that are less than 10 μm AED is equal to the respirable fraction. Therefore, the respirable fraction (particles less than 10 μm AED) of the total airborne release of radionuclides is applied to offsite public dose calculations with unfiltered releases.

This assumption applies only to releases that are not filtered by HEPA filters. As discussed in Assumption 3.2.8, all HEPA filtered releases are respirable.

3.2.10 Use of Mean Values for Intake Parameters and Exposure Times

Mean values for ingestion pathway consumption rates are used for normal operational releases, Category 1 event sequences, and Category 2 event sequences. Mean values for exposure times are used for normal operational releases and Category 1 event sequences.

Rationale: HLWRS-ISG-03, Reference 2.2.9 (p. 4) states:

> "For determining doses to real members of the public, beyond the boundary of the site, during normal operations, and for Category 1 event sequences, DOE should consider appropriate weather parameters, deposition factors, exposure pathways, and assumed exposure times, taking into account the uncertainties and limitations associated with models and data. Locations of a real member of the public should be based on specified geographical locations, the estimated time individual spent near the GROA facility, the distance the real individual is from the GROA, and/or other realistic factors that may affect radiological exposures. For Category 2 event sequences, doses to a real member located at or beyond the boundary of the site, DOE may conservatively calculate the doses using an exposure time of 30 days. However, DOE may justify a more realistic accident-exposure time, based on the site demographics, emergency planning, and/or the timing and exposure pathways of the actual Category 2 event sequence."

Therefore, realistic values, i.e., mean values, for these parameters are appropriate to determine compliance with the performance objectives presented in Table 1. A detailed uncertainty analysis is presented in Appendix III accounting for the uncertainties and limitations associated with the models and the data used.

3.2.11 Ingestion Doses

Offsite members of the public in the general environment receive a dose due to the ingestion of contaminated food and soil. Onsite radiation workers, onsite members of the public, and offsite members of the public not in the general environment do not receive a dose through the ingestion pathway.

Rationale: Radionuclides from an airborne release are depleted as the plume travels and is dispersed. The radionuclides are deposited on the soil, and on the vegetation, which can then be ingested by animals and people. Ground vegetation can also absorb the radionuclides from the soil and water as it grows, after which animals and people may ingest it. The ingestion dose is calculated from this ingestion intake of food crops and animal products containing nuclide concentrations as a result of an airborne release. No ingestion of contaminated food is expected for onsite radiation workers, onsite members of the public and offsite members of the public not in the general environment. Thus, ingestion dose is only calculated for offsite public in the general environment.

3.2.12 Bounding Fire Event Sequence

The bounding Category 2 fire event consists of a fire in the LLWF that consumes the entire combustible LLW inventory in the LLWF and damages the HEPA filters staged in B-25 boxes.

Rationale: The LLWF inventory includes combustible dry active waste (DAW) in bags and drums; WHF pool filters in HICs; WHF spent resins in HICs; and non-combustible waste including empty dual-purpose canisters (DPCs); the contents of the liquid waste collection tanks, and HEPA filters in B-25 boxes. Including the entire combustible inventory in the fire is conservative. It is unlikely that an actual fire could consume all the combustible material because (1) some of it is in non-flammable containers, (2) internal walls and building structure may prevent the spread of the fire to some of the waste, and (3) some waste containers may be stored in such a way that enough oxygen to support combustion cannot reach all of the containers.

3.2.13 Breathing Rates for Onsite Public and Public not in the General Environment

The breathing rate for the onsite public and the public located beyond the site boundary but not in the general environment, which is the acute breathing rate determined in Reference 2.2.10 and shown in Table 16, is used for normal releases and Category 1 and Category 2 event sequences.

Rationale: Because no one can live onsite or offsite not in the general environment (i.e. in the Nevada Test Site or in the Nevada Test and Training Range) individuals in these locations are workers or visitors that are performing various activities. Therefore, it is appropriate to use the higher breathing rate considered for the calculation of doses from acute releases.

3.2.14 Fraction of a Day Outdoor Inhalation and Air Submersion Occurs for Event Sequences

For evaluating event sequence dose consequences involving inhalation and air submersion, the fraction of the day that outdoor inhalation and air submersion occurs is 1.0.

Rationale: The exposure period applies to inhalation and outdoor air submersion. Thus, it is bounding to have an individual spend the entire exposure period outdoors because it maximizes the exposure to contaminated outdoor air.

3.2.15 Fall Season for Event Sequence Release Timing

In modeling the dose consequences from an event sequence, a fall season event is assumed and the input to the GENII model (Section 4.3.3) is September 1, at 0 hour.

Rationale: Ingestion exposure pathways include local farm products, local animal products, and inadvertent soil intake. As the radioactive plume passes, radionuclides deposit on the ground and directly contaminate soil and vegetation. Vegetation can also become contaminated indirectly by uptake of radionuclides from the soil during the growing season, during which radioactive decay occurs. The Category 2 event sequence exposure time is 30 days (Assumption 3.2.3), which is shorter than the growing season for most farm produce. A fall season event is modeled in the GENII code (Reference 2.2.12) because it occurs immediately before the harvest of the farm produce contaminated by the plume passage. This modeling approach yields the shortest time for radioactive decay, which maximizes the amount of radioactive material available for ingestion and thereby results in the highest calculated ingestion dose. Thus, this assumption is conservative.

3.2.16 HEPA Filter Replacement Schedule

It is assumed that the HEPA filters are replaced every 18 months.

Rationale: Radionuclide buildup occurs on the HEPA filters in the WHF during normal operations. Reference 2.2.13, Sections 3.1.9 and 6.1.6.7 gives a replacement schedule of 10 months in order to maintain the filters as Class C low-level waste. By assuming that the filters are replaced on an 18-month schedule, additional filter loading occurs resulting in higher concentrations of radionuclides and higher doses from accidents involving these filters.

3.3 ASSUMPTIONS NOT REQUIRING VERIFICATION THAT RESULT IN DESIGN OR OPERATIONAL REQUIREMENTS

3.3.1 Maximum Annual Receipt Rate

The nominal annual receipt rate of commercial SNF and HLW of 3,000 metric tons of heavy metal (MTHM) (Reference 2.2.14, Section 2.2.1.2) is conservatively increased by a factor of 20%.

Rationale: For the purposes of this calculation a maximum annual receipt rate of 3,600 MTHM of commercial SNF provides additional margin in the calculation of doses from normal operation releases. Therefore, this is a conservative assumption.

3.3.2 Primary Confinement Ventilation and Filtration Availability

The ventilation system and HEPA filters for all facilities except the IHF and Subsurface must be available for the duration of the event (30 days for Category 2 event sequences).

Rationale: The doses calculated in Sections 6.6 and 6.8 are based on HEPA filtration for the duration of the event. Per Assumption 3.2.3 the exposure duration for Category 2 event sequences is 30 days; therefore, the ventilation system and HEPA filtration must be available for at least 30 days from the onset of the event.

3.3.3 Doses to Onsite Public and Workers from Ground Contamination

Doses to onsite public and workers from ground contamination are not considered.

Rationale: The surface and subsurface facilities are under the control of the licensee and are monitored for potential radiation contamination. If elevated radiation levels are found, appropriate remedial steps will be taken to reduce the radiation levels.

4 METHODOLOGY

4.1 QUALITY ASSURANCE

This calculation is subject to the Quality Management Directive (Reference 2.1.1), because it pertains to preclosure safety analysis. This calculation was performed in accordance with procedures EG-PRO-3DP-G04B-00037, *Calculations and Analyses* (Reference 2.1.2), LS-PRO-0201, *Preclosure Safety Analyses Process* (Reference 2.1.3), and PA-PRO-0301, *Managing Technical Product Inputs* (Reference 2.1.4). Therefore, the approved version is designated as QA:QA.

4.2 USE OF SOFTWARE

4.2.1 Qualified Software

Qualified (Level 1) software (GENII computer code (Reference 2.2.12)) was used to calculate public doses for normal operations and Category 1 and Category 2 event sequences:

Program Name: GENII
Version/Revision Number: Version 2.05
Status/Operating System: Qualified/Windows XP
Software Tracking Number: 11211-2.05-01
Computer Type: Dell Optiplex GX620
Central Processing Unit Number: YMP004480, YMP004489, YMP004490, and YMP004475.

The input and output files for the various GENII calculations are contained on a compact disc (Appendix XI) with the files documented in Appendix X.

The GENII software was used only within the range of validation as documented in Reference 2.2.15. The software was obtained from Software Configuration Management in accordance with IT-PRO-0011, Software Management (Reference 2.1.5).

The GENII test cases were run and the output files were compared to the files provided with the code package. The results of this comparison are available in files *testcompare.txt* for each of the computers used and provided in Appendix XI.

4.2.2 Commercial Off-the Shelf Software

Microsoft® Excel software was used for performing calculations. The use of Microsoft® Excel 2003 is classified as Level 2 usage per procedure IT-PRO-0011, *Software Management* (Reference 2.1.5, Attachment 12) and is not required to be qualified. It is listed in the current *Globally Registered Controlled Software for Level 2 Usage*. Details of the software are given below:

Title: Excel
Version/Revision Number: Microsoft® Excel 2003, SP2 or SP3
This version is installed on Dell Optiplex GX620 and 745 personal computers running Microsoft® Windows XT with CPU numbers YMP004480 and YMP005050, respectively.

User-defined formulas, inputs, and results are documented in sufficient detail in Sections 4 and 6 to allow an independent checker to reproduce or verify the results without recourse to the originator. This information was verified by checks using hand calculations.

The Excel files used to perform the calculations are included in Appendix XI (Appendix X gives the file information for Appendix XI).

4.3 COMPUTATIONAL METHOD

Radiation doses from normal operations are conservatively estimated and include exposures due to releases of radioactive gases, volatile species, and particulates from surface and subsurface facility operations, as well as direct exposure from contained radiation sources within transportation casks, aging overpacks, shielded transfer casks, waste packages, and surface facilities and buildings. Preclosure dose analyses for airborne releases do not include ^{222}Rn and its daughter products that are part of the normal background radiation environment. The potential contribution to dose from ^{222}Rn and its daughter products is excluded by 10 CFR 20.1101(d) (Reference 2.2.2) for air emissions. The potential contribution to dose from offsite transportation is also not included, because it is excluded from the definition of management in 40 CFR 191.2 (Reference 2.2.16) as cited by 10 CFR 63.204 (Reference 2.2.1). This exclusion also applies to the rail transportation support facilities planned to be in the immediate vicinity of the site.

10 CFR Part 20, 10 CFR 63.111(a), 10 CFR 63.111(b), and 10 CFR 63.204 (References 2.2.1 and 2.2.2) establish preclosure performance objectives applicable to radiation workers and members of the public; numerical guides for design objectives are provided for:

- Total effective dose equivalent (TEDE)
- Total organ dose equivalent (TODE), which is the sum of the committed dose equivalent (CDE) plus the deep dose equivalent (DDE)
- Shallow dose equivalent to skin (SDE)
- Lens dose equivalent (LDE).

Two categories of individuals are relevant for the application of performance objectives and operational dose constraints: (1) radiation workers, who are individuals receiving occupational doses and (2) members of the public. Radiation workers are personnel who are assigned duties that involve exposure to radiation and/or to radioactive material. Members of the public include any individual not receiving an occupational dose. The members of the public are further divided into three subcategories: (1) members of the public in the general environment, (2) members of the public offsite but not in the general environment, and (3) onsite members of the public including construction workers.

Performance objectives for normal operations and Category 1 event sequences and for Category 2 event sequences are summarized in Table 1. Preclosure performance objectives for inside and outside of the geologic repository operations area (GROA) during normal operations and Category 1 event sequences are illustrated in Figure 1.

4.3.1 Dose Estimate Methodology

Doses to the public and to radiation workers are determined using the methodology described below. Doses to the public are calculated in this document; doses to radiation workers have been determined in other analyses, but are summarized and aggregated here to ensure that the performance objectives of Table 1 are satisfied.

Total Effective Dose Equivalent - Total effective dose equivalent to radiation workers is defined in 10 CFR 63.2 (Reference 2.2.1) as the sum of the deep dose equivalent for external exposures and the committed effective dose equivalent for internal exposures. For assessing the doses to members of the public, total effective dose equivalent is defined in 10 CFR 63.2 as the sum of the effective dose equivalent for external exposures and the committed effective dose equivalent for internal exposures. The total effective dose equivalent for both radiation workers and members of the public is the sum of the effective dose equivalent for external exposures plus the committed effective dose equivalent for internal exposures. *Use of the Effective Dose Equivalent in Place of the Deep Dose Equivalent in Dose Assessments* (Reference 2.2.17, p. 2) states that the effective dose equivalent should be used instead of the deep dose equivalent in situations that do not involve dose measurements using personnel dosimetry, such as in dose assessments made prior to actual operations that are based on calculations.

Total effective dose equivalent has five components: inhalation and ingestion, which are the committed effective dose equivalent portions of the dose with a dose commitment period of 50 years (Design Input 6.1.1.1); ground shine and air submersion, which are external doses from airborne releases; and external direct shine from contained sources. The last of those three are the effective dose equivalent portions of the dose. The total effective dose equivalent dose measure, described in Reference 2.2.8 (p. 10) with EDE used in place of DDE (Reference 2.2.17 p. 2), for dose assessment is expressed in Equation 1, without the contributor of direct shine from contained sources. Dose from direct shine of contained sources is added to Equation 1 for onsite individuals.

$$TEDE = CEDE + EDE$$
$$= \sum_j D^{inh}_{j,effective} + \sum_j D^{ing}_{j,effective} + \sum_j D^{ext}_j \qquad \text{Equation 1}$$

where

$TEDE$ = total effective dose equivalent (rem)

$CEDE$ = committed effective dose equivalent (rem)

EDE = effective dose equivalent (rem)

$D^{inh}_{j,effective}$ = whole body effective inhalation dose from the j^{th} nuclide (rem)

$D^{ing}_{j,effective}$ = whole body effective ingestion dose from the j^{th} nuclide (rem)

D^{ext}_j = whole body effective external dose from the jth nuclide (rem).

The inhalation dose in Equation 1 is expressed as (Reference 2.2.8, pp. 9 and 10):

$$D^{inh}_{j,effective} = \frac{ST_j}{\Delta t} \times T \times \frac{\chi}{Q} \times BR \times conv \times DCF^{inh}_{j,effective} \qquad \text{Equation 2}$$

where

$D^{inh}_{j,effective}$ = whole body effective inhalation radiation dose from the j^{th} nuclide (rem)

ST_j = release source term for the j^{th} nuclide (Ci)

Δt = release duration (s)

T = exposure duration (s)

$\frac{\chi}{Q}$ = atmospheric dispersion factor (s/m^3)

BR = breathing rate (m^3/s)

$conv$ = units conversion factor: 3.7×10^{12} [(rem ·Bq)/(Ci ·Sv)]

$DCF^{inh}_{j,effective}$ = whole body effective inhalation dose coefficient of the j^{th} nuclide (Sv/Bq).

The ingestion dose is calculated from the ingestion of food crops and animal products contaminated with radionuclides as a result of an airborne release. There are no liquid releases; therefore, groundwater and drinking water contamination are excluded. The concentrations of nuclides in the food crops and animal products are calculated with the GENII Version 2 environmental transport and dose assessment code (Reference 2.2.18) discussed in Section 4.3.3.

For the onsite public, offsite public not in the general environment, and radiation worker dose assessment, the dose from ingestion is dropped from Equation 1, because no ingestion of contaminated food, or soil is expected (Assumption 3.2.11).

$$D^{ing}_{j,effective} = \sum_n \left(C^n_j \times UT^n\right) \times conv \times DCF^{ing}_{j,effective}$$ Equation 3

where

$D^{ing}_{j,effective}$ = whole body effective ingestion radiation dose from the j^{th} nuclide (rem)

C^n_j = radiation concentration of the j^{th} nuclide in food type n as a result of an airborne release (Ci/kg or Ci/l)

UT^n = ingestion intake of food type n (kg or l)

$DCF^{ing}_{j,effective}$ = whole body effective ingestion dose coefficient of the j^{th} nuclide (Sv/Bq).

The external dose in Equation 1 is from airborne releases and is the sum of the ground shine dose and air submersion dose.

$$D^{ext}_j = D^{grd}_j + D^{sub}_j$$ Equation 4

where

D^{grd}_j = ground shine dose from the j^{th} nuclide (rem)

D^{sub}_j = air submersion dose from the j^{th} nuclide (rem).

The ground shine dose is calculated for the offsite public from the ground concentration of the j^{th} nuclide as a result of deposition from an airborne release.

$$D^{grd}_j = C^{grd}_j \times \rho \times d \times T \times conv \times DCF^{grd}_j$$ Equation 5

where

C^{grd}_j = ground concentration of the j^{th} nuclide as a result of deposition (Ci/kg)

ρ = soil bulk density (kg/m^3)

d = surface soil depth (m)

DCF^{grd}_j = ground shine dose coefficient of the j^{th} nuclide for a ground surface source [(Sv ·m^2)/(Bq ·s)].

The air submersion dose is calculated from the air concentration of the j^{th} nuclide from an airborne release.

$$D_j^{sub} = \frac{ST_j}{\Delta t} \times T \times \frac{\chi}{Q} \times conv \times DCF_j^{sub} \qquad \text{Equation 6}$$

where

D_j^{sub} = air submersion dose from the j^{th} nuclide (rem)

DCF_j^{sub} = air submersion dose coefficient of the j^{th} nuclide [(Sv ·m^3)/(Bq ·s)].

Total Organ Dose Equivalent - The TODE dose measure, described in Reference 2.2.8 (p. 10) with EDE used in place of DDE (Reference 2.2.17, p. 2), for dose assessment is expressed as:

$$TODE_k = CDE_k + EDE = \sum_j D_{j,k}^{inh} + \sum_j D_{j,k}^{ing} + \sum_j D_j^{ext} \qquad \text{Equation 7}$$

where $k \neq$ effective or skin

where

$TODE_k$ = total organ dose equivalent to the k^{th} organ (rem)

CDE_k = committed dose equivalent to the k^{th} organ (rem)

EDE = effective dose equivalent (rem)

$D_{j,k}^{inh}$ = inhalation dose from the j^{th} nuclide to the k^{th} organ (rem)

$D_{j,k}^{ing}$ = ingestion dose from the j^{th} nuclide to the k^{th} organ (rem)

D_j^{ext} = radiation dose from the j^{th} nuclide from external exposure (rem)

k = organ index, where organs are gonads, breast, lung, red marrow, bone surface, thyroid, colon, stomach wall, liver, bladder wall, esophagus, and remainder.

The inhalation dose in Equation 7 is expressed as (Reference 2.2.8, pp. 9 and 10):

$$D_{j,k}^{inh} = \frac{ST_j}{\Delta t} \times T \times \frac{\chi}{Q} \times BR \times conv \times DCF_{j,k}^{inh} \qquad \text{Equation 8}$$

where

$D_{j,k}^{inh}$ = inhalation dose from the j^{th} nuclide to the k^{th} organ (rem)

$DCF_{j,k}^{inh}$ = inhalation dose coefficient of the j^{th} nuclide for the k^{th} organ (Sv/Bq).

For the onsite public, offsite public not in the general environment, and radiation worker dose assessment, the term from ingestion is dropped from Equation 7, because no ingestion of contaminated food, water, or soil is expected (Assumption 3.2.11). For other receptors, the ingestion dose is calculated by:

$$D_{j,k}^{ing} = \sum_{n} \left(C_j^n \times UT^n \right) \times conv \times DCF_{j,k}^{ing} \qquad \text{Equation 9}$$

where

$DCF_{j,k}^{ing}$ = ingestion dose coefficient of the j^{th} nuclide to the k^{th} organ (Sv/Bq).

The external dose in Equation 7 is the same as the effective external dose from Equation 4.

Shallow Dose Equivalent to Skin - The shallow dose equivalent to skin (SDE) is from the air submersion. The SDE is defined for occupational exposures as applying to "the skin of the whole body or the skin to any extremity" and is the dose equivalent at a tissue depth of 0.007 cm (7 mg/cm^2) averaged over an area of 1 cm^2 (Reference 2.2.2, 10 CFR 20.1201(a)(2)(ii)). The SDE is cited in 10 CFR 63 as "the shallow dose equivalent to skin" (Reference 2.2.1, 10 CFR 63.111(b)(2)).

$$SDE = \sum_{j} D_{j,skin}^{sub} \qquad \text{Equation 10}$$

where

SDE = shallow dose equivalent to skin (rem)

$D_{j,skin}^{sub}$ = air submersion dose from the j^{th} nuclide to skin (rem).

Lens Dose Equivalent - NUREG-1567 (Reference 2.2.19, p. 9-14) provides a methodology for calculating the dose equivalent to the lens of the eye, and that methodology is employed to evaluate lens dose equivalent in this analysis. Lens dose equivalent is expressed as:

$$LDE = TEDE + SDE \qquad \text{Equation 11}$$

where

LDE = lens dose equivalent (rem)

$TEDE$ = total effective dose equivalent (Equation 1) (rem)

SDE = shallow dose equivalent to skin (Equation 10) (rem).

4.3.2 Dose Aggregation

In compliance with 10 CFR 63.111(b)(1) (Reference 2.2.1), doses from normal operations and Category 1 event sequences are aggregated. The estimated annual dose (TEDE, TODE, SDE, and LDE) to members of the public and radiation workers for normal operations and Category 1 event sequences is based on contributions from four sources:

1. Normal operational releases from surface facilities

2. Normal operational releases from the subsurface repository

3. Direct radiation dose from contained radiation sources

4. Category 1 event sequences.

For any given year of repository operation, the aggregate annual dose is calculated by summing the normal operation doses from direct radiation and airborne radioactivity with the doses from Category 1 event sequences that can occur in that year of operation.

To demonstrate compliance with 10 CFR 63.111(a)(1) and (2) (Reference 2.2.1), the total annual dose is compared with the regulatory performance objectives for the aggregate of normal operations and Category 1 event sequences summarized in Table 1.

4.3.3 Description of the GENII Computer Code

This section describes the GENII Version 2 (References 2.2.18 and 2.2.20) computer code used in this calculation to perform public airborne release dose calculations for normal operations and Category 1 and Category 2 event sequences.

The GENII Version 2 computer code was developed for the U.S. Environmental Protection Agency at the Pacific Northwest National Laboratory to incorporate the internal dosimetry models recommended by the International Commission on Radiological Protection (ICRP) in ICRP Publications 56 through 72 into updated versions of existing environmental pathway analysis models. The resulting environmental dosimetry computer code was compiled into the GENII Version 2 Environmental Dosimetry System. GENII Version 2 was developed to provide a state-of-the-art, technically peer-reviewed, and documented set of programs for calculating radiation dose and risk from radionuclides released to the environment.

GENII Version 2 includes the capabilities for calculating radiation doses following chronic and acute releases to air (ground level or elevated sources) and initial contamination of soil or surfaces. Radionuclide transport via air is considered. Air transport options include both puff and plume models; each allows use of an effective stack height or calculation of plume rise from buoyant or momentum effects (or both). Building wake effects can be included in acute atmospheric release scenarios.

Exposure pathways include direct exposure via soil (surface source), air (semi-infinite cloud and finite cloud geometries), inhalation, and ingestion pathways. The tritium model includes consideration of both gas and vapor, conversion of gas into vapor, and biological conversion of both into organically bound tritium. The code provides dose estimates for individuals or populations, including the effective dose, effective dose equivalent, and organ dose based on the updated ICRP internal dosimetry models.

Default exposure and consumption parameters are provided for both the average (population) and maximum individual; however, the user may change these to site-specific values. Source term information may be entered as radionuclide release quantities for transport scenarios or as basic radionuclide concentrations in environmental media (air). For input of basic or derived concentrations, decay of parent radionuclides and ingrowths of radioactive decay products prior to the start of the exposure scenario may be considered. A single code run can accommodate any number of radionuclides including the source term and any radionuclides that accumulate from decay of the parent, because the system works sequentially on individual decay chains.

The code package also provides interfaces, through FRAMES (Framework for Risk Analysis in Multimedia Environmental Systems), for external calculations of atmospheric dispersion, geohydrology, and biotic transport. Target populations are identified by direction and distance (radial or square grids) for individuals and populations.

GENII Version 2 is completely stochastic, using the FRAMES SUM^3 driver. FRAMES is currently designed for deterministic environmental and human health impact models. The Sensitivity/Uncertainty Multimedia Modeling Module (SUM^3) software product was designed to allow statistical analysis using the existing deterministic models available in FRAMES. SUM^3 randomly samples input variables and preserves the associated output values in an external file available to the user for evaluation. This enables the user to calculate deterministic values with variable inputs, producing a statistical distribution including the cumulative distribution function of results.

Within FRAMES, SUM^3 allows the user to conduct a sensitivity and/or uncertainty analysis to understand the influence and importance of the input parameter variability/uncertainty on contaminant flux, concentration, and human-health impacts. The sensitivity analysis can identify the key parameters that dominate the overall uncertainty. Statistical methods used in SUM^3 are based on the Monte Carlo approach using Latin Hypercube sampling.

4.3.4 GENII Methodology Adjustments

In order to efficiently use GENII to calculate doses from acute releases over an extended period of time with multiple χ/Q changes or to calculate doses from a chronic period less than one year following an acute release, the results obtained from the GENII runs need to be adjusted externally from the code. These adjustments are described in this section.

4.3.4.1 Time-Weighted Atmospheric Dispersion Factors

For oxidation releases, which occur over time and where the χ/Q changes for different time periods, five different GENII cases would have to be performed to determine the resultant doses. For efficiency and for calculating dose distributions using the FRAMES SUM^3 module, it is useful to develop a single GENII case with time-weighted χ/Qs.

The combination run uses a calculated time-weighted χ/Q for the duration of the release. This is shown in Equation 12.

$$\frac{\chi}{Q_e} = \frac{\left(\frac{\chi}{Q_{0-2}}\right)\times 2 + \left(\frac{\chi}{Q_{2-8}}\right)\times 6 + \left(\frac{\chi}{Q_{8-24}}\right)\times 16 + \left(\frac{\chi}{Q_{24-96}}\right)\times 72 + \left(\frac{\chi}{Q_{96-720}}\right)\times 624}{720} \qquad \text{Equation 12}$$

The time-weighted χ/Qs used for oxidation releases are determined in Section 6.2.2.

4.3.4.2 External Plume Submersion Adjustment

The GENII code is designed for either chronic, annual-average type conditions, or for acute, short duration releases that could be considered to be "nearly instantaneous" from an environmental-assessment point of view, generally intended to be on the order of one day or less. For inhalation, soil deposition, and food crops, the time-integral of the air concentration is used in dose calculations for acute releases and the average air concentration is used in dose calculations for chronic releases.

A slightly different approach is taken for air submersion doses. The GENII code has logic that compares the duration of the release (RELEND) (or plume passage time) with the daily plume submersion exposure time (UEXAIR). If the plume release time is less than the submersion time, then the actual time-integrated plume concentration is used. If the submersion time is less than the plume release time, the code reduces the air concentration by the ratio of the submersion time to the release duration. This is described in the GENII Software Design Document, Section 10.2.1 (Reference 2.2.20).

This particular logic is appropriate for releases that are less than 24 hours. When applied to releases that have a duration longer than 24 hours, the logic results in underestimating the submersion dose if the individual is assumed to remain within the plume. Without adjustments, the individual would be effectively removed from the submersion exposure calculation after 24 hours.

The GENII acute receptor intake module logic is that if the acute release period (RELEND) is longer than the daily submersion time (UEXAIR) (for example, the default YMP value for this parameter is 22 hours), it reduces the total exposure proportionately. In other words, if the input has an 11 hour/day daily plume submersion exposure time and the release lasts 22 hours, the time correction is 0.5.

Given that GENII assumes that the release does not last longer than 24 hours, the results are underestimated for releases involving oxidation and must be adjusted external to the code. For oxidation lasting up to 30 days after a drop event (Assumption 3.2.3), atmospheric dispersion factors change for time periods 0 – 2 hours, 2 – 8 hours, 8 – 24 hours, 1 – 4 days, and 4 – 30 days. The submersion correction is appropriate for the 2-hour, 6-hour, and 16-hour release periods, but the underestimate becomes progressively worse past that. For the entire 30 day period, the correction in GENII ends up being 0.0306 (22 hrs/720 hrs). To correct this problem the resultant plume submersion doses calculated by GENII for oxidation releases are adjusted using the inverse of the correction factor. This adjustment for oxidation releases is made in the Excel spreadsheets discussed in Section 6.5 by multiplying the GENII results by the inverse of the correction factor applied internally by GENII, or 32.73 (720 hrs/22hrs).

4.3.4.3 Tritium and ^{14}C Ingestion Pathway Dose Adjustments

As discussed in Section 8.6 of the GENII software design document (SDD) (Reference 2.2.20), during the period of plume passage, vegetation attains equilibrium with tritium in air moisture. Therefore, the initial tritium content of plants is directly proportional to the atmospheric concentration, which is proportional to the atmospheric dispersion factors (χ/Q). Following passage of the plume, for vegetation and the animals that eat them, the tritium decorporates according to an 8 hour retention half-life.

Uptake of ^{14}C into plants is through photosynthesis (Reference 2.2.20, Section 8.6). Thus, the GENII model treats carbon as behaving as CO_2. It models any new growth as fixing ^{14}C and ^{12}C at ratios the same as in the air during the passage of the plume. However, only a small portion of the total biomass of the plant would be fixed during the acute plume passage period. An approximation to the attained concentration is obtained by using the specific-activity approach multiplied by the fraction of the growing period represented by plume passage. Therefore, the initial ^{14}C content of plants is directly proportional to the atmospheric concentration, which is proportional to the atmospheric dispersion factor (χ/Qs).

Doses calculated using the time weighted χ/Qs discussed in Section 4.3.4.1 for the total oxidation period using GENII are correctly calculated for inhalation doses for all radionuclides and ingestion doses for all radionuclides except tritium and ^{14}C. As described above, the tritium and ^{14}C doses are directly proportional to the atmospheric concentration. Therefore, the dose contribution D_{H3} from tritium or ^{14}C for the total duration of the oxidation release where R_{H3} is the release rate of tritium or ^{14}C (constant for the total duration) can be expressed as:

$$D_{H3} \propto R_{H3} \sum_{i=1}^{n} \frac{\chi}{Q_i} \qquad \text{Equation 13}$$

Where χ/Q_i is the χ/Q for time period *i*, and *n* is the total number of time periods considered.

Using the time weighted χ/Qs, the dose contribution D_{H3} from tritium or ^{14}C in the GENII results would be:

$$D_{H3} \propto R_{H3} \left(\frac{\chi}{Q}_e \right) \qquad \text{Equation 14}$$

Where χ/Q_e is the time weighted χ/Q calculated using Equation 12 and presented in Table 22. Clearly, results using Equation 13 would be different than results using Equation 14.

To be able to use a single GENII run to calculate the doses from oxidation, the tritium or ^{14}C dose is adjusted by a factor F_{H3}, which is the ratio of Equation 13 to Equation 14:

$$F_{H3} = \frac{\sum_{i=1}^{n} \frac{\chi}{Q_i}}{\left(\frac{\chi}{Q}_e\right)}$$ Equation 15

For the contribution to the dose from tritium, GENII uses the concentration of tritium in air for the inhalation and air submersion pathways, and the concentration of tritiated water in air moisture to determine the concentration in vegetation, which is then used to calculate the dose from tritium from the ingestion pathways.

The concentration of tritiated water in air moisture is determined by dividing the tritium concentration in air by the absolute humidity (Reference 2.2.20, Section 9.6.1). Therefore, the absolute humidity can be adjusted using the adjustment factor F_{H3} when using a single GENII run to calculate the doses from oxidation. This adjustment is determined in Section 6.2.3.

A similar approach for ^{14}C is not available, since there is no unique parameter such as absolute humidity that is applicable only to the ^{14}C ingestion doses. Therefore, adjustments to the dose contribution from ^{14}C are performed in the Excel spreadsheets discussed in Section 6.5.

4.3.4.4 Inhalation Dose Breathing Rate Adjustment

The inhalation dose in Equation 2 is proportional to the release rate, the breathing rate, and the atmospheric dispersion factor. For short-term releases, the dose can be characterized as follows:

$$D_I \propto R \cdot BR \cdot \frac{\chi}{Q} \cdot T$$ Equation 16

where

R	=	release rate (Ci/s)
BR	=	breathing rate (m^3/s)
χ/Q	=	atmospheric dispersion factor (s/m^3)
T	=	exposure duration (s).

For longer release time periods, such as for oxidation releases, the breathing rates and atmospheric dispersion factors can change. Therefore, Equation 16 is modified as follows:

$$D_I \propto R \cdot \sum_{i=1}^{n} BR_i \cdot \frac{\chi}{Q_i} \cdot t_i$$ Equation 17

Where t_i is the duration of the i^{th} time period.

To use the time weighted χ/Qs, Equation 17 is modified as follows:

$$D_I \propto R \cdot \frac{\chi}{Q_e} \left[\frac{\sum_{i=1}^{n} BR_i \cdot \frac{\chi}{Q_i} \cdot t_i}{\frac{\chi}{Q_e} \cdot T} \right] \cdot T \qquad \text{Equation 18}$$

Now an effective breathing rate over all time periods can be defined as:

$$BR_e = \frac{\sum_{i=1}^{n} BR_i \cdot \frac{\chi}{Q_i} \cdot t_i}{\frac{\chi}{Q_e} \cdot T} \qquad \text{Equation 19}$$

Finally, the dose can be expressed as:

$$D_I \propto R \cdot BR_e \cdot \frac{\chi}{Q_e} \cdot T \qquad \text{Equation 20}$$

This breathing rate adjustment is determined in Section 6.2.4.

4.3.4.5 Category 2 Event Sequence 30-Day Dose Adjustment

For a Category 2 event sequence with an acute release, following the plume passage, GENII calculates a chronic dose from deposited radionuclides for a duration of one year. As discussed in Assumption 3.2.3, the exposure time is 30 days. Therefore, the doses from ground shine, soil inhalation, and ingestion calculated by GENII are adjusted using a ratio of 30/365 = 0.0822. This adjustment is performed in the Excel spreadsheets described in Section 6.5.2.3.

4.3.5 Source Term Release Inputs

The source term released during normal operations or from event sequences is a function of the material at risk, damage ratio, airborne release fraction, respirable fraction, and leak path factors for various confinement barriers as shown in the following equation (Reference 2.2.21, p. 1-2, Equation 1-1).

$$ST_j = MAR_j \times DR \times ARF_j \times RF_j \times LPF_{sys} \qquad \text{Equation 21}$$

where

ST_j	=	release source term for the *j*th nuclide (Ci)
MAR_j	=	material at risk for the *j*th nuclide (Ci)
DR	=	damage ratio (unitless)
ARF_j	=	airborne release fraction for the *j*th nuclide (unitless)
RF_j	=	respirable fraction for the *j*th nuclide (unitless)
LPF_{sys}	=	cumulative leak path factor for the system of confinement barriers (unitless).

The MAR is the amount of radionuclides initially available for release during normal operations or prior to an event sequence. The concentration or inventory of each radionuclide in the radioactive waste is expressed as curies per fuel assembly, curies per unit weight of waste form or curies per canister. The MAR for each waste form is provided in Design Input 6.1.2.

The damage ratio is the fraction of the MAR actually affected by a normal operation process or an event sequence. For a normal operation process involving commercial SNF, the damage ratio is equal to the fuel rod breakage percentage of 1% (Assumption 3.2.1). For event sequences, 100% of the commercial SNF or HLW involved in the event sequence is assumed to be affected, and thus the damage ratio is 1.0 (Assumption 3.2.1).

The ARF is the coefficient used to estimate the amount of a radioactive material suspended in air as an aerosol and thus available for transport. The RF is the fraction of airborne radionuclides as particles that can be transported through air and inhaled into the human respiratory system and commonly includes particles 10-µm AED and less. The ARF and RF are given in Design Input 6.1.3.

Leak path factors are the fractions of material transported out from a confinement barrier after the action of any depletion mechanisms. Depletion mechanisms include plate-out, precipitation, gravitational settling, filtration, and agglomeration of airborne particulate material. Confinement barriers include spent fuel cladding, transportation casks, canisters, waste packages, WHF pool water, buildings, and HEPA filters.

When multiple confinement barriers apply, the cumulative effect of leak path factors is expressed by one value for the system that combines all leak path factors as follows (Reference 2.2.22, Section 4.3):

$$LPF_{sys} = (LPF)_i \times (LPF)_{i+1} \times (LPF)_{i+2} \times .... \qquad \text{Equation 22}$$

where

$(LPF)_i$	=	leak path factor for i^{th} confinement barrier (unitless).

Leak path factors are given in Design Input 6.1.4.

4.4 NORMAL OPERATIONS AND EVENT SEQUENCES

This section discusses radionuclide releases from normal operations and event sequences. Waste forms involved in normal operations and in event sequences include pressurized water reactor (PWR) or boiling water reactor (BWR) SNF, LLW, and HLW.

Airborne release radiological dose consequences to the public are calculated for four locations: offsite public in the general environment, offsite public not in the general environment, onsite public 60 m (Reference 2.2.23, Section 3.2.7) from the surface facilities and onsite public 100 m (Reference 2.2.23, Section 3.2.7) from the subsurface exhaust shafts. For the onsite public at the two locations, the doses incurred are summed for all normal operations releases to each location and the highest dose is reported in Section 7 and compared after aggregation with Category 1 event sequence doses to the dose performance objectives in Table 1.

4.4.1 Normal Operations

Normal operations include surface operations and subsurface operations. Potential radiation doses from normal operations result from airborne releases of radioactive gases, volatile species, and particulates; resuspension of radioactive contamination remaining on the external surfaces of contained sources; neutron activation of air and silica dust inside the emplacement drifts that could become airborne, resuspension of waste package surface contamination during normal operations; as well as direct exposure from contained waste forms (calculated in other analyses). There are no liquid releases from the facilities to the environment. The maximum annual average χ/Q values at each of the four locations are used for determining the dose from normal operations.

4.4.1.1 Normal Surface Operations

Waste handling operations are performed in the GROA near the North Portal where the surface facilities are located. Radiation doses from normal surface operations can result from resuspension of radioactive contamination from external surfaces of contained sources, airborne releases from opening contained sources, and direct exposure from contained sources.

All naval SNF and approximately 98% of the Department of Energy (DOE) HLW are received in sealed canisters inside transportation casks. Approximately 90% of the commercial SNF is received in sealed canisters inside transportation casks. These canisters are placed inside waste packages for emplacement or aging overpacks for aging or transferring between buildings (Reference 2.2.14, Section 1.2.2 and Design Input 6.1.1.4). No airborne releases occur from these contained sources during normal operations. Radiation surveys of the external surfaces of aging overpacks and transportation casks are performed. Decontamination of these external surfaces is performed, if necessary. Surface contamination, however small, can be resuspended and contribute to normal operational doses. Resuspension of surface contamination of contained sources is discussed in Design Input 6.1.2.5 and in Section 6.7.3.

Direct radiation dose is a result of exposure to contained sources. Exposure of the public to the canisters that contain SNF and HLW is precluded by the shielding design of the facilities and the use of remote operations within facilities. There is potential for direct exposures to onsite individuals for operations involving shielded casks and overpacks. Due to the distance from the locations in the GROA where contained sources are processed, there is no direct radiation dose contribution to offsite members of the public. Direct radiation doses are included for radiation workers, as well as onsite members of the public because of the shorter distances to the operations locations.

Yucca Mountain facilities shall be capable of accommodating transportation, aging, and disposal (TAD) canisters and at least 90% of the commercial SNF shall be received in these TAD canisters (Reference 2.2.14, Section 2.2.1.3). The remaining 10% of commercial SNF will be received at the repository in DPCs or uncanistered in transportation casks (Design Input 6.1.1.3). In addition, approximately 2% of the DOE SNF of commercial origin can be received at the repository in DPCs or uncanistered in transportation casks (Design Input 6.1.1.4). DPCs can be transferred to aging overpacks and moved to the aging pads. No airborne releases occur during normal operations involving sealed DPCs. However, the commercial SNF in DPCs and the uncanistered fuel will be repackaged into TAD canisters in the WHF pool prior to being placed in waste packages for emplacement. Airborne releases of radionuclides during normal operations in the WHF are expected.

During the process of cutting open the DPCs and preparing the transportation casks for removing the lid, airborne releases contained within the inert atmosphere of the DPCs and transportation casks can be released. The damage ratio for normal operation is 0.01 (Assumption 3.2.1). Thus fission gases, volatile species, and fuel fines from 1% of the fuel in DPCs and uncanistered in transportation casks may be released from the WHF. Potential releases from the WHF are treated with HEPA filters to reduce airborne radioactive particulates prior to venting to the atmosphere. The HEPA filter particulate removal efficiency and $(LPF)_{HEPA}$ are discussed in Design Input 6.1.4.1.

The plume released from the WHF ventilation system contains fission product gases, volatile species, and any fuel fines and crud particulates that are not removed by the HEPA filters. The plume is dispersed en route to the site boundary or onsite locations of workers or the general public. This is a normal operations release occurring over a 1-year interval (Assumption 3.2.5). Exposures are modeled to result in an acute individual exposure during the plume passage and in a chronic individual exposure to ground contamination. Offsite members of the public in the general environment are also exposed through the contaminated food pathway for one year. Ground contamination and subsequent food pathway exposures include the buildup of contamination for the entire emplacement period of 50 years (Design Input 6.1.1.1). Doses from surface releases are also determined for onsite public at 200 ft (60 m) from the WHF (Reference 2.2.23, Section 3.2.7).

4.4.1.2 Normal Subsurface Operations

Normal operations at the Subsurface Facility involve the transport and placement of waste packages that are closed and sealed. Radiation exposures from direct radiation associated with subsurface placement of waste packages into emplacement drifts are accounted for in the radiation worker dose assessment for the Subsurface Facility as reported in Design Input 6.1.5.2.

During normal subsurface operations, neutron activation of air and silica dust inside the emplacement drifts and resuspension of waste package surface contamination can generate potential airborne releases of radioactive materials. Activated air and silica dust and resuspension of waste package surface contamination can be released to the environment through ventilation shafts.

Subsurface releases are through ventilation exhaust shafts that are not HEPA filtered (Reference 2.2.14, Sections 8.1 and 22). The plume is dispersed en route to the site boundary and is modeled to result in an acute individual exposure during plume passage and in a chronic individual exposure to ground contamination. Offsite members of the public in the general environment are also exposed through the contaminated food pathway for 1 year after plume passage. Doses from subsurface releases are also determined for onsite public at 100 m from the exhaust shafts (Reference 2.2.23, Section 3.2.7).

Subsurface airborne releases are discussed in Design Input 6.1.2.4.

4.4.2 Category 1 Event Sequences

No methodology is provided for calculating doses resulting from radioactive releases as a result of Category 1 event sequences because it has been concluded that there are no Category 1 event sequences involving airborne releases (Assumption 3.1.1).

4.4.3 Category 2 Event Sequences

Doses from Category 2 event sequences apply only to offsite members of the public (see Table 1).

Airborne releases from Category 2 event sequences occur inside HEPA filtered areas except those that occur in the IHF, LLWF, fire, or seismic events (Assumption 3.1.1). The release from a building is treated as a ground-level radioactive plume and the building wake effect is considered (Reference 2.2.23, Sections 3.2.2 and 3.2.5). The plume is dispersed en route to the site boundary, resulting in an acute individual exposure during plume passage and a chronic individual exposure to ground contamination and contaminated food after plume passage. Potential radiation doses from inhalation, resuspension inhalation, ingestion, air submersion, and groundshine pathways are considered for Category 2 event sequences. Because of the large distance to the location of the offsite receptor, doses to members of the public from direct radiation after a Category 2 event sequence or loss of shielding events are inconsequential (Reference 2.2.24, Section 7).

Rather than calculating dose consequences for each Category 2 event sequence identified in the categorization analyses, dose consequences are performed for a set of bounding events that encompass the end states and material at risk for event sequences discussed in Assumption 3.1.1 and listed in Appendix II. Table 2 identifies 14 cases that bound the identified end states identified in Appendix II. The 95^{th}-percentile χ/Qs are used for determining the dose from Category 2 event sequences.

Table 2. Bounding Category 2 Event Sequences

Bounding Event Number	Affected Waste Form or Canister	Description of End State	Material At Risk
2-01	LLWF inventory and HEPA filters	Seismic event resulting in LLWF collapse and failure of HEPA filters and ductwork in other facilities.	HEPA filters LLWF inventory (Table 3).
2-02	HLW canister in transportation cask	Breach of sealed HLW canisters in a sealed transportation cask	5 HLW canisters
2-03	HLW canister	Breach of sealed HLW canisters in an unsealed waste package[a]	5 HLW canisters
2-04	HLW canister	Breach of sealed HLW canister during transfer (one drops onto another)	2 HLW canisters
2-05	Uncanistered commercial SNF in transportation cask	Breach of uncanistered commercial SNF in a sealed truck transportation cask in air	4 PWR or 9 BWR commercial SNF
2-06	Uncanistered commercial SNF in pool	Breach of uncanistered commercial SNF in an unsealed truck transportation cask in pool	4 PWR or 9 BWR commercial SNF
2-07	DPC in air	Breach of a sealed DPC in air	36 PWR or 74 BWR commercial SNF
2-08	DPC in pool	Breach of commercial SNF in unsealed DPC in pool	36 PWR or 74 BWR commercial SNF
2-09	TAD canister in air	Breach of a sealed TAD canister in air within facility	21 PWR or 44 BWR commercial SNF
2-10	TAD canister in pool	Breach of commercial SNF in unsealed TAD canister in pool	21 PWR or 44 BWR commercial SNF
2-11	Uncanistered commercial SNF in pool	Breach of uncanistered commercial SNF assembly in pool (one drops onto another)	2 PWR or 2 BWR commercial SNF
2-12	Uncanistered commercial SNF in pool	Breach of uncanistered commercial SNF in pool	1 PWR or 1 BWR commercial SNF
2-13	Combustible and non combustible LLW	Fire involving LLWF inventory	Combustible and non-combustible inventory
2-14	Uncanistered commercial SNF in truck transportation cask	Breach of a sealed truck transportation cask due to a fire	4 PWR or 9 BWR commercial SNF

NOTES: [a]Waste packages that are co-disposal package containing 5 HLW canisters and 1 DOE SNF canister does not result in the breach of the DOE SNF canister per Assumption 3.1.1.

BWR = boiling water reactor, DAW = dry active waste, DPC = dual purpose canister, HEPA = high-efficiency particulate air, HLW = high-level waste, LLWF = Low-Level Waste Facility, LLW = Low-Level Waste, PWR = pressurized water reactor, SNF = spent nuclear fuel, TAD = transportation, aging and disposal.

Individual dose consequence calculations are performed for one HLW canister, one PWR commercial SNF assembly and one BWR commercial SNF assembly. The results of the dose consequences for each individual canister or fuel assembly is then multiplied by the MAR identified in Table 2 for each event to determine the dose consequence for that event.

The bounding Category 2 fire event sequence is assumed to consist of an all consuming fire in the LLWF (Assumption 3.2.12). The damage ratio for this event is conservatively taken to be 1.0 (Assumption 3.2.1). The only combustible waste form in the LLWF is the dry active waste

(DAW). The other waste forms are either non-combustible, consisting of empty DPCs, liquid waste and fiberglass HEPA filters in B-25 boxes, and pool filters in a HIC. However, the all consuming fire is assumed to breach the B-25 boxes and the HIC allowing for contamination to be released to the environment.

DAW is a type of LLW and contains a mixture of materials with the non-compactable portion comprised of equipment and small tools and the compactable portion comprised of paper, plastic, and cloth. Compacted and non-compacted DAW is in 0.21 m^3 (55-gallon) drums.

ARF and RF values are selected for a fire event involving combustible packaged and unpackaged contaminated waste.

The bounding Category 2 seismic event is postulated to result in the failure of the confinements for the solid and liquid LLW inventories in the LLWF. Given a seismic event, this is a credible event because the LLWF is not classified as important to safety and thus is not designed to withstand a bounding Category 2 seismic event (Reference 2.2.14, Section 30.1.2). The bounding Category 2 seismic event is also conservatively postulated to result in the failure of the HVAC HEPA filters, ducting and dampers in the WHF leading to the release of accumulated radioactive material. This is conservative because the HVAC system is expected to be designed to withstand the seismic event (Reference 2.2.14, Section 5.1). By assuming the failure of the HVAC system, accumulated particulates on the HEPA filters and ducting that could potentially become airborne and potentially released during the seismic event even without failure of the system are accounted for in the dose analysis. For simplicity, the buildup of radionuclides in the HVAC ducting and dampers is accounted for by the buildup on the HEPA filters.

The LLWF inventories include DAW in drums; WHF pool filters in HICs; HEPA filters in B-25 boxes; empty DPCs; and the contents of the liquid waste collection tanks. The activity on HEPA filters other than those from WHF is negligible (see Section 6.3.4.1). The seismic event source term also includes the dewatered spent resins in a HIC at the WHF (Assumption 3.1.2). The damage ratio for the bounding seismic event is conservatively taken to be 1.0 (Assumption 3.2.1).

4.4.4 Potential Releases from Retrieval Operations

The GROA must be designed to preserve the option of waste retrieval throughout the period during which wastes are emplaced and thereafter, until the Nuclear Regulatory Commission (NRC) review of the information obtained from a performance confirmation program is completed (Reference 2.2.1, 10 CFR 63.111(e)(1)). Permanent retrieval of any or all waste would require a separate license and possibly new facilities. Therefore, retrieval operations are not included in this dose evaluation.

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6 BODY OF CALCULATION

6.1 DESIGN INPUTS

This section summarizes design inputs to the calculation.

6.1.1 Site Specific Inputs

6.1.1.1 Emplacement Period

The repository is designed for 50 years of surface operations for emplacement of waste into the Subsurface Facility (Reference 2.2.14, Section 2.2.2.7).

6.1.1.2 Repository Maximum Regulatory Capacity

The repository is designed to accept 70,000 metric tons of heavy metal (MTHM) or the equivalent of SNF/HLW for disposal in the repository, allocated as follows (Reference 2.2.14, Section 2.2.1.1):

- 63,000 MTHM of commercial SNF and HLW
- 4,667 MTHM of Defense HLW
- 2,333 MTHM of DOE SNF and naval SNF.

6.1.1.3 Commercial Spent Nuclear Fuel Ratio

The repository is designed such that at least 90% of the commercial SNF are received in TAD canisters and the remaining 10% are received either in DPCs or as bare, intact assemblies in rail or truck transportation casks (Reference 2.2.14, Section 2.2.1.3).

6.1.1.4 Department of Energy Spent Nuclear Fuel Ratio

Approximately 98% of the heavy metal of DOE SNF is shipped to and handled at the repository in sealed canisters that are suitable for codisposal in waste packages with HLW without being opened. A small quantity of DOE SNF, approximately 2% of the heavy metal, in the possession of the DOE is intact SNF of commercial origin having no known defects and having handling features interchangeable with either BWR or PWR fuel assemblies (Reference 2.2.25, Section 3.2).

6.1.1.5 Radioactive Waste Storage Containers in Low-Level Waste Facility

The number and dimensions of waste form containers in the LLWF are those estimated from the general arrangement drawing (Reference 2.2.26). Reference 2.2.26 shows four shielded staging rooms for temporary storage of drums, B-25 boxes, HICs, and empty DPCs (rooms 1009 through 1011). Per Assumption 3.1.2 the spent resins may be transported to the LLWF in a HIC, and the pool filters will be placed in a HIC and transferred to the LLWF when full. Per Reference 2.2.29 Section 3.1.14 the HEPA filters will be packaged 12 to a shipping container and shipped offsite

12 times per year, and there are 10 containers per shipment. Therefore, the space provided in room 1009 is adequate for HEPA filters. Conservatively, the number of containers from Reference 2.2.26 was doubled to ensure that the LLWF was at full capacity during the postulated fire event sequence and the seismic event sequence. Reference 2.2.27 provides the dimensions for the waste containers and the expected amount of DAW in the sorting room. The number of containers is presented in Table 3.

Table 3. Number and Dimensions of Low-Level Waste Facility Waste Containers

Area Description	No. Containers	Waste Container Unit[d]
High-integrity container staging (room 1010)	28[a]	HIC (76 in diameter × 78 in height)
HEPA Filter staging (room 1009)	38[a]	B-25 Box (4 ft × 4 ft × 6 ft)
Liquid low-level waste collection tank (area 1016)	3	23,750 gallons (tank at 95% capacity)
Drum staging for DAW (room 1008)	216[a]	55-gallon drums
Sorting room[b] (rooms 1004 and 1005)	102	DAW bag (55 gallons of effective capacity); three days of storage at 15 bags per day from WHF, five from CRCF 1, five from CRCF 2, five from CRCF 3, one from Heavy Equipment Maintenance Facility, one from LLWF, one from aging, and one from subsurface

NOTES: CRCF = Canister Receipt and Closure Facilities; DAW = dry active waste; DPC = dual-purpose canister; HIC = high-integrity container; LLLW = low-level liquid radioactive waste; LLWF = Low-Level Waste Facility; WHF = Wet Handling Facility

Source: [a] Reference 2.2.26 × 2
[b] Reference 2.2.27, Table I-1.

6.1.1.6 Radionuclide Concentrations of Low-level Radioactive Waste

The radionuclide concentrations in each LLW form are those estimated for the conceptual design of the LLWF in Reference 2.2.28 (Table 14) as shown in Table 4. The spent resins are a low-level waste form that is processed in the WHF and placed in a HIC that may be transferred to the LLWF for temporary staging (Assumption 3.1.2).

Table 4. Radionuclide Concentrations for Each Low-Level Waste Form

Radionuclide	Dry Active Waste (Ci/m^3)	Pool Filter (Ci/m^3)	Spent Resin (Ci/m^3)	Liquid (Ci/m^3)
^{58}Co	5.59×10^{-3}	6.30	4.74	-
^{60}Co	1.42×10^{-2}	1.61×10^{1}	1.21×10^{1}	1.00×10^{-3}
^{134}Cs	6.30×10^{-3}	1.90	1.51×10^{1}	-
^{137}Cs	7.13×10^{-3}	2.15	1.71×10^{1}	1.50×10^{-3}
^{54}Mn	7.32×10^{-4}	1.84	2.48	-

Source: Reference 2.2.28, Table 14.

6.1.1.7 Spent Fuel Pool Filter Characteristics

The spent fuel pool filters are approximately 6 inches in diameter and 2 feet in length (Reference 2.2.29, Section 3.1.19). The filters are placed in a HIC and the HIC has a capacity of 200 filters (Reference 2.2.29, Section 3.1.19). Three HICs are needed to process all filters in a year (Reference 2.2.29, Section 3.1.19). The used filter cartriges will be processed three times a year (Reference 2.2.29, Section 3.1.15); therefore, there may be three HICs with pool filters transported to the LLWF annually (Assumption 3.1.2).

6.1.1.8 Spent Resins in WHF

Per Assumption 3.1.2, spent resins will be processed and may be shipped offsite directly from the WHF or shipped for interim storage in the LLWF. Per Reference 2.2.30 Section 6.2.4 each of the three treatment trains in the Pool Water Treatment System has an ion exchange vessel with one 50 ft^3 resin bed. The total volume of spent resins generated in one year will be 100 ft^3 (Reference 2.2.30 Table 7); therefore, there may be 100 ft^3 of spent resins transported to the LLWF annually.

6.1.1.9 Atmospheric Dispersion Factors

Downwind atmospheric dispersion factors (χ/Q) for acute (short-term) and chronic (long-term) exposures to radioactive materials from airborne releases are determined at locations of the general public, both onsite and beyond the site boundary, and at onsite radiation worker locations. The atmospheric dispersion factor value represents the dilution of airborne contamination from atmospheric mixing and turbulence based on site-specific atmospheric conditions, the relative configuration of the release point and the receptor, and the distance from the release point to the receptor of interest. It is the ratio of the contaminant air concentration at the receptor to the contaminant release rate at the release point, and it is used to determine the dose consequences for a receptor based on the quantity released, the atmospheric conditions, and the distance to the receptor.

Sector-dependent atmospheric dispersion factors are determined along the Yucca Mountain repository site boundary for general public exposures, at the minimum distance from a ground-level release point to the GROA restricted area boundary for onsite public exposures, from the subsurface exhaust shafts to GROA surface facilities, and from GROA surface facilities to subsurface intake shafts (Reference 2.2.23, Section 1).

Atmospheric dispersion factors are calculated at the site boundary for all 16 meteorological sectors from surface and subsurface effluent releases. The distances from the surface effluent releases to the site boundary for each sector are determined by calculating the minimum distance from the site boundary to an extended GROA boundary that encompasses all of the surface facilities that may contain radioactive materials. The distances from the subsurface effluent releases to the site boundary for each sector are determined by calculating the distances from each exhaust shaft to the site boundary and then selecting the minimum distance (Reference 2.2.23, Section 1). This is a conservative approach for both surface and subsurface releases as it minimizes the distance to the receptors and thereby maximizes the potential doses. The maximum annual average and 95^{th}-percentile χ/Qs at the site boundary are presented in Table 5.

The maximum annual average χ/Qs are used for normal operations and the 95th-percentile χ/Qs are used for Category 1 and Category 2 event sequences.

As the plume travels from the release point, radioactive material falls out and deposits on the ground and vegetation. The contaminant air concentration decreases as the material depletes out by deposition. The depleted χ/Qs and the deposition rates are also presented in Table 5. The undepleted χ/Qs, are used for doses from gaseous radionuclides; the depleted χ/Qs are used for doses from volatiles and particulates; and the deposition rates are used in the GENII model for groundshine, soil contamination and radionuclide uptake by vegetation.

For the onsite public, dose is calculated from airborne releases from the surface facilities and from the subsurface exhaust shafts. Because the onsite members of the public are relatively close to the potential release points, there is little deposition from the plume and so depleted χ/Qs are not calculated. The maximum annual average and 95th-percentile χ/Qs for the members of the public for these locations are also presented in Table 5.

Table 5. Atmospheric Dispersion Factor Values

Offsite Public in the General Environment – Releases from:						
	GROA			Exhaust Shafts		
Time Period	χ/Q (s/m^3)	Depleted χ/Q (s/m^3)	Deposition Rate (m^{-2})	χ/Q (s/m^3)	Depleted χ/Q (s/m^3)	Deposition Rate (m^{-2})
Annual Average	1.23×10^{-7}	5.12×10^{-8}	1.96×10^{-10}	1.30×10^{-7}	5.71×10^{-8}	2.18×10^{-10}
0 – 2 hours	1.24×10^{-5}	4.40×10^{-6}	1.17×10^{-8}	1.30×10^{-5}	4.89×10^{-6}	1.55×10^{-8}
2 – 8 hours	6.76×10^{-6}	2.46×10^{-6}	6.85×10^{-9}	7.09×10^{-6}	2.73×10^{-6}	7.57×10^{-9}
8 – 24 hours	3.94×10^{-6}	1.46×10^{-6}	4.24×10^{-9}	4.14×10^{-6}	1.62×10^{-6}	4.70×10^{-9}
1 – 4 days	1.73×10^{-6}	6.56×10^{-7}	2.04×10^{-9}	1.82×10^{-6}	7.30×10^{-7}	2.26×10^{-9}
4 – 30 days	5.26×10^{-7}	2.08×10^{-7}	7.11×10^{-10}	5.56×10^{-7}	2.32×10^{-7}	7.89×10^{-10}
Offsite Public Not in the General Environment – Releases from:						
	GROA			Exhaust Shafts		
Time Period	χ/Q (s/m^3)	Depleted χ/Q (s/m^3)	Deposition Rate (m^{-2})	χ/Q (s/m^3)	Depleted χ/Q (s/m^3)	Deposition Rate (m^{-2})
Annual Average	4.36×10^{-7}	2.52×10^{-7}	1.00×10^{-9}	3.01×10^{-7}	1.60×10^{-7}	6.38×10^{-10}
0 – 2 hours	2.76×10^{-5}	1.47×10^{-5}	4.48×10^{-8}	2.11×10^{-5}	1.01×10^{-5}	2.98×10^{-8}
2 – 8 hours	1.60×10^{-5}	8.49×10^{-6}	2.72×10^{-8}	1.21×10^{-5}	5.84×10^{-6}	1.80×10^{-8}
8 – 24 hours	9.86×10^{-6}	5.29×10^{-6}	1.74×10^{-8}	7.36×10^{-6}	3.60×10^{-6}	1.15×10^{-8}
1 – 4 days	4.69×10^{-6}	2.56×10^{-6}	8.82×10^{-9}	3.43×10^{-6}	1.72×10^{-6}	5.76×10^{-9}
4 – 30 days	1.61×10^{-6}	9.03×10^{-7}	3.32×10^{-9}	1.15×10^{-6}	5.91×10^{-7}	2.14×10^{-9}
Onsite Public at 200 ft from GROA – Releases from:						
Time Period	GROA χ/Q (s/m^3)			Exhaust Shafts χ/Q (s/m^3)		
Annual Average	3.33×10^{-4}			3.24×10^{-6}		
0 – 2 hours	2.03×10^{-3}			1.06×10^{-4}		
2 – 8 hours	1.64×10^{-3}			6.63×10^{-5}		
8 – 24 hours	4.01×10^{-4}			4.42×10^{-5}		
1 – 4 days	5.63×10^{-4}			2.37×10^{-5}		
4 – 30 days	5.14×10^{-4}			9.68×10^{-6}		
Onsite Public at 100 m from Exhaust Shafts – Releases from:						
Time Period	GROA χ/Q (s/m^3)			Exhaust Shafts χ/Q (s/m^3)		
Annual Average	3.42×10^{-7}			6.89×10^{-4}		
0 – 2 hours	2.53×10^{-5}			1.01×10^{-2}		
2 – 8 hours	1.43×10^{-5}			7.11×10^{-3}		
8 – 24 hours	8.67×10^{-6}			5.19×10^{-3}		
1 – 4 days	4.01×10^{-6}			3.21×10^{-3}		
4 – 30 days	1.33×10^{-6}			1.61×10^{-3}		

Source: Reference 2.2.23, Table 34.

6.1.1.10 Average Absolute Humidity

The average absolute humidity for the repository is 4.08×10^{-3} kg/m^3 (Reference 2.2.23, Section 6.10.1.1).

6.1.1.11 Surface Soil Depth

The surface soil depth is 0.25 m (Reference 2.2.10, Section 4.1.3.1).

6.1.1.12 Other Site Specific Inputs

Reference 2.2.10 provides the site-specific input files for use with GENII. As discussed in Assumption 3.2.10, this calculation uses the mean site specific parameters contained in files with the extension "*.pop*". Three site-specific parameter files are used by GENII: 1) *GNDFLcud.pop* - for chronic exposure; 2) *GNDFLaud.pop* - for acute exposure; and 3) *GNDFLiud.pop* - for receptor intake. Files *GNDFLcud.pop* and *GNDFLaud.pop* are the same as files *GNDFLcud.GE* and *GNDFLaud.GE* developed in Reference 2.2.10, Attachment E. The file *GNDFLiud.pop,* also developed in Reference 2.2.10, Attachment E, is used to calculate mean doses in the general environment.

The nuclide dependent database file *GENII.mdb* is replaced with a site-specific database file, *YMPGENII.mdb* developed in Reference 2.2.10, Attachment F. This file contains the YMP site-specific transfer coefficients for animal products, soil-to-plant transfer factors, soil water partition coefficients, and lung transfer inhalation class, or lung solubility class for all of the YMP radionuclides.

The default GENII inhalation dose coefficient file, *FGR13INH.hdb* is replaced with a site-specific inhalation dose coefficient file, *FGR13INH.ymp* developed in Reference 2.2.10, Attachment G. This revised file contains revised tritium inhalation dose coefficients for all organs to account for skin absorption.

6.1.2 Source Terms

6.1.2.1 Commercial Spent Nuclear Fuel Characteristics

The representative PWR and representative BWR Spent Fuel Assemblies (SFA) are used to calculate the mean dose for normal operations releases from commercial SNF. The maximum PWR and the maximum BWR SFAs are used to calculate bounding doses for event sequences involving commercial SNF. The characteristics of the commercial SNF are obtained from *Characteristics for the Representative Commercial Spent Fuel Assembly for Preclosure Normal Operations* (Reference 2.2.31) and are presented in Table 6.

Table 6. Commercial Spent Fuel Assembly Characteristics

Spent Fuel Assembly	Initial Enrichment (Percent)	Initial MTHM/assembly	Burnup (GWd/MTU)	Decay Time (Years)
Representative PWR[a]	4.2	0.475	50	10
Maximum PWR[b]	5.0	0.475	80	5
Representative BWR[a]	4.0	0.200	50	10
Maximum BWR[b]	5.0	0.200	75	5

NOTES: BWR = boiling water reactor; GWd = gigawatt days; MTHM = metric ton heavy metal; MTU = metric ton uranium; PWR = pressurized water reactor.

Sources: [a] Reference 2.2.31, Table 12
[b] Reference 2.2.31, Table II-1

6.1.2.2 Commercial Spent Nuclear Fuel Radionuclide Inventories

Radionuclide inventories in curies per fuel assembly (Ci/fuel assembly) for the representative and maximum PWR and the representative and maximum BWR SFAs are presented in Table 7.

Crud is activated corrosion products found on the exterior surface of commercial fuel assemblies. Crud can be released to the environment during an event sequence involving commercial SNF. Crud activities have been calculated in Reference 2.2.31 and are included in Table 7.

Table 7. Boiling Water Reactor and Pressurized Water Reactor Radionuclide Inventories

Radionuclide	Representative PWR[a] (Ci/fuel assembly)	Representative BWR[a] (Ci/fuel assembly)	Bounding PWR[b] (Ci/fuel assembly)	Bounding BWR[b] (Ci/fuel assembly)
^{241}Am	1.18×10^{3}	3.73×10^{2}	8.79×10^{2}	2.66×10^{2}
^{242}Am	7.27	2.87	1.01×10^{1}	3.39
^{242m}Am	7.30	2.88	1.02×10^{1}	3.40
^{243}Am	2.30×10^{1}	8.63	6.00×10^{1}	1.93×10^{1}
^{137m}Ba	5.70×10^{4}	2.27×10^{4}	9.89×10^{4}	3.65×10^{4}
^{14}C	4.21×10^{-1}	2.12×10^{-1}	5.35×10^{-1}	3.16×10^{-1}
^{113m}Cd	1.39×10^{1}	5.24	3.77×10^{1}	1.21×10^{1}
^{144}Ce	7.26×10^{1}	1.73×10^{1}	5.80×10^{3}	1.38×10^{3}
^{36}Cl	8.49×10^{-3}	3.48×10^{-3}	1.05×10^{-2}	4.99×10^{-3}
^{242}Cm	6.03	2.38	3.56×10^{1}	1.13×10^{1}
^{243}Cm	1.57×10^{1}	5.55	4.19×10^{1}	1.12×10^{1}
^{244}Cm	2.59×10^{3}	9.23×10^{2}	1.40×10^{4}	3.95×10^{3}
^{245}Cm	3.37×10^{-1}	9.07×10^{-2}	1.79	3.54×10^{-1}
^{246}Cm	1.16×10^{-1}	4.26×10^{-2}	1.21	2.97×10^{-1}
^{60}Co (crud)	1.69×10^{1}	5.66×10^{1}	3.26×10^{1}	1.09×10^{2}
^{134}Cs	4.08×10^{3}	1.31×10^{3}	4.05×10^{4}	1.16×10^{4}
^{135}Cs	3.74×10^{-1}	1.81×10^{-1}	6.34×10^{-1}	2.82×10^{-1}
^{137}Cs	6.04×10^{4}	2.41×10^{4}	1.05×10^{5}	3.87×10^{4}
^{154}Eu	2.36×10^{3}	7.73×10^{2}	6.15×10^{3}	1.79×10^{3}
^{155}Eu	4.94×10^{2}	1.92×10^{2}	1.80×10^{3}	6.25×10^{2}
^{55}Fe (crud)	2.09×10^{2}	9.84×10^{1}	7.45×10^{2}	3.50×10^{2}

Table 7. Boiling Water Reactor and Pressurized Water Reactor Radionuclide Inventories

Radionuclide	Representative PWR[a] (Ci/fuel assembly)	Representative BWR[a] (Ci/fuel assembly)	Bounding PWR[b] (Ci/fuel assembly)	Bounding BWR[b] (Ci/fuel assembly)
^{3}H	2.44×10^{2}	1.05×10^{2}	4.95×10^{2}	1.77×10^{2}
^{129}I	2.27×10^{-2}	9.22×10^{-3}	3.60×10^{-2}	1.36×10^{-2}
^{85}Kr	3.11×10^{3}	1.17×10^{3}	5.79×10^{3}	2.03×10^{3}
^{93m}Nb	3.44×10^{-1}	1.58×10^{-1}	3.94×10^{-1}	1.91×10^{-1}
^{94}Nb	6.31×10^{-5}	2.56×10^{-5}	1.02×10^{-4}	3.83×10^{-5}
^{237}Np	2.53×10^{-1}	8.74×10^{-2}	4.01×10^{-1}	1.33×10^{-1}
^{239}Np	2.30×10^{1}	8.63	6.00×10^{1}	1.93×10^{1}
^{231}Pa	3.00×10^{-5}	1.86×10^{-5}	4.18×10^{-5}	2.94×10^{-5}
^{107}Pd	8.65×10^{-2}	3.45×10^{-2}	1.60×10^{-1}	5.70×10^{-2}
^{147}Pm	6.36×10^{3}	2.11×10^{3}	2.29×10^{4}	7.46×10^{3}
^{144}Pr	7.26×10^{1}	1.73×10^{1}	5.80×10^{3}	1.38×10^{3}
^{238}Pu	2.77×10^{3}	1.02×10^{3}	6.80×10^{3}	2.11×10^{3}
^{239}Pu	1.80×10^{2}	5.41×10^{1}	1.83×10^{2}	5.36×10^{1}
^{240}Pu	3.20×10^{2}	1.27×10^{2}	4.01×10^{2}	1.48×10^{2}
^{241}Pu	5.20×10^{4}	1.57×10^{4}	8.00×10^{4}	2.25×10^{4}
^{242}Pu	1.68	7.08×10^{-1}	3.34	1.26
^{106}Ru	3.40×10^{2}	9.05×10^{1}	1.33×10^{4}	3.29×10^{3}
^{125}Sb	3.90×10^{2}	1.20×10^{2}	1.87×10^{3}	5.10×10^{2}
^{79}Se	4.75×10^{-2}	1.97×10^{-2}	7.35×10^{-2}	2.89×10^{-2}
^{151}Sm	2.45×10^{2}	6.73×10^{1}	3.19×10^{2}	8.22×10^{1}
^{126}Sn	3.97×10^{-1}	1.61×10^{-1}	6.83×10^{-1}	2.52×10^{-1}
^{90}Sr	4.10×10^{4}	1.66×10^{4}	6.52×10^{4}	2.52×10^{4}
^{99}Tc	9.32	3.88	1.34×10^{1}	5.35
^{230}Th	6.45×10^{-5}	3.06×10^{-5}	3.33×10^{-5}	2.05×10^{-5}
^{232}U	2.44×10^{-2}	8.74×10^{-3}	5.97×10^{-2}	2.00×10^{-2}
^{233}U	2.46×10^{-5}	0.00	2.42×10^{-5}	0.00
^{234}U	6.01×10^{-1}	2.39×10^{-1}	5.21×10^{-1}	2.26×10^{-1}
^{235}U	7.66×10^{-3}	2.11×10^{-3}	3.28×10^{-3}	9.40×10^{-4}
^{236}U	1.81×10^{-1}	7.45×10^{-2}	2.23×10^{-1}	9.55×10^{-2}
^{238}U	1.47×10^{-1}	6.24×10^{-2}	1.42×10^{-1}	6.07×10^{-2}
^{90}Y	4.10×10^{4}	1.66×10^{4}	6.53×10^{4}	2.52×10^{4}
^{93}Zr	8.34×10^{-1}	3.49×10^{-1}	1.25	5.01×10^{-1}

NOTES: Ci = curies.

^{144}Pr is treated as implicit progeny of ^{144}Ce by GENII; therefore it is not used in the calculation of doses.

Sources: [a] Reference 2.2.31, Table 20
[b] Reference 2.2.31, Table II-3 .

6.1.2.3 High-Level Waste Glass Inventory

HLW forms from the Savannah River Site, Hanford Site, West Valley Demonstration Project, and Idaho National Laboratory are received at the repository in sealed canisters inside transportation casks. The HLW maximum per canister inventory from the four sites is provided in Table 8 for the year 2017, except for Idaho National Laboratory HLW, which is provided for year 2035. These inventories are from Reference 2.2.33, Table 18.

