BSC | Design Calculation or Analysis Cover Sheet

Complete only applicable items.

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6. Group

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7. Document Status Designation

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8. Notes/Comments

The Preclosure Safety Analyses department should be consulted before any information herein is used for any purpose other than that stated herein and before any information herein is used by any individual other than authorized department personnel.

Revision C is an extensive revision; therefore, no revision bars have been used.

Attachments	Total Number of Pages
None	

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	19	13	J.H.C. Wang	J.S. Tang	S. Tsai	M.R. Wisenburg
00B	Revision to incorporate revised airborne dispersion factors, updated airborne release doses, updated facility worker doses, updated GROA drawings, and additional worker locations.	20	14	J.H.C. Wang	J.S. Tang	S. Tsai	M.R. Wisenburg
CACN001	Updated with the revised calculation Aging Facility and Site Worker Dose Assessment (000-00C-MGR0-04200-000-00B) and the new study Repository ALARA Goal Compliance (000-30R-MGR0-03300-000-001)	3	3	J.H.C. Wang	J.S. Tang	S. Tsai	M.R. Wisenburg
CACN002	Addressed CR 11843 that identified as error in the referenced *GROA Airborne Release Dose Calculation* (000-PSA-MGR0-01200-000-00B). Assumption of damage ratio for crud is changed to 100%. As a result the crud release source term and subsequent airborne doses for normal operation releases from the WHF are affected.	4	4	D.T. Dexheimer	J.H.C. Wang	S. Tsai	M.R. Wisenburg
00C	Revision to incorporate CACNs and new inputs from the revised GROA Airborne Release Dose Calculation, 000-PSA-MGR0-01200-000-00C.	18	13	J.H.C. Wang 3/27/2008	J.S. Tang 3/27/2008	S. Tsai 3/27/2008	D.Beckman 3/27/08

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.

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ACRONYMS

ALARA	as low as is reasonably achievable
GROA	Geologic Repository Operations Area
HP	Health Physics
LDE	lens dose equivalent
PCSA	Preclosure Safety Analyses
SDE	shallow dose equivalent
TEDE	total effective dose equivalent
TEV	transport and emplacement vehicle
TODE	total organ dose equivalent
χ/Q	atmospheric dispersion factor

1. PURPOSE

The purpose of this calculation is to estimate potential radiation doses received by personnel working in the geologic repository operations area (GROA). The scope of work presented in this calculation covers annual individual worker dose including the dose contributions from external and internal exposure to radiation from normal operations and Category 1 event sequences. The dose estimates are applicable to full-time workers (2,000 hr/yr) at the GROA. The results of this calculation will be used to support the design of surface and subsurface facilities and to provide occupational dose estimates for the license application.

The calculations contained in this document were developed by the Preclosure Safety Analyses (PCSA) organization and are intended for use in radiation worker and public dose assessments to support the preclosure consequence analyses for the license application. Yucca Mountain Project personnel from PCSA should be consulted before use of the calculations for purposes other than those stated herein and before use by individuals other than PCSA authorized personnel.

2. REFERENCES

2.1 PROCEDURES/DIRECTIVES

2.1.1 BSC (Bechtel SAIC Company) 2007. *Calculations and Analyses*. EG-PRO-3DP-G04B-00037, Rev. 10. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071018.0001.

2.1.2 BSC 2007. *Preclosure Safety Analyses Process*. LS-PRO-0201, Rev. 5. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071010.0021.

2.2 DESIGN INPUTS

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

2.2.2 BSC 2007. *Initial Handling Facility Worker Dose Assessment.* 51A-00C-IH00-00100-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070529.0035.

2.2.3 BSC 2007. *Canister Receipt and Closure Facility #1 Worker Dose Assessment.* 060-00C-CR00-00100-000-00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070425.0013; ENG.20070524.0004.

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2.2.5 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.

2.2.6 BSC 2008. *Aging Facility and Site Worker Dose Assessment.* 000-00C-MGR0-04200-000-00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080131.0001.

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

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2.2.11 Eckerman, K.F. and Ryman, J.C. 1993. *External Exposure to Radionuclides in Air, Water, and Soil, Exposure-to-Dose Coefficients for General Application, Based on the 1987 Federal Radiation Protection Guidance*. EPA 402-R-93-081. Federal Guidance Report No. 12. Washington, D.C.: U.S. Environmental Protection Agency, Office of Radiation and Indoor Air. TIC: 225472.

