BSC

Design Calculation or Analysis Cover Sheet

Complete only applicable items.

1. QA: QA
2. Page 1

3. System	4. Document Identifier
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Subsurface Worker Dose Assessment

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☐ Preliminary ☒ Committed ☐ Confirmed ☐ Cancelled/Superseded

8. Notes/Comments

This calculation supersedes *Subsurface Facility Worker Dose Assessment*. 800-00C-SS00-00100-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20040303.0026; ENG.20050816.0007.

The DEM and EGS have determined the required engineering design review distribution.

(B) 3/26/08 The administrative change does not impact the results, as the value was incorrectly typed.

Attachments	Total Number of Pages
Attachment 1: Microsoft® Excel® file 800 00C SS00 0600 000 00A.xls on one (1) compact disc	NA

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	65	65	Kevin R. Doody [signature] 6/20/07	David Lovett [signature] 6/20/07	Mark Johnson [signature] 6/20/07	David Darling [signature] 6/21/07
(B) 3/26/08 00B	Administrative change to page 63 only.			Tanya Sloma [signature] 3/31/08	Dorin Musat [signature] 3/31/08	Alfred Ogurek [signature] 3/31/2008	David Darling [signature] 3/31/08

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.

CONTENTS

TABLES

ACRONYMS AND ABBREVIATIONS

ACRONYMS

ALARA	as low as is reasonably achievable
ACC	access
ACD	Annual Collective External Dose
BOD	Basis of Design
BSC	Bechtel SAIC Company, LLC
BWR	boiling water reactor
CFR	Code of Federal Regulations
DHLW	defense high-level (radioactive) waste
DOE	U.S. Department of Energy
EXH	exhaust
ITS	Important to Safety
ITWI	Important to Waste Isolation
MGR	Monitored Geological Repository
PWR	pressurized water reactor
SC	safety category
SNF	spent nuclear fuel
TAD	Transport, Aging and Disposal
TEDE	total effective dose equivalent
TEV	Transport Emplacement Vehicle
YMP	Yucca Mountain Project

ABBREVIATIONS

empl	emplacement
cm	centimeter
dpm	disintegrations per minute
hr	hour
m	meter
mrem	millirem
yr	year

1.0 PURPOSE

The purpose of this calculation and analysis is to estimate radiation doses received by personnel working in the Subsurface Facility during repository operation and closure. The specific scope of work contained in this calculation covers both collective doses and individual worker doses on an annual basis from repository operations. Radiation dose contribution from Radon (Rn-222) is not considered in this calculation. The results of this calculation will be used to support ALARA design reviews for the Subsurface Facility and to provide occupational dose estimates for the license application.

The calculations contained in this document were developed by Nuclear and Radiological Engineering of the Repository Project Management organization and are intended solely for the use of the Repository Project Management in its work regarding facility design and operation. Yucca Mountain Project (YMP) personnel from Radiological and Nuclear Engineering should be consulted before use of the calculations for purposes other than those stated herein or use by individuals other than personnel in Nuclear and Radiological Engineering.

2.0 REFERENCES

2.1 PROCEDURES/DIRECTIVES

2.1.1 EG-PRO-3DP-G04B-00037. Rev.8, *Calculations and Analyses*. Las Vegas, NV. Bechtel SAIC Company. ACC: ENG.20070420.0002.

2.1.2 BSC (Bechtel SAIC Company) 2005. *Q-List*. 000-30R-MGR0-00500-000-003. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20050929.0008. (DIRS 175539)

2.1.3 IT-PRO-0011 Rev 005. *Software Management*. Las Vegas, NV. Bechtel SAIC Company. ACC: DOC.20070521.0001.

2.1.4 BSC 2007. *Application of ALARA in the YMP Design Process*. EG-DSK-3701 Rev. 1. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070312.0021.

2.1.5 BSC 2007. *Repository Project Management Automation Plan*. 000-PLN-MGR0-00200-000-00E. Las Vegas, NV. Bechtel SAIC Company. ACC: ENG.20070326.0019.

2.2 DESIGN INPUTS

2.2.1 DOE (U.S. Department of Energy) 2002. *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada*. DOE/EIS-0250. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20020524.0314; MOL.20020524.0315;

MOL.20020524.0316; MOL.20020524.0317; MOL.20020524.0318; MOL.20020524.0319;MOL.20020524.0320. (DIRS 155970)

2.2.2 BSC 2007. *Subsurface Emplacement Ventilation System Design Analysis*. 800-KVC-VUE0-00400-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070425.0003; ENG.20070508.0001. (DIRS 180537)

2.2.3 BSC 2007. *Subsurface Concept of Operations*. 800-30R-MGR0-00500-000 REV 00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070402.0001. (DIRS 179331)

2.2.4 BSC (Bechtel SAIC Company) 2007. *Integrated System Operation Report; Subsurface Facility*. 000-30R-MGR0-02400-000 REV 000. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070223.0007. (DIRS 179669)

2.2.5 Shideler, G.L. 2004. *Ground Support Maintenance Plan*. 800-30R-WIS0-00100-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20040113.0008. (DIRS 167858)

2.2.6 BSC 2004. *Performance Confirmation Plan*. TDR-PCS-SE-000001 REV 05. Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.20041122.0002. (DIRS 172452)

2.2.7 BSC 2006. *Project Design Criteria Document*. 000-3DR-MGR0-00100-000-006. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20061201.0005. (DIRS 178308)

2.2.8 BSC (Bechtel SAIC Company) 2006. *Design Change Request, Remove the Requirement for Design and Installation of Magma Bulkheads in the Subsurface Repository*. DCR-800-000001 REV 0. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20061128.0002: (DIRS 180562)

2.2.9 BSC 2006. *Dose Rate Calculation for Subsurface Ventilation Isolation Barrier*. 800-00C-SS00-00400-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20061129.0021. (DIRS 178553)

2.2.10 BSC 2005. *Dose Rate Calculation for an Optimized Turnout Drift Configuration*. 800-00C-SS00-00200-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20050127.0004. (DIRS 172596)

2.2.11 BSC 2004. *Dose Rate Calculation for 21-PWR Waste Package*. 000-00C-DSU0-01800-000-00C. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20041102.0003; ENG.20050815.0017. (DIRS 172227)

2.2.12 BSC 2002. *Subsurface Shielding Source Term Specification Calculation*. 000-00C-WER0-00100-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20021216.0076; ENG.20050815.0022. (DIRS 161120)

2.2.13 Yuan, Y. 2001. *Subsurface Contamination Control.* TDR-WER-NU-000002 REV 00 ICN 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC.MOL.20020107.0152. (DIRS 163120)

2.2.14 BSC 2003. *Radiological Releases Due to Air and Silica Dust Activation in Emplacement Drifts.* 800-00C-EBS0-00100-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20030509.0001; ENG.20050816.0006. (DIRS 164562)

2.3 DESIGN CONSTRAINTS

2.3.1 10 CFR 20. 2006 Energy: *Standards for Protection Against Radiation.* Internet Accessible.

2.4 DESIGN OUTPUTS

This calculation is performed in support of the license application.

3.0 ASSUMPTIONS

3.1 ASSUMPTIONS REQUIRING VERIFICATION

3.1.1 None

3.2 ASSUMPTIONS NOT REQUIRING VERIFICATION

3.2.1 Operation Phases To Be Considered

Assumption: Only the Operations (waste emplacement and post-emplacement) Phase and Closure Phase are associated with external radiation exposure associated with Subsurface Facility operations. The 'Operations Post-Emplacement Phase' is equivalent to the 'Operations Monitoring Phase'.

Rationale: The repository will be developed and operated in the following five phases:

- Site characterization
- Construction (development)
- Operations (waste emplacement and post-emplacement)
- Closure
- Post-closure.

There is no occupational radiation exposure associated with Site Characterization or Post-closure. Excluding these phases from consideration in the calculation and analysis simplifies the overall calculation.

Usage: This assumption is used in throughout.

3.2.2 Duration of Operations-Waste Emplacement Phase

Assumption: The Operations-Emplacement Phase will last 24 years.

Rationale: The operation and monitoring phase would last 100 to 324 years and would consist of an operations period and a monitoring period. Handling and emplacement activities would last 24 years for the higher-temperature operating mode and for the lower-temperature operating mode if surface aging is not used. If surface aging is used, the operations period would last 50 years. (Ref. 2.2.1, Vol. I, Chapter 4, Section 4.1)

This calculation and analysis assumes the operations and monitoring phase will last 100 years, and that handling and emplacement activities will last 24 years (higher-temperature operating mode). The selection of the 24 years duration for handling and emplacement activities is conservative and bounding because all waste packages are staged in an emplacement drift by the 24th year. Therefore, by the 24th year of operations activities, under this scenario, all emplacement drifts are full and the source term in the Subsurface Facility will be at a maximum.

DOE prepared Ref. 2.2.1 consistent with the National Environmental Policy Act and the Nuclear Waste Policy Act, as amended. (Ref. 2.2.1, section S1). The descriptions of operating modes and durations of operating modes contained in this document are the best available for encompassing the currently reviewed and possible modes of operations and durations of operations that may occur. The information contained in Ref. 2.2.1 with respect to operating modes and durations and is suitable for use in performing this dose assessment.

Usage: This assumption is used in sections 4.3, 6.2 and 6.3

3.2.3 Duration of Operations-Waste Emplacement Phase/Concurrent Development Activities

Assumption: There will be a 22 year period for continued construction (development) of underground repository features, including access drifts, emplacement drifts, shafts, etc., that occurs concurrent with the 24 year Operations-Waste Emplacement Phase. There will be two years (operational years 23 and 24) when development activities are complete and emplacement activities continue.

Rationale: The operations period would include continued development (excavation and preparation for use) of the subsurface repository, receipt and handling of spent nuclear fuel and high-level waste in surface facilities, and emplacement of these materials in the completed portions of the subsurface repository. Development activities would last 22 years for all operating modes, concurrent with handling and emplacement. (Ref. 2.2.1, Vol. I, Chapter 4, Section 4.1) There will be a period of two (2) years during which emplacement activities continue and development is complete because the Operations-Emplacement Phase lasts 24 years, and the concurrent development period lasts 22 years. DOE prepared Ref. 2.2.1 consistent with the National Environmental Policy Act and the Nuclear Waste Policy Act, as amended. (Ref. 2.2.1, section S1). The descriptions of operating modes and durations of operating modes contained in this document are the best available for encompassing the currently reviewed and possible modes of operations and durations of operations that may occur. The information contained in Ref. 2.2.1 with respect to operating modes and durations is suitable for use in performing this dose assessment.

Usage: This assumption is used in sections 4.3, 6.2 and 6.3.

3.2.4 Duration of Operations-Monitoring Phase

Assumption: The Operations-Monitoring Phase will begin when the last waste package is emplaced (after the 24 year Operations-Emplacement Phase) and will last 76 years. The Operations-Closure Phase will begin after the Operations-Monitoring Phase is complete.

Rationale: Monitoring of the emplaced material and maintenance of the repository would start with the first emplacement of waste packages and would continue through the closure phase. After the completion of emplacement, the monitoring period would begin during which monitoring would be the primary activity. DOE would maintain the repository in a configuration that would enable continued monitoring and inspection of the waste packages, continued investigations in support of predictions of long-term repository performance (the ability to isolate waste from the accessible environment), and the retrieval of waste packages, if necessary. This period would last from 76 to 300 years. (Ref. 2.2.1, Vol. I, Chapter 4, Section 4.1)

DOE prepared Ref. 2.2.1 consistent with the National Environmental Policy Act and the Nuclear Waste Policy Act, as amended. (Ref. 2.2.1, section S1). The descriptions of operating modes and durations of operating modes contained in this document are the best available for encompassing the currently reviewed and possible modes of operations and durations of operations that may occur. The information contained in Ref. 2.2.1 with respect to operating modes and durations and is suitable for use in performing this dose assessment.

Usage: This assumption is used in sections 4.3, 6.2 and 6.3.

3.2.5 Duration of Operations-Closure Phase

Assumption: The Operations-Closure Phase will last 10 years.

Rationale: Repository closure will occur after DOE applies for and receives a license amendment from the Nuclear Regulatory Commission. Closure could take 10 years for the higher-temperature operating mode and from 11 to 17 years for the lower-temperature operating mode, depending on the operating parameters that had been employed. For consistency purposes, the 10 years closure period is selected to coincide with the use of the 24 years emplacement period (higher-temperature operating mode) assumed in 3.2.2. (Ref. 2.2.1, Vol. I, Chapter 4, Section 4.1)

DOE prepared Ref. 2.2.1 consistent with the National Environmental Policy Act and the Nuclear Waste Policy Act, as amended. (Ref. 2.2.1, section S1). The descriptions of operating modes and durations of operating modes contained in this document are the best available for encompassing the currently reviewed and possible modes of operations and durations of operations that may occur. The information contained in Ref. 2.2.1 with respect to operating modes and durations is suitable for use in performing this dose assessment.