Table 8. Maximum Radionuclide Inventory per High-Level Waste Glass Canister at 2017

Nuclide	Radioactivity (Ci)			
	HS	SRS	WVDP	INL[a]
^{225}Ac	1.40×10^{-6}	1.39×10^{-4}	9.47×10^{-4}	4.26×10^{-17}
^{227}Ac	1.72×10^{-4}	2.09×10^{-8}	1.16×10^{-1}	1.85×10^{-17}
^{228}Ac	9.38×10^{-5}	9.87×10^{-4}	1.47×10^{-2}	2.33×10^{-14}
^{241}Am	4.61×10^{2}	3.38×10^{2}	4.97×10^{2}	1.41×10^{1}
^{242}Am	—	7.36×10^{-2}	2.46	6.32×10^{-5}
^{242m} Am	—	7.39×10^{-2}	2.47	—
^{243}Am	9.98×10^{-2}	1.37	3.27	1.05×10^{-4}
^{217}At	1.40×10^{-6}	1.39×10^{-4}	9.47×10^{-4}	4.26×10^{-17}
^{137m}Ba	5.62×10^{4}	4.15×10^{4}	1.84×10^{4}	1.14×10^{4}
^{210}Bi	2.51×10^{-6}	5.99×10^{-9}	5.17×10^{-7}	1.17×10^{-12}
^{211}Bi	1.72×10^{-4}	2.09×10^{-8}	1.16×10^{-1}	1.69×10^{-21}
^{212}Bi	4.85×10^{-4}	1.07×10^{-3}	4.74×10^{-2}	9.20×10^{-12}
^{213}Bi	1.40×10^{-6}	1.39×10^{-4}	9.47×10^{-4}	4.26×10^{-17}
^{214}Bi	1.29×10^{-5}	4.60×10^{-8}	1.95×10^{-6}	4.76×10^{-6}
^{14}C	1.06×10^{-7}	—	1.30	8.26×10^{-5}
^{113}Cd	1.47×10^{-9}	2.62×10^{-11}	—	1.48×10^{-9}
^{113m}Cd	1.91×10^{1}	—	2.07	—
^{142}Ce	1.17×10^{-5}	—	1.43×10^{-5}	—
^{144}Ce	—	4.74×10^{-4}	8.90×10^{-14}	—
^{249}Cf	—	2.29×10^{-2}	—	—
^{251}Cf	—	1.84×10^{-2}	—	—
^{242}Cm	6.54×10^{-6}	6.10×10^{-2}	2.04	7.71×10^{-5}
^{243}Cm	3.73×10^{-2}	3.31×10^{-1}	2.53×10^{-1}	3.36×10^{-6}
^{244}Cm	3.27×10^{-1}	2.97×10^{2}	2.57×10^{1}	7.71×10^{-5}
^{245}Cm	—	2.42×10^{-2}	3.19×10^{-3}	2.81×10^{-8}
^{246}Cm	—	2.90×10^{-2}	3.66×10^{-4}	6.61×10^{-10}
^{247}Cm	—	2.20×10^{-2}	—	2.37×10^{-16}
^{248}Cm	—	—	—	7.16×10^{-17}
^{60}Co	4.14×10^{-1}	4.91×10^{1}	6.63×10^{-1}	3.57×10^{-2}
^{134}Cs	2.12×10^{1}	6.48	4.09×10^{-3}	3.64×10^{-5}
^{135}Cs	—	2.16×10^{-1}	1.09	2.53×10^{-1}
^{137}Cs	5.95×10^{4}	4.39×10^{4}	1.95×10^{4}	1.21×10^{4}
^{152}Eu	3.45	—	3.28×10^{-1}	—
^{154}Eu	4.50	1.85×10^{2}	4.72×10^{1}	6.65
^{155}Eu	1.16×10^{2}	1.52×10^{-1}	1.67	3.75×10^{-2}
^{55}Fe	—	—	2.49×10^{-3}	—
^{221}Fr	1.40×10^{-6}	1.39×10^{-4}	9.47×10^{-4}	4.26×10^{-17}
^{223}Fr	2.37×10^{-6}	2.88×10^{-10}	1.60×10^{-3}	2.55×10^{-19}
^{152}Gd	5.22×10^{-14}	—	2.24×10^{-14}	—
^{3}H	—	—	6.54×10^{-2}	4.30
^{129}I	—	3.22×10^{-4}	7.64×10^{-4}	1.65×10^{-2}
^{40}K	1.07×10^{-5}	2.77×10^{-5}	7.17×10^{-5}	—
^{138}La	3.98×10^{-7}	3.04×10^{-8}	—	—
^{93m}Nb	3.30	2.33×10^{-1}	2.33	1.43
^{94}Nb	—	—	—	1.60×10^{-5}
^{144}Nd	4.12×10^{-9}	1.43×10^{-15}	6.77×10^{-10}	—
^{59}Ni	4.96×10^{-1}	8.44×10^{-1}	1.00	—

Table 8. Maximum Radionuclide Inventory per High-Level Waste Glass Canister at 2017

Nuclide	Radioactivity (Ci)			
	HS	SRS	WVDP	INL[a]
^{63}Ni	4.89×10^{1}	7.47×10^{1}	6.69×10^{1}	—
^{236}Np	—	—	8.97×10^{-2}	—
^{237}Np	2.51×10^{-1}	2.99×10^{-2}	1.53×10^{-1}	2.75×10^{-2}
^{238}Np	—	3.33×10^{-4}	1.11×10^{-2}	—
^{239}Np	9.98×10^{-2}	1.37	3.27	1.11×10^{-5}
^{231}Pa	4.24×10^{-4}	1.43×10^{-7}	1.44×10^{-1}	1.65×10^{-12}
^{233}Pa	2.51×10^{-1}	2.99×10^{-2}	1.53×10^{-1}	2.66×10^{-4}
^{234}Pa	1.31×10^{-5}	6.16×10^{-5}	4.33×10^{-6}	1.62×10^{-10}
^{234m}Pa	1.01×10^{-2}	4.74×10^{-2}	3.33×10^{-3}	3.55×10^{-7}
^{209}Pb	1.40×10^{-6}	1.39×10^{-4}	9.47×10^{-4}	1.27×10^{-17}
^{210}Pb	2.51×10^{-6}	5.99×10^{-9}	5.16×10^{-7}	6.77×10^{-11}
^{211}Pb	1.72×10^{-4}	2.09×10^{-8}	1.16×10^{-1}	1.69×10^{-21}
^{212}Pb	4.85×10^{-4}	1.07×10^{-3}	4.74×10^{-2}	1.40×10^{-11}
^{214}Pb	1.29×10^{-5}	4.60×10^{-8}	1.95×10^{-6}	4.76×10^{-6}
^{107}Pd	—	1.31×10^{-3}	1.04×10^{-1}	—
^{146}Pm	—	—	1.34×10^{-3}	—
^{147}Pm	—	1.53×10^{2}	2.55×10^{-1}	2.97×10^{-2}
^{210}Po	2.31×10^{-6}	5.29×10^{-9}	4.87×10^{-7}	5.61×10^{-16}
^{211}Po	4.74×10^{-7}	5.74×10^{-11}	3.20×10^{-4}	4.65×10^{-24}
^{212}Po	3.11×10^{-4}	6.87×10^{-4}	3.04×10^{-2}	5.90×10^{-12}
^{213}Po	1.37×10^{-6}	1.36×10^{-4}	9.27×10^{-4}	4.17×10^{-17}
^{214}Po	1.29×10^{-5}	4.60×10^{-8}	1.95×10^{-6}	4.75×10^{-6}
^{215}Po	1.72×10^{-4}	2.09×10^{-8}	1.16×10^{-1}	1.69×10^{-21}
^{216}Po	4.85×10^{-4}	1.07×10^{-3}	4.74×10^{-2}	8.11×10^{-11}
^{218}Po	1.29×10^{-5}	4.60×10^{-8}	1.95×10^{-6}	4.76×10^{-6}
^{144}Pr	—	4.74×10^{-4}	8.90×10^{-14}	—
^{144m}Pr	—	6.63×10^{-6}	1.25×10^{-15}	—
^{236}Pu	—	—	9.98×10^{-3}	—
^{238}Pu	2.17	9.10×10^{2}	3.36×10^{1}	9.99×10^{1}
^{239}Pu	2.13×10^{1}	1.74×10^{1}	8.75	2.01
^{240}Pu	6.42	8.78	6.35	1.75
^{241}Pu	8.70×10^{1}	5.17×10^{2}	1.13×10^{2}	2.15×10^{1}
^{242}Pu	9.91×10^{-4}	2.14×10^{-2}	8.17×10^{-3}	3.80×10^{-3}
^{243}Pu	—	2.20×10^{-2}	—	1.71×10^{-16}
^{223}Ra	1.72×10^{-4}	2.09×10^{-8}	1.16×10^{-1}	1.69×10^{-21}
^{224}Ra	4.85×10^{-4}	1.07×10^{-3}	4.74×10^{-2}	8.11×10^{-11}
^{225}Ra	1.40×10^{-6}	1.39×10^{-4}	9.47×10^{-4}	4.89×10^{-15}
^{226}Ra	1.29×10^{-5}	4.60×10^{-8}	1.95×10^{-6}	7.16×10^{-5}
^{228}Ra	9.38×10^{-5}	9.87×10^{-4}	1.47×10^{-2}	6.21×10^{-14}
^{87}Rb	7.42×10^{-6}	—	—	—
^{102}Rh	—	—	—	2.21×10^{-8}
^{106}Rh	1.37×10^{-4}	4.40×10^{-3}	5.14×10^{-10}	—
^{219}Rn	1.72×10^{-4}	2.09×10^{-8}	1.16×10^{-1}	1.69×10^{-21}
^{220}Rn	4.85×10^{-4}	1.07×10^{-3}	4.74×10^{-2}	8.11×10^{-11}
^{222}Rn	1.29×10^{-5}	4.60×10^{-8}	1.95×10^{-6}	4.76×10^{-6}
^{106}Ru	1.37×10^{-4}	4.40×10^{-3}	5.14×10^{-10}	—
^{125}Sb	3.16	9.17	2.85×10^{-2}	1.14×10^{-3}

Table 8. Maximum Radionuclide Inventory per High-Level Waste Glass Canister at 2017

Nuclide	Radioactivity (Ci)			
	HS	SRS	WVDP	INL[a]
^{126}Sb	8.04×10^{-2}	1.10×10^{-1}	1.38×10^{-1}	7.61×10^{-4}
^{126m}Sb	5.74×10^{-1}	7.83×10^{-1}	9.85×10^{-1}	2.59×10^{-1}
^{79}Se	9.15×10^{-2}	5.34×10^{-1}	5.70×10^{-1}	—
^{146}Sm	—	—	3.14×10^{-10}	—
^{147}Sm	—	5.12×10^{-8}	1.61×10^{-9}	2.02×10^{-16}
^{151}Sm	3.43×10^{3}	1.49×10^{2}	6.49×10^{2}	—
^{121}Sn	—	1.33	3.48×10^{-2}	—
^{121m}Sn	—	1.71	4.49×10^{-2}	—
^{126}Sn	5.74×10^{-1}	7.83×10^{-1}	9.85×10^{-1}	2.59×10^{-1}
^{90}Sr	6.21×10^{4}	2.67×10^{4}	1.67×10^{4}	1.16×10^{4}
^{99}Tc	2.31×10^{1}	9.16	8.72	9.92
^{123}Te	1.07×10^{-9}	—	—	—
^{125m}Te	7.72×10^{-1}	2.24	6.95×10^{-3}	1.19×10^{-6}
^{227}Th	1.70×10^{-4}	2.06×10^{-8}	1.15×10^{-1}	6.47×10^{-20}
^{228}Th	4.84×10^{-4}	1.07×10^{-3}	4.72×10^{-2}	2.31×10^{-9}
^{229}Th	1.40×10^{-6}	1.39×10^{-4}	9.47×10^{-4}	5.53×10^{-13}
^{230}Th	9.41×10^{-7}	1.35×10^{-5}	2.18×10^{-4}	1.06×10^{-9}
^{231}Th	5.56×10^{-4}	6.64×10^{-4}	3.72×10^{-4}	1.44×10^{-4}
^{232}Th	1.50×10^{-4}	1.40×10^{-3}	1.55×10^{-2}	4.96×10^{-10}
^{234}Th	1.01×10^{-2}	4.74×10^{-2}	3.33×10^{-3}	3.55×10^{-7}
^{206}Tl	3.32×10^{-12}	—	6.82×10^{-13}	1.55×10^{-18}
^{207}Tl	1.72×10^{-4}	2.08×10^{-8}	1.16×10^{-1}	1.69×10^{-21}
^{208}Tl	1.74×10^{-4}	3.85×10^{-4}	1.70×10^{-2}	3.31×10^{-12}
^{209}Tl	2.93×10^{-8}	2.91×10^{-6}	1.99×10^{-5}	8.94×10^{-19}
^{232}U	4.40×10^{-4}	2.69×10^{-4}	3.24×10^{-2}	6.15×10^{-6}
^{233}U	2.10×10^{-3}	5.59×10^{-2}	9.03×10^{-2}	6.06×10^{-6}
^{234}U	1.46×10^{-2}	7.23×10^{-2}	2.62×10^{-2}	1.11×10^{-1}
^{235}U	5.56×10^{-4}	6.64×10^{-4}	3.72×10^{-4}	6.57×10^{-4}
^{236}U	1.18×10^{-3}	3.67×10^{-3}	1.08×10^{-3}	1.71×10^{-3}
^{237}U	2.08×10^{-3}	1.24×10^{-2}	2.70×10^{-3}	1.96×10^{-5}
^{238}U	1.01×10^{-2}	4.74×10^{-2}	3.33×10^{-3}	3.27×10^{-5}
^{50}V	2.35×10^{-14}	—	—	—
^{90}Y	6.21×10^{4}	2.67×10^{4}	1.67×10^{4}	1.16×10^{4}
^{93}Zr	5.76	3.86×10^{-1}	2.58	—
Total	2.44×10^{5}	1.42×10^{5}	7.28×10^{4}	4.69×10^{4}

NOTES: [a]Radionuclide inventory for INL HLW canister is provided for year 2035.
HS = Hanford Site, INL = Idaho National Laboratory, SRS = Savannah River Site, WVDP = West Valley Demonstration Project.

Source: Reference 2.2.33, Table 18

6.1.2.4 Potential Subsurface Facility Releases

Under normal operations of the Subsurface Facility, there are three mechanisms with potential to generate airborne releases of radioactive materials, which are:

- Neutron activation of ventilating air inside the emplacement drifts
- Neutron activation of silica dust generated from host rock in the emplacement drifts.
- Re-suspension of emplaced waste package surface contamination.

Annual releases (Table 9) are based on the postulated activation of air and silica dust in the subsurface facilities and resuspension of waste package surface contamination during normal operations (Reference 2.2.34, Table II-2, Table III-3, and Table III-4). Although shown in Table 9, nitrogen-16 (^{16}N) is not considered in the dose assessment because of its 7.13 second half-life, (Reference 2.2.35, p. 41), which is very short when compared to the plume travel time from the release point to the receptor locations.

The releases from the subsurface exhaust shafts during normal operations are at ground level (Reference 2.2.23, Section 3.2.2).

Table 9. Annual Releases from Subsurface Facility Normal Operation

Normal Operations Release (Ci/yr)	
Waste Package Surface Contamination[a]	
^{241}Am	4.9×10^{-5}
^{243}Am	5.5×10^{-7}
^{243}Cm	2.6×10^{-7}
^{244}Cm	3.4×10^{-5}
^{60}Co (crud)	2.9×10^{-3}
^{60}Co	7.8×10^{-6}
^{137}Cs	6.8×10^{-3}
^{154}Eu	1.7×10^{-5}
^{63}Ni	6.3×10^{-6}
^{147}Pm	3.0×10^{-6}
^{238}Pu	5.7×10^{-5}
^{239}Pu	4.4×10^{-6}
^{240}Pu	7.9×10^{-6}
^{241}Pu	6.2×10^{-4}
^{151}Sm	5.3×10^{-6}
^{90}Sr	6.8×10^{-4}
^{90}Y	6.8×10^{-4}
Activated Air[b]	
^{41}Ar	1.5×10^{1}
^{16}N	5.8
Activated Dust[c]	
^{28}Al	4.0×10^{-3}
^{55}Fe	8.2×10^{-5}
^{42}K	8.0×10^{-4}
^{16}N	2.1×10^{-5}
^{24}Na	3.7×10^{-3}
^{31}Si	5.2×10^{-4}

Source: Reference 2.2.34, [a]Table II-2, [b]Table III-1 (as modified by CACN001 to Reference 2.2.34), and [c]Table III-4 (as modified by CACN001 to Reference 2.2.34)

6.1.2.5 Potential Aging Facility Releases

Airborne effluents from the Aging Facility under normal operations are the surface contamination resuspended from TAD canisters and DPCs inside aging overpacks. The nonfixed (removable) radioactive surface contamination is based on 1×10^{-4} μCi/cm^2 for beta-gamma emitters and low-toxicity alpha emitters and 1×10^{-5} μCi/cm^2 for all other alpha emitters. To simplify the calculation, ^{60}Co is used to bound the dose contribution of beta-gamma emitters and low-toxicity alpha emitters and ^{241}Am is used to bound the dose contribution of all other alpha emitters. The release rate for ^{60}Co is 2.89×10^{-2} Ci/yr and the release rate for ^{241}Am is 2.89×10^{-3} Ci/yr (Reference 2.2.36, Section 3.2.1 and Table 12).

6.1.3 Airborne Release Fractions and Respirable Fractions

6.1.3.1 Commercial SNF and HLW Airborne Release Fractions and Respirable Fractions

ARFs and RFs for both low burnup and high burnup (> 45 GWd/MTU) commercial SNF are shown in Table 10. ARFs and RFs for low-burnup intact and failed commercial SNF are used for normal operations. If oxidation can occur during normal operations, the low-burnup fuel oxidation ARF and RF values are used. For Category 1 and Category 2 event sequences (including post-accident oxidation), the ARFs and RFs for high burnup fuel, which are bounding are used. Table 10 also shows the ARFs and RFs for use with HLW sources. The radionuclide inventories for representative PWR and BWR SNF assemblies are evaluated at a burnup of 50 GWd/MTU (Table 6). However, using the release fractions for low-burnup fuel is appropriate because the fuel characteristics of the representative fuel provide margin to the fuel inventory in that the average PWR assembly from the full inventory is 41.70 GWd/MTU (Reference 2.2.37, Section 5.5) and the average BWR assembly from the full inventory is 33.6 GWd/MTU (Reference 2.2.38, Section 5.5.3).

Table 10. Airborne Release Fractions and Respirable Fractions for Commercial SNF and HLW

Radionuclides	Airborne Release Fraction / Respirable Fraction				
	Low Burnup Fuel		High Burnup Fuel		High Level Waste
	Intact & Failed Commercial SNF Assembly Cladding Burst	Fuel Oxidation After an Accident	Intact & Failed Commercial SNF Assembly Cladding Burst	Fuel Oxidation After an Accident	
^{3}H	0.3 / 1	0.7 / 1	0.3 / 1	0.7 / 1	NA
^{85}Kr	0.3 / 1	0.3 / 1	0.3 / 1	0.3 / 1	NA
^{129}I	0.3 / 1	0.3 / 1	0.3 / 1	0.3 / 1	7×10^{-3} / 0.01
All Cs	2×10^{-4} / 1	2×10^{-3} / 1	2×10^{-3} / 1	2×10^{-3} / 1	7×10^{-3} / 0.01
^{90}Sr	3×10^{-5} / 5×10^{-3}	2×10^{-3} / 0.1	3×10^{-5} / 1	2×10^{-3} / 1	7×10^{-3} / 0.01
^{106}Ru	2×10^{-4} / 1	2×10^{-3} / 1	2×10^{-3} / 1	2×10^{-3} / 1	7×10^{-3} / 0.01
Fuel Fines	3×10^{-5} / 5×10^{-3}	2×10^{-3} / 0.1	3×10^{-5} / 1	2×10^{-3} / 1	7×10^{-3} / 0.01
Crud (^{60}Co & ^{55}Fe)	0.015 / 1	NA	0.015 / 1	NA	NA

NOTES: SNF = spent nuclear fuel; HLW = high-level waste.

Source: Reference 2.2.32, Table 18.

6.1.3.2 Fire Event Release Fractions

DAW, spent resins and pool filters are available for combustion during a LLWF fire event (Assumption 3.2.12). The bounding ARF and RF for burning combustible packaged contaminated waste of 5×10^{-4} and 1.0, respectively (Reference 2.2.21, p. 5-13) are used for the DAW in drums, spent resins and pool filters in HICs. The bounding ARF and RF for burning uncontained combustible contaminated waste of 1×10^{-2} and 1.0, respectively (Reference 2.2.21, p. 5-15) is used for DAW in bags.

The bounding ARF and RF for heat-induced damage to a HEPA are 1×10^{-4} and 1.0, respectively (Reference 2.2.21, p. 5-30).

6.1.3.3 Seismic Event Release Fractions

ARF and RF values from DOE-HDBK-3010-94 (Reference 2.2.21) are selected for a large seismic event based on values for free-fall spills. Free-fall spill release fractions are used for seismic event releases because the collapse of structures, components, or falling debris onto materials at risk would be equivalent to a free-fall of the material onto an unyielding surface. The development of release fractions considers multiple seismic release effects including shock vibration, structure collapse, and debris turbulence.

As stated in Section 4.4.3, the seismic event is postulated to result in the failure of the WHF HEPA filters, ducting, dampers, LLWF DAW, pool filters, liquid waste tanks, and spent resin in a HIC. Therefore, release fractions are used for HEPA filters, powders, and liquid tanks.

HEPA Filters – During a seismic event, accumulated radioactivity on HEPA filters could be released if the HEPA filtration system suffers a severe shock or vibration. The seismic event is analyzed for the housing holding the filter banks being compromised and the material made airborne both in and out of the housing. The fragmentation of the HEPA filter media by the vibration and shock appears to be the principal mode for particle generation (Reference 2.2.21, Section 5.4.4). In addition, accumulated radioactivity inside the exhaust ducting could be released if the structural integrity of the ducting system is compromised during the seismic event. When HEPA filters and ducting undergo a free-fall, a part of the accumulated radioactivity would be suspended in air.

An ARF of 1×10^{-2} and an RF of 1 for an unenclosed filter media are conservatively used because they are higher than the ARF and RF for enclosed filter media (Reference 2.2.21, Section 5.4.4).

Powders – Reference 2.2.21 (Section 7.3.10.2.C) provides ARFs and RFs for three release effects during a large seismic event. The first is shock vibration of bulk-powder for which the ARF is 1×10^{-3} and the RF is 0.1 for contamination in clumps and piles (Reference 2.2.21, Section 4.4.3.3.1). The second is a free-fall spill as structures and components collapse, for which the bounding ARF is 2×10^{-3} and the RF is 0.3 for drop heights greater than 3 m (Reference 2.2.21, Section 4.4.3.1.2). The final phenomenon is turbulence generated by the impact debris for which the bounding ARF is 1×10^{-2} and the RF is 0.2 (Reference 2.2.21, Section 4.4.3.3.2). The combined ARF for all three release effects is:

$$ARF = 1 \times 10^{-3} + 2 \times 10^{-3} + 1 \times 10^{-2} = 1.3 \times 10^{-2}$$

The combined RF, based on weighting each by its corresponding ARF is:

$$RF = \frac{\left(1 \times 10^{-3} \times 0.1\right) + \left(2 \times 10^{-3} \times 0.3\right) + \left(1 \times 10^{-2} \times 0.2\right)}{1.3 \times 10^{-2}} = 0.21$$

Liquid Tank – Release of liquids from a tank is bounded by a free-fall spill followed by evaporation and resuspension of the surface contamination. The bounding ARF and RF for a free-fall spill of a solution are 2×10^{-4} and 0.5 for aqueous solutions with a density near 1 (Reference 2.2.21, Section 3.2.3).

The contamination remaining following evaporation is conservatively treated as a loose powder. The resuspension rate of a loose powder exposed to an external wind is 4×10^{-7}/hr (Reference 2.2.21, Section 3.2.4.5). Dose consequences are based on a 30 day exposure period (Assumption 3.2.3), therefore the resuspension ARF is:

$$ARF = 4 \times 10^{-7}\, hr^{-1} \times 30\, days \times 24\, hr/day = 3 \times 10^{-4} \text{ (rounded)}$$

A bounding RF of 1 is used.

The combined ARF for both release effects is:

$$ARF = 2 \times 10^{-4} + 3 \times 10^{-4} = 5 \times 10^{-4}$$

The combined RF based on weighting each by its corresponding ARF is:

$$RF = \frac{\left(2 \times 10^{-4} \times 0.5\right) + \left(3 \times 10^{-4} \times 1\right)}{5 \times 10^{-4}} = 0.8$$

Table 11 provides a summary of the ARFs and RFs used for the seismic event.

Table 11. Seismic Event Airborne Release Fractions and Respirable Fractions

	Airborne Release Fraction	Respirable Fraction
HEPA Filters	1.0×10^{-2}	1.0
Powders	1.3×10^{-2}	0.21
Liquid Tank	5×10^{-4}	0.8

6.1.4 Leak Path Factors

6.1.4.1 HEPA Filter Leak Path Factor

For a two-stage HEPA filtration system, a $(LPF)_{HEPA}$ of 1×10^{-4} is used (Reference 2.2.22, Section 7.1).

6.1.4.2 Transportation Cask, Waste Package, and Canister Leak Path Factors

A LPF of 0.1 is used for event sequences involving transportation casks, waste packages, DPCs, TAD canisters and HLW canisters (Reference 2.2.22, Section 7.3).

6.1.4.3 Fuel Pool Leak Path Factors

The leak path factors for the nuclides potentially released in the fuel pool during event sequences are listed in Table 12 (Reference 2.2.22, Section 7.4).

Table 12. Spent Fuel Pool Leak Path Factors

Group	Leak Path Factor (LPF)
I-131	0.005
Kr-85	1
Other Noble Gases (Xe, Kr)	1
Other Halogens (I)	0.005
Other Halogens (Br)	1
Alkali Metals (Cs, Rb)	0

Source: Reference 2.2.22, Section 7.4

6.1.5 Potential Radiation Worker Dose Results

6.1.5.1 Radiation Worker Doses from Airborne Releases

Doses to radiation workers from airborne releases were determined for the releases from the WHF, subsurface releases due to activation of air and silica dust and resuspension of waste package surface contamination, and resuspension of surface contamination from aging casks on the aging pads to workers located throughout the site. Radiation workers located at the WHF received the highest dose from airborne releases, which are shown in Table 13 (Reference 2.2.36, Table 23).

Table 13. Airborne Release Radiation Worker Dose Results

Facility Number	Facility Name	Total Effective Dose Equivalent (mrem/yr)	Total Organ Dose Equivalent[a] (mrem/yr)	Skin (mrem/yr)	Lens (mrem/yr)
60	Canister Receipt and Closure Facility-1	2.69×10^{-1}	6.56	1.80	2.07
70	Canister Receipt and Closure Facility-2	2.01×10^{-1}	6.61	5.63×10^{-1}	7.63×10^{-1}
80	Canister Receipt and Closure Facility-3	1.94×10^{-1}	6.73	3.88E-01	5.82×10^{-1}
200	Receipt Facility	2.40×10^{-1}	6.56	1.28	1.52
50	Wet Handling Facility	1.38×10^{1}	2.12×10^{2}	1.52×10^{2}	1.66×10^{2}
51A	Initial Handling Facility	1.24×10^{-1}	2.87	8.31×10^{-1}	9.55×10^{-1}
160	Low-Level Waste Facility	2.46×10^{-1}	5.21	1.97	2.21
17RE	Aging Pad R – East	2.68×10^{-1}	9.35	5.78×10^{-1}	8.46×10^{-1}
17RW	Aging Pad R - West	1.40×10^{-1}	4.08	5.86×10^{-1}	7.26×10^{-1}
17PN	Aging Pad P – North	1.92×10^{-1}	6.64	3.91×10^{-1}	5.83×10^{-1}
17PS	Aging Pad P – South	2.78×10^{-1}	9.98	4.70×10^{-1}	7.48×10^{-1}
IS2	Intake Shaft 2	1.53×10^{-1}	1.11	1.12×10^{-1}	2.65×10^{-1}
IS3	Intake Shaft 3	3.16×10^{-2}	4.59×10^{-1}	2.96×10^{-2}	6.13×10^{-2}
IS4	Intake Shaft 4	3.95×10^{-2}	4.81×10^{-1}	3.74×10^{-2}	7.68×10^{-2}
NC	North Construction Portal	3.34×10^{-2}	8.48×10^{-1}	1.35×10^{-1}	1.69×10^{-1}
NP	North Portal	1.18×10^{-1}	2.57	8.44×10^{-1}	9.61×10^{-1}
SP	South Portal	7.52×10^{-2}	1.42	5.83×10^{-1}	6.58×10^{-1}
220	Heavy Equipment Maintenance Facility	1.44×10^{-1}	3.09	1.08	1.22
240	Central Communications Control Facility	1.16×10^{-1}	3.13	5.73×10^{-1}	6.89×10^{-1}
230	Warehouse and Non-Nuclear Receipt Facility	1.06×10^{-1}	3.01	4.49×10^{-1}	5.55×10^{-1}
25A	Utilities Facility	1.01×10^{-1}	3.59	1.07×10^{-1}	2.08×10^{-1}
620	Administration Facility	2.34×10^{-1}	4.68	2.08×10^{-1}	4.41×10^{-1}
71A	Craft Shops	2.45×10^{-1}	5.15	2.27×10^{-1}	4.72×10^{-1}
30A	Central Security Station	1.04×10^{-1}	3.69	1.12×10^{-1}	2.16×10^{-1}
30B	Cask Receipt Security Station	9.38×10^{-2}	2.48	4.64×10^{-1}	5.58×10^{-1}
30C	North Perimeter Security Station	1.86×10^{-1}	2.82	4.11×10^{-1}	5.97×10^{-1}
27A	Switchyard	1.63×10^{-1}	3.35	1.32	1.48
780	Lower Muck Yard	2.00×10^{-1}	3.33	2.60×10^{-1}	4.60×10^{-1}
33A	Rail Buffer Area	1.01×10^{-1}	2.72	4.90×10^{-1}	5.91×10^{-1}
33B	Truck Buffer Area	9.50×10^{-2}	2.55	4.53×10^{-1}	5.48×10^{-1}

NOTE: [a]Highest organ dose is to the bone surface.

Source: Reference 2.2.36, Table 23 (as modified by CACN002 to Reference 2.2.36).

6.1.5.2 Radiation Worker Dose from Direct Radiation from Sources within Facilities

Table 14 summarizes the maximum radiation worker dose from direct radiation while performing their duties in each of the facilities based on the expected nominal throughputs during normal operations (Reference 2.2.39, Section 3.1.2).

Table 14. Maximum Radiation Worker Dose from Direct Radiation

Facility	Worker Group	Individual Worker Dose (mrem/yr)
Receipt Facility	Operator	1,300
	Health Physics Technician	800

Sources: Reference 2.2.39, Table 3

6.1.5.3 Dose from Direct Radiation and Airborne Releases at Facility Locations in the GROA

The direct radiation from contained sources external to facilities is from the TAD canisters and DPCs in aging overpacks located at the Aging Facility and from transportation casks located at the rail car and truck buffer areas. Airborne releases are the total from all surface and subsurface facility normal operation releases. Radiation dose to onsite workers or public due to direct radiation from contained sources and airborne releases is calculated in Reference 2.2.39. Table 6 of Reference 2.2.39 is duplicated herein (Table 15) and shows the annual dose for locations throughout the GROA. Per Reference 2.2.39, doses during movement of waste outside facilities are excluded.

Table 15. Normal Operation Direct and Airborne Doses At Facility Locations in the GROA

Area No.[a]	GROA Location	Direct Radiation TEDE[b, d] (mrem/yr)	Airborne Release TEDE[c, d] (mrem/yr)	Total TEDE (direct + airborne) (mrem/yr)
17P	Aging Pad 17P	1.0×10^{1}	2.8×10^{-1}	1.0×10^{1}
51A	Initial Handling Facility	3.7	1.2×10^{-1}	3.8
160	Low-Level Waste Facility	4.2×10^{-1}	2.5×10^{-1}	6.7×10^{-1}
050	Wet Handling Facility	4.0×10^{-1}	1.4×10^{1}	1.4×10^{1}
200	Receipt Facility	4.7×10^{-1}	2.4×10^{-1}	7.1×10^{-1}
060	Canister Receipt and Closure Facility 1	1.2×10^{-1}	2.7×10^{-1}	3.9×10^{-1}
070	Canister Receipt and Closure Facility 2	1.5	2.0×10^{-1}	1.7
080	Canister Receipt and Closure Facility 3	1.8	1.9×10^{-1}	2.0
220	Heavy Equipment Maintenance Facility	1.5	1.4×10^{-1}	1.7
240	Central Communication Control Facility	7.0	1.2×10^{-1}	7.1
230	Warehouse and Non-Nuclear Receipt Facility	1.7×10^{1}	1.1×10^{-1}	1.7×10^{1}
25A	Utility Facility	5.3×10^{-1}	1.0×10^{-1}	6.3×10^{-1}
620	Administration Facility	6.9×10^{-2}	2.3×10^{-1}	3.0×10^{-1}
71A	Craft Shop	1.1×10^{-1}	2.5×10^{-1}	3.6×10^{-1}
30A	Central Security Station	8.2×10^{-2}	1.0×10^{-1}	1.9×10^{-1}
30B	Cask Receipt Security Station	2.2	9.4×10^{-2}	2.3
30C	North Perimeter Security Station	9.7	1.9×10^{-1}	9.9
27A	Switchyard	3.6×10^{1}	1.6×10^{-1}	3.6×10^{1}
780	Lower Muck Yard	7.8×10^{1}	2.0×10^{-1}	7.8×10^{1}
33A	Railcar Buffer Area	NA	1.0×10^{-1}	1.0×10^{-1}
33B	Truck Buffer Area	NA	9.5×10^{-2}	9.4×10^{-2}

NOTES: [a]Areas are shown in References 2.2.40 and 2.2.41
[b]Direct radiation doses are the total external doses from aging overpacks on the aging pads (17P and 17R), and transportation casks in 33A (rail buffer area) and 33B (truck buffer area)
[c]Airborne release doses are the total from all surface and subsurface facility normal operation releases
[d]Doses are based on 2,000 hr/yr occupancy.

Source: Reference 2.2.39, Table 6 (as modified by CACN002 to Reference 2.2.39).

6.1.6 Other Inputs

6.1.6.1 Breathing Rates

For acute releases, Regulatory Guide 1.183 (Reference 2.2.42, Section 4.1.3) allows three different breathing rates. For the first 8 hours, the breathing rate for people offsite is 3.5×10^{-4} m^3/s (30.2 m^3/day). From 8 to 24 hours following the accident, the breathing rate is 1.8×10^{-4} m^3/s (15.6 m^3/day). After that and until the end of the accident, the breathing rate is 2.3×10^{-4} m^3/s (19.9 m^3/day). For chronic releases, the breathing rates are obtained from Reference 2.2.10, Table 93 and Section 7.5.4. Per Assumption 3.2.13, the breathing rate for the offsite public not in the general environment or onsite worker is the same as the breathing rate for an acute release. Table 16 provides a summary of the breathing rates used in the analysis.

Table 16. Breathing Rates

Individual	Condition	Period	Inhalation Rate (m^3/day) (Mean Value)	Inhalation Rate (m^3/day) Distribution and Value)
Offsite Public in the General Environment	Chronic	Continuous	21.7	Normal distribution: Mean = 21.7 Standard Deviation = 0.12 Min = 21.3 and Max = 22.1
	Acute	0 – 8 hr	30.2	Fixed value
		8 – 24 hrs	15.6	Fixed value
		> 24 hrs	19.9	Fixed value
Offsite Public Not within the General Environment, Onsite Public, or Radiation Worker	Chronic	Continuous	30.2	Fixed value
	Acute	Continuous	30.2	Fixed value

NOTE: Chronic inhalation rates are for normal operations and resuspension inhalation. Acute inhalation rates are for Category 1 and Category 2 event sequences.

Source: Reference 2.2.10, Table 93 and Section 7.5.4.

6.1.6.2 Dose Coefficients

Doses are determined in this calculation with the GENII code discussed in Section 4.3.3 for offsite releases using ingestion and inhalation dose coefficients from ICRP Publication 72, *Age-Dependent Doses to Members of the Public from Intake of Radionuclides: Part 5 Compilation of Ingestion and Inhalation Dose Coefficients* (Reference 2.2.43) and air submersion and groundshine dose coefficients from Federal Guidance Report No. 13 (Reference 2.2.44). These dose coefficients are contained in the database files for GENII discussed in Reference 2.2.10 Sections 4.1.7.3 to 4.1.7.7. The effective dose equivalents are based on the organ weighting factors from ICRP 60 (Reference 2.2.45). As discussed in Design Input 6.1.1.12 the default GENII inhalation dose coefficient file, *FGR13INH.hdb* is replaced with a site-specific inhalation dose coefficient file which contains revised tritium inhalation dose coefficients for all organs to account for skin absorption.

6.1.6.3 Summary Inhalation, Submersion and Groundshine Exposure Period Inputs

Table 17 provides a summary of the inhalation and submersion exposure period inputs.

Table 17. Inhalation and Submersion Exposure Periods

Individual	Condition	Exposure Period Category	Inhalation and Submersion Exposure Period (Mean Value)	Inhalation and Submersion Exposure Period (Distribution and Value)
Offsite Public in the General Environment	Normal operations	Yearly	365 (days/yr)	None
	Category 1 event sequences	Event	Duration of release (days)	None
	Category 2 event sequences	Event	Duration of release up to 30 (days)	None
	All	Daily	22 (hr/day)	Normal distribution: Mean = 22.0 Standard Deviation = 0.4, Min = 20.7, Max = 22.8
Offsite Public Not within the General Environment	Normal operations	Yearly	250 (days/yr)	Uniform distribution: Min = 225 and Max = 275
	Category 1 event sequences	Event	Duration of release (days)	None
	Category 2 event sequences	Event	Duration of release up to 30 (days)	None
	All	Daily	8.5 (hr/day)	Uniform distribution: Min = 8.0 and Max = 9.0
Onsite Public or Radiation Worker	Normal operations	Yearly	250 (days/yr)	Uniform distribution: Min = 225 and Max = 275
	Category 1 event sequences	Event	Duration of release (days)	None
	All	Daily	8.5 (hr/day)	Uniform distribution: Min = 8.0 and Max = 9.0

Sources: Reference 2.2.10, Tables 89 and 94 and Assumptions 3.2.2, 3.2.4, and 3.2.5.

Table 18 provides a summary of the external groundshine exposure period inputs.

Table 18. External Groundshine Exposure Periods

Individual	Condition	Exposure Period Category	External Groundshine Exposure Period (Mean Value)	External Groundshine Exposure Period (Distribution and Value)
Offsite Public in the General Environment	Normal operations and Category 1 event sequences	Yearly	365 (days/yr)	None
	Category 2 event sequences	Event	30 (days)	None
	All	Daily	24 (hr/day)	None
Offsite Public Not within the General Environment	Normal operations and Category 1 event sequences	Yearly	250 (days/yr)	Uniform distribution: Min = 225 and Max = 275
	Category 2 event sequences	Event	30 (days)	None
	All	Daily	8.5 (hr/day)	Uniform distribution: Min = 8.0 and Max = 9.0

Sources: Reference 2.2.10, Table 89 and Assumptions 3.2.2, 3.2.4, and 3.2.5.

Table 19 summarizes the inputs used for the fraction of a day inhalation and submersion occurs.

Table 19. Fraction of a Day for Inhalation and Submersion

Individual	Condition	Exposure Category	Fraction of a Day Outdoor Exposure Occurs (Mean Value)	Fraction of a Day Outdoor Exposure Occurs (Distribution and Value)
Offsite Public in the General Environment	Normal operations	Air inhalation and submersion	0.92	Normal distribution: Mean = 0.92 Standard Deviation = 0.02, Min = 0.86, Max = 0.95
	Category 1 and Category 2 event sequences	Air inhalation and submersion	1.0	None
	All	Resuspended soil inhalation	0.31	Normal distribution: Mean = 0.31 Standard Deviation = 0.014, Min = 0.27, Max = 0.35
Offsite Public Not within the General Environment	Normal operations	Air inhalation and submersion	0.35	Uniform distribution: Min = 0.33 and Max = 0.38
	Category 1 and Category 2 event sequences	Air inhalation and submersion	1.0	None
	All	Resuspended soil inhalation	0.35	Uniform distribution: Min = 0.33 and Max = 0.38
Onsite Public or Radiation Worker	Normal operations	Air inhalation and submersion	0.35	Uniform distribution: Min = 0.33 and Max = 0.38
	Category 1 event sequences	Air inhalation and submersion	1.0	None

Source: Reference 2.2.10, Table 95 and Assumption 3.2.14.

Table 20 summarizes the fraction of a day spent indoors and outdoors.

Table 20. Fraction of a Day Spent Indoors and Outdoors

Individual	Parameter	Fraction of a Day (Mean Value)	Fraction of a Day (Distribution and Value)
Offsite Public in the General Environment	Fraction of day spent outdoors	0.31	Normal distribution: Mean = 0.31 Standard Deviation = 0.014, Min = 0.27 and Max = 0.35
	Fraction of day spent indoors	0.61	Normal distribution: Mean = 0.61 Standard Deviation = 0.022 Min = 0.54 and Max = 0.67
Offsite Public Not within the General Environment	Fraction of day spent outdoors	0.35	Uniform distribution: Min = 0.33, Max = 0.38
	Fraction of day spent indoors	0.0	None
Onsite Public or Radiation Worker	Fraction of day spent outdoors	0.35	Uniform distribution: Min = 0.33, Max = 0.38
	Fraction of day spent indoors	0.0	None

Source: Reference 2.2.10, Table 90, Table 91 and Table 95; and Assumption 3.2.14.

6.2 GENII METHODOLOGY ADJUSTMENT FACTORS

6.2.1 Changes to GENII Default Files

The GENII default input files are taken from Reference 2.2.10. These input files are set up for a receptor located in the general environment. In order to apply them in this calculation, the parameters in these files need to be adjusted to account for this calculation's specific design inputs and assumptions. These adjustments are described in this section.

To calculate public doses onsite and offsite not in the general environment, the default values for ground shine, air submersion and air inhalation are modified in the YMP site-specific GENII input files as presented in Table 21. The fraction of a day for outdoor inhalation is set to 1.0 (Assumption 3.2.14) and a fall release input has been used (Assumption 3.2.15). The surface soil depth is set equal to 0.25 m (Design Input 6.1.1.11). The soil leaching rate constant is modified from the "GENII default leach rate" to the "Leach rate calculated from user input" (LEACHOPTION = 2).

As shown in Table 21, several parameters have been modified in the gid input files for acute releases due to fuel oxidation. The atmospheric dispersion factors have been updated to the time-weighted χ/Qs presented in Section 6.2.2. The absolute humidity has been updated as presented in Section 6.2.3 and the breathing rate has been updated as presented in Section 6.2.4.

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Table 21. Changes to GENII Default Files

		Chronic Default Files Values			Acute Default Files Values			
		Offsite	Offsite	Onsite	Offsite	Offsite	Onsite	
GENII Parameter	**Description (units)**	**General Environment**	**Non- General Environment**	**Worker or Public**	**General Environment**	**Non- General Environment**	**Worker or Public**	
Parameter Changes to Default File Values in *GNDFLiud.pop*								
Ground Shine								
UEXGRD	Daily exposure factor giving hours of exposure to contaminated ground per day (hr/day)	24[a]	8.5	8.5	24	8.5	8.5	Table 18
TEXGRD	Annual exposure factor giving days of exposure to contaminated ground per year (days/yr).	365[a]	250	250	30 (365 in run)	30 (365 in run)	30 (365 in run)	Table 18 adjusted in spreadsheet
FTIN	Fraction of time spent inside a home (dimensionless)	0.61[a]	0	0	0.61	0	0	Table 20
FTOUT	Fraction of time spent outside (dimensionless)	0.31[a]	1	1	0.31	1	1	Table 20
Air Submersion								
UEXAIR	Daily exposure factor giving hours of exposure to external plume per day (hr/day)	22[a]	8.5	8.5	22	8.5	8.5	Table 17
TEXAIR	Annual exposure factor giving days of exposure to external plume per year (days/yr)	365[a]	250	250	30 (365 in run)	30 (365 in run)	30 (365 in run)	Table 17 adjusted in spreadsheet
Air Inhalation								
UINH	Inhalation rate for outdoor air (m^3/day)	21.7	30.2[a]	30.2	30.2 (burst) 2.32×10^{-4} (oxidation)	30.2 (burst) 2.37×10^{-4} (oxidation)	30.2	Table 16 Section 6.2.4
TINH	Annual intake factor (days/yr)	365[a]	250	250	30 (365 in run)	30 (365 in run)	30 (365 in run)	Table 17 adjusted in spreadsheet
FRINH	Fraction of day that outdoor inhalation occurs (dimensionless)	0.92[a]	0.35	0.35	1.0	0.35 (1 in run)	0.35 (1 in run)	Table 19 adjusted in spreadsheet

Table 21. Changes to GENII Default Files

		Chronic Default Files Values			Acute Default Files Values			
		Offsite	Offsite	Onsite	Offsite	Offsite	Onsite	
GENII Parameter	**Description (units)**	**General Environment**	**Non- General Environment**	**Worker or Public**	**General Environment**	**Non- General Environment**	**Worker or Public**	
Resuspended Soil Inhalation								
UINHR	Inhalation rate for resuspended air (m^3/day)	21.7[a]	30.2	30.2	21.7	30.2	30.2	Table 16
TINHR	Annual resuspension intake factor (day/yr)	365[a]	250	250	30 (365 in run)	30 (365 in run)	30 (365 in run)	Table 17 adjusted in spreadsheet
FRINHR	Fraction of day that resuspension inhalation occurs (dimensionless)	0.31[a]	0.35	0.35	0.31	0.35	0.35	Table 19
Parameter Change to Default File Values in *GNDFLcud.GE* and *GNDFLaud.GE*								
Exposure Pathway Module								
LEACHOPTION[b]	Type of leach rate constant	2	2	2	2	2	2	Section 6.2.1
Parameter Change to Default Value within Heath Impacts Module								
Health Impacts Module								
SOILT[c]	Thickness of contaminated soil layer (m)	0.25	0.25	0.25	0.25	0.25	0.25	Design Input 6.1.1.11
Parameter Changes to Default File Values for Acute Oxidation Release								
Acute Oxidation Release (30 day)								
ABSHUM	Absolute humidity (kg/m^3)	-	-	-	1.30×10^{-4}	1.57×10^{-4}	NA	Section 6.2.3
JHOUR	Date/hour of release				1-Sep/0 hour	1-Sep/0 hour	1-Sep/0 hour	Assumption 3.2.15

NOTES: [a]Default value in *GNDFLiud.pop* from Reference 2.2.10.
[b]LEACHOPTION default value is 0 in both *GNDFLcud.GE* and *GNDFLaud.GE.*
[c]SOILT is not in a default file and must be entered directly into the Heath Impacts module screen.

6.2.2 Time-Weighted Atmospheric Dispersion Factors for Oxidation Release

Using the χ/Qs presented in Design Input 6.1.1.7, Equation 12 is used to determine the time weighed χ/Qs for a member of the public in the general environment, for a member of the public not in the general environment, and for an onsite member of the public. These are shown in Table 22.

Table 22. Time-Weighted Atmospheric Dispersion Factors for Various Time Periods

Offsite Public in General Environment Atmospheric Dispersion Factors (s/m^3)						
	0 - 2 hrs	**2 - 8 hrs**	**8 - 24 hrs**	**24-96 hrs**	**96-720 hrs**	**Weighted χ/Q (0 - 720 hrs)**
Undepleted	1.24×10^{-5}	6.76×10^{-6}	3.94×10^{-6}	1.73×10^{-6}	5.26×10^{-7}	8.07×10^{-7}
Depleted	4.40×10^{-6}	2.46×10^{-6}	1.46×10^{-6}	6.56×10^{-7}	2.08×10^{-7}	3.11×10^{-7}
Deposition Rate	1.17×10^{-8}	6.85×10^{-9}	4.24×10^{-9}	2.04×10^{-9}	7.11×10^{-10}	1.00×10^{-9}
Offsite Public Not in General Environment Atmospheric Dispersion Factors						
	0 - 2 hrs	**2 - 8 hrs**	**8 - 24 hrs**	**24-96 hrs**	**96 -720 hrs**	**Weighted χ/Q (0 - 720 hrs)**
Undepleted	2.76×10^{-5}	1.60×10^{-5}	9.86×10^{-6}	4.69×10^{-6}	1.61×10^{-6}	2.29×10^{-6}
Depleted	1.47×10^{-5}	8.49×10^{-6}	5.29×10^{-6}	2.56×10^{-6}	9.03×10^{-7}	1.27×10^{-6}
Deposition Rate	4.48×10^{-8}	2.72×10^{-8}	1.74×10^{-8}	8.82×10^{-9}	3.32×10^{-9}	4.50×10^{-9}
Onsite Public Atmospheric Dispersion Factors						
	0 - 2 hrs	**2 - 8 hrs**	**8 - 24 hrs**	**24-96 hrs**	**96 -720 hrs**	**Weighted χ/Q (0 - 720 hrs)**
Undepleted	2.03×10^{-3}	1.64×10^{-3}	4.01×10^{-4}	5.63×10^{-4}	5.14×10^{-4}	5.30×10^{-4}

Source: Worksheet *XQ Adjustment* of Excel file *Summary of Doses.xls.*

Using the χ/Qs from Table 22, the adjustment factor F_{H3} determined using Equation 15 for undepleted χ/Qs is 31.41 for the general environment location. The undepleted χ/Q adjustment factor is used when tritium or ^{14}C are treated as a gas.

6.2.3 Absolute Humidity Adjustment for Tritium Oxidation Release

For the contribution to the dose from tritium, GENII uses the concentration of tritium in air for the inhalation and air submersion pathways, and the concentration of tritiated water in air moisture to determine the concentration in vegetation which then is used to calculate the tritium dose from the ingestion pathways.

The concentration of tritiated water in air moisture is determined by dividing the tritium concentration in air by the absolute humidity as discussed in the GENII SDD Section 9.6.1 (Reference 2.2.20). Therefore, the absolute humidity can be adjusted using the adjustment factor, F_{H3}, when using a single GENII run to calculate the doses from oxidation. The site average absolute humidity is 4.08×10^{-3} kg/m^3 (Design Input 6.1.1.10). Therefore, the adjusted absolute humidity using the undepleted χ/Q adjustment factor is 1.30×10^{-4} kg/m^3 ($4.08 \times 10^{-3} \div 31.41$) for the general environment location.

6.2.4 Time-Weighted Breathing Rates for Oxidation Release

Using the breathing rates from Design Input 6.1.6.1, Equation 19, and the depleted and undepleted χ/Qs from Table 22, effective breathing rates are calculated and presented in Table 23. The undepleted time-weighted breathing rates are used for the oxidation cases.

Table 23. Time-Weighted Breathing Rates

Breathing Rates from Design Input 6.1.6.1 (m^3/s)						
	0 - 2 hrs	**2 - 8 hrs**	**8 - 24 hrs**	**24-96 hrs**	**96-720 hrs**	**Weighted Breathing Rate**
Breathing Rate	3.50×10^{-4}	3.50×10^{-4}	1.80×10^{-4}	2.30×10^{-4}	2.30×10^{-4}	Design Input 6.1.6.1
Effective Breathing Rates – Offsite Public in General Environment (m^3/s)						
Undepleted	8.68×10^{-10}	1.42×10^{-9}	1.13×10^{-8}	2.86×10^{-8}	7.55×10^{-8}	2.38×10^{-4}
Depleted	3.08×10^{-10}	5.17×10^{-10}	4.20×10^{-9}	1.09×10^{-8}	2.99×10^{-8}	2.32×10^{-4}
Effective Breathing Rates – Offsite Public Not in General Environment (m^3/s)						
Undepleted	1.93×10^{-9}	3.36×10^{-9}	2.84×10^{-8}	7.77×10^{-8}	2.31×10^{-7}	2.36×10^{-4}
Depleted	1.03×10^{-9}	1.78×10^{-9}	1.52×10^{-8}	4.24×10^{-8}	1.30×10^{-7}	2.37×10^{-4}

Source: Worksheet *XQ Adjustment* of Excel file *Summary of Doses.xls.*

6.2.5 Crud Source Term Adjustment for Burst Release

GENII provides the user with inventory release multipliers based on chemical families of radionuclides. Crud, consisting of ^{60}Co and ^{55}Fe, are in the noble metals family (Reference 2.2.18, p. 22). Elements in the noble metals family, besides cobalt and iron, include technetium, palladium, and tin, which are considered in this calculation but are classified as fuel fines in Design Input 6.1.3.1. The release fraction for crud is different than the release fraction for fuel fines (Table 10). Therefore, in order to use the release fractions as the GENII inventory release multipliers, the crud source term needs to be adjusted as follows.

The source terms for ^{60}Co and ^{55}Fe shown in Table 24 are obtained from Table 7.

Table 24. Crud Source Terms

	Source Term (Ci/fuel assembly)			
	Representative Fuel		**Maximum Fuel**	
	BWR	**PWR**	**BWR**	**PWR**
^{60}**Co**	5.66×10^{1}	1.69×10^{1}	1.09×10^{2}	3.26×10^{1}
^{55}**Fe**	9.84×10^{1}	2.09×10^{2}	3.50×10^{2}	7.45×10^{2}

Source: Table 7

The release fractions (ARF × RF) for fuel fines and crud are obtained from Table 10. The low-burnup fuel release fractions are used for the representative fuel assembly and the high-burnup fuel release fractions are used for the maximum fuel assembly. For releases through HEPA filters, the ARF from Table 10 is multiplied by a respirable fraction of one (Assumption 3.2.8).

For unfiltered releases the ARF is multiplied by the respirable fraction from Table 10. The adjustment factor is then the ratio of the crud release fraction to the fuel fines release fraction. Table 25 shows the fuel fines and crud release fractions for filtered and unfiltered releases.

Table 25. Burst Release Fractions for Filtered and Unfiltered Releases

	Representative Fuel		Maximum Fuel	
	HEPA	**No HEPA**	**HEPA**	**No HEPA**
Crud Release	1.5×10^{-2} [a]	1.5×10^{-2} [b]	1.5×10^{-2} [a]	1.5×10^{-2} [b]
Fuel Fines Release	3.0×10^{-5} [a]	1.5×10^{-7} [b]	3.0×10^{-5} [a]	3.0×10^{-5} [b]
Adjustment Factor	5.0×10^{2}	1.0×10^{5}	5.0×10^{2}	5.0×10^{2}

NOTES: [a]Value is the product of the ARF from Table 10 and an RF of 1 from Assumption 3.2.8.
[b]Value is the product of ARF and RF from Table 10.

The adjusted crud source term is then calculated by multiplying the source term by the adjustment factor. The adjusted crud source terms are shown in Table 26.

Table 26. Adjusted Crud Source Terms for Burst Release

Adjusted Source Term (Ci/fuel assembly) - HEPA				
	Representative Fuel		**Maximum Fuel**	
	BWR	**PWR**	**BWR**	**PWR**
^{60}Co	2.83×10^{4}	8.45×10^{3}	5.45×10^{4}	1.63×10^{4}
^{55}Fe	4.92×10^{4}	1.05×10^{5}	1.75×10^{5}	3.73×10^{5}
Adjusted Source Term (Ci/fuel assembly) - no HEPA				
	Representative Fuel		**Maximum Fuel**	
	BWR	**PWR**	**BWR**	**PWR**
^{60}Co	5.66×10^{6}	1.69×10^{6}	5.45×10^{4}	1.63×10^{4}
^{55}Fe	9.84×10^{6}	2.09×10^{7}	1.75×10^{5}	3.73×10^{5}

6.3 SOURCE TERM CALCULATIONS

6.3.1 Vitrified High-Level Waste Inventory

Radionuclides for vitrified HLW used in the analyses are based on the selection criteria in NUREG-1567 (Reference 2.2.19, p. 9-11) and SFPO-ISG-5 (Reference 2.2.8, Section 3). The radionuclide inventory for release includes the activity from iodine, other fission products that contribute greater than 0.1% of the HLW activity, and actinide activity that contributes greater than 0.01% of the HLW activity. A comparative analysis to identify radionuclides that are significant to offsite doses from preclosure events for SNF and HLW was performed (Reference 2.2.46). The table on page IV-4 of Reference 2.2.46 contains the list of DOE SNF radionuclides and their first generation daughter products. For consistency with Reference 2.2.46, the minimum list of fission products and actinides has been expanded to include the radionuclides given on page IV-4 of Reference 2.2.46, if radionuclide inventory is present. The nuclides ^{14}C and ^{3}H are also included in the selection of radionuclides because of their potential release into the atmosphere as gases.

The radionuclides presented in Table 8 for the canister source terms for HLW glass from the four sites were reviewed against the criteria discussed above, and the reduced list of radionuclides and their source terms used in this analysis are provided in Table 27.

Table 27. Maximum Radionuclide Inventory per High-Level Waste Glass Canister at 2017 Used in Consequence Analysis

Nuclide	Radioactivity (Ci)			
	HS	SRS	WVDP	INL[a]
^{227}Ac	1.72×10^{-4}	2.09×10^{-8}	1.16×10^{-1}	1.85×10^{-17}
^{241}Am	4.61×10^{2}	3.38×10^{2}	4.97×10^{2}	1.41×10^{1}
^{242m}Am	—	7.39×10^{-2}	2.47	—
^{243}Am	9.98×10^{-2}	1.37	3.27	1.05×10^{-4}
^{137m}Ba	5.62×10^{4}	4.15×10^{4}	1.84×10^{4}	1.14×10^{4}
^{14}C	1.06×10^{-7}	—	1.30	8.26×10^{-5}
^{113m}Cd	1.91×10^{1}	—	2.07	—
^{242}Cm	6.54×10^{-6}	6.10×10^{-2}	2.04	7.71×10^{-5}
^{243}Cm	3.73×10^{-2}	3.31×10^{-1}	2.53×10^{-1}	3.36×10^{-6}
^{244}Cm	3.27×10^{-1}	2.97×10^{2}	2.57×10^{1}	7.71×10^{-5}
^{245}Cm	—	2.42×10^{-2}	3.19×10^{-3}	2.81×10^{-8}
^{246}Cm	—	2.90×10^{-2}	3.66×10^{-4}	6.61×10^{-10}
^{247}Cm	—	2.20×10^{-2}	—	2.37×10^{-16}
^{60}Co	4.14×10^{-1}	4.91×10^{1}	6.63×10^{-1}	3.57×10^{-2}
^{134}Cs	2.12×10^{1}	6.48	4.09×10^{-3}	3.64×10^{-5}
^{135}Cs	—	2.16×10^{-1}	1.09	2.53×10^{-1}
^{137}Cs	5.95×10^{4}	4.39×10^{4}	1.95×10^{4}	1.21×10^{4}
^{154}Eu	4.50	1.85×10^{2}	4.72×10^{1}	6.65
^{155}Eu	1.16×10^{2}	1.52×10^{-1}	1.67	3.75×10^{-2}
^{55}Fe	—	—	2.49×10^{-3}	—
^{3}H	—	—	6.54×10^{-2}	4.30
^{129}I	—	3.22×10^{-4}	7.64×10^{-4}	1.65×10^{-2}
^{93m}Nb	3.30	2.33×10^{-1}	2.33	1.43
^{94}Nb	—	—	—	1.60×10^{-5}
^{59}Ni	4.96×10^{-1}	8.44×10^{-1}	1.00	—
^{63}Ni	4.89×10^{1}	7.47×10^{1}	6.69×10^{1}	—
^{237}Np	2.51×10^{-1}	2.99×10^{-2}	1.53×10^{-1}	2.75×10^{-2}
^{231}Pa	4.24×10^{-4}	1.43×10^{-7}	1.44×10^{-1}	1.65×10^{-12}
^{210}Pb	2.51×10^{-6}	5.99×10^{-9}	5.16×10^{-7}	6.77×10^{-11}
^{107}Pd	—	1.31×10^{-3}	1.04×10^{-1}	—
^{147}Pm	—	1.53×10^{2}	2.55×10^{-1}	2.97×10^{-2}
^{236}Pu	—	—	9.98×10^{-3}	—
^{238}Pu	2.17	9.10×10^{2}	3.36×10^{1}	9.99×10^{1}
^{239}Pu	2.13×10^{1}	1.74×10^{1}	8.75	2.01

Table 27. Maximum Radionuclide Inventory per High-Level Waste Glass Canister at 2017 Used in Consequence Analysis

Nuclide	Radioactivity (Ci)			
	HS	SRS	WVDP	INL[a]
^{240}Pu	6.42	8.78	6.35	1.75
^{241}Pu	8.70×10^{1}	5.17×10^{2}	1.13×10^{2}	2.15×10^{1}
^{242}Pu	9.91×10^{-4}	2.14×10^{-2}	8.17×10^{-3}	3.80×10^{-3}
^{226}Ra	1.29×10^{-5}	4.60×10^{-8}	1.95×10^{-6}	7.16×10^{-5}
^{228}Ra	9.38×10^{-5}	9.87×10^{-4}	1.47×10^{-2}	6.21×10^{-14}
^{106}Ru	1.37×10^{-4}	4.40×10^{-3}	5.14×10^{-10}	—
^{125}Sb	3.16	9.17	2.85×10^{-2}	1.14×10^{-3}
^{79}Se	9.15×10^{-2}	5.34×10^{-1}	5.70×10^{-1}	—
^{147}Sm	—	5.12×10^{-8}	1.61×10^{-9}	2.02×10^{-16}
^{151}Sm	3.43×10^{3}	1.49×10^{2}	6.49×10^{2}	—
^{126}Sn	5.74×10^{-1}	7.83×10^{-1}	9.85×10^{-1}	2.59×10^{-1}
^{90}Sr	6.21×10^{4}	2.67×10^{4}	1.67×10^{4}	1.16×10^{4}
^{99}Tc	2.31×10^{1}	9.16	8.72	9.92
^{229}Th	1.40×10^{-6}	1.39×10^{-4}	9.47×10^{-4}	5.53×10^{-13}
^{230}Th	9.41×10^{-7}	1.35×10^{-5}	2.18×10^{-4}	1.06×10^{-9}
^{232}Th	1.50×10^{-4}	1.40×10^{-3}	1.55×10^{-2}	4.96×10^{-10}
^{232}U	4.40×10^{-4}	2.69×10^{-4}	3.24×10^{-2}	6.15×10^{-6}
^{233}U	2.10×10^{-3}	5.59×10^{-2}	9.03×10^{-2}	6.06×10^{-6}
^{234}U	1.46×10^{-2}	7.23×10^{-2}	2.62×10^{-2}	1.11×10^{-1}
^{235}U	5.56×10^{-4}	6.64×10^{-4}	3.72×10^{-4}	6.57×10^{-4}
^{236}U	1.18×10^{-3}	3.67×10^{-3}	1.08×10^{-3}	1.71×10^{-3}
^{238}U	1.01×10^{-2}	4.74×10^{-2}	3.33×10^{-3}	3.27×10^{-5}
^{90}Y	6.21×10^{4}	2.67×10^{4}	1.67×10^{4}	1.16×10^{4}
^{93}Zr	5.76	3.86×10^{-1}	2.58	—

NOTES: [a]Radionuclide inventory for INL HLW canister is provided for year 2035.
HS = Hanford Site, INL = Idaho National Laboratory, SRS = Savannah River Site, WVDP = West Valley Demonstration Project.

Source: Table 8 and Excel spreadsheet *HLW Significant Isotopes.xls*

6.3.2 DOE Spent Nuclear Fuel of Commercial Origin

As stated in Design Input 6.1.1.4, two percent of the DOE SNF (2,333 MTHM from Design Input 6.1.1.2) consists of intact commercial BWR and PWR SNF. Thus, approximately 47 MTHM of the DOE SNF of commercial origin can be received at the repository uncanistered and be packaged into TAD canisters in the WHF.

The repository is designed to accept up to 10% of commercial SNF as uncanistered or in DPCs (Design Input 6.1.1.3). The annual commercial SNF receipt rate has conservatively been increased by 20% above the design basis receipt rate to 3,600 MTHM (Assumption 3.3.1). For normal operations, the annual receipt rate analyzed for the WHF is 360 MTHM, which is about 60 MTHM per year greater than the design basis receipt rate for the WHF. Thus, the annual receipt rate analyzed for the WHF encompasses within one year the approximate 47 MTHM of

DOE SNF of commercial origin that can be accepted during the entire 50- year emplacement period of the repository (Design Input 6.1.1.1).

The damage ratio for normal operations is 0.01, which means that 1% of the commercial SNF is assumed to have defects large enough to allow gases and particulates to be released from the fuel cladding. However, the 2% of the DOE SNF of commercial origin is stated to be intact, which means that it does not have defects in the cladding large enough to allow the release of fission product gases and particulates.

A review of the DOE SNF fuel characteristics shows that the BWR and PWR DOE SNF of commercial origin have decay times of at least 25 years, which is much greater than the 10-yr and 5-yr decay times used for the representative and maximum PWR and BWR commercial SNF (Design Input 6.1.2.1 and Reference 2.2.47, Appendixes B and C). The review also shows that the highest burnup for the BWR and PWR DOE SNF of commercial origin is approximately 47 GWd/MTU, which is less than the burnup for the representative and maximum PWR and BWR commercial SNF (Design Input 6.1.2.1 and Reference 2.2.47, Appendixes B and C).

Thus, the dose analysis for normal operation using the representative BWR and PWR fuel sources and 10% of the maximum receipt rate bounds the 2% of DOE SNF of commercial origin because (1) the amount of MTHM analyzed on a yearly basis above the design basis receipt rate exceeds the total MTHM of DOE SNF of commercial origin, (2) the DOE SNF of commercial origin is intact fuel without defects, (3) the shortest decay time of the DOE SNF of commercial origin is at least 15 years longer than the decay time of the representative BWR and PWR fuel (Table 6), and (4) the highest burnup of the DOE SNF of commercial origin is lower than the burnup of the representative BWR and PWR fuel (Table 6). The dose analysis for Category 1 and Category 2 event sequences for commercial SNF also bounds any event that may involve DOE SNF of commercial origin because the fuel characteristics of the DOE SNF of commercial origin are bounded by the fuel characteristics of the maximum BWR and PWR fuel (Table 6).

6.3.3 Fire Event Source Term

A fire event involves the combustible portion of the LLWF inventory, which includes DAW in bags and drums, pool filters and spent resins in HICs (Assumption 3.2.12). In addition, activity deposited on the HEPA filters stored in B-25 boxes may also be released.

6.3.3.1 Combustible LLW Source Term

The release source term for the fire event is determined using Equation 21. A bounding damage ratio of 1.0 is used (Assumption 3.2.1) and the ARFs and RFs are given in Design Input 6.1.3.2. A bounding LPF for the facility of 1.0 is also used (Assumption 3.2.6). The final parameter needed to calculate the source term is the MAR, which is determined as follows.

The unit volumes of individual waste containers in the LLWF are calculated in Table 28 based on dimensions from Table 3 in Design Input 6.1.1.5.

Table 28. Unit Volumes of Low-Level Radioactive Waste Storage Containers

Waste Container[a]	Dimensions[a]	Volume[b]	Units[b]	Unit Converion Factor[c]	Factor Units[c]	Unit Volume (m^3)[c]
55-gallon drum	24 in diameter × 36 in height	1.63×10^4	in^3	1.639×10^{-5}	$(m/in)^3$	2.67×10^{-1}

NOTES: [a] Data from Design Input 6.1.1.5.
[b] Drum volumes calculated as [$\pi \times (\text{diameter}/2)^2 \times \text{height}$]; box volume calculated as (L × W × H).
[c] Unit conversion based on 1 in^3 = $(2.54\ cm/in / 100\ cm/m)^3$; 1 ft^3 = $(30.48\ cm/ft / 100\ cm/m)^3$.

Per Assumption 3.1.2 there may be three HICs with pool filters and one HIC with spent resins transported to the LLWF annually. Per Design Input 6.1.1.5 the LLWF may store 28 HICs, 7 with spent resins and 21 with pool filters.

Per Design Input 6.1.1.8 the amount of spent resins in a HIC is 100 ft^3, or 2.83 m^3. The total volume of spent resins is then 19.8 m^3.

For the fuel pool filters, the volume of material in a HIC is 200 filters × volume per filter. The volume per filter is calculated using the dimensions from Design Input 6.1.1.7:

$$V_f = \pi \left(\frac{6\, in}{2} \right)^2 \times 24\, in = 679\, in^3 = 1.11 \times 10^{-2}\, m^3$$

The total volume of waste in the HIC is then 2.22 m^3. The total volume of pool filters is then 46.7 m^3.

The total volume of material available for release in a fire event is calculated from the unit volumes and the number of each waste container type in the LLWF. A volume release factor is calculated in Table 29 for each waste container as the product of the total volume and the ARF and RF values from Design Input 6.1.3.2 applicable to each waste container from Design Input 6.1.1.5.

Table 29. Release Factors for each Low-Level Radioactive Waste Storage Container

Waste Storage	Waste Container[a]	Number of Containers[a]	Unit Volume (m^3)[b]	Total Volume, V (m^3)[c]	ARF[d]	RF[d]	Volume Release Factor (m^3)[e]
Spent resin in WHF or LLWF[f]	HIC	7	2.83	1.98×10^{1}	5.0×10^{-4}	1.0	9.91×10^{-3}
Filter storage (pool filter)[g]	HIC	21	2.22	4.67×10^{1}	5.0×10^{-4}	1.0	2.34×10^{-2}
Drum for DAW	55-gallon drum	216	2.67×10^{-1}	5.76×10^{1}	5.0×10^{-4}	1.0	2.88×10^{-2}
Sorting room (DAW bags)	55-gallon drum, equivalent	102	2.67×10^{-1}	2.72×10^{1}	1.0×10^{-2}	1.0	2.72×10^{-1}
					Sub-total DAW		3.01×10^{-1}

NOTES:
[a] Data from Design Input 6.1.1.5
[b] From Table 28
[c] Calculated as Number of Containers × Unit Volume
[d] Design Input 6.1.3.2
[e] Calculated as (ARF × RF × V)
[f] Calculated from Design Input 6.1.1.8
[g] Calculated from Design Input 6.1.1.7.

Because the damage ratio and the LPF are both equal to 1.0, the LLW radionuclide concentration from Table 4 in Design Input 6.1.1.6 is multiplied by the volume release factor for the waste in Table 29 to determine the LLWF fire event source term, that is, the radionuclides released during a fire event. These are reported in Table 30.

Table 30. Low-Level Waste Facility Radionuclides Released During Fire Event

Radionuclide	Dry Active Waste (Ci)	Pool Filter (Ci)	Spent Resin (Ci)	Total (Ci)
^{137}Cs	2.15×10^{-3}	5.02×10^{-2}	1.69×10^{-1}	2.22×10^{-1}
^{60}Co	4.27×10^{-3}	3.76×10^{-1}	1.20×10^{-1}	5.00×10^{-1}
^{54}Mn	2.20×10^{-4}	4.30×10^{-2}	2.46×10^{-2}	6.78×10^{-2}
^{58}Co	1.68×10^{-3}	1.47×10^{-1}	4.70×10^{-2}	1.96×10^{-1}
^{134}Cs	1.90×10^{-3}	4.44×10^{-3}	1.50×10^{-1}	1.96×10^{-1}

6.3.3.2 WHF HEPA Filter Source Terms

In addition to the combustible LLW that may be released in a fire event, radioactive materials on the HEPA filters in B-25 boxes can be released due to the fire damaging the boxes and the HEPA filters inside the box. Conservatively it is assumed that the filters staged in the LLWF include those from a recent change-out of WHF filters.

For the buildup of radionuclides on the WHF HEPA filters, 3,600 MTHM of commercial SNF is assumed to be received at the repository each year (Assumption 3.3.1); 10% of which is processed in the WHF (Design Input 6.1.1.3) with a fuel rod breakage percentage of 1% (Assumption 3.2.1). Using the fuel characteristics from Table 6, 63 PWR (3,600 MTHM/yr ÷ 12 months/yr ÷ 0.475 MTHM/PWR assembly) or 150 BWR (3,600 MTHM/yr ÷ 12 months/yr ÷ 0.200 MTHM/BWR assembly) fuel assemblies are processed in the WHF on a monthly basis. It is assumed that the HEPA filters are replaced every 18 months (Assumption 3.2.16).

Releases from representative commercial SNF inventories are used for the buildup of radionuclides on the HEPA filters (Table 7). Using the ARF values for normal operations from Table 10 (low burnup fuel – cladding burst release), the buildup of radionuclides on the HEPA filter after 18 months of processing only PWR fuel or processing only BWR fuel is shown in Table 31. For conservatism, no credit is taken for radioactive decay during the 18-month accumulation period.

Table 31. Radionuclides Buildup on HEPA Filters after 18-Month Accumulation

Radionuclide	PWR (Ci)	BWR (Ci)
^{241}Am	4.02×10^{-1}	3.02×10^{-1}
^{242}Am	2.48×10^{-3}	2.32×10^{-3}
^{242m}Am	2.49×10^{-3}	2.33×10^{-3}
^{243}Am	7.84×10^{-3}	6.99×10^{-3}
^{137m}Ba	1.30×10^{2}	1.23×10^{2}
^{14}C	-	-
^{113m}Cd	4.74×10^{-3}	4.24×10^{-3}
^{144}Ce	2.48×10^{-2}	1.40×10^{-2}
^{36}Cl	-	-
^{242}Cm	2.06×10^{-3}	1.93×10^{-3}
^{243}Cm	5.35×10^{-3}	4.50×10^{-3}
^{244}Cm	8.83×10^{-1}	7.48×10^{-1}
^{245}Cm	1.15×10^{-4}	7.35×10^{-5}
^{246}Cm	3.96×10^{-5}	3.45×10^{-5}
^{60}Co (crud)[a]	2.88×10^{2}	2.29×10^{3}
^{134}Cs	9.28	7.07
^{135}Cs	8.50×10^{-4}	9.77×10^{-4}
^{137}Cs	1.37×10^{2}	1.30×10^{2}
^{154}Eu	8.05×10^{-1}	6.26×10^{-1}
^{155}Eu	1.68×10^{-1}	1.56×10^{-1}
^{55}Fe (crud)[a]	3.56×10^{3}	3.99×10^{3}
^{3}H	-	-
^{129}I	-	-
^{85}Kr	-	-
^{93m}Nb	1.17×10^{-4}	1.28×10^{-4}
^{94}Nb	2.15×10^{-8}	2.07×10^{-8}
^{237}Np	8.63×10^{-5}	7.08×10^{-5}
^{239}Np	7.84×10^{-3}	6.99×10^{-3}
^{231}Pa	1.02×10^{-8}	1.51×10^{-8}

Table 31. Radionuclides Buildup on HEPA Filters after 18-Month Accumulation

Radionuclide	PWR (Ci)	BWR (Ci)
^{107}Pd	2.95×10^{-5}	2.79×10^{-5}
^{147}Pm	2.17	1.71
^{144}Pr	2.48×10^{-2}	1.40×10^{-2}
^{238}Pu	9.45×10^{-1}	8.26×10^{-1}
^{239}Pu	$6.14 \times 1\ 0^{-2}$	4.38×10^{-2}
^{240}Pu	1.09×10^{-1}	1.03×10^{-1}
^{241}Pu	1.77×10^{1}	1.27×10^{1}
^{242}Pu	5.73×10^{-4}	5.73×10^{-4}
^{106}Ru	7.73×10^{-1}	4.89×10^{-1}
^{125}Sb	1.33×10^{-1}	9.72×10^{-2}
^{79}Se	1.62×10^{-5}	1.60×10^{-5}
^{151}Sm	8.36×10^{-2}	5.45×10^{-2}
^{126}Sn	1.35×10^{-4}	1.30×10^{-4}
^{90}Sr	1.40×10^{1}	1.34×10^{1}
^{99}Tc	3.18×10^{-3}	3.14×10^{-3}
^{230}Th	2.20×10^{-8}	2.48×10^{-8}
^{232}U	8.32×10^{-6}	7.08×10^{-6}
^{233}U	8.39×10^{-9}	-
^{234}U	2.05×10^{-4}	1.94×10^{-4}
^{235}U	2.61×10^{-6}	1.71×10^{-6}
^{236}U	6.17×10^{-5}	6.03×10^{-5}
^{238}U	5.01×10^{-5}	5.05×10^{-5}
^{90}Y	1.40×10^{1}	1.34×10^{1}
^{93}Zr	2.84×10^{-4}	2.83×10^{-4}
Total	4.18×10^{3}	6.58×10^{3}

NOTES: BWR – boiling water reactor; PWR = pressurized water reactor.

[a] CRUD source term considers releases from all processed SNF assemblies

Source: *18 mos HEPA Source Term.xls* Excel Spreadsheet.

Following the 18-month accumulation period, the HEPA filters are removed, moved to the LLWF, and placed in B-25 boxes (Design Input 6.1.1.5). Reference 2.2.28 (Section 3.1.2) provides the estimated annual number of HEPA filters changed out each year for all facilities as 7,601 (6,144 pre-filters + 1,365-1st stage + 92-2nd stage). That equates to about 146 filters per week. Per Design Input 6.1.1.5 the capacity of the filter storage area of the LLWF is equal to 38 B-25 boxes with 12 HEPA filters per box. Thus, the HEPA filter inventory must be turned over on a two-to three-week basis in order to prevent exceeding the storage capacity of the facility. The filter activity for the WHF HEPA filters that have the maximum activity from normal operations is based on an 18-month accumulation period. Hence, for purposes of determining the fire event source term, there would only be one set of contaminated HEPA filters from the WHF on-site at any time, either within the WHF or in the B-25 boxes.

6.3.4 Seismic Event Source Term

A seismic event, which is a Category 2 event sequence, generates radioactive material source terms by damaging HEPA filters in surface facilities and stored low-level waste in the LLWF. These source terms are determined in the following subsections.

6.3.4.1 HEPA Filter Source Terms

The HEPA source term is conservatively taken to be for WHF filters based on an 18-month accumulation period. This source term is the same as the source term for the fire event calculated in Section 6.3.3.2 and shown in Table 31.

In addition to filters from the WHF, the LLWF stores filters from the other facilities. Accumulation of radioactive material on filters from facilities other than the WHF can only be from resuspension of the surface contamination on casks, TAD canisters, or DPCs. At any one time, there would be a number of 1st stage HEPA filters in B-25 boxes in the LLWF.

The bases for the radioactive material accumulated on the 1st stage HEPA filters from facilities other than WHF are: (a) transportation cask contamination levels of 10^{-4} μCi/cm^2 for beta and gamma emitters and 10^{-5} μCi/cm^2 for alpha emitters (Reference 2.2.48, Section 3.2.8), (b) a cask surface area of 51 m^2 (Reference 2.2.48, Section 3.2.12), (c) a resuspension rate of 4×10^{-5} hr^{-1} (Reference 2.2.48, Section 3.2.9), and (d) 273 transportation casks per year (Reference 2.2.48, Section 4.32). Per Reference 2.2.48, Section 3.2.4 handling operations are performed 24 hours per day, 7 days per week. Therefore, each cask takes 32.09 hours to process on the average (8,760 hours/yr ÷ 273 casks/yr). The amount of radioactive material accumulated after 18 months on these filters is then calculated as follows.