2.2.12 ICRP (International Commission on Radiological Protection) 2001. *The ICRP Database of Dose Coefficients: Workers and Members of the Public.* ICRP Publications 68. [New York, New York]: Elsevier. TIC: 255638.

2.2.13 BSC 2008. *Repository ALARA Goal Compliance.* 000-30R-MGR0-04000-000-000. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080205.0014.

2.2.14 BSC 2008. *Subsurface Operations Reliability and Event Sequence Categorization Analysis.* 000-PSA-MGR0-00500-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080312.0034.

2.2.15 BSC 2008. *Intra-Site Operations and BOP Reliability and Event Sequence Categorization Analysis.* 000-PSA-MGR0-00900-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080312.0032.

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2.2.19 BSC 2008. *Initial Handling Facility Reliability and Event Sequence CategorizationAnalysis.* 51A-PSA-IH00-00200-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080312.0031.

2.3 DESIGN CONSTRAINTS

2.3.1 10 CFR 20. 2007. Energy: Standards for Protection Against Radiation. Internet Accessible.

2.3.2 10 CFR 63. 2007. Energy: Disposal of High-Level Radioactive Wastes in a Geologic Repository at Yucca Mountain, Nevada. Internet Accessible.

2.3.3 10 CFR 71. 2007. Energy: Packaging and Transportation of Radioactive Material. ACC: MOL.20070829.0114. Internet Accessible.

2.4 DESIGN OUTPUTS

The results of this calculation will be used to support the design of surface and subsurface facilities and to provide occupational dose estimates for the license application.

3. ASSUMPTIONS

3.1 ASSUMPTIONS REQUIRING VERIFICATION

3.1.1 Nominal Worker Doses

Assumption: The nominal worker doses from normal operations in facilities from *Repository ALARA Goal Compliance* (Ref.2.2.13, Table 1.0) are presented in Table 1. The nominal worker doses are based on expected nominal facility throughputs, repository full scale, steady state operation processing 500 casks (3,000 MTHM commercial spent nuclear fuel) annually, and the dose rate of design basis spent nuclear fuel source term.

Rationale: The reference is an informal engineering study with output designated QA:NA. Therefore, the information from the study is treated as an assumption requiring verification. The information is suitable for this calculation.

Table 1. Annual Nominal Worker TEDE Doses from Normal Facility Operations

Facility	Worker Group	Nominal Individual Worker Dose (rem/yr)
Receipt Facility	Operator	1.3
	HP Technician	0.8
Canister Receipt and Closure Facility	Operator	0.3
	HP Technician	0.2
Initial Handling Facility	Operator	0.8
	HP Technician	0.5
Aging Facility	Operator	0.2
	HP Technician	0.3
Wet Handling Facility	Operator	0.4
	HP Technician	0.3
Low-Level Waste Facility	Operator	0.7
	HP Technician	0.6
Cask Receipt Security Station	Security	0.2
	Operator	0.4
	HP Technician	0.4
Average (Assume rotation of workers in the category and similar tasks for worker category in each facility)	Operator	0.480
	HP Technician	0.358
	Security	0.200

Source: Ref. 2.2.13, Table 1.0.
Notes: HP = Health Physics

3.2 ASSUMPTIONS NOT REQUIRING VERIFICATION

3.2.1 Nominal Worker Doses for Subsurface Facility, GROA Transportation Cask Site Operations, GROA TEV Operations

Assumption: The maximum values of individual worker doses for subsurface facility, GROA transportation cask site operations, GROA TEV Operations are used for nominal worker doses from normal operations in the facilities.

Rationale: Because no information is available for nominal worker doses for these facilities, the use of maximum values of individual worker doses is conservative and requires no verification. The information is suitable for this calculation.

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4. METHODOLOGY

4.1 QUALITY ASSURANCE

This calculation was prepared in accordance with EG-PRO-3DP-G04B-00037, *Calculations and Analyses* (Ref. 2.1.1) and LS-PRO-0201, *Preclosure Safety Analyses Process* (Ref. 2.1.2). The results of this calculation will be used to evaluate radiological hazards in surface and subsurface facilities and to demonstrate compliance of the repository design to the performance objectives

of 10 CFR 63.111 (Ref. 2.3.2). Therefore, the approved record version of this calculation is designated as QA: QA.