Usage: This assumption is used in sections 4.3, 6.2 and 6.3.

3.2.6 Number of Emplacement Drifts in Subsurface Facility

Assumption: At full capacity, the Subsurface Facility will consist of 108 emplacement drifts.

Rationale: There are total of 108 drifts for the entire Monitored Geological Repository (MGR). (Ref. 2.2.2, Section 6.1) The total numbers of drifts constructed for each panel are listed in Table 1.

Table 1: Drift Quantities and Panel Locations

LOCATION [a]	DRIFT QUANTITY[a]
Panel 1	6
Panel 2	27
Panel 3 East	19
Panel 3 West	26
Panel 4	30
Total	108

a. Ref. 2.2.2, Section 6.1, Table 1

Reference 2.2.2 is output designated as QA:NA. This document contains the latest and best available emplacement drift information and is suitable for use in performing this dose assessment.

Usage: This assumption is used in sections 4.3 and 6.3.

3.2.7 Emplacement Drift Commissioning Schedule/Panel 1

Assumption: Emplacement drifts 1-1, 1-2, 1-3 and the Performance Confirmation Observation are placed in service during the first year of emplacement activities.

Rationale: Emplacement drifts 1-1, 1-2, 1-3 and the Performance Confirmation Observation Drift are completed first and placed in service to accept waste packages.

Emplacement drifts 1-4 and 1-5 are under construction at the same time. (Ref. 2.2.2, section 6.5)

Reference 2.2.2 is output designated as QA:NA. This document contains the latest and best available emplacement drift information and is suitable for use in performing this dose assessment.

Usage: This assumption is used in sections 4.3 and 6.3.

3.2.8 Emplacement Drift Commissioning Schedule/Remaining Drifts

Assumption: After the first year of emplacement activity, emplacement drifts are turned over at a rate of 5 drifts per year until all drifts are completed and commissioned in the 22nd year. Table 2 below demonstrates the commissioning schedule for the emplacement drifts.

Table 2: Number of Commissioned Emplacement Drifts by Emplacement Year

EMPLACEMENT YEAR	NUMBER OF COMMISSIONED DRIFTS	EMPLACEMENT YEAR	NUMBER OF COMMISSIONED DRIFTS
1	3	12	58
2	8	13	63
3	13	14	68
4	18	15	73
5	23	16	78
6	28	17	83
7	33	18	88
8	38	19	93
9	43	20	98
10	48	21	103
11	53	22	108

(Attachment 1: File 800 00C SS00 0600 000 00A.xls, Sheet Table 2)

Rationale: At full capacity, the Subsurface Facility will consist of 108 emplacement drifts. (Assumption 3.2.6) Emplacement drifts 1-1, 1-2, 1-3 and the Performance Confirmation Observation Drift are completed first and placed in service to accept waste packages. (Ref. 2.2.2, section 6.5). Adding 5 drifts per year results in completion and commissioning of all emplacement drifts in the 22nd year.

Reference 2.2.2 is output designated as QA:NA. This document contains the latest and best available emplacement drift information and is suitable for use in performing this dose assessment.

Usage: This assumption is used in sections 4.3 and 6.3

3.2.9 Tasks During the Operations-Emplacement Phase and Operations Monitoring Phase

Assumption: The assumed continuous work activities/tasks required during the Operations-Emplacement Phase and the Operations-Monitoring Phase are listed below:

- Operations and Operations Support
- Performance Confirmation Support
- Ground Support Maintenance
- Ventilation System/Mechanical Maintenance
- Electrical Maintenance
- Instrumentation and Controls Maintenance
- Facility Access (Security and Safeguards)
- Radiation Protection/Health Physics

Rationale: The assumptions for tasks/continuous activities during the Operations-Emplacement Phase and the Operations-Monitoring Phase are based on a review of the following references that describe the current state of design and operational plans related to subsurface activities:

- *Subsurface Concept of Operations.* (Ref. 2.2.3)
- *Subsurface Emplacement Ventilation System Design Analysis* (Ref. 2.2.2)
- *Performance Confirmation Plan.* (Ref. 2.2.6)
- *Integrated System Operation Report; Subsurface Facility.* (Ref. 2.2.4)
- *Ground Support Maintenance Plan.* (Ref. 2.2.5)

References 2.2.3, 2.2.4 and 2.2.5 are designated QA:NA. These documents contain the latest and best available design and operational information for the Subsurface Facility and are suitable for use in performing this dose assessment.

Usage: This assumption is used in Section 4.3, 6.2 and Section 6.3.

3.2.10 Infrequent/Periodic Tasks During Operations-Waste Emplacement Phase with Concurrent Development Activities

Assumption: The infrequent/periodic work activities/tasks that are outside the scope of routine operations during the Operations-Emplacement Phase with Concurrent Development Activities are listed below:

- Access Main Isolation Barrier Removal
- Exhaust Main Isolation Barrier Removal

Rationale: The assumption for infrequent/periodic tasks during the Operations-Emplacement Phase with Concurrent Development Activities is based on a review of the same references reviewed in support of Assumption 3.2.9. These tasks occur during the initial 22 year period for continued construction (development) of the underground repository that occurs concurrent with the 24 year Operations-Waste Emplacement Phase. After the 22nd year of operations, these tasks are no longer performed.

Usage: This assumption is used in section 4.3, 6.2 and 6.3.

3.2.11 Subsurface Facility Work Locations By Dose Rate Affected Areas

Assumption: For the purpose of the this dose assessment, it is assumed that areas listed below adequately and appropriately characterize the work locations and the radiation dose rate environment in the Subsurface Facility during the operational phases indicated:

1. North Portal Access Control Station (Operations-Emplacement, Monitoring and Closure Phases)

2. General Access Main (Operations-Emplacement, Monitoring and Closure Phases)

3. Access Mains Near Emplacement Drift Turnout (Operations-Emplacement, Monitoring and Closure Phases)

4. Emplacement Drift Turnout Bulkheads (Operations-Emplacement, Monitoring and Closure Phases)

5. Exhaust Mains Near Temporary Isolation Barrier (Operations-Emplacement Phase Only)

6. General Exhaust Mains (Closure Only)

Rationale: This assumption is based on a review of the same references reviewed in support of Assumption 3.2.9.

The majority of the occupied underground facility will consist of access mains. When traveling to any underground area, access mains will be used. A majority of the underground utilities and systems will be installed throughout the access mains (ground support, rail, utilities, etc.). Each emplacement drift turnout will be fitted with an Emplacement Drift Bulkhead to support the subsurface facility ventilation system and emplacement drift airflow rates. The bulkhead will be fitted with doors to allow movement of waste packages into the emplacement drifts. Emplacement drifts and exhaust mains will not normally be accessed due to high temperature and high radiation level conditions in these areas. There will be isolation barriers between the development side of the repository and the emplacement side of the repository in the access main and the exhaust main during concurrent emplacement/development activities, and limited access to the exhaust main will be required to periodically move the barriers as drifts are turned over to operations. Performance Confirmation facilities will be unaffected by waste package dose rates.

Usage: This assumption is used in sections 4.3, 6.1, and 6.2.

3.2.12 Task Hours In Dose Rate Affected Areas: Operations-Emplacement Phase/Concurrent Development Activities

Assumption: The number of hours per year that an individual subsurface worker will spend in dose rate affected areas (*j*) performing task (*k*) during the Operations-Emplacement Phase/Concurrent Development Phase is listed in Table 3.

Table 3: Task Hours Per Year By Work Location (Operations-Emplacement Phase/Concurrent Development Activities)

TASK NO. (k)	LOCATION DESIGNATION (j):	1	2	3	4	5	6	ON SITE
	Task Description	North Portal Access Control Station	General Access Main	Access Mains Near Empl Drift Turnout	Empl Drift Turnout Bulkhead	Exhaust Mains Near Temp. Isolation Barrier	Exhaust Main (Closure Only)	
1	Operations and Operations Support	300	1600	50	50	0	0	2000
2	Performance Confirmation Support	300	1600	50	50	0	0	2000
3	Ground Support Maintenance EXH Main Isolation Barrier ACC Main Isolation Barrier	300	1440	100	0	160	0	2000
4	Ventilation System & Mechanical Maintenance	300	1500	100	100	0	0	2000
5	Electrical Maintenance	300	1600	100	0	0	0	2000
6	Instrumentation and Controls Maintenance	300	1500	100	100	0	0	2000
7	Facility Access (Security and Safeguards)	1900	100	0	0	0	0	2000
8	Radiation Protection Health Physics	1000	785	100	100	15	0	2000

(Attachment 1: File 800 00C SS00 0600 000 00A.xls, Sheet Table 3)

Rationale: The tasks assumption is based on a review of the same references reviewed in support of Assumption 3.2.9. The hours spent on tasks in locations listed in Table 3 are based on subsurface engineering judgment considering the current state of Subsurface Facility design.

Usage: This assumption is used in Section 4.3 and 6.2.

3.2.13 Task Hours In Dose Rate Affected Areas: Operations-Emplacement Phase (Development Complete) and Operations-Monitoring Phase

Assumption: The number of hours per year that an individual subsurface worker will spend in dose rate affected areas (*j*) during Operations-Emplacement Phase (Development Complete) and Operations-Monitoring Phase performing task (*k*) is listed in Table 4.

Table 4: Task Hours Per Year By Work Location (Operations-Emplacement Phase (Development Complete) and Operations-Monitoring Phase)

TASK NO. (k)	LOCATION DESIGNATION (j):	1	2	3	4	5	6	ON SITE
	Task Description	North Portal Access Control Station	General Access Main	Access Mains Near Empl Drift Turnout	Empl Drift Turnout Bulkhead	Exhaust Mains Near Temp. Isolation Barrier	Exhaust Main (Closure Only)	
1	Operations and Operations Support	300	1600	50	50	0	0	2000
2	Performance Confirmation Support	300	1600	50	50	0	0	2000
3	Ground Support Maintenance EXH. Main Isolation Barrier ACC. Main Isolation Barrier	300	1600	100	0	0	0	2000
4	Ventilation System & Mechanical Maintenance	300	1500	100	100	0	0	2000
5	Electrical Maintenance	300	1600	100	0	0	0	2000
6	Instrumentation and Controls Maintenance	300	1500	100	100	0	0	2000
7	Facility Access (Security and Safeguards)	1900	100	0	0	0	0	2000
8	Radiation Protection Health Physics	1000	800	100	100	0	0	2000

(Attachment 1: File 800 00C SS00 0600 000 00A.xls, Sheet Table 4)

Rationale: The tasks assumption is based on a review of the same references reviewed in support of Assumption 3.2.9. The hours spent on tasks in locations listed in Table 4 are based on subsurface engineering judgment considering the current state of Subsurface Facility design.

Usage: This assumption is used in Section 4.3 and 6.2.

3.2.14 Staffing: Operations-Emplacement and Operations-Monitoring Phases

Assumption: The shift staffing and total subsurface facility staffing during the Operations-Emplacement and Operations-Monitoring Phases is listed in Table 5.

Table 5: Annual Staffing/Operations-Emplacement and Operations-Monitoring Phases

TASK NO.	TASK	ESTIMATED SHIFT CREW SIZE (# OF PEOPLE) [A]	ANNUAL STAFFING (# OF PERSONS) (a) [B]
1	Operations Support	2	10
2	Performance Confirmation Support	2	10
3	Ground Support Maintenance	3	15
4	Ventilation System/Mechanical Maintenance	2	10
5	Electrical Maintenance	2	10
6	Instrumentation and Controls Maintenance	2	10
7	Facility Access (Security and Safeguards)	1	5
8	Radiation Protection Health Physics	2	10
	TOTAL:	16	80

(Attachment 1: File 800 00C SS00 0600 000 00A.xls, Sheet Table 5)

a. Equal crew size times (5); [B] = [A] x 5

Rationale: Facility operations will be scheduled for three 8-hour shifts per day (24/7 operations). It will require five (5) shifts to support facility operations.

After the first year of emplacement activity, emplacement drifts are turned over at a rate of five (5) drifts per year until all one-hundred eight (108) drifts are completed and commissioned in the 22nd year. The staffing level increase will coincide with the increase in facility size until it peaks in the 22nd year of emplacement activities.

Crew size is based on subsurface engineering judgment. At least three crews are needed to support 24/7 operations. However, three crews would not allow for days off, holidays, vacation, sick leave or training. Staffing five (5) crews will ensure adequate shift coverage as well as allowing for days off, holidays, vacation, sick leave or training. This assumption is consistent with shift coverage practices at facilities operating under 24/7 schedules. Crew size is used to determine total staffing. Total staffing is used to calculate annual collective radiation exposure for subsurface activities during the Operations-Emplacement and Monitoring Phases.