The activity released from one cask is:

$$A_{\gamma,\beta} = \left(\frac{1\times10^{-4}\,\mu Ci}{cm^2}\right)\times 51m^2 \times \frac{(100\,cm)^2}{m^2}\times\left(\frac{4\times10^{-5}}{hr}\right)\times 32.09\,hr = 6.55\times10^{-2}\,\mu Ci$$

$$A_{\alpha} = \left(\frac{1\times10^{-5}\,\mu Ci}{cm^2}\right)\times 51m^2 \times \frac{(100\,cm)^2}{m^2}\times\left(\frac{4\times10^{-5}}{hr}\right)\times 32.09\,hr = 6.55\times10^{-3}\,\mu Ci$$

The total activity accumulated on the filters for an 18-month period (1.5 yr) is then:

$$A_{r} = \left(6.55\times10^{-2}\,\mu C + 6.55\times10^{-3}\,\mu C\right)\times\frac{273\,casks}{yr}\times 1.5\,yr = 29.5\,\mu Ci$$

This activity is negligible compared to the activity on the WHF filters of 367 Ci determined in Table 31. Consequently, the activity on these other filters can be ignored in the seismic event dose evaluation.

6.3.4.2 Low-Level Waste Facility Seismic Release Source Terms

During a seismic event, failure of confinements for the solid and liquid LLW inventories in the LLWF results in the release of that LLW inventory. The LLWF inventory is provided in Table 3. HEPA filters are not included in the LLWF inventory because their radionuclide content is already accounted for in the activity release from the WHF (Section 6.3.4.1). Empty DPCs are also not included due to the negligible doses that would result from releases involving their low contamination levels.

The unit volumes of the individual waste containers in the LLWF are calculated in Table 32 based on dimensions from Table 3.

Table 32. Unit Volumes for Low-Level Radioactive Waste Storage Containers

Waste Container[a]	Dimensions[a]	Volume[b]	Units[b]	Unit Converions Factor[c]	Factor Units[c]	Unit Volume (m^3)[c]
55-gallon drum	24 in diameter × 36 in height	1.63×10^4	in^3	1.639×10^{-5}	$(m/in.)^3$	2.67×10^{-1}
LLLW tank	23,750 gal	23,750	gal	3.785×10^{-4}	m^3/gal	8.99

NOTES: [a] Data from Design Input 6.1.1.5
[b] Drum and HIC volumes calculated as [π ×(diameter/2)^2 × height]; box volume calculated a (L × W × H).
[c] Unit conversion based on 1 in^3 = (2.54 cm/in. / 100 cm/m)^3; 1 ft^3 = (30.48 cm/ft / 100 cm/m)^3; and 2,642 gal = 1 m^3.

The total volume of material available for release in a seismic event is calculated from the unit volumes and the number of each waste container type in the LLWF. A volume release factor is calculated in Table 33 for each waste container as the product of the total volume and the ARF and RF values applicable to each waste container from Design Input 6.1.1.5.

Table 33. Release Factors for each Low-Level Radioactive Waste Storage Container

Waste Storage	Waste Container[a]	Number of Containers[a]	Unit Volume (m^3)[b]	Total Volume, V (m^3)[c]	ARF[d]	RF[d]	Volume Release Factor (m^3)[e]
Spent resin in WHF or LLWF[f]	HIC	7	2.83	1.98×10^{1}	1.3×10^{-2}	0.21	5.41×10^{-2}
Filter storage (pool filter)[g]	HIC	21	2.22	4.67×10^{1}	1.3×10^{-2}	0.21	1.28×10^{-1}
LLLW tank (liquid)	Tank	3	8.99	2.70×10^{1}	5.0×10^{-4}	0.8	1.08×10^{-2}
Drum for DAW	55-gallon drum	216	2.67×10^{-1}	5.76×10^{1}	1.3×10^{-2}	0.21	1.57×10^{-1}
Sorting room (DAW bags)	55-gallon drum, equivalent	102	2.67×10^{-1}	2.72×10^{1}	1.3×10^{-2}	0.21	7.43×10^{-2}
					Sub-total DAW		2.32×10^{-1}

NOTES:
[a] Data from Design Input 6.1.1.5
[b] From Table 32
[c] Calculated as Number of Containers × Unit Volume
[d] Design Input 6.1.3.3
[e] Calculated as (ARF × RF × V).
[f] Calculated from Design Input 6.1.1.8
[g] Calculated from Design Input 6.1.1.7

The total activity is calculated by multiplying the radionuclide concentration from Table 4 in Design Input 6.1.1.6 with the total volume in Table 33 and is presented in Table 34.

Table 34. Low-Level Waste Facility Radionuclide Inventory

Radionuclide	Dry Active Waste (Ci)	Pool Filter (Ci)	Spent Resin (Ci)	Liquid (Ci)	Total (Ci)
^{137}Cs	6.05×10^{-1}	1.00×10^{2}	3.39×10^{2}	4.05×10^{-2}	4.40×10^{2}
^{60}Co	1.21	7.52×10^{2}	2.40×10^{2}	2.70×10^{-2}	9.93×10^{2}
^{54}Mn	6.21×10^{-2}	8.59×10^{1}	4.92×10^{1}	-	1.35×10^{2}
^{58}Co	4.74×10^{-1}	2.94×10^{2}	9.40×10^{1}	-	3.89×10^{2}
^{134}Cs	5.35×10^{-1}	8.87×10^{1}	2.99×10^{2}	-	3.89×10^{2}
Total	2.88	1.32×10^{3}	1.02×10^{3}	6.74×10^{-2}	2.35×10^{3}

Because the damage ratio and the LPF are both equal to 1.0 (Assumptions 3.2.1 and 3.2.6), the radionuclide concentration from Table 4 in Design Input 6.1.1.6 is multiplied by the volume release factor for the waste in Table 33 to determine the LLWF seismic event source term, that is, the radionuclides released during a seismic event. These are reported in Table 35.

Table 35. Low-Level Waste Facility Radionuclides Released During Seismic Event

Radionuclide	Dry Active Waste (Ci)	Pool Filter (Ci)	Spent Resin (Ci)	Liquid (Ci)	Total (Ci)
^{137}Cs	1.65×10^{-3}	2.74×10^{-1}	9.25×10^{-1}	1.62×10^{-5}	1.20
^{60}Co	3.29×10^{-3}	2.05	6.55×10^{-1}	1.08×10^{-5}	2.71
^{54}Mn	1.70×10^{-4}	2.35×10^{-1}	1.34×10^{-1}	-	3.69×10^{-1}
^{58}Co	1.30×10^{-3}	8.03×10^{-1}	2.56×10^{-1}	-	1.06
^{134}Cs	1.46×10^{-3}	2.42×10^{-1}	8.17×10^{-1}	-	1.06

6.4 GENII INPUT FILE DEVELOPMENT

A GENII case run is performed for each scenario variation that includes waste type, release type, release location, receptor, χ/Q basis, and LPF considered. In this section the development of the input files for each of the scenarios is discussed. Each GENII run is constructed with six modules as illustrated in Figure 2. These modules are: *Constituent* (con1), *User_Defined* (usr2), *Air* (air3), *Exposure_Pathways* (exp4), *Receptor_Intakes* (rcp5), and *Health_Impacts* (hei6). The GENII input file, *.gid* contains a section for each of these modules.

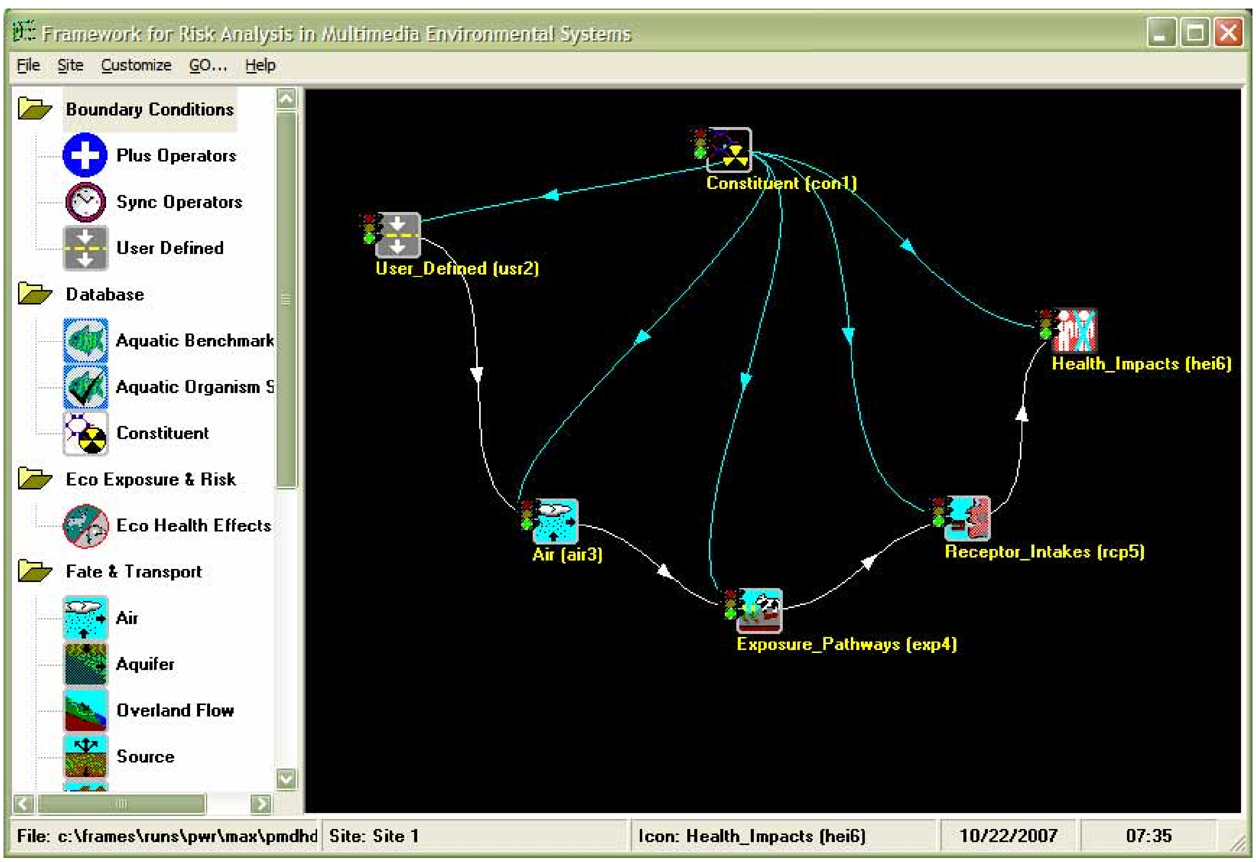


Figure 2. GENII Run Structure

6.4.1 Constituent Module Inputs

The input to the *Constituent* module is the list of radionuclides considered for each case. When the model is executed, the radionuclide dependent information, such as progeny, dose coefficients, risk factors, decay constants, etc. is extracted from the *GENII.mdb* database (Reference 2.2.10, Attachment F) and entered into the *.gid* input file.

6.4.2 User_Defined Module Inputs

The input to the *User_Defined* module consists of data needed to define the radionuclide release including the radionuclide activities and the effects of ARFs, RFs, and applicable LPFs on the inventory. The radionuclide activity release rate and the duration of the release are entered in the first tab of this module for each unit waste form (for example, activities per assembly for commercial SNF, per canister for HLW, etc.). The radionuclide activity release rates for normal releases are obtained from Table 7 and Table 26 for representative commercial SNF, Table 9 for annual Subsurface Facility releases, and Section 6.1.2.5 for the Aging Facility release rates. The radionuclide activities for the Category 2 event sequences are obtained from Table 7 and Table 26 for bounding commercial SNF, Table 27 for HLW, Table 30 for the LLWF fire event, Table 31 for the HEPA release in a seismic event, and Table 35 for the LLWF release in a seismic event. The duration of the release is one year for normal operations, one hour for drop/burst releases, and 30 days for oxidation releases.

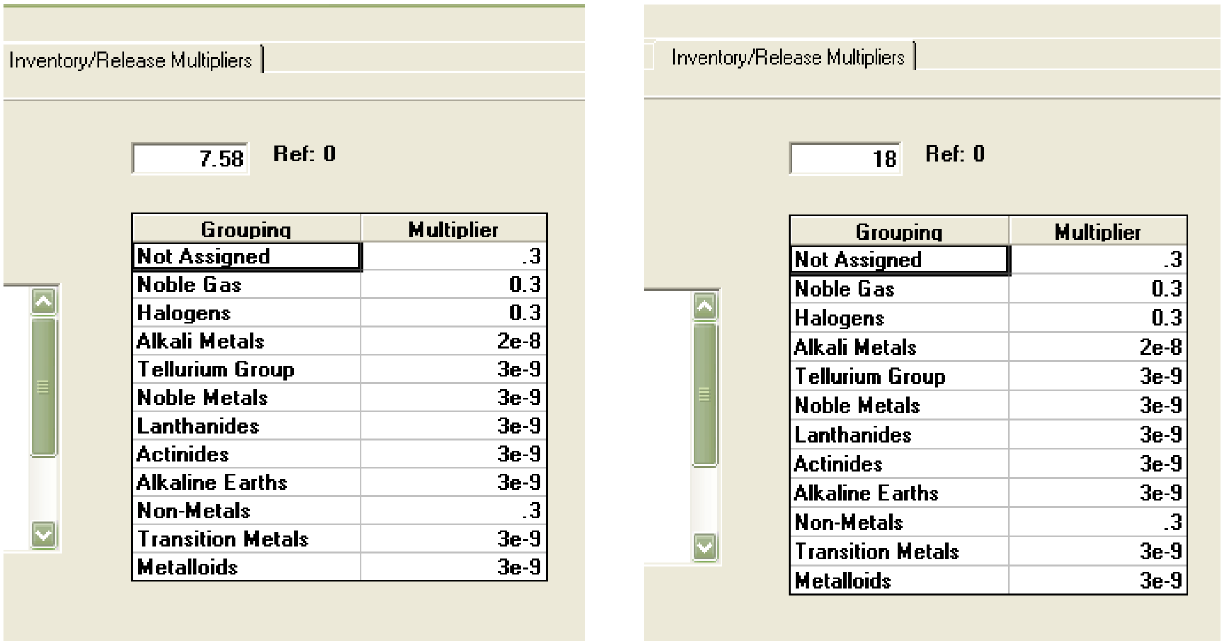
The ARFs and RFs from Table 10 for commercial SNF and HLW, applicable HEPA filtration LPFs from Design Input 6.1.4.1, canister or cask LPFs from Design Input 6.1.4.2, or fuel pool LPFs from Design Input 6.1.4.3 are entered in the second tab of this module as release rate multipliers. Two types of release rate multipliers are available, one that applies to all radionuclides, and a second that applies to radionuclides grouped by chemical classes. The uses of release rate multipliers are described in the following subsections.

6.4.2.1 Normal Operations

Commercial SNF – As discussed in Section 4.4.1.1, the only potential source of airborne releases from the surface facilities during normal operations is during re-packaging of uncanistered commercial SNF in transportation casks or from DPCs into TAD canisters in the WHF. Per Assumption 3.3.1, a maximum of 3,600 MTHM of commercial SNF is received at the surface facilities yearly. Ten percent of the commercial SNF (Design Input 6.1.1.3) are received in either DPCs or bare, intact assemblies in rail or truck transportation casks, 1% of which have cladding damage (Assumption 3.2.1). Using the fuel characteristics from Design Input 6.1.2.1, the number of failed assemblies processed through the WHF yearly that could contribute to potential airborne releases are:

PWR Assemblies $= 3{,}600\,MHTM/yr \times 0.1 \times 0.01 \div 0.475\,MTHM/assembly = 7.58/yr$
BWR Assemblies $= 3{,}600\,MHTM/yr \times 0.1 \times 0.01 \div 0.200\,MTHM/assembly = 18/yr$

Since the number of assemblies is common for all radionuclides, the above values are entered as the Inventory/Release Multiplier as shown in Figure 3. Crud release source term (^{60}Co and ^{55}Fe), from Table 26 is multiplied by 100 to account for releases from all SNF assemblies processed.



PWR Commercial SNF BWR Commercial SNF

Figure 3. Inventory/Release Multipliers for Commercial SNF Normal Operation Releases

The ARFs, RFs, and HEPA LPFs are dependent on radionuclide chemical class, and therefore are entered in the Chemical Group Multipliers window. For example, from Design Input 6.1.4.1, the HEPA LPF for particulates is 1×10^{-4}, the ARF for particulate radionuclides from Table 10 is 3×10^{-5}, the RF for filtered release per Assumption 3.2.8 is 1; therefore, the multiplication factor for particulate classes is:

$$M_p = (1 \times 10^{-4}) \times (3 \times 10^{-5}) \times 1 = 3 \times 10^{-9}$$

This value is shown for the particulate groupings in Figure 3.

Subsurface Releases – For subsurface releases, the activity release rate from Table 9 is entered in the first tab of the module. Because all releases are unfiltered, the inventory/release multipliers are all 1.

Aging Pad Releases – For releases from the aging pads, the activity release rate from Section 6.1.2.5 is entered in the first tab of the module. Because all releases are unfiltered, the inventory/release multipliers are all 1.

6.4.2.2 Event Sequences Involving Commercial SNF Assemblies in Air

Burst Release – Because Category 2 GENII runs are on a per unit basis, for a burst release, the inventory of a single maximum or representative commercial SNF assembly is considered to be available, therefore the Inventory/Release Multiplier common to all radionuclides is set to 1.

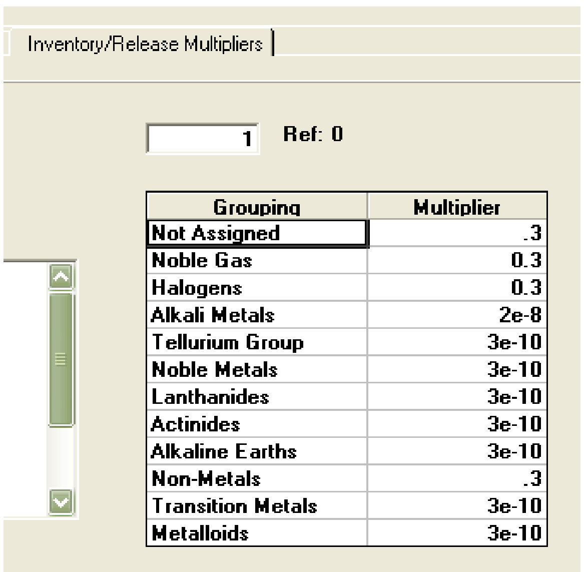
Radionuclide chemical class dependent multipliers consist of ARFs, RFs, Cask/Canister LPFs, and HEPA LPF. For example for the maximum commercial SNF release through HEPA filters, the canister LPF for particulate radionuclides is 0.1 (Design Input 6.1.4.2), the HEPA LPF for particulates is 1×10^{-4} (Design Input 6.1.4.1), the ARF for particulate radionuclides is 3×10^{-5} (Table 10), the RF for filtered release per is 1 (Assumption 3.2.8); therefore, the multiplication factor for particulate classes is:

$$M_p = 0.1 \times (1 \times 10^{-4}) \times (3 \times 10^{-5}) \times 1 = 3 \times 10^{-10}$$

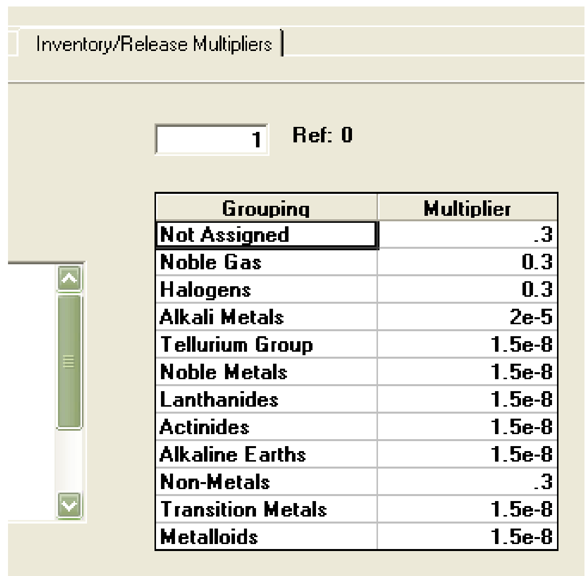
For a representative commercial SNF unfiltered release, the HEPA LPF is 1, the ARF for particulate radionuclides is 3×10^{-5} (Table 10), the RF is 5×10^{-3} (Table 10); therefore, the multiplication factor for particulate classes is:

$$M_p = 0.1 \times 1 \times (3 \times 10^{-5}) \times (5 \times 10^{-3}) = 1.5 \times 10^{-8}$$

The above calculated values are shown for the particulate classes in Figure 4.



Maximum Commercial SNF Filtered



Representative Commercial SNF Unfiltered

Figure 4. Inventory/Release Multipliers for Commercial SNF Burst Release

Oxidation Release – For an oxidation release, GENII runs are also on a per unit basis and the inventory of one assembly is assumed available for release over a 30-day period. The inventory of a single assembly is entered in the first tab of the module as a release rate in Ci/hr over a 30 day (720 hr) period. Therefore, to ensure that only the activity of one assembly is released over the 30-day period, the Inventory/Release Multiplier common to all radionuclides is set to 1 ÷ 720 = 0.00139.

Similar to the burst release, radionuclide chemical class dependent multipliers consist of ARFs, RFs, Cask/Canister LPFs, and HEPA LPF. For example, for the maximum commercial SNF release through HEPA filters, the canister LPF for particulate radionuclides is 0.1 (Design Input 6.1.4.2), the HEPA LPF for particulates is 1×10^{-4} (Design Input 6.1.4.1), the ARF for particulate radionuclides is 2×10^{-3} (Table 10), the RF for filtered release is 1 (Assumption 3.2.8); therefore, the multiplication factor for particulate classes is:

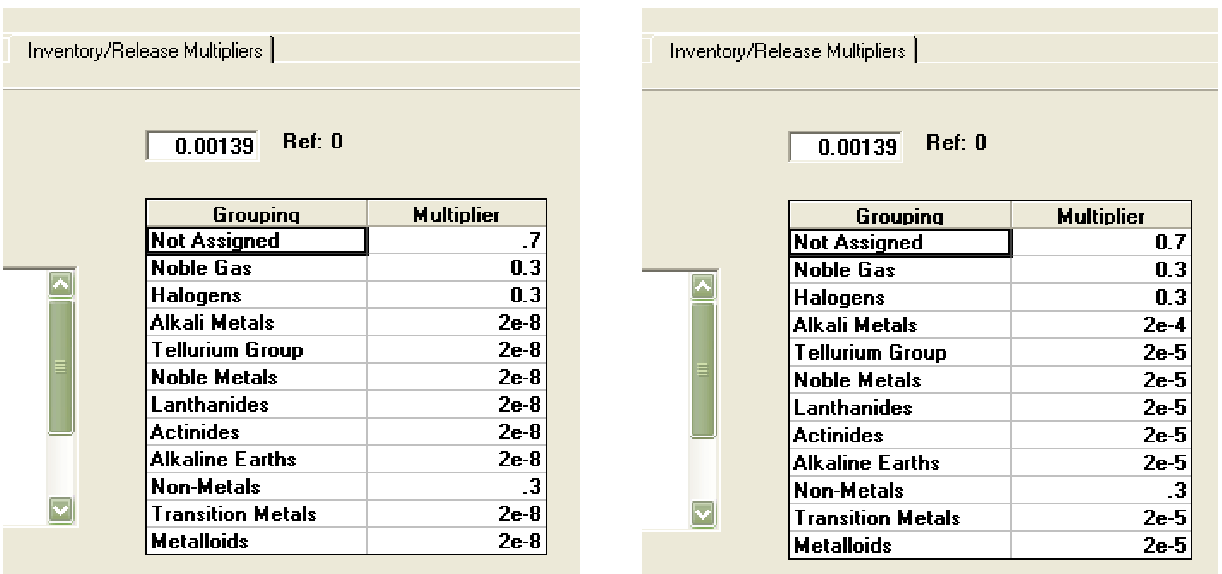
$M_p = 0.1 \times (1 \times 10^{-4}) \times (2 \times 10^{-3}) \times 1 = 2 \times 10^{-8}$

For a representative commercial SNF unfiltered release, the HEPA LPF is 1, the ARF for particulate radionuclides is 2×10^{-3} (Table 10), the RF is 0.1 (Table 10); therefore, the multiplication factor for particulate classes is:

$M_p = 0.1 \times 1 \times (2 \times 10^{-3}) \times 0.1 = 2 \times 10^{-5}$

For the alkali metals (Cs, Rb) all of the parameters are the same as for the particulate radionuclides, with the exception of the RF. The RF from Table 10 for this group is 1. Therefore, the multiplication factor for alkali metals is 2×10^{-4}.

The above calculated values are shown for the alkali metals and the particulate classes in Figure 5.



Maximum Commercial SNF Filtered Representative Commercial SNF Unfiltered

Figure 5. Inventory/Release Multipliers for Commercial SNF Oxidation Release

6.4.2.3 Event Sequences Involving Commercial SNF Assemblies in the Fuel Pool

Per Design Input 6.1.4.3, the pool LPF for particulates and alkali metals is 0, meaning no airborne releases of these radionuclide classes. Thus, only halogens (iodine) and gases are released. The LPF for gases is 1, and the LPF for halogens is 0.005. The ARF for both halogens and gases is 0.3 from Table 10. Thus, the ARF is entered as the Inventory/Release Multiplier applicable to all of the radionuclides, and the LPFs are entered as the Chemical Grouping Multipliers.

6.4.2.4 Event Sequences Involving HLW Canisters

HLW is received at the repository as a vitrified glass form inside canisters shipped in transportation casks. Since the waste is vitrified, all radionuclide releases are treated as particulates. A LPF of 0.1 is used for the HLW canister, and a LPF of 0.1 is used for the transportation cask (Design Input 6.1.4.2). The combined LPF of 0.01 is entered as the Inventory/Release Multiplier applicable to all of the radionuclides for event sequences involving an HLW canister inside a transportation cask. For an HLW canister outside a transportation cask, the leak path factor is 0.1. The ARF and RF from Table 10 are 7×10^{-3} and 0.01, respectively. The combined factor of 7×10^{-5} is entered as the Chemical Grouping Multipliers. If the event sequence includes HEPA filtration, an additional LPF of 1×10^{-4} (Design Input 6.1.4.1) is applied and the respirable fraction is set to 1.0 (Assumption 3.2.8).

6.4.2.5 Event Sequences Involving a Fire in the LLWF

The source term for a fire event determined in Section 6.3.3 considers all applicable ARFs, RFs, and LPFs; therefore, no further factors are required. All multiplication factors for this waste form are set to one.

6.4.2.6 Event Sequences Involving a Seismic Event

The source term for a seismic event determined in Section 6.3.4 considers all applicable ARFs, RFs, and LPFs; therefore, no further factors are required. All multiplication factors for this waste form are set to one.

6.4.3 Air Module Inputs

For an acute release, two parameters are input into this module: the start date and hour, and the name of the file containing the appropriate atmospheric dispersion factors. For a chronic release, only the name of the file is input. Per Assumption 3.2.15, a fall season release is assumed beginning on September 1, at 0 hour. The name of the atmospheric dispersion factor files for each release type and receptor combination are presented on Table 36 below. These files are provided in the Appendix XI CD and listed in Appendix X.

Table 36. Atmospheric Dispersion Factor Matrix

Receptor	Chronic Release from:		GROA Acute Release	
	GROA	Exhaust Shafts	Drop/Burst	Oxidation
95th percentile Meteorology				
Onsite GROA	-	-	*g0-2.xqo*	*g0-720.xqo*
Onsite Exhaust Shafts	-	-	*g0-2.xqe*	*g0-720.xqe*
Offsite General Environment	-	-	*g0-2.xqg*	*g0-720.xqg*
Offsite not in the General Environment	-	-	*g0-2.xqs*	*g0-720.xqs*
50th percentile Meteorology				
Onsite GROA	*g-chron.xqo*	*e-chron.xqo*	*g-annual.xqo*	
Onsite Exhaust Shafts	*g-chron.xqe*	*e-chron.xqe*	*g-annual.xqe*	
Offsite General Environment	*g-chron.xqg*	*e-chron.xqg*	*g-annual.xqg*	
Offsite not in the General Environment	*g-chron.xqs*	*e-chron.xqs*	*g-annual.xqs*	

6.4.4 Exposure_Pathways Module Inputs

Inputs to the *Exposure_Pathways* module are primarily from the YMP specific default files discussed in Design Input 6.1.1.12. This module has four tabs; Controls, Soil, Agriculture, and Pathways. In the Controls tab the duration of the release is entered (1 year for chronic, 1 hour for burst or drop event, and 30 days for oxidation). For the case of the public in the general environment receiving dose from an oxidation release, the adjusted absolute humidity calculated in Section 6.2.3 is also entered in the Control tab. The soil leaching rate constant, as discussed in Section 6.2.1, is modified from the "GENII default leach rate" to the "Leach rate calculated from user input" (LEACHOPTION = 2) in the Soil tab. For public onsite and public offsite not in the general environment receptors, the ingestion pathways are de-selected in the Pathways tab. No changes are required in the Agriculture tab.

6.4.5 Receptor_Intakes Module Inputs

Inputs to the *Receptor_Intakes* module are primarily from the YMP specific default files discussed in Design Input 6.1.1.12 with the changes discussed in Section 6.2.1 for the duration of exposure for the different receptors and the appropriate breathing rates. Pathways are selected from the *Pathway Selection* scroll menu. The changes in Table 21 are entered for the following pathway selections; groundshine – "External ground exposure", air submersion – "External exposure to air", air inhalation – "Air inhalation", and resuspended soil inhalation – "Resuspended soil inhalation".

6.4.6 Health_Impacts Module Inputs

Inputs to the *Health_Impacts* Module are primarily from the YMP specific default files discussed in Design Input 6.1.1.12. The soil thickness from Design Input 6.1.1.11 is entered in the Method Parameters tab.

6.5 DESCRIPTION OF GENII RESULT SPREADSHEETS

A GENII case run is performed for each scenario variation that includes waste type, release type, release location, receptor, χ/Q basis, and LPF considered. For each GENII case, an Excel® spreadsheet is created. These spreadsheets import the organ and TEDE dose results for each pathway and each radionuclide from the GENII output *.hif* files and perform the adjustments described in Section 6.2. The GENII cases considered in this calculation and the corresponding spreadsheet are shown in Table 37. The structure of these spreadsheets and calculations they perform are discussed in the following subsections.

Table 37. GENII Cases and Corresponding Results Spreadsheets

Waste Type	GENII File Name	GENII Results Spreadsheet	Release Type	Filtration	Leak Path Factor	Release Location	X/Q Basis	Receptor
Representative PWR	*nodhdgrg*	*Normal General Environment - PWR.xls*	Normal	Yes	No	GROA	50%ile	General Environment
Representative PWR	*nodhdgrs*	*Normal Site Boundary - PWR.xls*	Normal	Yes	No	GROA	50%ile	Max Site Boundary
Representative PWR	*nodhdgre*	*Normal Exhaust Shafts - PWR.xls*	Normal	Yes	No	GROA	50%ile	Exhaust Shafts
Representative PWR	*nodhdgro*	*Normal Onsite - PWR.xls*	Normal	Yes	No	GROA	50%ile	Onsite
Maximum PWR	*nmdhdgrg*	*Normal General Environment - Max PWR.xls*	Normal	Yes	No	GROA	50%ile	General Environment
Maximum PWR	*nmdhdgrs*	*Normal Site Boundary - Max PWR.xls*	Normal	Yes	No	GROA	50%ile	Max Site Boundary
Maximum PWR	*nmdhdgre*	*Normal Exhaust Shafts - Max PWR.xls*	Normal	Yes	No	GROA	50%ile	Exhaust Shafts
Maximum PWR	*nmdhdgro*	*Normal Onsite - Max PWR.xls*	Normal	Yes	No	GROA	50%ile	Onsite
Representative BWR	*nbdhdgrg*	*Normal General Environment - BWR.xls*	Normal	Yes	No	GROA	50%ile	General Environment
Representative BWR	*nbdhdgrs*	*Normal Site Boundary - BWR.xls*	Normal	Yes	No	GROA	50%ile	Max Site Boundary
Representative BWR	*nbdhdgre*	*Normal Exhaust Shafts - BWR.xls*	Normal	Yes	No	GROA	50%ile	Exhaust Shafts
Representative BWR	*nbdhdgro*	*Normal Onsite - BWR.xls*	Normal	Yes	No	GROA	50%ile	Onsite
Activation	*sfdhdsfg*	*Exhaust Shafts General Environment.xls*	Normal	No	No	Exhaust Shaft	50%ile	General Environment
Activation	*sfdhdsfs*	*Exhaust Shafts Site Boundary.xls*	Normal	No	No	Exhaust Shaft	50%ile	Max Site Boundary
Activation	*sfdhdsfe*	*Exhaust Shafts Exhaust Shafts.xls*	Normal	No	No	Exhaust Shaft	50%ile	Exhaust Shafts
Activation	*sfdhdsfo*	*Exhaust Shafts Onsite.xls*	Normal	No	No	Exhaust Shaft	50%ile	Onsite
Contamination	*cmdhdapg*	*Aging Pad General Environment.xls*	Normal	No	No	Aging Pad	50%ile	General

Table 37. GENII Cases and Corresponding Results Spreadsheets

Waste Type	GENII File Name	GENII Results Spreadsheet	Release Type	Filtration	Leak Path Factor	Release Location	X/Q Basis	Receptor
								Environment
Contamination	*cmdhdaps*	*Aging Pad Site Boundary.xls*	Normal	No	No	Aging Pad	50%ile	Max Site Boundary
Contamination	*cmdhdape*	*Aging Pad Exhaust Shafts.xls*	Normal	No	No	Aging Pad	50%ile	Exhaust Shafts
Contamination	*cmdhdapo*	*Aging Pad Onsite.xls*	Normal	No	No	Aging Pad	50%ile	Onsite
HLW Hanford	*hhdhlgrg*	*HLW Hanford General Environment.xls*	Drop	No	0.01	GROA	95%ile	General Environment
HLW Hanford	*hhdhlgrs*	*HLW Hanford Site Boundary.xls*	Drop	No	0.01	GROA	95%ile	Max Site Boundary
HLW INL	*hidhlgrg*	*HLW INL General Environment.xls*	Drop	No	0.01	GROA	95%ile	General Environment
HLW INL	*hidhlgrs*	*HLW INL Site Boundary.xls*	Drop	No	0.01	GROA	95%ile	Max Site Boundary
HLW SRS	*hsdhlgrg*	*HLW SRS General Environment.xls*	Drop	No	0.01	GROA	95%ile	General Environment
HLW SRS	*hsdhlgrs*	*HLW SRS Site Boundary.xls*	Drop	No	0.01	GROA	95%ile	Max Site Boundary
HLW WW	*hwdhlgrg*	*HLW WW General Environment.xls*	Drop	No	0.01	GROA	95%ile	General Environment
HLW WW	*hwdhlgrs*	*HLW WW Site Boundary.xls*	Drop	No	0.01	GROA	95%ile	Max Site Boundary
Maximum PWR	*pmpnlgrg*	*PWR Pool General Environment.xls*	Pool Drop	No	DF 200 ^{129}I	GROA	95%ile	General Environment
Maximum PWR	*pmpnlgrs*	*PWR Pool Site Boundary.xls*	Pool Drop	No	DF 200 ^{129}I	GROA	95%ile	Max Site Boundary
Maximum BWR	*bmpnlgrg*	*BWR Pool General Environment.xls*	Pool Drop	No	DF 200 ^{129}I	GROA	95%ile	General Environment
Maximum BWR	*bmpnlgrs*	*BWR Pool Site Boundary.xls*	Pool Drop	No	DF 200 ^{129}I	GROA	95%ile	Max Site Boundary
Maximum PWR	*pmdhlgrg*	*PWR Air General Environment.xls*	Burst	Yes	Yes	GROA	95%ile	General Environment
Maximum PWR	*pmohlgrg*	*PWR Air General Environment.xls*	Oxidation	Yes	Yes	GROA	95%ile	General Environment
Maximum PWR	*pmdhlgrs*	*PWR Air Site Boundary.xls*	Burst	Yes	Yes	GROA	95%ile	Max Site Boundary
Maximum PWR	*pmohlgrs*	*PWR Air Site Boundary.xls*	Oxidation	Yes	Yes	GROA	95%ile	Max Site Boundary
Maximum PWR	*pmdhlgrg*	*PWR Air General Environment 50%ile.xls*	Burst	Yes	Yes	GROA	50%ile	General Environment

Table 37. GENII Cases and Corresponding Results Spreadsheets

Waste Type	GENII File Name	GENII Results Spreadsheet	Release Type	Filtration	Leak Path Factor	Release Location	X/Q Basis	Receptor
Maximum PWR	*pmohlgrg*	*PWR Air General Environment 50%ile.xls*	Oxidation	Yes	Yes	GROA	50%ile	General Environment
Maximum PWR	*pmdhlgrs*	*PWR Air Site Boundary 50%ile.xls*	Burst	Yes	Yes	GROA	50%ile	Max Site Boundary
Maximum PWR	*pmohlgrs*	*PWR Air Site Boundary 50%ile.xls*	Oxidation	Yes	Yes	GROA	50%ile	Max Site Boundary
Maximum PWR	*pmdnlgrg*	*PWR Air General Environment no HEPA.xls*	Burst	No	Yes	GROA	95%ile	General Environment
Maximum PWR	*pmonlgrg*	*PWR Air General Environment no HEPA.xls*	Oxidation	No	Yes	GROA	95%ile	General Environment
Maximum PWR	*pmdnlgrs*	*PWR Air Site Boundary no HEPA.xls*	Burst	No	Yes	GROA	95%ile	Max Site Boundary
Maximum PWR	*pmonlgrs*	*PWR Air Site Boundary no HEPA.xls*	Oxidation	No	Yes	GROA	95%ile	Max Site Boundary
Maximum PWR	*p1dnlgrg*	*1% PWR Air General Environment no HEPA.xls*	Burst	No	Yes	GROA	95%ile	General Environment
Maximum PWR	*p1onlgrg*	*1% PWR Air General Environment no HEPA.xls*	Oxidation	No	Yes	GROA	95%ile	General Environment
Maximum PWR	*p1dnlgrs*	*1% PWR Air Site Boundary no HEPA.xls*	Burst	No	Yes	GROA	95%ile	Max Site Boundary
Maximum PWR	*p1onlgrs*	*1% PWR Air Site Boundary no HEPA.xls*	Oxidation	No	Yes	GROA	95%ile	Max Site Boundary
Maximum BWR	*bmdhlgrg*	*BWR Air General Environment.xls*	Burst	Yes	Yes	GROA	95%ile	General Environment
Maximum BWR	*bmohlgrg*	*BWR Air General Environment.xls*	Oxidation	Yes	Yes	GROA	95%ile	General Environment
Maximum BWR	*bmdhlgrs*	*BWR Air Site Boundary.xls*	Burst	Yes	Yes	GROA	95%ile	Max Site Boundary
Maximum BWR	*bmohlgrs*	*BWR Air Site Boundary.xls*	Oxidation	Yes	Yes	GROA	95%ile	Max Site Boundary
Maximum BWR	*bmdnlgrg*	*BWR Air General Environment no HEPA.xls*	Burst	No	Yes	GROA	95%ile	General Environment
Maximum BWR	*bmonlgrg*	*BWR Air General Environment no HEPA.xls*	Oxidation	No	Yes	GROA	95%ile	General Environment

Table 37. GENII Cases and Corresponding Results Spreadsheets

Waste Type	GENII File Name	GENII Results Spreadsheet	Release Type	Filtration	Leak Path Factor	Release Location	X/Q Basis	Receptor
Maximum BWR	*bmdnlgrs*	*BWR Air Site Boundary no HEPA.xls*	Burst	No	Yes	GROA	95%ile	Max Site Boundary
Maximum BWR	*bmonlgrs*	*BWR Air Site Boundary no HEPA.xls*	Oxidation	No	Yes	GROA	95%ile	Max Site Boundary
Maximum BWR	*b1dnlgrg*	*1% BWR Air General Environment no HEPA.xls*	Burst	No	Yes	GROA	95%ile	General Environment
Maximum BWR	*b1onlgrg*	*1% BWR Air General Environment no HEPA.xls*	Oxidation	No	Yes	GROA	95%ile	General Environment
Maximum BWR	*b1dnlgrs*	*1% BWR Air Site Boundary no HEPA.xls*	Burst	No	Yes	GROA	95%ile	Max Site Boundary
Maximum BWR	*b1onlgrs*	*1% BWR Air Site Boundary no HEPA.xls*	Oxidation	No	Yes	GROA	95%ile	Max Site Boundary
Representative PWR	*padhlgrg*	*Representative PWR Air General Environment.xls*	Burst	Yes	Yes	GROA	95%ile	General Environment
Representative PWR	*paohlgrg*	*Representative PWR Air General Environment.xls*	Oxidation	Yes	Yes	GROA	95%ile	General Environment
Representative PWR	*padhlgrs*	*Representative PWR Air Site Boundary.xls*	Burst	Yes	Yes	GROA	95%ile	Max Site Boundary
Representative PWR	*paohlgrs*	*Representative PWR Air Site Boundary.xls*	Oxidation	Yes	Yes	GROA	95%ile	Max Site Boundary
Representative PWR	*padhlgro*	*Representative PWR Air Onsite.xls*	Burst	Yes	Yes	GROA	95%ile	Onsite
Representative PWR	*paohlgro*	*Representative PWR Air Onsite.xls*	Oxidation	Yes	Yes	GROA	95%ile	Onsite
Representative PWR	*padhlgro*	*Representative PWR Air Onsite 50%ile.xls*	Burst	Yes	Yes	GROA	50%ile	Onsite
Representative PWR	*paohlgro*	*Representative PWR Air Onsite 50%ile.xls*	Oxidation	Yes	Yes	GROA	50%ile	Onsite
Representative PWR	*padnlgrg*	*Representative PWR Air General Environment no HEPA.xls*	Burst	No	Yes	GROA	95%ile	General Environment

Table 37. GENII Cases and Corresponding Results Spreadsheets

Waste Type	GENII File Name	GENII Results Spreadsheet	Release Type	Filtration	Leak Path Factor	Release Location	X/Q Basis	Receptor
Representative PWR	*paonlgrg*	*Representative PWR Air General Environment no HEPA.xls*	Oxidation	No	Yes	GROA	95%ile	General Environment
Representative PWR	*padnlgrs*	*Representative PWR Air Site Boundary no HEPA.xls*	Burst	No	Yes	GROA	95%ile	Max Site Boundary
Representative PWR	*paonlgrs*	*Representative PWR Air Site Boundary no HEPA.xls*	Oxidation	No	Yes	GROA	95%ile	Max Site Boundary
Representative BWR	*badhlgrg*	*Representative BWR Air General Environment.xls*	Burst	Yes	Yes	GROA	95%ile	General Environment
Representative BWR	*baohlgrg*	*Representative BWR Air General Environment.xls*	Oxidation	Yes	Yes	GROA	95%ile	General Environment
Representative BWR	*badhlgrs*	*Representative BWR Air Site Boundary.xls*	Burst	Yes	Yes	GROA	95%ile	Max Site Boundary
Representative BWR	*baohlgrs*	*Representative BWR Air Site Boundary.xls*	Oxidation	Yes	Yes	GROA	95%ile	Max Site Boundary
Representative BWR	*badhlgro*	*Representative BWR Air Onsite.xls*	Burst	Yes	Yes	GROA	95%ile	Onsite
Representative BWR	*baohlgro*	*Representative BWR Air Onsite.xls*	Oxidation	Yes	Yes	GROA	95%ile	Onsite
Representative BWR	*badhlgro*	*Representative BWR Air Onsite 50%ile.xls*	Burst	Yes	Yes	GROA	50%ile	Onsite
Representative BWR	*baohlgro*	*Representative BWR Air Onsite 50%ile.xls*	Oxidation	Yes	Yes	GROA	50%ile	Onsite
Representative BWR	*badnlgrg*	*Representative BWR Air General Environment no HEPA.xls*	Burst	No	Yes	GROA	95%ile	General Environment
Representative BWR	*baonlgrg*	*Representative BWR Air General Environment no HEPA.xls*	Oxidation	No	Yes	GROA	95%ile	General Environment
Representative BWR	*badnlgrs*	*Representative BWR Air Site Boundary no HEPA.xls*	Burst	No	Yes	GROA	95%ile	Max Site Boundary
Representative BWR	*baonlgrs*	*Representative BWR Air Site Boundary no HEPA.xls*	Oxidation	No	Yes	GROA	95%ile	Max Site Boundary

Table 37. GENII Cases and Corresponding Results Spreadsheets

Waste Type	GENII File Name	GENII Results Spreadsheet	Release Type	Filtration	Leak Path Factor	Release Location	X/Q Basis	Receptor
LLWF Inventory	*lwfndgrg*	*LLW Fire General Environment.xls*	Fire	No	No	GROA	95%ile	General Environment
LLWF Inventory	*lwfndgrs*	*LLW Fire Site Boundary.xls*	Fire	No	No	GROA	95%ile	Max Site Boundary
LLWF Inventory	*lwsndgrg*	*LLW Seismic General Environment.xls*	Seismic	No	No	GROA	95%ile	General Environment
LLWF Inventory	*lwsndgrs*	*LLW Seismic Site Boundary.xls*	Seismic	No	No	GROA	95%ile	Max Site Boundary
HEPA Inventory PWR	*hpsndgrg*	*HEPA Seismic General Environment.xls*	Seismic	No	No	GROA	95%ile	General Environment
HEPA Inventory PWR	*hpsndgrs*	*HEPA Seismic Site Boundary.xls*	Seismic	No	No	GROA	95%ile	Max Site Boundary
HEPA Inventory BWR	*hbsndgrg*	*HEPA Seismic General Environment - BWR.xls*	Seismic	No	No	GROA	95%ile	General Environment
HEPA Inventory BWR	*hbsndgrs*	*HEPA Seismic Site Boundary - BWR.xls*	Seismic	No	No	GROA	95%ile	Max Site Boundary

NOTES: BWR = boiling water reactor; DF = decontamination factor; GROA = geologic repository operations area; HEPA = high-efficiency particulate air; HLW = high-level waste; PWR = pressurized water reactor.

Source: *Summary of Doses.xls-Result Matrix*

6.5.1 Normal Operations Spreadsheets

Spreadsheets are developed for each GENII run that evaluates normal operations releases from the surface facilities, Subsurface Facility, and the aging pads for each receptor. Receptors considered are members of the public in the general environment, members of the public beyond the site boundary not in the general environment, members of the public near the surface facilities, and members of the public near the subsurface exhaust shafts. Each spreadsheet has three worksheets: *Results*, *Burst Isotopic Results*, and *Burst hif*. Examples provided in the following subsections are from the *Normal General Environment – PWR.xls* spreadsheet and the *Normal Onsite – PWR.xls* spreadsheet.

6.5.1.1 *Burst hif* Worksheet

This worksheet contains the *.hif* output file generated by a single GENII run. On row 5 of the worksheet, the date and time of the GENII run that generated the results is displayed. The dose results for each radionuclide in ascending alphabetical order begin on row 13. There are two rows for each dose pathway beginning two rows below the radionuclide name. The first of these two rows contains the name of the dose pathway, and the second contains the dose from that pathway for each of the 23 ICRP-60 (Reference 2.2.45) organs listed on row 10 and the effective dose (shown in column X).

The dose pathways depend on the location of the receptor for the particular GENII case. Ingestion pathways are only included for receptors located in the general environment (Assumption 3.2.11). So for the general environment cases, as represented in *Normal General Environment – PWR.xls*, the dose pathways and their row offset from the radionuclide row (shown in parentheses) are:

Pathway	**Row Offset**
Air submersion	(3)
Air inhalation	(5)
Eggs ingestion	(7)
Fruit ingestion	(9)
Grain ingestion	(11)
Groundshine exposure	(13)
Leafy vegetable ingestion	(15)
Meat ingestion	(17)
Milk ingestion	(19)
Poultry ingestion	(21)
Root vegetable ingestion	(23)
Soil ingestion	(25)
Resuspended soil inhalation	(27)

For all other cases where ingestion is not included, as represented in *Normal Onsite – PWR.xls*, the dose pathways and their row offset from the radionuclide row (shown in parentheses) are:

Pathway	**Row Offset**
Air submersion	(3)
Air inhalation	(5)
Groundshine exposure	(7)
Resuspended soil inhalation	(9)

6.5.1.2 *Burst Isotopic Results* Worksheet

This worksheet extracts the dose results from the *Burst hif* worksheet and organizes the information into tables by the dose pathway discussed in Section 6.5.1.1. One table is provided for each dose pathway. These tables have the radionuclide names in column C, the organ doses associated with each of those radionuclides in columns D through Z, and the effective dose in column AA. The dose results from the *Burst hif* worksheet are extracted as follows:

1. The column locations for each organ dose in the *Burst hif* worksheet are specified in cells D1 through AA1.

2. In the *Burst hif* worksheet, there are 28 rows per radionuclide for the general environment cases and 10 rows per radionuclide for the all other cases. The first radionuclide name is located in row 13. With this information, the row numbers where the radionuclide names are located in the *Burst hif* worksheet are determined and specified in cells A4 through A83 of the *Burst Isotopic Results* worksheet.

3. The cell location of the radionuclide name in the *Burst hif* worksheet is determined by using two Excel® built-in functions, CONCATENATE and INDIRECT. CONCATENATE combines the worksheet name, which is in cell C1, with the column location in the *Burst hif* worksheet for the radionuclide name (column A), and with the row number for the radionuclide from column A determined in step 2, above. For example, from the *Normal General Environment – PWR.xls* spreadsheet, the cell location for ^{242m}Am is ‘Burst hif’!A125. INDIRECT then locates the value from cell ‘Burst hif’!A125 and places it into cell C8. From the *Normal Onsite – PWR.xls* spreadsheet, the cell location for ^{242m}Am is ‘Burst hif’!A53. INDIRECT then locates the value from cell ‘Burst hif’!A53 and places it into cell C8.

4. The cell location of the organ dose for each radionuclide and pathway is determined using the same two Excel® built-in functions used in step 3 above. CONCATENATE combines the worksheet name, which is in cell C1, with the column location for the organ dose, shown in row 1, with the row number for the radionuclide from column A plus the offset for the particular pathway dose, discussed and indicated in Section 6.5.1.1. For example from the *Normal General Environment – PWR.xls* spreadsheet, the location of the brain dose from ^{155}Eu groundshine is determined as follows. For ^{155}Eu the brain dose is in column D (per row 1), the row for the radionuclide name is 629 (per cell A26), and the offset for the groundshine dose is 13 rows (from Section 6.5.1.1). Therefore, the cell location for the brain dose from groundshine is ‘Burst hif’!D642.

The value from the *Burst hif* worksheet is 4.48×10^{-13}, which is the value shown in cell D278. For the *Normal Onsite – PWR.xls* spreadsheet, the procedure is the same, but the row for the radionuclide name is 233 (per cell A26) and the row offset for the groundshine dose is 7 rows (from Section 6.5.1.1). Therefore, the cell location for the brain dose from groundshine in the *Normal Onsite – PWR.xls* spreadsheet is 'Burst hif'!D240, which is zero and shown as a blank in cell D278. This procedure is performed for each organ and for up to 80 radionuclides per dose pathway. If there are less than 80 radionuclides of radionuclides in the *Burst hif* worksheet, the extra rows will have zero values.

5. Step 4 is performed for each individual pathway.

6. The doses from each pathway are then summed for each radionuclide and presented in cells C1094 through AA1176 for the general environment case and C338 through AA420 for all other cases.

7. In columns AC through BA the fraction of the dose that each radionuclide contributes to each pathway is determined using a "greater than" filter criterion based on the value in cell A2. If the contribution for a particular radionuclide is less than the criterion (0.1%), then the cell is blanked out. As an example, in the *Normal General Environment – PWR.xls* spreadsheet the total effective dose from ^{137}Cs is 1.89×10^{-8} Sv (cell AA1116), and the total for all radionuclides is 5.91×10^{-8} Sv (cell AA1176). Thus, the percentage of the total that ^{137}Cs is then $1.89 \times 10^{-8} \div 5.91 \times 10^{-8} \times 100 = 32.0\%$, which is the value presented in cell BA1116.

8. The maximum fraction of the total organ dose for any single radionuclide is determined in cells AD1176 through BA1176 for the general environment cases and AD420 through BA420 for all other cases. In the next row the maximum contributing radionuclide is determined using the Excel® built-in functions INDEX and MATCH. For example, in the *Normal General Environment – PWR.xls* spreadsheet by inspecting cells BA1096 through BA1175, the maximum contributing radionuclide is ^{3}H and its corresponding contribution is 34.7% of the total dose. These are shown in cells BA1177 and BA1176, respectively.

6.5.1.3 *Results* Worksheet

This worksheet summarizes the TEDE and organ doses from the *Burst Isotopic Results* worksheet. The effective doses for each pathway are presented in columns G and H and summed in column I. The percent contribution for each pathway is calculated in column J. The total organ doses are presented in cells L1 through M29. The maximum organ dose and corresponding organ are determined in cells M30 and M31, respectively.

The radionuclide contributing the largest fraction of the total effective dose and its fraction of the total is presented in cells C30 and D30, respectively. The radionuclide contributing the largest fraction of the maximum organ dose and its corresponding fraction of the total are presented in cells C31 and D31, respectively.

6.5.2 Acute Release Spreadsheets

Spreadsheets are developed for each GENII run that evaluates airborne releases during an event sequence from the surface facilities. Receptors considered are members of the public in the general environment, members of the public beyond the site boundary not in the general environment, and members of the public near the surface facilities. Each spreadsheet has three worksheets: *Results*, *Burst Isotopic Results*, and *Burst hif*. The spreadsheets for the commercial SNF waste forms contain two additional worksheets: *Oxidation Isotopic Results* and *Oxidation hif*. Examples provided in the following subsections are from the *BWR Air General Environment.xls* spreadsheet and the *BWR Air Site Boundary.xls* spreadsheet.

6.5.2.1 *Burst hif* Worksheet

This worksheet is similar to the *Burst hif* worksheet for normal operations releases described in Section 6.5.1.1 with the following differences.

The results in the *.hif* file include acute and chronic doses. Acute doses include doses from the plume passage for each radionuclide and each dose pathway. Chronic doses include doses for a one-year duration from the material deposited on the ground.

The dose pathways depend on the location of the receptor for the particular GENII case. Ingestion pathways are only included for receptors located in the general environment (Assumption 3.2.11). So for the general environment cases, as represented in *BWR Air General Environment.xls*, the dose pathways and their row offset from the radionuclide row (shown in parentheses) are:

Pathway	**Acute Row Offset**	**Chronic Row Offset**
Air submersion	(3)	(30)
Air inhalation	(5)	(32)
Eggs ingestion	(7)	(34)
Fruit ingestion	(9)	(36)
Grain ingestion	(11)	(38)
Groundshine exposure	(13)	(40)
Leafy vegetable ingestion	(15)	(42)
Meat ingestion	(17)	(44)
Milk ingestion	(19)	(46)
Poultry ingestion	(21)	(48)
Root vegetable ingestion	(23)	(50)
Soil ingestion	(25)	(52)
Resuspended soil inhalation	(27)	(54)

For all other cases where ingestion is not included, as represented in *BWR Air Site Boundary.xls*, the dose pathways and their row offset from the radionuclide row (shown in parentheses) are:

Pathway	**Acute Row Offset**	**Chronic Row Offset**
Air submersion	(3)	(12)
Air inhalation	(5)	(14)
Groundshine exposure	(7)	(16)
Resuspended soil inhalation	(9)	(18)

6.5.2.2 *Oxidation hif* Worksheet

This worksheet is similar in format to the *Burst hif* worksheet described above except that it provides results related to the post-accident oxidation of fuel.

6.5.2.3 *Burst Isotopic Results* and *Oxidation Isotopic Results* Worksheets

These two worksheets have the same structure. The following discussion for the *Burst Isotopic Results* worksheet also applies to the *Oxidation Isotopic Results* worksheet.

The *Burst Isotopic Results* worksheet extracts the dose results from the *Burst hif* worksheet and organizes the information into several tables. One table is provided for each dose pathway. These tables have the radionuclide names in column C, the organ doses associated with each of those radionuclides in columns D through Z, and the effective dose in column AA. The dose results from the *Burst hif* worksheet are extracted as follows:

1. The column locations for each organ dose in the *Burst hif* worksheet are specified in cells D1 through AA1.

2. In the *Burst hif* worksheet, there are 55 rows per radionuclide for the general environment case and 19 rows per radionuclide for all other cases. The first radionuclide name is located in row 13. With this information, the row numbers where the radionuclide names are located are determined and specified in cells A4 through A76 (Some worksheets have 80 radionuclides, for these worksheets the range is extended to A83. The discussion in this section applies to these extended worksheets).

3. The cell location of the radionuclide name in the *Burst hif* worksheet is determined by using two Excel® built-in functions, CONCATENATE and INDIRECT. CONCATENATE combines the worksheet name, which is in cell C1, with the column location for the radionuclide name (column A), and with the row number for the radionuclide from column A determined in step 2, above. For example, the cell location for ^{242m}Am is 'Burst hif'!A178. INDIRECT then locates the value from cell 'Burst hif'!A178 and places it into cell C7.

4. The cell location of the organ dose for each radionuclide and pathway is determined using the same two Excel® built-in functions used in step 3 above. CONCATENATE combines the worksheet name, which is in cell C1, with the column location for the organ dose with the row number for the radionuclide from column A plus the offset for the particular pathway dose, discussed and indicated in Section 6.5.2.1. For example,

from the *BWR Air General Environment.xls* spreadsheet, the location of the skin dose from ^{85}Kr due to air submersion is determined as follows. For ^{85}Kr the skin dose is in column R (per Row 1), the row for the radionuclide name from cell A29 is 1388, and the offset for the submersion dose is 3 rows. Therefore, the cell location for the skin dose from submersion is 'Burst hif'!R1391. The value from the *Burst hif* worksheet is 3.69×10^{-6}, which is the value shown in cell U29. This procedure is performed for each organ and for up to 73 radionuclides per dose pathway. If there are less than 73 radionuclides of radionuclides in the *Burst hif* worksheet, the extra rows have zero values.

5. Step 4 is performed for each individual pathway.

6. Adjustments are performed as appropriate for each dose pathway. The submersion pathway doses are adjusted by a factor specified in cell A3. This adjustment factor is 1 for a burst release and 720/22 = 32.73 for an oxidation release as discussed in Section 4.3.4.2. The resuspension inhalation dose, ground shine dose and ingestion pathway doses are adjusted by a factor of 30/365 for both burst and oxidation releases because, per Assumption 3.2.3,the exposure duration is 30 days but GENII calculates a one year dose.

7. As discussed in Section 4.3.4.3, the ^{14}C ingestion dose from oxidation must further be adjusted by the factor F_{H3}. This factor is determined in Section 6.2.2 to be 31.41 and is set in cell A1 of the *Oxidation Isotopic Results* worksheet. This factor is applied to the ingestion doses by checking if the radionuclide name is "C14" and if the release is for oxidation. If not, the adjustment factor is set to 1.0.

8. As discussed in Section 4.3.4.3, GENII assumes that ^{3}H attains equilibrium quickly with the vegetation and its initial concentration in plants is directly proportional to its atmospheric concentration. Therefore, following plume passage ^{3}H no longer accumulates in plants. This means that the ^{3}H dose calculated by GENII is based on accumulation only during the plume passage so the ^{3}H dose does not need to be adjusted to a 30-day dose from a one-year dose, as discussed in step 6 above. Consequently, if the radionuclide name is "H3", the adjustment factor is set to 1.

9. The doses from each pathway are then summed for each radionuclide and presented in cells C1005 through AA1078 for the general environment case and C312 through AA385 for all other cases.

10. In columns AC through BA the fraction of the dose that each radionuclide contributes to each pathway is determined using the "greater than" filter criterion based on the value in cell A2. If the contribution for a particular radionuclide is less than the criterion (0.1%), then the cell is blanked out. For example, from the *BWR Air General Environment.xls* spreadsheet the total effective dose from ^{3}H is 7.55×10^{-7} Sv (cell AA1028), and the total for all radionuclides is 8.65×10^{-7} Sv (cell AA1078). Thus, the percentage of the total that ^{3}H is then $7.55 \times 10^{-7} \div 8.65 \times 10^{-7} \times 100 = 87.3\%$, which is the value presented in cell BA1028.

11. The maximum fraction of the total organ dose for any single radionuclide is determined in cells AD1078 through BA1078 for the general environment case and AD385 through BA385 for all other cases. In the next row the maximum contributing radionuclide is determined using the Excel® built-in functions INDEX and MATCH. For example, by inspecting cells BA1005 through BA1077 in the *BWR Air General Environment.xls* spreadsheet, the maximum contributing radionuclide is ^{3}H and its corresponding contribution is 87.3% of the total dose. These are shown in cells BA1079 and BA1078, respectively.

6.5.2.4 *Results* Worksheet

This worksheet summarizes the TEDE and organ doses from the *Burst Isotopic Results* and *Oxidation Isotopic Results* worksheets. The effective doses for each pathway are presented in columns C and D and summed in column E for the oxidation release and in columns G and H and summed in column I for the burst release. The percent contribution for each pathway is calculated in column F for the oxidation release and column J for the burst release. The oxidation and burst release doses are summed in columns K through M with the percent contribution for each pathway presented in column N.

The total organ doses are presented in cells P1 through S29. The maximum organ dose and corresponding organ are determined in cells S30 and S31, respectively.

The radionuclide contributing the largest fraction of the total effective dose and its fraction of the total is presented in cells C30 and D30, respectively, for the burst release and cells E30 and F30 for the oxidation release, respectively. The radionuclide contributing the largest fraction of the maximum organ dose and its corresponding fraction of the total are presented in cells C31 and D31, respectively, for the burst release and cells E31 and F31, respectively, for the oxidation release.

6.5.3 Summary of Doses Spreadsheet

The *Summary of Doses.xls* spreadsheet summarizes the dose results from each individual spreadsheet identified in Table 37 and described in Sections 6.5.1 and 6.5.2. This spreadsheet contains five worksheets: *Bounding Category 2 Events*, *Result Matrix*, *XQ Adjustment*, *Crud Adjustment Factors*, and *Seismic and Fire Organ Doses*. Each of these worksheets is described in the following subsections.

6.5.3.1 *XQ Adjustment* Worksheet

This worksheet calculates the time-weighted χ/Q values in cells H4 to H19 using Equation 12. The time-weighted χ/Q values are presented in Section 6.2.2.

This worksheet also calculates the adjustment factors, F_{H3}, in cells J4 to J15, as discussed in Section 4.3.4.3. The absolute humidity adjustment factor, discussed in Section 6.2.3, are calculated in cells K4 to K14 and the time weighted breathing rates are calculated using Equation 19 in cells H27 to H36.

6.5.3.2 *Crud Adjustment Factors* Worksheet

This worksheet calculates the adjusted crud source term for the burst release in cells B16 to E23 as discussed in Section 6.2.5.

6.5.3.3 *Seismic and Fire Organ Doses* Worksheet

The doses from bounding Category 2 seismic and fire events are from two sources, the inventory in the Low-Level Waste Facility and the inventory accumulated on the HEPA filters. The doses for the LLW inventory are in Cells B4 to B26 and E4 to E26 for the seismic event and in cells B33 to B55 and E33 to E55 for the fire event. The doses from releases of the HEPA accumulated activity are in Cells C4 to C26 and F4 to F26 for the seismic event and in cells C33 to C55 and F33 to F55 for the fire event. The fire event HEPA organ doses are calculated by dividing the seismic event HEPA organ doses by 100. The doses are calculated in three GENII runs (two for the seismic event and one for the fire event). To determine the maximum organ dose, the organ doses in spreadsheets from each of the contributions are summed in the *Seismic and Fire Organ Doses* worksheet in cells D4 to D26 and G4 to G26 for the seismic event and in cells D33 to D55 and E33 to E55 for the fire event. Maximum organ doses are determined in cells B27 to G28 for the seismic event and in cells B56 to G57 for the fire event.

6.5.3.4 *Result Matrix* Worksheet

This worksheet summarizes the dose results for each GENII run. A description of each case is provided in columns A through I. Column A identifies the waste type. Column B provides the GENII file name using the naming convention discussed in Appendix VI. Column C provides the spreadsheet name with the GENII run results. Column D identifies the event type (normal release, drop, pool dose, burst, oxidation, fire, or seismic). Column E indicates if HEPA filtration is considered. Column F indicates if a cask and/or canister or pool LPF is used and its value. column G provides a code for the release location: GROA = surface facilities, ES = subsurface exhaust shafts, AP = aging pads. Column H indicates whether annual average atmospheric dispersion factors 50^{th} percentile or 95^{th} percentile atmospheric dispersion factors are used and column I provides the public receptor location.

Columns J through S provide the numerical results for each case. Column J links to the *Results* worksheet for each of the spreadsheets discussed in Sections 6.5.1 and 6.5.2 to obtain the total effective dose. Column K is used to sum the burst and oxidation results for commercial SNF. This column is not used for other waste forms. Column L links to the name of the maximum organ determined in *Results* worksheet and column M to the dose value for the maximum organ. Column N links to the maximum organ for both burst and oxidation for commercial SNF and column O to the dose value for the maximum organ. These two columns are not used for other waste forms. Column P links to the skin dose which is used to calculate the LDE in column Q using Equation 11. Column R adds the skin dose from burst and oxidation releases for commercial SNF and Column S adds the lens dose from burst and oxidation releases for commercial SNF. There two columns are not used for other waste forms.

6.5.3.5 *Bounding Category 2 Events* Worksheet

This worksheet determines the doses from normal operations and for each of the bounding Category 2 event sequences shown in Table 2.

Columns A through D describe the normal operations or the event sequences. Column E presents the MAR. Columns F and G provide a description of the confinement and mitigation credited for each event sequence. Columns H through O provide further information including the damage ratio, LPFs credited for casks, canisters, and HEPA filters.

Column P presents the number of waste forms used to multiply the doses from the *Result Matrix* worksheet. Column Q presents the waste form type.

For normal operation doses, the total effective dose is presented in columns R through U. The total effective dose consists of the doses from the surface facilities (which are airborne releases from the WHF), the contribution from activation of air and silica dust and resuspension of waste package surface contamination from the Subsurface facilities, and the resuspension of contamination from the canisters located on the aging pads discussed in Section 4.4.1. Four receptors are considered: onsite public near the surface facilities (GROA), onsite public near the subsurface exhaust shafts (ES), the maximally exposed public located at the site boundary in the general environment, and the maximally exposed public located at the site boundary not in the general environment. For compliance with the performance objectives listed in Table 1, organ doses are not required; therefore, columns V through AK for rows 3, 4, and 5 are not used.

For compliance with the performance objectives listed in Table 1 for the bounding Category 2 event sequences, doses to the onsite public or to the radiation workers are not calculated; therefore, columns R, S, V, W, Z, AA, AD, AE, AH, and AI are not used.

The effective doses from column K of the *Result Matrix* worksheet for commercial SNF in air and from column J for all other waste forms are multiplied by the number of waste forms shown in column P to determine the total effective dose for each bounding Category 2 event. Results for the maximally exposed member of the public located at the site boundary in the general environment are presented in column T, and for the maximally exposed member of the public located at the site boundary not in the general environment in column U. This approach is repeated for the maximum organ dose using column O of the *Result Matrix* worksheet for commercial SNF in air and using column M for all other waste forms. Resultant organ doses for the public in the general environment are presented in column AB, and for the public not in the general environment in column AC. The maximum organs are identified in columns X and Y using a similar approach.

A special case is the treatment of HLW waste. HLW is received at the repository as a vitrified glass form inside canisters. Therefore, all radionuclide releases are treated as particulates. For each of the HLW sources (Hanford Site, Idaho National Laboratory, Savannah River Site, and West Valley), a GENII run is performed using a LPF of 0.01 (0.1 for the canister and 0.1 for the transportation cask), a respirable fraction of 0.01, and no HEPA filtration. Because all of the HLW releases are treated as particulates, the resulting doses are determined for any event sequence by ratioing the appropriate LPFs considered in the event sequence and by the respirable fraction consistent with filtration credit. For example, Event 2-03 considers the LPF from the canister only. Therefore, the doses from Event 2-02 are multiplied by 10 to determine the doses for Event 2-03. Similarly, if HEPA filtration is considered, the unfiltered doses are multiplied by the HEPA filter LPF factor of 1×10^{-4} and multiplied by 100 to account for the respirable fraction of one (1) (Assumption 3.2.8) to determine the filtered doses.

6.6 DOSES FOR INDIVIDUAL WASTE FORMS

This section presents the dose results for individual waste forms on a per unit basis.

6.6.1 Pressurized Water Reactor Commercial Spent Nuclear Fuel

This section presents the annual results for normal operations, which are airborne releases from the WHF discussed in Section 4.4.1.1, assuming that only PWR fuel is processed. This section also presents the results for a Category 2 event sequence involving a single PWR commercial SNF assembly. Table 38 provides the results when using a representative PWR assembly in the analyses. Table 39 provides the results when using a maximum PWR assembly in the analyses.

It should be noted that Table 39 also includes results for normal operations with maximum PWR fuel even though such fuel is normally only applicable to Category 1 and 2 event sequences (Section 6.1.2.2). These additional results are presented to provide additional confidence that normal operation performance objectives will not be exceeded even under conditions not expected to be encountered during normal repository operation.

Table 38. Representative Pressurized Water Reactor Assembly Results

	Total Effective Dose Equivalent (mrem)	Highest Total Organ Dose Equivalent (mrem)	Shallow Dose Equivalent to Skin (mrem)	Lens Dose Equivalent (mrem)
Representative PWR-Normal Release-Filtered-50% χ/Q (Annual Dose)				
Onsite[a]	2.77	2.94×10^{1} (Skin)	2.94×10^{1}	3.22×10^{1}
Exhaust Shafts[b]	2.84×10^{-3}	3.02×10^{-2} (Skin)	3.02×10^{-2}	3.31×10^{-2}
Offsite Public in the General Environment[c]	1.01×10^{-2}	5.63×10^{-2} (Skin)	5.63×10^{-2}	6.64×10^{-2}
Offsite Public Not in the General Environment[c]	1.76×10^{-2}	7.24×10^{-2} (Skin)	7.24×10^{-2}	9.00×10^{-2}
Representative PWR-Burst Release-Filtered-50% χ/Q (Dose/Event)				
Onsite[a]	1.27	1.60×10^{1} (Skin)	1.60×10^{1}	1.72×10^{1}
Representative PWR-Oxidation Release-Filtered-50% χ/Q (Dose/Event)				
Onsite[a]	1.40	1.68×10^{1} (Bone Surface)	6.11	7.51
Representative PWR-Burst and Oxidation Release Combined-Filtered-50% χ/Q (Dose/Event)				
Onsite[a]	2.67	2.21×10^{1} (Skin)	2.21×10^{1}	2.47×10^{1}
Representative PWR-Burst Release-Filtered-95% χ/Q (Dose/Event)				
Onsite[a]	7.70	9.76×10^{1} (Skin)	9.76×10^{1}	1.05×10^{2}

Table 38. Representative Pressurized Water Reactor Assembly Results

Offsite Public in the General Environment[c]	1.20×10^{-1}	6.66×10^{-1} (Skin)	6.66×10^{-1}	7.87×10^{-1}
Offsite Public Not in the General Environment[c]	9.99×10^{-2}	1.33 (Skin)	1.33	1.43
Representative PWR-Oxidation Release- Filtered-95% χ/Q (Dose/Event)				
Onsite[a]	2.24	2.68×10^{1} (Bone Surface)	9.71	1.20×10^{1}
Offsite Public in the General Environment[c]	5.73×10^{-3}	4.08×10^{-2} (Skin)	4.08×10^{-2}	4.66×10^{-2}
Offsite Public Not in the General Environment[c]	7.85×10^{-3}	6.65×10^{-2} (Bone Surface)	4.21×10^{-2}	5.00×10^{-2}
Representative PWR- Burst and Oxidation Release Combined - Filtered-95% χ/Q (Dose/Event)				
Onsite[a]	9.94	1.07×10^{2} (Skin)	1.07×10^{2}	1.17×10^{2}
Offsite Public in the General Environment[c]	1.26×10^{-1}	7.07×10^{-1} (Skin)	7.07×10^{-1}	8.33×10^{-1}
Offsite Public Not in the General Environment[c]	1.08×10^{-1}	1.37 (Skin)	1.37	1.48
Representative PWR-Burst Release-Not Filtered-95% χ/Q (Dose/Event)				
Offsite Public in the General Environment[c]	2.78×10^{-1}	8.89×10^{-1} (Skin)	8.89×10^{-1}	1.17
Offsite Public Not in the General Environment[c]	4.18×10^{-1}	1.89 (Bone Surface)	1.81	2.23
Representative PWR-Oxidation Release- Not Filtered -95% χ/Q (Dose/Event)				
Offsite Public in the General Environment[c]	1.12	2.90×10^{1} (Bone Surface)	3.08×10^{-1}	1.43
Offsite Public Not in the General Environment[c]	2.30	6.12×10^{1} (Bone Surface)	6.70×10^{-1}	2.97
Representative PWR- Burst and Oxidation Release Combined - Not Filtered -95% χ/Q (Dose/Event)				
Offsite Public in the General Environment[c]	1.40	2.98×10^{1} (Bone Surface)	1.20	2.60
Offsite Public Not in the General Environment[c]	2.72	6.31×10^{1} (Bone Surface)	2.48	5.20

NOTES: [a]Onsite receptor location is 60 m from aging pad or building HVAC exhaust vent.
[b]Exhaust shaft receptor location is 100 m from subsurface exhaust shaft.
[c]Offsite public receptor locations are shown on Figure 1.

Source: *Summary of Doses. xls-Result Matrix*

Table 39. Maximum Pressurized Water Reactor Assembly Results

	Total Effective Dose Equivalent (mrem)	Highest Total Organ Dose Equivalent (mrem)	Shallow Dose Equivalent to Skin (mrem)	Lens Dose Equivalent (mrem)
Maximum PWR-Normal Release-Filtered-50% χ/Q (Annual Dose)				
Onsite[a]	6.02	5.53×10^{1} (Skin)	5.53×10^{1}	6.13×10^{1}
Exhaust Shafts[b]	6.18×10^{-3}	5.66×10^{-2} (Skin)	5.66×10^{-2}	6.28×10^{-2}

Table 39. Maximum Pressurized Water Reactor Assembly Results

	Total Effective Dose Equivalent (mrem)	Highest Total Organ Dose Equivalent (mrem)	Shallow Dose Equivalent to Skin (mrem)	Lens Dose Equivalent (mrem)
Offsite Public in the General Environment[c]	5.24×10^{-2}	2.12×10^{-1} (Skin)	2.12×10^{-1}	2.65×10^{-1}
Offsite Public Not in the General Environment[c]	1.07×10^{-1}	3.74×10^{-1} (Skin)	3.74×10^{-1}	4.80×10^{-1}
Maximum PWR-Burst Release-Filtered-50% χ/Q (Dose/Event)				
Offsite Public in the General Environment[c]	2.42×10^{-3}	1.25×10^{-2} (Skin)	1.25×10^{-2}	1.49×10^{-2}
Offsite Public Not in the General Environment[c]	3.15×10^{-3}	3.93×10^{-2} (Skin)	3.93×10^{-2}	4.25×10^{-2}
Maximum PWR-Oxidation Release-Filtered-50% χ/Q (Dose/Event)				
Offsite Public in the General Environment[c]	1.95×10^{-3}	1.60×10^{-2} (Bone Surface)	1.17×10^{-2}	1.36×10^{-2}
Offsite Public Not in the General Environment[c]	3.45×10^{-3}	3.95×10^{-2} (Bone Surface)	1.51×10^{-2}	1.86×10^{-2}
Maximum PWR-Burst and Oxidation Release Combined-Filtered-50% χ/Q (Dose/Event)				
Offsite Public in the General Environment[c]	4.37×10^{-3}	2.41×10^{-2} (Skin)	2.41×10^{-2}	2.85×10^{-2}
Offsite Public Not in the General Environment[c]	6.60×10^{-3}	5.44×10^{-2} (Skin)	5.44×10^{-2}	6.10×10^{-2}
Maximum PWR-Burst Release-Filtered-95% χ/Q (Dose/Event)				
Offsite Public in the General Environment[c]	2.42×10^{-1}	1.26 (Skin)	1.26	1.50
Offsite Public Not in the General Environment[c]	1.98×10^{-1}	2.48 (Skin)	2.48	2.68
Maximum PWR-Oxidation Release- Filtered-95% χ/Q (Dose/Event)				
Offsite Public in the General Environment[c]	1.24×10^{-2}	9.81×10^{-2} (Bone Surface)	7.66×10^{-2}	8.90×10^{-2}
Offsite Public Not in the General Environment[c]	1.77×10^{-2}	1.99×10^{-1} (Bone Surface)	7.96×10^{-2}	9.73×10^{-2}
Maximum PWR- Burst and Oxidation Release Combined - Filtered-95% χ/Q (Dose/Event)				
Offsite Public in the General Environment[c]	2.54×10^{-1}	1.33 (Skin)	1.33	1.59
Offsite Public Not in the General Environment[c]	2.16×10^{-1}	2.56 (Skin)	2.56	2.78
Maximum PWR-Burst Release-Not Filtered-95% χ/Q (Dose/Event)				
Offsite Public in the General Environment[c]	1.36×10^{1}	2.80×10^{2} (Bone Surface)	8.39	2.19×10^{1}
Offsite Public Not in the General Environment[c]	3.92×10^{1}	9.29×10^{2} (Bone Surface)	1.81×10^{1}	5.73×10^{1}
Maximum PWR-Oxidation Release- Not Filtered -95% χ/Q (Dose/Event)				
Offsite Public in the General Environment[c]	3.07×10^{1}	8.93×10^{2} (Bone Surface)	2.72	3.35×10^{1}
Offsite Public Not in the General Environment[c]	6.47×10^{1}	1.88×10^{3} (Bone Surface)	6.43	7.12×10^{1}
Maximum PWR- Burst and Oxidation Release Combined - Not Filtered -95% χ/Q (Dose/Event)				

Table 39. Maximum Pressurized Water Reactor Assembly Results

	Total Effective Dose Equivalent (mrem)	Highest Total Organ Dose Equivalent (mrem)	Shallow Dose Equivalent to Skin (mrem)	Lens Dose Equivalent (mrem)
Offsite Public in the General Environment[c]	4.43×10^{1}	1.17×10^{3} (Bone Surface)	1.11×10^{1}	5.54×10^{1}
Offsite Public Not in the General Environment[c]	1.04×10^{2}	2.81×10^{3} (Bone Surface)	2.45×10^{1}	1.29×10^{2}
Maximum PWR- Pool Drop -95% χ/Q (Dose/Event)				
Offsite Public in the General Environment[c]	2.34×10^{-1}	1.26 (Skin)	1.26	1.49
Offsite Public Not in the General Environment[c]	1.87×10^{-1}	2.49 (Skin)	2.49	2.68

NOTES: [a]Onsite receptor location is 60 m from aging pad or building HVAC exhaust vent.
[b]Exhaust shaft receptor location is 100 m from subsurface exhaust shaft.
[c]Offsite public receptor locations are shown on Figure 1.