4.2 USE OF COMPUTER SOFTWARE

None.

4.3 METHOD

Calculated annual doses to repository workers include contributions from external radiation and from inhalation of airborne radioactivity directly caused by indoor and outdoor facility operations. The total effective dose equivalent (TEDE) is calculated by summing the dose contributions from inhalation, air submersion, and direct external radiation exposure. This document manually summarizes the results from facility worker doses (Section 4.3.1), doses from airborne releases (Section 4.3.2), and direct doses from radiation sources outside the facilities (Section 4.3.3).

4.3.1 WORKER DOSES FROM FACILITY NORMAL OPERATIONS

The facility worker doses are obtained by summarizing the results from the following repository facility worker dose assessments (listed by the source document from which the facility dose assessment data are compiled) and Assumption 3.1.1:

- *Receipt Facility Worker Dose Assessment*, 200-00C-RF00-00100-000-00A (Ref. 2.2.1)
- *Initial Handling Facility Worker Dose Assessment*, 51A-00C-IH00-00100-000-00A (Ref. 2.2.2)
- *Canister Receipt and Closure Facility #1 Worker Dose Assessment*, 060-00C-CR00-00100-000-00B (Ref. 2.2.3)
- *Subsurface Worker Dose Assessment*, 800-00C-SS00-00600-000-00A (Ref. 2.2.4)
- *Wet Handling Facility and Low-level Waste Facility Worker Dose Assessment*, 050-00C-WH00-00200-000-00A (Ref. 2.2.5)

The worker doses calculated in the above calculations are based on the maximum throughputs for each individual facility and maximum source terms. The sum of these individual facility throughputs is greater than the maximum annual receipt rate for the repository. Therefore, nominal individual worker doses based on facility throughputs normalized to the maximum receipt rate are to be used for comparison with regulatory dose limits (Table 2).

4.3.2 Worker Dose from Normal Operation Airborne Releases

The worker dose assessments for the individual facilities in Section 4.3.1 do not include radiation doses due to airborne materials released from the facility ventilation systems into the outside atmosphere during normal repository operations and potential Category 1 event sequences. Doses from these airborne releases take into account atmospheric dispersion following the release from a facility ventilation system. In this document, the TEDEs due to these airborne releases are summarized from *GROA Airborne Release Dose Calculation*, 000-PSA-MGR0-01200-000-00C (Ref. 2.2.9). Worker doses in addition to the TEDE (e.g., skin, organs, the lens

of the eye) are subject to regulatory dose limits (Section 4.4.1). Based on the airborne release dose calculation, doses to worker skin, organs, and the lens of the eye are also reported in this document.

4.3.3 Worker Dose from Direct Radiation

The worker dose assessments for the individual facilities in Section 4.3.1 do not include the radiation sources from loaded casks stored at various areas within the GROA. These areas include the two aging pads (17P and 17R), the railcar buffer area (33A), and the truck buffer area (33B).

Calculation of dose rates due to onsite casks in aging pads and buffer areas in the GROA involves deep-penetration shielding analyses with complicated geometry. For this air-over-ground environment, three conditions influence the transport of radiation particles that determine the dose rate: the attenuation effect of the air between the sources and the points of interest; the scattering effect of the ground; and the scattering effect of air above the casks, which is also known as sky shine.

Radiation shielding by construction materials and by temporary shielding that could be provided for construction activities is not considered for conservatism.

In this document, the dose rates due to the onsite casks on the aging pads or in the transportation buffer areas are summarized from *GROA External Dose Rate Calculation*, 000-PSA-MGR0-01300-000-00A (Ref. 2.2.7).

4.4 REGULATIONS

4.4.1 10 CFR Part 63 and 10 CFR Part 20

Radiation dose limits for normal operations and Category 1 event sequences before permanent closure of the GROA are specified in 10 CFR Part 63 (Ref. 2.3.2, 111(b)(1)) and 10 CFR Part 20 (Ref. 2.3.1). These regulations, summarized in Table 2, specify worker dose limits during normal operations and Category 1 event sequences.