Usage: This assumption is used in Section 4.3 and 6.3.

3.2.15 Removal of Magma Chambers From Design Calculation

Assumption: Magma chambers will be removed from the Closure design.

Rationale: Per the document *Design Change Request, Remove the Requirements for Design and Installation of Magma Bulkheads in the Subsurface Repository*, (Ref. 2.2.8) Magma chambers will be removed from the Closure design. This will reduce the complexity of closure activities, reduce person-hours and increase work location flexibility allowing for reduced radiation exposure to complete the Closure Phase.

Reference 2.2.8 is designated QA:NA. This document contains the latest and best available design information related to removal of magma bulkheads and chambers from Closure Phase design and is suitable for use in performing this dose assessment.

Usage: This assumption is used indirectly in section 4.3, 6.2 and 6.3 by exclusion of consideration work related to Magma Chambers during the Closure Phase.

3.2.16 Task Hours In Dose Rate Affected Areas: Operations-Closure Phase

Assumption: The number of hours per year that an individual subsurface worker will spend in dose rate affected areas (*j*) performing task (k) during the Operations-Closure Phase is listed in Table 6.

Table 6: Task Hours Per Year By Work Location (Operations-Closure Phase)

TASK NO. (k)	LOCATION DESIGNATION (j):	1	2	3	4	5	6	ON SITE
	Task Description	North Portal Access Control Station	General Access Main	Access Mains Near Empl Drift Turnout	Empl Drift Turnout Bulkhead	Exhaust Mains Near Temp. Isolation Barrier [(a)]	Exhaust Main (Closure Only)	
1	Install Drip Shields/Shielding in Drifts	300	1650	50	0	0	0	2000
2	Remove Non-committed Materials	300	1300	200	200	0	0	2000
3 [(b)]	Install Backfill In Exhaust Mains Install Backfill In Ramps/Shafts Install Backfill in Access Mains/Turnouts	700	700	300	0	0	300	2000
4	Facility Access (Security and Safeguards)	1900	100	0	0	0	0	2000
5	Radiation Protection/Health Physics	1000	620	300	0	0	80	2000

(Attachment 1: File 800 00C SS00 0600 000 00A.xls, Sheet Table 6)

[a] Not applicable during Closure Phase.

[b] Backfilling Operations occur in three major areas. Individuals involved in backfilling activities will work in all areas.

Rationale: The tasks assumption is based on a review of the same references reviewed in support of Assumption 3.2.9. The hours spent on tasks in locations listed in Table 6 are based on subsurface engineering judgment considering the current state of Subsurface Facility design.

Usage: This assumption is used in sections 4.3 and 6.2.

3.2.17 Staffing: Operations-Closure Phase

Assumption: The shift staffing and total subsurface facility staffing during the Operations-Closure Phase is listed in Table 7.

Table 7: Annual Staffing/ Operations-Closure Phase

TASK NO.	TASK	ESTIMATED SHIFT CREW SIZE (# OF PEOPLE) [A]	ANNUAL STAFFING (# OF PERSONS) [(a)] [B]
1	Install Drip Shields/Shielding in Drifts	2	10
2	Remove Noncommitted Materials	4	20
3	Install Backfill In Exhaust Mains	36	180
	Install Backfill In Ramps/Shafts		
	Install Backfill in Access Mains/Turnouts		
4	Facility Access (Security and Safeguards)	2	10
5	Radiation Protection Health Physics	2	10
	Total:	46	230

(Attachment 1: File 800 00C SS00 0600 000 00A.xls, Sheet Table 7)

a. Equal crew size times (5); [B] = [A] x 5

Rationale: Facility operations will be scheduled for three 8-hour shifts per day (24/7 operations). It will require five (5) shifts to support facility operations. Crew size is based on subsurface engineering judgment. At least three crews are needed to support 24/7 operations. However, three crews would not allow for days off, holidays, vacation, sick leave or training. Staffing five (5) crews will ensure adequate shift coverage as well as allowing for days off, holidays, vacation, sick leave or training. This assumption is consistent with shift coverage practices at facilities operating under 24/7 schedules. Crew size is used to determine total staffing. Total Staffing is used to calculate annual collective radiation exposure for subsurface activities during the Operations-Closure.

Usage: This assumption is used in sections 4.3 and 6.3.

3.2.18 Average Source Term Calculations Used for Dose Rate Estimates in the Subsurface Facility

Assumption: Dose rates used as input to this occupational dose calculation are based on the average 21-PWR waste package source term.

Rationale: Reference 2.2.12 compares the surface dose rates at maximum and average source term for 21-PWR, 44-BWR, DHLW/DOE SNF Co-disposal and Naval SNF waste packages. This comparison demonstrates that the 21-PWR waste package is limiting with respect to dose rate. (Ref. 2.2.12, Section 5.2, Table 7)

The 21-PWR waste package maximum or design basis source terms are intended for use in shielding design. The design basis source term covers a minimum of 95% of the total inventory, with provisions made available to accommodate the remaining 5%. The maximum source term represents the bounding fuel assembly in the entire inventory to be received at the repository. (Ref. 2.2.7, section 4.10.1.4) To more accurately and adequately reflect actual exposures received during repository operation, it is appropriate to use the average basis source term.

The 21-PWR waste package design is being superseded by a TAD waste package design, which incorporates a shielded TAD canister inside the waste package. Current knowledge indicates that the 21-PWR waste package dose rate calculations are higher and more conservative than the TAD waste package. As such, it is appropriate to use the average 21-PWR waste package source term as the bounding source term for this dose assessment.

Usage: This assumption is used in sections 4.3 and 6.1 and is the foundation for all dose rate estimates in this calculation.

3.2.19 Dose Rates in the Access Mains from Emplaced Waste Packages

Assumption: Dose rates in the access mains from emplaced work packages, during the Operations-Emplacement and Operations-Monitoring Phase, are equal to the 21-PWR Average Basis Source Term Calculated Access Main dose rates listed in Table 8.

Table 8: Dose Rates in the Access Mains from Emplaced Waste Packages

RELATIVE DISTANCE FROM CENTER OF ACCESS MAIN IN TURNOUT (meters) [a]	21-PWR AVERAGE BASIS SOURCE TERM CALCULATED ACCESS MAIN DOSE RATE (mrem/hr) [b]	21-PWR DESIGN BASIS SOURCE TERM CALCULATED ACCESS MAIN DOSE RATE (mrem/hr) [c]	AVERAGE BASIS TO DESIGN BASIS RATIO [d]
	[A]	[B]	[C]
-100	9.34E-05	7.58E-04	0.12
-50	3.84E-03	2.54E-02	0.15
-20	9.82E-02	7.05E-01	0.14
-10	3.14E-01	2.18E+00	0.14
-5	5.37E-01	3.73E+00	0.14
-2	7.26E-01	5.11E+00	0.14
-1	7.54E-01	5.35E+00	0.14
-0.5	7.66E-01	5.27E+00	0.15
0	7.34E-01	5.06E+00	0.15
0.5	6.74E-01	4.46E+00	0.15
1	5.23E-01	3.50E+00	0.15
2	6.79E-02	4.81E-01	0.14
5	2.19E-02	1.54E-01	0.14
10	6.24E-03	3.97E-02	0.16
20	1.21E-03	8.67E-03	0.14
50	6.80E-05	4.72E-04	0.14
100	3.72E-06	3.79E-05	0.10
		Average [e]:	0.14

(Attachment 1: File 800 00C SS00 0600 000 00A.xls, Sheet Table 8)

a. Ref. 2.2.9, Table 15, Column 1; Positive distance toward development side, negative distances toward emplacement side.
b. Reference 2.2.9, Table 15, Column 2
c. Reference 2.2.9, Table 15, Column 6
d. Calculation: [C] = [A] / [B]
e. Simple arithmetic average of values in column 4

Rationale: The dose rate calculations in Ref. 2.2.9 are the best available for this purpose. Emplacement drifts are filled with waste packages from the exhaust end of the drift back toward the turnout/access main. (Ref. 2.2.4, Appendix A, section A3.1.3).

Reference 2.2.4 is output designated as QA:NA. This document contains the latest and best available emplacement drift loading information and is suitable for use in performing this dose assessment.

The dose rates calculated in the access main result from a 'full drift' model with the last emplaced waste packages located in the turnout/access main end of the emplacement drift. It is conservative to assume that the drift is full during the Operations-

Emplacement Phase in a dose calculation because dose rates in the access main will be higher in this configuration than they would be when the emplacement drift is not full due to distance between the waste package and the access main. For much of the time, until the emplacement drift is full, dose rates in the access mains from emplaced waste packages will be much lower than the 'full drift' model dose rates.

The calculated dose rates in the access mains include both average and design basis source term dose rates for the 21-PWR waste package. This allows for calculation of the relationship (ratio) in dose rates that results from the use of either source term as listed in Table 8, column 4.

Usage: This assumption is used in section 4.3 and 6.1.

3.2.20 Dose Rates at the Drift Turnout Bulkhead From Emplaced Waste Packages

Assumption: The dose rates at the emplacement drift turnout bulkhead are equal to the average 21-PWR average basis dose rates listed in Table 9.

Table 9: Dose Rates at the Drift Turnout Bulkhead From Emplaced Waste Packages

LOCATION NEAR BULKHEAD/ DOOR IN CALCULATION (a)	21-PWR DESIGN BASIS SOURCE TERM CALCULATED TURNOUT BULKHEAD DOSE RATE (mrem/hr) (b)	AVERAGE BASIS TO DESIGN BASIS RATIO (c)	21-PWR AVERAGE BASIS SOURCE TERM CALCULATED TURNOUT BULKHEAD DOSE RATE (mrem/hr) (d)
	[A]	[B]	[C]
A	4.11E+00	0.14	5.75E-01
B	6.88E+00	0.14	9.63E-01
C	8.36E+00	0.14	1.17E+00
D	6.18E+00	0.14	8.65E-01
Average (e):	6.38E+00		8.94E-01

(Attachment 1: File 800 00C SS00 0600 000 00A.xls, Sheet Table 9)

a. Ref. 2.2.10, Table 10, Column 1.
b. Reference 2.2.10, Table 10, Column 9.
c. Table 8, Column 4, Row 20.
d. Calculation: [C] = [A] x [B].
e. Simple arithmetic average of values above.

Rationale: The dose rate calculations in Ref. 2.2.10 are the best available for this purpose. The design basis source term dose rates listed in Table 9 are adjusted to average source term dose rates by applying the average of the Average Basis to Design Basis Ratio (0.14) to the design basis dose rates at the drift turnout bulkhead. It is appropriate to apply the average of the Average Basis to Design Basis Ratio to the design dose rates in this case because the geometry of the model used to generate the design dose rates in Ref. 2.2.10 is similar to the geometry used to generate the design dose rates in Ref. 2.2.9.

The locations listed in Table 9 are at the Turnout bulkhead and oriented reasonably uniformly across the drift opening, thus a simple arithmetic average will appropriately represent the dose rates at the drift turnout bulkhead. The calculated dose rates result from a 'full drift' model with the last emplaced waste package located in the turnout/access main end of the emplacement drift.

Usage: This assumption is used in section 4.3 and 6.1.

3.2.21 Dose Rates in the Exhaust Mains from Emplaced Waste Packages

Assumption: Dose Rates in the Subsurface Facility Exhaust Mains during the Operations-Emplacement and Operations-Monitoring Phase are equal to the 21-PWR Average Basis Source Term Calculated Exhaust Main dose rates listed in Table 10.

Table10: Dose Rates in the Exhaust Mains from Emplaced Waste Packages

RELATIVE DISTANCE FROM CENTER OF EXHAUST MAIN/DRIFT INTERSECTION (meters) (a)	21-PWR AVERAGE BASIS SOURCE TERM CALCULATED EXHAUST MAIN DOSE RATE (mrem/hr) (b)	21-PWR DESIGN BASIS SOURCE TERM CALCULATED EXHAUST MAIN DOSE RATE (mrem/hr) (c)
-128	1.21E-02	5.71E-02
-64	1.88E-01	8.75E-01
-32	1.96E+00	9.68E+00
-16	1.59E+01	7.47E+01
-8	7.21E+01	3.23E+02
-4	5.41E+02	2.95E+03
-2	6.86E+02	3.83E+03
-1	7.70E+02	4.30E+03
0	8.64E+02	4.76E+03
1	9.50E+02	5.19E+03
2	1.04E+03	5.63E+03
4	1.11E+03	5.83E+03
8	3.99E+01	1.89E+02
16	9.92E+00	4.34E+01
32	1.11E+00	4.78E+00
64	6.52E-02	2.91E-01
128	2.51E-03	1.35E-02

(Attachment 1: File 800 00C SS00 0600 000 00A.xls, Sheet Table 10)

a. Reference 2.2.9, Table 16, Column 1; Negative distance toward development side, positive distances toward emplacement side.

b. Reference 2.2.9, Table 16, Column 2.

c. Reference 2.2.9, Table 16, Column 6.