Source: *Summary of Doses.xls-Result Matrix*

6.6.2 Boiling Water Reactor Commercial Spent Nuclear Fuel

This section presents the annual results for normal operations, which are airborne releases from the WHF discussed in Section 4.4.1.1, assuming that only BWR fuel is processed. This section also presents the results for a Category 2 event sequence involving a single BWR commercial SNF. Table 40 provides the results when using a representative BWR assembly in the analyses. Table 41 provides the results when using a maximum BWR assembly in the analyses.

Table 40. Representative Boiling Water Reactor Assembly Results

	Total Effective Dose Equivalent (mrem)	Highest Total Organ Dose Equivalent (mrem)	Shallow Dose Equivalent to Skin (mrem)	Lens Dose Equivalent (mrem)
Representative BWR-Normal Release-Filtered-50% χ/Q (Annual Dose)				
Onsite[a]	3.09	2.66×10^{1} (Skin)	2.66×10^{1}	2.97×10^{1}
Exhaust Shafts[b]	3.18×10^{-3}	2.74×10^{-2} (Skin)	2.74×10^{-2}	3.05×10^{-2}
Offsite Public in the General Environment[c]	3.99×10^{-2}	8.75×10^{-2} (Skin)	8.75×10^{-2}	1.27×10^{-1}
Offsite Public Not in the General Environment[c]	8.31×10^{-2}	1.46×10^{-1} (Skin)	1.46×10^{-1}	2.29×10^{-1}
Representative BWR-Burst Release-Filtered-50% χ/Q (Dose/Event)				
Onsite[a]	5.25×10^{-1}	6.06 (Skin)	6.06	6.58
Representative BWR-Oxidation Release-Filtered-50% χ/Q (Dose/Event)				
Onsite[a]	5.51×10^{-1}	5.77 (Bone Surface)	2.33	2.88
Representative BWR-Burst and Oxidation Release Combined-Filtered-50% χ/Q (Dose/Event)				
Onsite[a]	1.08	8.39 (Skin)	8.39	9.46

Table 40. Representative Boiling Water Reactor Assembly Results

	Total Effective Dose Equivalent (mrem)	Highest Total Organ Dose Equivalent (mrem)	Shallow Dose Equivalent to Skin (mrem)	Lens Dose Equivalent (mrem)
Representative BWR-Burst Release-Filtered-95% χ/Q (Dose/Event)				
Onsite[a]	3.20	3.69×10^{1} (Skin)	3.69×10^{1}	4.01×10^{1}
Offsite Public in the General Environment[c]	5.13×10^{-2}	2.56×10^{-1} (Skin)	2.56×10^{-1}	3.07×10^{-1}
Offsite Public Not in the General Environment[c]	4.17×10^{-2}	5.04×10^{-1} (Skin)	5.04×10^{-1}	5.45×10^{-1}
Representative BWR-Oxidation Release- Filtered-95% χ/Q (Dose/Event)				
Onsite[a]	8.80×10^{-1}	9.21 (Bone Surface)	3.72	4.60
Offsite Public in the General Environment[c]	2.34×10^{-3}	1.55×10^{-2} (Skin)	1.55×10^{-2}	1.78×10^{-2}
Offsite Public Not in the General Environment[c]	3.16×10^{-3}	2.31×10^{-2} (Bone Surface)	1.61×10^{-2}	1.93×10^{-2}
Representative BWR- Burst and Oxidation Release Combined - Filtered-95% χ/Q (Dose/Event)				
Onsite[a]	4.08	4.07×10^{1} (Skin)	4.07×10^{1}	4.47×10^{1}
Offsite Public in the General Environment[c]	5.36×10^{-2}	2.72×10^{-1} (Skin)	2.72×10^{-1}	3.25×10^{-1}
Offsite Public Not in the General Environment[c]	4.48×10^{-2}	5.20×10^{-1} (Skin)	5.20×10^{-1}	5.65×10^{-1}
Representative BWR-Burst Release-Not Filtered-95% χ/Q (Dose/Event)				
Offsite Public in the General Environment[c]	1.36×10^{-1}	3.58×10^{-1} (Skin)	3.58×10^{-1}	4.94×10^{-1}
Offsite Public Not in the General Environment[c]	2.32×10^{-1}	7.29×10^{-1} (Skin)	7.29×10^{-1}	9.62×10^{-1}
Representative BWR-Oxidation Release- Not Filtered -95% χ/Q (Dose/Event)				
Offsite Public in the General Environment[c]	3.94×10^{-1}	9.90 (Bone Surface)	1.18×10^{-1}	5.12×10^{-1}
Offsite Public Not in the General Environment[c]	8.31×10^{-1}	2.08×10^{1} (Bone Surface)	2.49×10^{-1}	1.05
Representative BWR- Burst and Oxidation Release Combined - Not Filtered -95% χ/Q (Dose/Event)				
Offsite Public in the General Environment[c]	5.30×10^{-1}	1.02×10^{1} (Bone Surface)	4.76×10^{-1}	1.01
Offsite Public Not in the General Environment[c]	1.04	2.15×10^{1} (Bone Surface)	9.78×10^{-1}	2.01

NOTES: [a]Onsite receptor location is 60 m from aging pad or building HVAC exhaust vent.
[b]Exhaust shaft receptor location is 100 m from subsurface exhaust shaft.
[c]Offsite public receptor locations are shown on Figure 1.

Source: *Summary of Doses.xls-Result Matrix*

Table 41. Maximum Boiling Water Reactor Assembly Results

	Total Effective Dose Equivalent (mrem)	Highest Total Organ Dose Equivalent (mrem)	Shallow Dose Equivalent to Skin (mrem)	Lens Dose Equivalent (mrem)
Maximum BWR-Burst Release-Filtered-95% χ/Q (Dose/Event)				
Offsite Public in the General Environment[a]	8.65×10^{-2}	4.43×10^{-1} (Skin)	4.43×10^{-1}	5.30×10^{-1}
Offsite Public Not in the General Environment[a]	7.06×10^{-2}	8.72×10^{-1} (Skin)	8.72×10^{-1}	9.42×10^{-1}
Maximum BWR-Oxidation Release- Filtered-95% χ/Q (Dose/Event)				
Offsite Public in the General Environment[a]	4.22×10^{-3}	2.86×10^{-2} (Bone Surface)	2.68×10^{-2}	3.11×10^{-2}
Offsite Public Not in the General Environment[a]	5.93×10^{-3}	5.83×10^{-2} (Bone Surface)	2.78×10^{-2}	3.38×10^{-2}
Maximum BWR- Burst and Oxidation Release Combined - Filtered-95% χ/Q (Dose/Event)				
Offsite Public in the General Environment[a]	9.07×10^{-2}	4.70×10^{-1} (Skin)	4.70×10^{-1}	5.61×10^{-1}
Offsite Public Not in the General Environment[a]	7.65×10^{-2}	9.00×10^{-1} (Skin)	9.00×10^{-1}	9.76×10^{-1}
Maximum BWR-Burst Release-Not Filtered-95% χ/Q (Dose/Event)				
Offsite Public in the General Environment[a]	4.14	8.07×10^{1} (Bone Surface)	2.75	6.89
Offsite Public Not in the General Environment[a]	1.18×10^{1}	2.66×10^{2} (Bone Surface)	6.10	1.79×10^{1}
Maximum BWR-Oxidation Release- Not Filtered -95% χ/Q (Dose/Event)				
Offsite Public in the General Environment[a]	8.91	2.55×10^{2} (Bone Surface)	8.69×10^{-1}	9.78
Offsite Public Not in the General Environment[a]	1.89×10^{1}	5.44×10^{2} (Bone Surface)	2.09	2.10×10^{1}
Maximum BWR- Burst and Oxidation Release Combined - Not Filtered -95% χ/Q (Dose/Event)				
Offsite Public in the General Environment[a]	1.30×10^{1}	3.36×10^{2} (Bone Surface)	3.61	1.67×10^{1}
Offsite Public Not in the General Environment[a]	3.07×10^{1}	8.10×10^{2} (Bone Surface)	8.18	3.89×10^{1}
Maximum BWR- Pool Drop -95% χ/Q (Dose/Event)				
Offsite Public in the General Environment[a]	8.37×10^{-2}	4.43×10^{-1} (Skin)	4.43×10^{-1}	5.27×10^{-1}
Offsite Public Not in the General Environment[a]	6.62×10^{-2}	8.71×10^{-1} (Skin)	8.71×10^{-1}	9.38×10^{-1}

NOTE: [a]Offsite public receptor locations are shown on Figure 1.

Source: *Summary of Doses.xls-Result Matrix*

6.6.3 High-Level Waste

Table 42 contains the results for one canister for each of the HLW waste form sources. The results in Table 42 are determined with a 0.01 LPF, which means a LPF was credited for the canister itself, as well as the cask containing the canister. Because the waste form is vitrified glass and the releases are only particulates, the results are directly proportional to the LPFs.

Thus, if an event should only have a LPF of 0.1, the results are multiplied by 10. Unfiltered releases include a respirable fraction of 0.01, while filtered releases do not.

Table 42. One Canister of High-Level Waste Results

	Total Effective Dose Equivalent (mrem/canister)	Highest Total Organ Dose Equivalent (mrem/canister)	Shallow Dose Equivalent to Skin (mrem/canister)	Lens Dose Equivalent (mrem/canister)
Hanford Site – Drop – Not Filtered-95% χ/Q				
Offsite Public in the General Environment[a]	9.53×10^{-2}	3.25 (Bone Surface)	4.07×10^{-2}	1.36×10^{-1}
Offsite Public Not in the General Environment[a]	3.03×10^{-1}	1.07×10^{1} (Bone Surface)	1.02×10^{-1}	4.05×10^{-1}
Idaho National Laboratory – Drop – Not Filtered-95% χ/Q				
Offsite Public in the General Environment[a]	1.22×10^{-2}	1.80×10^{-1} (Bone Surface)	6.98×10^{-3}	1.91×10^{-2}
Offsite Public Not in the General Environment[a]	3.74×10^{-2}	5.71×10^{-1} (Bone Surface)	1.69×10^{-2}	5.43×10^{-2}
Savannah River Site – Drop – Not Filtered-95% χ/Q				
Offsite Public in the General Environment[a]	1.57×10^{-1}	4.07 (Bone Surface)	2.38×10^{-2}	1.81×10^{-1}
Offsite Public Not in the General Environment[a]	5.14×10^{-1}	1.35×10^{1} (Bone Surface)	6.24×10^{-2}	5.76×10^{-1}
West Valley Demonstration Project – Drop – Not Filtered-95% χ/Q				
Offsite Public in the General Environment[a]	9.48×10^{-2}	3.59 (Bone Surface)	1.59×10^{-2}	1.11×10^{-1}
Offsite Public Not in the General Environment[a]	3.11×10^{-1}	1.19×10^{1} (Bone Surface)	4.35×10^{-2}	3.55×10^{-1}

NOTE: [a]Offsite public receptor locations are shown on Figure 1.
Source: *Summary of Doses.xls-Result Matrix*

6.7 DOSES FROM NORMAL OPERATIONS

6.7.1 Potential Doses from Normal Operation Airborne Releases from Wet Handling Facility

Sections 6.6.1 and 6.6.2 provides the summary doses for PWR and BWR fuel. The highest TEDE dose from normal operations is chosen for each location. Table 43 summarizes the dose for normal airborne releases from the WHF and identifies the fuel type that results in that dose.

Table 43. Doses from Airborne Releases from WHF – Representative SNF

	Total Effective Dose Equivalent (mrem/yr)	Highest Total Organ Dose Equivalent (mrem/yr)	Shallow Dose Equivalent to Skin (mrem/yr)	Lens Dose Equivalent (mrem/yr)
Normal Releases – Filtered-50% χ/Q				
Onsite[a] (BWR)	3.09	2.66×10^{1} (Skin)	2.66×10^{1}	2.97×10^{1}
Exhaust Shafts[b] (BWR)	3.18×10^{-3}	2.74×10^{-2} (Skin)	2.74×10^{-2}	3.05×10^{-2}
Offsite Public in the General Environment[c] (BWR)	3.99×10^{-2}	8.75×10^{-2} (Skin)	8.75×10^{-2}	1.27×10^{-1}
Offsite Public Not in the General Environment[c] (BWR)	8.31×10^{-2}	1.46×10^{-1} (Skin)	1.46×10^{-1}	2.29×10^{-1}

NOTES: [a]Onsite receptor location is 60 m from aging pad or building HVAC exhaust vent.
[b]Exhaust shaft receptor location is 100 m from subsurface exhaust shaft.
[c]Offsite public receptor locations are shown on Figure 1.

Sources: Table 38 and Table 40

6.7.2 Potential Doses from Normal Operation Subsurface Releases

The subsurface airborne release doses are presented in Table 44. Results are from the spreadsheet *Summary of Doses xls-Result Matrix.*

Table 44. Doses from Subsurface Airborne Release of Activated Air and Dust

	Total Effective Dose Equivalent (mrem/yr)	Highest Total Organ Dose Equivalent (mrem/yr)	Shallow Dose Equivalent to Skin (mrem/yr)	Lens Dose Equivalent (mrem/yr)
Normal Releases – Not Filtered-50% χ/Q				
Onsite[a]	7.04×10^{-3}	1.35×10^{-1} (Bone Surface)	4.65×10^{-3}	1.17×10^{-2}
Exhaust Shafts[b]	1.50	2.87×10^{1} (Bone Surface)	9.88×10^{-1}	2.49
Offsite Public in the General Environment[c]	2.92×10^{-3}	1.02×10^{-2} (Bone Surface)	9.16×10^{-3}	1.21×10^{-2}
Offsite Public Not in the General Environment[c]	3.40×10^{-3}	1.12×10^{-2} (Skin)	1.12×10^{-2}	1.46×10^{-2}

NOTES: [a]Onsite receptor location is 60 m from aging pad or building HVAC exhaust vent.
[b]Exhaust shaft receptor location is 100 m from subsurface exhaust shaft.
[c]Offsite public receptor locations are shown on Figure 1.

Source: *Summary of Doses.xls-Result Matrix*

6.7.3 Potential Doses from Normal Operation Resuspension of Surface Contamination

The dose results from the resuspension of surface contamination on the canisters contained in aging overpacks are presented in Table 45. Results are from the spreadsheet *Summary of Doses.xls-Result Matrix.*

Table 45. Doses from Aging Facility Resuspension of Surface Contamination

	Total Effective Dose Equivalent (mrem/yr)	Highest Total Organ Dose Equivalent (mrem/yr)	Shallow Dose Equivalent to Skin (mrem/yr)	Lens Dose Equivalent (mrem/yr)
Normal Releases – Not Filtered-50% χ/Q				
Onsite[a]	1.26×10^{1}	5.09×10^{2} (Bone Surface)	8.79×10^{-1}	1.35×10^{1}
Exhaust Shafts[b]	1.29×10^{-2}	5.23×10^{-1} (Bone Surface)	9.02×10^{-4}	1.38×10^{-2}
Offsite Public in the General Environment[c]	1.18×10^{-2}	2.26×10^{-1} (Bone Surface)	8.18×10^{-3}	2.00×10^{-2}
Offsite Public Not in the General Environment[c]	2.40×10^{-2}	4.08×10^{-1} (Bone Surface)	1.81×10^{-2}	4.21×10^{-2}

NOTES: [a]Onsite receptor location is 60 m from aging pad or building HVAC exhaust vent.
[b]Exhaust shaft receptor location is 100 m from subsurface exhaust shaft.
[c]Offsite public receptor locations are shown on Figure 1.

Source: *Summary of Doses.xls-Result Matrix*

6.7.4 Total Potential Offsite Public Normal Operation Airborne Release Dose

The total airborne release dose to the offsite public due to normal operations is shown in Table 46 based on the doses given in Table 43, Table 44, and Table 45.

Table 46. Total Offsite Public Dose – Normal Operation

	Total Effective Dose Equivalent (mrem/yr)	Highest Total Organ Dose Equivalent (mrem/yr)[a]	Shallow Dose Equivalent to Skin (mrem/yr)[a]	Lens Dose Equivalent (mrem/yr)
Offsite Public in the General Environment[b]	5.47×10^{-2}	2.93×10^{-1} (Bone Surface)	1.05×10^{-1}	1.60×10^{-1}
Offsite Public Not in the General Environment[b]	1.11×10^{-1}	5.39×10^{-1} (Bone Surface)	1.76×10^{-1}	2.87×10^{-1}

NOTES: [a]Values from worksheet *Normal Operations Organ Doses* of *Summary of Doses.xls*.
[b]Offsite public receptor locations are shown on Figure 1.

Sources: Table 43, Table 44, Table 45, and worksheet *Normal Operations Organ Doses* of *Summary of Doses.xls*

6.7.5 Total Potential Onsite Public Normal Operations Dose

Reference 2.2.40 shows the layout of the GROA with the security fence. Locations outside of the security fence are areas where onsite public may be located. Construction workers are needed to complete construction on the second and third CRCF and for the second aging pad. Table 47 summarizes the total direct and airborne radiation dose at onsite locations where construction workers or other onsite public may be located. Entries in the table are from Table 15.

Table 47. Potential Onsite Public Doses from Normal Operation

Area No.[a]	GROA Location	Direct Radiation TEDE[b, d] (mrem/yr)	Airborne Release TEDE[c, d] (mrem/yr)	Total TEDE (direct + airborne) (mrem/yr)
Construction Worker Locations				
17P	Aging Pad 17P	1.0×10^{1}	2.8×10^{-1}	1.0×10^{1}
200	Receipt Facility	4.7×10^{-1}	2.4×10^{-1}	7.1×10^{-1}
070	Canister Receipt and Closure Facility 2	1.5	2.0×10^{-1}	1.7
080	Canister Receipt and Closure Facility 3	1.8	1.9×10^{-1}	2.0
620	Administration Facility	6.9×10^{-2}	2.3×10^{-1}	3.0×10^{-1}
71A	Craft Shop	1.1×10^{-1}	2.5×10^{-1}	3.6×10^{-1}
30C	North Perimeter Security Station	9.7	1.9×10^{-1}	9.9
Other Onsite Areas				
220	Heavy Equipment Maintenance Facility	1.5	1.4×10^{-1}	1.7
240	Central Communication Control Facility	7.0	1.2×10^{-1}	7.1
230	Warehouse and Non-Nuclear Receipt Facility	1.7×10^{1}	1.1×10^{-1}	1.7×10^{1}
25A	Utility Facility	5.3×10^{-1}	1.0×10^{-1}	6.3×10^{-1}
30A	Central Security Station	8.2×10^{-2}	1.0×10^{-1}	1.9×10^{-1}
27A	Switchyard	3.6×10^{1}	1.6×10^{-1}	3.6×10^{1}
780	Lower Muck Yard	7.8×10^{1}	2.0×10^{-1}	7.8×10^{1}

NOTES: [a]Areas are shown in References 2.2.40 and 2.2.41
[b]Direct radiation doses are the total external doses from aging overpacks on the aging pads (17P and 17R), and transportation casks in 33A (rail buffer area) and 33B (truck buffer area)
[c]Airborne release doses are the total from all surface and subsurface facility normal operation releases
[d]Doses are based on 2,000 hr/yr occupancy.
GROA = geologic repository operations area; TEDE = total effective dose equivalent.

Source: Table 15

As stated in Section 4.4.1, the normal operation onsite public dose from airborne releases from surface facilities is determined at 60 m from each surface facility, which are the WHF and the Aging Pads and 100 m from the subsurface exhaust shafts. Because an individual cannot physically be located at multiple locations at the same time, the results from these three areas are not summed to give an overall airborne release dose to onsite public. The total onsite public normal operations dose for the maximum dose location for construction workers and other onsite public and are shown in Table 48.

Table 48. Total Onsite Pubic Normal Operation Dose

Category of Individual	Total Effective Dose Equivalent Site (Preclosure Controlled Area) (mrem/yr)
Onsite Public (Lower Muck Yard)	7.8×10^{1}
Construction Worker (Aging Pad 17P)	1.0×10^{1}

NOTE: At maximum dose location for onsite public and construction worker.

Source: Table 47.

6.8 BOUNDING CATEGORY 2 EVENT SEQUENCES

Table 49 summarizes the input parameters for the 13 bounding Category 2 event sequence cases.

Table 49. Bounding Category 2 Event Sequences Input Summary

No.	Affected Waste Form or Canister	Material at Risk	Confinement Credit	Mitigating Structures Systems and Compontents	DR	Burst ARF x RF	Oxidation ARF x RF	Pool LPF	Cask LPF	Canister LPF	Facility LPF	HEPA LPF
2-01	LLWF inventory & HEPA filters	LLWF inventory & HEPA filters	[a]None	None	1	Table 33	NA	NA	NA	NA	NA	NA
2-02	HLW canister in transportation cask	5 canisters	[a]Transportation cask and HLW canister	HEPA available - not credited Credit for cask and canister LPFs	1	Table 10 HLW	NA	NA	0.1	0.1	1	1
			Transportation cask, HLW canister, and building ventilation	HEPA credited Credit for cask and canister LPFs	1	Table 10 HLW[b]	NA	NA	0.1	0.1	1	1×10^{-4}
2-03	HLW canister in unsealed waste package	5 canisters	[a]HLW canister	HEPA available - not credited Credit for canister LPF	1	Table 10 HLW	NA	NA	NA	0.1	1	1
			HLW canister, and building ventilation	HEPA credited Credit for canister LPF	1	Table 10 HLW[b]	NA	NA	NA	0.1	1	1×10^{-4}
2-04	HLW canister	2 canisters (one drops onto another)	[a]HLW canister	HEPA available - not credited Credit for canister LPF	1	Table 10 HLW	NA	NA	NA	0.1	1	1
			HLW canister, and building ventilation	HEPA credited Credit for canister LPF	1	Table 10 HLW[b]	NA	NA	NA	0.1	1	1×10^{-4}

Table 49. Bounding Category 2 Event Sequences Input Summary

No.	Affected Waste Form or Canister	Material at Risk	Confinement Credit	Mitigating Structures Systems and Compontents	DR	Burst ARF x RF	Oxidation ARF x RF	Pool LPF	Cask LPF	Canister LPF	Facility LPF	HEPA LPF
2-05	Uncanistered commercial SNF in transportation cask	4 PWR or 9 BWR SNF	Transportation cask	HEPA available - not credited Credit for cask LPF	1	Table 10 High Burnup Fuel	NA	NA	0.1	NA	1	1
					1	Table 10 High Burnup Fuel	Table 10 High Burnup Fuel	NA	0.1	NA	1	1
			Building ventilation and transportation cask	HEPA credit, Credit for cask LPF	1	Table 10 High Burnup Fuel[c]	NA	NA	0.1	NA	1	1×10^{-4}
					[a]1	Table 10 High Burnup Fuel[c]	Table 10 High Burnup Fuel	NA	0.1	NA	1	1×10^{-4}
2-06	Uncanistered commercial SNF in pool	4 PWR or 9 BWR SNF	[a]Pool retention	HEPA available - not credited Pool LPF credit	1	Table 12	NA	X	NA	NA	1	1
2-07	DPC in air	36 PWR or 74 BWR SNF	DPC	HEPA available - not credited, Credit for canister LPF	1	Table 10 High Burnup Fuel	NA	NA	NA	0.1	1	1
					1	Table 10 High Burnup Fuel	Table 10 High Burnup Fuel	NA	NA	0.1	1	1
			Building ventilation and DPC	HEPA credit, Credit for cask LPF	1	Table 10 High Burnup Fuel[c]	NA	NA	NA	0.1	1	1×10^{-4}
					[a]1	Table 10 High Burnup Fuel[c]	Table 10 High Burnup Fuel	NA	NA	0.1	1	1×10^{-4}
2-08	DPC in pool	36 PWR or 74 BWR SNF	Pool retention	HEPA available - not credited Pool LPF credit	1	Table 12	NA	X	NA	NA	1	1

Table 49. Bounding Category 2 Event Sequences Input Summary

No.	Affected Waste Form or Canister	Material at Risk	Confinement Credit	Mitigating Structures Systems and Compontents	DR	Burst ARF x RF	Oxidation ARF x RF	Pool LPF	Cask LPF	Canister LPF	Facility LPF	HEPA LPF
2-09	TAD canister in air	21 PWR or 44 BWR SNF	TAD canister	HEPA available - not credited Credit for canister LPF	1	Table 10 High Burnup Fuel	Table 10 High Burnup Fuel	NA	NA	0.1	1	1
			[a]Building ventilation and TAD canister	HEPA credit, Credit for cask LPF	1	Table 10 High Burnup Fuel[c]	Table 10 High Burnup Fuel	NA	NA	0.1	1	1×10^{-4}
2-10	TAD canister in pool	21 PWR or 44 BWR SNF	[a]Pool retention	HEPA available - not credited Pool LPF credit	1	Table 12	NA	X	NA	NA	1	1
2-11	Uncanistered commercial SNF	2 PWR or 2 BWR SNF (one drops onto another)	[a]Pool retention	HEPA available - not credited Pool LPF credit	1	Table 12	NA	X	NA	NA	1	1
2-12	Uncanistered commercial SNF	1 PWR or 1 BWR SNF	[a]Pool retention	HEPA available - not credited Pool LPF credit	1	Table 12	NA	X	NA	NA	1	1
2-13	Combustible and non-combustible LLW	Combustible and non-combustible LLW	[a]None	None	1	Table 29	NA	NA	NA	NA	1	NA
2-14	Uncanistered commercial SNF in transportation cask	4 PWR or 9 BWR SNF	Transportation cask	Credit for cask LPF	0.01	Table 10 High Burnup Fuel	Table 10 High Burnup Fuel	NA	0.1	NA	1	1

NOTES: [a]Results reported in Table 67 and Table 68
[b,c]The RF is set to one (1) when the HEPA filters are credited per Assumption 3.2.8

ARF = airborne release fraction; BWR = boiling water reactor; DAW = dry active waste; DPC = dual-purpose canister; HEPA = high-effeciency particulate air; HLW = high-level waste; LLWF = low-level waste facility; LPF = leak path factor; PWR = pressurized water reactor; RF = respirable fraction; SNF = spent nuclear fuel; TAD = transportation, aging and disposal.

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6.8.1 Bounding Seismic Event (2-01)

The dose consequences for the unfiltered releases from the bounding Category 2 seismic event discussed in Section 6.3.4 are calculated with the GENII code for each of the two postulated releases: release from the failure of the HVAC HEPA filters, ducting, and dampers in the WHF leading to the discharge of accumulated radioactive material; and release from the failure of the confinements for the solid and liquid LLW inventories in the LLWF. The doses from the seismic event releases are summarized in Table 50. Results are from spreadsheet *Summary of Doses.xls-Result Matrix*.

Table 50. Itemized Seismic Event Dose

	Total Effective Dose Equivalent (mrem)	Highest Total Organ Dose Equivalent (mrem)	Shallow Dose Equivalent to Skin (mrem)	Lens Dose Equivalent (mrem)
Low-Level Waste Facility Inventory				
Offsite Public in the General Environment	1.20	3.60 (Lungs)	9.54×10^{-1}	2.16
Offsite Public Not in the General Environment	3.17	1.12×10^{1} (Lungs)	2.28	5.45
Pressurized Water Reactor Fuel HEPA Inventory				
Offsite Public in the General Environment	4.76	1.03×10^{2} (Bone Surface)	1.09	5.85
Offsite Public Not in the General Environment	1.51×10^{1}	3.43×10^{2} (Bone Surface)	2.80	1.79×10^{1}
Boiling Water Reactor Fuel HEPA Inventory				
Offsite Public in the General Environment	1.05×10^{1}	8.83×10^{1} (Bone Surface)	5.00	1.55×10^{1}
Offsite Public Not in the General Environment	3.14×10^{1}	2.89×10^{2} (Bone Surface)	1.28×10^{1}	4.42×10^{1}

NOTE: Receptor locations for offsite public are shown on Figure 1.
Source: *Summary of Doses. xls-Result Matrix.*

As can be seen in Table 50, the BWR HEPA filter inventory results in higher TEDE doses than the PWR HEPA filter inventory. Adding the dose from the LLWF to the dose from the BWR HEPA filter inventory, the results of the seismic event are summarized in Table 51.

Table 51. Seismic Event (2-01)

	Total Effective Dose Equivalent (mrem)[a]	Highest Total Organ Dose Equivalent (mrem)[b]	Shallow Dose Equivalent to Skin (mrem)[a]	Lens Dose Equivalent (mrem)[a]
Offsite Public in the General Environment	1.17×10^{1}	8.94×10^{1} (Bone Surface)	5.95	1.77×10^{1}
Offsite Public Not in the General Environment	3.46×10^{1}	2.92×10^{2} (Bone Surface)	1.51×10^{1}	4.97×10^{1}

NOTE: Receptor locations for offsite public are shown on Figure 1.
Sources: [a] Table 50
[b] *Summary of Doses.xls-Seismic and Fire Organ Doses.*

6.8.2 Breach of Five Sealed High-Level Waste Canisters in Sealed Transportation Cask (2-02)

Event 2-02 consists of the unfiltered release from the breach of five HLW canisters in a sealed transportation cask. The individual results for each HLW source in Table 42 are multiplied by five to give the results for this event, which is shown in Table 52. The actual data source for the table is *Summary of Doses.xls – Bounding Category 2 Events*, therefore, slight variations in values may occur due to rounding.

Table 52. Breach of Five of High-Level Waste Canisters (2-02)

	Total Effective Dose Equivalent (mrem)	Highest Total Organ Dose Equivalent (mrem)	Shallow Dose Equivalent to Skin (mrem)	Lens Dose Equivalent (mrem)
Hanford Site – Drop – Not Filtered-95% χ/Q				
Offsite Public in the General Environment	4.77×10^{-1}	1.62×10^{1} (Bone Surface)	2.04×10^{-1}	6.80×10^{-1}
Offsite Public Not in the General Environment	1.51	5.37×10^{1} (Bone Surface)	5.10×10^{-1}	2.02
Idaho National Laboratory – Drop – Not Filtered-95% χ/Q				
Offsite Public in the General Environment	6.08×10^{-2}	9.00×10^{-1} (Bone Surface)	3.49×10^{-2}	9.57×10^{-2}
Offsite Public Not in the General Environment	1.87×10^{-1}	2.85 (Bone Surface)	8.44×10^{-2}	2.72×10^{-1}
Savannah River Site – Drop – Not Filtered-95% χ/Q				
Offsite Public in the General Environment	7.86×10^{-1}	2.04×10^{1} (Bone Surface)	1.19×10^{-1}	9.05×10^{-1}
Offsite Public Not in the General Environment	2.57	6.73×10^{1} (Bone Surface)	3.12×10^{-1}	2.88
West Valley Demonstration Project – Drop – Not Filtered-95% χ/Q				
Offsite Public in the General Environment	4.74×10^{-1}	1.79×10^{1} (Bone Surface)	7.97×10^{-2}	5.54×10^{-1}
Offsite Public Not in the General Environment	1.56	5.95×10^{1} (Bone Surface)	2.17×10^{-1}	1.77

NOTE: Receptor locations for offsite public are shown on Figure 1.
Source: Values in Table 42 × 5 and *Summary of Doses.xls – Bounding Category 2 Events*.

6.8.3 Breach of Five Sealed High-Level Waste Canisters in Unsealed Waste Package (2-03)

Event 2-03 consists of the unfiltered release from the breach of five HLW canisters in an unsealed waste package. The individual results for each HLW source in Table 42 takes credit for both a canister LPF and a cask LPF. Event 2-03 only takes credit for a canister LPF. Thus, the results in Table 53 are the values in Table 42, multiplied by five for the number of canisters involved in the event and multiplied by 10 to remove the credit for cask LPF. The actual data source for the table is *Summary of Doses.xls – Bounding Category 2 Events*, therefore, slight variations in values may occur due to rounding.

Table 53. Breach of Five of High-Level Waste Canisters in Unsealed Waste Package (2-03)

	Total Effective Dose Equivalent (mrem)	Highest Total Organ Dose Equivalent (mrem)	Shallow Dose Equivalent to Skin (mrem)	Lens Dose Equivalent (mrem)
Hanford Site – Drop – Not Filtered-95% χ/Q				
Offsite Public in the General Environment	4.77	1.63×10^{2} (Bone Surface)	2.04	6.81
Offsite Public Not in the General Environment	1.51×10^{1}	5.35×10^{2} (Bone Surface)	5.10	2.02×10^{1}
Idaho National Laboratory – Drop – Not Filtered-95% χ/Q				
Offsite Public in the General Environment	6.08×10^{-1}	9.00 (Bone Surface)	3.49×10^{-1}	9.57×10^{-1}
Offsite Public Not in the General Environment	1.87	2.85×10^{1} (Bone Surface)	8.44×10^{-1}	2.72
Savannah River Site – Drop – Not Filtered-95% χ/Q				
Offsite Public in the General Environment	7.86	2.04×10^{2} (Bone Surface)	1.19	9.05
Offsite Public Not in the General Environment	2.57×10^{1}	6.73×10^{2} (Bone Surface)	3.12	2.88×10^{1}
West Valley Demonstration Project – Drop – Not Filtered-95% χ/Q				
Offsite Public in the General Environment	4.74	1.79×10^{2} (Bone Surface)	7.97×10^{-1}	5.54×10^{-1}
Offsite Public Not in the General Environment	1.56×10^{1}	5.95×10^{2} (Bone Surface)	2.17	1.77×10^{1}

NOTE: Receptor locations for offsite public are shown on Figure 1.
Source: Values in Table 42 × 5 × 10 and *Summary of Doses.xls – Bounding Category 2 Events*.

6.8.4 Breach of Two Sealed High-Level Waste Canisters during Transfer (2-04)

Event 2-04 consists of the unfiltered release from a drop of one sealed HLW canister onto another resulting in the breach of two sealed HLW canisters. The individual results for each HLW source in Table 42 takes credit for both a canister LPF and a cask LPF. Event 2-04 only takes credit for a canister LPF. Thus, the results in Table 54 are the values in Table 42, multiplied by two for the number of canisters involved in the event and multiplied by 10 to remove the credit for cask LPF. The actual data source for the table is *Summary of Doses.xls – Bounding Category 2 Events*, therefore, slight variations in values may occur due to rounding.

Table 54. Breach of Two of High-Level Waste Canisters (2-04)

	Total Effective Dose Equivalent (mrem)	Highest Total Organ Dose Equivalent (mrem)	Shallow Dose Equivalent to Skin (mrem)	Lens Dose Equivalent (mrem)
Hanford Site – Drop – Not Filtered-95% χ/Q				
Offsite Public in the General Environment	1.91	6.49×10^{1} (Bone Surface)	8.14×10^{-1}	2.72
Offsite Public Not in the General Environment	6.05	2.15×10^{2} (Bone Surface)	2.04	8.09
Idaho National Laboratory – Drop – Not Filtered-95% χ/Q				
Offsite Public in the General Environment	2.43×10^{-1}	3.60 (Bone Surface)	1.40×10^{-1}	3.83×10^{-1}
Offsite Public Not in the General Environment	7.49×10^{-1}	1.14×10^{1} (Bone Surface)	3.38×10^{-1}	1.09
Savannah River Site – Drop – Not Filtered-95% χ/Q				
Offsite Public in the General Environment	3.14	8.14×10^{1} (Bone Surface)	4.76×10^{-1}	3.62
Offsite Public Not in the General Environment	1.03×10^{1}	2.69×10^{2} (Bone Surface)	1.25	1.15×10^{1}
West Valley Demonstration Project – Drop – Not Filtered-95% χ/Q				
Offsite Public in the General Environment	1.90	7.18×10^{1} (Bone Surface)	3.19×10^{-1}	2.21
Offsite Public Not in the General Environment	6.22	2.38×10^{2} (Bone Surface)	8.69×10^{-1}	7.09

NOTE: Receptor locations for offsite public are shown on Figure 1.

Source: Values in Table 42 × 2 × 10 and *Summary of Doses.xls – Bounding Category 2 Events*.

6.8.5 Breach of Uncanistered Commercial Spent Nuclear Fuel in Sealed Truck Transportation Cask in Air (2-05)

Event 2-05 consists of the filtered burst and oxidation release from a drop of a sealed truck transportation cask without impact limiters containing either four uncanistered maximum PWR commercial SNF assemblies or nine uncanistered maximum BWR commercial SNF assemblies. A cask LPF is credited, as well as HEPA filtration. The PWR results in Table 55 are the results from Table 39 for filtered release, multiplied by four. The BWR results in Table 55 are the results from Table 41 for a filtered release, multiplied by nine. The actual data source for the table is *Summary of Doses.xls – Bounding Category 2 Events*, therefore, slight variations in values may occur due to rounding.

Table 55. Breach of Uncanistered Commercial Spent Nuclear Fuel in Sealed Truck Transportation Cask in Air (2-05)

	Total Effective Dose Equivalent (mrem)	Highest Total Organ Dose Equivalent (mrem)	Shallow Dose Equivalent to Skin (mrem)	Lens Dose Equivalent (mrem)
Four Pressurized Water Reactor Fuel Assemblies - Filtered-95% χ/Qa				
Offsite Public in the General Environment	1.02	5.34 (Skin)	5.34	6.35
Offsite Public Not in the General Environment	8.62×10^{-1}	1.03×10^{1} (Skin)	1.03×10^{1}	1.11×10^{1}
Nine Boiling Water Reactor Fuel Assemblies - Filtered-95% χ/Qb				
Offsite Public in the General Environment	8.16×10^{-1}	4.23 (Skin)	4.23	5.05
Offsite Public Not in the General Environment	6.89×10^{-1}	8.10 (Skin)	8.10	8.79

NOTE: Receptor locations for offsite public are shown on Figure 1.

Sources: [a] Values in Table 39 × 4 and *Summary of Doses.xls – Bounding Category 2 Events*.

[b] Values in Table 41 × 9 and *Summary of Doses.xls – Bounding Category 2 Events*.

6.8.6 Breach of Uncanistered Commercial Spent Nuclear Fuel in Unsealed Truck Transportation Cask in Pool (2-06)

Event 2-06 consists of the release through the pool water from the drop of a lid onto an open truck transportation cask in the WHF pool containing either four uncanistered PWR commercial SNF assemblies or nine uncanistered BWR commercial SNF assemblies. The HEPA filter is available, but not credited. The pool LPFs from Design Input 6.1.4.3 are credited. The fuel assemblies are either maximum BWR or maximum PWR fuel. The PWR results in Table 56 are the results from Table 39 for a pool release, multiplied by four. The BWR results in Table 56 are the results from Table 41 for a pool release, multiplied by nine. The actual data source for the table is *Summary of Doses.xls – Bounding Category 2 Events*, therefore, slight variations in values may occur due to rounding.

Table 56. Breach of Uncanistered Commercial Spent Nuclear Fuel in Unsealed Truck Transportation Cask in Pool (2-06)

	Total Effective Dose Equivalent (mrem)	Highest Total Organ Dose Equivalent (mrem)	Shallow Dose Equivalent to Skin (mrem)	Lens Dose Equivalent (mrem)
Four Pressurized Water Reactor Fuel Assemblies – Pool Release-95% χ/Qa				
Offsite Public in the General Environment	9.37×10^{-1}	5.03 (Skin)	5.03	5.97
Offsite Public Not in the General Environment	7.47×10^{-1}	9.98 (Skin)	9.98	1.07×10^{1}
Nine Boiling Water Reactor Fuel Assemblies – Pool Release-95% χ/Qb				
Offsite Public in the General Environment	7.54×10^{-1}	3.99 (Skin)	3.99	4.74
Offsite Public Not in the General Environment	5.96×10^{-1}	7.84 (Skin)	7.84	8.44

NOTE: Receptor locations for offsite public are shown on Figure 1.
Sources: [a] Values in Table 39 × 4 and *Summary of Doses.xls – Bounding Category 2 Events*.
[b] Values in Table 41 × 9 and *Summary of Doses.xls – Bounding Category 2 Events*.

6.8.7 Breach of Sealed Dual-Purpose Canister in Air (2-07)

Event 2-07 consists of the filtered burst and oxidation release from an event, such as a drop, that results in the breach of a sealed DPC containing either 36 maximum PWR commercial SNF assemblies or 74 maximum BWR commercial SNF assemblies. The HEPA filter is available and a canister LPF is credited. The PWR results in Table 57 are the results from Table 39 for a filtered release, multiplied by 36. The BWR results in Table 57 are the results from Table 41 for a filtered release, multiplied by 74. The actual data source for the table is *Summary of Doses.xls – Bounding Category 2 Events*, therefore, slight variations in values may occur due to rounding.

Table 57 Breach of Sealed Dual-Purpose Canister in Air (2-07)

	Total Effective Dose Equivalent (mrem)	Highest Total Organ Dose Equivalent (mrem)	Shallow Dose Equivalent to Skin (mrem)	Lens Dose Equivalent (mrem)
36 Pressurized Water Reactor Fuel Assemblies – Filtered-95% χ/Qa				
Offsite Public in the General Environment	9.15	4.80×10^{1} (Skin)	4.80×10^{1}	5.72×10^{1}
Offsite Public Not in the General Environment	7.76	9.23×10^{1} (Skin)	9.23×10^{1}	1.00×10^{2}
74 Boiling Water Reactor Fuel Assemblies – Filtered -95% χ/Qb				
Offsite Public in the General Environment	6.71	3.48×10^{1} (Skin)	3.48×10^{1}	4.15×10^{1}
Offsite Public Not in the General Environment	5.66	6.66×10^{1} (Skin)	6.66×10^{1}	7.22×10^{1}

NOTE: Receptor locations for offsite public are shown on Figure 1.
Sources: [a] Values in Table 39 × 36 and *Summary of Doses.xls – Bounding Category 2 Events*.
[b] Values in Table 41 × 74 and *Summary of Doses.xls – Bounding Category 2 Events*.

6.8.8 Breach of Commercial Spent Nuclear Fuel in Unsealed Dual-Purpose Canister in Pool (2-08)

Event 2-08 consists of the release through the pool water from a drop of an unsealed DPC during a transfer operation in the pool, which results in the breach of either 36 maximum PWR commercial SNF assemblies or 74 maximum BWR commercial SNF assemblies. The HEPA filter is available, but not credited. The pool LPFs from Design Input 6.1.4.3 are credited. The PWR results in Table 58 are the results from Table 39 for a pool release, multiplied by 36. The BWR results in Table 58 are the results from Table 41 for a pool release, multiplied by 74. The actual data source for the table is *Summary of Doses.xls – Bounding Category 2 Events*, therefore, slight variations in values may occur due to rounding.

Table 58. Breach of Commercial Spent Nuclear Fuel in Unsealed Dual-Purpose Canister in Pool (2-08)

	Total Effective Dose Equivalent (mrem)	Highest Total Organ Dose Equivalent (mrem)	Shallow Dose Equivalent to Skin (mrem)	Lens Dose Equivalent (mrem)
36 Pressurized Water Reactor Fuel Assemblies – Pool Release - 95% χ/Qa				
Offsite Public in the General Environment	8.43	4.53×10^{1} (Skin)	4.53×10^{1}	5.37×10^{1}
Offsite Public Not in the General Environment	6.72	8.98×10^{1} (Skin)	8.98×10^{1}	9.65×10^{1}
74 Boiling Water Reactor Fuel Assemblies - Pool Release -95% χ/Qb				
Offsite Public in the General Environment	6.20	3.28×10^{1} (Skin)	3.28×10^{1}	3.90×10^{1}
Offsite Public Not in the General Environment	4.90	6.45×10^{1} (Skin)	6.45×10^{1}	6.94×10^{1}

NOTE: Receptor locations for offsite public are shown on Figure 1.
Sources: [a] Values in Table 39 × 36 and *Summary of Doses.xls – Bounding Category 2 Events*.
[b] Values in Table 41 × 74 and *Summary of Doses.xls – Bounding Category 2 Events*.

6.8.9 Breach of Sealed Transportation, Aging, and Disposal Canister in Air (2-09)

Event 2-09 consists of the filtered burst and oxidation release from an event, such as a drop, that results in the breach of a sealed TAD canister containing either 21 maximum PWR commercial SNF assemblies or 44 maximum BWR commercial SNF assemblies. The HEPA filter is available and a canister LPF is credited. The PWR results in Table 59 are the results from Table 39 for a filtered release, multiplied by 21. The BWR results in Table 59 are the results from Table 41 for a filtered release, multiplied by 44. The actual data source for the table is *Summary of Doses.xls – Bounding Category 2 Events*, therefore, slight variations in values may occur due to rounding.

Table 59. Breach of Sealed Transportation, Aging, and Disposal Canister in Air (2-09)

	Total Effective Dose Equivalent (mrem)	Highest Total Organ Dose Equivalent (mrem)	Shallow Dose Equivalent to Skin (mrem)	Lens Dose Equivalent (mrem)
21 Pressurized Water Reactor Fuel Assemblies – Filtered-95% χ/Qa				
Offsite Public in the General Environment	5.34	2.80×10^1 (Skin)	2.80×10^1	3.34×10^1
Offsite Public Not in the General Environment	4.53	5.39×10^1 (Skin)	5.39×10^1	5.84×10^1
44 Boiling Water Reactor Fuel Assemblies – Filtered -95% χ/Qb				
Offsite Public in the General Environment	3.99	2.07×10^1 (Skin)	2.07×10^1	2.47×10^1
Offsite Public Not in the General Environment	3.37	3.96×10^1 (Skin)	3.96×10^1	4.30×10^1

NOTE: Receptor locations for offsite public are shown on Figure 1.

Sources: [a] Values in Table 39 × 21 and *Summary of Doses.xls – Bounding Category 2 Events*.
[b] Values in Table 41 × 44 and *Summary of Doses.xls – Bounding Category 2 Events*.

6.8.10 Breach of Commercial Spent Nuclear Fuel in Unsealed Transportation, Aging, and Disposal Canister in Pool (2-10)

Event 2-10 consists of the release through the pool water from a drop of an unsealed TAD canister during a transfer operation in the pool, which results in the breach of either 21 maximum PWR commercial SNF assemblies or 44 maximum BWR commercial SNF assemblies. The HEPA filter is available, but not credited. The pool LPFs from Design Input 6.1.4.3 are credited. The PWR results in Table 60 are the results from Table 39 for a pool release, multiplied by 21. The BWR results in Table 60 are the results from Table 41 for a pool release, multiplied by 44. The actual data source for the table is *Summary of Doses.xls – Bounding Category 2 Events*, therefore, slight variations in values may occur due to rounding.

Table 60. Breach of Commercial Spent Nuclear Fuel in Unsealed Transportation, Aging, and Disposal Canister in Pool (2-10)

	Total Effective Dose Equivalent (mrem)	Highest Total Organ Dose Equivalent (mrem)	Shallow Dose Equivalent to Skin (mrem)	Lens Dose Equivalent (mrem)
21 Pressurized Water Reactor Fuel Assemblies – Pool Release - 95% χ/Qa				
Offsite Public in the General Environment	4.92	2.64×10^1 (Skin)	2.64×10^1	3.13×10^1
Offsite Public Not in the General Environment	3.92	5.24×10^1 (Skin)	5.24×10^1	5.63×10^1
44 Boiling Water Reactor Fuel Assemblies - Pool Release -95% χ/Qb				
Offsite Public in the General Environment	3.68	1.95×10^1 (Skin)	1.95×10^1	2.32×10^1
Offsite Public Not in the General Environment	2.91	3.83×10^1 (Skin)	3.83×10^1	4.13×10^1

NOTE: Receptor locations for offsite public are shown on Figure 1.

Sources: [a] Values in Table 39 × 21 and *Summary of Doses.xls – Bounding Category 2 Events*.
[b] Values in Table 41 × 44 and *Summary of Doses.xls – Bounding Category 2 Events*.

6.8.11 Breach of Uncanistered Commercial Spent Nuclear Fuel Assemblies in Pool (2-11)

Event 2-11 consists of the release through the pool water from a drop of an uncanistered commercial SNF assembly onto another uncanistered assembly resulting in the breach of either two maximum PWR assemblies or two maximum BWR assemblies. The HEPA filter is available, but not credited. The pool LPFs from Design Input 6.1.4.3 are credited. The PWR results in Table 61 are the results from Table 39 for a pool release, multiplied by two. The BWR results in Table 61 are the results from Table 41 for a pool release, multiplied by two. The actual data source for the table is *Summary of Doses.xls – Bounding Category 2 Events*, therefore, slight variations in values may occur due to rounding.

Table 61. Breach of Uncanistered Commercial Spent Nuclear Fuel Assemblies in Pool (2-11)

	Total Effective Dose Equivalent (mrem)	Highest Total Organ Dose Equivalent (mrem)	Shallow Dose Equivalent to Skin (mrem)	Lens Dose Equivalent (mrem)
Two Pressurized Water Reactor Fuel Assemblies – Pool Release - 95% χ/Qa				
Offsite Public in the General Environment	4.69×10^{-1}	2.51 (Skin)	2.51	2.98
Offsite Public Not in the General Environment	3.74×10^{-1}	4.99 (Skin)	4.99	5.36
Two Boiling Water Reactor Fuel Assemblies - Pool Release -95% χ/Qb				
Offsite Public in the General Environment	1.67×10^{-1}	8.86×10^{-1} (Skin)	8.86×10^{-1}	1.05
Offsite Public Not in the General Environment	1.32×10^{-1}	1.74 (Skin)	1.74	1.88

NOTE: Receptor locations for offsite public are shown on Figure 1.

Sources: [a] Values in Table 39 × 2 and *Summary of Doses.xls – Bounding Category 2 Events*.
[b] Values in Table 41 × 2 and *Summary of Doses.xls – Bounding Category 2 Events*.

6.8.12 Breach of Uncanistered Commercial Spent Nuclear Fuel Assembly in Pool (2-12)

Event 2-12 consists of a breach of one uncanistered commercial SNF assembly of either a maximum PWR assembly or a maximum BWR assembly. The HEPA filter is available, but not credited. The pool LPFs from Design Input 6.1.4.3 are credited. The PWR results in Table 62 are the results from Table 39 for a pool release, and the BWR results in Table 62 are the results from Table 41 for a pool release.

Table 62. Breach of Uncanistered Commercial Spent Nuclear Fuel Assembly in Pool (2-12)

	Total Effective Dose Equivalent (mrem)	Highest Total Organ Dose Equivalent (mrem)	Shallow Dose Equivalent to Skin (mrem)	Lens Dose Equivalent (mrem)
One Pressurized Water Reactor Fuel Assembly – Pool Release - 95% χ/Qa				
Offsite Public in the General Environment	2.34×10^{-1}	1.26 (Skin)	1.26	1.49
Offsite Public Not in the General Environment	1.87×10^{-1}	2.49 (Skin)	2.49	2.68
One Boiling Water Reactor Fuel Assembly - Pool Release -95% χ/Qb				
Offsite Public in the General Environment	8.37×10^{-2}	4.43×10^{-1} (Skin)	4.43×10^{-1}	5.27×10^{-1}
Offsite Public Not in the General Environment	6.62×10^{-2}	8.71×10^{-1} (Skin)	8.71×10^{-1}	9.38×10^{-1}

NOTE: Receptor locations for offsite public are shown on Figure 1.
Sources: [a] Values in Table 39.
[b] Values in Table 41.

6.8.13 Bounding Fire Event (2-13)

The dose consequences for the bounding Category 2 fire event discussed in Section 6.3.3 are unfiltered releases as a result of a fire consuming the combustible portion of the LLWF inventory and damaging the HEPA filters in B-25 boxes. The dose consequences are calculated with the GENII code for each of the two postulated releases: release of accumulated radioactive material from the damaged HEPA filters; and release from the combustible LLW inventory in the LLWF. Since the difference in the HEPA filter dose consequences between the fire event and the seismic event are the ARF × RF, the results from the seismic event are multiplied by the ratio of the respective ARF × RF. This ratio is $1 \times 10^{-4} \div 1 \times 10^{-2} = 1 \times 10^{-2}$.

The doses from the fire event releases are summarized in Table 63. Results are from spreadsheet *Summary of Doses.xls-Result Matrix*.

Table 63. Itemized Fire Event Dose

	Total Effective Dose Equivalent (mrem)	Highest Total Organ Dose Equivalent (mrem)	Shallow Dose Equivalent to Skin (mrem)	Lens Dose Equivalent (mrem)
Low-Level Waste Facility Inventory[a]				
Offsite Public in the General Environment	2.22×10^{-1}	6.61×10^{-1} (Lungs)	1.766×10^{-1}	3.98×10^{-1}
Offsite Public Not in the General Environment	5.84×10^{-1}	2.07 (Lungs)	4.21×10^{-1}	1.00
Pressurized Water Reactor Fuel HEPA Inventory[b]				
Offsite Public in the General Environment	4.76×10^{-2}	1.03 (Bone Surface)	1.09×10^{-2}	5.85×10^{-2}
Offsite Public Not in the General Environment	1.51×10^{-1}	3.43 (Bone Surface)	2.80×10^{-2}	1.79×10^{-1}

Table 63. Itemized Fire Event Dose

	Total Effective Dose Equivalent (mrem)	Highest Total Organ Dose Equivalent (mrem)	Shallow Dose Equivalent to Skin (mrem)	Lens Dose Equivalent (mrem)
Boiling Water Reactor Fuel HEPA Inventory[b]				
Offsite Public in the General Environment	1.05×10^{-1}	8.83×10^{-1} (Bone Surface)	5.00×10^{-2}	1.55×10^{-1}
Offsite Public Not in the General Environment	3.14×10^{-1}	2.89 (Bone Surface)	1.28×10^{-1}	4.42×10^{-1}

NOTE: Receptor locations for offsite public are shown on Figure 1.

Source: [a] *Summary of Doses. xls-Result Matrix.*
[b] Table 50 × 1 × 10^{-2}

As can be seen in Table 63, the BWR HEPA filter inventory results in higher TEDE doses than the PWR HEPA filter inventory. Adding the dose from the combustible LLW to the dose from the BWR HEPA filter inventory, the results of the fire event are summarized in Table 64. Results are from spreadsheet *Summary of Doses.xls-Result Matrix*.

Table 64. Fire Event (2-13)

	Total Effective Dose Equivalent (mrem)	Highest Total Organ Dose Equivalent (mrem)	Shallow Dose Equivalent to Skin (mrem)	Lens Dose Equivalent (mrem)
Offsite Public in the General Environment	3.27×10^{-1}	1.08 (Bone Surface)	2.26×10^{-1}	5.53×10^{-1}
Offsite Public Not in the General Environment	8.98×10^{-1}	3.36 (Bone Surface)	5.49×10^{-1}	1.45

NOTE: Receptor locations for offsite public are shown on Figure 1.

Source: *Summary of Doses.xls-Seismic and Fire Organ Doses.*

6.8.14 Breach of a Sealed Truck Transportation Cask Due to a Fire (2-14)

Event 2-14 consists of the unfiltered burst and oxidation release from a loss of confinement due to a fire event for a CSNF truck transportation cask without impact limiters containing either four uncanistered maximum PWR assemblies or nine uncanistered maximum BWR assemblies. The cladding temperatures during this event are maintained below the threshold for cladding damage. This event does not lead to cladding damage; therefore, a damage ratio of 0.01 is considered (Assumption 3.2.1) for fission product and fuel fine releases. A damage ration of 1 is considered for crud releases (^{60}Co and ^{55}Fe) since crud may be released from all fuel assemblies in the cask. A cask LPF is credited, no HEPA filtration is considered. The PWR results in Table 64a below are the results for the 1% Maximum PWR case from *Summary of Doses.xls –* ***Result Matrix*** for a burst and oxidation release combined, unfiltered release with a 95th percentile χ/Q, multiplied by 4. The BWR results in Table 64a below are the results for the 1% Maximum BWR case from *Summary of Doses.xls – Result Matrix* for a burst and oxidation release combined, unfiltered release with a 95th percentile χ/Q, multiplied by 9. The data manipulation for the table is performed in *Summary of Doses.xls – Bounding Category 2 Events*.

Table 64a. Loss of Truck Transportation Cask Confinement Due to a Fire Event (2-14)

	Total Effective Dose Equivalent (mrem)	Highest Total Organ Dose Equivalent (mrem)	Shallow Dose Equivalent to Skin (mrem)	Lens Dose Equivalent (mrem)
Four Pressurized Water Reactor Fuel Assemblies – Burst and Oxidation – Unfiltered-95% χ/Q				
Offsite Public in the General Environment	1.85	4.70×10^{1} (Bone surface)	4.86×10^{-1}	2.33
Offsite Public Not in the General Environment	4.37	1.13×10^{2} (Bone surface)	1.08	5.45
Nine Boiling Water Reactor Fuel Assemblies – Burst and Oxidation – Unfiltered-95% χ/Q				
Offsite Public in the General Environment	1.65	3.06×10^{1} (Bone surface)	6.17×10^{-1}	2.27
Offsite Public Not in the General Environment	4.13	7.34×10^{1} (Bone surface)	2.12	6.25

NOTE: Receptor locations for offsite public are shown on Figure 1.
Sources: *Summary of Doses.xls – Bounding Category 2 Events*.

6.9 RADIATION WORKER DOSE SUMMARY

In compliance with 10 CFR 63.111(b)(1) (Reference 2.2.1), doses from normal operations and Category 1 event sequences are aggregated. However, per Assumption 3.1.1, there are no Category 1 event sequences. Table 65 summarizes the doses to an individual radiation worker in the maximally exposed crew from normal operations only. That crew is the Receipt Facility operator worker group per Table 14.

Dose results are the highest dose from each of the three sources; airborne releases from normal operations, external radiation from routine operations and external radiation from contained sources located outside of facilities. No one radiation worker can receive the sum of these doses since the doses are determined for a worker that spends 2,000 hours per year at the work location. The radiation worker doses shown in Table 65 are to the maximally exposed worker, which is an operator at the Receipt Facility. Thus, the TEDE dose reported in Table 65 is the dose received by a worker at the Receipt Facility from each of the three sources.

Table 65. Worker Dose from Normal Operations and Category 1 Event Sequences

Dose Contributions	Total Effective Dose Equivalent (mrem/yr)	Highest Total Organ Dose Equivalent (mrem/yr)	Shallow Dose Equivalent to Skin (mrem/yr)	Lens Dose Equivalent (mrem/yr)
Normal operations airborne releases to Receipt Facility	0.24	6.6	1.3	1.5
Direct radiation during operations within the Receipt Facility	1,300	-	-	-
Direct radiation from external contained sources at Receipt Facility	0.47	-	-	-

Source: Table 14, Table 15.

6.10 PUBLIC NORMAL OPERATIONS AND CATEGORY 1 EVENT SEQUENCE DOSE SUMMARY

In compliance with 10 CFR 63.111(b)(1) (Reference 2.2.1), doses from normal operations and Category 1 event sequences are aggregated. However, per Assumption 3.1.1, there are no Category 1 event sequences. Therefore, Table 66 summarizes the public doses from normal operations only.

Table 66. Public Dose from Normal Operations and Category 1 Event Sequences

Event Sequence Type	Category of Individual	Site (Preclosure Controlled Area) (mrem/yr)	General Environment (Unrestricted Area) (mrem/yr)	Offsite, but not within the General Environment (Unrestricted Area) (mrem/yr)
Aggregate of Normal Operation and Category 1 Event Sequence Dose	Public	7.8×10^{1}	5.5×10^{-2}	1.1×10^{-1}
Aggregate of Normal Operation and Category 1 Event Sequence Dose	Construction Worker	1.0×10^{1}	-	-

Source: Table 46 and Table 47.

6.11 CATEGORY 2 EVENT SEQUENCE DOSE SUMMARY

The Category 2 event sequence dose results are tabulated in Section 6.8 with a subsection for each Category 2 event sequence. The results summarized in Table 67 and Table 68, can be found in the individual subsections in Section 6.8. Dose locations are shown in Figure 1.

Table 67. Offsite Public in General Environment Category 2 Event Sequence Dose

Bounding Category 2 Event Sequence	Total Effective Dose Equivalent (mrem)	Highest Total Organ Dose Equivalent (mrem)	Shallow Dose Equivalent to Skin (mrem)	Lens Dose Equivalent (mrem)
2-01 Seismic event resulting in LLWF collapse and failure of HEPA filters and ductwork in other facilities	1.17×10^{1}	8.94×10^{1} (Bone Surface)	5.95	1.77×10^{1}
2-02 Breach of sealed SRS HLW canisters in a sealed transportation cask	7.86×10^{-1}	2.04×10^{1} (Bone Surface)	1.19×10^{-1}	9.05×10^{-1}
2-03 Breach of sealed SRS HLW canisters in an unsealed waste package	7.86	2.04×10^{2} (Bone Surface)	1.19	9.05
2-04 Breach of sealed SRS HLW canister during transfer (one drops onto another)	3.14	8.14×10^{1} (Bone Surface)	4.76×10^{-1}	3.62
2-05 Breach of uncanistered commercial SNF in a sealed truck transportation cask in air	1.02	5.34 (Skin)	5.34	6.36
2-06 Breach of uncanistered commercial SNF in an unsealed truck transportation cask in pool	9.37×10^{-1}	5.03 (Skin)	5.03	5.97
2-07 Breach of a sealed DPC in air	9.15	4.80×10^{1} (Skin)	4.80×10^{1}	5.72×10^{1}
2-08 Breach of commercial SNF in unsealed DPC in pool	8.43	4.53×10^{1} (Skin)	4.53×10^{1}	5.37×10^{1}
2-09 Breach of a sealed TAD canister in air within facility	5.34	2.80×10^{1} (Skin)	2.80×10^{1}	3.34×10^{1}
2-10 Breach of commercial SNF in unsealed TAD canister in pool	4.92	2.64×10^{1} (Skin)	2.64×10^{1}	3.13×10^{1}
2-11 Breach of uncanistered commercial SNF assembly in pool (one drops onto another)	4.69×10^{-1}	2.51 (Skin)	2.51	2.98
2-12 Breach of uncanistered commercial SNF in pool	2.34×10^{-1}	1.26 (Skin)	1.26	1.49
2-13 Fire involving LLWF inventory	3.27×10^{-1}	1.08 (Bone Surface)	2.26×10^{-1}	5.53×10^{-1}
2-14 Breach of a sealed truck transportation cask due to a fire	1.85	4.70×10^{1} (Bone Surface)	4.86×10^{-1}	2.33

Table 68. Offsite Public Not in General Environment Category 2 Event Sequence Dose

Bounding Category 2 Event Sequence	Total Effective Dose Equivalent (mrem)	Highest Total Organ Dose Equivalent (mrem)	Shallow Dose Equivalent to Skin (mrem)	Lens Dose Equivalent (mrem)
2-01 Seismic event resulting in LLWF collapse and failure of HEPA filters and ductwork in other facilities	3.46×10^{1}	2.92×10^{2} (Bone Surface)	1.51×10^{1}	4.97×10^{1}
2-02 Breach of sealed SRS HLW canisters in a sealed transportation cask	2.57	6.73×10^{1} (Bone Surface)	3.12×10^{-1}	2.88
2-03 Breach of sealed SRS HLW canisters in an unsealed waste package	2.57×10^{1}	6.78×10^{2} (Bone Surface)	3.12	2.88×10^{1}
2-04 Breach of sealed SRS HLW canister during transfer (one drops onto another)	1.03×10^{1}	2.70×10^{2} (Bone Surface)	1.25	1.15×10^{1}
2-05 Breach of uncanistered commercial SNF in a sealed truck transportation cask in air	8.62×10^{-1}	1.03×10^{1} (Skin)	1.03×10^{1}	1.11×10^{1}
2-06 Breach of uncanistered commercial SNF in an unsealed truck transportation cask in pool	7.47×10^{-1}	9.98 (Skin)	9.98	1.07×10^{1}
2-07 Breach of a sealed DPC in air	7.76	9.23×10^{1} (Skin)	9.23×10^{1}	1.00×10^{2}
2-08 Breach of commercial SNF in unsealed DPC in pool	6.20	8.98×10^{1} (Skin)	8.98×10^{1}	9.65×10^{1}
2-09 Breach of a sealed TAD canister in air within facility	4.53	5.39×10^{1} (Skin)	5.39×10^{1}	5.84×10^{1}
2-10 Breach of commercial SNF in unsealed TAD canister in pool	3.92	5.24×10^{1} (Skin)	5.24×10^{1}	5.63×10^{1}
2-11 Breach of uncanistered commercial SNF assembly in pool (one drops onto another)	3.74×10^{-1}	4.99 (Skin)	4.99	5.36
2-12 Breach of uncanistered commercial SNF in pool	1.87×10^{-1}	2.49 (Skin)	2.49	2.68
2-13 Fire involving LLWF inventory	8.98×10^{-1}	3.36 (Bone Surface)	5.49×10^{-1}	1.45
2-14 Breach of a sealed truck transportation cask due to a fire	4.37	1.13×10^{2} (Bone Surface)	1.08	5.45

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7 RESULTS AND CONCLUSIONS

Table 69 contains the final results and compares the results with the performance objectives (Table 1). Table 69 shows that all performance objectives have been met.

These results are dependent on two design features and 9 procedural safety controls.

Design Features:

HEPA filtration is maintained with an LPF of 1×10^{-4} for a 30-day duration to mitigate the consequences from all Category 2 event sequences. This design feature applies to the RF, CRCFs, and WHF, but not IHF, where no HEPA filtration is credited in the consequence analysis. To achieve an LPF of 1×10^{-4}, the design features shall include two stages of HEPA filtration with 99% efficiency per stage, and prefilters and demisters.

The WHF pool structure and system is capable of maintaining a minimum of 23 feet of water above the active fuel region of staged (e.g. in racks, open canisters, or open transportation casks) commercial SNF under normal, off-normal and Category 1 and Category 2 event sequence conditions.

Procedural Safety Controls:

The procedural safety controls are presented in Table 70.

Table 69. Summary Preclosure Dose Performance Objectives and Evaluation Results

Category	Standard	Limits	Results	Source
Public Exposure – Offsite in General Environment	Preclosure standard: 10 CFR 63.204; preclosure performance objective for normal operations and Category 1 event sequences per 10 CFR 63.111 (a)(2)	15 mrem/yr total effective dose equivalent	0.05 mrem/yr	Table 66
	Dose limits for individual members in any unrestricted area from external sources during normal operations and Category 1 event sequences: 10 CFR 20.1301 (a)(2)[a]	2 mrem/hr in any unrestricted area from external sources	Negligible	
	Operational dose constraint specified for air emissions of radioactive material to the environment; not a dose limitation: 10 CFR 20.1101(d)[b]	10 mrem/yr total effective dose equivalent	0.05 mrem/yr	Table 66
	Preclosure performance objective for any Category 2 event sequence: 10 CFR 63.111 (b)(2)	5 rem total effective dose equivalent	0.01 rem	Table 67
		50 rem organ or tissue dose other than the lens of the eye	0.20 rem	Table 67
		15 rem lens of the eye dose	0.06 rem	Table 67
		50 rem shallow dose to skin	0.05 rem	Table 67
Public Exposure – Offsite Not in General Environment	Preclosure performance objective for normal operations and Category 1 event sequences per 10 CFR 20.1301 (a)(1)[a]	100 mrem/yr total effective dose equivalent	0.11 mrem/yr	Table 66
	Dose limits for individual members in any unrestricted area from external sources during normal operations and Category 1 event sequences: 10 CFR 20.1301 (a)(2)[a]	2 mrem/hr in any unrestricted area from external sources	Negligible	
	Operational dose constraint specified for air emissions of radioactive material to the environment; not a dose limitation: 10 CFR 20.1101(d)[b]	10 mrem/yr total effective dose equivalent	0.11 mrem/yr	Table 66
	Preclosure performance objective for any Category 2 event sequence: 10 CFR 63.111 (b)(2)	5 rem total effective dose equivalent	0.03 rem	Table 68
		50 rem organ or tissue dose other than the lens of the eye	0.68 rem	Table 68
		15 rem lens of the eye dose	0.10 rem	Table 68
		50 rem shallow dose to skin	0.09 rem	Table 68
Public Exposure – Onsite	Dose limits for onsite individual members of the public for normal operations and Category 1 event sequences: 10 CFR 20.1301 (a)(1)	100 mrem/yr [c,d] total effective dose equivalent	78 mrem/yr	Table 66
Public Exposure – Construction Workers	Dose limits for onsite individual members of the public for normal operations and Category 1 event sequences: 10 CFR 20.1301 (a)(1)[b]	100 mrem/yr[c,d] total effective dose equivalent	10 mrem/yr	Table 66

Table 69. Summary Preclosure Dose Performance Objectives and Evaluation Results

Category	Standard	Limits	Results	Source
Radiation Workers' Exposure	Occupational dose limits for adults from normal operations and Category 1 event sequences: 10 CFR 20.1201[a]	5 rem/yr total effective dose equivalent	1.3 rem/yr	Table 65
		50 rem/yr organ or tissue dose other than the lens of the eye	<0.01 rem/yr	Table 65
		15 rem/yr lens of the eye dose	<0.01 rem/yr	Table 65
		50 rem/yr shallow dose to skin	<0.01 rem/yr	Table 65

Note: [a] 10 CFR 63.111(b)(1) requires repository design objectives for Category 1 and normal operations to address 10 CFR 63.111(a)(1) requirements (10 CFR part 20).
[b] 10 CFR 63.111(a)(1) requires operations area to address the requirements of 10 CFR part 20.
[c] 10 CFR 20.1301(a)(1); dose limit to the extent applicable.
[d] Maximum of general public and construction worker.

Table 70. Procedural Safety Controls

Facility	Procedural Safety Controls	Basis for Selection
Aging Facility	The surface contamination on TAD canisters and DPCs sent to the Aging Facility shall be less than 1×10^{-4} μCi/cm^2 for beta-gamma emitters and low-toxicity alpha emitters and 1×10^{-5} μCi/cm^2 for all other alpha emitters	This control is to ensure that the dose consequences from airborne releases of contamination from the canisters on the aging pads are within the calculated values presented in Table 45.
All, except IHF	The maximum burnup for commercial SNF shall be limited to 80 GWd/MTU for PWRs and 75 GWd/MTU for BWRs.	This control is to ensure that the dose consequences from Category 2 event sequences involving these waste forms are within the values presented in Table 67 and Table 68.
All, except IHF	The maximum initial enrichment for commercial SNF shall be limited to 5% ^{235}U.	This control is to ensure that the dose consequences from Category 2 event sequences involving these waste forms are within the values presented in Table 67 and Table 68.
All, except IHF	The minimum decay time of commercial SNF prior to shipment to the repository shall be 5 years.	This control is to ensure that the dose consequences from Category 2 event sequences involving these waste forms are within the values presented in Table 67 and Table 68.
All	The individual radionuclide inventories per canister for HLW shall be at most the values presented in Table 8.	This control is to ensure that the dose consequences from Category 2 event sequences involving these waste forms are within the values presented in Table 67 and Table 68.
WHF	The height of water above the top of the active portions of staged commercial SNF assemblies in the WHF pool shall be maintained at least 23 feet	This control is to ensure that the pool leak path factors presented in Table 12 are maintained.
WHF/LLWF	The total radionuclide inventory on the WHF pool resins and on the WHF pool filters in the WHF or LLWF staged in HICs shall be below 2,300 Ci (Table 34).	This control is to ensure that the dose consequences from Category 2 event sequences involving these waste forms are within the values presented in Table 67 and Table 68.

Table 70. Procedural Safety Controls

Facility	Procedural Safety Controls	Basis for Selection
LLWF	The total radionuclide inventory on the WHF Stage 1 ITS HEPA filters shall be below 6,600 Ci (Table 31).	This control is to ensure that the dose consequences from Category 2 event sequences involving these waste forms are within the values presented in Table 67 and Table 68.
LLWF	The radionuclide concentration in the low-level liquid waste tank shall be limited to dose equivalents of 1×10^{-3} Ci/m^3 of ^{60}Co and 1.5×10^{-3} Ci/m^3 of ^{137}Cs.	This control is to ensure that consequences of a low-level liquid waste tank spill are within the values presented in Appendix IV and the event may be considered as an off-normal event.

APPENDIX I E-MAIL FROM MICHAEL FRANK TO MARK WISENBURG (REFERENCE 2.2.3)

Michael Frank
10/19/2007 12:58 PM

To: Mark Wisenburg/YM/RWDOE@CRWMS
cc: Kathryn Ashley/YM/RWDOE@CRWMS, Sen-Sung Tsai/YM/RWDOE@CRWMS, Dale Dexheimer/YM/RWDOE@CRWMS
Subject: Preliminary Information on Event Sequence Diagrams and End States: Rev 1. Please disregard the original transmission

LSN: Not Relevant - Not Privileged
User Filed as: Excl/AdminMgmt-14-4/QA:N/A

At the request of Dr. Tsai, please find attached preliminary information from draft event sequence analyses of internal events. The information includes lists of event sequence diagram designators and descriptions, corresponding initiating events, and material at risk for each of the six analysis areas. The format was developed in conjunction with Dr. Tsai. The information is the best currently available but is subject to change, perhaps substantial change. In particular, the list does not include seismic event sequences. Such event sequences have the potential to significantly increase the stated material at risk. Aircraft crashes have been screened out probabilistically. It is my expectation that external events, other than seismic, will not result in releases.

The seventh attachment includes a list of end states and our current judgment about categorization entitled: Expectations Related to Potential End States. Quantification is just beginning and the information can not be considered stable.

Attachments:

Preliminary IHF Initiating Events and Material at Risk (4 pages)
Preliminary WHF Initiating Events and Material at Risk (7 pages)
Preliminary CRCF Initiating Events and Material at Risk (6 pages)
Preliminary RF Initiating Events and Material at Risk (3 pages)
Preliminary Subsurface Initiating Events and Material at Risk (3 pages)
Preliminary Intra-Site Initiating Events and Material at Risk (2 pages)
Preliminary Information on End States of Initiating Events (3 pages)

Att 1 - IHF ESD Table.doc
Att 2 - WHF ESD Table.doc
Att 3 - CRCF ESD Table.doc
Att 4 - RF ESD Table.doc
Att 5 - Subsurface ESD Table.doc
Att 6 - Intra-site ESD Table.doc
Att 7 - End State Preliminary Information and Assumptions.doc

Note: The attachments to this E-mail are available in the Appendix XI CD-ROM.