Table 2. Worker Dose Standards

Event Sequence Type	Dose Type	Dose Standards*
Normal operations and Category 1 event sequences [Aggregate radiation exposures for Category 1 event sequences per 10 CFR 63.111(b)(1)]	Annual TEDE during normal operations and for Category 1 event sequences	ALARA
	TEDE	5 rem/yr
	The highest of the TODE	50 rem/yr
	LDE	15 rem/yr
	SDE	50 rem/yr

Note: *10 CFR 20.1201 *Occupational Dose Limits for Adults*. (Ref. 2.3.1)

ALARA = as low as reasonably achievable, LDE = lens dose equivalent; SDE = shallow dose equivalent; TODE = total organ dose equivalent, TEDE = total effective dose equivalent.

4.4.2 10 CFR Part 71

The 10 CFR 71.47 external radiation requirements state that for the transport of spent nuclear fuel under normal conditions, the dose rate on a plane 2 m from the outer lateral surfaces of the vehicle must not exceed 10 mrem/hr (Ref. 2.3.3).

4.5 CRITERIA

As low as is reasonably achievable (ALARA) design goals (Ref. 2.2.10, Section 4.10.3) for occupational workers ensure that individual and collective annual doses are maintained at or below ALARA levels during normal operations and as a result of potential Category 1 event sequences.

The ALARA design goal established for the design process for individual radiation worker doses is to minimize the number of individuals that have the potential of receiving more than 500 mrem/yr TEDE. This goal is 10 percent of the annual TEDE limit in 10 CFR 20.1201 (Ref. 2.3.1, Section 1201) and includes internal and external exposures (Ref. 2.2.10, Section 4.10.3.3.1).

5. LIST OF ATTACHMENTS

	Number of Pages
None	None

6. CALCULATIONS

6.1 DESIGN INPUTS

6.1.1 Worker Dose from Facility Normal Operations

Doses to worker extremities, skin, organs, and the lens of the eye are not reported in this document. The annual TEDE doses to individual workers from normal operations by facility and worker group are calculated in the documents referenced in Section 4.3.1 and the results are summarized in Table 3.

Table 3. Annual Maximum and Nominal Worker TEDE Doses from Normal Facility Operations

Facility	Worker Group	Maximum Individual Worker Dose[a] (rem/yr)	Source of Maximum Individual Worker Dose	Nominal Individual Worker Dose[b] (rem/yr)
Receipt Facility	Operator	4.5	Ref. 2.2.1, Table 6	1.3
	HP Technician	2.9		0.8
Canister Receipt and Closure Facility	Operator	2.5	Ref. 2.2.3, Table 5	0.3
	HP Technician	1.8		0.2
Initial Handling Facility	Operator	1.7	Ref. 2.2.2, Table 5.	0.8
	HP Technician	1.1		0.5
Subsurface Facility	Operator	0.2	Ref. 2.2.4, Table 19	0.2[c]
	HP Technician	0.2		0.2[c]
Aging Facility	Operator	0.9	Ref. 2.2.6, Table 7.17	0.2
	HP Technician	1.3		0.3
Wet Handling Facility	Operator	1.1	Ref. 2.2.5, Table 7	0.4
	HP Technician	0.7		0.3
Low-Level Waste Facility	Operator	1.5	Ref. 2.2.5, Table 7	0.7
	HP Technician	1.2		0.6
GROA Transportation Cask Site Operations	Operator	0.1	Ref. 2.2.6, Table 7.15	0.1[c]
	HP Technician	0.1		0.1[c]
GROA TEV Operations	Operator	0.1	Ref. 2.2.6, Table 7.16	0.1[c]
	HP Technician	0.1		0.1[c]
Cask Receipt Security Station	Security	0.7	Ref. 2.2.6, Table 7.14	0.2
	Operator	1.4		0.4
	HP Technician	1.3		0.4

Notes: [a]Based on bounding maximum throughputs and maximum source terms.
[b]Assumption 3.1.1 (Nominal individual worker doses are to be used for comparison with regulatory dose limits).
[c]Assumption 3.2.1.
HP = Health Physics, GROA = Geological Repository Operation Areas, TEV = transport and emplacement vehicle.