Rationale: The dose rate calculations in Ref. 2.2.9 are the best available. The calculated exhaust main dose rates listed in Table 10 are the dose rates for the model with the 25-foot diameter exhaust main with a 45-degree interface angle with the emplacement drift. This orientation was determined to be the most conservative dose rate configuration (i.e., higher dose rate) in the current facility design. (Ref. 2.2.9, section 7.1.4)

Usage: This assumption is used in section 4.3 and 6.1.

3.2.22 Use of Weighted Average Dose Rates In Access and Exhaust Mains to Represent Dose Rate Fields.

Assumption: It is appropriate to use weighted average dose rates to represent the dose rates in specified intervals in the access and exhaust mains when calculating external worker doses.

Rationale: The dose rate data provided in Ref. 2.2.9 is not provided by linear interval, as can be seen in Tables 8 and 10. Performing a simple arithmetic average calculation with the data would significantly overestimate the average dose rates in an interval (provide too much weight to the dose rates in shorter/smaller intervals). Therefore, use of a weighted average, based on dose rate interval length, is more appropriate for use in calculating estimated external doses in the access mains and the exhaust mains.

Usage: This assumption is used in section 4.3 and 6.1.

3.2.23 Annual Collective External Radiation Dose During Concurrent Development and Emplacement Activities.

Assumption: The collective annual external radiation dose in the subsurface facility during any year of emplacement with concurrent development is directly proportional to the number of active emplacement drifts in that emplacement year.

Rationale: The peak staffing and peak collective annual external radiation exposure will occur during the 22nd year of emplacement activities.

As stated and shown in Assumption 3.2.8, the number of commissioned emplacement drifts starts out at (3) drifts in the first emplacement year and reaches the full complement of 108 emplacement drifts in the 22nd emplacement year. As the size and extent of the subsurface facility increases during concurrent development, more staff will be added to manage the facility. Therefore, peak emplacement side staff is reached in the 22nd emplacement year. Once development is complete in the 22nd emplacement year, adding staff will no longer be required, and the annual collective external radiation dose due to staff size levels off.

As stated and shown in Assumption 3.2.10, movement of temporary isolation barriers occurs during the initial 22-year period for continued construction (development). This increases annual collective external radiation dose during development. After the 22nd year of operations, these tasks are no longer performed, and the annual collective external radiation dose resulting from temporary isolation barrier movement will not be incurred.

After calculating the collective external radiation dose in the 22nd year of emplacement, the collective dose during any emplacement year between 1 through 22 can be estimated by multiplying the collective annual external dose in year 22 by the ratio of the number of emplacement drifts in service divided by the total number of emplacement drifts in service in the 22nd emplacement year.

Usage: This assumption is used in sections 4.3 and 6.3.

3.2.24 Dose Rates During the Closure Phase

Assumption: Dose rates in the Subsurface Facility will be lower by a factor of 8.72E-02 when the Closure Phase begins due to radioactive decay.

Rationale: The Operations-Emplacement Phase duration is 24 years. The Operations-Monitoring Phase duration is 76 years. Waste package source terms will decay following emplacement. Assuming that the waste packages are placed over a 24-year period, then the average age of emplaced waste packages will be 12 years or one-half of the emplacement period duration. Adding 76 years for the monitoring phase duration to the 12 years average emplacement age for waste packages results in an overall average decay period of 88 years prior to closure.

Ref. 2.2.11, Table 6.4-4 lists gamma energy deposition rate reduction factors by emplacement year for the average 21-PWR waste packages. To determine the decay reduction factor at 88 years after emplacement, linear interpolation was performed for the data for the waste package bottom lid at emplacement years 95 and 60. This results in a reduction factor of 8.72E-2 for the 88-year decay period prior to closure.

Usage: This assumption is used in section 4.3 and 6.1.

3.2.25 Subsurface Category 1 Events

Assumption: There is no Category 1 Event sequence associated with subsurface facility operations.

Rationale: Normal subsurface facility operations involve the transport and placement of waste packages that are closed and sealed. No Category 1 or Category 2 event sequences resulting in radiological releases have been identified for any of the subsurface facility operations. (Ref. 2.2.4, Appendix C, section C2.1).

Reference 2.2.4 is designated QA:NA. This document contains the latest and best available design information related to event categorization in the Subsurface Facility and is suitable for use in performing this dose assessment.

Usage: This assumption is used throughout this assessment. There are no credible Category 1 or Category 2 event sequences resulting in radiological releases identified for any of the subsurface facility operations. Category 1 or Category 2 event sequences are not considered

3.2.26 Subsurface Worker Internal Dose Estimates

Assumption: The potential for internal dose to subsurface facility workers is insignificant and trivial and therefore it is not necessary to add this to the external dose for the workers.

Rationale: Normal subsurface facility operations involve the transport and placement of waste packages that are closed and sealed. Any residual contamination on the surface of a waste package may be re-suspended in the emplacement drift, entrained in the ventilation airflow, and released to the environment through the shafts.

It has been determined that waste packages contaminated to levels of 520 dpm/100 cm^2 alpha or 21,000 dpm/100 cm^2 beta-gamma (based on most restrictive radionuclides) or up to 1,3000,000 dpm/100 cm^2 (Co-60) would result in less than or equal to 0.36 mrem/yr internal dose. (Ref. 2.2.13, section 6.1.2.2.2) The potential internal dose is an insignificant fraction of allowable limits.

The potential for radiological releases in the subsurface and to the environment from the activation of air and silica dust in the emplacement drifts has been evaluated (Ref. 2.2.14). The potential releases were determined to be insignificant fractions of allowable limits.

Usage: This assumption is used throughout this assessment. Internal dose is not considered.

3.2.27 Use of Radiation Shielding in Emplacement Drift During the Closure Phase

Assumption: Two tenth-value layers of radiation shielding will be installed in front of, and as near as possible to, the last waste package at the exhaust main end of the emplacement drift to reduce radiation levels prior to commencing backfill operations in the exhaust main.

Rationale: The number of person-hours that could be spent in the exhaust main during closure is significant. Two tenth-value layers of radiation shielding, in conjunction with radioactive decay, will reduce radiation levels in the exhaust main by a factor of 1000 or more. For purposes of this dose assessment, it is reasonable and appropriate to assume that the shielding is temporary shielding that is installed and removed by remote methods.

As a recommendation for the future, this suggested shielding could be included as an integral piece of the drip shield that will be installed over the last waste package on the exhaust main end of the emplacement drifts, thus allowing for completely remote installation. It would operate similar to the shield door on the TEV. The shielding could be considered committed material and be approved for permanent placement, negating the need to remove it prior to closure.

This option should be considered in detail at the time of facility closure and should be based on actual conditions/dose rates measured in the exhaust main prior to closure. At this time, however, it would be premature to design and fabricate shielding for this purpose.

Usage: This assumption is used in sections 4.3 and 6.1.

3.2.28 Dose Rate at the North Portal Access Control Station

Assumption: The dose rate at the North Portal Access Control Station is equal to 5.00E-02 mrem/hr.

Rationale: In general personnel spend time at surface facilities, such as the North Portal, for lunch, breaks, etc. It is conservative to assume that personnel will be exposed to external dose rates equal to 5.00E-02 mrem/hr when not directly engaged in work activities, or when engaged in activities that are in areas not affected by dose rates from waste packages. The selection of the 5.00E-02 mrem/hr dose rate for this area corresponds with the upper end restricted area boundary criteria specified for this type of area in the *Project Design Criteria Document* for shielding design. (Ref. 2.2.7, section 4.10.1.3, Table 4.10.1-1)

Usage: This assumption is used in sections 4.3 and 6.1.

4.0 METHODOLOGY

4.1 QUALITY ASSURANCE

This calculation was prepared in accordance with EG-PRO-3DP-G04B-00037, *Calculations and Analyses* (Ref. 2.1.1).

Several aspects of the Subsurface Facility are classified in accordance with the *Q-List* (Ref. 2.1.2) as follows:

- Subsurface Facility Emplacement/nonemplacement openings (North Portal, North Ramp, access main, and turnouts), are classified as Important to Safety (ITS) (Ref. 2.1.2, Appendix A, Table A-1),

- Subsurface Facility Emplacement/Emplacement Drifts, are classified as Important to Safety (ITS) and as Important to Waste Isolation (ITWI) (Ref. 2.1.2, Appendix A, Table A-1),

- Subsurface Facility Emplacement/ Emplacement Drift Invert (ballast), is classified as Important to Waste Isolation (ITWI) (Ref. 2.1.2, Appendix A, Table A-1),

- Subsurface Facility Emplacement/ Waste Package Emplacement Pallets, are classified as Important to Safety (ITS) and as Important to Waste Isolation (ITWI) (Ref. 2.1.2, Appendix A, Table A-1),

- Subsurface Facility Emplacement/Drip Shields, are classified as Important to Waste Isolation (ITWI) (Ref. 2.1.2, Appendix A, Table A-1),

- Subsurface Facility Postemplacement/ Closure (backfill in access mains, exhaust mains, and turnouts) is classified as Important to Waste Isolation (ITWI) (Ref. 2.1.2, Appendix A, Table A-1),

- Subsurface Development (Excavation) and Subsurface Ventilation (Entire) are categorized as Non-SC (Ref. 2.1.2, Appendix A, Table A-1).

Results of this calculation provide worker dose assessments that identify radiological hazards for facilities important to safety or important to waste isolation. Therefore, the approved version is designated as QA:QA.

4.2 USE OF SOFTWARE

Microsoft® Excel®, a spreadsheet program, is used in this calculation. Microsoft® Excel® is included as an integral part of the Microsoft® Office 2000 Professional suite.

Excel® was used to generate tables listing the following:

- The number of commissioned emplacement drifts by emplacement year;
- Tasks and task hours in dose rate affected areas;
- Shift and total subsurface facility staffing;
- Access main, exhaust main and turnout main dose rates;
- Average dose rate calculations;
- Annual individual and collective external doses.

Microsoft® Office 2000 Professional is installed on a personnel computer running Microsoft® Windows 2000 Professional (Central Processing number 152191). User-defined formulas (derived in Section 4.3), design inputs and assumptions (discussed in Sections 2.2 and 3.2), and results are documented in sufficient detail in Section 6 to allow hand checking for independent duplication of the various computations without recourse to the originator per Ref. 2.1.1.

Microsoft® Office 2000 Professional is listed on the Controlled Software Report and is identified in the Repository Project Management automation plan. The use of Excel® constitutes level 2 software usage per Ref. 2.1.3 and does not require qualification. All calculation results generated from Excel were verified by hand calculation.

4.3 SUBSURFACE WORKER DOSE CALCULATION

4.3.1 General Information

This calculation estimates individual and collective occupational radiation doses in the Subsurface Facility during the Operations-Emplacement Phase, the Operations-Monitoring Phase and the Closure Phase. It does not include internal or external doses resulting from naturally occurring radioactive materials such as Radon, or material in subsurface rock.

In order to calculate occupational radiation doses, it is necessary to have an understanding of facility design and operations, as well as an understanding of the radiological conditions in work areas and radiation fields to which workers will be exposed. Total occupational radiation dose to an individual is the sum of the individual's internal radiation dose and their external radiation dose. Total occupational dose to a group of individuals or to a work force at a facility is called collective dose.

Internal radiation doses result from the inhalation, ingestion, injection/injury or absorption of radioactive material in the human body. External radiation doses result from proximity to sources of penetrating radiation and increase with time spent in the resulting external radiation fields. Internal radiation dose is not a credible concern in the subsurface facility. (Assumption 3.2.26) Therefore, the total occupational dose calculated in this dose assessment is equal to the total external dose workers receive while performing activities in the Subsurface Facility.

Waste packages in emplacement drifts are responsible for 100% of the external radiation dose that will be received by workers in the Subsurface Facility. The expected radiation dose rates in potentially occupied areas in the Subsurface Facility have been reasonably well characterized through the performance of detailed calculations. (Ref. 2.2.9; Ref. 2.2.10) Knowledge of the limiting waste package configuration, source term and radioactive decay can be derived from existing calculations as well. (Ref. 2.2.12) The information obtained and developed from these sources will be used to complete this external radiation dose assessment.

Facility operations and design have been reasonably well described in existing project documents. These documents serve as a basis for determining the nature and location of work activities that will take place in the Subsurface Facility during operations. This information was further evaluated in order to estimate the number of hours that will be spent by workers during the year in subsurface facilities and to estimate the total Subsurface Facility staffing needed to support operations.