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APPENDIX II END STATES FOR EVENT SEQUENCES

The event sequence categorization process is performed and documented by facility and separately for seismic initiating events. Facilities include the Initial Handling Facility, Canister Receipt and Closure Facility, Receipt Facility, Wet Handling Facility, Intrasite Operation and Balance of Plant Facilities, and Subsurface Operations Facilities. Phase one of the process is a qualitative analysis by facility to identify and develop potential event sequences. Phase two is a quantitative analysis of event sequences for the purpose of categorization in accordance with the definitions of Category 1 and Category 2 event sequences.

The first phase includes the development of master logic diagrams, event sequence diagrams (ESD) and event trees. For each facility, the end states of the event trees and the material involved in the event are provided in Reference 2.2.3.

Five possible end states are considered in the ESDs. The first end state addresses absence of radiation exposure; the other four end states classify the type of radiation exposure that could occur, as follows:

I1. OK–Indicates the absence of radiation exposure.

I2. Direct Exposure–Indicates a personnel exposure to direct or reflected shine.

I3. Radionuclide Release–Indicates a release of radioactive material to the environment.

I4. Radionuclide Release, Also Important to Criticality–Refers to a situation in which a breach of a waste form container has occurred (resulting in a radionuclide release), and moderator has entered the canister.

I5. Important to Criticality–Specific to those event sequences involving one or more spent nuclear fuel (SNF) assemblies immersed in the pool of the Wet Handling Facility (WHF), associated with event sequences in which a change in reactivity is considered possible.

For the development of event trees, the above end states are further developed to differentiate the consequences of the various states of release and exposure. The eight end states include:

E1. OK–Indicates the absence of radiation exposure.

E2. Direct Exposure, Degraded Shielding–Indicates a personnel exposure to direct or reflected shine without a breach of a waste form shielded container.

E3. Direct Exposure, Loss of Shielding–Indicates a personnel exposure to direct or reflected shine from a breached waste form shielded container.

E4. Radionuclide Release, Filtered–Indicates a release of radioactive material to the environment through a filtered path.

E5. Radionuclide Release, Unfiltered–Indicates a release of radioactive material to the environment through an unfiltered path.

E6. Radionuclide Release, Filtered, Important to Criticality–Refers to a situation in which a breach of a waste form container has occurred (resulting in a radionuclide release), and moderator has entered the canister. The release of radioactive material to the environment is through a filtered path.

E7. Radionuclide Release, Unfiltered, Important to Criticality–Refers to a situation in which a breach of a waste form container has occurred (resulting in a radionuclide release), and moderator has entered the canister. The release of radioactive material to the environment is through an unfiltered path.

E8. Important to Criticality–Specific to those event sequences involving one or SNF assemblies immersed in the pool of the WHF, associated with event sequences in which a change in reactivity is considered possible.

The end states "radionuclide release (filtered or unfiltered), important to criticality" and "important to criticality" segregate event sequences for which some of the conditions leading to a criticality event have been met. This does not imply, however, that a criticality event is inevitable.

The end states have been cross referenced to the bounding Category 2 event sequences evaluated in the calculation. The first four columns of the tables are the input provided in Reference 2.2.3. The last column is the cross-reference to the bounding Category 2 event sequence.

Table II - 1. Initial Handling Facility Event Sequences

Event Sequence Number	Event Sequence Description	Initiating Events	Material at Risk	Bounding Category 2 Event
IHF-ESD-01[a]	Receipt of Naval or HLW Transportation Casks on Railcar or Truck Trailer in Cask Preparation Area and Transfer of Naval Transportation Cask to Cask Transfer Trolley	1. Cask handling crane drops object (such as handling equipment) onto the naval transportation cask 2. Cask handling crane drops naval transportation cask 3. Railcar derailment 4. HLW truck trailer rollover 5. Railcar or truck trailer collision (for example, with another vehicle) 6. Collision involving naval transportation cask off of railcar (while the cask is being carried by the cask handling crane) 7. Naval transportation cask tip-over (after placement into the cask transfer trolley).	Naval transportation cask containing a single naval SNF canister and received on railcar HLW transportation cask containing five HLW canisters and received by railcar HLW transportation cask containing a single HLW canister and received by truck trailer	2-02
IHF-ESD-02[a]	Removal of Impact Limiters, Upending and Transfer of HLW Cask to cask transfer trolley and Removal of Impact Limiters from Naval Transportation Cask	1. Drop of HLW transportation cask 2. Unplanned carrier movement causes HLW transportation cask impact 3. Collision involving side impact to HLW or naval transportation cask (during transfer by crane) 4. Drop of heavy object (such as handling equipment) onto the naval or HLW transportation cask.	HLW transportation cask containing five HLW canisters and received by railcar HLW transportation cask containing a single HLW canister and received by truck trailer Naval transportation cask containing a single naval canister and received by railcar	2-02
IHF-ESD-03	Cask Preparation Activities Associated with Unbolting and Lid Adapter Installation for the HLW Cask	1. Transportation cask tip over (due to interference with the cask preparation crane) 2. Side impact to transportation cask (due to interference with the cask preparation crane) 3. Drop of heavy object (such as handling equipment associated with the cask preparation crane) onto the transportation cask	HLW transportation cask containing five HLW canisters HLW transportation cask containing a single HLW canister	2-02
IHF-ESD-04[a]	Removal of the Naval Cask Lid and Installing the Naval Canister Lifting Adapter	1. Side impact to transportation cask (handling equipment collision, for example) 2. Drop of a heavy object (such as handling equipment or the cask lid) onto the canister 3. Transportation cask tip over (after placement into the cask transfer trolley).	Naval transportation cask containing a single naval SNF canister	N/A
IHF-ESD-05[a]	Transfer of a Cask on Cask Transfer Trolley from the Cask Preparation Area to Cask Unloading Room	1. Cask transfer trolley or cask catches crane hook or rigging resulting in impact to cask 2. Cask transfer trolley impact collision with another vehicle, facility structures, or equipment (except shield door).	Naval SNF canister in a transportation cask HLW canister in a transportation cask	2-03

Table II - 1. Initial Handling Facility Event Sequences

Event Sequence Number	Event Sequence Description	Initiating Events	Material at Risk	Bounding Category 2 Event
IHF-ESD-06 [a]	Collision of Cask Transfer Trolley with Cask Unloading Room Shield Door	A collision between a cask transfer trolley carrying a HLW or naval cask and the shield door of the Cask Unloading Room.	Naval transportation cask (without a lid) containing a single naval SNF canister in a cask transfer trolley HLW transportation cask (with lid in place but unbolted) containing five HLW canisters in a cask transfer trolley HLW transportation cask (with a lid in place but unbolted) containing a single HLW canister in a cask transfer trolley.	2-03
IHF-ESD-07 [a]	Transfer of a Canister to or from a Transportation Cask or Waste Package with Canister Transfer Machine	1. Canister impact due to movement of the with canister transfer machine, cask transfer trolley, or waste package transfer trolley during lift 2. Drop of an object onto the canister 3. Canister dropped during transfer (drop through a port) 4. Canister collision or impact (for example, with the inside of the shield bell) 5. Side impact (due to inadvertent closure of a slide gate) 6. Canister dropped inside the canister transfer machine (i.e., not through a port).	Naval SNF canister HLW canister.	2-03
IHF-ESD-08 [a]	Waste Package Transfer from Waste Package Loading Room to Closing Position in Waste Package Positioning Room below waste package Closure Room	1. Waste Package Transfer Trolley collision with facility structures or facility equipment 2. Impact from Waste Package Transfer Trolley premature tilt-down 3. Waste Package Transfer Trolley derailment	Naval SNF canister in waste package HLW canisters in waste package	2-03
IHF-ESD-09 [a]	Event Sequences Associated with Assembly and Closure of the Waste Package	1. Welding damages the canister(s) 2. Remote Handling System drops object (such as the waste package outer lid or handling equipment) onto the waste package.	Waste package containing a single naval SNF canister in the waste package transfer trolley Waste package containing five HLW canisters in the waste package transfer trolley	2-03

Table II - 1. Initial Handling Facility Event Sequences

Event Sequence Number	Event Sequence Description	Initiating Events	Material at Risk	Bounding Category 2 Event
IHF-ESD-10 [a]	Transfer of the Waste Package from the Waste Package Positioning Room to the Waste Package Transfer Trolley Docking Station	1. Waste Package Transfer Trolley collision 2. Impact due to improper tilt-down or departure of the Waste Package Transfer Trolley 3. Waste Package Transfer Trolley derailment	Waste package containing naval SNF Waste package containing HLW	2-02
IHF-ESD-11 [a]	Exporting a Waste Package	1. Transport and Emplacement Vehicle collision 2. Impact due to object dropped on waste package 3. Crane interference with Transport and Emplacement Vehicle or Waste Package Transfer Trolley 4. Impact due to malfunction of the Waste Package Transfer Trolley or the waste package transfer carriage	Naval SNF in a waste package HLW in a waste package	2-02
IHF-ESD-12	Direct Exposure During Various Activities	1. Temporary loss of shielding of the canister transfer machine shield bell function (due to inadvertent lifting of bell skirt) while the canister is being lifted from a transportation cask 2. Inadvertent displacement of the naval cask shield ring from cask or waste package or improper installation of waste package shield ring on waste package (No operational node association. Condition caused by shipper) 3. Direct exposure during exporting a loaded waste package. 4. Temporary loss of shielding due to inadvertent opening of Cask Unloading Room or Loading Room shield door while a canister is lifted from or lowered into a cask or a waste package by the canister transfer machine	Naval SNF in a transportation cask, the canister transfer machine, or waste package HLW in a canister in the canister transfer machine or waste package	Assumption 3.1.1 Section 4.4.3

Table II - 1. Initial Handling Facility Event Sequences

Event Sequence Number	Event Sequence Description	Initiating Events	Material at Risk	Bounding Category 2 Event
IHF-ESD-13	Events Sequences for Fires Occurring in the IHF	1. Localized fire threatens a waste package in the Waste Package Loadout Room 2. Localized fire threatens a waste package in the Waste Package Loading Room 3. Localized fire threatens a transportation cask in the Cask Unloading Room 4. Localized fire threatens a waste package in the Waste Package Positioning Room 5. Localized fire threatens a transportation cask in the Cask Preparation Area 6. Localized fire threatens a canister in the Canister Transfer Machine 7. Large fire threatens waste forms anywhere in the IHF.	Naval SNF HLW	Assumption 3.1.1

Notes: [a] Per Appendix IX a drop of a naval canister is a beyond Category 2 event

Table II - 2. Wet Handling Facility Event Sequences

Event Sequence Number	Event Sequence Description	Initiating Events	Material at Risk	Bounding Category 2 Event
WHF-ESD-01	Receipt of Transportation Casks on Truck Trailer in Transportation Cask Vestibule and Movement into Cask Preparation Area	1. Truck Trailer rollover 2. Collision involving truck trailer and structure or equipment	Transportation cask containing commercial SNF	2-05
WHF-ESD-02	Receipt of Transportation Casks on railcar in Transportation Cask Vestibule and Movement into Cask Preparation Area	1. Railcar derailment 2. Collision involving railcar and structure or equipment	Transportation cask containing DPC	2-07
WHF-ESD-03	Receipt of Aging Overpack on Site Transporter in Site Transporter Vestibule	1. Site Transporter rollover 2. Collision involving Site Transporter and structure or equipment	Aging Overpack containing DPC	2-07
WHF-ESD-04	Receipt of Horizontal Shielded Transfer Cask on Cask Tractor Trailer in Transportation Cask Vestibule and Movement into Cask Preparation Area	1. Site transporter rollover 2. Collision involving site transporter and structure or equipment	Horizontal shielded transfer cask containing a horizontal canister on a cask tractor trailer	2-07
WHF-ESD-05	Removal of Impact Limiters, Upending and Transfer of Transportation Cask or Commercial SNF to Preparation station	1. Drop of transportation cask 2. Transportation cask tipover 3. Collision involving side impact to transportation cask (during transfer by crane) 4. Drop of heavy object (such as handling equipment) onto transportation cask.	Transportation cask containing commercial SNF	2-05 2-07

Table II - 2. Wet Handling Facility Event Sequences

Event Sequence Number	Event Sequence Description	Initiating Events	Material at Risk	Bounding Category 2 Event
WHF-ESD-06	Removal of Impact Limiters, Upending and Transfer of transportation cask with DPC to cask transfer trolley in Preparation station	1. Drop of transportation cask 2. Transportation cask tipover 3. Collision involving side impact to transportation cask (during transfer by crane) 4. Drop of heavy object (such as handling equipment) onto transportation cask.	Transportation cask containing DPC	2-07
WHF-ESD-07	Cask Preparation Activities Associated with installation of lid lift fixture on transportation cask with DPC or Horizontal Site Transfer Cask with DPC	1. Transportation cask tip over (due to interference with the cask preparation crane) 2. Impact to transportation cask (due to collision of cask transfer trolley and a vehicle) 3. Drop of heavy object (such as handling equipment) onto the transportation cask 4. Transportation cask drop due to cask transfer trolley movement while the cask is still attached to the crane	Transportation cask containing DPC Horizontal Site Transfer Cask with horizontal canister	2-07
WHF-ESD-08	Cask Preparation Activities Associated with installation of Lid Lift Fixture on Transportation Cask with Commercial SNF	1. Transportation cask tip over (due to interference with the cask preparation crane) 2. Impact to transportation cask (due to collision of cask transfer trolley and a vehicle) 3. Drop of heavy object (such as handling equipment) onto the transportation cask 4. Transportation cask drop due to cask transfer trolley movement while the cask is still attached to the crane	Transportation cask containing commercial SNF	2-05 2-07
WHF-ESD-09	Removal of the Transportation Cask Lid and Installation of DPC Lift Fixture	1. Impact to transportation cask (handling equipment or vehicular collision, for example) 2. Drop of a heavy object (such as handling equipment or the cask lid) onto the canister 3. Transportation cask drop due to cask transfer trolley movement while the cask is still attached to the crane	Transportation cask containing DPC Horizontal Site Transfer Cask with horizontal canister	2-07
WHF-ESD-10	Transfer of a Cask on Cask Transfer Trolley from the Cask Preparation Area to Cask Unloading Room	1. Cask transfer trolley or cask catches crane hook or rigging resulting in impact to cask 2. Cask transfer trolley impact collision with another vehicle, facility structures, or equipment (except shield door).	Transportation cask containing DPC Horizontal Site Transfer Cask with horizontal canister	2-07

Table II - 2. Wet Handling Facility Event Sequences

Event Sequence Number	Event Sequence Description	Initiating Events	Material at Risk	Bounding Category 2 Event
WHF-ESD-11	Transfer of an Aging Overpack on Site Transporter from the Site Transporter Vestibule to Aging Overpack Access Platform and into Loading Room	1. Impact to Aging Overpack and canister (handling equipment or vehicular collision, for example) 2. Drop of a heavy object (such as handling equipment or the cask lid) onto Aging Overpack or canister 3. Aging Overpack and DPC tipover due to Site Transporter movement or jib crane malfunction	Aging Overpack containing DPC	2-07
WHF-ESD-12	Collision Of Cask Transfer Trolley with Cask Unloading Room shield door or Site Transporter with Loading Room Shield Door	A collision between a cask transfer trolley carrying a Transportation Cask with DPC and the shield door of the Cask Unloading Room or Site Transporter carrying an Aging Overpack with DPC and the shield door of the Loading Room.	Transportation cask containing a DPC in a cask transfer trolley Aging Overpack containing a DPC in Site Transporter Horizontal Site Transfer Cask with horizontal canister	2-07
WHF-ESD-13	Transfer of a Canister to or from Aging Overpack, Site Transfer Cask, or Transportation Cask with Canister Transfer Machine	1. Canister impact due to movement of the Canister Transfer Machine, cask transfer trolley, or Site Transporter during lift 2. Drop of an object onto the canister 3. Canister dropped during transfer (drop through a port) 4. Canister collision or impact (for example, with the inside of the shield bell) 5. Side impact (due to inadvertent closure of a slide gate) 6. Canister dropped inside the Canister Transfer Machine (i.e., not through a port).	DPC Horizontal canister	2-07
WHF-ESD-14	Transfer of Site Transfer Cask with DPC on Cask Transfer Trolley from Cask Unloading Room to Cask Preparation Area	1. Cask transfer trolley or cask catches crane hook or rigging resulting in impact to cask 2. Cask transfer trolley impact collision with another vehicle, facility structures, or equipment (except shield door).	Canister Transfer Machine containing DPC	2-07

Table II - 2. Wet Handling Facility Event Sequences

Event Sequence Number	Event Sequence Description	Initiating Events	Material at Risk	Bounding Category 2 Event
WHF-ESD-15	Transfer of Site Transfer Cask with DPC from Preparation Station to DPC Cutting Station	1. Site Transfer Cask with DPC tip over (due to interference with the cask preparation crane) 2. Impact to Site Transfer Cask with DPC (due to collision of cask transfer trolley and a vehicle) 3. Drop of heavy object (such as handling equipment) onto Site Transfer Cask with DPC 4. Drop of Site Transfer Cask with DPC from Cask Handling Crane	Site Transfer Cask containing DPC	2-07
WHF-ESD-16	Event Sequences associated with Transportation Cask with Commercial SNF Preparation Activities at Preparation Station – Sampling Activities	1. Sampling line break resulting in release of radioactive materials 2. Cask impact due to crane mishaps	Transportation cask containing commercial SNF	2-05 2-07
WHF-ESD-17	Event Sequences associated with Site Transfer Cask with DPC Preparation Activities at DPC Cutting Station – Sampling Activities	1. Sampling line break resulting in direct exposure 2. Failure to install shield ring or access port cut too deep prior to DPC lid cutting resulting in direct exposure	DPC containing commercial SNF	Assumption 3.1.1
WHF-ESD-18	Event Sequences associated with Transportation Cask with Commercial SNF Preparation Activities at Preparation Station – Sampling Activities	1. Access port damage or fuel assembly damage due to uncovering activities 2. Sampling line break resulting in direct exposure	Transportation cask containing commercial SNF	2-07 and Assumption 3.1.1
WHF-ESD-19	Event Sequences associated with Site Transfer Cask with DPC Preparation Activities at DPC Cutting Station - Sampling Activities	1. Sampling line break resulting in release of radioactive materials 2. Impact to canister due to jib crane mishaps	DPC containing commercial SNF	2-07 and Assumption 3.1.1

Table II - 2. Wet Handling Facility Event Sequences

Event Sequence Number	Event Sequence Description	Initiating Events	Material at Risk	Bounding Category 2 Event
WHF-ESD-20	Site Transfer Cask with DPC Preparation Activities at DPC Cutting Station – DPC Lid Cutting Activities	1. Drop of heavy load on canister 2. Over-pressurization of canister	DPC containing commercial SNF	2-07
WHF-ESD-21	Transfer of Site Transfer Cask with DPC from DPC Cutting Station to Pool Ledge	1. Site Transfer Cask with DPC tip over 2. Side impact to Site Transfer Cask with DPC (due to collision with structure or equipment) 3. Drop of heavy object (such as handling equipment) onto Site Transfer Cask with DPC 4. Drop of Site Transfer Cask with DPC from Cask Handling Crane	Site Transfer Cask containing a cut DPC	2-07
WHF-ESD-22	Transfer of Transportation Cask with Commercial SNF from Preparation Station to Pool Ledge	1. Transportation cask with commercial SNF tip over 2. Side impact to transportation cask with commercial SNF (due to collision with structure or equipment) 3. Drop of heavy object (such as handling equipment) onto transportation cask with commercial SNF 4. Drop of transportation cask with commercial SNF from Cask Handling Crane	Transportation cask containing commercial SNF	2-05 2-07
WHF-ESD-23	Lowering Site Transfer Cask with DPC or Transportation Cask with Commercial SNF from Pool Ledge to Pool Floor	1. Side impact to Site Transfer Cask with DPC or transportation cask with commercial SNF (due to collision with structure or equipment) 2. Drop of heavy object (such as handling equipment) onto Site Transfer Cask with DPC 3. Drop of Site Transfer Cask with DPC or transportation cask with commercial SNF from Cask Handling Crane	Site Transfer Cask containing a cut DPC with one fuel assembly slid out Transportation cask containing commercial SNF with one fuel assembly slid out	2-08
WHF-ESD-24	Transfer of Fuel Assembly from DPC or Transportation Cask to TAD Canister or Fuel Staging Rack	1. Drop of fuel assembly 2. Drop of heavy object onto TAD canister or fuel staging rack	One fuel assembly damaged on top of a fuel rack or DPC or TAD canister	2-12
WHF-ESD-25	Misloading TAD Canister – Thermal Output Concern to TSPA	Misloading TAD canister	TAD canister	No Release

Table II - 2. Wet Handling Facility Event Sequences

Event Sequence Number	Event Sequence Description	Initiating Events	Material at Risk	Bounding Category 2 Event
WHF-ESD-26	Unsafe Lifting Height During Fuel Assembly Movement to and from DPC, Transportation Cask, TAD Canister and Fuel Staging Rack	Human or mechanical failure	One fuel assembly	2-12
WHF-ESD-27	Event Sequences Associated with Maintaining Criticality Control in Pool	Debris in pool in unsafe configuration – failure to keep pool clean	Debris in pool	No release
WHF-ESD-28	Splashing of pool water onto worker – direct exposure	Human failure	Lots of contaminated pool water	No release Assumption 3.1.1
WHF-ESD-29	Export of Empty Commercial SNF cask or DPC from Pool – Spill of Pool Water	1. Drop of cask or DPC full of pool water onto facility floor 2. Improper decontamination activities caused spill 3. Collision of DPC or cask with structure or equipment caused spill	Lots of contaminated pool water	No release Assumption 3.1.1
WHF-ESD-30	Export of Empty Commercial SNF cask or DPC from Pool – Improper Decontamination Leading to Direct Exposure Due to Residual	Human failure	Residual contamination	No release Assumption 3.1.1
WHF-ESD-31	Handling of Low Level Liquid Waste Generated by Pool Operations	Human or mechanical failure (pipe break releasing contaminated pool water)	Lots of contaminated pool water Spent ion exchange resin	2-01
WHF-ESD-32	Transfer of Site Transfer Cask with TAD Canister from Pool to TAD Canister Closure Station	1. Site Transfer Cask with TAD canister tip over 2. Side impact to Site Transfer Cask with TAD canister (due to collision with structure or equipment) 3. Drop of heavy object (such as handling equipment) onto Site Transfer Cask with TAD canister 4. Drop of Site Transfer Cask / TAD canister from Cask Handling Crane	Site Transfer Cask containing an unsealed TAD canister	2-09

Table II - 2. Wet Handling Facility Event Sequences

Event Sequence Number	Event Sequence Description	Initiating Events	Material at Risk	Bounding Category 2 Event
WHF-ESD-33	Event Sequences associated with TAD Canister Preparation and Closure Activities at TAD Closure Station	Drop of heavy object onto TAD canister	Site Transfer Cask containing an unsealed TAD canister	2-09
WHF-ESD-34	Event sequences Associated with TAD Canister Closure Activities at TAD Closure Station – TAD Canister Drying and Inerting Process	1. Human failure – fails to drain TAD canister 2. Mechanical failure during TAD canister draining	Site Transfer Cask containing an unsealed TAD canister	No release
WHF-ESD-35	Event Sequences Associated with TAD Canister Closure Activities at TAD Closure Station – TAD Canister Welding, Drying and Inerting Process	1. Welding faults 2. Line break	Site Transfer Cask containing an unsealed TAD canister	No release
WHF-ESD-36	Transfer of Site Transfer Cask with TAD canister from TAD Closure Station into Cask Transfer Trolley in Preparation Station	1. Site Transfer Cask with TAD canister tip over (due to interference with the cask preparation crane) 2. Impact to Site Transfer Cask with TAD canister (due to collision of cask transfer trolley and a vehicle) 3. Drop of heavy object (such as handling equipment) onto Site Transfer Cask with TAD canister 4. Drop of Site Transfer Cask with TAD canister from Cask Handling Crane	Site Transfer Cask containing a sealed TAD canister	2-09
WHF-ESD-37	Transfer of Site Transfer Cask with TAD canister on Cask Transfer Trolley from Preparation Station to Cask Unloading Room	1. Cask transfer trolley or cask catches crane hook or rigging resulting in impact to cask 2. Cask transfer trolley impact collision with another vehicle, facility structures, or equipment (except shield door).	Site Transfer Cask containing a sealed TAD canister	2-09

Table II - 2. Wet Handling Facility Event Sequences

Event Sequence Number	Event Sequence Description	Initiating Events	Material at Risk	Bounding Category 2 Event
WHF-ESD-38	Transfer of a Canister to or from Aging Overpack, Site Transfer Cask, or Transportation Cask with Canister Transfer Machine	1. Canister impact due to movement of the Canister Transfer Machine, cask transfer trolley, or Site Transporter during lift 2. Drop of an object onto the canister 3. Canister dropped during transfer (drop through a port) 4. Canister collision or impact (for example, with the inside of the shield bell) 5. Side impact (due to inadvertent closure of a slide gate) 6. Canister dropped inside the Canister Transfer Machine (i.e., not through a port).	TAD canister	2-09
WHF-ESD-39	Collision of cask transfer trolley with Cask Unloading Room Shield Door or Site Transporter with Loading Room Shield Door	A collision between a cask transfer trolley carrying a Site Transfer Cask with TAD canister and the shield door of the Cask Unloading Room or Site Transporter carrying an Aging Overpack with TAD canister and the shield door of the Loading Room.	Site Transfer Cask containing TAD canister in cask transfer trolley Aging Overpack containing a TAD canister in Site Transporter	2-09
WHF-ESD-40	Transfer of an Aging Overpack with TAD Canister on Site Transporter from the Loading Room to Aging Overpack Access Platform and into Site Transporter Vestibule	1. Impact to Aging Overpack and canister (handling equipment or vehicular collision, for example) 2. Drop of a heavy object (such as handling equipment or the cask lid) onto Aging Overpack or canister 3. Aging Overpack and DPC tipover due to Site Transporter movement or jib crane malfunction	Aging Overpack containing TAD canister	2-09
WHF-ESD-41	Direct Exposure During Canister Transfer Machine Activities	Temporary loss of shielding – Inadvertent opening of Cask Unloading Room or Loading shield door while the canister is being lifted from or lowered into a transportation cask or and Site Transfer Cask or Aging Overpack	DPC TAD canister	Assumption 3.1.1 Section 4.4.3
WHF-ESD-42	Events Sequences for Fires Occurring in the WHF	1. Localized fire threatens 2. Localized fire threatens 3. Localized fire threatens 4. Localized fire threatens 5. Localized fire threatens 6. Localized fire threatens a canister in the Canister Transfer Machine 7. Large fire threatens waste forms anywhere in the WHF.	DPC TAD canister Transportation cask with commercial SNF	2-14

Table II - 3. Receipt Facility Event Sequences

Event Sequence Number	Event Sequence Description	Initiating Events	Material at Risk	Bounding Category 2 Event
RF-ESD-01	Receipt of Transportation Casks on Railcar in Transportation Cask Vestibule and Movement into Cask Preparation Room	1. Railcar derailment 2. Collision involving railcar and structure or equipment	Transportation cask containing DPC or TAD	2-07 2-09
RF-ESD-02	Removal of Impact Limiters, Upending and Transfer of transportation Cask with DPC to Cask Transfer Trolley in Preparation Station	1. Drop of transportation cask 2. Transportation cask tipover 3. Collision involving side impact to transportation cask (during transfer by crane) 4. Drop of heavy object (such as handling equipment) onto transportation cask.	Transportation cask containing DPC or TAD	2-07 2-09
RF-ESD-03	Cask Preparation Activities Associated with Installation of Lid Lift Fixture on Transportation Cask with DPC	1. Transportation cask tip over (due to interference with the cask preparation crane) 2. Impact to transportation cask (due to collision of cask transfer trolley and a vehicle) 3. Drop of heavy object (such as handling equipment) onto the transportation cask 4. Transportation cask drop due to cask transfer trolley movement while the cask is still attached to the crane	Transportation cask containing DPC or TAD	2-07 2-09
RF-ESD-04	Removal of the Transportation Cask Lid and Installation of DPC Lift Fixture	1. Impact to transportation cask (handling equipment or vehicular collision, for example) 2. Drop of a heavy object (such as handling equipment or the cask lid) onto the canister 3. Transportation cask tip over	Transportation cask containing DPC or TAD	2-07 2-09
RF-ESD-05	Transfer of a Cask on Cask Transfer Trolley from the Cask Preparation Area to Cask Unloading Room	1. Cask transfer trolley or cask catches crane hook or rigging resulting in impact to cask 2. Cask transfer trolley impact collision with another vehicle, facility structures, or equipment (except shield door).	Transportation cask containing DPC or TAD	2-07 2-09

Table II - 3. Receipt Facility Event Sequences

Event Sequence Number	Event Sequence Description	Initiating Events	Material at Risk	Bounding Category 2 Event
RF-ESD-06	Collision of Cask Transfer Trolley with Cask Unloading Room Shield Door or Site Transporter with Loading Room Shield Door	A collision between a cask transfer trolley carrying a transportation cask with DPC and the shield door of the Cask Unloading Room or Site Transporter carrying an Aging Overpack with DPC and the shield door of the Loading Room.	Transportation cask containing a DPC or TAD in a cask transfer trolley	2-07 2-09
RF-ESD-07	Transfer of a Canister to or from Aging Overpack or Transportation Cask with Canister Transfer Machine	1. Canister impact due to movement of the Canister Transfer Machine, cask transfer trolley, or Site Transporter during lift 2. Drop of an object onto the canister 3. Canister dropped during transfer (drop through a port) 4. Canister collision or impact (for example, with the inside of the shield bell) 5. Side impact (due to inadvertent closure of a slide gate) 6. Canister dropped inside the Canister Transfer Machine (i.e., not through a port).	DPC or TAD	2-07 2-09
RF-ESD-08	Assembly and Closure of an Aging Overpack (Aging Overpack)	1. Aging Overpack tip over due to crane mishaps 2. Aging Overpack impact. 3. Drop object on Aging Overpack 4. Aging Overpack drop	DPC or TAD	2-07 2-09
RF-ESD-09	Exporting Aging Overpack from Receit Facility	1. Impact to Aging Overpack and canister (handling equipment or vehicular collision, for example) 2. Drop of Aging Overpack 3. Aging Overpack and DPC tipover due to Site Transporter movement or jib crane malfunction	Aging Overpack containing DPC Aging Overpack containing a TAD canister	2-07 2-09
RF-ESD-10	Direct Exposure During DPC Handling Activities	Human Failure – fails to install shield ring prior to installation of DPC lift fixture	DPC or TAD	Assumption 3.1.1 Section 4.4.3
RF-ESD-11	Direct Exposure During Canister Transfer Machine Activities	Temporary loss of shielding – Inadvertent opening of Cask Unloading Room or Loading shield door while the canister is being lifted from or lowered into a transportation cask or Aging Overpack	DPC TAD canister	Assumption 3.1.1 Section 4.4.3

Table II - 3. Receipt Facility Event Sequences

Event Sequence Number	Event Sequence Description	Initiating Events	Material at Risk	Bounding Category 2 Event
RF-ESD-12	Removal of Horizontal cask Removal from Railcar and Transfer to Cask Transfer Trolley in Preparation Station	1. Drop of transportation cask 2. Transportation cask tipover 3. Collision involving side impact to transportation cask (during transfer by crane) 4. Drop of heavy object (such as handling equipment) onto transportation cask.	Transportation cask containing DPC	2-07
RF-ESD-13	Exporting Horizontal Cask on Cask Transfer Trailer	1. Cask tractor trailer rollover 2. Collision involving cask tractor trailer and structure or equipment	Horizontal cask containing a horizontal canister on a cask tractor trailer	Assumption 3.1.1
RF-ESD-14	Events Sequences for Fires Occurring in the Receipt Facility Affecting an Aging Overpack	1. Localized fire threatens Aging Overpack in Loading Room 2. Localized fire threatens Aging Overpack in Vestibule or Lid Bolting Room 3. Localized fire threatens Aging Overpack in Canister Transfer Room 4. Large fire threatens waste forms anywhere in the Receipt Facility.	DPC TAD canister	Assumption 3.1.1
RF-ESD-15	Events Sequences for Fires Occurring in the Receipt Facility Affecting a Transportation Cask	1. Localized fire threatens transportation cask in Cask Unloading Room 2. Localized fire threatens transportation cask in Vestibule/Annex, Cask Preparation Room, or Canister Transfer Machine Maintenance Room 3. Large fire threatens waste forms anywhere in the Receipt Facility.	DPC TAD canister	Assumption 3.1.1

Table II - 4. Canister Receipt and Closure Facility Event Sequences

Event Sequence Number	Event Sequence Description	Initiating Events	Material at Risk	Bounding Category 2 Event
CRC-ESD-01	Receipt of Transportation Casks on Truck Trailer with DOE SNF in Transportation Cask Vestibule and Movement into Cask Preparation Room	1. Truck Trailer rollover 2. Collision involving truck trailer or railcar and structure or equipment 3. Railcar derailment	DOE SNF	Assumption 3.1.1
CRC-ESD-02	Receipt of Aging Overpack on Site Transporter in Site Transporter Vestibule and Movement into Cask Preparation Room	1. Site Transporter rollover 2. Collision involving Site Transporter and structure or equipment	Aging Overpack containing TAD canister	2-09
CRC-ESD-03	Removal of Impact Limiters, Upending and Transfer of Transportation Cask with DPC To Cask Transfer Trolley in Preparation Station	1. Drop of transportation cask 2. Transportation cask tipover 3. Collision involving side impact to transportation cask (during transfer by crane) 4. Drop of heavy object (such as handling equipment) onto transportation cask.	Transportation cask containing DPC Transportation cask with 5 HLW canisters Transportation cask with 5 DOE SNF canisters Transportation cask with 4 DOE Multicanister Overpacks Transportation cask containing a TAD canister	2-02 2-07 2-09 Assumption 3.1.1
CRC-ESD-04	Cask Preparation Activities Associated with Transportation Cask Preparation Activities (e.g., Installation of Lid Lift Fixture)	1. Transportation cask tip over (due to interference with the cask preparation crane) 2. Impact to transportation cask (due to collision of cask transfer trolley and a vehicle) 3. Drop of heavy object (such as handling equipment) onto the transportation cask 4. Transportation cask drop due to cask transfer trolley movement while the cask is still attached to the crane	Transportation cask containing DPC Transportation cask with 5 HLW canisters Transportation cask with 5 DOE SNF canisters Transportation cask with 4 DOE Multicanister Overpacks Transportation cask containing a TAD canister	2-02 2-07 2-09 Assumption 3.1.1
CRC-ESD-05	Cask Preparation Activities Associated with Aging Overpack Preparation Activities (e.g., Lid Bolt Removal, Lid Removal, or Installation Of Lid Lift Fixture (if required)	1. Aging Overpack tip over 2. Drop of heavy object (such as handling equipment) onto the transportation cask 3. Aging Overpack drop	Aging Overpack containing TAD canister	2-09

Table II - 4. Canister Receipt and Closure Facility Event Sequences

Event Sequence Number	Event Sequence Description	Initiating Events	Material at Risk	Bounding Category 2 Event
CRC-ESD-06	Transfer of a Transportation Cask on Cask Transfer Trolley or Aging Overpack on Site Transporter from the Cask Preparation Room to Cask Unloading Room	1. Cask transfer trolley or cask, Site Transporter or Aging Overpack catches crane hook or rigging resulting in impact to cask 2. Cask transfer trolley or Site Transporter impact collision with another vehicle, facility structures, or equipment (except shield door).	Transportation cask containing DPC Aging Overpack containing TAD canister Transportation cask with 5 HLW canisters Transportation cask with 5 DOE SNF canisters Transportation cask with 4 DOE Multicanister Overpacks Transportation cask containing a TAD canister	2-02 2-07 2-09 Assumption 3.1.1
CRC-ESD-07	Collision of Cask Transfer Trolley with Cask Unloading Room Shield Door or Site Transporter with Loading Room Shield Door	A collision between a cask transfer trolley carrying a transportation cask /DPC and the shield door of the Cask Unloading Room or Site Transporter carrying an Aging Overpack /DPC and the shield door of the Loading Room.	Transportation cask containing a DPC in a cask transfer trolley Aging Overpack containing a TAD canister in Site Transporter Transportation cask with 5 HLW canisters in a cask transfer trolley Transportation cask with 5 DOE SNF canisters in a cask transfer trolley Transportation cask with 4 DOE Multicanister Overpacks in cask transfer trolley Transportation cask containing a TAD canister in cask transfer trolley	2-02 2-07 2-09 Assumption 3.1.1
CRC-ESD-08	Collision of Two Canister Transfer Machines Loaded with Canister	Human or mechanical failure	DOE SNF canister and TAD canister DOE SNF canister and HLW DOE SNF canister and DPC DOE SNF canister and DOE Multicanister Overpack DOE SNF canister and DOE SNF canister DOE Multicanister Overpack and TAD canister DOE Multicanister Overpack and HLW DOE Multicanister Overpack and DPC DOE Multicanister Overpack and DOE Multicanister Overpack TAD canister and DPC TAD canister and HLW TAD canister and TAD canister DPC and HLW DPC and DPC HLW and HLW	2-04 2-07 2-09 Assumption 3.1.1

Table II - 4. Canister Receipt and Closure Facility Event Sequences

Event Sequence Number	Event Sequence Description	Initiating Events	Material at Risk	Bounding Category 2 Event
CRC-ESD-09	Transfer of a Canister to or from Staging, Transportation Cask, Waste Package, or Aging Overpack with Canister Transfer Machine	1. Canister impact due to movement of the Canister Transfer Machine, cask transfer trolley, Site Transporter, or Waste Package Transfer Trolley during lift 2. Drop of an object onto the canister 3. Canister dropped during transfer (drop through a port) 4. Canister collision or impact (for example, with the inside of the shield bell) 5. Side impact (due to inadvertent closure of a slide gate) 6. Canister dropped inside the Canister Transfer Machine (i.e., not through a port).	DPC TAD canister DOE SNF canister (1 DOE SNF on 1 HLW canister) HLW canister (1 HLW canister on another HLW or DOE SNF canister or DOE Multicanister Overpack) DOE Multicanister Overpack (1 DOE Multicanister Overpack on 1 HLW canister)	2-04 2-07 2-09 Assumption 3.1.1
CRC-ESD-10	Transfer from Positioning Room to Closing Position in Waste Package Positioning Room below Waste Package Closure Room	1. Waste Package Transfer Trolley derailment 2. Waste Package Transfer Trolley impact collision with facility structures, or equipment 3. Waste Package Transfer Trolley premature tilt-down	2 HLW canisters and 2 DOE Multicanister Overpacks 1 DOE SNF canister and 5 HLW canisters 1 TAD canister	2-03 2-04 2-09 Assumption 3.1.1
CRC-ESD-11	Event Sequences Associated with Assembly and Closure of the Waste Package	1. Welding damages the canister(s) 2. Remote Handling System drops object (such as the waste package outer lid or handling equipment) onto the waste package. 3. Canister Transfer Machine drops object on canister	2 HLW canisters and 2 DOE Multicanister Overpacks 1 DOE SNF canister and 5 HLW canisters 1 TAD canister	2-03 2-04 2-09 Assumption 3.1.1
CRC-ESD-12	Event Sequences Associated with Assembly and Closure of an Aging Overpack	1. Aging Overpack tip over due to crane mishaps 2. Aging Overpack impact. 3. Drop object on Aging Overpack	1 TAD canister 1 DPC	2-07 2-09
CRC-ESD-13	Transfer of the Waste Package from the Waste Package Closure Room to the Waste Package Loadout Room	1. Waste Package Transfer Trolley impact 2. Impact due to improper tilt-down or departure of the Waste Package Transfer Trolley 3. Waste Package Transfer Trolley derailment	2 HLW canisters and 2 DOE Multicanister Overpacks 1 DOE SNF canister and 5 HLW canisters 1 TAD canister	2-02 2-09 Assumption 3.1.1

Table II - 4. Canister Receipt and Closure Facility Event Sequences

Event Sequence Number	Event Sequence Description	Initiating Events	Material at Risk	Bounding Category 2 Event
CRC-ESD-14	Transfer of an Aging Overpack with TAD canister or Aging Overpack with DPC on Site Transporter from the Cask Unloading Room to Cask Preparation Room	Side impact to Aging Overpack (due to collision with structure or equipment)	Aging Overpack containing TAD canister Aging Overpack containing DPC	2-07 2-09
CRC-ESD-15	Exporting a Waste Package	1. Transport and Emplacement Vehicle collision 2. Impact due to object dropped on waste package 3. Crane interference with Transport and Emplacement Vehicle or Waste Package Transfer Trolley 4. Impact due to malfunction of the Waste Package Transfer Trolley or the waste package transfer carriage	2 HLW canisters and 2 DOE Multicanister Overpacks 1 DOE SNF canister and 5 HLW canisters 1 TAD canister	2-02 2-09 Assumption 3.1.1
CRC-ESD-16	Exporting an Aging Overpack	1. Aging Overpack dropped 2. Aging Overpack impact due to collision	1 TAD canister 1 DPC	Assumption 3.1.1
CRC-ESD-17	Direct Exposure during Cask Preparation Activities	Failure to install shield ring prior to installation of canister lift fixture	DPC TAD canister 5 HLW canisters 4 DOE Multicanister Overpacks 5 DOE SNF canisters	Assumption 3.1.1 Section 4.4.3
CRC-ESD-18	Direct Exposure during Canister Transfer Machine Activities	Temporary loss of shielding – Inadvertent opening of Cask Unloading Room or Loading shield door while the canister is being lifted from or lowered into a transportation cask, a Waste Package, or an Aging Overpack	DPC TAD canister HLW canister DOE Multicanister Overpack DOE SNF canister	Assumption 3.1.1 Section 4.4.3
CRC-ESD-19	Direct Exposure during Exporting a Waste Package	Temporary loss of shielding – Inadvertent opening of shield door while Waste Package is being loaded into Transport and Emplacement Vehicle	2 HLW canisters and 2 DOE Multicanister Overpacks 1 DOE SNF canister and 5 HLW canisters 1 TAD canister	Assumption 3.1.1 Section 4.4.3

Table II - 4. Canister Receipt and Closure Facility Event Sequences

Event Sequence Number	Event Sequence Description	Initiating Events	Material at Risk	Bounding Category 2 Event
CRC-ESD-20	Events Sequences for Fires Occurring in the CRCF Affecting Waste Package	1. Localized fire threatens Waste Package in Loadout Room 2. Localized fire threatens Waste Package in Positioning Room or Gas Bottle Storage Room 3. Localized fire threatens Waste Package in Cask Preparation Room, Cask Unloading Room, or Canister Staging Area 4. Localized fire threatens Waste Package in Vestibule 5. Localized fire threatens Waste Package in Canister Transfer Room 6. Large fire threatens waste forms anywhere in the CRCF.	2 HLW canisters and 2 DOE Multicanister Overpacks 1 DOE SNF canister and 5 HLW canisters 1 TAD canister	Assumption 3.1.1
CRC-ESD-21	Events Sequences for Fires Occurring in the CRCF Affecting Aging Overpack	1. Localized fire threatens Aging Overpack in Cask Preparation Room, Cask Unloading Room, or Canister Staging Area 2. Localized fire threatens Aging Overpack in Vestibule 3. Localized fire threatens Aging Overpack in Canister Transfer Room 4. Large fire threatens waste forms anywhere in the CRCF.	DPC TAD canister	Assumption 3.1.1
CRC-ESD-22	Events Sequences for Fires Occurring in the CRCF Affecting Transportation Cask	1. Localized fire threatens transportation cask in Cask Preparation Room, Cask Unloading Room 2. Localized fire threatens transportation cask in Vestibule 3. Localized fire threatens transportation cask in Canister Transfer Room 4. Large fire threatens waste forms anywhere in the CRCF.	Transportation cask containing a DPC Transportation cask with 5 HLW canisters Transportation cask with 5 DOE SNF canisters Transportation cask with 4 DOE Multicanister Overpacks Transportation cask containing a TAD canister	Assumption 3.1.1

Table II - 5. Subsurface Event Sequences

Event Sequence Number	Event Sequence Description	Initiating Events	Material at Risk	Bounding Category 2 Event
SSO-ESD-01	Transport and Emplacement Vehicle Activities inside the Facility (IHF or CRCF) in the Waste Package Loadout Area	1. Drop of heavy load on Transport and Emplacement Vehicle with Waste Package 2. Transport and Emplacement Vehicle Waste Package Impact 3. Drop of Waste Package from Transport and Emplacement Vehicle	Waste Package - 2 HLW canisters and 2 DOE Multicanister Overpacks Waste Package - 1 DOE SNF canister and 5 HLW canisters Waste Package - 1 TAD canister Waste Package - 1 Naval canister	Assumption 3.1.1
SSO-ESD-02	Transport and Emplacement Vehicle Activities during Transit from Facility (IHF or CRCF) to North Portal	1. Waste Package impact due to collision 2. Waste Package drop from Transport and Emplacement Vehicle 3. Thermal impact due to Transport and Emplacement Vehicle overheating 4. Drop of heavy object (such as rockfall) onto Transport and Emplacement Vehicle with Waste Package. 5. Transport and Emplacement Vehicle derailment	Waste Package - 2 HLW canisters and 2 DOE Multicanister Overpacks Waste Package - 1 DOE SNF canister and 5 HLW canisters Waste Package - 1 TAD canister Waste Package - 1 Naval canister	Assumption 3.1.1
SSO-ESD-03	Transport and Emplacement Vehicle Activities during Transit from North Portal to Turnout	1. Waste Package impact due to collision 2. Waste Package drop from Transport and Emplacement Vehicle 3. Drop of heavy object (such as rockfall) onto Transport and Emplacement Vehicle with Waste Package. 4. Transport and Emplacement Vehicle derailment	Waste Package - 2 HLW canisters and 2 DOE Multicanister Overpacks Waste Package - 1 DOE SNF canister and 5 HLW canisters Waste Package - 1 TAD canister Waste Package - 1 Naval canister	Assumption 3.1.1
SSO-ESD-04	Transport and Emplacement Vehicle Activities during Waste Package Emplacement in Emplacement Drift	1. Waste Package impact due to collision 2. Waste Package drop from Transport and Emplacement Vehicle 3. Drop of heavy object (such as rockfall) onto Transport and Emplacement Vehicle with Waste Package.	Waste Package - 2 HLW canisters and 2 DOE Multicanister Overpacks Waste Package - 1 DOE SNF canister and 5 HLW canisters Waste Package - 1 TAD canister Waste Package - 1 Naval canister	Assumption 3.1.1
SSO-ESD-05	Waste Package at during Emplacement and Monitoring Phase	1. Drop of heavy object (e.g., rockfall) on Waste Package 2. Thermal impact due to Waste Package overheating	Waste Package - 2 HLW canisters and 2 DOE Multicanister Overpacks Waste Package - 1 DOE SNF canister and 5 HLW canisters Waste Package - 1 TAD canister Waste Package - 1 Naval canister	Assumption 3.1.1
SSO-ESD-06	Installation of Drip Shields	1. Drop of heavy object (e.g., rockfall) on Waste Package 2. Impact on Waste Package due to collision	2 Waste Packages	Assumption 3.1.1

Table II - 5. Subsurface Event Sequences

Event Sequence Number	Event Sequence Description	Initiating Events	Material at Risk	Bounding Category 2 Event
SSO-ESD-07	Loss or Lack of Shielding	1. Mechanical failure of the Transport and Emplacement Vehicle 2. Human failure	Waste Package - 2 HLW canisters and 2 DOE Multicanister Overpacks Waste Package - 1 DOE SNF canister and 5 HLW canisters Waste Package - 1 TAD canister Waste Package - 1 Naval canister	Assumption 3.1.1
SSO-ESD-08	Transport and Emplacement Vehicle with Waste Package impact due to External Events	1. External events caused Transport and Emplacement Vehicle with Waste Package overheating conditions (e.g., ashfall block Transport and Emplacement Vehicle vent) 2. Transport and Emplacement Vehicle / Waste Package impact (e.g., rockfall). 3. Transport and Emplacement Vehicle / Waste Package impact due to airborne missile	Waste Package - 2 HLW canisters and 2 DOE Multicanister Overpacks Waste Package - 1 DOE SNF canister and 5 HLW canisters Waste Package - 1 TAD canister Waste Package - 1 Naval canister	Assumption 3.1.1
SSO-ESD-09	Internal Fire Affecting Transport and Emplacement Vehicle with Waste Package	1. Fire during transit 2. Fire in the drift	1 Waste Package if fire occurs during transit Multiple Waste Package s if fire occurs in the drift	Assumption 3.1.1

Table II - 6. Intra-Site Event Sequences

Event Sequence Number	Event Sequence Description	Initiating Events	Material at Risk	Bounding Category 2 Event
ISO-ESD-01	Event Sequences Associated with Movement of Transportation Cask on Railcar	1. Railcar derailment 2. Railcar collision	Transportation cask containing 5 HLW canisters Transportation cask containing 5 DOE SNF canisters Transportation cask containing 1 TAD canister Transportation cask containing 4 DOE multicanister overpacks Transportation cask containing 1 Naval canister Transportation cask containing commercial SNF Transportation cask containing 1 DPC	Assumption 3.1.1
ISO-ESD-02	Event Sequences Associated with Movement of Transportation Cask on Truck Trailer	1. Truck trailer rollover 2. Truck trailer collision	Transportation cask containing 1 HLW canister	Assumption 3.1.1
ISO-ESD-03	Event Sequences Associated with Transportation Cask Receipt	1. Improper inspection leads to release 2. Drop of equipment on transportation cask	Transportation cask containing 5 HLW canisters Transportation cask containing 5 DOE SNF canisters Transportation cask containing 1 TAD canister Transportation cask containing 4 DOE multicanister overpacks Transportation cask containing 1 Naval canister Transportation cask containing commercial SNF Transportation cask containing 1 DPC Transportation cask containing 1 HLW canister	Assumption 3.1.1
ISO-ESD-04	Event Sequences Associated with Aging Overpack Placement and Retrieval	1. Drop of aging overpack due to site transporter failure 2. Impact to aging overpack during site transporter movement at Aging facility	Aging overpack containing 1 TAD canister Aging overpack containing 1 DPC	Assumption 3.1.1
ISO-ESD-05	Event Sequences Associated with Transporting a Horizontal Shielded Transfer Cask Containing Horizontal Canister	1. Drop cask from conveyance 2. Impact of cask while it is on the conveyance	Transportation cask containing horizontal canister Horizontal shielded transfer cask containing horizontal canister	Assumption 3.1.1

Table II - 6. Intra-Site Event Sequences

Event Sequence Number	Event Sequence Description	Initiating Events	Material at Risk	Bounding Category 2 Event
ISO-ESD-06	Event Sequence Associated Canisters within Aging Overpack, Horizontal Shielded Transfer Cask, or Horizontal Aging Module Overheating	1. Blocked vents on horizontal aging module leads to loss of natural air circulation 2. Blocked vents on Aging Overpack leads to loss of natural air circulation	Horizontal aging module with horizontal canister Aging Overpack containing a TAD canister Aging Overpack containing a DPC	Assumption 3.1.1
ISO-ESD-07	Event Sequences Associated with Horizontal Shielded Transfer Cask Transport within the Confines of the Aging Facility	1. Cask tractor trailer failure leads to cask drop 2. Impact to cask due to inadvertent movement of cask tractor trailer	Transportation cask containing horizontal canister Aging Overpack containing a TAD canister Aging Overpack containing a DPC	Assumption 3.1.1
ISO-ESD-08	Event Sequences Associated with Auxiliary Equipment at Horizontal Aging Module	1. Canister impact caused by cask tractor trailer ram 2. Auxiliary equipment drops on horizontal shielded transfer cask 3. Collision involving auxiliary equipment	Transportation cask containing horizontal canister Horizontal shielded transfer cask containing horizontal canister	Assumption 3.1.1
ISO-ESD-09	Event Sequences Associated with Horizontal Aging Module Emplacement or Retrieval	1. Drop of horizontal shielded transfer cask or horizontal cask at horizontal aging module 2. Impact to horizontal shielded transfer cask or horizontal cask due to operations at horizontal aging module	Transportation cask containing horizontal canister Horizontal shielded transfer cask containing horizontal canister	Assumption 3.1.1
ISO-ESD-10	Event Sequences Associated with Low Level Dry Active Waste Operations	Release of low level waste	LLW	2-01
ISO-ESD-11	Event Sequences Associated with Low Level Wet Solid Waste Operations	Release of LLW	LLW	2-01
ISO-ESD-12	Event Sequences Associated with Low Level Liquid Waste O perations	Release of LLW	LLW	2-01

APPENDIX III UNCERTAINTY STUDY

The preclosure consequence analysis for worker and public doses is performed using a deterministic methodology with fixed values of input parameters. Worker and onsite public doses are dominated by direct radiation and inhalation exposures. The methodology for both those pathways is based on fixed parameters with conservative or bounding values with no associated uncertainty distributions. For offsite public doses, that use a combination of the fixed parameters (including many conservative or bounding values) and those based on developed distributions, an uncertainty is performed for both chronic and acute release scenarios.

Preclosure dose consequence results for offsite public calculated using GENII version 2 (GENII) (Section 4.2.1) are expressed as single values in dose per event or per time period and are compared to single-value dose performance objectives in Table 1. It is generally understood, however, that in consequence analyses, virtually every input parameter and every output value has uncertainty associated with it. The uncertainties in consequence analyses are addressed primarily by using conservative and bounding inputs and modeling assumptions. To provide additional reasonable assurance that performance objectives have been met, an uncertainty analysis is performed in this appendix.

Preclosure dose consequences for offsite public are calculated based on material at risk, damage ratios, airborne release and respirable fractions, leak path factors, atmospheric dispersion factors, and other input parameters that are used to model radionuclide release and transport in the environment and receptor exposure (Section 6.4). Among these inputs, many parameter values have been developed as distributions in *Site-Specific Input Files for Use with GENII Version 2* (Reference 2.2.10) and can be used in this uncertainty analysis. Other parameters are developed as fixed and input values are based on conservative or bounding data (Section 6.1).

The use of conservative or bounding input parameters is discussed in Section III.1 for normal operations and Category 1 and Category 2 event sequences. The methodology for performing uncertainty analysis with GENII Version 2 is discussed in Section III.2. Because GENII Version 2 can only take a limited number of uncertain input parameters for each run, a screening process is used to identify dose significant radionuclides and input parameters within high dose contributed pathways in order to focus the uncertainty analysis. The screening process for radionuclides and dose pathways is performed in Section III.3. Input values and distributions for the parameters associated with the selected pathways are also provided in Section III.3.

The uncertainty analysis is performed for two release scenarios 1) a normal operation chronic release and 2) an event sequence acute release. This is because the significance of the input parameters is different for the two release types. The uncertainty analysis focuses on the relative importance of the input parameters that contribute uncertainty to calculated dose results.

The uncertainty analysis calculations and results are discussed in Sections III.4 for chronic releases and Section III.5 for acute releases. Conclusions are presented in Section III.6.

III.1 USE OF CONSERVATIVE OR BOUNDING INPUT PARAMETERS

This section discusses the use of conservative or bounding inputs and assumptions used in the consequence analyses for normal operations and Category 1 and Category 2 event sequences. The assumptions are discussed in Section 3 and inputs are discussed in Section 6.1 of this calculation. The conservative or bounding inputs are fixed values and do not contribute the uncertainty of calculated dose in this appendix. However, the relative importance of input parameters and variation of calculated dose in this uncertainty analysis are valid only for the selected set of input parameters, including these conservative and bounding inputs. Therefore, it is useful to identify some of these conservative or bounding inputs to provide insight into the overall dose methodology uncertainty.

III.1.1 Normal Operations

Normal operation dose consequences are calculated with many conservative or bounding parameter values. A number of examples of these are listed below, including the reference or section number where each parameter or value is discussed.

- For normal operations, it is conservatively assumed that 1% of the commercial SNF rods received at the repository and handled in the Wet Handling Facility have damaged cladding. The releases of fission product gases, volatile species, and fuel fines from that 1% are included in the normal operation dose for public and workers for the commercial SNF arriving in DPCs or uncanistered in transportation casks as discussed in Assumption 3.2.1. This assumption is conservative, because it does not credit any release of fission products prior to the fuel being loaded into a DPC or transportation cask for shipment to the repository.

- The commercial SNF radionuclide inventories used for normal operation release analyses are conservative. The representative annual average fuel assembly for BWR and PWR fuel types discussed in Reference 2.2.31 is determined assuming a maximum annual rate of receipt of 3,600 MTHM. Using 3,600 MTHM per year results in receiving fuel that has had less time for radioactive decay than using the average annual rate of receipt of 3,000 MTHM per year to determine the representative fuel assembly. Further, the representative annual average fuel assembly characteristics are based on the receipt year with the highest average heat load per fuel assembly that correlates with the highest radionuclide inventory (Reference 2.2.31, Section 3.2.1).

- All surface and subsurface facilities are assumed to be fully operational and to be operating consistent with the repository maximum rate of receipt. Surface facility staging areas and subsurface emplacement drifts are assumed to be at full capacities (Section 4.4.1).

III.1.2 Category 1 and Category 2 Event Sequences

Category 1 and Category 2 event sequence dose consequences are calculated with many conservative or bounding parameter values including material at risk, damage ratio, airborne release and respirable fractions, leak path factors, and atmospheric dispersion factors. A number of these conservative and bounding parameters are listed below, including the section number or reference where each is discussed.

- Category 1 and 2 event sequence dose calculations use the commercial SNF parameters for the maximum BWR and PWR fuel assemblies, that bound the parameters of fuel anticipated to be received at the repository. (Design Input 6.1.2.1) For example, from Section 6.6.1, the TEDE dose for the offsite pubic in the general environment using 95% χ/Qs and a filtered release for the scenario of burst and oxidation release combined is about twice as large with maximum PWR fuel (2.54×10^{-1} mrem) than with representative PWR fuel (1.26×10^{-1} mrem).

- The fission gas release fraction for low burnup commercial SNF is used for high burnup fuel even though the release from high burnup fuel is less even when fission gases in the rim region are included (Reference 2.2.32, Section 6.5.2).

- The airborne release fraction used for volatile radionuclides released from low burnup commercial SNF is multiplied by 10 for use with high burnup fuel even though this would include volatiles in the grain boundary that would not normally be released unless that region were fully broken, which is unlikely (Reference 2.2.32, Section 6.5.3).

- The respirable fraction for fuel fines released from high burnup commercial SNF is set at the bounding value of 1.0 (Design Input 6.1.3.1).

- HLW radionuclide inventories for Category 1 and 2 event sequences use the maximum vitrified HLW per canister inventories (Design Input 6.1.2.3).

- For Category 1 and 2 event sequence dose calculations involving commercial SNF or HLW, the material at risk is assumed to be subject to forces imposed by the event, that is, the damage ratio is 1.0, which is a bounding value (Assumption 3.2.1).

- For the Category 2 event sequences, the activity present on the WHF HEPA filters is based on an 18-month replacement frequency, which is much longer than would be expected and leads to higher activity accumulation at the time of the postulated event. In addition, it is assumed that the WHF is processing fuel with 1% fuel rod defects, which is a conservative value (Assumptions 3.2.1 and 3.2.16).

- The airborne release fraction for HEPA filters subject to the loads of a seismic event is based on unenclosed filter media, which allows the radioactive material to undergo a free fall. Although large portions of the filters and ducting are not completely enclosed, other portions are enclosed and these would exhibit a lower airborne release fraction (Design Input 6.1.3.3).

- For the spill of a liquid tank following a seismic event, the contamination remaining after evaporation of the spilled liquid is conservatively treated as a loose powder for determining its airborne release fraction. In addition, the respirable fraction for this material is set at the bounding value of 1.0 (Design Input 6.1.3.3 (the 2nd paragraph in Liquid Tank)).

- The leak path factors for commercial SNF cladding is set at the bounding value of 1.0 (Assumption 3.2.7).

- The leak path factor of 0.1 used for a transportation cask is based on a leak area 10 times greater than the leak area recommended by NUREG/CR-6672 (Sprung et al. 2000 [DIRS 152476]), is more conservative than the leak path factors determined by mathematical models for powders, and bounds allowable leak rates for casks designed to meet 10 CFR 71 (Design Input 6.1.4.2 and Reference 2.2.22, Section 7.3).

- The conservative leak path factor of 0.1 used for a transportation cask, which is mechanically closed, is also used for canisters, which are welded, and for waste packages, which are also welded. Applying a leak path factor to welded vessels that is based on a leak area 10 times larger than the leak area recommended for a bolted cask is conservative (Design Input 6.1.4.2 and Reference 2.2.22, Section 7.3).

- The leak path factors for buildings are set at a bounding value of 1.0. Although the buildings are not designed to be leak tight, accidental releases within the process areas must travel though other building spaces before reaching the environment, during which plateout, settling, and other removal processes may occur (Assumption 3.2.6).

- The 95th percentile atmospheric dispersion factors (Sections 4.4.2 and 4.4.3) are used for Category 1 and Category 2 event sequences. When comparing the doses for the similar cases presented in Sections 6.6.1 and 6.6.2 where only the χ/Qs differ, the use of the 95th-percentile atmospheric dispersion parameters is over a factor of three higher than the average value for the representative PWR burst and oxidation filtered release and the representative BWR burst and oxidation filtered release. Although the above comparison was made based on onsite public, this factor of three higher is also valid for offsite public, when compared with χ/Qs for offsite public between annual average (50%) and a short term average (95%) shown in Table 5.

III.1.3 Common Conservatism or Bounding Inputs

This section discusses several common conservative or bounding input parameters used in consequence analyses for both normal operations and Category 1 and Category 2 event sequences.

- Although HEPA filters have been demonstrated to have efficiencies of 99.8% or more, a conservative value of only 99% is credited for each of two stages of HEPA filters (combined leak path factor of 10^{-4}). If both stages of HEPA filters were credited with being 99.8% efficient, the combined leak path factor would be 25 times lower. (Design Input 6.1.4.1 and Reference 2.2.22, Section 7.1)

- The 10 μm AED cut-off size used for respirable particles is conservative and may be overly conservative because the particle mass is a function of the particle diameter cubed (Reference 2.2.32, Attachment C).

III.2 UNCERTAINTY ANALYSIS WITH GENII

The uncertainty analysis provides a quantitative estimate of the range of model outputs resulting from uncertainties in the structure of a software model or inputs to a model. This analysis can also be extended to identify the input parameters that contribute most to overall uncertainty. Uncertainty in model predictions can arise from a number of sources, including specification of a problem, formulation of conceptual models, formulation of computational models, estimation of parameter values, calculation, interpretation, and documentation of results. Of these sources, only uncertainties resulting from the estimation of parameter values can be quantified in a straightforward way by applying a statistical approach to deterministic models.

GENII Version 2 is currently designed for deterministic environmental and human health impact models. The SUM^3 module performs sensitivity and uncertainty analysis using the existing deterministic models available in GENII Version 2 for understanding the influence and importance of the variability/uncertainty of the input parameters on contaminant flux, concentration, and human-health impacts. A study for uncertainty and sensitivity analysis with GENII Version 2 was performed (Reference 2.2.50).

Within FRAMES, SUM^3 allows the user to conduct a sensitivity and uncertainty analysis. The sensitivity analysis can identify the key parameters that dominate the overall uncertainty. Statistical methods used in SUM^3 are based on the Monte Carlo approach using Latin Hypercube sampling (LHS) (Reference 2.2.18).

To account for the uncertainty associated with parameters employed in the modeling exercise, a Monte Carlo analysis was implemented with the LHS technique. The LHS is a generalization of the Latin square experimental design to k dimensions, which correspond to the number of input variables selected of the model. Each input variable is assumed to be a random variable, which is governed by a probability density function. Stratification is accomplished by dividing the range of input variable into n intervals of equal (1/n) probability. Each equally probable interval is randomly sampled once for each variable. The output of sampling can be considered an $n \times k$ matrix, where columns represent variables and rows contain sample values for the appropriate interval. Values within a column are then randomly permuted, so a row represents a random vector of input variables. The environmental model is then run n times with the values of the input variables equal to the rows of the matrix.

The LHS is one such widely used variant of the standard Monte Carlo method. In this method, the range of probable values for each uncertain input parameter is divided into ordered segments of equal probability. Thus, the whole parameter space, consisting of all the uncertain parameters, is partitioned into cells having equal probability, and they are sampled in an “efficient" manner such that each parameter is sampled once from each of its possible segments. The advantage of this approach is that the random samples are generated from all the ranges of possible values, thus giving insight into the extremes of the probability distributions of the outputs.

Results from FRAMES SUM^3 can be used to derive the confidence limits and intervals to provide a quantitative statement about the effect of varying a parameter on the model prediction. Due to the complexity of multimedia environmental interaction with GENII, the model cannot be reduced to simple additive or multiplicative structure; distributions of input values and model output are complex. Rank transformations are useful for representing a variety of relationships between parameter values and model predictions and for minimizing the effects of extreme values.

The correlation coefficients calculated from ranks of parameter values and model predictions are a better indicator of parameter importance than those from simple regression analysis (Reference 2.2.49, pp. 11–34) because the latter will only work when there is a linear relation between the variables. In this calculation, Spearman rank-order correlation coefficients are calculated to examine the relative importance of parameters. The approximate relative contribution of each selected parameter to the variance of the monitored (chosen) output (e.g., peak dose) was analyzed. The parameters having the greatest effect are selected for further analysis.

Because the SUM^3 in GENII Version 2 can only take a limited number of uncertain parameters for each run, radionuclides and pathways are screened to eliminate some uncertain parameters that are associated with unimportant radionuclides and low dose contributed pathways. For one scenario from each of chronic or acute release, an uncertainty analysis for each selected radionuclide with all stochastic input parameters for the selected pathways is performed to select high correlation input parameters that are important for at least one radionuclide. Once it is done, those selected high correlation input parameters are used in the related scenarios, which provide stochastic results for these scenarios of interest.

III.3 RADIONUCLIDE AND INPUT PARAMETER SCREENING

The selection of radionuclides and input parameters for the uncertainty analysis is discussed in this section.

III.3.1 Radionuclide Screening

A large number of radionuclides are used to calculate preclosure dose consequences from commercial SNF, HLW, LLW, and contamination and activation releases (Sections 6.1.1.6 and 6.1.2). A small number of those radionuclides are more important than others in terms of dose contributions for normal operations and Category 1 and Category 2 event sequences. A screening process is used to identify the more significant radionuclides so that uncertainty analysis focuses on those with a high contribution on dose consequences.

The screening process uses the results of GENII runs for normal operations (chronic release and doses) and Category 1 and Category 2 event sequences (acute release and doses) described in Section 6.4. Only the runs with dose consequence within the general environment are considered because they include all exposure pathways, including ingestion.

The normal operations GENII runs with chronic release and doses include:

- **Normal PWR** - Normal release from WHF (*Normal General Environment - PWR.xls* with GENII file *nodhdgrg.gid*)

- **Exhaust Shafts** - Subsurface facility exhaust shafts release (*Exhaust Shafts General Environment.xls*),

- **Aging Pad** - Aging pad contamination release (*Aging Pad General Environment.xls*).

The Category 1 and Category 2 event sequence GENII runs with acute releases and doses include:

- **PWR Burst and PWR Oxidation** - PWR burst and oxidation releases with HEPA filtration (*PWR Air General Environment.xls* with GENII file *pmdhlgrg.gid*),

- **PWR No HEPA Burst and PWR No HEPA Oxidation** - PWR burst and oxidation releases without HEPA filtration (*PWR Air General Environment no HEPA.xls* with GENII file *pmohlgrg.gid*),

- **HLW SRS Burst** - HLW release for SRS without HEPA filtration (*HLW SRS General Environment.xls* with GENII file *hsdhlgrg.gid*),

- **HEPA Seismic** - Seismic event with HEPA filter source terms (*HEPA Seismic General Environment.xls*)

- **LLW Seismic** - Seismic event LLW release (*LLW Seismic General Environment.xls*),

The results of radionuclide contribution for each above case are taken from the Excel files provided, which are included in Appendix X. Some GENII file names are also provided here, because they are used as base files for the uncertainty analysis later. From each case, radionuclides that contribute more than 1% of the total dose are identified for further radionuclide screening. The 1% criterion is selected because it is sufficiently low to include all important radionuclides. The screening results indicate there are 19 radionuclides whose contributions are above 1% in any scenarios considered, as shown in Table III - 1. As can be seen, a total fraction of radionuclides listed in Table III - 1 is more than 98% for each case, which indicates that the 1% criterion is reasonable. Of those 19 radionuclides, 11 are selected for further study on input parameter uncertainty and are indicated by the green highlighting. The reduction from 19 to 11 is based on:

- ^{41}Ar is excluded because it is only in the subsurface activation release and the doses from those releases are not significant (3.56×10^{-3} mrem/yr from Table 44) when compared to normal releases from the WHF (2.70 mrem/yr from Table 43).

- Where there are multiple radionuclides for an element, only one is selected for study. This is because many of the input parameters are element dependent rather than nuclide dependent so it is not necessary to study multiple nuclides for the same element. Therefore ^{58}Co, ^{134}Cs, ^{239}Pu, ^{240}Pu, and ^{241}Pu are excluded.

- Organically bound tritium is always included as a form of tritium whenever ^{3}H is in a GENII run. Therefore its dose contribution is included in all runs and need not be included separately.

- ^{54}Mn is excluded because it is only a 1% contributor to the LLW seismic event and that event has small consequences.

- ^{90}Y is a decay product of ^{90}Sr, and its half-life is much shorter than ^{90}Sr. It is already included as a daughter product when ^{90}Sr is present. Therefore its dose contribution is not evaluated separately

Table III - 1. Fraction of TEDE Dose From Each Radionuclide for Each GENII Run

Nuclide	PWR Burst	PWR Oxidation	PWR No HEPA Burst	PWR No HEPA Oxidation	HLW SRS Burst	HEPA Seisimc	Normal PWR	LLW Seismic	Exhaust Shafts	Aging Pad
^{41}Ar									1.0	
^{241}Am		0.02	0.05	0.07	0.36	0.26	0.01			0.46
^{14}C							0.02			
^{244}Cm		0.17	0.47	0.67	0.20	0.36	0.01			
^{58}Co								0.02		
^{60}Co							0.01	0.56		0.54
^{134}Cs			0.10				0.01	0.24		
^{137}Cs			0.15	0.01	0.02	0.04	0.32	0.16		
^{3}H	0.87	0.62	0.02				0.35			
$^{3}H^{*}$	0.01						0.02			
^{129}I	0.02	0.03					0.12			
^{85}Kr	0.08	0.10					0.12			
^{54}Mn								0.01		
^{238}Pu		0.05	0.14	0.20	0.37	0.23	0.01			
^{239}Pu				0.01	0.01	0.02				
^{240}Pu			0.01	0.01		0.03				
^{241}Pu		0.01	0.02	0.03		0.05				
^{106}Ru			0.04							
^{90}Sr				0.01	0.03	0.01				
^{90}Y							0.01			
TOTAL	0.99	0.99	0.98	0.98	0.99	0.98	0.99	1.00	1.00	1.00

NOTES: *Organically bound tritium.
Blank cells have values less than 0.005.
Green highlight indicates that the nuclide has been selected for further study.
Yellow highlight indicates key nuclides for specific consequence scenarios.
TOTAL is the sum of fraction of TEDE from radionuclides considered, and may contain rounding error.

Source: Worksheet *Combined* of Excel file *RnList.xls*

III.3.2 Input Parameter Screening

There are 519 input parameters for GENII Version 2 that use site-specific input values as discussed in Reference 2.2.10 (Section 5.3.1). A summary file, *GENII_Parameter_Summary.xls*, contains all parameter values and distributions developed in Reference 2.2.10 (Attachment H). Of the 519 input parameters, distributions are developed in Reference 2.2.10 for 426 parameters, and they are available for stochastic evaluations with GENII Version 2. Of the other 93 parameters with fixed values, 14 define the release and exposure scenario, 43 determine the lung solubility classes, 4 are not used in the GENII runs, 16 use bounding values, 16 are based on site-specific agricultural data, and one is based on a conservative indoor shielding factor (Reference 2.2.10, p.93).

The 426 parameters with distributions that are available for stochastic evaluations with GENII Version 2 are screened to determine the more important parameters for YMP preclosure consequence analyses. The first selection process is based on a pathway analysis to identify the most important pathways. This selection is needed, because the SUM^3 in GENII version 2 can only take a limited number of uncertain parameters for each run. The input parameters for those important pathways are then identified for use in the uncertainty process using the SUM^3 module with GENII Version 2.

Pathway Analysis for Input Parameter Screening

The screening process uses the results of the pathway analysis for normal operations and Category 1 and Category 2 event sequences described in the radionuclide screening in Section III.3.1. From the same Excel files used for radionuclide screening, pathways that contribute more than 5% of the total dose are identified and the input parameters for those pathways are selected for the uncertainty analysis. The value of 5% is selected because it is high enough to eliminate less important pathways, and it is low enough to keep potential important pathways. This screening indicates that there are six pathways whose contributions are above 5% in any scenarios considered, as shown in Table III - 2 indicated by the green highlighting. They are external air and ground shine, inhalation, and ingestion of fruit, leafy vegetables, and root vegetables. Yellow highlighting in Table III - 2 indicates the important pathways for each of the GENII runs. As can be seen, a total fraction of pathways selected with this method is more than 93% for each case (see TOTAL in Table III - 2), which indicates that 5% criterion is reasonable.

A low percentage pathway that has a limited contribution to calculated dose usually is not a significant contributor for the overall uncertainty of calculated dose, unless an uncertain parameter associated with this pathway has a distribution with a much larger range when compared with uncertain parameters for other pathways. This is the basis for the pathway screening process, because input parameters between various ingestion pathways are in a comparable range (see Table III - 4). Therefore, excluding uncertainty contributions from a low percentage pathway will not negatively impact on the overall uncertainty of stochastic results. However, a high percentage pathway that has a significant contribution to calculated dose, for example, inhalation and external exposures in Table III - 2, is not necessary significant contributor for the overall uncertainty of stochastic results. This is because many uncertain input parameters associated with these pathways have a distribution with a relatively narrow range.

Table III - 2. Fraction of TEDE Dose From Each Pathway for Each GENII Run

Pathway	PWR Burst	PWR Oxidation	PWR No HEPA Burst	PWR No HEPA Oxidation	HLW SRS Burst	HEPA Seisimc	Normal PWR	LLW Seismic	Exhaust Shafts	Aging Pad
External										
Air	0.08	0.10					0.12	0.01	1.0	
Ground			0.10	0.01	0.01	0.02	0.38	0.43		0.54
Inhalation	0.28	0.79	0.79	0.99	0.97	0.96	0.32	0.42		0.45
Ingestion										
Eggs	0.04	0.01					0.03			
Fruit	0.34	0.06	0.05				0.07	0.03		
Grain										
Leafy	0.09	0.02	0.04	0.01	0.01	0.01	0.03	0.06		
Meat	0.02		0.01				0.02	0.02		
Milk	0.03	0.01	0.01				0.02	0.01		
Poultry										
Root	0.11	0.02	0.01				0.02	0.01		
Soil										
TOTAL	0.93	0.98	0.99	1.00	1.00	1.00	0.95	0.98	1.00	1.00

NOTES: Blank cells have values less than 0.005.
Green highlight indicates that the pathway has been selected for further study.
Yellow highlight indicates key pathways with more than 5% of TEDE for specific consequence scenarios.
TOTAL is the sum of fraction of TEDE from the seven pathways (green highlight), and may contain rounding error.

Source: Worksheet *pathway* of Excel file *RnList.xls*

Input Parameters Selected for Uncertainty Analysis

The input parameters associated with those pathways in each case considered that contribute more than 5% of the total dose are selected for the uncertainty analysis. Besides the pathways that are identified in Table III - 2 as important, meat ingestion pathway is also included based on results of a previous uncertainty and sensitivity analysis study (Reference 2.2.50, p.23 and 29). The study indicates that several input parameters associated with meat ingestion pathway are major contributors for the dose uncertainty.