6.1.2 Worker Dose from Normal Operations Airborne Releases

The potential airborne releases during normal operations include the releases from the surface facilities, the aging pads, and the subsurface emplacement drifts. The release of radionuclides from the surface facilities is primarily due to processing of failed commercial spent nuclear fuel at the Wet Handling Facility during normal operations. Airborne releases from aging pads under normal operations are the surface contamination resuspended from aging casks. Airborne releases from subsurface facilities are the radionuclides generated by neutron activation of ventilation air and silica dust inside the emplacement drifts, and resuspension of residual surface contamination on waste packages (Ref. 2.2.9, Section 4.3.1).

Atmospheric dispersion factors (χ/Qs) listed in Table 4 are provided in *GROA Airborne Release Dispersion Factor Calculation*, 000-PSA-MGR0-00600-000-00B (Ref. 2.2.8, Table 32). The table is a matrix of the χ/Q from one facility to another facility.

The two potential pathways for worker dose from airborne releases are internal inhalation and external exposure due to immersion in contaminated air. The inhalation dose coefficients are taken from ICRP 68 (Ref. 2.2.12) and the external dose coefficients are taken from the U.S. Environmental Protection Agency Federal Guidance Report No. 12 (Ref. 2.2.11, Table III.1).

The onsite worker doses at various receptor locations from airborne releases during normal operations were calculated in *GROA Airborne Release Dose Calculation*, 000-PSA-MGR0-01200-000-00C (Ref. 2.2.9) and are summarized in Table 5.

6.1.3 Worker Dose from Direct Radiation

Dose rates at various site locations due to staging transportation casks in the buffer areas and aging casks on the aging pads were calculated in *GROA External Dose Rate Calculation*, 000-PSA-MGR0-01300-000-00A (Ref. 2.2.7). The calculated annual doses to a full time worker (2000 hr/yr) at several selected locations due to direct radiation dose from the casks in buffer areas or aging pads and due to airborne release doses from normal operations are summarized in Table 6.

6.1.4 Worker Dose from Category 1 Event Sequences

Since no Category 1 event sequences are postulated (Ref 2.2.14, Table 6.8-3; Ref. 2.2.15, 2.2.16, 2.2.17, 2.2.18 and 2.2.19; Table 6.8-2), there is no corresponding worker dose.