Annual individual external occupation radiation doses will be estimated from calculated radiation levels and the estimated work activities/hours spent per year in the Subsurface Facility to support operations. Annual collective external occupation radiation doses will be estimated from the calculated annual individual external occupation radiation doses and estimated total annual staffing needed to support Subsurface Facility operations.

Collective external radiation doses can be estimated for each year of facility operation through the closure phase based on the information related to facility design, schedule and operating phases.

4.3.2 Description of Subsurface Facility Design and Operations

The following description of the current state of design and planned operations is developed in support of this assessment:

The Operations-Emplacement Phase is twenty-four (24) years in duration, and begins in year 1 with the commissioning of three (3) emplacement drifts in Emplacement Panel 1. During the first twenty-two (22) years of the Operations-Emplacement Phase, concurrent construction/development activities take place in the Subsurface Facility, and emplacement drifts are turned over from construction to operations at rate of approximately five (5) drifts per year. By the 22^{nd} year of emplacement activities, all 108 planned emplacement drifts will be in operation and ready to accept waste packages.

Waste packages will be delivered to subsurface emplacement drifts from the surface facilities over a rail system through the use of the electrically powered, remotely operated, shielded vehicle called the Transport Emplacement Vehicle (TEV). The Subsurface Ventilation System ensures that ambient air from the surface is routed through the emplacement side of the repository via the access mains, through the emplacement drifts, through the exhaust mains, and out the exhaust shafts back to the environment, providing fresh air for subsurface personnel and providing cooling for the waste packages. Once waste packages are staged in a drift, normal personnel access to the emplacement drift is restricted due to the high temperature and high radiation levels that may be present.

Each emplacement drift access, called a turnout (long-radius curved tunnel), is barricaded with an emplacement drift turnout bulkhead. The curvature of the turnout serves to avoid direct radiation exposure in the access mains from the waste packages. An emplacement drift airflow control system is installed on each bulkhead to regulate the airflow though the drift to the desired levels. The bulkhead also has remotely operated access doors that allow the TEV to enter and exit the emplacement drift when required while minimizing the disturbance to the drift airflow. Additionally, the bulkhead restricts unauthorized personnel access to the high radiation and high temperature environment inside the emplacement drift.

Waste packages are emplaced in the drifts starting at the exhaust main end of the drift. Once waste packages are staged in a drift, normal personnel access to the emplacement drift and the ventilation system exhaust main (due to direct access to the drifts from the exhaust main) is restricted due to the high temperature and high radiation levels that may be present. Further, as waste packages are emplaced in a drift, radiation dose rates from the waste packages, at the emplacement drift turnout bulkhead, and in the access main, slowly increase due to scattered radiation until the full capacity of the drift is reached, at which point dose rate increases stop and the radiation levels remain relatively stable.

The Subsurface Facility will include electric power distribution, communications systems and instrumentation and controls related to the ventilation system components and emplacement activities, as well as geotechnical and radiological monitoring equipment. Performance confirmation activities (inspections, sampling, drilling, monitoring and measurements of the rock and ambient conditions) will be in progress from the start of emplacement activities until Closure. Operations personnel will be performing rounds/inspections, and supporting emplacement. Periodic maintenance activities will be performed to ensure reliable operation and performance of subsurface equipment and facilities. When an inspection of emplacement drifts containing waste packages or the exhaust main is required, remotely operated equipment will be used because of the high radiation levels and high temperature conditions that could be present.

During the twenty-two (22) year period when concurrent development and emplacement activities are taking place, temporary isolation barriers will be installed in the subsurface access and exhaust mains to separate the ventilation system and activities on the emplacement side of the repository from the ventilation system and activities on the construction/development side of the repository. Periodically, approximately once a year when emplacement drifts are turned over from construction to operation, these isolation barriers will need to be removed and barriers will need to be installed in new locations further towards the development side of the repository so that concurrent construction/emplacement activities can continue.

Following the twenty-four (24) year Operations-Emplacement Phase, the Operations Monitoring Phase begins. During this phase, no emplacement activity is taking place. Workers will no longer be required to commission new emplacement drifts or remove and reinstall temporary isolation barriers in the access and exhaust mains. The remainder of the activities occurring during the Operations-Emplacement Phase will continue during the Operations-Monitoring Phase. The Operations-Monitoring Phase will last approximately seventy-six (76) years or until a decision is made to permanently close the repository. During this phase, waste package source terms will continue to decrease due to radioactive decay, causing dose rates in the Subsurface Facility to decrease by a factor of ten (10) or more by the end of the Operations-Monitoring Phase.

Once a decision is made to close the Subsurface Facility, the Closure Phase begins. Drip shields will be installed over the waste packages in the emplacement drifts using an electrically powered and remotely operated Drip Shield Emplacement Gantry. Materials that may have a detrimental effect on long-term subsurface facility performance (non-committed materials) will be removed. Emplacement drift turnout bulkheads will be removed. Access mains and emplacement turnouts (up to the location of the turnout bulkheads leaving a cavity on the emplacement drift side of the emplacement drift turnout) will be backfilled. Exhaust mains will be backfilled, leaving a cavity in the backfill near the intersection of the exhaust main with each emplacement drift. Backfilling operations will be completed using high volume conveying systems and heavy-duty placement equipment that can be operated either remotely or via tethered controls. It will not be necessary to remove materials from the emplacement drifts and they will not be backfilled. Ramps and ventilation shafts will be backfilled and the subsurface facility will be secured from intrusion. The Closure Phase is expected to last ten (10) years.

4.3.3 North Portal Access Control Station Dose Rate

The dose rate at the North Portal Access Control Station is equal to 5.00E-02 mrem/hr (DR_1 = 5.00E-02 mrem/hr). (Assumption 3.2.28)

Radioactive decay is taken into account for dose rate reductions at the beginning of the Operations-Closure Phase. For the Operations-Closure Phase, the average dose rate at the North Portal Access Control Station and unaffected areas, such as ramps, is designated DRC_1 and is equal to DR_1 x RF_C.

$$DRC_1 = DR_1 \times RF_C \qquad \text{Equation 1}$$

Where:

DR_1 =	Average dose rate assumed at the North Portal Access Control Station during the Operations-Emplacement and Operations-Monitoring Phases (mrem/hr)
RF_C =	Decay correction factor; equal to 8.72E-02 (unitless) (Assumption 3.2.24)
DRC_1 =	Average dose rate at the North Portal Access Control Station during the Operations-Closure Phase (mrem/hr)

Equation 1 will be used in section 6.1.1 to calculate the average access main dose rate during the Closure Phase.

4.3.4 Weighted Average Dose Rate Estimates Based On Irregular Intervals Between Dose Points

It is appropriate to use weight average dose rates to represent the dose rates in specified intervals in the access and exhaust mains when calculating external worker doses. (Assumption 3.2.22)

A weighted average dose rate in an interval is calculated by determining a linear average dose rate between two (2) data points, determining the length of the interval, determining total length of the interval for all dose rate data, weighting the average dose rate in an interval based on the total length of the interval for all dose rate data, and then summing the weighted average dose rates from each interval to obtain the weighted average dose rate for use in the external dose calculations.

The equations used to perform this calculation are as follows:

$$\overline{DR_n} = \frac{(DRP_{m+1} + DRP_m)}{2} \qquad m=n = 1 \ldots m-1 \qquad \text{Equation 2}$$

Where:

$n=$	index: 1 to the total number of intervals
$m=$	index: 1 to total number of data points in interval n
$DRP_{m+1}=$	Dose rate at point P_{m+1} (mrem/hr)
$DRP_m=$	Dose rate at point P_m (mrem/hr)
$\overline{DR}_n=$	Linear average dose rate in interval n (mrem/hr)

$$L_n = P_{m+1} - P_m \qquad m=n = 1\ldots m\text{-}1 \qquad \text{Equation 3}$$

Where:

$n=$	index: 1 to the total number of intervals
$m=$	index: 1 to total number of data points in interval n
$L_n=$	Length of dose rate interval n (meters)
$P_{m+1}=$	Start location/distance of dose rate point from reference point 0 (meters)
$P_m=$	End location/distance of dose rate point from reference point 0 (meters)

$$I = \sum_n L_n \qquad \text{Equation 4}$$

Where:

$n=$	index: 1 to the total number of intervals
$L_n=$	Length of dose rate interval n (meters)
$I=$	Total length/sum of all n dose rate data intervals (meters)

$$WDR_n = \frac{L_n}{I} \times \overline{DR_n} \qquad \text{Equation 5}$$

Where:

$n=$	index: 1 to the total number of intervals
$L_n=$	Length of interval n in (meters)
$I=$	Total sum of all intervals L_n (meters)
$\overline{DR}_n=$	Linear average dose rate in interval n (mrem/hr)
$WDR_n=$	Weighted dose rate in interval n (mrem/hr)

$$DR = \sum_n WDR_n \qquad \text{Equation 6}$$

Where:

$n=$	index: 1 to the total number of intervals
$WDR_n =$	Weighted dose rate in interval n (mrem/hr)
$DR =$	Weighted Average dose rate in area of interest (mrem/hr)

Equations 2 through 6 will be used in sections 6.1.2, 6.1.3, 6.1.5 and 6.1.6 to calculate average dose rates in areas of interest where dose rate data has been provided at linear irregular length intervals.

4.3.5 General Access Main Dose Rate

Dose rates used as input to this occupational dose calculation are based on the average 21-PWR waste package source term. (Assumption 3.2.18)

The calculation for the average dose rate in the access mains during the Operations-Emplacement and Operations-Monitoring Phases (DR_2) is performed in section 6.1.2 using Equations 2 through 6 with DR_2=DR in Equation 6. The distance and dose rate input data is listed in Table 8.

The area of interest in the access mains is the region between –100 meters and 100 meters. This region approximately corresponds to the area between emplacement drift turnouts. Because dose rates are so low in the access main at greater than fifty (50) meters from the turnout areas, additive effects of the radiation fields from adjacent emplacement drift turnouts can be ignored. There are seventeen (17) (m=17) dose rate data points and sixteen (n=16) intervals derived from the input data.

Radioactive decay is taken into account for dose rate reductions at the beginning of the Operations-Closure Phase. For the Operations-Closure Phase, the average dose rate in the access main is designated DRC_2 and is equal to DR_2 x RF_C.

$$DRC_2 = DR_2 \times RF_C \qquad \text{Equation 7}$$

Where:

$DR_2 =$	Average dose rate in the access mains during the Operations-Emplacement and Operations-Monitoring Phases (mrem/hr)
$RF_C =$	Decay correction factor; equal to 8.72E-02 (unitless) (Assumption 3.2.24)
$DRC_2 =$	Average dose rate in the access mains during the Operations-Closure Phase (mrem/hr)

Equation 7 will be used in section 6.1.2 to calculate the average access main dose rate during the Operations-Closure Phase.

4.3.6 Access Main Dose Rate Near Turnout

Dose rates used as input to this occupational dose calculation are based on the average 21-PWR waste package source term. (Assumption 3.2.18)

The calculation for the average dose rate in the vicinity of a turnout in the access main during the Operations-Emplacement and Operations-Monitoring Phases (DR_3) is performed in section 6.1.3 using Equations 2 through 6 with $DR_3 = DR$ in Equation 6. The distance and dose rate input data is listed in Table 8. (Assumption 3.2.19)

The area of interest in the access main near the turnout is the region between –20 meters and 20 meters. This region (-20 meters to 20 meters) corresponds to the area between the point of the rail switch and the nose of the turnout drift. There are thirteen (13) (m=13) dose rate data points and twelve (n=12) intervals derived from the input data.

Radioactive decay is taken into account for dose rate reductions during the Operations-Closure Phase. For the Operations-Closure Phase, the average dose rate in the vicinity of a turnout in the access main is designated DRC_3 and is equal to DR_3 x RF_C.

$$DRC_3 = DR_3 \times RF_C \qquad \text{Equation 8}$$

Where:

$DR_3 =$	Average dose rate in the access main near a turnout during the Operations-Emplacement and Operations-Monitoring Phases (mrem/hr)
$RF_C =$	Decay correction factor; equal to 8.72E-02 (unitless) (Assumption 3.2.24)
$DRC_3 =$	Average dose rate in the access main near a turnout during the Operations-Closure Phase (mrem/hr)

Equation 8 will be used in section 6.1.3 to calculate the average dose rate in the vicinity of a turnout in the access main during the Operations-Closure Phase.