The input parameters selected for the uncertainty analysis are shown in Table III - 3. Some of these parameters are radionuclide dependent. Other parameters are either the same value as another or are correlated to another parameter as indicated in Table III - 3.

Table III - 3. Input Parameters Selected for Uncertainty Analysis

No.	Symbol	Parameter Description	Distribution	Notes
1	AMBTMP	Ambient air temperature	Normal	
2	ABSHUM	Absolute humidity, used only for tritium model	Lognormal	
3	AVALSL	Depth of top soil available for resuspension	Uniform	
4	BIOMAMT	Standing animal feed biomass (wet) -- meat	Lognormal	correlated with YELDMT
5	BIOMALV	Standing biomass (wet) -- leafy vegetables	Lognormal	correlated with YELDLV
6	BIOMARV	Standing biomass (wet) -- root vegetables	Lognormal	correlated with YELDRV
7	BIOMAFR	Standing biomass (wet) -- fruits	Lognormal	correlated with YELDFR
8	BULKD	Surface soil bulk density	Normal	
9	DPVRES	Deposition velocity from soil to plant surfaces	Lognormal	
10	DRYFAMT	Animal feed dry/wet ratio -- meat	Uniform	
11	DRYFALV	Dry/wet ratio -- leafy vegetables	Normal	
12	DRYFARV	Dry/wet ratio -- root vegetables	Lognormal	
13	DRYFAFR	Dry/wet ratio -- fruits	Loguniform	
14	LEAFRS	Re-suspension factor from soil to plant surfaces	Lognormal	
15	MOISTC	Surface soil moisture content	Uniform	
16	RAIN	Average daily rain rate	Lognormal	
17	SLDN	Surface soil areal density	Normal	SLDNA is used later
18	SOILKD	Soil adsorption coefficient	Lognormal	same as CLKD radionuclide dependent
19	SSLDN	Surface soil density	Normal	same as BULKD
20	SURCM	Surface soil layer thickness used for density	Uniform	same as THICK
21	THICK	Surface soil thickness	Uniform	
22	VLEACH	Total infiltration rate	Lognormal	
23	WTIM	Weathering rate constant from plants	Lognormal	
24	XMLF	Mass loading factor for re-suspension model	Lognormal	
25	YELDLV	Yield -- leafy vegetables	Lognormal	correlated with BIOMAMT
26	YELDRV	Yield -- root vegetables	Lognormal	correlated with BIOMALV
27	YELDFR	Yield -- fruits	Lognormal	correlated with BIOMARV
28	YELDMT	Yield for animal feed -- meat	Lognormal	correlated with BIOMAFR
29	FRINHR	Fraction of a day inhalation occurs (for resuspension)	Normal	
30	FTIN	Fraction of time spent indoors	Normal	
31	FTOUT	Fraction of time spent outdoors	Normal	
32	TANMMT	Animal product consumption period -- meat	Lognormal	
33	TCRPLV	Crop consumption period -- leafy vegetables	Lognormal	
34	TCRPRV	Crop consumption period -- root vegetables	Lognormal	
35	TCRPFR	Crop consumption period -- fruits	Lognormal	
36	UANMMT	Animal product consumption rate -- meat	Normal	
37	UCRPLV	Crop consumption rate -- leafy vegetables	Normal	
38	UCRPRV	Crop consumption rate -- root vegetables	Normal	
39	UCRPFR	Crop consumption rate -- fruits	Normal	
40	UEXAIR	Daily plume submersion exposure time	Normal	
41	UINH	Air inhalation rate	Normal	Used for chronic only
42	UINHR	Re-suspended soil inhalation rate	Normal	Used for chronic only
43	SOILT	Thickness of contaminated soil/sediment layer	Uniform	same as THICK
44	SSLDN	Density of contaminated soil/sediment layer	Normal	same as BULKD

Table III - 3. Input Parameters Selected for Uncertainty Analysis

No.	Symbol	Parameter Description	Distribution	Notes
45	CLBVAF	Bioconcentration in Wet Animal Forage from Soil	Lognormal	radionuclide dependent
46	CLBVFR	Bioconcentration in Wet Fruit from Soil	Lognormal	radionuclide dependent
47	CLBVLV	Bioconcentration in Wet Leafy Vegetables from Soil	Lognormal	radionuclide dependent
48	CLBVRV	Bioconcentration in Wet Root Vegetables from Soil	Lognormal	radionuclide dependent
49	CLFMT	Feed to Meat Transfer Factor	Lognormal	radionuclide dependent
50	CLKD	The dry soil-water partition coefficient	Lognormal	same as SOILKD radionuclide dependent
51	CLVD	The atmospheric deposition velocity	Lognormal	
52	JHOUR	Julian hour	Uniform	Used for acute only

Source: Parameter Symbols defined in this table are used in this appendix only, and not listed in ACRONYMS. Worksheet *SUM3* of Excel file *GENII_Parameter_Summary.xls.*

Input Parameter Values and Distributions

The input parameter values and distributions for the selected parameters listed in Table III - 3 are provided in Table III - 4. The radionuclide dependent parameters are not shown in this table, but their parameter values and distributions are taken from the file *GENII_Parameter_Summary.xls* (Reference 2.2.10, Attachment H). Some lower and upper bounds are modified to be suitable for the GENII version 2 (as shown yellow highlight in Table III - 4), because the original bounds are beyond the allowable input limits for GENII.

Table III - 4. Input Parameter Values and Distributions

No.	Symbol	Distribution	Units	AM or GM	SD or GSD	Log(GM)	Log(GSD)	LB	UB
1	AMBTMP	Normal	^{o}C	17.04	10.13	-	-	-7.50	42.31
2	ABSHUM	Lognormal	kg/m^3	0.00363	1.63	-2.44	0.21	0.00039	0.0164
3	AVALSL	Uniform	cm	-	-	-	-	0.1	0.3
4	BIOMAMT	Lognormal	kg/m^2	1.83	1.72	0.262	0.236	0.69	6.28
5	BIOMALV	Lognormal	kg/m^2	2.83	1.65	0.452	0.217	1.08	7.85
6	BIOMARV	Lognormal	kg/m^2	4.81	1.54	0.682	0.188	2.11	9.82
7	BIOMAFR	Lognormal	kg/m^2	5.54	1.50	0.744	0.176	3.18	9.51
8	BULKD	Normal	g/cm^3	1.5	0.082	-	-	1.3	1.7
9	DPVRES	Lognormal	cm/s	0.008	5.6	-2.10	0.75	0.0003	0.099
10	DRYFAMT	Uniform	-	-	-	-	-	0.182	0.238
11	DRYFALV	Normal	-	0.071	0.015	-	-	0.051	0.093
12	DRYFARV	Lognormal	-	0.089	1.52	-1.051	0.182	0.051	0.24
13	DRYFAFR	Loguniform	-	-	-	-	-	0.062	0.194
14	LEAFRS	Lognormal	1/m	4.59E-10	1.83	-9.34	0.26	8.37E-11	2.52E-09
15	MOISTC	Uniform	-	-	-	-	-	0.15	0.28
16	RAIN	Lognormal	mm/d	0.10	6.62	-1.00	0.82	0.011	100

Table III - 4. Input Parameter Values and Distributions

No.	Symbol	Distribution	Units	AM or GM	SD or GSD	Log(GM)	Log(GSD)	LB	UB
17	SLDN	Normal	kg/m^2	262	109	-	-	69	488
18	SOILKD	Lognormal	mL/g	radionuclide dependent					
19	SSLDN	Normal	kg/m^3	1500	82	-	-	1300	1700
20	SURCM	Uniform	cm	-	-	-	-	5	30
21	THICK	Uniform	cm	-	-	-	-	5	30
22	VLEACH	Lognormal	cm/yr	6.4	2.34	0.81	0.37	0.90	27.5
23	WTIM	Lognormal	d	14	1.65	1.15	0.22	5	30
24	XMLF	Lognormal	g/m^3	0.0006	1.5	-3.22	0.18	0.0002	0.0014
25	YELDLV	Lognormal	kg/m^2	2.83	1.65	0.452	0.217	1.08	7.85
26	YELDRV	Lognormal	kg/m^2	4.06	1.20	0.609	0.079	2.80	6.61
27	YELDFR	Lognormal	kg/m^2	2.70	1.37	0.431	0.137	0.73	6.89
28	YELDMT	Lognormal	kg/m^2	1.83	1.72	0.262	0.236	0.69	6.28
29	FRINHR	Normal	-	0.31	0.014	-	-	0.27	0.35
30	FTIN	Normal	-	0.61	0.022	-	-	0.54	0.67
31	FTOUT	Normal	-	0.31	0.014	-	-	0.27	0.35
32	TANMMT	Lognormal	d/yr	15.1	3.14	1.179	0.497	0.001	364.99
33	TCRPLV	Lognormal	d/yr	17.9	2.82	1.253	0.450	0.001	364.99
34	TCRPRV	Lognormal	d/yr	22.5	2.47	1.352	0.393	0.001	364.99
35	TCRPFR	Lognormal	d/yr	54.0	2.08	1.732	0.318	0.001	364.99
36	UANMMT	Normal	kg/d	0.098	0.008	-	-	0.078	0.119
37	UCRPLV	Normal	kg/d	0.123	0.022	-	-	0.067	0.180
38	UCRPRV	Normal	kg/d	0.141	0.010	-	-	0.116	0.167
39	UCRPFR	Normal	kg/d	0.185	0.008	-	-	0.163	0.206
40	UEXAIR	Normal	hr	22	0.4	-	-	20.7	22.8
41	UINH	Normal	m^3/d	21.7	0.12	-	-	21.3	22.1
42	UINHR	Normal	m^3/d	21.7	0.12	-	-	21.3	22.1
43	SOILT	Uniform	m	-	-	-	-	0.05	0.30
44	SSLDN	Normal	kg/m^3	1500	82	-	-	1300	1700
45	CLBVAF	Lognormal	kg/kg	radionuclide dependent					
46	CLBVFR	Lognormal	kg/kg	radionuclide dependent					
47	CLBVLV	Lognormal	kg/kg	radionuclide dependent					
48	CLBVRV	Lognormal	kg/kg	radionuclide dependent					
49	CLFMT	Lognormal	d/kg	radionuclide dependent					
50	CLKD	Lognormal	mL/g	radionuclide dependent					
51	CLVD	Lognormal	m/s	0.008	5.6	-2.10	0.75	0.0003	0.30
52	JHOUR	Uniform	hr	-	-	-	-	0.01	8759.99

NOTES: AM = arithmetic mean, GM = geometric mean, GSD = geometric standard deviation, LB = lower bound, SD = standard deviation, UB = upper bound.

Source: Excel file *GENII_Parameter_Summary.xls.*

III.4 UNCERTAINTY ANALYSIS FOR A CHRONIC RELEASE

III.4.1 Radionuclide Dose Uncertainty for Chronic Release

For each of the 11 important radionuclides identified in Table III - 1, a GENII SUM^3 run for a chronic release is performed using the selected pathway input parameters and distributions from Table III - 4. The chronic release scenario is the normal release from WHF scenario used for radionuclide screening in Section III.3.1. The GENII run file is *nodhdgrg.gid*, and it is used as a start file to add the SUM^3 module.

Within the start file, *nodhdgrg.gid*, all radionuclides are deleted except one (^{137}Cs) for a given radionuclide run. A total of 51 input parameter distributions as shown in Table III - 4 are added to SUM^3 module. The parameters with the same distributions and correlations between parameters are included in the module. The number of iterations is selected as 500, the maximum number allowed by GENII, which also meets the guideline suggesting that the number of iterations typically be two to three times the number of uncertain input parameters (Reference 2.2.51, p. 59). The random seed number is selected as one (1).

The uncertainty result files (with a names of *.suf) from each of the radionuclide GENII runs are imported into 11 Excel spreadsheets for statistical analysis. Excel files are named the same as GENII files, except for extension name (*.xls). Calculations of mean, standard deviation, minimum, geometric mean, and maximum are performed in the worksheet, and results are listed in Table III - 5 with a comparison of TEDE dose results between deterministic and stochastic runs. The deterministic results are for the GENII run with 1) multiple radionuclides (taken from *nodhdgrg.gid*) and 2) that single radionuclide.

Table III - 5. Comparison of Deterministic and Stochastic TEDE Dose Results (mrem/yr) for Single Radionuclides

GENII Filename	Radio-nuclide	Deterministic Multiple[c]	Deterministic Single[d]	Stochastic Results[e]				
				Median	5th %ile	95th %ile	Mean	SD
ch5cam1	^{241}Am[a]	5.0×10^{-5}	3.1×10^{-7}	3.1×10^{-7}	3.0×10^{-7}	3.1×10^{-7}	3.1×10^{-7}	3.2×10^{-9}
ch5cc14	^{14}C	1.2×10^{-4}	1.2×10^{-4}	1.4×10^{-4}	8.5×10^{-5}	3.0×10^{-4}	1.6×10^{-4}	7.2×10^{-5}
ch5ccm4	^{244}Cm/ ^{240}Pu[b]	7.4×10^{-5}	7.4×10^{-5}	7.4×10^{-5}	7.3×10^{-5}	7.5×10^{-5}	7.4×10^{-5}	5.1×10^{-7}
ch5cco0	^{60}Co	4.3×10^{-5}	4.3×10^{-5}	4.2×10^{-5}	1.4×10^{-5}	1.1×10^{-4}	4.9×10^{-5}	3.3×10^{-5}
ch5ccs7	^{137}Cs	1.9×10^{-3}	1.9×10^{-3}	1.9×10^{-3}	6.4×10^{-4}	5.0×10^{-3}	2.2×10^{-3}	1.5×10^{-3}
ch5ch3	^{3}H	2.2×10^{-3}	2.2×10^{-3}	2.4×10^{-3}	1.8×10^{-3}	4.1×10^{-3}	2.6×10^{-3}	7.6×10^{-4}
ch5ci29	^{129}I	6.9×10^{-4}	6.9×10^{-4}	8.4×10^{-4}	3.4×10^{-4}	2.5×10^{-3}	1.1×10^{-3}	8.8×10^{-4}
ch5ckr5	^{85}Kr	7.1×10^{-4}	7.1×10^{-4}	7.1×10^{-4}	6.9×10^{-4}	7.3×10^{-4}	7.1×10^{-4}	1.2×10^{-5}
ch5cpu8	^{238}Pu	4.6×10^{-5}	4.6×10^{-5}	4.5×10^{-5}	4.4×10^{-5}	4.6×10^{-5}	4.5×10^{-5}	5.3×10^{-7}
ch5cru6	^{106}Ru	4.0×10^{-7}	4.0×10^{-7}	4.1×10^{-7}	2.0×10^{-7}	9.4×10^{-7}	4.7×10^{-7}	2.6×10^{-7}
ch5csr0	^{90}Sr/^{90}Y[b]	3.5×10^{-5}	3.5×10^{-5}	3.1×10^{-5}	6.5×10^{-6}	9.1×10^{-5}	3.8×10^{-5}	2.9×10^{-5}

NOTES: [a] The ^{241}Am results in the deterministic multiple radionuclide run (Column 3) includes contributions as a daughter of several nuclides, such as ^{241}Pu, ^{245}Cm.
[b] Dose contributions from the implicit daughters ^{240}Pu and ^{90}Y are included with ^{244}Cm and ^{90}Sr, respectively.
[c] Results taken from GENII run *nodhdgrg.gid.*
[d] Results are deterministic taken from GENII runs listed in GENII Filename
[e] Results are stochastic taken from GENII runs listed in GENII Filename

Source: Worksheet *RN_Dose* of Excel file *chronic summary.xls.*

III.4.2 Input Parameter Rank Correlation Coefficients for Chronic Release

A statistical analysis is performed for each of the 11 radionuclides considered in an individual Excel file. Ranking of each parameter is done using Excel standard data analysis – Rank and Percentile function. The results are then saved in a new worksheet named *ranking*. Percentile results are sorted in descending order of iteration and then ranked in the same worksheet *ranking*. The rank correlation coefficients are calculated in the worksheet named *RCC* using the standard Excel function CORREL. The rank correlation coefficient, instead of raw (or value) correlation coefficients, is used in this uncertainty analysis because the rank correlation coefficient is less affected by a few extreme input-result pairs, as discussed in Section III.2.

The summary Table III - 6 provides results of rank correlation coefficients for each radionuclide. The yellow highlighted cells are rank correlation coefficients higher than 10% absolute value, which is determined based on the statistical significance. The approach is presented in the text by Steel and Torrie (Reference 2.2.52, p. 279), and used in *Biosphere Model Report* (Reference 2.2.53, p.6-303, and 6-361). To test the null hypothesis of the true correlation coefficient being zero, the measured correlation coefficient (r) is used to calculate t value using Equation III-1.

$$t = \frac{r}{\sqrt{\frac{(1-r^2)}{n-2}}} \qquad \text{(Eq. III-1)}$$

The value of t is then compared with Student's t for n–2 degrees of freedom (n = the number of data points used to derive r) for the required confidence interval. For an iteration number of 500 (n) and correlation coefficient of 0.10 (r), calculated t value is 2.243 using Equation III-1. The corresponding absolute value of the correlation coefficient at the 97.5% confidence interval (t = 2.248) for rejecting the null hypothesis is 0.10. In other words the rank correlation coefficients equal to or less than 0.10 absolute value are not significant at the 97.5% confidence interval. Therefore, it is convenient to use 10% as a criterion for selecting important parameters for uncertainty of calculated doses.

The green highlighted cells are high correlation input parameters that are important for at least one radionuclide. Two of the input parameters highlighted are radionuclide dependent (CLKD and SOILKD) and are considered important for two nuclides (^{129}I and ^{90}Sr), thus, they are evaluated separately. Therefore, a total of 20 input parameters, including CLKD and SOILKD counted twice, are important for dose uncertainty and are considered for further uncertainty analysis.

Table III - 6. Summary of Rank Correlation Coefficients for Single Radionuclides for a Chronic Release

Radio-nuclide	^{241}Am	^{14}C	^{244}Cm	^{60}Co	^{137}Cs	^{3}H	^{129}I	^{85}Kr	^{238}Pu	^{106}Ru	^{90}Sr
CLVD	-0.02	0.00	-0.03	0.01	0.01	0.00	0.00	-0.02	-0.02	0.01	0.02
CLFMT	-0.01	0.00	0.01	-0.02	-0.02	-0.01	0.21	-0.01	0.03	0.07	0.00
CLBVLV	-0.01	-0.01	0.01	-0.01	-0.01	0.00	0.10	0.00	0.00	0.00	0.03
CLBVRV	-0.02	-0.02	0.01	-0.04	-0.04	-0.01	-0.01	0.00	-0.02	-0.04	-0.02
CLBVAF	-0.02	0.01	0.01	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.02
CLBVFR	-0.01	0.00	0.02	0.00	0.00	0.01	0.05	-0.02	0.00	0.00	0.05
CLKD	0.07	-0.01	0.03	0.02	0.02	-0.01	0.59	-0.02	0.02	0.01	0.46
AMBTEMP	0.01	0.01	0.02	-0.02	-0.02	0.01	-0.01	-0.01	0.01	-0.01	-0.01
ABSHUM	-0.01	-0.06	-0.02	0.01	0.01	-0.71	-0.02	0.00	-0.03	0.00	-0.02
XMLF	0.16	0.01	0.13	-0.01	-0.01	0.02	0.00	0.01	0.14	-0.01	0.01
AVALSL	0.01	-0.04	0.01	0.01	0.01	-0.04	-0.01	0.01	-0.01	-0.01	-0.03
YELDMT	-0.01	-0.01	0.01	0.02	0.02	-0.01	-0.08	0.00	0.00	-0.01	-0.01
YELDLV	-0.02	-0.01	-0.05	-0.02	-0.02	-0.01	-0.04	-0.01	-0.07	-0.03	-0.01
YELDRV	0.00	0.00	0.01	-0.02	-0.02	-0.01	0.00	0.00	0.00	-0.01	-0.02
YELDFR	-0.02	0.05	-0.02	0.01	0.01	0.02	-0.03	0.01	-0.04	0.01	-0.02
SSLDN2	0.04	-0.05	-0.01	0.06	0.06	-0.04	0.00	0.01	0.00	0.05	0.06
WTIM	0.13	-0.01	0.19	-0.02	-0.02	-0.01	0.23	0.00	0.33	0.01	0.00
RAIN	0.05	0.01	0.04	-0.01	-0.01	0.03	0.00	0.02	0.04	-0.01	-0.01
THICK	0.35	0.04	0.03	0.75	0.75	0.02	0.33	0.01	0.03	0.73	0.64
MOISTC	-0.02	0.02	0.00	-0.01	-0.01	0.01	0.00	0.00	-0.01	-0.01	-0.02
BULKD	0.04	-0.05	-0.01	0.06	0.06	-0.04	0.00	0.01	0.00	0.05	0.06
VLEACH	-0.02	0.02	-0.02	0.01	0.01	-0.01	-0.25	0.02	0.00	0.01	-0.22
LEAFRS	0.00	0.02	-0.04	0.00	0.00	-0.01	0.01	-0.01	0.00	0.00	0.01
DPVRES	0.00	0.01	0.02	0.02	0.02	0.03	0.04	0.02	0.01	0.03	0.00
SLDNA	-0.53	0.01	-0.19	-0.60	-0.60	0.01	-0.22	0.01	-0.25	-0.58	-0.45
SURCM	0.35	0.04	0.03	0.75	0.75	0.02	0.33	0.01	0.03	0.73	0.64
BIOMAMT	-0.01	-0.01	0.01	0.02	0.02	-0.01	-0.08	0.00	0.00	-0.01	-0.01
BIOMALV	-0.02	-0.01	-0.05	-0.02	-0.02	-0.01	-0.04	-0.01	-0.07	-0.03	-0.01
BIOMARV	0.00	0.00	0.01	-0.02	-0.02	-0.01	0.00	0.00	0.00	-0.01	-0.02
BIOMAFR	-0.02	0.05	-0.02	0.01	0.01	0.02	-0.03	0.01	-0.04	0.01	-0.02
DRYFAMT	0.03	0.02	0.00	0.03	0.03	0.00	0.02	0.02	-0.01	0.03	0.01
DRYFALV	-0.01	-0.01	0.02	0.01	0.01	0.01	-0.02	0.01	0.05	0.00	-0.03
DRYFARV	0.01	-0.01	0.00	0.00	0.00	0.01	0.03	-0.01	0.01	-0.01	0.02
DRYFAFR	0.02	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.01
SOILKD	0.07	-0.01	0.03	0.02	0.02	-0.01	0.59	-0.02	0.02	0.01	0.46
UEXAIR	-0.02	-0.02	-0.03	0.00	0.00	0.00	0.01	1.00	-0.01	0.00	-0.01
FTIN	0.03	-0.02	0.00	0.02	0.02	-0.02	0.03	-0.01	0.01	0.01	0.01
FTOUT	0.01	-0.01	-0.01	0.02	0.02	0.00	0.01	0.01	0.01	0.03	-0.01
UCRPLV	0.01	-0.01	0.03	0.00	0.00	0.02	0.00	0.02	0.05	0.01	-0.02

Table III - 6. Summary of Rank Correlation Coefficients for Single Radionuclides for a Chronic Release

Radio-nuclide	^{241}Am	^{14}C	^{244}Cm	^{60}Co	^{137}Cs	^{3}H	^{129}I	^{85}Kr	^{238}Pu	^{106}Ru	^{90}Sr
UCRPRV	0.02	0.05	0.02	-0.01	-0.01	0.04	0.01	-0.01	0.06	-0.01	0.00
UCRPFR	0.00	0.05	0.02	-0.01	-0.01	0.01	-0.01	0.01	0.00	-0.02	0.01
TCRPLV	0.22	0.27	0.33	0.00	0.00	0.24	0.22	0.00	0.53	0.04	0.03
TCRPRV	0.02	0.31	0.04	0.01	0.01	0.25	0.04	0.01	0.08	0.00	0.02
TCRPFR	0.09	0.63	0.12	0.02	0.02	0.49	0.09	0.00	0.20	0.03	0.05
UANMMT	0.02	0.04	0.00	0.00	0.00	0.01	-0.01	-0.01	0.01	0.01	0.01
TANMMT	0.02	0.47	0.01	0.02	0.03	0.13	0.23	-0.03	0.02	0.08	0.03
UINH	0.57	-0.02	0.81	0.01	0.01	0.02	0.00	-0.01	0.55	0.00	0.00
UINHR	0.02	0.02	0.03	0.00	0.00	0.01	0.02	0.01	0.03	0.00	0.01
FRINHR	0.01	-0.02	0.01	-0.01	-0.01	0.00	-0.01	0.00	0.02	-0.02	0.00
SOILT	0.35	0.04	0.03	0.75	0.75	0.02	0.33	0.01	0.03	0.73	0.64
SSLDN	0.04	-0.05	-0.01	0.06	0.06	-0.04	0.00	0.01	0.00	0.05	0.06

NOTES: Green highlights indicate high correlation input parameters that are important for at least one radionuclide.
Yellow highlights indicate rank correlation coefficients higher than 10% absolute value.

Source: Worksheet *RN_RCC* of Excel file *chronic summary.xls.*

III.4.3 Uncertainty Analysis for Chronic Release

The high correlation input parameters identified in Table III - 6 are used in a chronic release run including the entire list of radionuclides in the normal release from the WHF. The distribution and standard deviation for the calculated dose is determined. In addition, the number of important input parameters is further reduced based on the rank correlation coefficients calculated from that scenario.

The selected chronic release scenario for uncertainty analysis is the same as the one used for radionuclide screening and pathway analyses for a normal operation with representative PWR inventory in Section III.3.1 (GENII file is *nodhdgrg.gid*). The other two chronic scenarios (Exhaust Shafts and Aging Pad in Table III - 1) are not selected, because they are dominated by inhalation and external exposure (Table III-2). A SUM^3 module is added into the GENII file. The 20 high correlation input parameters from Table III - 6 are input. Calculated doses for the scenario are shown in Table III - 7 with four cases of different number of iterations and random seed number. The means and standard deviations do not vary significantly among these four cases.

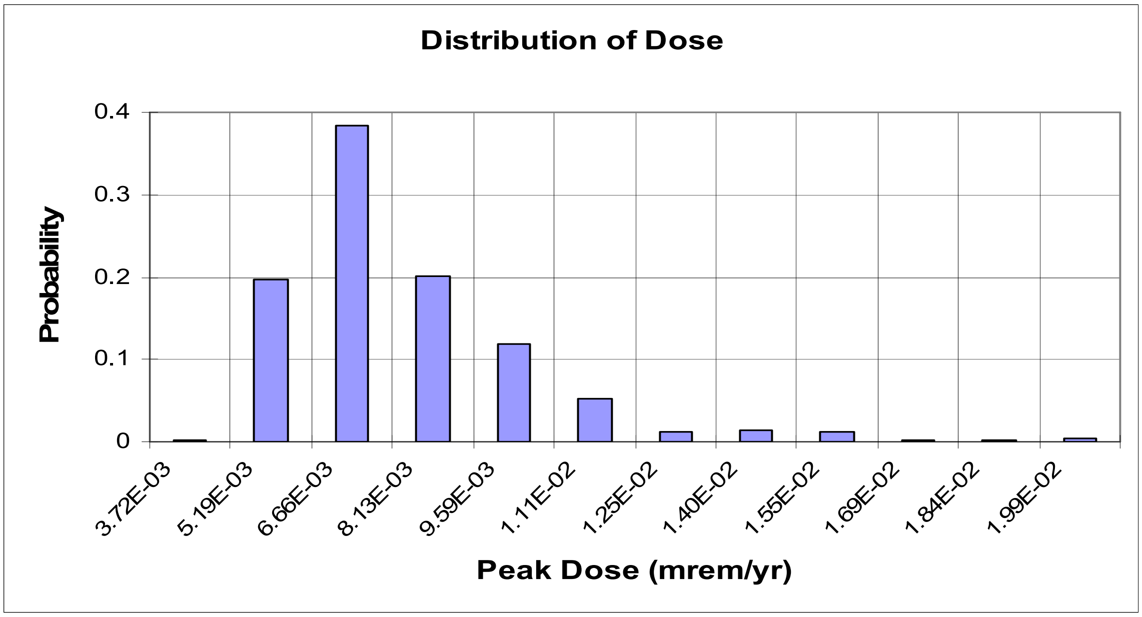
The results indicate that the uncertainty of the calculated dose is relatively small, with a ratio of less than two between the 95th percentile and median values (see Table III - 7) compared with the large uncertainty for input parameters such as TCRPLV, TCRPRV and TCRPFR (see Table III - 4). The low uncertainty of dose distribution for the chronic release scenario is mostly because more than 80% of dose comes from external and inhalation pathways (see Normal PWR column in Table III - 2), which have only a few input parameters with distributions. Some major stochastic parameters for these two pathways have relatively small distribution. For examples, SSLDN (soil density, important in ground shine pathway) has a mean of 1500 kg/m^3 with a standard deviation of 82 kg/m^3 and UINH (inhalation rate, important to inhalation pathway) has a mean of 21.7 m^3/d with a standard deviation of 0.12 m^3/d. Most inputs for these two pathways are conservative fixed values.

In addition, a comparison between the the deterministic and stochastic calculations indicates that the median dose calculated from the stochastic run is close to the deterministic result (see Table III - 7), while the difference between the mean from stochasitic run and deterministic result is slightly larger. This is because the high correlation input parameters (such as TCRPLV, TCRPRV and TCRPFR) have lognormal distributions, and geometric means instead of arithmetic means of the lognormal distributions are used for the deterministic calculations. The distribution of calculated doses for the normal operation chronic release scenario is shown in Figure III-1.

Table III - 7. TEDE Dose Distributions for Normal Operation Chronic Release

Filename	**nodhdst**	**nodhdst2**	**nodhdst5**	**nodhdst6**
Base file	nodhdgrg.gid	nodhdgrg.gid	nodhdgrg.gid	nodhdgrg.gid
Iterations	100	200	500	500
Seed number	1	1	1	23456
Deterministic (mrem/yr)	5.91×10^{-3}	5.91×10^{-3}	5.91×10^{-3}	5.91×10^{-3}
Median (mrem/yr)	6.47×10^{-3}	6.44×10^{-3}	6.34×10^{-3}	6.31×10^{-3}
5^{th} %ile (mrem/yr)	4.31×10^{-3}	4.30×10^{-3}	4.48×10^{-3}	4.51×10^{-3}
95^{th} %ile (mrem/yr)	1.05×10^{-2}	1.09×10^{-2}	1.06×10^{-2}	1.12×10^{-2}
Mean (mrem/yr)	6.90×10^{-3}	6.91×10^{-3}	6.88×10^{-3}	6.86×10^{-3}
STD (mrem/yr)	2.20×10^{-3}	2.26×10^{-3}	2.23×10^{-3}	2.22×10^{-3}
Ratio of 95th/median	1.6	1.7	1.7	1.8
Stochastic (Median) / Deterministic	1.09	1.09	1.07	1.07

Source: Worksheet *Chronic_Dose* of Excel file *chronic summary.xls.*



(Source: Worksheet *nodhdst5* of Excel file *nodhdst5.xls*.)

Figure III - 1. TEDE Dose Distribution for Normal Operation Chronic Release

The calculated rank correlation coefficients for the chronic release scenario are shown in Table III - 8. Similar to the process used in Section III.4.2 for single radionuclide runs, the yellow highlighted cells are the rank correlation coefficients higher than 10% absolute value, and the green highlighted cells are important parameters for uncertainty of calculated dose. The rank correlation coefficients are evaluated only for those with 500 iteration runs, because the 10% criterion is selected based on the statisitical significance at the 97.5% confidence interval as discussed in Section III.4.2. There are initially 10 high correlation input parameters. Because CLKDI and SOILKDI are the same parameter, and THICK, SURCM and SOILT are equivalent parameters, the number of high correlation parameters is reduced to seven.

Table III - 8. Summary of Rank Correlation Coefficients for Normal Operation Chronic Release

Filename	nodhdst	nodhdst2	nodhdst5	nodhdst6
Base file	nodhdgrg.gid	nodhdgrg.gid	nodhdgrg.gid	nodhdgrg.gid
CLFMTI (CLFMT for I-129)	0.04	-0.03	0.00	-0.02
CLBVLV	-0.05	0.06	0.03	0.00
CLKDI (CLKD for I-129)	0.22	0.16	0.17	0.16
CLKDSR CLKD for Sr-90)	0.07	0.01	-0.02	0.03
ABSHUM	-0.26	-0.22	-0.25	-0.21
XMLF	0.01	0.00	-0.01	0.03
WTIM	-0.01	0.06	0.08	0.07
THICK	0.64	0.61	0.64	0.63
VLEACH	-0.11	-0.10	-0.06	-0.07
SLDNA	-0.46	-0.54	-0.51	-0.51
SURCM	0.64	0.61	0.64	0.63
SOILKDI (SOILKD for I-129)	0.22	0.16	0.17	0.16
SOILKDSR (SOILKD for Sr-90)	0.07	0.01	-0.02	0.03
UEXAIR	0.01	0.02	0.01	0.04
TCRPLV	0.14	0.13	0.13	0.14
TCRPRV	0.16	0.07	0.11	0.14
TCRPFR	0.26	0.23	0.27	0.25
TANMMT	0.05	0.13	0.06	0.08
UINH	0.01	0.01	-0.01	0.03
SOILT	0.64	0.61	0.64	0.63

NOTES: Green highlights indicate high correlation input parameters

Yellow highlights indicate rank correlation coefficients higher than 10% absolute value.

Nodhdst.gid and hodhdst2.gid are run on 100 and 200 iterations, respectively. They are not used for selecting important input parameters because 10% value is not valid at the 97.5% confidence interval.

Source: Worksheet *Chronic_RCC* of Excel file *chronic summary.xls.*

III.5 UNCERTAINTY ANALYSIS FOR AN ACUTE RELEASE

III.5.1 Radionuclide Dose Uncertainty for Acute Release

For each of the 11 important radionuclide identified in Table III - 1, a GENII SUM^3 run for an acute release is performed using the selected pathway input parameters and distributions from Table III - 4. The acute release scenario is the burst rupture release with bounding PWR inventory used for radionuclide screening in Section III.3.1. The GENII run file is *pmdhlgrg.gid*, and it is used as a start file to add the SUM^3 module.

Within the start file, *pmdhlgrg.gid*, all radionuclides are deleted except one (^{137}Cs) for a given radionuclide run. A total of 49 input parameter distributions as shown in Table III - 4 are added to the SUM^3 module. The parameters with the same distributions and correlations between parameters are included in the module. The parameter Julian hour (JHOUR) is not included for the uncertainty analysis for individual radionuclides, because it is known from experience to be a high correlation input parameter and a deterministic run does not use this parameter. The number of iterations is selected as 500, the maximum number allowed by GENII, which meets the guideline suggesting that the number of iterations typically be two to three times the number of uncertain input parameter (Reference 2.2.51, p. 59). The random seed number is selected as one (1).

Using the same input parameter values and distributions as used for chronic scenario in Section III.4, the acute scenario files are created from the same radionuclide input files for the chronic scenario by switching to GENII V.2 Air XQ Acute Module, and changing the release fraction multipliers, air dispersion factor, time release and other release specific parameters applicable to an acute release. Verification was made by comparing the doses from each radionuclide between the all radionuclide deterministic run (*pmdhlgrg.gid*) and a single radionuclide deterministic run (Table III - 9).

The uncertainty result files (with a names of *.suf) from each of the radionuclide GENII runs are imported into 11 Excel spreadsheets for statistical analysis. Calculations of mean, standard deviation, minimum, geometric mean, and maximum are done in the worksheet, and results are listed in Table III - 9 and Table III - 10 with a comparison between deterministic and stochastic results.

It is noted that the GENII acute release results consist of doses for two time periods, 1) an initial period from 0 to the end of release (1 hour), and 2) a long-term period from the end of release to one year. Consequence analysis results for offsite public for compliance are reported for a 30-day period for Category 2 event sequences and therefore use prorated long-term doses from GENII. The initial period dose consists of external cloud and inhalation pathways and the long-term dose includes all pathways except external cloud.

Because the uncertainty analysis is based on the effective peak dose in either time period, a radionuclide is screened out from further uncertainty analysis if its initial dose is larger than its long-term dose. This is because the parameters that determine the initial period dose are fixed (e.g. atmospheric dispersion, breathing rate, and exposure period) and do not have distributions for an uncertainty analysis. This results in screening out the radionuclides ^{241}Am, ^{244}Cm, and ^{238}Pu. ^{85}Kr is also screened out, because its dose contribution is dominated by cloud submersion that is determined by fixed parameters.

Table III - 9. Comparison of Deterministic TEDE Dose Results for an Acute Release

GENII Filename	Radionuclide	All Radionuclide Deterministic[c]		Single Radionuclide Deterministic[d]	
		Initial Period (mrem)	Long-term (mrem)	Initial Period (mrem)	Long-term (mrem)
ac5cam1	^{241}Am[a]	6.26×10^{-5}	1.41×10^{-6}	6.26×10^{-5}	1.31×10^{-6}
ac5cc14	^{14}C	1.61×10^{-5}	6.50×10^{-3}	1.61×10^{-5}	6.50×10^{-3}
ac5ccm4	$^{244}Cm/^{240}Pu$[b]	6.36×10^{-4}	1.23×10^{-5}	6.36×10^{-4}	1.23×10^{-5}
ac5cco0	^{60}Co	8.63×10^{-7}	8.41×10^{-6}	8.63×10^{-7}	8.41×10^{-6}
ac5ccs7	^{137}Cs	5.65×10^{-5}	1.82×10^{-3}	5.65×10^{-5}	1.82×10^{-3}
ac5ch3	^{3}H	6.45×10^{-2}	1.47×10^{-1}	6.45×10^{-2}	1.47×10^{-1}
ac5ci29	^{129}I	2.21×10^{-3}	4.31×10^{-2}	2.21×10^{-3}	4.31×10^{-2}
ac5ckr5	^{85}Kr	1.91×10^{-2}	3.94×10^{-2}	1.91×10^{-2}	3.94×10^{-2}
ac5cpu8	^{238}Pu	1.86×10^{-4}	1.13×10^{-5}	1.86×10^{-4}	1.13×10^{-5}
ac5cru6	^{106}Ru	4.25×10^{-5}	8.50×10^{-5}	4.25×10^{-5}	8.50×10^{-5}
ac5csr0	$^{90}Sr/^{90}Y$[b]	3.95×10^{-6}	1.40×10^{-5}	3.95×10^{-6}	1.40×10^{-5}

NOTES: [a] The ^{241}Am results in the deterministic all radionuclide run includes contributions as a daughter of several nuclides, such as ^{241}Pu, ^{245}Cm.
[b] Dose contributions from the implicit daughters ^{240}Pu and ^{90}Y are included with ^{244}Cm and ^{90}Sr, respectively.
[c] Results are taken from GENII run *pmdhlgrg.gid.*
[d] Results are taken from GENII runs listed in GENII Filename.

Source: Worksheet *RN_Dose* of Excel file *acute summary.xls.*

Table III - 10. Comparison of Deterministic and Stochastic TEDE Dose Results for Single Radionuclide (mrem)

GENII Filename	Radionuclide	Deterministic Results[c]	Time Period	Stochastic Results[d] Median	5th %ile	95th %ile	Mean	SD
ac5cam1	^{241}Am[a]	6.26×10^{-5}	Initial	-[e]	-	-	-	-
ac5cc14	^{14}C	6.50×10^{-3}	Long-term	7.88×10^{-3}	4.32×10^{-3}	1.89×10^{-2}	9.28×10^{-3}	4.89×10^{-3}
ac5ccm4	$^{244}Cm/^{240}Pu$[b]	6.36×10^{-4}	Initial	-	-	-	-	-
ac5cco0	^{60}Co	8.41×10^{-6}	Long-term	8.61×10^{-6}	3.37×10^{-6}	2.18×10^{-5}	9.97×10^{-6}	6.29×10^{-6}
ac5ccs7	^{137}Cs	1.82×10^{-3}	Long-term	2.17×10^{-3}	1.13×10^{-3}	5.38×10^{-3}	2.56×10^{-3}	1.41×10^{-3}
ac5ch3	^{3}H	1.47×10^{-1}	Long-term	2.52×10^{-1}	8.42×10^{-2}	7.91×10^{-1}	3.20×10^{-1}	2.36×10^{-1}
ac5ci29	^{129}I	4.31×10^{-2}	Long-term	5.21×10^{-2}	2.77×10^{-2}	1.41×10^{-1}	6.21×10^{-2}	3.81×10^{-2}
ac5ckr5	^{85}Kr	1.91×10^{-2}	Initial	-	-	-	-	-
ac5cpu8	^{238}Pu	1.86×10^{-4}	Initial	-	-	-	-	-
ac5cru6	^{106}Ru	8.50×10^{-5}	Long-term	1.04×10^{-4}	4.89×10^{-5}	2.79×10^{-4}	1.23×10^{-4}	7.20×10^{-5}
ac5csr0	$^{90}Sr/^{90}Y$[b]	1.40×10^{-5}	Long-term	1.95×10^{-5}	8.53×10^{-6}	5.87×10^{-5}	2.48×10^{-5}	1.80×10^{-5}

NOTES: [a] The ^{241}Am results in the deterministic all radionuclide run includes contributions as a daughter of several nuclides, such as ^{241}Pu, ^{245}Cm.
[b] Dose contributions from the implicit daughters ^{240}Pu and ^{90}Y are included with ^{244}Cm and ^{90}Sr, respectively.
[d] Results are deterministic taken from GENII runs listed in GENII Filename.
[d] Results are stochastic taken from GENII runs listed in GENII Filename.
[e] The calculated dose is dominated from the initial period during the acute release, which has no uncertainty input parameters associated with.

Source: Worksheet *RN_Dose* of Excel file *acute summary.xls.*

III.5.2 Input Parameter Rank Correlation Coefficients for Acute Release

The uncertainty result files (with a names of *.suf) from each of the radionuclide GENII runs are imported into 11 Excel spreadsheets for statistical analysis. Ranking of each parameter is done using Excel standard data analysis – Rank and Percentile function. The results are then saved in a new worksheet named *ranking*. Percentile results are sorted in an order of iteration and ranked in the same worksheet *ranking*. The rank correlation coefficients are calculated in the worksheet named *RCC*. The rank correlation coefficient, instead of raw (or value) correlation coefficients, is used in this uncertainty analysis because the rank correlation coefficient is less affected by a few extreme input-result pairs, as discussed in Section III.2.

The summary Table III - 11 provides results of rank correlation coefficients for each radionuclide. The yellow highlighted cells are rank correlation coefficients higher than 10%, which is determined based on the statistical significance as discussed in Section III.4.2. Based on the discussions in Section III.4.2, for 500 iterations, the rank correlation coefficients equal to or less than 0.10 absolute value are not significant at the 97.5% confidence interval. Therefore, it is convenient to use 10% as a criterion for selecting important parameters for uncertainty of calculated doses.

The green highlighted cells are high correlation input parameters that are important for at least one radionuclide. One of the input parameters highlighted is radionuclide dependent (CLFMT) and is important for three nuclides (^{137}Cs, ^{129}I and ^{106}Ru). Therefore, a total of 17 input parameters, including CLFMT counted three times, are important for dose uncertainty and are considered for further uncertainty analyses.

Table III - 11. Summary of Rank Correlation Coefficients for Single Radionuclides for an Acute Release

Radionuclide	^{241}Am	^{14}C	^{244}Cm	^{60}Co	^{137}Cs	^{3}H	^{129}I	^{85}Kr	^{238}Pu	^{106}Ru	^{90}Sr
CLVD	-	0.00	-	0.02	0.03	0.00	0.01	-	-	0.01	0.00
CLFMT	-	0.00	-	0.01	0.24	-0.01	0.23	-	-	0.26	0.09
CLBVLV	-	-0.02	-	0.00	-0.02	0.00	-0.01	-	-	-0.02	-0.01
CLBVRV	-	-0.02	-	-0.03	-0.04	-0.01	-0.03	-	-	-0.05	-0.03
CLBVAF	-	0.02	-	0.00	0.01	0.01	0.03	-	-	0.01	0.04
CLBVFR	-	-0.01	-	-0.01	-0.03	0.01	-0.02	-	-	-0.02	-0.02
CLKD	-	-0.01	-	0.01	-0.02	-0.01	-0.03	-	-	0.00	-0.03
AMBTEMP	-	0.01	-	-0.02	0.02	0.01	0.01	-	-	0.02	0.02
ABSHUM	-	-0.07	-	0.01	-0.03	-0.71	-0.05	-	-	-0.03	-0.04
XMLF	-	0.01	-	0.00	-0.01	0.02	0.00	-	-	0.01	0.01
AVALSL	-	-0.03	-	0.00	-0.02	-0.03	-0.03	-	-	-0.02	-0.02
YELDMT	-	-0.01	-	0.00	-0.10	-0.01	-0.07	-	-	-0.08	-0.03
YELDLV	-	-0.01	-	-0.03	-0.09	-0.02	-0.11	-	-	-0.10	-0.12
YELDRV	-	0.01	-	-0.02	-0.02	-0.01	-0.01	-	-	-0.02	-0.02
YELDFR	-	0.05	-	0.01	-0.01	0.02	-0.06	-	-	-0.02	-0.07
SSLDN2	-	-0.04	-	0.06	0.01	-0.04	-0.04	-	-	0.02	-0.03
WTIM	-	-0.01	-	-0.02	-0.01	-0.01	-0.01	-	-	-0.03	-0.01
RAIN	-	0.01	-	0.00	0.04	0.04	0.04	-	-	0.05	0.04

Table III - 11. Summary of Rank Correlation Coefficients for Single Radionuclides for an Acute Release

Radionuclide	^{241}Am	^{14}C	^{244}Cm	^{60}Co	^{137}Cs	^{3}H	^{129}I	^{85}Kr	^{238}Pu	^{106}Ru	^{90}Sr
THICK	-	0.04	-	0.75	0.43	0.02	0.02	-	-	0.48	0.09
MOISTC	-	0.02	-	-0.01	0.02	0.01	0.00	-	-	0.00	-0.01
BULKD	-	-0.04	-	0.06	0.02	-0.04	-0.04	-	-	0.02	-0.03
VLEACH	-	0.02	-	0.02	0.02	-0.01	0.02	-	-	0.01	0.02
LEAFRS	-	0.02	-	0.00	-0.01	-0.01	0.00	-	-	-0.01	0.01
DPVRES	-	0.01	-	0.02	0.02	0.03	-0.01	-	-	0.01	-0.01
SLDNA	-	0.01	-	-0.58	-0.33	0.01	-0.01	-	-	-0.37	-0.08
SURCM	-	0.04	-	0.75	0.43	0.02	0.02	-	-	0.48	0.09
BIOMAMT	-	-0.01	-	0.00	-0.10	-0.01	-0.07	-	-	-0.08	-0.03
BIOMALV	-	-0.01	-	-0.03	-0.09	-0.02	-0.11	-	-	-0.10	-0.12
BIOMARV	-	0.01	-	-0.02	-0.02	-0.01	-0.01	-	-	-0.02	-0.02
BIOMAFR	-	0.05	-	0.01	-0.01	0.02	-0.06	-	-	-0.02	-0.07
DRYFAMT	-	0.03	-	0.03	0.01	0.01	0.00	-	-	0.01	-0.01
DRYFALV	-	0.01	-	0.01	0.05	0.01	0.08	-	-	0.05	0.09
DRYFARV	-	-0.02	-	0.00	0.02	0.01	0.02	-	-	0.02	0.03
DRYFAFR	-	-0.01	-	0.01	0.03	0.00	0.03	-	-	0.03	0.05
SOILKD	-	-0.01	-	0.01	-0.02	-0.01	-0.03	-	-	0.00	-0.03
UEXAIR	-	-0.03	-	0.00	-0.01	0.00	-0.01	-	-	0.00	-0.01
FTIN	-	-0.01	-	0.02	0.03	-0.02	-0.01	-	-	0.03	-0.02
FTOUT	-	-0.01	-	0.02	0.03	0.00	0.02	-	-	0.03	0.01
UCRPLV	-	0.00	-	0.01	0.04	0.02	0.08	-	-	0.06	0.10
UCRPRV	-	0.04	-	0.00	0.03	0.04	0.03	-	-	0.04	0.05
UCRPFR	-	0.04	-	-0.01	0.00	0.01	0.01	-	-	0.00	0.02
TCRPLV	-	0.34	-	0.07	0.52	0.24	0.78	-	-	0.49	0.83
TCRPRV	-	0.37	-	0.02	0.08	0.25	0.13	-	-	0.06	0.14
TCRPFR	-	0.42	-	0.04	0.19	0.49	0.27	-	-	0.16	0.31
UANMMT	-	0.03	-	0.01	0.02	0.01	0.02	-	-	0.01	0.02
TANMMT	-	0.57	-	0.05	0.30	0.13	0.22	-	-	0.16	0.07
FRINHR	-	-0.02	-	0.00	-0.01	0.00	-0.01	-	-	-0.01	0.00
SOILT	-	0.04	-	0.75	0.43	0.02	0.02	-	-	0.48	0.09
SSLDN1	-	-0.04	-	0.06	0.01	-0.04	-0.04	-	-	0.02	-0.03

NOTES: Green highlights indicate high correlation input parameters that are important for at least one radionuclide. Yellow highlights indicate rank correlation coefficients higher than 10% absolute value.

"-" indicates that calculated dose has no uncertainty, and no ranking correlation coefficients are calculated.

Source: Worksheet *RN_RCC* of Excel file *acute summary.xls*

III.5.3 Uncertainty Analysis for Acute Release

The 17 input parameters with high correction identified in Table III - 11 are used with three acute release runs, including all their radionuclides. The distribution and standard deviation for the calculated dose is determined. In addition, a number of important input parameters are further reduced based on the rank correlation coefficients calculated from those scenarios.

The selected acute release scenarios for uncertainty analysis are 1) PWR burst rupture with HEPA filtration, 2) PWR oxidation release with HEPA filtration, and 3) HLW SRS burst runs.

They are the same as used for radionuclide screening and pathway analyses for Category 1 and Category 2 event sequences in Section III.3.1. Other two acute scenarios (HEPA Seismic and LLW Seismic in Table III - 1) are not selected, because they are dominated by inhalation and external exposure (Table III-2). Their GENII files are *pmdhlgrg.gid*, *pmohlgrg.gid*, and *hsdhlgrg.gid*, respectively. A SUM^3 module is added to each GENII file.

Similar to single radionuclide analysis for acute releases discussed in Section III.5.1, uncertainty analyses select the peak dose in either the initial or long-term time periods. If the initial period dose is larger than the long-term dose, the scenario uncertainty is considered low because the dominant parameters for the initial release are fixed without distributions. That is true for two scenarios, (*pmohlgrg.gid* and *hsdhlgrg.gid*), as shown in Table III - 12. The number of uncertain parameters is based on the results in Table III - 11. All calculations are based on 500 iterations with a random seed number of 1.

The uncertain parameter, Julian hour (JHOUR) that accounts for seasonality of the release, is also included in one scenario (*pmdhlgrg.gid*) as shown in Table III - 12. This parameter does not change the dose very much in this scenario, because ^3H is the major dose contributor (Table III - 1, column PWR Burst), and it is not seasonally dependent.

The results indicate that the uncertainty of the calculated dose for the acute release scenario is larger than those for the chronic release scenario with a ratio of less than three between the 95^{th} percentile and median values (see Table III - 12). This is due to the seasonality effect (JHOUR) and the long-term exposure period considered in which the ingestion pathway becomes more important. In addition, a comparison between the the deterministic and stochastic calculations indicates that the median dose calculated from the stochastic run is higher (up to 38%) than the deterministic result for the case without JHOUR included (see Table III - 12). This is because some high correlation input parameters have lognormal distributions, and geometric means instead of arithmetic means of the lognormal distributions are used for the deterministic calculations.

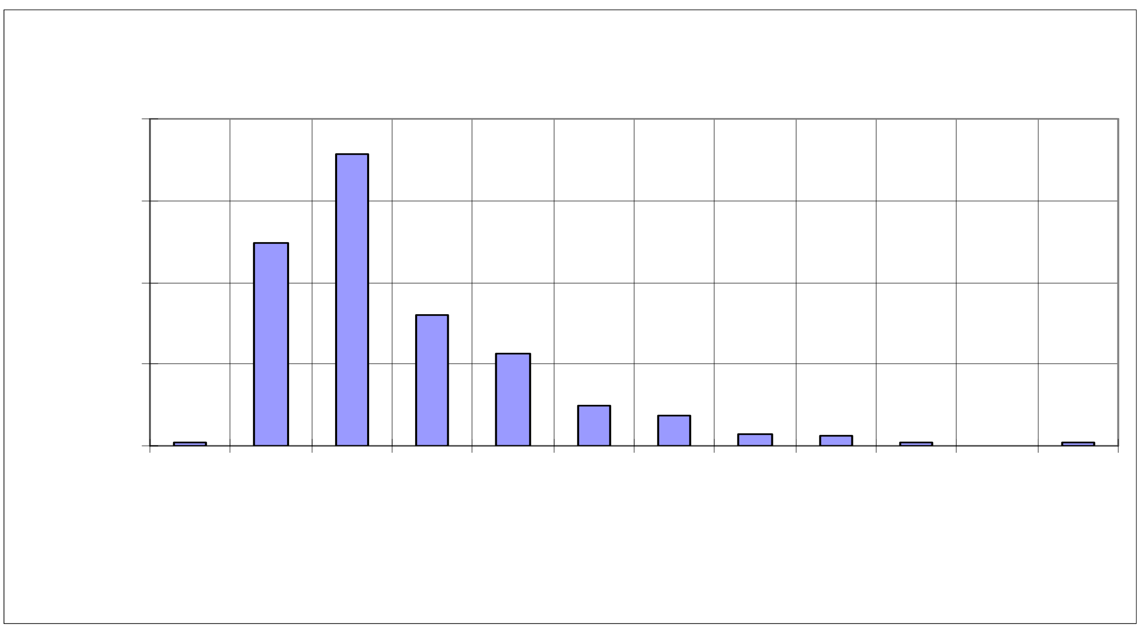
The distribution of calculated doses for the PWR burst rupture acute release sceanrio with HEPA filtration is shown in Figure III-2. Note that the distribution in Figure III-2 is based on a 1-year, long-term exposure period rather than the 30-day period used in the consequence analyses. Because the dominant input parameters for the initial time period are fixed without distributions, the distribution for a 30-day period would be narrower than that shown in Figure III-2 with a 1-year, long-term exposure period.

Table III - 12. Radiation Dose (mrem) Distributions for Acute Release Scenarios

Filename	pmdhlst	pmdhlstj	pmohlst	hsdhlst
Base file	pmdhlgrg.gid	pmdhlgrg.gid	pmohlgrg.gid	hsdhlgrg.gid
With Jhour	No	Yes	No	No
Initial period	8.73×10^{-2}	8.73×10^{-2}	9.86×10^{-3}	1.53×10^{-1}
Long-term period	2.39×10^{-1}	2.39×10^{-1}	5.47×10^{-3}	4.83×10^{-2}
Time period	Long-term period		Initial period	Initial period
Median	3.30×10^{-1}	2.80×10^{-1}	-	-
5^{th} %ile	1.41×10^{-1}	1.07×10^{-1}	-	-
95^{th} %ile	8.58×10^{-1}	7.79×10^{-1}	-	-
Mean	3.92×10^{-1}	3.47×10^{-1}	-	-
STD	2.38×10^{-1}	2.39×10^{-1}	-	-
Ratio of 95th/median	2.6	2.8	-	-
Stochastic (Median) / Deterministic (Long)	1.38	1.17	-	-

Source: Worksheet *Acute_Dose* of Excel file *acute summary.xls*

"-" indicates that calculated dose is dominated from the initial period during the acute release, which has no uncertainty input parameters associated with



(Source: Worksheet *pmdhlst5* of Excel file *pmdhlst5.xls*)

Figure III - 2. TEDE Dose Distribution for PWR Burst Rupture Acute Release

The calculated rank correlation coefficients for the acute release scenarios are shown in Table III - 13. Similar to single radionuclide runs in Table III - 11, the yellow highlighted cells are the rank correlation coefficients higher than 10% abusolute value, and the five green highlighted cells are important parameters for uncertainty of calculated dose for the PWR burst rupture acute release scenario with HEPA filtration. As can be seen from Table III - 13, the important input parameter list depends on the acute release scenario. As discussed in Section III.4.2, the 10% criterion for the rank correlation coefficients is selected based on the statisitical significance with 500 iterations at the 97.5% confidence interval.

Table III - 13. Summary of Rank Correlation Coefficients for Acute Release Scenarios

Filename	pmdhlst	pmdhlstj	pmohlst	hsdhlst
Base file	pmdhlgrg.gid	pmdhlgrg.gid	pmohlgrg.gid	hsdhlgrg.gid
With Jhour	No	Yes	No	No
CLFMTCS	0.01	0.01	-	-
CLFMTI	0.02	0.01	-	-
CLFMTRU	0.03	0.00	-	-
JHOUR	-	0.07	-	-
ABSHUM	-0.63	-0.68	-	-
YELDMT	-0.02	-0.03	-	-
YELDLV	0.00	0.02	-	-
THICK	0.01	0.03	-	-
SLDNA	0.02	0.00	-	-
SURCM	0.01	0.03	-	-
BIOMAMT	-0.02	-0.03	-	-
BIOMALV	0.00	0.02	-	-
UCRPLV	0.06	0.01	-	-
TCRPLV	0.34	0.26	-	-
TCRPRV	0.22	0.24	-	-
TCRPFR	0.50	0.50	-	-
TANMMT	0.17	0.11	-	-
SOILT	0.01	0.03	-	-

NOTES: Green highlights indicate high correlation input parameters for case PWR burst rupture with HEPA filtration (based on pmdhlgrg.gid).

Yellow highlights indicate rank correlation coefficients higher than 10% absolute value.

"-" indicates that calculated dose has no uncertainty, and no ranking correlation coefficients are calculated.

Source: Worksheet *Acute_RCC* of Excel file *acute summary.xls.*

III.6 CONCLUSIONS

The preclosure consequence analysis for worker and public doses is performed using a deterministic methodology with fixed values of input parameters. The fixed values include conservative or bounding values for such parameters as the material at risk, damage ratios, airborne release and respirable fractions, leak path factors and atmospheric dispersion factors that reduce the overall uncertainty. For other parameters that model offsite radionuclide transport in the environment and receptor exposure and have available developed distributions, mean or geometric mean values of their distributions are used.

The preclosure consequence analysis for worker and onsite public doses is dominated by direct radiation and inhalation exposures. The methodology for both those pathways is based on fixed parameters with conservative or bounding values with no associated uncertainty distributions. The doses provided in Table 69 for demonstrating compliance with the performance objectives for those categories are already bounding values.

For offsite public doses, the uncertainty analysis is performed for both chronic and acute release scenarios that use a combination of the fixed conservative parameters and those based on developed distributions. The majority of those distribution-based parameters are related to the ingestion dose pathway and therefore uncertainties for scenarios without significant contributions from ingestion are low. The following conclusions can be drawn from this uncertainty analysis for the offsite release scenarios evaluated:

1. The offsite doses provided in Table 69 for demonstrating compliance with the performance objectives are based on the deterministic methodology described in Section 4.3 using fixed values of input parameters. Because many of those fixed values are conservative or bounding, the doses shown would be higher than the mean or median values if all distribution-based parameters were used. Even with the conservatisms, all of the offsite doses provided in Table 69 are orders of magnitude below the performance objectives.

2. For the offsite chronic release scenario, the ratio between the 95th percentile and median values from uncertainty analysis is about two. The offsite TEDE dose in Table 69 is 0.02 mrem/yr for an individual in the general environment that includes the ingestion pathway. Even with a factor of two for a 95th percentile level, the dose is still orders of magnitude below the performance objectives.

3. For the offsite acute release scenarios, the ratio between the 95th percentile and median values from uncertainty analysis is about three. The offsite TEDE dose in Table 69 is less than 0.01 mrem per event for an individual in the general environment that includes the ingestion pathway. Even with a factor of three for a 95th percentile level, the dose is still orders of magnitude below the performance objectives.

4. For offsite public acute release scenarios, the dose consists of two portions, a short-term dose and long-term dose due to radionuclides in the environment following the short-term release. The short-term dose is dominated by the inhalation pathway. There is no uncertainty in the short-term dose methodology because the inhalation pathway dose is based on fixed parameters with conservative or bounding values.

5. For offsite acute release scenario long-term doses where the ingestion pathway is a significant contributor, the preclosure consequence analysis dose results using the deterministic methodology are within 40% of the median values from the stochastic calculation (Table III - 12). This similarity in results is expected because the high

correlation input parameters for the stochastic calculations (e.g. TCRPLV, TCRPRV and TCRPFR) have lognormal distributions, and geometric means of the lognormal distributions are used in the deterministic calculation.

6. For the offsite chronic release scenario, the preclosure consequence analysis dose result using the deterministic methodology is within 10% of the median values from the stochastic calculation (Table III - 7). This similarity in results is expected for the same reasons as the offsite acute release scenario.

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APPENDIX IV OFF-NORMAL EVENT – LOW-LEVEL LIQUID WASTE SPILL

Low-level liquid waste is processed at the repository using mobile processing equipment. Once the mobile processing equipment is brought onsite, it is placed near the low-level waste tank and connected to the tank. A potential event leading to radiation exposure is a break or misconnection of the hose resulting in a low-level waste spill. A calculation is performed in this appendix to determine the radiological consequences to radiation workers near the spill.

IV.1 ASSUMPTIONS NOT REQUIRING VERIFICATION

IV.1.1 Amount of Low-level Liquid Waste Spilled

Assumption: All of the contents of the low-level waste tank are spilled on the ground due to the break or misconnection.

Rationale: This is a bounding assumption because it assumes that the tank is full and that no credit is taken for operator action limiting the spill by shutting off valves or taking other mitigating actions.

IV.1.2 Spill Rate from the Break or Misconnection

Assumption: A nominal flow rate of 100 gallons per minute (gpm) is used for the spill through the break

Rationale: The dose from the initial spill is a linear function of both the airborne concentration and the duration of the spill. The airborne concentration is directly proportional to the flow rate, while the duration of the spill is inversely proportional to the flow rate; therefore, the flow rate of the spill does not affect the resultant dose.

IV.1.3 Depth of Final Spill Pond

Assumption: The depth of the spill is 1 cm.

Rationale: NUREG-0570 (Reference 2.2.54, p. 5) states that in most cases the area of the spill cannot be easily computed. In these cases, the maximum area of the spill is estimated from the initial volume by assuming a spill thickness of 1 cm. This minimum thickness is realistic yet still conservative.

IV.1.4 Wind Speed over the Spill

Assumption: The wind speed over the spill is 1 m/s.

Rationale: Lower wind speeds would result in higher concentration in the immediate vicinity of the spill since the air is not clearing out the airborne releases as fast. Although higher wind speeds would increase the evaporation release from the spilled liquid, the contribution to the dose from this phase of the event is negligible to the contribution from the initial spill or the shine from the ground contamination (see Section IV.4).

IV.1.5 Duration of Exposure

Assumption: A radiation worker remains near the spill and is exposed to the released radioactive materials for the duration of a work day (8 hours).

Rationale: In the event of a spill, radiation workers in the area would be evacuated and mitigating measures would be taken to limit the exposure. It is bounding to assume that no such actions will be taken and the workers remain for a full work day without any personal protective equipment.

IV.2 DESIGN INPUTS

IV.2.1 Low-level Liquid Waste Tank Volume

The low-level liquid waste tank volume is 23,750 gallons (Design Input 6.1.1.5).

IV.2.2 Radionuclide Concentrations

The radionuclide concentrations in the low-level liquid waste tank are: 1×10^{-3} Ci/m^3 for ^{60}Co and 1.5×10^{-3} Ci/m^3 for ^{137}Cs (Design Input 6.1.1.6).

IV.2.3 Dose Coefficients

Air submersion and ground plane shine dose coefficients are obtained from Federal Guidance Report 13 (Reference 2.2.44). The inhalation dose coefficients are obtained from ICRP-68 (Reference 2.2.55) using the ICRP database (Software Tracking Number: 610362-2.01-00) (Reference 2.2.56). The inhalation dose coefficients are based on the solubility classes of “slow” for cobalt and “fast” for cesium (Reference 2.2.10, Table 107).

Pathway	^{137}Cs	^{60}Co	Units
Air Submersion[a]	9.28×10^{-17}	1.19×10^{-13}	Sv m^3 Bq^{-1} s^{-1}
Ground Plane Shine[a]	2.99×10^{-18}	2.30×10^{-15}	Sv m^2 Bq^{-1} s^{-1}
Inhalation[b]	4.80×10^{-9}	2.90×10^{-8}	Sv Bq^{-1}

Source: [a] Reference 2.2.44, [b] Reference 2.2.55 and 2.2.56

IV.2.4 Breathing Rate

The breathing rate of a radiation worker is 3.5×10^{-4} m^3/s (Design Input 6.1.6.1).

IV.3 METHODOLOGY/CALCULATION

The exposure from a low-level liquid waste spill may be from three phases: (1) the initial spill phase; (2) spray release from the resulting pond, and (3) resuspension and shine from ground contamination.

IV.3.1 Initial Spill

Exposure from the initial spill is due to suspension of material splashing on the ground surface and suspension due to turbulence from flow of liquid from the break. This airborne material is then swept by the wind over the surface. To determine the air concentration that an individual may be subjected to, the airborne release is considered to enter a volume of air that may be occupied by a worker nearby (roughly 1 m × 1 m in area and a height of 2 m). The concentration inside this volume can be determined as:

$$\frac{dC}{dt} = \frac{R}{a^2 h} - \frac{w \cdot ah}{a^2 h} C \qquad \text{Equation 23}$$

where

C	=	airborne concentration (Ci/m^3)
R	=	release rate from the spill (Ci/s)
a	=	length and width of the air volume (1 m)
h	=	height of the air volume (2 m)
w	=	wind speed (m/s)

In equilibrium, Equation 23 reduces to:

$$0 = \frac{R}{a^2 h} - \frac{w \cdot ah}{a^2 h} C$$

$$\frac{R}{a^2 h} = \frac{w \cdot ah}{a^2 h} C \qquad \text{Equation 24}$$

$$C = \frac{R}{ahw}$$

The inhalation dose is calculated using Equation 2 and the air submersion dose is calculated using Equation 6. The term $\frac{ST_j}{\Delta t} \times \frac{\chi}{Q}$ in both equations is replaced with the concentration determined using Equation 24.

The release rate from the break is the flow rate through the break multiplied by the concentration in the tank, the ARF and the RF. From DOE-HDBK-3010-94 (Reference 2.2.21, Section 3.2.3.1) for a free-fall spill of solutions with a density near 1, a bounding ARF is 2×10^{-4} with an RF of 0.5. From Assumption IV.1.2, the flow rate from the break is 100 gpm (6.31×10^{-3} m^3/s). The release rate is then:

$$R\left({}^{137}Cs\right) = 6.31\times10^{-3} \times 1.5\times10^{-3} \times 2\times10^{-4} \times 0.5 = 9.47\times10^{-10}\ Ci \cdot s^{-1}$$

$$R\left({}^{60}Co\right) = 6.31\times10^{-3} \times 1.0\times10^{-3} \times 2\times10^{-4} \times 0.5 = 6.31\times10^{-10}\ Ci \cdot s^{-1}$$

Using a wind speed of 1 m/s (Assumption IV.1.4) the air concentration is:

$$C\left({}^{137}Cs\right) = \frac{9.47\times10^{-10}}{1\times1\times2} = 4.73\times10^{-10}\ Ci\cdot m^{-3}$$
$$C\left({}^{60}Co\right) = \frac{6.31\times10^{-10}}{1\times1\times2} = 3.16\times10^{-10}\ Ci\cdot m^{-3}$$

The duration of this phase is the time it takes to completely empty the tank (Assumption IV.1.1). From Assumption IV.1.2 the flow rate is 100 gpm. From Section IV.2.1 the tank volume is 23,750 gal. Therefore, the time to empty the tank is:

$$T = 23{,}750 \div 100 = 237.5\,\text{min} = 14{,}250\ \text{sec}$$

The inhalation dose, calculated using Equation 2 is:

$$\begin{aligned}
D^{inh}_{j,effective} &= C_j \times T \times BR \times conv \times DCF^{inh}_{j,effective} \\
D^{inh}_{Cs137,effective} &= 4.73\times10^{-10}\times14{,}250\times3.7\times10^{12}\times3.5\times10^{-4}\times4.80\times10^{-9} \\
&= 4.19\times10^{-5}\ rem = 4.19\times10^{-2}\ mrem \\
D^{inh}_{Co60,effective} &= 3.16\times10^{-10}\times14{,}250\times3.7\times10^{12}\times3.5\times10^{-4}\times2.90\times10^{-8} \\
&= 1.69\times10^{-4}\ rem = 1.69\times10^{-1}\ mrem
\end{aligned}$$

The total inhalation dose is then 2.11×10^{-1} mrem.

The air submersion dose, calculated using Equation 6 is:

$$\begin{aligned}
D^{sub}_{j} &= C_j \times T \times conv \times DCF^{sub}_{j} \\
D^{sub}_{Cs137} &= 4.73\times10^{-10}\times14{,}250\times3.7\times10^{12}\times9.28\times10^{-17} \\
&= 2.32\times10^{-9}\ rem = 2.32\times10^{-6}\ mrem \\
D^{sub}_{Co60} &= 3.16\times10^{-10}\times14{,}250\times3.7\times10^{12}\times1.19\times10^{-13} \\
&= 1.98\times10^{-6}\ rem = 1.98\times10^{-3}\ mrem
\end{aligned}$$

The total air submersion dose is then 1.98×10^{-3} mrem.

The total dose from the initial spill phase is the sum of the inhalation dose and the air submersion dose, or 2.13×10^{-1} mrem.

IV.3.2 Spray Release from Resultant Pond

Liquid can be made airborne by the passage of air over its surface. An empirical formula for determining the air concentration over a large outdoor pool is presented in DOE-HDBK-3010-94 (Reference 2.2.21, Section 3.2.4.1) as:

$$C_{air} = C_{water} \times 3 \times 10^{-11} \times 10^{0.098039\ w} \qquad \text{Equation 25}$$

where

C_{air}	=	airborne concentration (Ci/m^3)
C_{water}	=	concentration in the water (Ci/m^3)
w	=	wind speed (m/s)

Using a wind speed of 1 m/s (Assumption IV.1.4) the air concentration is:

$$C\left({}^{137}Cs\right) = 1.5 \times 10^{-3} \times 3 \times 10^{-11} \times 10^{0.098039 \cdot 1} = 5.64 \times 10^{-14}\ Ci \cdot m^{-3}$$
$$C\left({}^{60}Co\right) = 1.0 \times 10^{-3} \times 3 \times 10^{-11} \times 10^{0.098039 \cdot 1} = 3.76 \times 10^{-14}\ Ci \cdot m^{-3}$$

Per Assumption IV.1.5 the duration of the exposure is 8 hours or 28,800 s.

The inhalation dose, calculated using Equation 2 is:

$$D_{j,k}^{inh} = C_j \times T \times BR \times conv \times DCF_{j,k}^{inh}$$
$$D_{Cs137,k}^{inh} = 5.64 \times 10^{-14} \times 28{,}800 \times 3.7 \times 10^{12} \times 3.5 \times 10^{-4} \times 4.80 \times 10^{-9}$$
$$= 1.01 \times 10^{-8}\ rem = 1.01 \times 10^{-5}\ mrem$$
$$D_{Co60,k}^{inh} = 3.76 \times 10^{-14} \times 28{,}800 \times 3.7 \times 10^{12} \times 3.5 \times 10^{-4} \times 2.90 \times 10^{-8}$$
$$= 4.07 \times 10^{-8}\ rem = 4.07 \times 10^{-5}\ mrem$$

The total inhalation dose is then 5.08 × 10^{-5} mrem.

The air submersion dose, calculated using Equation 6 is:

$$D_j^{sub} = C_j \times T \times conv \times DCF_j^{sub}$$
$$D_{Cs137}^{sub} = 1.33 \times 10^{-12} \times 28{,}800 \times 3.7 \times 10^{12} \times 9.28 \times 10^{-17}$$
$$= 5.58 \times 10^{-13}\ rem = 5.58 \times 10^{-10}\ mrem$$
$$D_{Co60}^{sub} = 8.87 \times 10^{-13} \times 28{,}800 \times 3.7 \times 10^{12} \times 1.19 \times 10^{-13}$$
$$= 4.77 \times 10^{-10}\ rem = 4.77 \times 10^{-7}\ mrem$$

The total air submersion dose is then 4.77 × 10^{-7} mrem.

The total dose from the spray release from the pond phase is the sum of the inhalation dose and the air submersion dose, or 5.12 × 10^{-5} mrem.

IV.3.3 Resuspension from Ground Contamination

Once the resultant pond has evaporated, the contaminants spread over the surface of the ground that the pond covered. A worker can be exposed to airborne contaminants that are re-suspended and from direct shine from the contaminated ground.

The area of the spill can be calculated by the volume spilled divided by the depth of the pool. Per Assumption IV.1.1, the total volume of the tank is spilled, or 23,750 gallons (89.92 m^3). Per Assumption 2.1.3, the depth of the pool is 1 cm. Therefore, the total area of the spill is 8,992 m^2. Assuming that the spill is circular, the radius of the spill is 53.50 m.

The total activity available for ground contamination and airborne release is the activity in the tank (the activity released in the previous two phases is negligible compared with the total activity available). Therefore, the total activity of ^{137}Cs is 1.5×10^{-3} Ci/m^3 × 89.92 m^3 = 0.135 Ci. The total activity of ^{60}Co is 1.0×10^{-3} Ci/m^3 × 89.92 m^3 = 0.0899 Ci.

The ground concentration is then the total activity divided by the spill surface area. For ^{137}Cs the ground concentration is 0.135 Ci ÷ 8,992 m^2 = 1.5×10^{-5} Ci/m^2. For ^{60}Co the ground concentration is 0.0899 Ci ÷ 8,992 m^2 = 1.0×10^{-5} Ci/m^2.

DOE-HDBK-3010-94 (Reference 2.2.21, p. 4-101) provides a bounding resuspension rate of powder exposed to ambient condition to be 4×10^{-5} hr^{-1}. Therefore, the resuspension rate (or release rate) for ^{137}Cs is 0.135 Ci × 4×10^{-5} hr^{-1} = 5.40×10^{-6} Ci/hr or 1.50×10^{-9} Ci/s. For ^{60}Co the resuspension rate is 0.0899 Ci × 4×10^{-5} hr^{-1} = 3.60×10^{-6} Ci/hr or 9.99×10^{-10} Ci/s.

Using Equation 24, a wind speed of 1 m/s (Assumption IV.1.4), a width equal to the radius of the spill, and a height of 2 meters, the air concentration is:

$$C\left({}^{137}Cs\right) = \frac{1.50 \times 10^{-9}}{1 \times 53.5 \times 2} = 1.40 \times 10^{-11}\ Ci \cdot m^{-3}$$

$$C\left({}^{60}Co\right) = \frac{9.99 \times 10^{-10}}{1 \times 53.5 \times 2} = 9.34 \times 10^{-12}\ Ci \cdot m^{-3}$$

Per Assumption IV.1.5 the duration of the exposure is 8 hours or 28,800 s.

The inhalation dose, calculated using Equation 2 is:

$$D_{j,k}^{inh} = C_j \times T \times BR \times conv \times DCF_{j,k}^{inh}$$

$$D_{Cs137,k}^{inh} = 1.40 \times 10^{-11} \times 28{,}800 \times 3.7 \times 10^{12} \times 3.5 \times 10^{-4} \times 4.80 \times 10^{-9}$$

$$= 2.51 \times 10^{-6}\ rem = 2.51 \times 10^{-3}\ mrem$$

$$D_{Co60,k}^{inh} = 9.34 \times 10^{-12} \times 28{,}800 \times 3.5 \times 10^{-4} \times 3.77 \times 10^{4}$$

$$= 1.01 \times 10^{-5}\ rem = 1.01 \times 10^{-2}\ mrem$$

The total inhalation dose is then 1.26×10^{-2} mrem.