Table 4. Onsite Annual Average Atmospheric Dispersion Factor Values

Receptor Location	Annual Average Atmospheric Dispersion Factor (s/m^3) for Release from Facility											
	50	160	17RE	17RW	17PN	17PS	ES1	ES2	ES3N	ES3S	ES4	ECRB
60	2.15E-05	1.53E-05	3.47E-06	4.12E-06	2.26E-06	2.50E-06	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
70	6.53E-06	5.49E-06	6.04E-06	5.50E-06	2.89E-06	3.32E-06	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
80	4.42E-06	4.05E-06	6.79E-06	5.26E-06	3.15E-06	3.64E-06	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
200	1.52E-05	9.33E-06	4.58E-06	4.62E-06	2.51E-06	2.86E-06	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
50	1.83E-03	4.90E-05	1.56E-06	2.81E-06	1.59E-06	1.59E-06	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
51A	9.84E-06	3.48E-06	1.14E-06	1.74E-06	1.15E-06	1.12E-06	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
160	2.35E-05	5.53E-05	1.42E-06	3.09E-06	1.62E-06	1.47E-06	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
17RE	6.65E-06	4.82E-06	NA	7.87E-06	7.17E-06	1.03E-05	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
17RW	6.86E-06	5.47E-06	2.66E-06	NA	3.92E-06	3.51E-06	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
17PN	4.46E-06	1.72E-06	2.24E-06	2.38E-06	NA	1.06E-05	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
17PS	5.34E-06	2.08E-06	3.82E-06	3.52E-06	3.22E-05	NA	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
IS2	2.40E-08	1.70E-08	1.39E-07	1.50E-07	1.48E-07	1.43E-07	4.58E-06	4.22E-07	8.66E-07	1.03E-06	2.29E-06	1.13E-06
IS3	3.33E-08	3.03E-08	1.57E-07	1.79E-07	1.65E-07	1.59E-07	5.07E-07	1.95E-07	1.27E-05	9.13E-07	5.90E-07	3.25E-07
IS4	1.10E-08	9.45E-09	1.11E-07	1.18E-07	1.17E-07	1.15E-07	4.25E-06	2.65E-07	4.33E-07	3.25E-07	1.47E-05	8.27E-07
NC	1.53E-06	6.29E-07	4.34E-07	6.09E-07	4.40E-07	4.11E-07	3.33E-07	2.08E-07	2.21E-06	6.53E-07	4.25E-07	2.63E-07
NP	1.00E-05	2.40E-06	8.66E-07	1.41E-06	9.91E-07	9.08E-07	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
SP	6.87E-06	9.03E-07	3.82E-07	4.67E-07	4.15E-07	4.08E-07	1.12E-06	9.37E-07	7.97E-07	1.05E-06	9.57E-07	1.24E-06
220	1.28E-05	4.24E-06	9.84E-07	1.65E-06	1.09E-06	1.05E-06	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
240	6.72E-06	2.86E-06	1.63E-06	2.38E-06	1.51E-06	1.51E-06	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
230	5.23E-06	2.33E-06	1.82E-06	2.26E-06	1.51E-06	1.59E-06	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
25A	1.10E-06	9.17E-07	3.11E-06	3.03E-06	2.03E-06	2.22E-06	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
620	1.26E-06	8.46E-07	3.53E-06	3.27E-06	2.23E-06	2.46E-06	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
71A	1.50E-06	7.78E-07	4.13E-06	3.50E-06	2.46E-06	2.76E-06	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
30A	1.16E-06	1.12E-06	3.15E-06	3.23E-06	2.06E-06	2.25E-06	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
30B	5.42E-06	2.34E-06	1.47E-06	1.51E-06	1.22E-06	1.26E-06	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
30C	3.88E-06	2.84E-06	9.58E-06	6.17E-06	3.75E-06	4.55E-06	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
27A	1.57E-05	5.58E-06	1.03E-06	1.42E-06	1.04E-06	1.04E-06	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
780	1.95E-06	1.12E-06	1.99E-06	2.03E-06	1.52E-06	1.64E-06	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
33A	5.73E-06	2.35E-06	1.52E-06	1.84E-06	1.36E-06	1.39E-06	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07
33B	5.29E-06	2.23E-06	1.51E-06	1.66E-06	1.26E-06	1.30E-06	9.92E-07	2.45E-07	1.23E-06	1.80E-06	1.10E-06	3.92E-07

Source: Reference 2.2.8, Table 32.

Notes: 17PN = Aging Pad 17P – North, 17PS = Aging Pad 17P – South, 17RE = Aging Pad 17R – East, 17RW = Aging Pad 17R – West, 25A = Utilities Facility, 27A = Switchyard, 30A = Central Security Station, 30B = Cask Receipt Security Station, 30C = North Perimeter Security Station, 33A = Rail Buffer Area, 33B = Truck Buffer Area, 50 = Wet Handling Facility, 51A = Initial Handling Facility, 60 = Canister Receipt and Closure Facility 1, 70 = Canister Receipt and Closure Facility 2, 71A = Craft Shops, 80 = Canister Receipt and Closure Facility 3, 160 = Low-Level Waste Facility, 200 = Receipt Facility, 220 = Heavy Equipment Maintenance Facility, 230 = Warehouse and Non-Nuclear Receipt Facility, 240 = Central Communications Control Facility, 620 = Administration Facility, 780 = Lower Muck Yard, ES1 = Exhaust Shaft 1, ES2 = Exhaust Shaft 2, ES3N = Exhaust Shaft 3N, ES3S = Exhaust Shaft 3S, ES4 = Exhaust Shaft 4, ECRB = ECRB Exhaust Shaft (enhanced characterization of the repository block (drift)), IS2 = Intake Shaft 2, IS3 = Intake Shaft 3, IS4 = Intake Shaft 4 (formerly Intake Shaft 1), NC = North Construction Portal, NP = North Portal, SP = South Portal.