4.3.7 Dose Rate at Emplacement Drift Turnout Bulkhead

Dose rates used as input to this occupational dose calculation are based on the average 21-PWR waste package source term. (Assumption 3.2.18)

The average dose rate at the emplacement drift turnout bulkhead during the Operations-Emplacement Phase and the Operations-Monitoring Phase is designated DR_4. (Assumption 3.2.20; Table 9)

Radioactive decay is taken into account at the beginning of the Operations-Closure Phase. During the Closure phase, the average dose rate at the emplacement drift turnout bulkhead is designated DRC_4 and is equal to DR_4 x RF_C.

$$DRC_4 = DR_4 \times RF_C$$ Equation 9

Where:

$DR_4 =$ Average dose rate at an emplacement drift turnout bulkhead during the Operations-Emplacement and Operations-Monitoring Phases (mrem/hr)
$RF_C =$ Decay correction factor; equal to 8.72E-02 (unitless) (Assumption 3.2.24)
$DRC_4 =$ Average dose rate at an emplacement drift turnout bulkhead during the Operations-Closure Phase (mrem/hr)

Equation 9 will be used in section 6.1.4 to calculate the average dose rate at the emplacement drift turnout bulkhead during the Operations-Closure Phase.

4.3.8 Dose Rate In Exhaust Main (Temporary Isolation Barrier Locations)

Dose rates used as input to this occupational dose calculation are based on the average 21-PWR waste package source term. (Assumption 3.2.18)

The calculation for the average dose rate in the vicinity of a temporary isolation barrier in the exhaust main during the Operations-Emplacement Phase is performed in section 6.1.5 using Equations 2 through 6 with $DR_5 = DR$ in Equation 6. The area of interest in the exhaust main near the barrier is the region between –128 meters and -32 meters. This region corresponds to the anticipated location of the barrier in the exhaust main. There are three (3) (m=3) dose rate data points and two (n=2) intervals derived from the input data. The distance and dose rate input data is listed in Table 10. (Assumption 3.2.21)

Once the Operations-Emplacement Phase is complete, it is no longer necessary to move temporary isolation barriers in the exhaust main. Therefore, it is not necessary to estimate this dose rate during the Operations-Monitoring Phase or the Operations-Closure Phase.

4.3.9 Dose Rate In Exhaust Main (Closure)

Dose rates used as input to this occupational dose calculation are based on the average 21-PWR waste package source term. (Assumption 3.2.18)

The average dose rate in the exhaust main is not needed for the Operations-Emplacement Phase or the Operations-Monitoring Phase because general access to this area is restricted during these phases due to high radiation levels and high temperatures. During the Closure Phase, however, it will be necessary for personnel to routinely enter the exhaust mains to perform backfilling activities. Therefore, the average dose rate in the exhaust main is calculated using dose rate data for Operations-Emplacement Phase and the Operations-Monitoring Phase so that it can then be decayed to the start of the Operations-Closure Phase.

The calculation for the average dose rate in the exhaust main during the Operations-Emplacement Phase and the Operations-Monitoring Phase is performed in section 6.1.6

using Equations 2 through 6 with DR_6=DR in Equation 6. The distance and dose rate input data is listed in Table 10. (Assumption 3.2.21)

The area of interest in the exhaust main is the region between –64 meters and 64 meters. This region roughly corresponds to the anticipated distance between two emplacement drift intersections in the exhaust main. There are fifteen (15) (m=15) dose rate data points and fourteen (n=14) intervals derived from the input data.

Radioactive decay is taken into account for dose rate reductions at the beginning of the Operations-Closure Phase through the use of a radiation decay reduction factor. This factor is designated RF_C.

Repository design includes twenty (20) emplacement drift/exhaust main intersections between emplacement panel 3-1W and emplacement panel 4 that are directly across from each other (ten (10) pairs). There are a total of (108) drifts and exhaust main drift intersections in the repository. The dose rates from directly opposed emplacement drifts in these areas are additive. To account for this effect in the dose estimate for the Closure Phase, the average dose rates in the exhaust main will be increased by a factor of (2) X (10/108) = 0.18 (rounded to 0.2). The factor of two (2) accounts for the additive effect in dose rate of the two opposed drifts in the exhaust main. The '(10/108)' factor accounts for the fraction of emplacement drifts that are affected by this condition. This correction factor is designated CF_{od} and is equal to 1 + 0.2 = 1.2 (unitless).

Temporary shielding will be installed as near as possible to the last waste package in each emplacement drift, between the waste package and the exhaust main intersection. Remote installation and removal is readily achievable using current technology. A shielding reduction factor equal to 0.01 will be used in this calculation to account for the use of temporary shielding between the last waste package and the exhaust main during the Closure Phase. (Assumption 3.2.27) This shielding reduction factor is designated SRF and is equal to 0.01 (unitless).

$$DRC_6 = DR_6 \times RF_C \times CF_{od} \times SRF \qquad \text{Equation 10}$$

Where:

DR_6=	Average dose rate in the exhaust main during the Operations-Emplacement and Operations-Monitoring Phases (mrem/hr)
RF_C =	Decay correction factor; equal to 8.72E-02 (unitless) (Assumption 3.2.24)
CF_{od}=	Opposing drift dose rate correction factor; equal to 1.2 (unitless)
SRF=	Shielding reduction factor; equal to 0.01 (unitless)
DRC_6 =	Average dose rate in the exhaust mains during the Operations-Closure Phase (mrem/hr)

Equation 10 will be used in section 6.1.6 to estimate the average dose rate in the exhaust main during the Closure Phase.

4.3.10 Annual Individual External Dose Calculation

Equation 11 will be used to calculate an individual worker's annual external exposure for each task (k) identified during a given phase/timeframe:

$$ED_k = \sum_j DR_j \times T_{kj} \qquad \text{Equation 11}$$

Where:

j=	index: 1 to 6; areas of interest
k=	index: 1 to total number of tasks performed during phase/timeframe under consideration.
DR_j=	Average dose rate, in dose rate area of interest (j) (mrem/hr).
T_{kj}=	Hours per year spent by the worker on task (k), in dose rate area of interest (j) (hours/year)(Assumption 3.2.12; Assumption 3.2.13; 3.2.16)
ED_k=	Annual individual worker external radiation dose for task (k) (mrem/year)

DR_j will be calculated as described in the previous sections, with j = 1 to 6. The phases/timeframes to be considered are:

1. Operations-Emplacement/Concurrent Development Phase (first 22 years of Operations),
2. Operations-Emplacement Phase (Development Complete)/Operations Monitoring (last two (2) years of Operations Emplacement activity and 76 years of Operations-Monitoring),
3. Operations-Closure.

The Operations-Emplacement Phase lasts 24 years (Assumption 3.2.2). The Operations-Emplacement/Concurrent Development Phase lasts 22 years. (Assumption 3.2.3) During the Operations-Emplacement/Concurrent Development Phase, non-routine, infrequent periodic movement of isolation barriers is required to allow expansion of the repository during emplacement with concurrent development. After the 22nd year of operation, isolation barrier movement is no longer required. (Assumption 3.2.10) There is a two (2) year period at the end of the Operations-Emplacement Phase (operational years 23 and 24) when emplacement continues and development has been completed. The Operations-Monitoring Phase will begin when the last waste package is emplaced (after the 24 year Operations-Emplacement Phase) and will last 76 years. The Operations-Closure Phase will begin after the Operations-Monitoring Phase is complete. (Assumption 3.2.4) The Operations-Closure Phase will last 10 years. (Assumption 3.2.5)

There are eight (8) tasks *(k)* performed in the Subsurface Facility during the Operations-Emplacement Phase and the Operations-Monitoring Phases. (Assumption 3.2.9) There are two (2) infrequent, periodic tasks to be performed during the Operations-

Emplacement Phase. (Assumption 3.2.10) There are five (5) tasks (*k*) to be performed during the Operations-Closure Phase. (Assumption 3.2.16)

There are six (6) work locations and dose rate areas of interest (*j*) associated with any operational phase work in the Subsurface Facility (Assumption 3.2.11). The average dose rates for each of the dose rate areas of interest will be calculated and will be used in dose calculations.

For the Operations-Emplacement Phase, when concurrent development activities are occurring, the number of task hours per year, spent by an individual worker performing one (1) of the eight (8) identified tasks (*k*), in each of the (6) dose rate areas of interest (*j*) has been determined and is uniquely identified in Table 3. (Assumption 3.2.12) Using the available information and data, the annual external radiation dose received by a subsurface worker performing the identified tasks (*k*) during the Operations-Emplacement Phase with Concurrent Development Activities is calculated in section 6.2.1 by using Equation 11.

When development activities are completed, the Operations-Emplacement Phase and the Operations-Monitoring Phase become equal in terms of work activities performed in the Subsurface Facility. This occurs after the 22nd year of emplacement activities. (Assumption 3.2.3) For the Operations-Emplacement Phase (Development Complete) and Operations-Monitoring Phases, the number of task hours per year, spent by an individual worker performing one (1) of the eight (8) identified tasks (*k*), in each of the (6) dose rate areas of interest (*j*) has been determined and is uniquely identified in Table 4. (Assumption 3.2.13) Using the available information and data, the annual external radiation dose received by subsurface workers performing the identified tasks during the Operations-Emplacement Phase (Development Complete) and Operations-Monitoring Phases is calculated in section 6.2.2 by using Equation 11.

For the Operations-Closure Phase, the number of task hours per year, spent by an individual worker performing one (1) of the five (5) identified tasks (*k*), in each of the (6) dose rate areas of interest (*j*) has been determined and is uniquely identified in Table 6. (Assumption 3.2.16) Using the available information and data, the annual external radiation dose received by a subsurface worker performing the identified tasks during the Operations-Closure Phase is calculated in section 6.2.3 by using Equation 11.

4.3.11 Annual Collective External Dose Calculation

Equation 12 will be used to calculate the maximum annual external collective dose for the Operations-Emplacement (Concurrent Development) Phase, Operations-Emplacement (Development Complete) Phase and Operations-Monitoring Phases, and for the Operations-Closure Phase.

$$ACD_{Phase} = \sum_k ED_k \times S_k \qquad \text{Equation 12}$$

Where:

k=	index: 1 to total number of tasks performed during phase/timeframe under consideration.
ED_k =	Annual individual worker external radiation dose for task (k) (mrem/year)
S_k=	Annual staff needed to perform task (k) (# persons)
ACD_{phase} =	Annual Collective External Dose for a phase (person-mrem/year)

ED_k is calculated using Equation 11.

This calculation considers three phases:

1. Operations-Emplacement/Concurrent Development Phase (first 22 years of Operations),

2. Operations-Emplacement Phase (Development Complete)/Operations Monitoring Phase (last two (2) years of Operations Emplacement activity and 76 years of Operations-Monitoring),

3. Operations-Closure.

There are eight (8) tasks (*k*) performed in the Subsurface Facility during the Operations-Emplacement Phase and the Operations-Monitoring Phases. (Assumption 3.2.9) The annual staffing (*S*) for each of the eight (8) identified tasks (*k*) during the Operations-Emplacement and Operations-Monitoring Phases is listed in Table 5. (Assumption 3.2.14)

During the Operations-Emplacement/Concurrent Development Phase, non-routine, infrequent periodic movement of isolation barriers is required to allow expansion of the repository during emplacement with concurrent development. After the 22nd year of operation, isolation barrier movement is no longer required. (Assumption 3.2.10) *ACD* for the Operations-Emplacement/Concurrent Development Phase is calculated in section 6.3.1 using Equation 12.

Staffing is peak staffing and coincides with the 22nd year of emplacement activities. The established staffing level continues through year 24 of emplacement operations. Once emplacement activities are complete, the Operations-Monitoring Phase begins and lasts for 76 years. The staffing level established during the emplacement period continues throughout the remainder of the Operations-Monitoring Phase until closure

The Operations-Closure Phase duration is 10 years. There are five (5) tasks (*k*) to be performed during the Operations-Closure Phase. (Assumption 3.2.16) The annual staffing (*S*) for each of the five (5) identified tasks (*k*) during the Operations-Closure Phase is listed in Table 7. (Assumption 3.2.17) This staffing continues throughout the Closure Phase. *ACD* for the Operations-Closure Phase is calculated in section 6.3.4 using Equation 12.

4.3.12 Annual Collective External Dose During Emplacement Year 1 through 22

Equation 13 will be used to calculate the collective annual external radiation dose in the subsurface facility during any year of emplacement with concurrent development activities.

$$ACD_t = ACD_{22} \times \frac{ND_t}{ND_{22}} \qquad t = 1 \ldots 22 \qquad \text{Equation 13}$$

Where:

$t=$	index: 1 to 22; emplacement year
$ACD_{22}=$	Annual Collective External Dose for the Operations-Emplacement /Concurrent Development Phase (person-mrem/year)
$ND_t =$	Number of emplacement drifts in service during emplacement year (t).
$ND_{22} =$	108; Number of emplacement drifts in service during 22nd emplacement year.
$ACD_t=$	Annual Collective External Dose for Emplacement Year (t) (person-mrem/year)

The total number of emplacement drifts in the Subsurface Facility at full capacity will be 108. (Assumption 3.2.6) The number of emplacement drifts placed in service in emplacement year t=one (1) will be three (3). (Assumption 3.2.7) Emplacement drifts will be turned over at a rate of five (5) drifts per year until all 108 drifts are completed and commissioned in the t=22, the 22nd emplacement year. (Assumption 3.2.8, Table 2) The collective annual external radiation dose in the subsurface facility during any year of emplacement with concurrent development is directly proportional to the number of active emplacement drifts in that emplacement year. (Assumption 3.2.23) The Annual Collective External Dose for the Operations-Emplacement /Concurrent Development Phase (person-mrem/year) (ACD_{22}) will be calculated per section 4.3.11. Thus, given the above information and data, Equation 13 will be used in section 6.3.2 to calculate the Annual Collective External Dose By Emplacement Year (t) for the Operations-Emplacement /Concurrent Development Phase (ACD_t) (person-mrem/year).