The air submersion dose, calculated using Equation 6 is:

$$\begin{aligned}
D_j^{sub} &= C_j \times T \times conv \times DCF_j^{sub} \\
D_{Cs137}^{sub} &= 1.40 \times 10^{-11} \times 28{,}800 \times 3.7 \times 10^{12} \times 9.28 \times 10^{-17} \\
&= 1.39 \times 10^{-10}\ rem = 1.39 \times 10^{-7}\ mrem \\
D_{Co60}^{sub} &= 9.34 \times 10^{-12} \times 28{,}800 \times 3.7 \times 10^{12} \times 1.19 \times 10^{-13} \\
&= 1.18 \times 10^{-7}\ rem = 1.18 \times 10^{-4}\ mrem
\end{aligned}$$

The total air submersion dose is then 1.19×10^{-4} mrem.

The ground shine dose is calculated using Equation 5 with the ground plane concentration calculated above substituting the term $C_j^{grd} \times \rho \times d$:

$$\begin{aligned}
D_j^{grd} &= C^{grd} \times T \times conv \times DCF_j^{grd} \\
D_{Cs137}^{grd} &= 1.5 \times 10^{-5} \times 28{,}800 \times 3.7 \times 10^{12} \times 2.99 \times 10^{-18} \\
&= 4.78 \times 10^{-6}\ rem = 4.78 \times 10^{-3}\ mrem \\
D_{Co60}^{grd} &= 1.0 \times 10^{-5} \times 28{,}800 \times 3.7 \times 10^{12} \times 2.30 \times 10^{-15} \\
&= 2.45 \times 10^{-3}\ rem = 2.45\ mrem
\end{aligned}$$

The total dose from ground shine is then 2.46 mrem.

The total dose from all pathways for the resuspension from ground contamination phase is 2.47 mrem.

IV.4 RESULTS AND CONCLUSIONS

The total dose to a worker from a spill of low-level liquid waste is the sum of the dose from the initial spill, the release from the pond, and the resuspension from the ground contamination. The total dose is:

Phase	Dose (mrem)
Initial spill	2.13×10^{-1}
Spray release from resultant pond	5.12×10^{-5}
Resuspension from ground contamination	2.47
Total	2.7

The above results show that shine from ground contamination is by far the most significant contributor to the total dose. The other pathways are negligible. These results also indicate that this event can be classified as an off-normal event since the consequences to a worker are a small fraction of the performance objectives.

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APPENDIX V OFF-NORMAL EVENT – DROP OF SOLID WASTE

Low-level radioactive waste is temporarily stored in the LLWF. If a radioactive waste container were dropped during placement, container failure could occur resulting in a release of radioactive waste. This appendix determines the potential radiological consequences to a radiation worker in the LLWF from such an event. There are two scenarios considered: (1) the drop of a drum containing DAW, and (2) the drop of non-WHF HEPA filters in a B-25 box. For these two scenarios, the release of radioactive material from the facility to the environment is not significant because of the small amount of radioactive material released and the atmospheric dispersion to potential receptors in other facilities.

V.1 ASSUMPTIONS NOT REQUIRING VERIFICATION

V.1.1 Airborne Release Fraction and Respirable Fraction for the Drop of DAW

Assumption: The ARF and RF for the drop of DAW in a drum are 1×10^{-3} and 0.1, respectively.

Rationale: The ARF and RF values for the drop of a DAW drum are based on DOE-HDBK-3010-94 (Reference 2.2.21, Section 5.2.3.2), for the situation where the combustible material is packaged in a reasonably robust container (e.g., a drum) that fails due to impact. The bounding ARF and RF values given in the Handbook for this situation are 1×10^{-3} and 0.1. These values are the same as those assigned to the suspension of powder in a can due to debris impact (Reference 2.2.21, Section 4.4.3.3.2), which bounds this scenario.

V.1.2 Airborne Release Fraction and Respirable Fraction for the Drop of a non-WHF HEPA filter

Assumption: The ARF and RF for the drop of non-WHF HEPA filter in a container are 5×10^{-4} and 1, respectively

Rationale: The ARF and RF values for the drop of a non-WHF HEPA filter container are based on DOE-HDBK-3010-94 (Reference 2.2.21, Section 5.4.4.1) for enclosed HEPA filter media. The Handbook reports two sets of test results that show the ARF ranges from 1×10^{-5} to 5×10^{-5}. The recommended bounding ARF and RF values are given as 5×10^{-4} and 1, which include an additional order of magnitude increase over the ARF imposed on the test results for uncertainties. Consequently, the bounding Handbook ARF and RF values of 5×10^{-4} and 1 are appropriate for this scenario.

V.1.3 Location of Drum/Box/Container Drop and Dispersion of Radioactive Material

Assumption: A drum, box, or container is dropped in a staging room in the LLWF, and the released radioactive material is uniformly mixed with air in the staging rooms and packaging area without ventilation.

Rationale: A drop of a drum, box, or container is more likely to occur during placement in a staging room than in any other area of the LLWF. The staging rooms are relatively confined spaces without a ceiling where released radioactive material will most likely mix with the room air in a short period of time. Furthermore, the assumption that the ventilation system does not remove radionuclides from a staging room is a conservative approach, because all staging rooms have an open ceiling and releases would be mixed in a much larger volume.

V.1.4 Radionuclides in Non-WHF HEPA Filter

Assumption: The radionuclides on a non-WHF HEPA filter are represented by ^{60}Co for β-γ emitters and ^{241}Am for α emitters.

Rationale: The radionuclides present on a non-WHF HEPA filter are not specified in Section 6.3.4.1. Nevertheless, this assumption is conservative because the inhalation dose coefficients for these two radionuclides are the highest among the radionuclides in their respective categories.

V.1.5 Staging Room Volume

Assumption: The volume of a staging room for determining the post-drop radioactive material concentration is 850 m^3.

Rationale: A staging room is an open ceiling room with floor dimensions about 50 feet by 30 feet (Reference 2.2.26, 160-P10-LW00-00102-000-00A) containing a number of drums, boxes, or containers of staged waste. The room walls are shield walls about 20 feet high (Reference 2.2.58, 160-P10-LW00-00105-000-00A). In a drop event, the released material would be drawn out of the room by the ventilation system and would have the entire LLWF volume to disperse into. In this calculation, the room volume is determined as if there were a ceiling at the wall height and there were no removal by the ventilation system (i.e., volume = 50 ft × 30 ft × 20 ft = 30,000 ft^3, or 850 m^3). This is a very conservative approach because radionuclide concentrations calculated in this assumed staging room volume are much higher than those that would be calculated for the entire LLWF. Consequently, no reduction in the net volume of the room for any contained waste is deemed necessary

V.1.6 Worker Exposure Time

Assumption: After a drop event, a radiation worker remains in the staging room for one hour.

Rationale: It is likely that, following a drop accident, a radiation worker who has been trained in handling radioactive material, would evacuate the area immediately. It is also considered unlikely that a simple drop event would produce a condition where evacuation paths would be blocked for an extended period. Therefore, the use of a one hour exposure time is conservative, allowing more than enough time for the worker to safely exit the room after the event.

V.2 DESIGN INPUTS

V.2.1 Radionuclide Concentrations

The radionuclide concentrations for the DAW are taken from Design Input 6.1.1.6 and are shown in Table V - 1 below.

Table V - 1. Radionuclide Concentrations for the DAW

Radionuclide	DAW Concentration (Ci/m^3)
^{58}Co	5.59×10^{-3}
^{60}Co	1.42×10^{-2}
^{134}Cs	6.30×10^{-3}
^{137}Cs	7.13×10^{-3}
^{54}Mn	7.32×10^{-4}

Source: Design Input 6.1.1.6.

The total activity accumulated on a non-WHF HEPA filter for an 18 month period is estimated as 29.5 μCi in Section 6.3.4.1. That value is based on contamination levels where the β-γ emitter activity is 10 times the α emitter activity. Therefore, the non-WHF HEPA filter β-γ emitter activity is 26.8 μCi (treated as all ^{60}Co per Assumption V.1.4) and the α emitter activity is 2.7 μCi (treated as all ^{241}Am per Assumption V.1.4).

V.2.2 DAW Unit Waste Volumes

For DAW, the contained activity is expressed in Section V.2.1 in units of Ci/m^3, so unit waste volumes are required to determine the total activity. Unit waste volumes are calculated in Section 6.3.4.2. A 55-gallon drum contains 0.267 m^3 of DAW. For a non-WHF HEPA filter, Section V.2.1 gives the total contained activity for one filter, and a B-25 box contains 12 filters.

V.2.3 Dose Coefficients

Workers in the vicinity of a drum, box, or container drop are exposed to radioactive materials through the air submersion and inhalation pathways. Air submersion dose coefficients are obtained from Federal Guidance Report 13 (Reference 2.2.44). The inhalation dose coefficients are obtained from ICRP-68 (Reference 2.2.55) using the ICRP database (Software Tracking Number 610362-2.01-00) (Reference 2.2.56). The inhalation dose coefficients, which are selected based on the lung solubility class recommended in Reference 2.2.10 (Table 107), are for a particle size of 1 micron, which is conservative.

Table V - 2. Dose Coefficients and Lung Solubility

Radionuclide	Inhalation Dose Coefficients [a] (Sv/Bq)	Lung Solubility Class [b]	Air Submersion Dose Coefficients [c] (Sv/s)/(Bq/m^3)
^{58}Co	2.0×10^{-9}	slow	4.45×10^{-14}
^{60}Co	2.9×10^{-8}	slow	1.19×10^{-13}
^{134}Cs	6.8×10^{-9}	fast	7.07×10^{-14}
^{137}Cs	4.8×10^{-9}	fast	9.28×10^{-17}
^{54}Mn	1.5×10^{-9}	medium	3.83×10^{-14}
^{241}Am	3.9×10^{-5}	medium	6.77×10^{-16}

Source: [a] Reference 2.2.56; [b] Reference 2.2.10 (Table 107); and [c] Reference 2.2.44

V.2.4 Breathing Rate

The breathing rate for a radiation worker is 3.5×10^{-4} m^3/s (Design Input 6.1.6.1).

V.3 METHODOLOGY

Particulates released from a dropped radioactive waste drum, box, or container cause inhalation and submersion doses to workers inside the LLWF in the vicinity of the event. The external exposure from a drum, box, or container dropped on the ground surface is not considered in this appendix because the external dose from the failed drum, box, or container to a worker is expected to be similar to the dose rate when it is in an undamaged state.

When a drum, box, or container is dropped, radioactive material is postulated to be released into the air. This material mixes uniformly in the staging room with no credit taken for the removal of radionuclides by the building ventilation system (Assumption V.1.3). For DAW, the concentration of any radionuclide in the staging room air is calculated by:

$$C_j = \frac{C_{j,waste} \times V_{waste} \times ARF \times RF}{V_{room}}$$

where

C_j = radionuclide concentration in the staging room air, Ci/m^3
$C_{j,waste}$ = radionuclide concentration in DAW, Ci/m^3 (Section V.2.1)
V_{waste} = volume of a DAW waste drum or box, m^3 (Section V.2.2),
ARF = airborne release fraction (Assumptions V.1.1 and V.1.2)
RF = respirable fraction (Assumptions V.1.1 and V.1.2)
V_{room} = volume of the staging room, m^3 (Assumption V.1.5)

For the non-WHF HEPA filter, the concentration of any radionuclide in the staging room air can be calculated using the above equation with following replacements:

$C_{j,waste}$ = radionuclide activity per non-WHF HEPA filter, Ci/filter (Section V.2.1)
V_{waste} = one filter for the non-WHF HEPA filter (Section V.2.2).

The inhalation dose for the radionuclide is then calculated using by:

$$D^{inh}_{j,effective} = C_j \times T \times BR \times conv \times DCF^{inh}_{j,effective}$$

where

$D^{inh}_{j,effective}$ = effective inhalation dose from radionuclide (j),mrem
T = exposure time = 3600 s (Assumption V.1.6)
BR = breathing rate = 3.5×10^{-4} m^3/s (Section V.2.4)
$DCF^{inh}_{j,effective}$ = inhalation dose coefficients, Sv/Bq (Section V.2.3)
$conv$ = unit conversion factor: 3.7×10^{12} [(rem ·Bq)/(Ci ·Sv)]

The air submersion dose for the radionuclide is calculated using by:

$$D_j^{sub} = C_j \times T \times conv \times DCF_j^{sub}$$

where

D^{sub}_j = air submersion dose from radionuclide (j), mrem
DCF^{sub}_j = air submersion dose coefficients, [(Sv/s)/(m^3/Bq)] (Section V.2.3).

The inhalation and submersion doses are added to get the total dose for each radionuclide. The total radionuclide doses are then summed for all radionuclides present in the waste to get the total worker dose for the drop event.

V.4 CALCULATIONS

V.4.1 Drop of DAW Drum

For the drop of a single DAW drum, the inhalation and submersion doses are calculated as shown in Table V - 3.

Table V - 3. Dose Calculations for the Drop of a Single DAW Drum

Radionuclide	Air Conc. (Ci/m^3)	Inhalation Dose Coefficient (Sv/Bq)	Inhalation Dose (mrem)	Air Submersion Coefficient (Sv/s)/(Bq/m3)	Air Submersion (mrem)	Total Dose (mrem)
^{58}Co	1.76×10^{-10}	2.0×10^{-9}	1.6×10^{-3}	4.45×10^{-14}	1.04×10^{-4}	1.7×10^{-3}
^{60}Co	4.46×10^{-10}	2.9×10^{-8}	6.0×10^{-2}	1.19×10^{-13}	7.07×10^{-4}	6.1×10^{-2}
^{134}Cs	1.98×10^{-10}	6.8×10^{-9}	6.3×10^{-3}	7.07×10^{-14}	1.86×10^{-4}	6.5×10^{-3}
^{137}Cs	2.24×10^{-10}	4.8×10^{-9}	5.0×10^{-3}	9.28×10^{-17}	2.77×10^{-7}	5.0×10^{-3}
^{54}Mn	2.30×10^{-11}	1.5×10^{-9}	1.6×10^{-4}	3.83×10^{-14}	1.17×10^{-5}	1.7×10^{-4}
Total						0.074

Source: see *DrumDrop3.xls*

As shown in the table, the total dose is 0.074 mrem for the drop of a single DAW drum. If multiple drums of waste were involved in the event, the resulting dose would be proportionately higher. In the staging room, drums could be handled as a pallet of nine, which could then drop onto another pallet of nine thereby failing a total of 18 drums. This situation, which is judged to be the worst credible case for DAW drums, results in a total dose of less than 1.4 mrem (0.074 mrem/drum × 18 drums).

V.4.2 Drop of Non-WHF HEPA Filter

For the drop of a container containing a non-WHF HEPA filter, the inhalation and submersion doses are calculated as shown in Table V - 4 below.

Table V - 4. Dose Calculations for the Drop of a Single non-WHF HEPA Filter Container

Radionuclide	Air Conc. (Ci/m^3)	Inhalation Dose Coefficient (Sv/Bq)	Inhalation Dose (mrem)	Air Submersion Coefficient (Sv/s)/(Bq/m3)	Air Submersion (mrem)	Total Dose (mrem)
^{60}Co	1.58×10^{-11}	2.9×10^{-8}	2.1×10^{-3}	1.19×10^{-13}	2.50×10^{-5}	2.2×10^{-3}
^{241}Am	1.59×10^{-12}	3.9×10^{-5}	2.9×10^{-1}	6.77×10^{-16}	1.43×10^{-8}	2.9×10^{-1}
Total						0.29

Source: see *DrumDrop3.xls*

As shown in Table V - 4 the dose for this event from one non-WHF filter is 0.29 mrem. If multiple containers of waste were involved in the event (e.g., one container falling onto another), the resulting dose would be proportionally higher. If two B-25 boxes containing non-WHF HEPA filters were involved in a drop event (which is judged to be the worst credible case for this waste form), the total dose with all 24 filters failing would be 7.0 mrem (0.29 mrem/filter × 24 filters).

V.5 RESULTS AND CONCLUSIONS

The total dose to a worker (including both inhalation and air submersion doses), as calculated in Section V.4, are 0.074 mrem for the drop of a single drum of DAW, 1.4 mrem for the drop of a pallet of 9 drums containing DAW onto another pallet of 9 drums containing DAW, and 0.29 mrem for the drop of a single container holding one non-WHF HEPA filter and 7.0 mrem for the drop of a B-25 box with non-WHF HEPA filters onto another box. Section V.4 also demonstrates that the total dose due to the failure of the worst credible number of drums, boxes, or containers in any event is also relatively low (less than 7 mrem). Therefore, the drop events analyzed in this appendix can be classified as off-normal because the consequences to a radiation worker are a small fraction of the performance objectives.

APPENDIX VI SUMMARY OF DOSES FOR EVENT USING REPRESENTATIVE INPUTS

Numerous commercial SNF burst and oxidation GENII computer cases were performed using inputs other than the inputs used for determining the doses for the bounding Category 2 event sequence. Specifically, representative source terms are used for burst and oxidation instead of bounding source terms and 50%-ile χ/Qs are used instead of 95%-ile χ/Qs. Tables 38 through 43 show the results for individual waste forms for the GENII computer cases described in Table 37. Table 38 and Table 40 show the results for the representative PWR and BWR fuel, which gives dose results for the onsite location for burst and oxidation releases. The results from these cases can be used for emergency planning for evaluating appropriate responses to postulated events.

The following table summarizes the results of the event sequences at onsite locations involving commercial SNF using representative source terms and 50%-ile χ/Qs. While the results of these events do not use bounding inputs for source terms and χ/Qs, a damage ratio of 1 is used in the analysis, which means that 100% of the fuel is affected by the event. Thus, the results for these events are conservative

Table VI - 5. Summary of Onsite Doses for Events Using Representative Source Terms

	Total Effective Dose Equivalent (mrem)	Highest Total Organ Dose Equivalent (mrem)	Shallow Dose Equivalent to Skin (mrem)	Lens Dose Equivalent (mrem)
Representative PWR fuel with 50% χ/Qs				
Event Involving the Breach of a Transportation Cask with Uncanistered PWR Fuel (4 fuel assemblies)	1.1×10^{1}	8.8×10^{1}	8.8×10^{1}	9.9×10^{1}
Event Involving the Breach of a TAD Canister (21 fuel assemblies)	5.6×10^{1}	4.6×10^{2}	4.6×10^{2}	5.2×10^{2}
Event Involving the Breach of a DPC (36 fuel assemblies)	9.6×10^{1}	8.0×10^{2}	8.0×10^{2}	8.9×10^{2}
Representative BWR fuel with 50% χ/Qs				
Event Involving the Breach of a Transportation Cask with Uncanistered PWR Fuel (9 fuel assemblies)	9.7	7.6×10^{1}	7.6×10^{1}	8.5×10^{1}
Event Involving the Breach of a TAD Canister (44 fuel assemblies)	4.8×10^{1}	3.7×10^{2}	3.7×10^{2}	4.2×10^{2}
Event Involving the Breach of a DPC (74 fuel assemblies)	8.0×10^{1}	6.2×10^{2}	6.2×10^{2}	7.0×10^{2}

Sources: Table 38 for PWR fuel, Table 40 for BWR fuel.

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APPENDIX VII EXPECTED QUANTITIES OF FAILED COMMERCIAL SNF

Commercial SNF fuel assembly reliability is based on industrial experience reported by DOE and the Electric Power Research Institute (EPRI). Failed assemblies have been characterized as damaged and leaking. Damaged fuel is defined as fuel with defects greater in size than a pinhole leak or hairline crack (Reference 2.2.59) that must be placed in damaged fuel cans for transportation. Leaking fuel is defined as fuel with hairline cracks or pinholes. Leaking fuel is often treated as intact fuel (ISG-1) for storage and transportation but is considered failed for repository operations.

VII.1 ASSEMBLY RELIABILITY

From 1968 through 2003, the average assembly-based failure rate for United States commercial SNF is 3.0 percent with the BWRs having 3.2 percent and PWRs having 2.8 percent failure rates (Table VII - 1). This data is skewed by the 1970s period when BWRs had a high failure rate because of pellet cladding interaction failures. Similarly, PWR fuel performed poorly in the early 1990s. In the last 10 years, the assembly failure rate has been 1.1 percent with the BWRs (0.5 percent failures) outperforming the PWRs (1.9 percent failures). The stainless steel clad fuel included in the above inventory represents 1 percent of the inventory. If separated, it would have an assembly failure rate of about 1.8 percent, close to that of the total inventory.

Table VII - 1. Failed Fuel Estimates for BWR and PWR Assemblies

Year	BWR Assemblies Discharged[a]	BWR Assemblies Failed	PWR Assemblies Discharged[a]	PWR Assemblies Failed
1968	5		0	
1969	97	32	0	
1970	29	29	99	0
1971	413	87	113	0
1972	801	68	282	36
1973	564	323	165	4
1974	1,290	671	575	32
1975	1,223	463	797	36
1976	1,666	297	931	33
1977	2,047	108	1,107	16
1978	2,239	119	1,665	16
1979	2,131	124	1,642	42
1980	3,330	112	1,457	9
1981	2,467	42	1,590	34
1982	1,951	59	1,491	40
1983	2,649	26	1,779	85
1984	2,735	81	1,933	35
1985	2,989	99	2,032	35
1986	2,552	41	2,254	94
1987	3,316	24	2,567	106
1988	2,956	64	2,574	108

Table VII - 1. Failed Fuel Estimates for BWR and PWR Assemblies

Year	BWR Assemblies Discharged[a]	BWR Assemblies Failed	PWR Assemblies Discharged[a]	PWR Assemblies Failed
1989	3,803	57	2,721	204
1990	3,487	15	3,435	104
1991	3,191	24	2,803	111
1992	3,932	12	3,588	122
1993	3,759	15	3,400	104
1994	3,777	15	2,747	55
1995	4425	4	3,741	73
1996	4,690	15	3,536	74
1997	3,849	10	3,414	53
1998	3,867	30	2,166	62
1999	4,586	13	3,637	63
2000	4,361	6	3,177	51
2001	3,904	2	3,019	44
2002	4,274	50	3,854	75
2003	4,198[b]	51	3,171[b]	51
Sum	97,553	3,188	73,462	2,007
% Failed (all years)		3.27		2.73
% Failed (1994–2003)		0.47		1.85

NOTES: [a] Source for the number of discharged assemblies through 2002 is the Energy Information Administration website: www.eia.doe.gov/cneaf/nuclear/spent_fuel/ussnftab3.html/ (Reference 2.2.60).

[b] Number discharged in 2003 is estimated as an average of the previous 5 years.

[c] Sources for number of damaged assemblies: 1969–1985, Reference 2.2.61, Table 30; 1986-1988, BWRs Reference 2.2.62, Table 2; PWRs based on average failure rate using 6 years (1983-1985 and 1989-1991); 1989, Reference 2.2.63, Table 2; 1990-2003 Reference 2.2.64.

The trend today in fuel failures is constant or slightly decreasing fuel reliability (Reference 2.2.64). While the Institute of Nuclear Power Operations has established goals toward reducing failures and reaching zero failure, economic pressure exists at utilities to increase fuel duties. Most utilities try to identify the cause of all fuel rod failures and make the necessary changes in design or operation to preclude future failures. This has led to detailed poolside inspections of failed fuel and close monitoring of the primary water chemistry. Failures from debris fretting have led to filters on the assembly endfittings and a greater effort to clean the primary system after maintenance. Failures from water baffle jetting have led to using more robust fuel grid spacers. Recent pellet-clad interaction failures led to new operating procedures to restrict power changes. Fuel manufacturers have also introduced best practice lines and improved quality assurance programs to reduce manufacturing defects. Counteracting these improvements is a trend toward higher burnups and duty cycles. Many plants have been licensed for stretched power, and some plants have gone to 24-month fuel cycles. Fuel burnup has nearly doubled (30 to 54 GWd/MTHM) over the past decade, but additional burnup increases will be limited by the uranium enrichment limit of 5 percent. Deregulation has also pushed the nuclear utilities to maximize plant availability and capacity factors while decreasing costs. Overall, the historical fuel reliability of 3 to 4 percent should be used to characterize current and future fuels.

The number of known failed assemblies reported by the utilities will differ from the number of failed assemblies received at the repository because of assembly reconstitution and fuel inspections. If the failed assembly was scheduled to go back into the core, the failed rod may be removed and a substitute rod inserted into the assembly. The failed rod is then placed with other failed rods into a damaged fuel can. Some of the early assembly designs did not easily permit reconstitution. For some last cycle assemblies, the failed rods are removed from the assembly for root cause analysis and then may be placed in a damaged fuel can. Sometimes a failed rod is reinserted into the assembly and placed in the pool. In some cases where the failures are on the outside of the assembly, the rods are not removed from the assembly. Some failed rods are never located.

VII.2 ROD RELIABILITY

The above data and discussion are based on fuel assemblies. Assemblies have different numbers of rods in them and, therefore, the rod reliability is different than the assembly reliability. PWR assemblies vary in design with the earlier plants using 14 × 14 rods (about 164 rods per assembly since not all locations have fuel rods in them) and the newer designs using 17 × 17 (about 264 rods per assembly). The number of rods in an assembly cannot be changed for a specific plant design. The average for all PWRs is 207 rods per assembly (Reference 2.2.65). The number of failed rods in a failed assembly varies with time and failure cause. Debris fretting often causes two rods to fail (Reference 2.2.66, p. 2-5). Baffle jetting or grid fretting might cause many rods along the outer row to fail. In one case of grid fretting, 32 failed rods were identified in one PWR assembly. In that same batch of fuel another fuel assembly contained 25 failed rods.

Manufacturing failures tend to be single-rod failures, although some manufacturing events have led to the failure of many rods in many assemblies. For the early period (before 1986), the number of rods failed per failed assembly averaged 2.2 (Reference 2.2.67), but this decreased to 1.4 rods per PWR failed fuel assembly (Reference 2.2.65). Using the assembly failure rates presented in Table VII - 1 and the rod data cited above, the total failure percent on a rod basis for PWR fuel is 0.02 percent (Table VII - 2).

BWR assemblies are smaller and have fewer rods in them. Earlier designs were 7 × 7 (around 48 or 49 rods per assembly), but later designs were 10 × 10 (about 96 rods per assembly). The latest designs are 11 × 11. BWRs can change the number of rods per assembly over time. The average for all BWRs is approximately 62 rods/assembly (Reference 2.2.65). For the early period (before 1986), the number of rods failed per failed assembly averaged 2.2 (EPRI 1997 [DIRS 100444]), but this has decreased to 1.1 rods per BWR assembly (Reference 2.2.65). Using the assembly failure rate presented in Table VII - 1 and the rod data presented in this paragraph, the total failure percent for BWR rods is 0.11 percent (Table VII - 2).

For both PWRs and BWRs combined, the total failure percent for the rods is 0.05 percent. This is well below the 1% failed fuel assumed in this calculation (Assumption 3.2.1).

Table VII - 2 Rod Failure Rates for United States PWR and BWR Fuel

Year	BWR Rods Discharged	BWR Rods Failed	PWR Rods Discharged	PWR Rods Failed
1968	310	0	0	0
1969	6,014	70.4	0	0
1970	1,798	63.8	20,493	0
1971	25,606	191.4	23,391	0
1972	49,662	149.6	58,374	79.2
1973	34,968	710.6	34,155	8.8
1974	79,980	1476.2	119,025	70.4
1975	75,826	1018.6	164,979	79.2
1976	103,292	653.4	192,717	72.6
1977	126,914	237.6	229,149	35.2
1978	138,818	261.8	344,655	35.2
1979	132,122	272.8	339,894	92.4
1980	206,460	246.4	301,599	19.8
1981	152,954	92.4	329,130	74.8
1982	120,962	129.8	308,637	88
1983	164,238	57.2	368,253	187
1984	169,570	178.2	400,131	77
1985	185,318	217.8	420,624	77
1986	158,224	45.1	466,578	131.6
1987	205,592	26.4	531,369	148.4
1988	183,272	70.4	532,818	151.2
1989	235,786	62.7	563,247	285.6
1990	216,194	16.5	711,045	145.6
1991	197,842	26.4	580,221	155.4
1992	243,784	13.2	742,716	170.8
1993	233,058	16.5	703,800	145.6
1994	234,174	16.5	568,629	77
1995	274,350	4.4	774,387	102.2
1996	290,780	16.5	731,952	103.6
1997	238,638	11	706,698	74.2
1998	239,754	33	448,362	86.8
1999	284,332	14.3	752,859	88.2
2000	270,382	6.6	657,639	71.4
2001	242,048	2.2	624,933	61.6
2002	264,988	55	797,778	105
2003	260,300	56.1	656,314	71.4
Sum	6,048,311	6,521	15,206,551	3,172
% Failed (all years)		**0.11**		**0.02**
% Failed (all years) PWR & BWR		**0.05 %**		

APPENDIX VIII FIRE ENGULFING A TAD

A fire engulfing a TAD may cause the TAD to leak at a higher (off-normal) leakage rate. This appendix determines if the specified leakage rate is sufficiently low to ensure that any resultant doses are well below the performance objectives presented in Table 1.

VIII.1 ASSUMPTIONS NOT REQUIRING VERIFICATION

VIII.1.1 Duration of Release

Assumption: The release is assumed to last for 30 days.

Rationale: This assumption is consistent with Assumption 3.2.3.

VIII.1.2 Fuel Failure Due to Fire

Assumption: One percent of the fuel rods in the TAD are assumed to be failed (Assumption 3.2.1). No additional fuel failures occur due to the fire.

Rationale: Per Reference 2.2.68, Section 3.1.3(3) the fully engulfing fire has an average flame temperature of 1,720 ºF (938 ºC) lasting for 30 minutes. During normal conditions, the SNF cladding will not exceed 752 ºF (400 ºC). The short duration of the fire will not elevate the cladding temperature to the thermal burst temperature of 750 ºC (Reference 2.2.69, Section 7.2.5.2).

VIII.1.3 HEPA Availability

Assumption: HEPA filters are not available following a fire event.

Rationale: The particulate and ash mass loading from the fire renders the HEPA filters unavailable for removing any releases from the TAD.

VIII.2 DESIGN INPUTS

VIII.2.1 Source Term

The source term consists of the maximum PWR and maximum BWR SNF source term presented in Table 7.

VIII.2.2 Leakage Rate

The leakage rate following a fully-engulfing fire is 9.3×10^{-10} fraction of canister free volume per second (Reference 2.2.68, Section 3.1.3(3)).

VIII.2.3 Release Fractions

The burst release fractions for high burnup fuel from Table 10 are used.

VIII.2.4 Time-weighted Atmospheric Dispersion Factors

The time-weighted atmospheric dispersion factors for a 30-day release period from Table 22 are used.

VIII.2.5 Time-weighted Breathing Rates

The time-weighted breathing rates for a 30-day release period from Table 23 are used.

VIII.3 CALCULATION

The resultant doses are calculated using the GENII code discussed in Section 4.3.3. The inputs used to calculate the doses from commercial SNF as discussed in Sections 6.1, 6.2, and Section 6.4 are used with the following exceptions.

The inventory of one SNF assembly is entered into the first tab of the GENII *User_Defined* module. The burst release fractions from Table 10 are entered in the second tab in the Chemical Group Multipliers window.

The Inventory/Relase Multiplier is calculated as follows:

The duration of the event is 30 days; therefore, the total volume released from the TAD is

$$V_r = 9.3 \times 10^{-10}\,\text{sec}^{-1} \times 30\,days \times 24\,hr/day \times 3{,}600\,\text{sec}/hr = 2.41 \times 10^{-3}$$

The inventory of one SNF assembly was entered in the first tab of the *User_Defined* module as a release rate in Ci/hr. To ensure that only the activity of one assembly is released over a 30 day period, a multiplier of 1 ÷ 720 = 1.39×10^{-3} is used.

The failed fuel percentage is 1%. Therefore, the total Inventory/Relase Multiplier is:

$$M_p = 2.41 \times 10^{-3} \times 1.39 \times 10^{-3} \times 0.01 = 3.35 \times 10^{-8}$$

As calculated above, only 0.24% of the total TAD free volume is released during the 30-day period; therefore, insufficient oxygen leaked in to cause oxidation of the fuel in the failed rods.

The resultant doses for PWR and BWR single assemblies are presented in Table VIII - 1.

Table VIII - 1. Fire Event One SNF Assembly Results

	Total Effective Dose Equivalent (mrem)	Highest Total Organ Dose Equivalent (mrem)	Shallow Dose Equivalent to Skin (mrem)	Lens Dose Equivalent (mrem)
Maximum PWR- Unfiltered-95% χ/Q (Dose/Event)				
Offsite Public in the General Environment[a]	1.79×10^{-4}	3.30×10^{-3} (Bone Surface)	1.39×10^{-4}	3.18×10^{-4}
Offsite Public Not in the General Environment[a]	3.47×10^{-4}	6.95×10^{-3} (Bone Surface)	3.32×10^{-4}	6.79×10^{-4}
Maximum BWR- Unfiltered-95% χ/Q (Dose/Event)				
Offsite Public in the General Environment[c]	5.52×10^{-5}	9.49×10^{-4} (Bone Surface)	4.48×10^{-5}	1.00×10^{-4}
Offsite Public Not in the General Environment[c]	1.06×10^{-4}	2.00×10^{-3} (Bone Surface)	1.03×10^{-4}	2.10×10^{-4}

NOTES: [a]Offsite public receptor locations are shown on Figure 1.
Source: *Summary of Doses.xls-Result Matrix*

The results for a leaking TAD with 21 PWR assemblies or 44 BWR assemblies is presented in Table VIII - 2.

Table VIII - 2. Breach of Sealed Transportation, Aging, and Disposal Canister after a Fire

	Total Effective Dose Equivalent (mrem)	Highest Total Organ Dose Equivalent (mrem)	Shallow Dose Equivalent to Skin (mrem)	Lens Dose Equivalent (mrem)
21 Pressurized Water Reactor Fuel Assemblies – Unfiltered-95% χ/Qa				
Offsite Public in the General Environment	3.75×10^{-3}	6.92×10^{-2} (Bone Surface)	2.92×10^{-3}	6.68×10^{-3}
Offsite Public Not in the General Environment	7.28×10^{-3}	1.46×10^{-1} (Bone Surface)	6.98×10^{-3}	1.43×10^{-2}
44 Boiling Water Reactor Fuel Assemblies – Unfiltered-95% χ/Qb				
Offsite Public in the General Environment	2.43×10^{-3}	4.17×10^{-2} (Bone Surface)	1.97×10^{-3}	4.40×10^{-3}
Offsite Public Not in the General Environment	4.68×10^{-3}	8.81×10^{-2} (Bone Surface)	4.54×10^{-3}	9.23×10^{-3}

NOTE: Receptor locations for offsite public are shown on Figure 1.
Sources: *Summary of Doses.xls – Bounding Category 2 Events*.

VIII.4 RESULTS/CONCLUSIONS

From Table VIII - 2, the maximum dose to the offsite public is 7.3×10^{-3} mrem, which is well below the performance objectives presented in Table 1. Therefore, the leakage rate specified in Reference 2.2.68, Section 3.1.3(3) is adequately low.

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APPENDIX IX E-MAIL FROM MICHAEL FRANK TO DALE DEXHEIMER (REFERENCE 2.2.4)

Michael Frank
01/11/2008 10:30 AM

To: Dale Dexheimer/YM/RWDOE@CRWMS
cc: Sen-Sung Tsai/YM/RWDOE@CRWMS, Mark Wisenburg/YM/RWDOE@CRWMS
Subject: Preliminary IHF Event Sequence results

LSN: Not Relevant - Not Privileged
User Filed as: Excl/AdminMgmt-14-4/QA:N/A

At the request of Dr. Tsai, the following information is provided for use in defining the scope of preclosure consequence analyses.

Preliminary information from draft event sequence analyses of internal events involving naval SNF canisters indicates that there are no Category 1 or Category 2 event sequences resulting in a breach of a naval SNF canister and radioactivity release. The preliminary draft event sequence analysis results are based on the frequency of initiating events that might pose a threat to the integrity of canisters, the number of handling operations involving naval SNF canisters over the preclosure period, and the robustness of the analyzed canisters to survive drop, other impact events, fire events, seismic events and other external event that are within or might affect the Initial Handling Facility.

Mike

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APPENDIX X LISTING OF ELECTRONIC FILES CONTAINED IN APPENDIX XI

The electronic files consists of the GENII input and output files and Excel spreadsheets. The GENII files are named using the following convention.

- χ/Q data and other default information to reside in *C:\FRAMES\Data*
- Input and output files to reside in *C:\FRAMES\Runs*

GENII file names:

wwrflrrp.ext

ww – waste type (2 characters)

pa – Representative PWR commercial SNF
pm – Maximum PWR commercial SNF
ph – High burnup maximum PWR
ba – Representative BWR commercial SNF
bm – Maximum BWR commercial SNF
nc – Navy canister – Using non-respirable source term
nr – Navy canister – Using respirable source term
hs – HLW SRS canister
hh – HLW Hanford canister
hw – HLW West Valley canister
hi – HLW INL canister
hp – HEPA accumulated activity release – PWR
hb – HEPA accumulated activity release – BWR
lw – Low level waste release
no – Normal operations releases – Representative PWR commercial SNF
nm – Normal operation releases – Maximum PWR commercial SNF
nb – Normal operations releases – Representative BWR commercial SNF
cm – TAD canister or DPC contamination release
sf – Subsurface facility releases

r – release type (1 character)

d – drop
o – oxidation
p – pool release
s – seismic
f – fire

f – filter status (1 character)

h – HEPA considered
n – HEPA not considered

l – leak path factor (LPF) (1 character)

l – LPF included
d – direct leakage

rr – release location (2 characters)

gr – GROA surface facilities
ap – Aging pad
sf – Subsurface facility releases

p – receptor location (1 character)

g – general environment
n – nearest resident
s – site boundary
e – subsurface exhaust shaft
o – onsite public

χ/Q data file naming convention

rdur.xqp

r – release location (1 character)

g – GROA
s – Subsurface
a – Aging pad

dur – release duration (maximum of 7 characters)

e.g. 0-2, 2-8, 2-720, etc. for event sequences
annual – annual average values

xq – denotes data as χ/Q file

p – receptor location

g – general environment
n – nearest resident
s – site boundary
e – subsurface exhaust shaft
o – onsite public

File attributes in the following list include file directory, date, time, size, and name.

File Name	Size/Type	Date	Time
D:\			
===			
DATA	DIR	10/23/2007	6:36:42
FACILITY ESD TABLES	DIR	1/21/2008	15:35:12
GENII RESULT SPREADSHEETS	DIR	1/17/2008	7:17:21
GENII VERIFICATION	DIR	10/17/2007	6:46:03
OTHER SPREADSHEETS	DIR	1/23/2008	14:26:58
RUNS	DIR	1/11/2008	9:05:50
UNCERTAINTY	DIR	1/10/2008	13:54:09
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e-chron.xqg	285	8/29/2007	7:44:02
e-chron.xqo	270	8/29/2007	7:46:50
e-chron.xqs	271	8/28/2007	12:58:24
g-annual.xqg	286	7/26/2007	13:23:18
g-annual.xqo	263	7/24/2007	11:34:08
g-annual.xqs	285	7/23/2007	11:39:42
g-chron.xqe	264	8/28/2007	12:33:14
g-chron.xqg	288	8/27/2007	8:46:02
g-chron.xqo	265	8/28/2007	6:44:42
g-chron.xqs	287	8/28/2007	6:44:10
g0-2.xqg	279	8/30/2007	11:06:20
g0-2.xqo	261	7/25/2007	12:07:20
g0-2.xqs	279	7/25/2007	12:12:44
g0-720.xqg	282	7/20/2007	11:52:16
g0-720.xqo	263	7/23/2007	12:24:40
g0-720.xqs	282	7/23/2007	13:41:02
g2-720.xqg	283	8/30/2007	11:13:00
g2-720.xqs	282	6/15/2007	8:01:50
g2-8.xqg	282	7/18/2007	7:39:24
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Att 1 - IHF ESD Table.doc	34,816	9/27/2007	12:40:16
Att 2 - WHF ESD Table.doc	61,952	9/27/2007	12:42:37
Att 3 - CRCF ESD Table.doc	51,712	9/27/2007	12:43:06
Att 4 - RF ESD Table.doc	41,984	10/5/2007	10:27:06
Att 5 - Subsurface ESD Table.doc	32,256	9/27/2007	12:44:21
Att 6 - Intra-site ESD Table.doc	32,256	10/1/2007	14:59:05
Att 7 - End State Preliminary Information and Assumptions.doc	26,624	9/27/2007	12:44:45
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1% BWR Air Site Boundary no HEPA.xls	**2,152,448**	**3/8/2008**	**17:52:40**
1% PWR Air General Environment no HEPA.xls	**9,432,064**	**3/8/2008**	**17:21:35**
1% PWR Air Site Boundary no HEPA.xls	**2,172,928**	**3/8/2008**	**17:27:37**
Aging Pad Exhaust Shafts.xls	1,189,888	10/23/2007	8:08:23
Aging Pad General Environment.xls	2,492,928	10/23/2007	7:56:26
Aging Pad Onsite.xls	1,199,104	10/23/2007	8:11:17
Aging Pad Site Boundary.xls	1,194,496	10/23/2007	8:10:52
BWR Air General Environment no HEPA.xls	9,387,008	12/5/2007	10:52:00
BWR Air General Environment.xls	9,360,896	12/5/2007	10:42:18
BWR Air Site Boundary no HEPA.xls	2,152,448	12/5/2007	10:57:48
BWR Air Site Boundary.xls	2,185,728	12/5/2007	10:46:34
BWR Fire General Environment.xls	4,695,552	12/6/2007	5:48:32
BWR Fire Site Boundary.xls	1,076,736	12/6/2007	5:55:22
BWR Pool General Environment.xls	4,645,376	10/23/2007	9:21:09
BWR Pool Site Boundary.xls	1,146,368	10/23/2007	9:35:53
Exhaust Shafts Exhaust Shafts.xls	**1,132,544**	**3/8/2008**	**15:58:41**
Exhaust Shafts General Environment.xls	**2,521,088**	**3/8/2008**	**16:00:14**
Exhaust Shafts Onsite.xls	**1,134,592**	**3/8/2008**	**16:01:40**
Exhaust Shafts Site Boundary.xls	**1,147,392**	**3/8/2008**	**16:02:51**
HEPA Seismic General Environment - BWR.xls	**5,085,184**	**3/8/2008**	**16:16:01**
HEPA Seismic General Environment.xls	**5,101,568**	**3/8/2008**	**16:21:05**
HEPA Seismic Site Boundary - BWR.xls	**1,177,088**	**3/8/2008**	**16:18:07**
HEPA Seismic Site Boundary.xls	**1,184,256**	**3/8/2008**	**16:23:32**
HLW Hanford General Environment.xls	5,164,032	10/23/2007	12:10:28
HLW Hanford Site Boundary.xls	1,230,848	10/23/2007	12:17:59
HLW INL General Environment.xls	5,185,024	10/23/2007	12:24:43
HLW INL Site Boundary.xls	1,236,992	10/23/2007	12:31:31
HLW SRS General Environment.xls	5,234,688	10/23/2007	12:58:31
HLW SRS Site Boundary.xls	1,255,936	10/23/2007	12:49:31
HLW WW General Environment.xls	5,276,160	10/23/2007	12:54:34
HLW WW Site Boundary.xls	1,267,712	10/23/2007	13:08:28
LLW Fire General Environment.xls	4,557,312	1/23/2008	8:21:24
LLW Fire Site Boundary.xls	1,007,616	1/23/2008	8:24:02
LLW Seismic General Environment.xls	4,556,800	1/23/2008	15:32:36
LLW Seismic Site Boundary.xls	1,007,616	1/23/2008	8:30:13
Normal Exhaust Shafts - BWR.xls	**1,189,888**	**3/8/2008**	**15:14:48**
Normal Exhaust Shafts - Max PWR.xls	**1,172,992**	**3/8/2008**	**15:40:23**
Normal Exhaust Shafts - PWR.xls	**1,193,984**	**3/8/2008**	**15:49:59**
Normal General Environment - BWR.xls	**2,718,208**	**3/8/2008**	**15:32:32**
Normal General Environment - Max PWR.xls	**2,742,272**	**3/8/2008**	**15:42:43**
Normal General Environment - PWR.xls	**2,741,760**	**3/8/2008**	**15:52:20**
Normal Onsite - BWR.xls	**1,189,888**	**3/8/2008**	**15:34:46**
Normal Onsite - Max PWR.xls	**1,193,984**	**3/8/2008**	**15:45:14**
Normal Onsite - PWR.xls	**1,193,984**	**3/8/2008**	**15:54:37**
Normal Site Boundary - BWR.xls	**1,224,192**	**3/8/2008**	**15:37:46**
Normal Site Boundary - Max PWR.xls	**1,230,336**	**3/8/2008**	**15:47:29**
Normal Site Boundary - PWR.xls	**1,230,336**	**3/8/2008**	**15:56:47**
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PWR Air General Environment no HEPA.xls	9,572,864	10/24/2007	11:44:51

File Name	Size/Type	Date	Time
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PWR Air Site Boundary 50%ile.xls	2,169,344	10/24/2007	12:11:11
PWR Air Site Boundary no HEPA.xls	2,312,704	10/24/2007	12:11:04
PWR Air Site Boundary.xls	2,310,144	10/24/2007	12:28:59
PWR Fire General Environment.xls	4,733,952	12/6/2007	6:03:20
PWR Fire Site Boundary.xls	1,093,120	12/6/2007	6:09:34
PWR Pool General Environment.xls	4,683,264	10/24/2007	12:28:49
PWR Pool Site Boundary.xls	1,102,848	10/24/2007	12:27:13
Representative BWR Air General Environment no HEPA.xls	9,502,208	10/25/2007	6:50:28
Representative BWR Air General Environment.xls	9,501,184	10/25/2007	7:21:11
Representative BWR Air Onsite 50%ile.xls	2,196,992	10/25/2007	7:39:55
Representative BWR Air Onsite.xls	2,196,992	10/25/2007	7:44:28
Representative BWR Air Site Boundary no HEPA.xls	2,266,112	1/16/2008	14:42:09
Representative BWR Air Site Boundary.xls	2,403,840	10/25/2007	8:02:21
Representative PWR Air General Environment no HEPA.xls	9,432,064	12/5/2007	13:06:08
Representative PWR Air General Environment.xls	9,430,016	12/5/2007	12:47:14
Representative PWR Air Onsite 50%ile.xls	2,212,352	12/5/2007	13:16:46
Representative PWR Air Onsite.xls	2,212,352	12/5/2007	12:41:30
Representative PWR Air Site Boundary no HEPA.xls	2,285,568	12/5/2007	13:11:02
Representative PWR Air Site Boundary.xls	2,283,008	12/5/2007	12:53:02
Summary of Doses.xls	**211,968**	**3/9/2008**	**6:24:40**

D:\GENII VERIFICATION
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TestCompare - YMP004480.txt	2,622	7/27/2007	9:04:27
TestCompare - YMP004489.txt	2,622	7/27/2007	8:59:50
TestCompare - YMP004490.txt	2,622	7/27/2007	9:06:33

D:\OTHER SPREADSHEETS
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DrumDrop3.xls	18,432	12/27/2007	7:58:22
HLW Significant Isotopes.xls	70,144	10/3/2007	9:21:18
LLW MAR and Source Term.xls	26,624	1/23/2008	8:06:10

D:\RUNS
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HEPA	DIR	10/29/2007	15:11:30
HLW	DIR	10/29/2007	15:11:39
LLW	DIR	10/29/2007	15:11:41
NORMAL	DIR	10/29/2007	15:11:59
PWR	DIR	10/29/2007	15:12:18

File Name	Size/Type	Date	Time
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POOL	DIR	10/29/2007	15:11:16
REP	DIR	10/29/2007	15:11:25
REP50%	DIR	10/29/2007	15:11:27
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b1dnlgrg.hls	**830**	**3/8/2008**	**17:02:26**
b1dnlgrg.ref	**77**	**3/8/2008**	**16:59:31**
b1dnlgrg.rif	**116,011**	**3/8/2008**	**17:02:23**
b1dnlgrg.rls	**5,484**	**3/8/2008**	**17:02:23**
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b1dnlgrs.hif	**164,962**	**3/8/2008**	**17:05:50**
b1dnlgrs.hls	**830**	**3/8/2008**	**17:05:50**
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b1dnlgrs.rls	**5,484**	**3/8/2008**	**17:05:47**
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b1onlgrg.hif	**507,664**	**3/8/2008**	**17:09:29**
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b1onlgrg.rls	**5,390**	**3/8/2008**	**17:09:27**
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b1onlgrs.aff	**6,223**	**3/8/2008**	**17:10:52**
b1onlgrs.ato	**9,164**	**3/8/2008**	**17:10:52**

File Name	Size/Type	Date	Time
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b1onlgrs.epf	**23,176**	**3/8/2008**	**17:11:18**
b1onlgrs.gid	**634,695**	**3/8/2008**	**17:11:52**
b1onlgrs.hif	**160,202**	**3/8/2008**	**17:11:29**
b1onlgrs.hls	**830**	**3/8/2008**	**17:11:29**
b1onlgrs.ref	**77**	**3/8/2008**	**17:10:34**
b1onlgrs.rif	**40,165**	**3/8/2008**	**17:11:26**
b1onlgrs.rls	**5,390**	**3/8/2008**	**17:11:26**
b1onlgrs.wlm	**89**	**3/8/2008**	**17:11:26**
b1onlgrs.wrn	**0**	**3/8/2008**	**17:10:52**
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bmdhlgrg.ato	9,607	8/30/2007	11:09:46
bmdhlgrg.els	26,175	8/30/2007	11:10:06
bmdhlgrg.epf	70,932	8/30/2007	11:10:06
bmdhlgrg.gid	645,808	9/12/2007	12:57:08
bmdhlgrg.hif	522,796	9/12/2007	12:57:02
bmdhlgrg.hls	830	9/12/2007	12:57:02
bmdhlgrg.ref	77	8/30/2007	11:05:22
bmdhlgrg.rif	116,011	9/12/2007	12:57:00
bmdhlgrg.rls	5,484	9/12/2007	12:57:00
bmdhlgrg.wlm	267	9/12/2007	12:57:00
bmdhlgrg.wrn	0	8/30/2007	11:09:46
bmdhlgrs.aff	6,591	8/30/2007	11:20:28
bmdhlgrs.ato	9,604	8/30/2007	11:20:28
bmdhlgrs.els	26,175	8/30/2007	11:20:52
bmdhlgrs.epf	24,092	8/30/2007	11:20:52
bmdhlgrs.gid	645,813	9/12/2007	9:18:36
bmdhlgrs.hif	164,962	9/12/2007	9:18:22
bmdhlgrs.hls	830	9/12/2007	9:18:22
bmdhlgrs.ref	77	8/30/2007	11:19:26
bmdhlgrs.rif	41,353	9/12/2007	9:18:20
bmdhlgrs.rls	5,484	9/12/2007	9:18:20
bmdhlgrs.wlm	267	9/12/2007	9:18:20
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bmdnlgrg.ato	9,503	9/24/2007	8:52:10
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bmdnlgrg.hif	522,796	9/24/2007	8:52:40
bmdnlgrg.hls	830	9/24/2007	8:52:40
bmdnlgrg.ref	77	9/14/2007	6:47:18
bmdnlgrg.rif	116,011	9/24/2007	8:52:38
bmdnlgrg.rls	5,484	9/24/2007	8:52:38
bmdnlgrg.wlm	178	9/24/2007	8:52:38
bmdnlgrg.wrn	0	9/24/2007	8:52:10
bmdnlgrs.aff	6,651	9/24/2007	8:57:14
bmdnlgrs.ato	9,517	9/24/2007	8:57:14
bmdnlgrs.els	26,175	9/24/2007	8:57:34
bmdnlgrs.epf	23,943	9/24/2007	8:57:34

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bmdnlgrs.ref	77	9/14/2007	6:58:52
bmdnlgrs.rif	41,353	9/24/2007	8:57:40
bmdnlgrs.rls	5,484	9/24/2007	8:57:40
bmdnlgrs.wlm	178	9/24/2007	8:57:40
bmdnlgrs.wrn	0	9/24/2007	8:57:14
bmohlgrg.aff	6,236	8/30/2007	11:17:18
bmohlgrg.ato	9,252	8/30/2007	11:17:18
bmohlgrg.els	25,385	8/30/2007	11:26:08
bmohlgrg.epf	68,744	8/30/2007	11:26:08
bmohlgrg.gid	634,690	10/18/2007	11:45:48
bmohlgrg.hif	507,664	10/18/2007	11:45:42
bmohlgrg.hls	830	10/18/2007	11:45:42
bmohlgrg.ref	77	8/30/2007	11:11:44
bmohlgrg.rif	112,659	10/2/2007	13:20:22
bmohlgrg.rls	5,390	10/2/2007	13:20:22
bmohlgrg.wlm	267	10/2/2007	13:20:22
bmohlgrg.wrn	0	8/30/2007	11:17:18
bmohlgrs.aff	6,236	8/30/2007	11:23:28
bmohlgrs.ato	9,235	8/30/2007	11:23:28
bmohlgrs.els	25,385	8/30/2007	11:23:50
bmohlgrs.epf	23,164	8/30/2007	11:23:50
bmohlgrs.gid	634,693	10/18/2007	12:11:48
bmohlgrs.hif	160,202	10/18/2007	12:11:19
bmohlgrs.hls	830	10/18/2007	12:11:20
bmohlgrs.ref	77	8/30/2007	11:22:00
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bmohlgrs.rls	5,390	10/3/2007	7:00:49
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bmonlgrg.epf	68,327	9/24/2007	8:55:20
bmonlgrg.gid	634,690	10/18/2007	11:49:03
bmonlgrg.hif	507,664	10/18/2007	11:48:52
bmonlgrg.hls	830	10/18/2007	11:48:52
bmonlgrg.ref	77	9/14/2007	6:50:44
bmonlgrg.rif	112,659	10/2/2007	13:26:04
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bmonlgrg.wrn	0	9/24/2007	8:55:00
bmonlgrs.aff	6,244	9/24/2007	8:59:04
bmonlgrs.ato	9,129	9/24/2007	8:59:04
bmonlgrs.els	25,385	9/24/2007	8:59:28
bmonlgrs.epf	23,085	9/24/2007	8:59:28
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File Name	Size/Type	Date	Time
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bmonlgrs.rls	5,390	10/3/2007	7:03:19
bmonlgrs.wlm	356	10/3/2007	7:03:19
bmonlgrs.wrn	0	9/24/2007	8:59:04

D:\RUNS\BWR\POOL
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bmpnlgrg.epf	6,041	8/30/2007	9:04:58
bmpnlgrg.gid	61,724	9/12/2007	12:51:18
bmpnlgrg.hif	46,032	9/12/2007	12:51:12
bmpnlgrg.hls	830	9/12/2007	12:51:12
bmpnlgrg.ref	77	8/30/2007	9:03:30
bmpnlgrg.rif	10,317	9/12/2007	12:51:12
bmpnlgrg.rls	1,434	9/12/2007	12:51:12
bmpnlgrg.wlm	178	9/12/2007	12:51:12
bmpnlgrg.wrn	0	8/30/2007	9:04:56
bmpnlgrs.aff	1,004	8/30/2007	9:07:24
bmpnlgrs.ato	1,003	8/30/2007	9:07:24
bmpnlgrs.els	3,897	8/30/2007	9:07:24
bmpnlgrs.epf	2,218	8/30/2007	9:07:24
bmpnlgrs.gid	61,729	9/12/2007	12:47:32
bmpnlgrs.hif	14,916	9/12/2007	12:47:26
bmpnlgrs.hls	830	9/12/2007	12:47:26
bmpnlgrs.ref	77	8/30/2007	9:06:08
bmpnlgrs.rif	3,825	9/12/2007	12:47:26
bmpnlgrs.rls	1,434	9/12/2007	12:47:26
bmpnlgrs.wlm	267	9/12/2007	12:47:26
bmpnlgrs.wrn	0	8/30/2007	9:07:24

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badhlgrg.aff	6,601	9/24/2007	9:06:42
badhlgrg.ato	9,629	9/24/2007	9:06:42
badhlgrg.els	26,175	9/24/2007	9:07:12
badhlgrg.epf	71,023	9/24/2007	9:07:12
badhlgrg.gid	645,778	9/24/2007	9:07:30
badhlgrg.hif	522,796	9/24/2007	9:07:24
badhlgrg.hls	830	9/24/2007	9:07:24
badhlgrg.ref	77	9/7/2007	9:46:28
badhlgrg.rif	116,011	9/24/2007	9:07:22
badhlgrg.rls	5,484	9/24/2007	9:07:22
badhlgrg.wlm	267	9/24/2007	9:07:22
badhlgrg.wrn	0	9/24/2007	9:06:42

File Name	Size/Type	Date	Time
badhlgro.aff	6,601	9/24/2007	9:09:34
badhlgro.ato	8,966	9/24/2007	9:09:34
badhlgro.els	26,175	9/24/2007	9:09:58
badhlgro.epf	23,103	9/24/2007	9:09:58
badhlgro.gid	645,783	10/18/2007	8:58:50
badhlgro.hif	164,962	10/18/2007	8:58:45
badhlgro.hls	830	10/18/2007	8:58:45
badhlgro.ref	77	9/10/2007	6:45:44
badhlgro.rif	41,353	10/18/2007	8:58:43
badhlgro.rls	5,484	10/18/2007	8:58:43
badhlgro.wlm	445	10/18/2007	8:58:43
badhlgro.wrn	0	9/24/2007	9:09:34
badhlgrs.aff	6,601	9/24/2007	9:11:42
badhlgrs.ato	9,621	9/24/2007	9:11:42
badhlgrs.els	26,175	9/24/2007	9:12:02
badhlgrs.epf	24,116	9/24/2007	9:12:02
badhlgrs.gid	645,783	9/24/2007	9:12:20
badhlgrs.hif	164,962	9/24/2007	9:12:14
badhlgrs.hls	830	9/24/2007	9:12:14
badhlgrs.ref	77	9/10/2007	6:29:24
badhlgrs.rif	41,353	9/24/2007	9:12:12
badhlgrs.rls	5,484	9/24/2007	9:12:12
badhlgrs.wlm	356	9/24/2007	9:12:12
badhlgrs.wrn	0	9/24/2007	9:11:42
badnlgrg.aff	6,631	9/24/2007	9:15:12
badnlgrg.ato	9,575	9/24/2007	9:15:12
badnlgrg.els	26,175	9/24/2007	9:15:36
badnlgrg.epf	70,826	9/24/2007	9:15:36
badnlgrg.gid	645,785	9/24/2007	9:15:52
badnlgrg.hif	522,796	9/24/2007	9:15:46
badnlgrg.hls	830	9/24/2007	9:15:46
badnlgrg.ref	77	9/14/2007	9:30:08
badnlgrg.rif	116,011	9/24/2007	9:15:44
badnlgrg.rls	5,484	9/24/2007	9:15:44
badnlgrg.wlm	178	9/24/2007	9:15:44
badnlgrg.wrn	0	9/24/2007	9:15:12
badnlgrs.aff	6,631	9/24/2007	9:21:18
badnlgrs.ato	9,565	9/24/2007	9:21:18
badnlgrs.els	26,175	9/24/2007	9:21:40
badnlgrs.epf	24,058	9/24/2007	9:21:40
badnlgrs.gid	645,790	9/24/2007	9:21:54
badnlgrs.hif	164,962	9/24/2007	9:21:48
badnlgrs.hls	830	9/24/2007	9:21:48
badnlgrs.ref	77	9/14/2007	9:41:22
badnlgrs.rif	41,353	9/24/2007	9:21:46
badnlgrs.rls	5,484	9/24/2007	9:21:46
badnlgrs.wlm	178	9/24/2007	9:21:46
badnlgrs.wrn	0	9/24/2007	9:21:18
baohdlgrs.els	25,385	9/10/2007	6:38:46
baohlgrg.aff	6,238	9/7/2007	10:11:48

File Name	Size/Type	Date	Time
baohlgrg.ato	9,276	9/7/2007	10:11:48
baohlgrg.els	25,385	9/7/2007	10:12:10
baohlgrg.epf	68,786	9/7/2007	10:12:10
baohlgrg.gid	634,657	10/2/2007	13:31:08
baohlgrg.hif	507,664	10/2/2007	13:31:01
baohlgrg.hls	830	10/2/2007	13:31:01
baohlgrg.ref	77	9/7/2007	10:05:08
baohlgrg.rif	112,659	10/2/2007	13:30:59
baohlgrg.rls	5,390	10/2/2007	13:30:59
baohlgrg.wlm	178	10/2/2007	13:30:59
baohlgrg.wrn	0	9/7/2007	10:11:48
baohlgro.aff	6,236	9/10/2007	6:48:20
baohlgro.ato	8,627	9/10/2007	6:48:20
baohlgro.els	25,385	9/10/2007	6:48:40
baohlgro.epf	22,211	9/10/2007	6:48:40
baohlgro.gid	634,660	10/2/2007	13:39:17
baohlgro.hif	160,202	10/2/2007	13:39:11
baohlgro.hls	830	10/2/2007	13:39:11
baohlgro.ref	77	9/10/2007	6:47:48
baohlgro.rif	40,165	10/2/2007	13:39:10
baohlgro.rls	5,390	10/2/2007	13:39:10
baohlgro.wlm	267	10/2/2007	13:39:10
baohlgro.wrn	0	9/10/2007	6:48:20
baohlgrs.aff	6,236	9/10/2007	6:38:26
baohlgrs.ato	9,259	9/10/2007	6:38:26
baohlgrs.epf	23,171	9/10/2007	6:38:46
baohlgrs.gid	634,660	10/3/2007	7:09:58
baohlgrs.hif	160,202	10/3/2007	7:09:51
baohlgrs.hls	830	10/3/2007	7:09:51
baohlgrs.ref	77	9/10/2007	6:33:26
baohlgrs.rif	40,165	10/3/2007	7:09:49
baohlgrs.rls	5,390	10/3/2007	7:09:49
baohlgrs.wlm	534	10/3/2007	7:09:49
baohlgrs.wrn	0	9/10/2007	6:38:26
baonlgrg.aff	6,236	9/24/2007	9:18:18
baonlgrg.ato	9,167	9/24/2007	9:18:18
baonlgrg.els	25,385	9/24/2007	9:18:44
baonlgrg.epf	68,583	9/24/2007	9:18:44
baonlgrg.gid	634,657	10/2/2007	13:48:10
baonlgrg.hif	507,664	10/2/2007	13:45:27
baonlgrg.hls	830	10/2/2007	13:45:27
baonlgrg.ref	77	9/14/2007	9:35:30
baonlgrg.rif	112,659	10/2/2007	13:45:26
baonlgrg.rls	5,390	10/2/2007	13:45:26
baonlgrg.wlm	267	10/2/2007	13:45:25
baonlgrg.wrn	0	9/24/2007	9:18:18
baonlgrs.aff	6,236	9/24/2007	9:23:42
baonlgrs.ato	9,139	9/24/2007	9:23:42
baonlgrs.els	25,385	1/15/2008	15:48:41
baonlgrs.epf	23,152	1/15/2008	15:48:41

File Name	Size/Type	Date	Time
baonlgrs.gid	634,661	1/15/2008	15:49:06
baonlgrs.hif	160,202	1/15/2008	15:48:51
baonlgrs.hls	830	1/15/2008	15:48:51
baonlgrs.ref	77	9/14/2007	9:45:58
baonlgrs.rif	40,165	1/15/2008	15:48:49
baonlgrs.rls	5,390	1/15/2008	15:48:49
baonlgrs.wlm	445	1/15/2008	15:48:49
baonlgrs.wrn	0	9/24/2007	9:23:42

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badhlgro.aff	6,604	9/17/2007	11:39:18
badhlgro.ato	8,975	9/17/2007	11:39:18
badhlgro.els	26,175	9/17/2007	11:39:42
badhlgro.epf	23,113	9/17/2007	11:39:42
badhlgro.gid	645,787	10/18/2007	9:02:01
badhlgro.hif	164,962	10/18/2007	9:01:52
badhlgro.hls	830	10/18/2007	9:01:52
badhlgro.ref	77	9/17/2007	11:39:02
badhlgro.rif	41,353	10/18/2007	9:01:50
badhlgro.rls	5,484	10/18/2007	9:01:50
badhlgro.wlm	178	10/18/2007	9:01:50
badhlgro.wrn	0	9/17/2007	11:39:18
baohlgro.aff	6,239	9/17/2007	11:40:54
baohlgro.ato	8,633	9/17/2007	11:40:56
baohlgro.els	25,385	9/17/2007	11:41:16
baohlgro.epf	22,211	9/17/2007	11:41:16
baohlgro.gid	634,662	10/2/2007	13:58:50
baohlgro.hif	160,202	10/2/2007	13:58:38
baohlgro.hls	830	10/2/2007	13:58:38
baohlgro.ref	77	9/17/2007	11:40:40
baohlgro.rif	40,165	10/2/2007	13:58:37
baohlgro.rls	5,390	10/2/2007	13:58:37
baohlgro.wlm	178	10/2/2007	13:58:36
baohlgro.wrn	0	9/17/2007	11:40:56

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hbsndgrg.aff	**6,198**	**3/8/2008**	**16:14:38**
hbsndgrg.ato	**8,813**	**3/8/2008**	**16:14:39**
hbsndgrg.els	**24,448**	**3/8/2008**	**16:15:04**
hbsndgrg.epf	**65,787**	**3/8/2008**	**16:15:04**
hbsndgrg.gid	**614,848**	**3/8/2008**	**16:15:22**
hbsndgrg.hif	**484,976**	**3/8/2008**	**16:15:17**
hbsndgrg.hls	**830**	**3/8/2008**	**16:15:17**
hbsndgrg.ref	**197**	**9/18/2007**	**13:05:48**
hbsndgrg.rif	**107,641**	**3/8/2008**	**16:15:13**
hbsndgrg.rls	**5,218**	**3/8/2008**	**16:15:14**

File Name	**Size/Type**	**Date**	**Time**
hbsndgrg.wlm	**623**	**3/8/2008**	**16:15:13**
hbsndgrg.wrn	**0**	**3/8/2008**	**16:14:39**
hbsndgrs.aff	**6,198**	**3/8/2008**	**16:17:00**
hbsndgrs.ato	**8,798**	**3/8/2008**	**16:17:00**
hbsndgrs.els	**24,448**	**3/8/2008**	**16:17:25**
hbsndgrs.epf	**22,318**	**3/8/2008**	**16:17:25**
hbsndgrs.gid	**614,853**	**3/8/2008**	**16:17:42**
hbsndgrs.hif	**153,072**	**3/8/2008**	**16:17:37**
hbsndgrs.hls	**830**	**3/8/2008**	**16:17:37**
hbsndgrs.ref	**197**	**10/19/2007**	**10:08:28**
hbsndgrs.rif	**38,393**	**3/8/2008**	**16:17:35**
hbsndgrs.rls	**5,218**	**3/8/2008**	**16:17:35**
hbsndgrs.wlm	**267**	**3/8/2008**	**16:17:35**
hbsndgrs.wrn	**0**	**3/8/2008**	**16:17:00**
hpsndgrg.aff	**6,536**	**3/8/2008**	**16:19:39**
hpsndgrg.ato	**9,081**	**3/8/2008**	**16:19:40**
hpsndgrg.els	**25,320**	**3/8/2008**	**16:20:08**
hpsndgrg.epf	**69,833**	**3/8/2008**	**16:20:08**
hpsndgrg.gid	**666,824**	**3/8/2008**	**16:20:33**
hpsndgrg.hif	**515,246**	**3/8/2008**	**16:20:20**
hpsndgrg.hls	**830**	**3/8/2008**	**16:20:20**
hpsndgrg.ref	**77**	**8/30/2007**	**7:39:34**
hpsndgrg.rif	**114,351**	**3/8/2008**	**16:20:17**
hpsndgrg.rls	**5,535**	**3/8/2008**	**16:20:17**
hpsndgrg.wlm	**356**	**3/8/2008**	**16:20:17**
hpsndgrg.wrn	**0**	**3/8/2008**	**16:19:40**
hpsndgrs.aff	**6,536**	**3/8/2008**	**16:22:06**
hpsndgrs.ato	**9,065**	**3/8/2008**	**16:22:06**
hpsndgrs.els	**25,320**	**3/8/2008**	**16:22:37**
hpsndgrs.epf	**23,670**	**3/8/2008**	**16:22:37**
hpsndgrs.gid	**666,829**	**3/8/2008**	**16:22:59**
hpsndgrs.hif	**162,598**	**3/8/2008**	**16:22:53**
hpsndgrs.hls	**830**	**3/8/2008**	**16:22:53**
hpsndgrs.ref	**77**	**8/30/2007**	**7:41:10**
hpsndgrs.rif	**40,775**	**3/8/2008**	**16:22:50**
hpsndgrs.rls	**5,535**	**3/8/2008**	**16:22:50**
hpsndgrs.wlm	**534**	**3/8/2008**	**16:22:50**
hpsndgrs.wrn	**0**	**3/8/2008**	**16:22:06**

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hbsndgrg.aff	6,203	10/19/2007	9:06:06
hbsndgrg.ato	8,804	10/19/2007	9:06:06
hbsndgrg.els	24,448	10/19/2007	9:06:26
hbsndgrg.epf	65,806	10/19/2007	9:06:26
hbsndgrg.gid	614,848	10/19/2007	9:06:40
hbsndgrg.hif	484,976	10/19/2007	9:06:35
hbsndgrg.hls	830	10/19/2007	9:06:35
hbsndgrg.rif	107,641	10/19/2007	9:06:33

File Name	Size/Type	Date	Time
hbsndgrg.rls	5,218	10/19/2007	9:06:33
hbsndgrg.wlm	534	10/19/2007	9:06:33
hbsndgrg.wrn	0	10/19/2007	9:06:06
hbsndgrs.aff	6,203	10/19/2007	9:09:44
hbsndgrs.ato	8,789	10/19/2007	9:09:44
hbsndgrs.els	24,448	10/19/2007	9:10:04
hbsndgrs.epf	22,321	10/19/2007	9:10:04
hbsndgrs.gid	614,853	10/19/2007	9:10:22
hbsndgrs.hif	153,072	10/19/2007	9:10:13
hbsndgrs.hls	830	10/19/2007	9:10:13
hbsndgrs.ref	197	10/19/2007	9:08:27
hbsndgrs.rif	38,393	10/19/2007	9:10:11
hbsndgrs.rls	5,218	10/19/2007	9:10:11
hbsndgrs.wlm	267	10/19/2007	9:10:11
hbsndgrs.wrn	0	10/19/2007	9:09:44
hhdhlgrg.aff	5,869	8/29/2007	15:56:38
hhdhlgrg.ato	8,498	8/29/2007	15:56:38
hhdhlgrg.els	24,506	8/29/2007	15:56:58
hhdhlgrg.epf	63,598	8/29/2007	15:56:58
hhdhlgrg.gid	622,942	9/12/2007	13:17:46
hhdhlgrg.hif	462,264	9/12/2007	13:17:42
hhdhlgrg.hls	830	9/12/2007	13:17:42
hhdhlgrg.ref	77	8/29/2007	15:28:26
hhdhlgrg.rif	102,599	9/12/2007	13:17:40
hhdhlgrg.rls	5,156	9/12/2007	13:17:40
hhdhlgrg.wlm	267	9/12/2007	13:17:40
hhdhlgrg.wrn	0	8/29/2007	15:56:38
hhdhlgrs.aff	5,869	8/29/2007	15:58:42
hhdhlgrs.ato	8,480	8/29/2007	15:58:42
hhdhlgrs.els	24,506	8/29/2007	15:58:58
hhdhlgrs.epf	21,479	8/29/2007	15:58:58
hhdhlgrs.gid	622,947	9/12/2007	13:20:48
hhdhlgrs.hif	145,918	9/12/2007	13:20:42
hhdhlgrs.hls	830	9/12/2007	13:20:42
hhdhlgrs.ref	77	8/29/2007	15:30:32
hhdhlgrs.rif	36,597	9/12/2007	13:20:40
hhdhlgrs.rls	5,156	9/12/2007	13:20:40
hhdhlgrs.wlm	534	9/12/2007	13:20:40
hhdhlgrs.wrn	0	8/29/2007	15:58:42
hidhlgrg.aff	6,148	9/11/2007	13:52:28
hidhlgrg.ato	8,910	9/11/2007	13:52:28
hidhlgrg.els	25,705	9/11/2007	13:52:54
hidhlgrg.epf	66,945	9/11/2007	13:52:54
hidhlgrg.gid	657,994	9/12/2007	13:23:04
hidhlgrg.hif	484,960	9/12/2007	13:22:44
hidhlgrg.hls	830	9/12/2007	13:22:44
hidhlgrg.ref	77	8/29/2007	15:39:44
hidhlgrg.rif	107,625	9/12/2007	13:22:42
hidhlgrg.rls	5,383	9/12/2007	13:22:42
hidhlgrg.wlm	534	9/12/2007	13:22:42

File Name	Size/Type	Date	Time
hidhlgrg.wrn	0	9/11/2007	13:52:28
hidhlgrs.aff	6,148	9/11/2007	13:55:12
hidhlgrs.ato	8,898	9/11/2007	13:55:12
hidhlgrs.els	25,705	9/11/2007	13:55:36
hidhlgrs.epf	22,473	9/11/2007	13:55:36
hidhlgrs.gid	657,999	9/12/2007	13:25:32
hidhlgrs.hif	153,056	9/12/2007	13:25:24
hidhlgrs.hls	830	9/12/2007	13:25:24
hidhlgrs.ref	77	8/29/2007	15:42:02
hidhlgrs.rif	38,377	9/12/2007	13:25:24
hidhlgrs.rls	5,383	9/12/2007	13:25:24
hidhlgrs.wlm	445	9/12/2007	13:25:24
hidhlgrs.wrn	0	9/11/2007	13:55:12
hpsndgrg.aff	6,531	10/19/2007	9:11:53
hpsndgrg.ato	9,072	10/19/2007	9:11:54
hpsndgrg.els	25,320	10/19/2007	9:12:17
hpsndgrg.epf	69,857	10/19/2007	9:12:17
hpsndgrg.gid	666,824	10/19/2007	9:14:17
hpsndgrg.hif	515,246	10/19/2007	9:12:26
hpsndgrg.hls	830	10/19/2007	9:12:26
hpsndgrg.rif	114,351	10/19/2007	9:12:25
hpsndgrg.rls	5,535	10/19/2007	9:12:25
hpsndgrg.wlm	356	10/19/2007	9:12:25
hpsndgrg.wrn	0	10/19/2007	9:11:54
hpsndgrs.aff	6,531	10/19/2007	9:19:52
hpsndgrs.ato	9,056	10/19/2007	9:19:52
hpsndgrs.els	25,320	10/19/2007	9:20:15
hpsndgrs.epf	23,674	10/19/2007	9:20:15
hpsndgrs.gid	666,829	10/19/2007	9:20:38
hpsndgrs.hif	162,598	10/19/2007	9:20:25
hpsndgrs.hls	830	10/19/2007	9:20:25
hpsndgrs.rif	40,775	10/19/2007	9:20:23
hpsndgrs.rls	5,535	10/19/2007	9:20:23
hpsndgrs.wlm	534	10/19/2007	9:20:23
hpsndgrs.wrn	0	10/19/2007	9:19:52
hsdhlgrg.aff	6,673	8/29/2007	15:47:12
hsdhlgrg.ato	9,782	8/29/2007	15:47:12
hsdhlgrg.els	28,144	8/29/2007	15:47:38
hsdhlgrg.epf	72,449	8/29/2007	15:47:38
hsdhlgrg.gid	721,989	9/12/2007	13:27:40
hsdhlgrg.hif	530,378	9/12/2007	13:27:30
hsdhlgrg.hls	830	9/12/2007	13:27:30
hsdhlgrg.ref	77	8/29/2007	15:45:48
hsdhlgrg.rif	117,703	9/12/2007	13:27:30
hsdhlgrg.rls	5,794	9/12/2007	13:27:30
hsdhlgrg.wlm	178	9/12/2007	13:27:28
hsdhlgrg.wrn	0	8/29/2007	15:47:12
hsdhlgrs.aff	6,673	8/29/2007	15:53:16
hsdhlgrs.ato	9,760	8/29/2007	15:53:18
hsdhlgrs.els	28,144	8/29/2007	15:53:42