Table 5. Total Airborne Release Dose from Normal Operations

Area Number	GROA Location	TEDE (mrem/yr)	TODE* (mrem/yr)	SDE (mrem/yr)	LDE (mrem/yr)
60	Canister Receipt and Closure Facility 1	2.88E-01	6.37E+00	1.63E+00	1.92E+00
70	Canister Receipt and Closure Facility 2	2.07E-01	6.63E+00	5.08E-01	7.15E-01
80	Canister Receipt and Closure Facility 3	1.98E-01	6.77E+00	3.50E-01	5.48E-01
200	Receipt Facility	2.54E-01	6.46E+00	1.16E+00	1.41E+00
50	Wet Handling Facility	1.53E+01	1.86E+02	1.37E+02	1.53E+02
51A	Initial Handling Facility	1.34E-01	2.85E+00	7.49E-01	8.83E-01
160	Low-Level Waste Facility	2.66E-01	4.99E+00	1.77E+00	2.04E+00
17RE	Aging Pad R – East	2.75E-01	9.37E+00	5.21E-01	7.96E-01
17RW	Aging Pad R – West	1.47E-01	4.10E+00	5.28E-01	6.75E-01
17PN	Aging Pad P – North	1.97E-01	6.69E+00	3.53E-01	5.49E-01
17PS	Aging Pad P – South	2.83E-01	1.00E+01	4.24E-01	7.08E-01
IS2	Intake Shaft 2	2.48E-02	5.52E-01	1.60E-02	4.08E-02
IS3	Intake Shaft 3	3.50E-02	7.52E-01	2.34E-02	5.84E-02
IS4	Intake Shaft 4	4.40E-02	8.82E-01	2.91E-02	7.31E-02
NC	North Construction Portal	3.56E-02	9.05E-01	1.21E-01	1.57E-01
NP	North Portal	1.27E-01	2.54E+00	7.60E-01	8.87E-01
SP	South Portal	8.22E-02	1.44E+00	5.25E-01	6.07E-01
220	Heavy Equipment Maintenance Facility	1.55E-01	3.02E+00	9.71E-01	1.13E+00
240	Central Communications Control Facility	1.23E-01	3.14E+00	5.16E-01	6.39E-01
230	Warehouse and Non-Nuclear Receipt Facility	1.12E-01	3.05E+00	4.04E-01	5.16E-01
25A	Utilities Facility	1.03E-01	3.68E+00	9.61E-02	1.99E-01
620	Administration Facility	1.13E-01	4.06E+00	1.09E-01	2.22E-01
71A	Craft Shops	1.26E-01	4.53E+00	1.27E-01	2.54E-01
30A	Central Security Station	1.06E-01	3.79E+00	1.01E-01	2.07E-01
30B	Cask Receipt Security Station	9.96E-02	2.51E+00	4.17E-01	5.17E-01
30C	North Perimeter Security Station	8.41E-02	2.25E+00	3.02E-01	3.86E-01
27A	Switchyard	1.78E-01	3.24E+00	1.19E+00	1.37E+00
780	Lower Muck Yard	8.45E-02	2.73E+00	1.58E-01	2.43E-01
33A	Rail Buffer Area	1.07E-01	2.75E+00	4.41E-01	5.48E-01
33B	Truck Buffer Area	1.01E-01	2.59E+00	4.08E-01	5.08E-01

Sources: Ref. 2.2.9, Table 15.

Notes: *Highest organ dose is to the bone surface.

GROA = geologic repository operations area; TEDE = total effective dose equivalent; TODE = total organ dose equivalent; SDE = shallow dose equivalent; LDE = lens dose equivalent.