5.0 LIST OF ATTACHMENTS

		Number of Pages
Attachment 1:	Microsoft® Excel® file 800 00C SS00 0600 000 00A.xls on one (1) compact disc	NA

6.0 BODY OF CALCULATION

6.1 DOSE RATE CALCULATIONS

For the purpose of the this dose assessment, it is assumed that areas listed below adequately and appropriately characterize the work locations and the radiation dose rate environment in the Subsurface Facility during the operational phases indicated:

1. North Portal Access Control Station (Operations-Emplacement, Monitoring and Closure Phases)

2. General Access Main (Operations-Emplacement, Monitoring and Closure Phases)

3. Access Mains Near Emplacement Drift Turnout (Operations-Emplacement, Monitoring and Closure Phases)

4. Emplacement Drift Turnout Bulkheads (Operations-Emplacement, Monitoring and Closure Phases)

5. Exhaust Mains Near Temporary Isolation Barrier (Operations-Emplacement Phase Only)

6. General Exhaust Mains (Closure Only) (Assumption 3.2.11)

Calculation of average dose rates in these areas is performed in section 6.1. Dose rates used in this occupational dose calculation are based on the average 21-PWR waste package source term. (Assumption 3.2.18)

6.1.1 North Portal Access Control Station

The dose rate at the North Portal Access Control Station during the Operations-Emplacement Phase and Operations-Monitoring Phase is equal to 5.00E-02 mrem/hr (DR_1 = 5.00E-02 mrem/hr). (See Assumption 3.2.28).

Equation 1 is used to calculate the dose rate at the North Portal Access Control Station during the Operations-Closure Phase.

Given:

DR_1 = 5.00E-02 mrem/hr
RF_C = 8.72E-02 (unitless) (Assumption 3.2.24)

Then: DRC_1 = 0.05 mrem/hour X 8.72E-02 = 4.36E-03 mrem/hr

In summary:

DR_1 = 5.00E-02 mrem/hr	Dose rate at the North Portal Access Control Station During Operations-Emplacement Phase and Operations-Monitoring Phase
DRC_1 = 4.36E-03 mrem/hr	Dose rate at the North Portal Access Control Station During Operations-Closure Phase.

6.1.2 General Access Main

It is appropriate to use weighted average dose rates to represent the dose rates in specified intervals in the access and exhaust mains when calculating external worker doses. (Assumption 3.2.22) Equations 2 through 6 were used in MS Excel 2000 to calculate the general access main dose rate during the Operations-Emplacement Phase and Operations-Monitoring Phase (DR_2). The calculation input data and results are listed in Table 11.

Table 11: General Access Main Dose Rate Calculation Results

m	P_m	DRP_m	L_n	$\overline{DR}_n$	WDR_n
	Dose Rate Location (meters) [(a)]	Calculated Dose Rate (mrem/hr) [(b)]	Interval Length (meters)	Average Dose Rate in Interval (mrem/hr)	Weighted Dose Rate in Interval (mrem/hr)
1	-100	9.34E-05	50	1.97E-03	4.92E-04
2	-50	3.84E-03	30	5.10E-02	7.65E-03
3	-20	9.82E-02	10	2.06E-01	1.03E-02
4	-10	3.14E-01	5	4.26E-01	1.06E-02
5	-5	5.37E-01	3	6.32E-01	9.47E-03
6	-2	7.26E-01	1	7.40E-01	3.70E-03
7	-1	7.54E-01	0.5	7.60E-01	1.90E-03
8	-0.5	7.66E-01	0.5	7.50E-01	1.88E-03
9	0	7.34E-01	0.5	7.04E-01	1.76E-03
10	0.5	6.74E-01	0.5	5.99E-01	1.50E-03
11	1	5.23E-01	1	2.95E-01	1.48E-03
12	2	6.79E-02	3	4.49E-02	6.74E-04
13	5	2.19E-02	5	1.41E-02	3.52E-04
14	10	6.24E-03	10	3.73E-03	1.86E-04
15	20	1.21E-03	30	6.39E-04	9.59E-05
16	50	6.80E-05	50	3.59E-05	8.97E-06
17	100	3.72E-06			
		Σ	200	DR_2	5.21E-02

(Attachment 1: File 800 00C SS00 0600 000 00A.xls, Sheet Table 11)

a. Data Source: Table 8, Column 1 (Assumption 3.2.19)

b. Data Source: Table 8, Column 2 (Assumption 3.2.19)

Equation 7 is used to calculate the general access main dose rate during the Operations-Closure Phase (DRC_2).

Given:

$DR_2 =$ 5.21E-02 mrem/hr
$RF_C =$ 8.72E-02 (unitless) (Assumption 3.2.24)

Then: $DRC_2 =$ 5.21E-02 mrem/hr X 8.72E-02 = 4.54E-03 mrem/hr

In summary:

DR_2 = 5.21E-02 mrem/hr	Dose rate in the General Access Mains During Operations-Emplacement Phase and Operations-Monitoring Phase
DRC_2 = 4.54E-03 mrem/hr	Dose rate in the General Access Mains During Operations-Closure Phase

6.1.3 Access Main Near Turnout

It is appropriate to use weight average dose rates to represent the dose rates in specified intervals in the access and exhaust mains when calculating external worker doses. (Assumption 3.2.22) Equations 2 through 6 were used in MS Excel 2000 to calculate the access main dose rate near a turnout (DR_3). The calculation input data and results are listed in Table 12.

Table 12: Access Main Dose Rate Near Turnout Calculation Results

m	P_m	DRP_m	L_n	$\overline{DR}_n$	WDR_n
	Dose Rate Location (meters) [(a)]	Calculated Dose Rate (mrem/hr) [(b)]	Interval Length (meters)	Average Dose Rate in Interval (mrem/hr)	Weighted Dose Rate in Interval (mrem/hr)
1	-20	9.82E-02	10	2.06E-01	5.15E-02
2	-10	3.14E-01	5	4.26E-01	5.32E-02
3	-5	5.37E-01	3	6.32E-01	4.74E-02
4	-2	7.26E-01	1	7.40E-01	1.85E-02
5	-1	7.54E-01	0.5	7.60E-01	9.50E-03
6	-0.5	7.66E-01	0.5	7.50E-01	9.38E-03
7	0	7.34E-01	0.5	7.04E-01	8.80E-03
8	0.5	6.74E-01	0.5	5.99E-01	7.48E-03
9	1	5.23E-01	1	2.95E-01	7.39E-03
10	2	6.79E-02	3	4.49E-02	3.37E-03
11	5	2.19E-02	5	1.41E-02	1.76E-03
12	10	6.24E-03	10	3.73E-03	9.31E-04
13	20	1.21E-03			
		I	40	DR_3	2.19E-01

(Attachment 1: File 800 00C SS00 0600 000 00A.xls, Sheet Table 12)

a. Data Source: Table 8, Column 1 (Assumption 3.2.19)

b. Data Source: Table 8, Column 2 (Assumption 3.2.19)

Equation 8 is used to calculate the access main dose rate near a turnout during the Operations-Closure Phase (DRC_3).

Given:

DR_3 = 2.19E-01 mrem/hr
RF_C = 8.72E-02 (unitless) (Assumption 3.2.24)

Then: DRC_3 = 2.19E-01 mrem/hr X 8.72E-02 = 1.91E-02 mrem/hr

In summary:

DR_3 = 2.19E-01 mrem/hr — Average dose rate in the Access Main Near Turnout During Operations-Emplacement Phase and Operations-Monitoring Phase

DRC_3 = 1.91E-02 mrem/hr — Average dose rate in the Access Main Near Turnout During Operations-Closure Phase

6.1.4 Emplacement Drift Turnout Bulkhead

The dose rate at a typical emplacement drift bulkhead during the Operations-Emplacement Phase and Operations-Monitoring Phase is the simple average of four (4) dose rate data points at the emplacement drift turnout bulkhead location. (See Assumption 3.2.20; Table 9, Column 4) DR_4 = 8.94E-01 mrem/hr.

Equation 9 is used to calculate the average dose rate at the emplacement drift turnout bulkhead (DRC_4) during the Operations-Closure Phase.

Given:

DR_4 = 8.94E-01 mrem/hr
RF_C = 8.72E-02 (unitless) (Assumption 3.2.24)

Then:

DRC_4 = 8.94E-01 mrem/hr X 8.72E-02 = 7.78E-02 mrem/hr.

In summary:

DR_4 = 8.94E-01 mrem/hr	Average dose rate at Emplacement Drift Turnout Bulkhead During Operations-Emplacement Phase and Operations-Monitoring Phase
DRC_4 = 7.78E-02 mrem/hr	Average dose rate at Emplacement Drift Turnout Bulkhead During Operations-Closure Phase

6.1.5 Exhaust Main (Temporary Isolation Barrier Locations)

It is appropriate to use weighted average dose rates to represent the dose rates in specified intervals in the access and exhaust mains when calculating external worker doses. (Assumption 3.2.22) Equations 2 through 6 were used in MS Excel 2000 to calculate DR_5. Once the Operations-Emplacement Phase is complete, it is no longer necessary to move temporary isolation barriers in the exhaust main. Therefore, it is not necessary to estimate this dose rate during the Operations-Monitoring Phase or the Operations-Closure Phase. The distance and dose rate input data is listed in Table 10. (Assumption 3.2.21) The calculation input data and results are listed in Table 13.

Table 13: Exhaust Main Dose Rate (Temporary Isolation Barrier Locations) Calculation/Results

m	P_m	DRP_m	L_n	$\overline{DR}_n$	WDR_n
	Dose Rate Location (meters) [a]	Calculated Dose Rate (mrem/hr) [b]	Interval Length (meters)	Average Dose Rate in Interval (mrem/hr)	Weighted Dose Rate in Interval (mrem/hr)
1	-128	1.21E-02	64	1.00E-01	6.67E-02
2	-64	1.88E-01	32	1.07E+00	3.58E-01
3	-32	1.96E+00	[illegible]	[illegible]	[illegible]
		I	96	DR_5	4.25E-01

(Attachment 1: File 800 00C SS00 0600 000 00A.xls, Sheet Table 13

a. Data Source: Table 10, Column 1 (Assumption 3.2.21)

b. Data Source: Table 10, Column 2 (Assumption 3.2.21)

In summary:

DR_5 = 4.25E-01 mrem/hr Average dose rate at Exhaust Main (Temporary Isolation Barrier Locations) During Operations-Emplacement Phase

6.1.6 Exhaust Main (Closure)

It is appropriate to use weight average dose rates to represent the dose rates in specified intervals in the access and exhaust mains when calculating external worker doses. (Assumption 3.2.22) Equations 2 through 6 were used in MS Excel 2000 to calculate the average exhaust main dose (DR_6) during the Operations-Emplacement Phase and Operations-Monitoring Phase. The distance and dose rate input data is listed in Table 10 (Assumption 3.2.21)

The calculation input data and results are listed in Table 14.

Table 14: Exhaust Main Dose Rate Calculation Results

m	P_m Dose Rate Location (meters) [(a)]	DRP_m Calculated Dose Rate (mrem/hr) [(b)]	L_n Interval Length (meters)	$\overline{DR}_n$ Average Dose Rate in Interval (mrem/hr)	WDR_n Weighted Dose Rate in Interval (mrem/hr)
1	-64	1.88E-01	32	1.07E+00	2.69E-01
2	-32	1.96E+00	16	8.93E+00	1.12E+00
3	-16	1.59E+01	8	4.40E+01	2.75E+00
4	-8	7.21E+01	4	3.07E+02	9.58E+00
5	-4	5.41E+02	2	6.14E+02	9.59E+00
6	-2	6.86E+02	1	7.28E+02	5.69E+00
7	-1	7.70E+02	1	8.17E+02	6.38E+00
8	0	8.64E+02	1	9.07E+02	7.09E+00
9	1	9.50E+02	1	9.95E+02	7.77E+00
10	2	1.04E+03	2	1.08E+03	1.68E+01
11	4	1.11E+03	4	5.75E+02	1.80E+01
12	8	3.99E+01	8	2.49E+01	1.56E+00
13	16	9.92E+00	16	5.52E+00	6.89E-01
14	32	1.11E+00	32	5.88E-01	1.47E-01
15	64	6.52E-02			
		I	128	DR_6	8.74E+01

(Attachment 1: File 800 00C SS00 0600 000 00A.xls, Sheet Table 14

a. Data Source: Table 10, Column 1 (Assumption 3.2.21)

b. Data Source: Table 10, Column 2 (Assumption 3.2.21)

General personnel access to the exhaust mains is restricted during the Operations-Emplacement Phase and Operations-Monitoring Phase due to high temperatures and high radiation levels. Therefore, DR_6 will not be used directly in dose calculations because personnel exposure to these dose rates will not occur. However, during the Operations-Closure Phase, it will be necessary to enter the exhaust mains to perform backfill operations. DR_6 is used as input to calculate the exhaust main dose rates during the Operations-Closure Phase.