File Name	Size/Type	Date	Time
hsdhlgrs.epf	24,571	8/29/2007	15:53:42
hsdhlgrs.gid	721,994	9/12/2007	13:29:48
hsdhlgrs.hif	167,358	9/12/2007	13:29:38
hsdhlgrs.hls	830	9/12/2007	13:29:38
hsdhlgrs.ref	77	8/29/2007	15:52:14
hsdhlgrs.rif	41,963	9/12/2007	13:29:38
hsdhlgrs.rls	5,794	9/12/2007	13:29:38
hsdhlgrs.wlm	356	9/12/2007	13:29:38
hsdhlgrs.wrn	0	8/29/2007	15:53:18
hwdhlgrg.aff	7,109	9/11/2007	13:30:46
hwdhlgrg.ato	10,511	9/11/2007	13:30:46
hwdhlgrg.els	30,033	9/11/2007	13:31:22
hwdhlgrg.epf	77,972	9/11/2007	13:31:22
hwdhlgrg.gid	763,007	9/12/2007	13:31:40
hwdhlgrg.hif	568,204	9/12/2007	13:31:30
hwdhlgrg.hls	830	9/12/2007	13:31:30
hwdhlgrg.ref	77	8/29/2007	15:23:38
hwdhlgrg.rif	126,079	9/12/2007	13:31:28
hwdhlgrg.rls	6,084	9/12/2007	13:31:28
hwdhlgrg.wlm	356	9/12/2007	13:31:28
hwdhlgrg.wrn	0	9/11/2007	13:30:46
hwdhlgrs.aff	7,109	9/11/2007	13:34:20
hwdhlgrs.ato	10,476	9/11/2007	13:34:20
hwdhlgrs.els	30,033	9/11/2007	13:34:54
hwdhlgrs.epf	26,309	9/11/2007	13:34:54
hwdhlgrs.gid	763,012	9/12/2007	13:34:04
hwdhlgrs.hif	179,254	9/12/2007	13:33:48
hwdhlgrs.hls	830	9/12/2007	13:33:48
hwdhlgrs.ref	77	8/29/2007	15:07:24
hwdhlgrs.rif	44,929	9/12/2007	13:33:48
hwdhlgrs.rls	6,084	9/12/2007	13:33:48
hwdhlgrs.wlm	534	9/12/2007	13:33:46
hwdhlgrs.wrn	0	9/11/2007	13:34:20

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lwfndgrg.aff	966	1/23/2008	8:20:11
lwfndgrg.ato	998	1/23/2008	8:20:12
lwfndgrg.els	3,750	1/23/2008	8:20:13
lwfndgrg.epf	5,177	1/23/2008	8:20:13
lwfndgrg.gid	53,224	1/23/2008	8:20:25
lwfndgrg.hif	38,478	1/23/2008	8:20:14
lwfndgrg.hls	830	1/23/2008	8:20:14
lwfndgrg.ref	77	8/30/2007	5:52:28
lwfndgrg.rif	8,653	1/23/2008	8:20:13
lwfndgrg.rls	1,356	1/23/2008	8:20:13
lwfndgrg.wlm	623	1/23/2008	8:20:13
lwfndgrg.wrn	0	1/23/2008	8:20:12
lwfndgrs.aff	966	1/23/2008	8:23:14

File Name	Size/Type	Date	Time
lwfndgrs.ato	1,000	1/23/2008	8:23:14
lwfndgrs.els	3,750	1/23/2008	8:23:15
lwfndgrs.epf	1,934	1/23/2008	8:23:15
lwfndgrs.gid	53,227	1/23/2008	8:23:41
lwfndgrs.hif	12,548	1/23/2008	8:23:15
lwfndgrs.hls	830	1/23/2008	8:23:15
lwfndgrs.ref	77	8/30/2007	5:56:58
lwfndgrs.rif	3,243	1/23/2008	8:23:15
lwfndgrs.rls	1,356	1/23/2008	8:23:15
lwfndgrs.wlm	712	1/23/2008	8:23:15
lwfndgrs.wrn	0	1/23/2008	8:23:14
lwsndgrg.aff	978	1/23/2008	15:18:47
lwsndgrg.ato	1,005	1/23/2008	15:18:47
lwsndgrg.els	3,750	1/23/2008	15:18:48
lwsndgrg.epf	5,148	1/23/2008	15:18:48
lwsndgrg.gid	53,236	1/23/2008	15:18:56
lwsndgrg.hif	38,478	1/23/2008	15:18:49
lwsndgrg.hls	830	1/23/2008	15:18:49
lwsndgrg.ref	77	8/30/2007	6:18:02
lwsndgrg.rif	8,653	1/23/2008	15:18:48
lwsndgrg.rls	1,356	1/23/2008	15:18:48
lwsndgrg.wlm	712	1/23/2008	15:18:48
lwsndgrg.wrn	0	1/23/2008	15:18:47
lwsndgrs.aff	978	1/23/2008	8:29:42
lwsndgrs.ato	1,019	1/23/2008	8:29:42
lwsndgrs.els	3,750	1/23/2008	8:29:43
lwsndgrs.epf	1,922	1/23/2008	8:29:43
lwsndgrs.gid	53,240	1/23/2008	8:29:47
lwsndgrs.hif	12,548	1/23/2008	8:29:43
lwsndgrs.hls	830	1/23/2008	8:29:43
lwsndgrs.ref	77	8/30/2007	6:25:20
lwsndgrs.rif	3,243	1/23/2008	8:29:43
lwsndgrs.rls	1,356	1/23/2008	8:29:43
lwsndgrs.wlm	712	1/23/2008	8:29:43
lwsndgrs.wrn	0	1/23/2008	8:29:42

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File Name	Size/Type	Date	Time
cmdhdape.aff	611	10/19/2007	8:24:14
cmdhdape.ato	472	10/19/2007	8:24:14
cmdhdape.els	2,378	10/19/2007	8:24:15
cmdhdape.epf	600	10/19/2007	8:24:15
cmdhdape.gid	36,575	10/19/2007	8:24:24
cmdhdape.hif	3,050	10/19/2007	8:24:16
cmdhdape.hls	830	10/19/2007	8:24:16
cmdhdape.ref	77	8/29/2007	7:48:36
cmdhdape.rif	889	10/19/2007	8:24:15
cmdhdape.rls	1,215	10/19/2007	8:24:15
cmdhdape.wlm	267	10/19/2007	8:24:15

File Name	Size/Type	Date	Time
cmdhdape.wrn	0	10/19/2007	8:24:14
cmdhdapg.aff	611	10/19/2007	8:29:54
cmdhdapg.ato	494	10/19/2007	8:29:55
cmdhdapg.els	2,378	10/19/2007	8:29:55
cmdhdapg.epf	1,362	10/19/2007	8:29:55
cmdhdapg.gid	36,574	10/19/2007	8:30:00
cmdhdapg.hif	8,236	10/19/2007	8:29:56
cmdhdapg.hls	830	10/19/2007	8:29:56
cmdhdapg.ref	197	8/29/2007	7:42:42
cmdhdapg.rif	1,971	10/19/2007	8:29:56
cmdhdapg.rls	1,215	10/19/2007	8:29:56
cmdhdapg.wlm	267	10/19/2007	8:29:56
cmdhdapg.wrn	0	10/19/2007	8:29:55
cmdhdapo.aff	611	10/19/2007	8:32:14
cmdhdapo.ato	465	10/19/2007	8:32:14
cmdhdapo.els	2,378	10/19/2007	8:32:14
cmdhdapo.epf	594	10/19/2007	8:32:14
cmdhdapo.gid	36,575	10/19/2007	8:32:19
cmdhdapo.hif	3,050	10/19/2007	8:32:15
cmdhdapo.hls	830	10/19/2007	8:32:15
cmdhdapo.ref	197	8/29/2007	7:45:52
cmdhdapo.rif	889	10/19/2007	8:32:15
cmdhdapo.rls	1,215	10/19/2007	8:32:15
cmdhdapo.wlm	267	10/19/2007	8:32:15
cmdhdapo.wrn	0	10/19/2007	8:32:14
cmdhdaps.aff	611	10/19/2007	8:34:35
cmdhdaps.ato	492	10/19/2007	8:34:35
cmdhdaps.els	2,378	10/19/2007	8:34:36
cmdhdaps.epf	624	10/19/2007	8:34:36
cmdhdaps.gid	36,575	10/19/2007	8:34:41
cmdhdaps.hif	3,050	10/19/2007	8:34:36
cmdhdaps.hls	830	10/19/2007	8:34:36
cmdhdaps.ref	77	8/29/2007	7:48:56
cmdhdaps.rif	889	10/19/2007	8:34:36
cmdhdaps.rls	1,215	10/19/2007	8:34:36
cmdhdaps.wlm	267	10/19/2007	8:34:36
cmdhdaps.wrn	0	10/19/2007	8:34:35
nbdhdgre.aff	**4,557**	**3/8/2008**	**15:13:35**
nbdhdgre.ato	**9,353**	**3/8/2008**	**15:13:36**
nbdhdgre.els	**25,890**	**3/8/2008**	**15:14:06**
nbdhdgre.epf	**12,333**	**3/8/2008**	**15:14:06**
nbdhdgre.gid	**643,229**	**3/8/2008**	**15:14:19**
nbdhdgre.hif	**83,680**	**3/8/2008**	**15:14:14**
nbdhdgre.hls	**830**	**3/8/2008**	**15:14:14**
nbdhdgre.ref	**77**	**9/20/2007**	**9:44:12**
nbdhdgre.rif	**21,688**	**3/8/2008**	**15:14:12**
nbdhdgre.rls	**5,484**	**3/8/2008**	**15:14:12**
nbdhdgre.wlm	**356**	**3/8/2008**	**15:14:12**
nbdhdgre.wrn	**0**	**3/8/2008**	**15:13:36**
nbdhdgrg.aff	**4,557**	**3/8/2008**	**15:31:18**

File Name	Size/Type	Date	Time
nbdhdgrg.ato	9,880	3/8/2008	15:31:18
nbdhdgrg.els	25,890	3/8/2008	15:31:52
nbdhdgrg.epf	38,929	3/8/2008	15:31:52
nbdhdgrg.gid	643,224	3/8/2008	15:32:03
nbdhdgrg.hif	262,597	3/8/2008	15:31:58
nbdhdgrg.hls	830	3/8/2008	15:31:58
nbdhdgrg.ref	77	9/20/2007	8:59:52
nbdhdgrg.rif	59,017	3/8/2008	15:31:57
nbdhdgrg.rls	5,484	3/8/2008	15:31:57
nbdhdgrg.wlm	267	3/8/2008	15:31:57
nbdhdgrg.wrn	0	3/8/2008	15:31:18
nbdhdgro.aff	4,541	3/8/2008	15:33:33
nbdhdgro.ato	9,248	3/8/2008	15:33:33
nbdhdgro.els	25,890	3/8/2008	15:34:06
nbdhdgro.epf	12,319	3/8/2008	15:34:06
nbdhdgro.gid	643,229	3/8/2008	15:34:19
nbdhdgro.hif	83,680	3/8/2008	15:34:14
nbdhdgro.hls	830	3/8/2008	15:34:14
nbdhdgro.ref	77	9/20/2007	9:46:44
nbdhdgro.rif	21,688	3/8/2008	15:34:12
nbdhdgro.rls	5,484	3/8/2008	15:34:12
nbdhdgro.wlm	445	3/8/2008	15:34:12
nbdhdgro.wrn	0	3/8/2008	15:33:33
nbdhdgrs.aff	4,557	3/8/2008	15:36:03
nbdhdgrs.ato	9,885	3/8/2008	15:36:03
nbdhdgrs.els	25,890	3/8/2008	15:36:38
nbdhdgrs.epf	13,301	3/8/2008	15:36:38
nbdhdgrs.gid	643,229	3/8/2008	15:37:00
nbdhdgrs.hif	83,680	3/8/2008	15:36:45
nbdhdgrs.hls	830	3/8/2008	15:36:45
nbdhdgrs.ref	77	9/20/2007	9:37:44
nbdhdgrs.rif	21,688	3/8/2008	15:36:43
nbdhdgrs.rls	5,484	3/8/2008	15:36:43
nbdhdgrs.wlm	356	3/8/2008	15:36:43
nbdhdgrs.wrn	0	3/8/2008	15:36:03
nmdhdgre.aff	5,915	3/8/2008	15:39:08
nmdhdgre.ato	9,622	3/8/2008	15:39:08
nmdhdgre.els	26,760	3/8/2008	15:39:41
nmdhdgre.epf	13,023	3/8/2008	15:39:41
nmdhdgre.gid	696,129	3/8/2008	15:39:53
nmdhdgre.hif	88,494	3/8/2008	15:39:48
nmdhdgre.hls	830	3/8/2008	15:39:48
nmdhdgre.ref	77	9/7/2007	10:14:32
nmdhdgre.rif	22,930	3/8/2008	15:39:47
nmdhdgre.rls	5,801	3/8/2008	15:39:47
nmdhdgre.wlm	979	3/8/2008	15:39:47
nmdhdgre.wrn	0	3/8/2008	15:39:08
nmdhdgrg.aff	5,915	3/8/2008	15:41:31
nmdhdgrg.ato	10,157	3/8/2008	15:41:31
nmdhdgrg.els	26,760	3/8/2008	15:42:08

File Name	Size/Type	Date	Time
nmdhdgrg.epf	**41,088**	**3/8/2008**	**15:42:08**
nmdhdgrg.gid	**696,122**	**3/8/2008**	**15:42:19**
nmdhdgrg.hif	**277,783**	**3/8/2008**	**15:42:15**
nmdhdgrg.hls	**830**	**3/8/2008**	**15:42:15**
nmdhdgrg.ref	**77**	**9/7/2007**	**9:15:48**
nmdhdgrg.rif	**62,423**	**3/8/2008**	**15:42:13**
nmdhdgrg.rls	**5,801**	**3/8/2008**	**15:42:13**
nmdhdgrg.wlm	**534**	**3/8/2008**	**15:42:13**
nmdhdgrg.wrn	**0**	**3/8/2008**	**15:41:31**
nmdhdgro.aff	**5,915**	**3/8/2008**	**15:43:54**
nmdhdgro.ato	**9,501**	**3/8/2008**	**15:43:54**
nmdhdgro.els	**26,760**	**3/8/2008**	**15:44:27**
nmdhdgro.epf	**12,981**	**3/8/2008**	**15:44:27**
nmdhdgro.gid	**696,127**	**3/8/2008**	**15:44:55**
nmdhdgro.hif	**88,494**	**3/8/2008**	**15:44:35**
nmdhdgro.hls	**830**	**3/8/2008**	**15:44:35**
nmdhdgro.ref	**77**	**9/7/2007**	**10:17:12**
nmdhdgro.rif	**22,930**	**3/8/2008**	**15:44:33**
nmdhdgro.rls	**5,801**	**3/8/2008**	**15:44:33**
nmdhdgro.wlm	**890**	**3/8/2008**	**15:44:33**
nmdhdgro.wrn	**0**	**3/8/2008**	**15:43:54**
nmdhdgrs.aff	**5,915**	**3/8/2008**	**15:46:16**
nmdhdgrs.ato	**10,159**	**3/8/2008**	**15:46:16**
nmdhdgrs.els	**26,760**	**3/8/2008**	**15:46:53**
nmdhdgrs.epf	**14,025**	**3/8/2008**	**15:46:53**
nmdhdgrs.gid	**696,127**	**3/8/2008**	**15:47:11**
nmdhdgrs.hif	**88,494**	**3/8/2008**	**15:47:02**
nmdhdgrs.hls	**830**	**3/8/2008**	**15:47:02**
nmdhdgrs.ref	**77**	**9/7/2007**	**9:57:42**
nmdhdgrs.rif	**22,930**	**3/8/2008**	**15:47:00**
nmdhdgrs.rls	**5,801**	**3/8/2008**	**15:47:00**
nmdhdgrs.wlm	**890**	**3/8/2008**	**15:47:00**
nmdhdgrs.wrn	**0**	**3/8/2008**	**15:46:16**
nodhdgre.aff	**6,001**	**3/8/2008**	**15:48:37**
nodhdgre.ato	**9,623**	**3/8/2008**	**15:48:38**
nodhdgre.els	**26,760**	**3/8/2008**	**15:49:11**
nodhdgre.epf	**13,025**	**3/8/2008**	**15:49:11**
nodhdgre.gid	**696,267**	**3/8/2008**	**15:49:26**
nodhdgre.hif	**88,494**	**3/8/2008**	**15:49:19**
nodhdgre.hls	**830**	**3/8/2008**	**15:49:19**
nodhdgre.ref	**77**	**8/28/2007**	**13:34:08**
nodhdgre.rif	**22,930**	**3/8/2008**	**15:49:18**
nodhdgre.rls	**5,801**	**3/8/2008**	**15:49:18**
nodhdgre.wlm	**445**	**3/8/2008**	**15:49:17**
nodhdgre.wrn	**0**	**3/8/2008**	**15:48:38**
nodhdgrg.aff	**6,001**	**3/8/2008**	**15:51:07**
nodhdgrg.ato	**10,156**	**3/8/2008**	**15:51:07**
nodhdgrg.els	**26,760**	**3/8/2008**	**15:51:46**
nodhdgrg.epf	**41,126**	**3/8/2008**	**15:51:46**
nodhdgrg.gid	**696,262**	**3/8/2008**	**15:52:00**

File Name	Size/Type	Date	Time
nodhdgrg.hif	277,783	3/8/2008	15:51:55
nodhdgrg.hls	830	3/8/2008	15:51:55
nodhdgrg.ref	77	8/27/2007	8:25:56
nodhdgrg.rif	62,423	3/8/2008	15:51:53
nodhdgrg.rls	5,801	3/8/2008	15:51:53
nodhdgrg.wlm	979	3/8/2008	15:51:53
nodhdgrg.wrn	0	3/8/2008	15:51:07
nodhdgro.aff	6,001	3/8/2008	15:53:28
nodhdgro.ato	9,507	3/8/2008	15:53:28
nodhdgro.els	26,760	3/8/2008	15:54:04
nodhdgro.epf	12,993	3/8/2008	15:54:04
nodhdgro.gid	696,267	3/8/2008	15:54:18
nodhdgro.hif	88,494	3/8/2008	15:54:13
nodhdgro.hls	830	3/8/2008	15:54:13
nodhdgro.ref	77	8/28/2007	8:15:14
nodhdgro.rif	22,930	3/8/2008	15:54:10
nodhdgro.rls	5,801	3/8/2008	15:54:10
nodhdgro.wlm	534	3/8/2008	15:54:10
nodhdgro.wrn	0	3/8/2008	15:53:28
nodhdgrs.aff	6,001	3/8/2008	15:55:36
nodhdgrs.ato	10,161	3/8/2008	15:55:36
nodhdgrs.els	26,760	3/8/2008	15:56:11
nodhdgrs.epf	14,037	3/8/2008	15:56:11
nodhdgrs.gid	696,267	3/8/2008	15:56:25
nodhdgrs.hif	88,494	3/8/2008	15:56:19
nodhdgrs.hls	830	3/8/2008	15:56:19
nodhdgrs.ref	77	8/28/2007	7:47:08
nodhdgrs.rif	22,930	3/8/2008	15:56:17
nodhdgrs.rls	5,801	3/8/2008	15:56:17
nodhdgrs.wlm	445	3/8/2008	15:56:17
nodhdgrs.wrn	0	3/8/2008	15:55:36
sfdhdsfe.aff	1,899	3/8/2008	15:58:01
sfdhdsfe.ato	3,890	3/8/2008	15:58:01
sfdhdsfe.els	10,866	3/8/2008	15:58:04
sfdhdsfe.epf	4,321	3/8/2008	15:58:04
sfdhdsfe.gid	179,541	3/8/2008	15:58:09
sfdhdsfe.hif	28,312	3/8/2008	15:58:06
sfdhdsfe.hls	830	3/8/2008	15:58:06
sfdhdsfe.ref	77	12/6/2007	10:58:01
sfdhdsfe.rif	7,398	3/8/2008	15:58:05
sfdhdsfe.rls	2,369	3/8/2008	15:58:05
sfdhdsfe.wlm	267	3/8/2008	15:58:05
sfdhdsfe.wrn	0	3/8/2008	15:58:01
sfdhdsfg.aff	1,899	3/8/2008	15:59:42
sfdhdsfg.ato	4,045	3/8/2008	15:59:42
sfdhdsfg.els	10,866	3/8/2008	15:59:45
sfdhdsfg.epf	13,266	3/8/2008	15:59:45
sfdhdsfg.gid	179,536	3/8/2008	15:59:51
sfdhdsfg.hif	87,951	3/8/2008	15:59:46
sfdhdsfg.hls	830	3/8/2008	15:59:46

File Name	Size/Type	Date	Time
sfdhdsfg.ref	**197**	**12/6/2007**	**10:33:21**
sfdhdsfg.rif	**19,841**	**3/8/2008**	**15:59:46**
sfdhdsfg.rls	**2,369**	**3/8/2008**	**15:59:46**
sfdhdsfg.wlm	**178**	**3/8/2008**	**15:59:46**
sfdhdsfg.wrn	**0**	**3/8/2008**	**15:59:42**
sfdhdsfo.aff	**1,899**	**3/8/2008**	**16:01:05**
sfdhdsfo.ato	**3,894**	**3/8/2008**	**16:01:05**
sfdhdsfo.els	**10,866**	**3/8/2008**	**16:01:08**
sfdhdsfo.epf	**4,329**	**3/8/2008**	**16:01:08**
sfdhdsfo.gid	**179,541**	**3/8/2008**	**16:01:14**
sfdhdsfo.hif	**28,312**	**3/8/2008**	**16:01:10**
sfdhdsfo.hls	**830**	**3/8/2008**	**16:01:10**
sfdhdsfo.ref	**77**	**12/6/2007**	**11:04:37**
sfdhdsfo.rif	**7,398**	**3/8/2008**	**16:01:09**
sfdhdsfo.rls	**2,369**	**3/8/2008**	**16:01:09**
sfdhdsfo.wlm	**178**	**3/8/2008**	**16:01:09**
sfdhdsfo.wrn	**0**	**3/8/2008**	**16:01:05**
sfdhdsfs.aff	**1,899**	**3/8/2008**	**16:02:21**
sfdhdsfs.ato	**4,042**	**3/8/2008**	**16:02:21**
sfdhdsfs.els	**10,866**	**3/8/2008**	**16:02:24**
sfdhdsfs.epf	**4,671**	**3/8/2008**	**16:02:24**
sfdhdsfs.gid	**179,541**	**3/8/2008**	**16:02:29**
sfdhdsfs.hif	**28,312**	**3/8/2008**	**16:02:25**
sfdhdsfs.hls	**830**	**3/8/2008**	**16:02:25**
sfdhdsfs.ref	**77**	**12/6/2007**	**10:49:42**
sfdhdsfs.rif	**7,398**	**3/8/2008**	**16:02:25**
sfdhdsfs.rls	**2,369**	**3/8/2008**	**16:02:25**
sfdhdsfs.wlm	**178**	**3/8/2008**	**16:02:25**
sfdhdsfs.wrn	**0**	**3/8/2008**	**16:02:21**

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MAX	DIR	10/29/2007	15:12:06
MAX50%	DIR	10/29/2007	15:12:09
POOL	DIR	10/29/2007	15:12:10
REP	DIR	10/29/2007	15:12:18
REP50%	DIR	10/29/2007	15:12:20

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p1dnlgrg.aff	**6,944**	**3/8/2008**	**17:18:11**
p1dnlgrg.ato	**9,806**	**3/8/2008**	**17:18:11**
p1dnlgrg.els	**27,047**	**3/8/2008**	**17:18:45**
p1dnlgrg.epf	**74,803**	**3/8/2008**	**17:18:45**
p1dnlgrg.gid	**697,740**	**3/8/2008**	**17:19:04**
p1dnlgrg.hif	**553,066**	**3/8/2008**	**17:18:59**
p1dnlgrg.hls	**830**	**3/8/2008**	**17:18:59**
p1dnlgrg.ref	**77**	**3/8/2008**	**17:17:04**
p1dnlgrg.aff	**6,944**	**3/8/2008**	**17:18:11**

File Name	Size/Type	Date	Time
p1dnlgrg.rif	**122,721**	**3/8/2008**	**17:18:55**
p1dnlgrg.rls	**5,801**	**3/8/2008**	**17:18:55**
p1dnlgrg.wlm	**89**	**3/8/2008**	**17:18:55**
p1dnlgrg.wrn	**0**	**3/8/2008**	**17:18:11**
p1dnlgrs.aff	**6,944**	**3/8/2008**	**17:24:45**
p1dnlgrs.ato	**9,799**	**3/8/2008**	**17:24:45**
p1dnlgrs.els	**27,047**	**3/8/2008**	**17:25:17**
p1dnlgrs.epf	**25,371**	**3/8/2008**	**17:25:17**
p1dnlgrs.gid	**697,743**	**3/8/2008**	**17:25:35**
p1dnlgrs.hif	**174,488**	**3/8/2008**	**17:25:31**
p1dnlgrs.hls	**830**	**3/8/2008**	**17:25:31**
p1dnlgrs.ref	**77**	**3/8/2008**	**17:22:03**
p1dnlgrs.rif	**43,735**	**3/8/2008**	**17:25:28**
p1dnlgrs.rls	**5,801**	**3/8/2008**	**17:25:28**
p1dnlgrs.wlm	**178**	**3/8/2008**	**17:25:28**
p1dnlgrs.wrn	**0**	**3/8/2008**	**17:24:45**
p1onlgrg.aff	**6,517**	**3/8/2008**	**17:20:15**
p1onlgrg.ato	**9,430**	**3/8/2008**	**17:20:15**
p1onlgrg.els	**26,257**	**3/8/2008**	**17:20:48**
p1onlgrg.epf	**72,684**	**3/8/2008**	**17:20:48**
p1onlgrg.gid	**686,620**	**3/8/2008**	**17:21:05**
p1onlgrg.hif	**537,934**	**3/8/2008**	**17:21:01**
p1onlgrg.hls	**830**	**3/8/2008**	**17:21:01**
p1onlgrg.ref	**77**	**3/8/2008**	**17:19:58**
p1onlgrg.rif	**119,369**	**3/8/2008**	**17:20:58**
p1onlgrg.rls	**5,707**	**3/8/2008**	**17:20:58**
p1onlgrg.wlm	**89**	**3/8/2008**	**17:20:58**
p1onlgrg.wrn	**0**	**3/8/2008**	**17:20:15**
p1onlgrs.aff	**6,517**	**3/8/2008**	**17:26:23**
p1onlgrs.ato	**9,421**	**3/8/2008**	**17:26:24**
p1onlgrs.els	**26,257**	**3/8/2008**	**17:26:53**
p1onlgrs.epf	**24,509**	**3/8/2008**	**17:26:53**
p1onlgrs.gid	**686,623**	**3/8/2008**	**17:27:11**
p1onlgrs.hif	**169,728**	**3/8/2008**	**17:27:06**
p1onlgrs.hls	**830**	**3/8/2008**	**17:27:06**
p1onlgrs.ref	**77**	**3/8/2008**	**17:26:04**
p1onlgrs.rif	**42,547**	**3/8/2008**	**17:27:03**
p1onlgrs.rls	**5,707**	**3/8/2008**	**17:27:03**
p1onlgrs.wlm	**89**	**3/8/2008**	**17:27:03**
p1onlgrs.wrn	**0**	**3/8/2008**	**17:26:24**
pmdhlgrg.aff	6,931	8/30/2007	10:04:48
pmdhlgrg.ato	9,874	8/30/2007	10:04:48
pmdhlgrg.els	27,047	8/30/2007	10:05:30
pmdhlgrg.epf	74,973	8/30/2007	10:05:30
pmdhlgrg.gid	697,744	10/18/2007	5:51:28
pmdhlgrg.hif	553,066	10/18/2007	5:50:33
pmdhlgrg.hls	830	10/18/2007	5:50:33
pmdhlgrg.ref	77	8/30/2007	10:03:18
pmdhlgrg.rif	122,721	10/18/2007	5:50:31
pmdhlgrg.rls	5,801	10/18/2007	5:50:31

File Name	Size/Type	Date	Time
pmdhlgrg.wlm	267	10/18/2007	5:50:31
pmdhlgrg.wrn	0	8/30/2007	10:04:48
pmdhlgrs.aff	6,931	8/30/2007	10:32:52
pmdhlgrs.ato	9,861	8/30/2007	10:32:52
pmdhlgrs.els	27,047	8/30/2007	10:33:34
pmdhlgrs.epf	25,409	8/30/2007	10:33:34
pmdhlgrs.gid	697,749	9/12/2007	11:34:42
pmdhlgrs.hif	174,488	9/12/2007	11:34:36
pmdhlgrs.hls	830	9/12/2007	11:34:36
pmdhlgrs.ref	77	8/30/2007	10:32:02
pmdhlgrs.rif	43,735	9/12/2007	11:34:34
pmdhlgrs.rls	5,801	9/12/2007	11:34:34
pmdhlgrs.wlm	178	9/12/2007	11:34:34
pmdhlgrs.wrn	0	8/30/2007	10:32:52
pmdnlgrg.aff	6,995	9/6/2007	10:10:54
pmdnlgrg.ato	9,778	9/6/2007	10:10:54
pmdnlgrg.els	27,047	9/6/2007	10:11:20
pmdnlgrg.epf	74,438	9/6/2007	10:11:20
pmdnlgrg.gid	697,737	10/18/2007	6:00:53
pmdnlgrg.hif	553,066	10/18/2007	6:00:37
pmdnlgrg.hls	830	10/18/2007	6:00:37
pmdnlgrg.ref	77	9/6/2007	10:10:00
pmdnlgrg.rif	122,721	10/18/2007	6:00:36
pmdnlgrg.rls	5,801	10/18/2007	6:00:36
pmdnlgrg.wlm	267	10/18/2007	6:00:36
pmdnlgrg.wrn	0	9/6/2007	10:10:54
pmdnlgrs.aff	6,995	9/6/2007	10:12:22
pmdnlgrs.ato	9,774	9/6/2007	10:12:22
pmdnlgrs.els	27,047	9/6/2007	10:12:48
pmdnlgrs.epf	25,258	9/6/2007	10:12:48
pmdnlgrs.gid	697,740	9/12/2007	11:47:44
pmdnlgrs.hif	174,488	9/12/2007	11:47:34
pmdnlgrs.hls	830	9/12/2007	11:47:34
pmdnlgrs.ref	77	9/6/2007	10:11:46
pmdnlgrs.rif	43,735	9/12/2007	11:47:32
pmdnlgrs.rls	5,801	9/12/2007	11:47:32
pmdnlgrs.wlm	178	9/12/2007	11:47:32
pmdnlgrs.wrn	0	9/6/2007	10:12:22
pmohlgrg.aff	6,536	8/30/2007	10:18:20
pmohlgrg.ato	9,505	8/30/2007	10:18:20
pmohlgrg.els	26,257	8/30/2007	10:18:58
pmohlgrg.epf	72,779	8/30/2007	10:18:58
pmohlgrg.gid	686,618	10/2/2007	14:29:45
pmohlgrg.hif	537,934	10/2/2007	14:29:38
pmohlgrg.hls	830	10/2/2007	14:29:38
pmohlgrg.ref	77	8/30/2007	10:17:44
pmohlgrg.rif	119,369	10/2/2007	14:29:37
pmohlgrg.rls	5,707	10/2/2007	14:29:37
pmohlgrg.wlm	267	10/2/2007	14:29:37
pmohlgrg.wrn	0	8/30/2007	10:18:20

File Name	Size/Type	Date	Time
pmohlgrs.aff	6,536	8/30/2007	10:35:34
pmohlgrs.ato	9,481	8/30/2007	10:35:36
pmohlgrs.els	26,257	8/30/2007	10:36:06
pmohlgrs.epf	24,513	8/30/2007	10:36:06
pmohlgrs.gid	686,621	10/3/2007	6:39:39
pmohlgrs.hif	169,728	10/3/2007	6:39:22
pmohlgrs.hls	830	10/3/2007	6:39:22
pmohlgrs.ref	77	8/30/2007	10:35:00
pmohlgrs.rif	42,547	10/3/2007	6:39:21
pmohlgrs.rls	5,707	10/3/2007	6:39:21
pmohlgrs.wlm	534	10/3/2007	6:39:21
pmohlgrs.wrn	0	8/30/2007	10:35:36
pmonlgrg.aff	6,528	9/6/2007	10:17:10
pmonlgrg.ato	9,388	9/6/2007	10:17:10
pmonlgrg.els	26,257	9/6/2007	10:17:36
pmonlgrg.epf	72,261	9/6/2007	10:17:36
pmonlgrg.gid	686,618	10/2/2007	14:39:46
pmonlgrg.hif	537,934	10/2/2007	14:39:40
pmonlgrg.hls	830	10/2/2007	14:39:40
pmonlgrg.ref	77	9/6/2007	10:16:20
pmonlgrg.rif	119,369	10/2/2007	14:39:38
pmonlgrg.rls	5,707	10/2/2007	14:39:38
pmonlgrg.wlm	267	10/2/2007	14:39:38
pmonlgrg.wrn	0	9/6/2007	10:17:10
pmonlgrs.aff	6,528	9/6/2007	10:18:32
pmonlgrs.ato	9,399	9/6/2007	10:18:32
pmonlgrs.els	26,257	9/6/2007	10:18:56
pmonlgrs.epf	24,403	9/6/2007	10:18:56
pmonlgrs.gid	686,621	10/3/2007	6:43:00
pmonlgrs.hif	169,728	10/3/2007	6:42:46
pmonlgrs.hls	830	10/3/2007	6:42:46
pmonlgrs.ref	77	9/6/2007	10:18:02
pmonlgrs.rif	42,547	10/3/2007	6:42:45
pmonlgrs.rls	5,707	10/3/2007	6:42:45
pmonlgrs.wlm	356	10/3/2007	6:42:44
pmonlgrs.wrn	0	9/6/2007	10:18:32

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pmdhlgrg.aff	6,934	9/18/2007	9:09:42
pmdhlgrg.ato	9,913	9/18/2007	9:09:42
pmdhlgrg.els	27,047	9/18/2007	9:10:08
pmdhlgrg.epf	75,036	9/18/2007	9:10:08
pmdhlgrg.gid	697,748	10/18/2007	9:05:35
pmdhlgrg.hif	553,066	10/18/2007	9:05:29
pmdhlgrg.hls	830	10/18/2007	9:05:29
pmdhlgrg.ref	77	9/18/2007	9:09:24
pmdhlgrg.rif	122,721	10/18/2007	9:05:28
pmdhlgrg.rls	5,801	10/18/2007	9:05:28

File Name	Size/Type	Date	Time
pmdhlgrg.wlm	178	10/18/2007	9:05:27
pmdhlgrg.wrn	0	9/18/2007	9:09:42
pmdhlgrs.aff	6,934	9/18/2007	9:17:24
pmdhlgrs.ato	9,901	9/18/2007	9:17:24
pmdhlgrs.els	27,047	9/18/2007	9:17:48
pmdhlgrs.epf	25,438	9/18/2007	9:17:48
pmdhlgrs.gid	697,753	9/18/2007	9:18:08
pmdhlgrs.hif	174,488	9/18/2007	9:18:00
pmdhlgrs.hls	830	9/18/2007	9:18:00
pmdhlgrs.ref	77	9/18/2007	9:17:06
pmdhlgrs.rif	43,735	9/18/2007	9:17:58
pmdhlgrs.rls	5,801	9/18/2007	9:17:58
pmdhlgrs.wlm	89	9/18/2007	9:17:58
pmdhlgrs.wrn	0	9/18/2007	9:17:24
pmohlgrg.aff	6,539	9/18/2007	9:14:56
pmohlgrg.ato	9,534	9/18/2007	9:14:56
pmohlgrg.els	26,257	9/18/2007	9:15:20
pmohlgrg.epf	72,785	9/18/2007	9:15:20
pmohlgrg.gid	686,620	10/18/2007	12:56:50
pmohlgrg.hif	537,934	10/18/2007	12:56:38
pmohlgrg.hls	830	10/18/2007	12:56:38
pmohlgrg.ref	77	9/18/2007	9:11:42
pmohlgrg.rif	119,369	10/18/2007	12:56:37
pmohlgrg.rls	5,707	10/18/2007	12:56:37
pmohlgrg.wlm	267	10/18/2007	12:56:36
pmohlgrg.wrn	0	9/18/2007	9:14:56
pmohlgrs.aff	6,539	9/18/2007	9:19:14
pmohlgrs.ato	9,505	9/18/2007	9:19:14
pmohlgrs.els	26,257	9/18/2007	9:19:40
pmohlgrs.epf	24,504	9/18/2007	9:19:40
pmohlgrs.gid	686,623	10/18/2007	13:04:34
pmohlgrs.hif	169,728	10/18/2007	13:03:58
pmohlgrs.hls	830	10/18/2007	13:03:58
pmohlgrs.ref	77	9/18/2007	9:19:00
pmohlgrs.rif	42,547	10/18/2007	13:03:56
pmohlgrs.rls	5,707	10/18/2007	13:03:56
pmohlgrs.wlm	356	10/18/2007	13:03:56
pmohlgrs.wrn	0	9/18/2007	9:19:14

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pmpnlgrg.aff	1,014	8/30/2007	8:48:36
pmpnlgrg.ato	1,004	8/30/2007	8:48:36
pmpnlgrg.els	3,897	8/30/2007	8:48:38
pmpnlgrg.epf	6,040	8/30/2007	8:48:38
pmpnlgrg.gid	61,726	10/18/2007	5:45:14
pmpnlgrg.hif	46,032	10/18/2007	5:45:05
pmpnlgrg.hls	830	10/18/2007	5:45:05
pmpnlgrg.ref	77	8/30/2007	8:48:24

File Name	Size/Type	Date	Time
pmpnlgrg.rif	10,317	10/18/2007	5:45:04
pmpnlgrg.rls	1,434	10/18/2007	5:45:04
pmpnlgrg.wlm	267	10/18/2007	5:45:04
pmpnlgrg.wrn	0	8/30/2007	8:48:36
pmpnlgrs.aff	1,014	8/30/2007	8:51:22
pmpnlgrs.ato	1,004	8/30/2007	8:51:24
pmpnlgrs.els	3,897	8/30/2007	8:51:24
pmpnlgrs.epf	2,222	8/30/2007	8:51:24
pmpnlgrs.gid	61,731	9/12/2007	12:44:42
pmpnlgrs.hif	14,916	9/12/2007	12:44:38
pmpnlgrs.hls	830	9/12/2007	12:44:38
pmpnlgrs.ref	77	8/30/2007	8:51:08
pmpnlgrs.rif	3,825	9/12/2007	12:44:38
pmpnlgrs.rls	1,434	9/12/2007	12:44:38
pmpnlgrs.wlm	267	9/12/2007	12:44:38
pmpnlgrs.wrn	0	8/30/2007	8:51:24

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File Name	Size/Type	Date	Time
padhlgrg.aff	6,913	9/24/2007	9:30:12
padhlgrg.ato	9,895	9/24/2007	9:30:12
padhlgrg.els	27,047	9/24/2007	9:30:40
padhlgrg.epf	75,058	9/24/2007	9:30:40
padhlgrg.gid	697,702	9/24/2007	9:32:38
padhlgrg.hif	553,066	9/24/2007	9:30:52
padhlgrg.hls	830	9/24/2007	9:30:52
padhlgrg.ref	77	9/5/2007	8:48:12
padhlgrg.rif	122,721	9/24/2007	9:30:50
padhlgrg.rls	5,801	9/24/2007	9:30:50
padhlgrg.wlm	356	9/24/2007	9:30:50
padhlgrg.wrn	0	9/24/2007	9:30:12
padhlgro.aff	6,913	9/24/2007	9:42:34
padhlgro.ato	9,218	9/24/2007	9:42:34
padhlgro.els	27,047	9/24/2007	9:43:12
padhlgro.epf	24,393	9/24/2007	9:43:14
padhlgro.gid	697,707	9/24/2007	9:43:38
padhlgro.hif	174,488	9/24/2007	9:43:32
padhlgro.hls	830	9/24/2007	9:43:32
padhlgro.ref	77	9/5/2007	12:14:52
padhlgro.rif	43,735	9/24/2007	9:43:28
padhlgro.rls	5,801	9/24/2007	9:43:28
padhlgro.wlm	356	9/24/2007	9:43:28
padhlgro.wrn	0	9/24/2007	9:42:34
padhlgrs.aff	6,913	9/24/2007	9:45:24
padhlgrs.ato	9,872	9/24/2007	9:45:24
padhlgrs.els	27,047	9/24/2007	9:46:06
padhlgrs.epf	25,451	9/24/2007	9:46:06
padhlgrs.gid	697,707	10/18/2007	8:25:24
padhlgrs.hif	174,488	10/18/2007	8:25:18

File Name	Size/Type	Date	Time
padhlgrs.hls	830	10/18/2007	8:25:18
padhlgrs.ref	77	9/5/2007	11:53:18
padhlgrs.rif	43,735	10/18/2007	8:25:16
padhlgrs.rls	5,801	10/18/2007	8:25:16
padhlgrs.wlm	445	10/18/2007	8:25:16
padhlgrs.wrn	0	9/24/2007	9:45:24
padnlgrg.aff	6,893	9/24/2007	9:49:22
padnlgrg.ato	9,835	9/24/2007	9:49:24
padnlgrg.els	27,047	9/24/2007	9:50:04
padnlgrg.epf	74,847	9/24/2007	9:50:04
padnlgrg.gid	697,709	10/18/2007	6:05:56
padnlgrg.hif	553,066	10/18/2007	6:05:51
padnlgrg.hls	830	10/18/2007	6:05:51
padnlgrg.ref	77	9/14/2007	8:11:14
padnlgrg.rif	122,721	10/18/2007	6:05:49
padnlgrg.rls	5,801	10/18/2007	6:05:49
padnlgrg.wlm	267	10/18/2007	6:05:49
padnlgrg.wrn	0	9/24/2007	9:49:24
padnlgrs.aff	6,893	9/24/2007	9:59:02
padnlgrs.ato	9,821	9/24/2007	9:59:02
padnlgrs.els	27,047	9/24/2007	9:59:40
padnlgrs.epf	25,398	9/24/2007	9:59:40
padnlgrs.gid	697,714	9/24/2007	10:00:00
padnlgrs.hif	174,488	9/24/2007	9:59:54
padnlgrs.hls	830	9/24/2007	9:59:54
padnlgrs.ref	77	9/14/2007	8:22:48
padnlgrs.rif	43,735	9/24/2007	9:59:52
padnlgrs.rls	5,801	9/24/2007	9:59:52
padnlgrs.wlm	178	9/24/2007	9:59:52
padnlgrs.wrn	0	9/24/2007	9:59:02
paohlgrg.aff	6,528	9/5/2007	11:38:20
paohlgrg.ato	9,527	9/5/2007	11:38:20
paohlgrg.els	26,257	9/5/2007	11:38:46
paohlgrg.epf	72,801	9/5/2007	11:38:46
paohlgrg.gid	686,571	10/2/2007	14:07:06
paohlgrg.hif	537,934	10/2/2007	14:07:00
paohlgrg.hls	830	10/2/2007	14:07:00
paohlgrg.ref	77	9/5/2007	11:34:48
paohlgrg.rif	119,369	10/2/2007	14:06:59
paohlgrg.rls	5,707	10/2/2007	14:06:59
paohlgrg.wlm	267	10/2/2007	14:06:59
paohlgrg.wrn	0	9/5/2007	11:38:20
paohlgro.aff	6,527	9/5/2007	12:17:30
paohlgro.ato	8,892	9/5/2007	12:17:30
paohlgro.els	26,257	9/5/2007	12:17:54
paohlgro.epf	23,499	9/5/2007	12:17:54
paohlgro.gid	686,574	10/2/2007	14:09:30
paohlgro.hif	169,728	10/2/2007	14:09:25
paohlgro.hls	830	10/2/2007	14:09:25
paohlgro.ref	77	9/5/2007	12:16:42

File Name	Size/Type	Date	Time
paohlgro.rif	42,547	10/2/2007	14:09:23
paohlgro.rls	5,707	10/2/2007	14:09:23
paohlgro.wlm	267	10/2/2007	14:09:23
paohlgro.wrn	0	9/5/2007	12:17:30
paohlgrs.aff	6,528	9/5/2007	11:58:24
paohlgrs.ato	9,497	9/5/2007	11:58:24
paohlgrs.els	26,257	9/5/2007	12:01:22
paohlgrs.epf	24,508	9/5/2007	12:01:22
paohlgrs.gid	686,574	10/3/2007	6:51:08
paohlgrs.hif	169,728	10/3/2007	6:51:02
paohlgrs.hls	830	10/3/2007	6:51:02
paohlgrs.ref	77	9/5/2007	11:57:02
paohlgrs.rif	42,547	10/3/2007	6:51:00
paohlgrs.rls	5,707	10/3/2007	6:51:00
paohlgrs.wlm	445	10/3/2007	6:51:00
paohlgrs.wrn	0	9/5/2007	11:58:24
paonlgrg.aff	6,530	9/24/2007	9:56:00
paonlgrg.ato	9,411	9/24/2007	9:56:02
paonlgrg.els	26,257	9/24/2007	9:56:36
paonlgrg.epf	72,544	9/24/2007	9:56:36
paonlgrg.gid	686,571	10/2/2007	14:14:21
paonlgrg.hif	537,934	10/2/2007	14:14:14
paonlgrg.hls	830	10/2/2007	14:14:14
paonlgrg.ref	77	9/14/2007	8:17:30
paonlgrg.rif	119,369	10/2/2007	14:14:13
paonlgrg.rls	5,707	10/2/2007	14:14:13
paonlgrg.wlm	356	10/2/2007	14:14:13
paonlgrg.wrn	0	9/24/2007	9:56:02
paonlgrs.aff	6,530	9/24/2007	10:03:52
paonlgrs.ato	9,411	9/24/2007	10:03:52
paonlgrs.els	26,257	9/24/2007	10:04:34
paonlgrs.epf	24,463	9/24/2007	10:04:34
paonlgrs.gid	686,574	10/18/2007	12:49:15
paonlgrs.hif	169,728	10/18/2007	12:49:08
paonlgrs.hls	830	10/18/2007	12:49:08
paonlgrs.ref	77	9/14/2007	8:25:04
paonlgrs.rif	42,547	10/18/2007	12:49:07
paonlgrs.rls	5,707	10/18/2007	12:49:07
paonlgrs.wlm	534	10/18/2007	12:49:07
paonlgrs.wrn	0	9/24/2007	10:03:52

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padhlgro.aff	6,916	9/17/2007	11:32:48
padhlgro.ato	9,230	9/17/2007	11:32:48
padhlgro.els	27,047	9/17/2007	11:33:14
padhlgro.epf	24,415	9/17/2007	11:33:14
padhlgro.gid	697,711	9/17/2007	11:33:34
padhlgro.hif	174,488	9/17/2007	11:33:24

File Name	Size/Type	Date	Time
padhlgro.hls	830	9/17/2007	11:33:24
padhlgro.ref	77	9/17/2007	11:32:16
padhlgro.rif	43,735	9/17/2007	11:33:22
padhlgro.rls	5,801	9/17/2007	11:33:22
padhlgro.wlm	89	9/17/2007	11:33:22
padhlgro.wrn	0	9/17/2007	11:32:48
paohlgro.aff	6,529	9/17/2007	11:35:02
paohlgro.ato	8,888	9/17/2007	11:35:02
paohlgro.els	26,257	9/17/2007	11:35:26
paohlgro.epf	23,493	9/17/2007	11:35:26
paohlgro.gid	686,576	10/2/2007	14:01:06
paohlgro.hif	169,728	10/2/2007	14:00:57
paohlgro.hls	830	10/2/2007	14:00:57
paohlgro.ref	77	9/17/2007	11:34:48
paohlgro.rif	42,547	10/2/2007	14:00:55
paohlgro.rls	5,707	10/2/2007	14:00:55
paohlgro.wlm	178	10/2/2007	14:00:55
paohlgro.wrn	0	9/17/2007	11:35:02

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ACUTE RELEASE	DIR	1/10/2008	13:53:56
CHRONIC RELEASE	DIR	1/10/2008	13:54:20
GENII_Parameter_Summary.xls	144,384	3/15/2007	12:23:28
RnList.xls	24,064	1/10/2008	13:52:03

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EXCEL FILES	DIR	1/10/2008	13:54:09
GENIIV2 FILES	DIR	1/10/2008	13:53:52

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ac5cam1.xls	478,720	12/14/2007	8:26:06
ac5cc14.xls	6,034,432	12/14/2007	8:16:12
ac5ccm4.xls	478,208	12/14/2007	8:16:42
ac5cco0.xls	6,033,408	12/14/2007	8:17:52
ac5ccs7.xls	6,016,000	12/14/2007	8:18:53
ac5ch3.xls	6,024,704	12/14/2007	8:20:21
ac5ci29.xls	6,037,504	12/14/2007	8:21:01
ac5ckr5.xls	478,208	12/14/2007	8:21:19
ac5cpu8.xls	478,208	12/14/2007	8:21:36
ac5cru6.xls	6,026,240	12/14/2007	8:22:07
ac5csr0.xls	6,033,408	12/14/2007	8:22:46
Acute summary.xls	46,592	1/10/2008	13:49:10
hsdhlst5.xls	197,120	12/14/2007	8:23:13
pmdhlst5.xls	2,234,880	12/14/2007	8:25:10

File Name	Size/Type	Date	Time
pmdhlstj.xls	2,325,504	12/14/2007	8:25:41
pmohlst5.xls	198,144	12/14/2007	8:26:03

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ACUTE REL	DIR	1/10/2008	13:53:56
RN UNCERTAINTY	DIR	1/10/2008	13:53:52

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hsdhlst5.aff	6,676	11/27/2007	16:05:31
hsdhlst5.ato	9,782	11/27/2007	16:05:32
hsdhlst5.els	28,144	11/27/2007	16:06:03
hsdhlst5.epf	72,449	11/27/2007	16:06:03
hsdhlst5.gid	744,542	11/28/2007	6:50:44
hsdhlst5.hif	530,378	11/27/2007	16:06:13
hsdhlst5.hls	830	11/27/2007	16:06:13
hsdhlst5.ref	77	11/27/2007	16:05:14
hsdhlst5.rif	117,703	11/27/2007	16:06:12
hsdhlst5.rls	5,794	11/27/2007	16:06:12
hsdhlst5.suf	123,759	11/27/2007	22:19:34
hsdhlst5.wlm	89	11/27/2007	16:06:12
hsdhlst5.wrn	106,496	11/27/2007	22:19:34
pmdhlst5.aff	6,934	11/28/2007	16:17:30
pmdhlst5.ato	9,874	11/28/2007	16:17:31
pmdhlst5.els	27,047	11/28/2007	16:17:54
pmdhlst5.epf	74,973	11/28/2007	16:17:54
pmdhlst5.gid	721,159	11/29/2007	6:48:29
pmdhlst5.hif	553,066	11/28/2007	16:18:03
pmdhlst5.hls	830	11/28/2007	16:18:03
pmdhlst5.ref	77	11/28/2007	16:17:16
pmdhlst5.rif	122,721	11/28/2007	16:18:02
pmdhlst5.rls	5,801	11/28/2007	16:18:02
pmdhlst5.suf	127,071	11/28/2007	21:52:31
pmdhlst5.wlm	89	11/28/2007	16:18:01
pmdhlst5.wrn	106,496	11/28/2007	21:52:31
pmdhlstj.aff	6,934	11/27/2007	15:27:37
pmdhlstj.ato	9,874	11/27/2007	15:27:37
pmdhlstj.els	27,047	11/27/2007	15:28:07
pmdhlstj.epf	74,973	11/27/2007	15:28:07
pmdhlstj.gid	722,153	11/28/2007	6:53:28
pmdhlstj.hif	553,066	11/27/2007	15:28:18
pmdhlstj.hls	830	11/27/2007	15:28:18
pmdhlstj.ref	77	11/27/2007	15:27:20
pmdhlstj.rif	122,721	11/27/2007	15:28:16
pmdhlstj.rls	5,801	11/27/2007	15:28:16
pmdhlstj.suf	133,552	11/27/2007	21:05:11
pmdhlstj.wlm	89	11/27/2007	15:28:16

File Name	Size/Type	Date	Time
pmdhlstj.wrn	106,496	11/27/2007	21:05:11
pmohlst5.aff	6,539	11/27/2007	15:29:04
pmohlst5.ato	9,505	11/27/2007	15:29:05
pmohlst5.els	26,257	11/27/2007	15:29:30
pmohlst5.epf	72,779	11/27/2007	15:29:30
pmohlst5.gid	710,036	11/28/2007	6:54:29
pmohlst5.hif	537,934	11/27/2007	15:29:41
pmohlst5.hls	830	11/27/2007	15:29:41
pmohlst5.ref	77	11/27/2007	15:28:47
pmohlst5.rif	119,369	11/27/2007	15:29:39
pmohlst5.rls	5,707	11/27/2007	15:29:39
pmohlst5.suf	123,511	11/27/2007	20:48:27
pmohlst5.wlm	89	11/27/2007	15:29:39
pmohlst5.wrn	106,496	11/27/2007	20:48:27

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ac5cam1.aff	553	11/28/2007	6:55:33
ac5cam1.ato	316	11/28/2007	6:55:33
ac5cam1.els	2,170	11/28/2007	6:55:33
ac5cam1.epf	1,271	11/28/2007	6:55:33
ac5cam1.gid	89,627	11/28/2007	7:20:21
ac5cam1.hif	8,212	11/28/2007	6:55:34
ac5cam1.hls	830	11/28/2007	6:55:34
ac5cam1.ref	77	11/28/2007	6:55:22
ac5cam1.rif	1,947	11/28/2007	6:55:33
ac5cam1.rls	1,168	11/28/2007	6:55:34
ac5cam1.suf	334,148	11/28/2007	7:19:32
ac5cam1.wlm	89	11/28/2007	6:55:33
ac5cam1.wrn	106,496	11/28/2007	7:19:32
ac5cc14.aff	557	11/28/2007	7:21:01
ac5cc14.ato	308	11/28/2007	7:21:01
ac5cc14.els	2,170	11/28/2007	7:21:02
ac5cc14.epf	1,206	11/28/2007	7:21:02
ac5cc14.gid	89,459	11/28/2007	7:48:52
ac5cc14.hif	8,208	11/28/2007	7:21:02
ac5cc14.hls	830	11/28/2007	7:21:02
ac5cc14.ref	77	11/28/2007	7:20:50
ac5cc14.rif	1,943	11/28/2007	7:21:02
ac5cc14.rls	1,168	11/28/2007	7:21:02
ac5cc14.suf	335,297	11/28/2007	7:40:20
ac5cc14.wlm	89	11/28/2007	7:21:02
ac5cc14.wrn	106,496	11/28/2007	7:40:20
ac5ccm4.aff	651	11/28/2007	7:49:22
ac5ccm4.ato	491	11/28/2007	7:49:22
ac5ccm4.els	2,665	11/28/2007	7:49:22
ac5ccm4.epf	2,327	11/28/2007	7:49:22
ac5ccm4.gid	100,034	11/28/2007	8:19:46
ac5ccm4.hif	15,780	11/28/2007	7:49:23

File Name	Size/Type	Date	Time
ac5ccm4.hls	830	11/28/2007	7:49:23
ac5ccm4.ref	77	11/28/2007	7:49:13
ac5ccm4.rif	3,625	11/28/2007	7:49:23
ac5ccm4.rls	1,246	11/28/2007	7:49:23
ac5ccm4.suf	334,148	11/28/2007	8:09:28
ac5ccm4.wlm	89	11/28/2007	7:49:23
ac5ccm4.wrn	106,496	11/28/2007	8:09:28
ac5cco0.aff	551	11/28/2007	8:20:03
ac5cco0.ato	313	11/28/2007	8:20:03
ac5cco0.els	2,170	11/28/2007	8:20:03
ac5cco0.epf	1,265	11/28/2007	8:20:03
ac5cco0.gid	90,099	11/28/2007	9:50:07
ac5cco0.hif	8,210	11/28/2007	8:20:04
ac5cco0.hls	830	11/28/2007	8:20:04
ac5cco0.ref	77	11/28/2007	8:19:52
ac5cco0.rif	1,945	11/28/2007	8:20:04
ac5cco0.rls	1,168	11/28/2007	8:20:04
ac5cco0.suf	342,495	11/28/2007	8:39:23
ac5cco0.wlm	89	11/28/2007	8:20:04
ac5cco0.wrn	106,496	11/28/2007	8:39:23
ac5ccs7.aff	553	11/28/2007	9:50:26
ac5ccs7.ato	311	11/28/2007	9:50:26
ac5ccs7.els	2,170	11/28/2007	9:50:27
ac5ccs7.epf	1,242	11/28/2007	9:50:27
ac5ccs7.gid	89,555	11/28/2007	10:10:09
ac5ccs7.hif	8,212	11/28/2007	9:50:28
ac5ccs7.hls	830	11/28/2007	9:50:28
ac5ccs7.ref	77	11/28/2007	9:50:17
ac5ccs7.rif	1,947	11/28/2007	9:50:27
ac5ccs7.rls	1,168	11/28/2007	9:50:27
ac5ccs7.suf	337,104	11/28/2007	10:09:42
ac5ccs7.wlm	89	11/28/2007	9:50:27
ac5ccs7.wrn	106,496	11/28/2007	10:09:42
ac5ch3.aff	620	11/28/2007	10:10:28
ac5ch3.ato	333	11/28/2007	10:10:28
ac5ch3.els	2,317	11/28/2007	10:10:29
ac5ch3.epf	2,157	11/28/2007	10:10:29
ac5ch3.gid	98,592	11/28/2007	10:47:50
ac5ch3.hif	15,770	11/28/2007	10:10:29
ac5ch3.hls	830	11/28/2007	10:10:29
ac5ch3.ref	77	11/28/2007	10:10:20
ac5ch3.rif	3,615	11/28/2007	10:10:29
ac5ch3.rls	1,246	11/28/2007	10:10:29
ac5ch3.suf	335,860	11/28/2007	10:30:06
ac5ch3.wlm	89	11/28/2007	10:10:29
ac5ch3.wrn	106,496	11/28/2007	10:30:06
ac5ci29.aff	552	11/28/2007	10:48:07
ac5ci29.ato	313	11/28/2007	10:48:07
ac5ci29.els	2,170	11/28/2007	10:48:08
ac5ci29.epf	1,238	11/28/2007	10:48:08

File Name	Size/Type	Date	Time
ac5ci29.gid	89,508	11/28/2007	11:16:51
ac5ci29.hif	8,210	11/28/2007	10:48:08
ac5ci29.hls	830	11/28/2007	10:48:08
ac5ci29.ref	77	11/28/2007	10:47:58
ac5ci29.rif	1,945	11/28/2007	10:48:08
ac5ci29.rls	1,168	11/28/2007	10:48:08
ac5ci29.suf	336,964	11/28/2007	11:07:18
ac5ci29.wlm	89	11/28/2007	10:48:08
ac5ci29.wrn	106,496	11/28/2007	11:07:18
ac5ckr5.aff	519	11/28/2007	11:17:11
ac5ckr5.ato	310	11/28/2007	11:17:11
ac5ckr5.els	2,170	11/28/2007	11:17:12
ac5ckr5.epf	1,188	11/28/2007	11:17:12
ac5ckr5.gid	89,199	11/28/2007	12:54:56
ac5ckr5.hif	8,210	11/28/2007	11:17:12
ac5ckr5.hls	830	11/28/2007	11:17:12
ac5ckr5.ref	77	11/28/2007	11:16:58
ac5ckr5.rif	1,945	11/28/2007	11:17:12
ac5ckr5.rls	1,168	11/28/2007	11:17:12
ac5ckr5.suf	330,645	11/28/2007	11:36:19
ac5ckr5.wlm	89	11/28/2007	11:17:12
ac5ckr5.wrn	106,496	11/28/2007	11:36:19
ac5cpu8.aff	554	11/28/2007	12:55:12
ac5cpu8.ato	316	11/28/2007	12:55:12
ac5cpu8.els	2,170	11/28/2007	12:55:13
ac5cpu8.epf	1,270	11/28/2007	12:55:13
ac5cpu8.gid	89,672	11/28/2007	13:19:21
ac5cpu8.hif	8,212	11/28/2007	12:55:13
ac5cpu8.hls	830	11/28/2007	12:55:13
ac5cpu8.ref	77	11/28/2007	12:55:00
ac5cpu8.rif	1,947	11/28/2007	12:55:13
ac5cpu8.rls	1,168	11/28/2007	12:55:13
ac5cpu8.suf	334,148	11/28/2007	13:15:44
ac5cpu8.wlm	89	11/28/2007	12:55:13
ac5cpu8.wrn	106,496	11/28/2007	13:15:44
ac5cru6.aff	553	11/28/2007	13:19:37
ac5cru6.ato	312	11/28/2007	13:19:37
ac5cru6.els	2,170	11/28/2007	13:19:38
ac5cru6.epf	1,259	11/28/2007	13:19:38
ac5cru6.gid	89,596	11/28/2007	13:58:47
ac5cru6.hif	8,212	11/28/2007	13:19:38
ac5cru6.hls	830	11/28/2007	13:19:38
ac5cru6.ref	77	11/28/2007	13:19:24
ac5cru6.rif	1,947	11/28/2007	13:19:38
ac5cru6.rls	1,168	11/28/2007	13:19:38
ac5cru6.suf	336,731	11/28/2007	13:38:54
ac5cru6.wlm	89	11/28/2007	13:19:38
ac5cru6.wrn	106,496	11/28/2007	13:38:54
ac5csr0.aff	645	11/28/2007	14:01:17
ac5csr0.ato	480	11/28/2007	14:01:17

File Name	Size/Type	Date	Time
ac5csr0.els	2,665	11/28/2007	14:01:18
ac5csr0.epf	2,310	11/28/2007	14:01:18
ac5csr0.gid	99,832	11/28/2007	14:22:18
ac5csr0.hif	15,774	11/28/2007	14:01:18
ac5csr0.hls	830	11/28/2007	14:01:18
ac5csr0.ref	77	11/28/2007	13:58:51
ac5csr0.rif	3,619	11/28/2007	14:01:18
ac5csr0.rls	1,246	11/28/2007	14:01:18
ac5csr0.suf	337,440	11/28/2007	14:21:39
ac5csr0.wlm	89	11/28/2007	14:01:18
ac5csr0.wrn	106,496	11/28/2007	14:21:39

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EXCEL FILES	DIR	1/10/2008	13:54:41
GENIIV2 FILES	DIR	1/10/2008	13:54:17

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ch5cam1.xls	6,811,648	12/14/2007	8:15:14
ch5cc14.xls	6,827,008	12/14/2007	7:59:04
ch5ccm4.xls	6,810,624	12/14/2007	7:58:51
ch5cco0.xls	6,247,936	12/14/2007	7:59:50
ch5ccs7.xls	7,049,728	12/14/2007	8:01:05
ch5ch3.xls	6,809,600	12/14/2007	8:01:56
ch5ci29.xls	6,831,104	12/14/2007	8:02:43
ch5ckr5.xls	6,809,600	12/14/2007	8:03:25
ch5cpu8.xls	6,810,624	12/14/2007	8:03:54
ch5cru6.xls	6,811,136	12/14/2007	8:04:29
ch5csr0.xls	6,826,496	12/14/2007	8:06:08
Chronic Summary.xls	43,520	12/14/2007	14:38:26
nodhdst.xls	570,880	12/14/2007	8:10:50
nodhdst2.xls	1,113,088	12/14/2007	8:09:22
nodhdst5.xls	2,531,328	12/14/2007	8:11:41
nodhdst6.xls	2,523,648	12/14/2007	8:13:30

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CHRONIC REL	DIR	1/10/2008	13:54:20
RN UNCERTAINTY	DIR	1/10/2008	13:54:17

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nodhdst.aff	5,996	10/4/2007	13:24:02
nodhdst.ato	10,156	10/4/2007	13:24:02
nodhdst.els	26,760	10/4/2007	13:24:29

File Name	Size/Type	Date	Time
nodhdst.epf	41,142	10/4/2007	13:24:29
nodhdst.gid	722,519	10/4/2007	14:26:29
nodhdst.hif	277,783	10/4/2007	13:24:35
nodhdst.hls	830	10/4/2007	13:24:35
nodhdst.ref	77	10/4/2007	13:23:47
nodhdst.rif	62,423	10/4/2007	13:24:34
nodhdst.rls	5,801	10/4/2007	13:24:34
nodhdst.suf	30,221	10/4/2007	14:23:35
nodhdst.wlm	89	10/4/2007	13:24:34
nodhdst.wrn	21,696	10/4/2007	14:23:35
nodhdst2.aff	5,996	10/4/2007	14:52:07
nodhdst2.ato	10,156	10/4/2007	14:52:07
nodhdst2.els	26,760	10/4/2007	14:52:34
nodhdst2.epf	41,142	10/4/2007	14:52:34
nodhdst2.gid	722,521	10/5/2007	5:50:47
nodhdst2.hif	277,783	10/4/2007	14:52:40
nodhdst2.hls	830	10/4/2007	14:52:40
nodhdst2.ref	77	10/4/2007	14:51:52
nodhdst2.rif	62,423	10/4/2007	14:52:39
nodhdst2.rls	5,801	10/4/2007	14:52:39
nodhdst2.suf	58,607	10/4/2007	16:50:23
nodhdst2.wlm	89	10/4/2007	14:52:39
nodhdst2.wrn	42,896	10/4/2007	16:50:23
nodhdst5.aff	5,996	10/4/2007	14:49:13
nodhdst5.ato	10,156	10/4/2007	14:49:14
nodhdst5.els	26,760	10/4/2007	14:49:41
nodhdst5.epf	41,142	10/4/2007	14:49:41
nodhdst5.gid	722,521	10/5/2007	5:49:09
nodhdst5.hif	277,783	10/4/2007	14:49:47
nodhdst5.hls	830	10/4/2007	14:49:47
nodhdst5.ref	77	10/4/2007	14:48:55
nodhdst5.rif	62,423	10/4/2007	14:49:45
nodhdst5.rls	5,801	10/4/2007	14:49:45
nodhdst5.suf	143,771	10/4/2007	19:45:20
nodhdst5.wlm	89	10/4/2007	14:49:45
nodhdst5.wrn	106,496	10/4/2007	19:45:20
nodhdst6.aff	5,996	10/4/2007	14:27:00
nodhdst6.ato	10,156	10/4/2007	14:27:00
nodhdst6.els	26,760	10/4/2007	14:27:27
nodhdst6.epf	41,142	10/4/2007	14:27:27
nodhdst6.gid	722,525	10/5/2007	5:45:51
nodhdst6.hif	277,783	10/4/2007	14:27:33
nodhdst6.hls	830	10/4/2007	14:27:33
nodhdst6.ref	77	10/4/2007	14:26:45
nodhdst6.rif	62,423	10/4/2007	14:27:32
nodhdst6.rls	5,801	10/4/2007	14:27:32
nodhdst6.suf	143,771	10/4/2007	19:22:19
nodhdst6.wlm	89	10/4/2007	14:27:32
nodhdst6.wrn	106,496	10/4/2007	19:22:19

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ch5cam1.aff	517	10/4/2007	13:00:19
ch5cam1.ato	313	10/4/2007	13:00:19
ch5cam1.els	1,985	10/4/2007	13:00:19
ch5cam1.epf	808	10/4/2007	13:00:19
ch5cam1.gid	91,136	10/4/2007	13:19:37
ch5cam1.hif	4,441	10/4/2007	13:00:20
ch5cam1.hls	830	10/4/2007	13:00:20
ch5cam1.ref	77	10/4/2007	13:00:03
ch5cam1.rif	1,121	10/4/2007	13:00:20
ch5cam1.rls	1,168	10/4/2007	13:00:20
ch5cam1.suf	347,740	10/4/2007	13:19:25
ch5cam1.wlm	89	10/4/2007	13:00:20
ch5cam1.wrn	106,496	10/4/2007	13:19:25
ch5cc14.aff	521	10/4/2007	13:19:56
ch5cc14.ato	303	10/4/2007	13:19:56
ch5cc14.els	1,985	10/4/2007	13:19:56
ch5cc14.epf	763	10/4/2007	13:19:56
ch5cc14.gid	90,966	10/4/2007	13:40:15
ch5cc14.hif	4,437	10/4/2007	13:19:57
ch5cc14.hls	830	10/4/2007	13:19:57
ch5cc14.ref	77	10/4/2007	13:19:46
ch5cc14.rif	1,117	10/4/2007	13:19:56
ch5cc14.rls	1,168	10/4/2007	13:19:56
ch5cc14.suf	346,760	10/4/2007	13:38:49
ch5cc14.wlm	89	10/4/2007	13:19:56
ch5cc14.wrn	106,496	10/4/2007	13:38:50
ch5ccm4.aff	578	10/4/2007	13:40:31
ch5ccm4.ato	496	10/4/2007	13:40:31
ch5ccm4.els	2,478	10/4/2007	13:40:32
ch5ccm4.epf	1,400	10/4/2007	13:40:32
ch5ccm4.gid	101,535	10/4/2007	14:01:14
ch5ccm4.hif	8,238	10/4/2007	13:40:33
ch5ccm4.hls	830	10/4/2007	13:40:33
ch5ccm4.ref	77	10/4/2007	13:40:21
ch5ccm4.rif	1,973	10/4/2007	13:40:32
ch5ccm4.rls	1,246	10/4/2007	13:40:32
ch5ccm4.suf	347,750	10/4/2007	14:01:09
ch5ccm4.wlm	89	10/4/2007	13:40:32
ch5ccm4.wrn	106,496	10/4/2007	14:01:09
ch5cco0.aff	517	10/4/2007	14:01:30
ch5cco0.ato	312	10/4/2007	14:01:30
ch5cco0.els	1,985	10/4/2007	14:01:30
ch5cco0.epf	806	10/4/2007	14:01:30
ch5cco0.gid	91,091	10/4/2007	14:28:16
ch5cco0.hif	4,439	10/4/2007	14:01:31
ch5cco0.hls	830	10/4/2007	14:01:31
ch5cco0.ref	77	10/4/2007	14:01:21

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ch5cco0.rls	1,168	10/4/2007	14:01:31
ch5cco0.suf	347,278	10/4/2007	14:20:28
ch5cco0.wlm	89	10/4/2007	14:01:31
ch5cco0.wrn	106,496	10/4/2007	14:20:28
ch5ccs7.aff	537	10/4/2007	14:28:38
ch5ccs7.ato	313	10/4/2007	14:28:39
ch5ccs7.els	1,985	10/4/2007	14:28:39
ch5ccs7.epf	802	10/4/2007	14:28:39
ch5ccs7.gid	93,190	10/4/2007	14:47:52
ch5ccs7.hif	4,441	10/4/2007	14:28:40
ch5ccs7.hls	830	10/4/2007	14:28:40
ch5ccs7.ref	77	10/4/2007	14:28:23
ch5ccs7.rif	1,121	10/4/2007	14:28:39
ch5ccs7.rls	1,168	10/4/2007	14:28:39
ch5ccs7.suf	371,658	10/4/2007	14:47:37
ch5ccs7.wlm	89	10/4/2007	14:28:39
ch5ccs7.wrn	106,496	10/4/2007	14:47:37
ch5ch3.aff	570	10/5/2007	6:18:58
ch5ch3.ato	326	10/5/2007	6:18:58
ch5ch3.els	2,132	10/5/2007	6:18:59
ch5ch3.epf	1,236	10/5/2007	6:18:59
ch5ch3.gid	100,088	10/5/2007	6:38:56
ch5ch3.hif	8,228	10/5/2007	6:18:59
ch5ch3.hls	830	10/5/2007	6:18:59
ch5ch3.ref	77	10/5/2007	6:18:50
ch5ch3.rif	1,963	10/5/2007	6:18:59
ch5ch3.rls	1,246	10/5/2007	6:18:59
ch5ch3.suf	346,278	10/5/2007	6:38:38
ch5ch3.wlm	89	10/5/2007	6:18:59
ch5ch3.wrn	106,496	10/5/2007	6:38:39
ch5ci29.aff	521	10/5/2007	5:59:07
ch5ci29.ato	311	10/5/2007	5:59:07
ch5ci29.els	1,985	10/5/2007	5:59:08
ch5ci29.epf	794	10/5/2007	5:59:08
ch5ci29.gid	91,025	10/5/2007	6:18:23
ch5ci29.hif	4,439	10/5/2007	5:59:08
ch5ci29.hls	830	10/5/2007	5:59:08
ch5ci29.ref	77	10/5/2007	5:58:58
ch5ci29.rif	1,119	10/5/2007	5:59:08
ch5ci29.rls	1,168	10/5/2007	5:59:08
ch5ci29.suf	346,936	10/5/2007	6:18:14
ch5ci29.wlm	89	10/5/2007	5:59:08
ch5ci29.wrn	106,496	10/5/2007	6:18:14
ch5ckr5.aff	521	10/5/2007	6:39:14
ch5ckr5.ato	301	10/5/2007	6:39:14
ch5ckr5.els	1,985	10/5/2007	6:39:14
ch5ckr5.epf	721	10/5/2007	6:39:14
ch5ckr5.gid	90,743	10/5/2007	6:59:47
ch5ckr5.hif	4,439	10/5/2007	6:39:15

File Name	Size/Type	Date	Time
ch5ckr5.hls	830	10/5/2007	6:39:15
ch5ckr5.ref	77	10/5/2007	6:39:04
ch5ckr5.rif	1,119	10/5/2007	6:39:15
ch5ckr5.rls	1,168	10/5/2007	6:39:15
ch5ckr5.suf	344,235	10/5/2007	6:58:18
ch5ckr5.wlm	89	10/5/2007	6:39:15
ch5ckr5.wrn	106,496	10/5/2007	6:58:18
ch5cpu8.aff	517	10/5/2007	7:00:02
ch5cpu8.ato	314	10/5/2007	7:00:02
ch5cpu8.els	1,985	10/5/2007	7:00:03
ch5cpu8.epf	806	10/5/2007	7:00:03
ch5cpu8.gid	91,171	10/5/2007	7:22:33
ch5cpu8.hif	4,441	10/5/2007	7:00:03
ch5cpu8.hls	830	10/5/2007	7:00:03
ch5cpu8.ref	77	10/5/2007	6:59:53
ch5cpu8.rif	1,121	10/5/2007	7:00:03
ch5cpu8.rls	1,168	10/5/2007	7:00:03
ch5cpu8.suf	347,739	10/5/2007	7:19:10
ch5cpu8.wlm	89	10/5/2007	7:00:03
ch5cpu8.wrn	106,496	10/5/2007	7:19:10
ch5cru6.aff	517	10/5/2007	7:22:49
ch5cru6.ato	313	10/5/2007	7:22:49
ch5cru6.els	1,985	10/5/2007	7:22:50
ch5cru6.epf	803	10/5/2007	7:22:50
ch5cru6.gid	91,111	10/5/2007	7:42:06
ch5cru6.hif	4,441	10/5/2007	7:22:51
ch5cru6.hls	830	10/5/2007	7:22:51
ch5cru6.ref	77	10/5/2007	7:22:40
ch5cru6.rif	1,121	10/5/2007	7:22:50
ch5cru6.rls	1,168	10/5/2007	7:22:50
ch5cru6.suf	347,173	10/5/2007	7:41:55
ch5cru6.wlm	89	10/5/2007	7:22:50
ch5cru6.wrn	106,496	10/5/2007	7:41:55
ch5csr0.aff	578	10/5/2007	7:42:22
ch5csr0.ato	488	10/5/2007	7:42:22
ch5csr0.els	2,478	10/5/2007	7:42:22
ch5csr0.epf	1,373	10/5/2007	7:42:22
ch5csr0.gid	101,288	10/5/2007	8:05:29
ch5csr0.hif	8,232	10/5/2007	7:42:23
ch5csr0.hls	830	10/5/2007	7:42:23
ch5csr0.ref	77	10/5/2007	7:42:11
ch5csr0.rif	1,967	10/5/2007	7:42:23
ch5csr0.rls	1,246	10/5/2007	7:42:23
ch5csr0.suf	347,662	10/5/2007	8:02:23
ch5csr0.wlm	89	10/5/2007	7:42:23
ch5csr0.wrn	106,496	10/5/2007	8:02:23

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APPENDIX XI CD

CD containing the files listed in Appendix X is attached separately.

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