Table 6. Normal Operation Direct Radiation and Airborne Release Worker Doses

Area Nunmber	GROA Location	Direct Radiation TEDE[a, c] (mrem/yr)	Airborne Release TEDE[b, c] (mrem/yr)	Total TEDE (direct + airborne) (mrem/yr)
51A	Initial Handling Facility	3.7E+00	1.3E-01	3.8E+00
160	Low-Level Waste facility	4.2E-01	2.7E-01	6.9E-01
050	Wet Handling Facility	4.0E-01	1.5E+01	1.5E+01
200	Receipt Facility	4.7E-01	2.5E-01	7.2E-01
060	Canister Receipt and Closure Facility 1	1.2E-01	2.9E-01	4.1E-01
070	Canister Receipt and Closure Facility 2	1.5E+00	2.1E-01	1.7E+00
080	Canister Receipt and Closure Facility 3	1.8E+00	2.0E-01	2.0E+00
220	Heavy Equipment Maintenance Facility	1.5E+00	1.6E-01	1.7E+00
240	Central Communication Control Facility	7.0E+00	1.2E-01	7.1E+00
230	Warehouse and Non-Nuclear Receipt Facility	1.7E+01	1.1E-01	1.7E+01
25A	Utility Facility	5.3E-01	1.0E-01	6.3E-01
620	Administration Facility	6.9E-02	1.1E-01	1.8E-01
71A	Craft Shop	1.1E-01	1.3E-01	2.4E-01
30A	Central Security Station	8.2E-02	1.1E-01	1.9E-01
30B	Cask Receipt Security Station	2.2E+00	1.0E-01	2.3E+00
30C	North Perimeter Security Station	9.7E+00	8.4E-02	9.8E+00
27A	Switchyard	3.6E+01	1.8E-01	3.6E+01
780	Lower Muck Yard	7.8E+01	8.5E-02	7.8E+01
33A	Rail Car Buffer Area	N/A[d]	1.1E-01	N/A
33B	Truck Buffer Area	N/A[d]	1.0E-01	N/A
17P	Aging Pad 17P	1.0E+01[e]	2.8E-01	1.0E+01

Notes: [a]Direct radiation doses are the total external doses from aging overpacks on the aging pads, and transportation casks on 33A and 33B. (Ref. 2.2.7, Table 9)

[b]Airborne release doses are the total from all surface and subsurface facility releases during normal operations. (Table 5)

[c]Doses are based on 2,000 hr/yr worker occupancy.

[d]The direct radiation doses to radiation workers in these areas are from contained sources within the area rather from external sources. The direct doses from the contained sources are included in the assessment of worker doses within facilities for those areas.

[e]The dose rate is estimated at the center of an empty 17P due to a fully loaded Aging Pad 17R. This is equivalent to a construction worker at Aging Pad 17P.

GROA = geologic repository operations area; TEDE = total effective dose equivalent.

7. RESULTS AND CONCLUSION

Worker doses reported in this document are based on the methodology described in Section 4.3, the assumption in Section 3, and calculations in Section 6. The inputs used in the dose calculations are supported by appropriate data and conservative assumptions. The worker doses reported are reasonable compared to the input, and the results are suitable for the intended use. Uncertainties are taken into account by consistently using a conservative approach. The calculations, therefore, yield a conservatively bounding set of results.

The maximum worker doses are summarized in Table 7. The maximally exposed onsite worker dose due to airborne release is evaluated to be 15 mrem/yr at the location of the Wet Handling Facility. The maximally exposed onsite worker dose due to the external radiation from the casks in buffer areas and aging pads is evaluated to be 78 mrem/yr on the west side of the Lower Muck Yard. The major contribution comes from the transportation casks on the nearby Rail Car Buffer Area (33A). These two values are well below the ALARA goal of 500 mrem/yr (Section 4.5). The estimated TEDE to the maximally exposed worker who serves as an operator for cask handling, emplacement, and retrieval at the Receipt Facility is about 4,500 mrem/yr, and the corresponding nominal worker dose is about 1,300 mrem/yr. The results from Table 1 indicate that average individual worker doses of 0.5 rem per year or less are achievable for repository facility handling operations in compliance with the ALARA goal. The calculated TEDEs to repository workers from normal operations and Category 1 events are below the regulatory limit of 5,000 mrem/yr (Section 4.4.1) for an individual worker.

Table 7. Onsite Worker Dose Summary

	Description of Exposure Scenario	TEDE (mrem/year)
Maximally Exposed Onsite Worker	Airborne releases from normal operations (Worker in the Wet Handling Facility)	15 (**Table 5**)
	Radiation exposures from normal facility operations (Operator in the Receipt Facility)	4,500 (Maximally individual worker, Table 3)
		1,300 (Nominal individual worker, Table 3)
	Maximum direct radiation + airborne release outside facilities (Operator at the Lower Muck Yard)	78 (Table 6)
	Category 1 event sequences	None (Section 6.1.4)

Note: TEDE = total effective dose equivalent.