Equation 10 is used to calculate the average exhaust main dose rate during the Operations-Closure Phase (DRC_6). It is assumed that two (2) tenth-value layers of shielding will be installed in front of, and as near as possible to, the last waste package at the exhaust main end of the emplacement drift to reduce radiation levels prior to commencing backfill operations in the exhaust main (Assumption 3.2.27). Numerical consideration is given for the additive effect of radiation dose rates at opposing emplacement drifts in the exhaust main.

Given:

DR_6 = 8.74E+01 mrem/hr
RF_C = 8.72E-02 (unitless) (Assumption 3.2.24)
CF_{od} = 1.2 (unitless)
SRF = 0.01 (unitless)

Then: DRC_6 = 8.74E+01 mrem/hr X 8.72E-02 X 1.2 X 0.01 = 9.15E-02 mrem/hr

In summary:

DR_6 = 8.74E+01 mrem/hr — Average dose rate in the Exhaust Main During Operations-Emplacement Phase and Operations-Monitoring Phase

DRC_6 = 9.15E-02 mrem/hr — Average dose rate in the Exhaust Main During Operations-Closure Phase

6.1.7 Dose Rate Calculation Results Summary

Table 15 summarizes the average dose rate calculation results for the Subsurface Facility during applicable operational phases. These dose rate data serve as input to annual individual external dose calculations.

Table 15: Dose Rate Calculation Results Summary

j	Subsurface Facility Dose Rate Location	DR_j (mrem/hr) Operations-Emplacement/ Concurrent Development Phase	DR_j (mrem/hr) Operations-Emplacement Phase and Operations-Monitoring Phase	DRC_j (mrem/hr) Operations-Closure Phase
1	North Portal Access Control Station		5.00E-02	4.36E-03
2	General Access Main		5.21E-02	4.54E-03
3	Access Main Near Turnout		2.19E-01	1.91E-02
4	Emplacement Drift Turnout Bulkhead		8.94E-01	7.78E-02
5	Exhaust Main (Temporary Isolation Barrier Locations)	4.25E-01		
6	Exhaust Main (Closure)			9.15E-02

6.2 ANNUAL INDIVIDUAL EXTERNAL DOSE CALCULATIONS

6.2.1 Operations-Emplacement/Concurrent Development Phase

There are eight (8) tasks (*k*) performed in the Subsurface Facility during the Operations-Emplacement Phase and the Operations-Monitoring Phases. (Assumption 3.2.9) There are two (2) infrequent, periodic tasks to be performed during the Operations-Emplacement/Concurrent Development Phase. (Assumption 3.2.10)

Equation 11 is used in MS Excel 2000 to calculate an individual worker's annual external dose for each of the eight (8) tasks (k=1...8) identified during Operations-Emplacement/Concurrent Development Phase. (Assumptions 3.2.2 and 3.2.3)

Dose rate areas of interest in the Subsurface Facility have been identified. (Assumption 3.2.11) Dose rates for these areas (DR_j) were calculated in section 6.1 and are listed and summarized in Table 15. Person-hours per year spent in dose rate area DR_j per task (*k*) (T_{kj}) is listed in Table 3. (Assumption 3.2.12) The calculation input data and results are listed in Table 16.

Table 16: Estimated Annual Individual External Dose for Operations Emplacement/Concurrent Development Phase

Task No. (*k*)	Location No (*j*):	1	2	3	4	5	Annual Individual Dose for Task (k) (mrem/year)
	Average Dose Rate:	*DR*j (mrem/hr)					
		5.00E-02	5.21E-02	2.19E-01	8.94E-01	4.25E-01	
	Location Description	North Portal Access Control Station	General Access Main	Access Mains Near Empl Drift Turnout	Empl Drift Turnout Bulkhead	Exhaust Mains Near Temporary Isolation Barrier	
	Task Description	T_{kj} (hours/year)					
1	Operations and Operations Support	300	1600	50	50	0	1.54E+02
2	Performance Confirmation Support	300	1600	50	50	0	1.54E+02
3	Ground Support Maintenance EXH Main Isolation Barrier ACC Main Isolation Barrier	300	1440	100	0	160	1.80E+02
4	Ventilation System & Mech. Maintenance	300	1500	100	100	0	2.04E+02
5	Electrical Maintenance	300	1600	100	0	0	1.20E+02
6	Instrumentation and Controls Maintenance	300	1500	100	100	0	2.04E+02
7	Facility Access (Security and Safeguards)	1900	100	0	0	0	1.00E+02
8	Radiation Protection Health Physics	1000	785	100	100	15	2.09E+02

Attachment 1: File 800 00C SS00 0600 000 00A.xls, Sheet Table 16

The dose rates for the Exhaust Main (Closure Phase) (DR_6) are not included in the calculation because they are not applicable to the Operations-Emplacement Phase.

6.2.2 Operations-Emplacement Phase (Development Complete)/Operations Monitoring Phase

There are eight (8) tasks (k) performed in the Subsurface Facility during the Operations-Emplacement Phase and the Operations-Monitoring Phases. (Assumption 3.2.9)

Equation 11 is used in MS Excel 2000 to calculate an individual worker's annual external dose for each of the eight (8) tasks (k=1...8) identified during the Operations-Emplacement Phase (Development Complete) and the Operations-Monitoring Phase. (Assumptions 3.2.2, 3.2.3 and 3.2.4) During these timeframes (greater than 22 years of operation), there is no longer a need to move temporary isolation barriers, resulting in overall reduction in radiation exposure.

Dose rate areas of interest in the Subsurface Facility have been identified. (Assumption 3.2.11) Dose rates for these areas (DR_j) were calculated in section 6.1 and are listed and summarized in Table 15. Hours per year spent by a worker in dose rate area DR_j per task (k) (T_{kj}) is listed in Table 4. (Assumption 3.2.13) The calculation input data and results are listed in Table 17.

Table 17: Annual Individual External Dose - Operations-Emplacement Phase (Development Complete) and the Operations-Monitoring Phase

Task No. (*k*)	Location No (*j*):	1	2	3	4	Annual Individual Dose for Task (k) (mrem/year)
	Average Dose Rate:	DRj (mrem/hr)				
		5.00E-02	5.21E-02	2.19E-01	8.94E-01	
	Location Description	North Portal Access Control Station	General Access Main	Access Mains Near Empl Drift Turnout	Empl Drift Turnout Bulkhead	
	Task Description	T_{kj} (hours/year)				
1	Operations and Operations Support	300	1600	50	50	1.54E+02
2	Performance Confirmation Support	300	1600	50	50	1.54E+02
3	Ground Support Maintenance	300	1600	100	0	1.20E+02
4	Ventilation System & Mech. Maintenance	300	1500	100	100	2.04E+02
5	Electrical Maintenance	300	1600	100	0	1.20E+02
6	Instrumentation and Controls Maintenance	300	1500	100	100	2.04E+02
7	Facility Access (Security and Safeguards)	1900	100	0	0	1.20E+02
8	Radiation Protection Health Physics	1000	800	100	100	2.03E+02

Attachment 1: File 800 00C SS00 0600 000 00A.xls, Sheet Table 17

The dose rates for the Exhaust Main (Closure Phase) (DR_6) and Exhaust Main (Temporary Isolation Barrier Locations) (DR_5) are not included in the calculation because they are not applicable to the Operations-Emplacement Phase (Development Complete) and the Operations-Monitoring Phase.

6.2.3 Operations-Closure Phase

There are five (5) tasks (k) to be performed during the Operations-Closure Phase. (Assumption 3.2.16)

Equation 11 is used in MS Excel 2000 to calculate an individual worker's annual external dose for each of the five (5) tasks (k=1…5) identified during the Operations-Closure Phase (Assumption 3.2.5).

Dose rate areas of interest in the Subsurface Facility have been identified. (Assumption 3.2.11) Dose rates for these areas (DRC_j) were calculated and are listed in Table 15. Hours per year spent by a worker in dose rate area DRC_j per task (k) (T_{kj}) is listed in Table 6. (Assumption 3.2.16) The calculation input data and results are listed in Table 18.

Table 18: Annual Individual External Dose - Operations-Closure Phase

Task No. (k)	Location No (j):	1	2	3	4	6	Annual Individual Dose for Task (k) (mrem/year)
	Average Dose Rate:	DRCj (mrem/hr)					
		4.36E-03	4.54E-03	1.91E-02	7.78E-02	9.15E-02	
	Location Description	North Portal Access Control Station	General Access Main	Access Mains Near Empl Drift Turnout	Empl Drift Turnout Bulkhead	Exhaust Mains (Closure)	
	Task Description	T_{kj} (hours/year)					
1	Install Drip Shields/Shielding in Drifts	300	1650	50	0	0	9.75E+00
2	Remove Non-committed Materials	300	1300	200	200	0	2.66E+01
3	Install Backfill In Exhaust Mains Install Backfill In Ramps/Shafts Install Backfill in Access Mains/Turnouts	700	700	300	0	300	3.94E+01
4	Facility Access (Security and Safeguards)	1900	100	0	0	0	8.74E+00
5	Radiation Protection/Health Physics	1000	620	300	0	80	2.02E+01

Attachment 1: File 800 00C SS00 0600 000 00A.xls, Sheet Table 18

The dose rate for the Exhaust Main (Temporary Isolation Barrier Locations) (DR_5) is not included in the calculation because it is not applicable to the Operations-Closure Phase.

6.2.4 Summary of Annual Individual External Dose Calculations

Table 19 summarizes the annual individual external dose calculations for the Subsurface Facility by listing the maximum annual individual external dose accrued by the associated work group during the applicable operational phase.

Table 19: Summary of Annual Individual External Dose Calculations Results

OPERATIONAL PHASE	WORK GROUP	MAXIMUM ANNUAL INDIVIDUAL DOSE (mrem/year)
Operations-Emplacement/Concurrent Development Phase	Radiation Protection Health Physics	2.09E+02[(a)]
Operations-Emplacement Phase (Development Complete)/Operations Monitoring Phase	Ventilation System & Mech. Maintenance: Instrumentation and Controls Maintenance	2.04E+02[(b)]
Operations-Closure Phase	Backfilling Operations	3.94E+01[(c)]

a. Data Source: Table 16, Task 8, Column 8.
b. Data Source: Table 17, Tasks 4 and 6, Column 8
c. Data Source: Table 18, Task 3, Column 8

6.3 ANNUAL COLLECTIVE EXTERNAL DOSE CALCULATIONS

6.3.1 Operations-Emplacement/Concurrent Development Phase

The Operations-Emplacement/Concurrent Development Phase is twenty-two (22) years in duration. (Assumptions 3.2.2 and 3.2.3) There are eight (8) tasks (*k*) performed in the Subsurface Facility during the Operations-Emplacement Phase and the Operations-Monitoring Phases. (Assumption 3.2.9) There are two (2) infrequent, periodic tasks to be performed during the Operations-Emplacement/Concurrent Development Phase. (Assumption 3.2.10)

Equation 12 is used in MS Excel 2000 to calculate the annual collective external dose for Subsurface Facility operations during the Operations-Emplacement/Concurrent Development Phase during the 22nd year of emplacement activities. As noted previously, peak staffing and operations occur in the 22nd emplacement year as development is finishing and emplacement continues.

The individual annual external dose in person-mrem per year for a task (k) during this phase is obtained from Table 16, column 8. Annual staffing per task (k) (S_k) is listed in Table 5. (Assumption 3.2.14) The calculation input data and results for *ACD* during the Operations-Emplacement/Concurrent Development Phase are listed in Table 20.

Table 20: Annual Collective External Dose Calculation Results for the Operations-Emplacement/Concurrent Development Phase (22nd Emplacement Year)

Task No. (k)	Task Description	Annual Individual Dose for Task (k) (mrem/year) [(a)]	Annual Staffing for Task (k) (#-persons) [(b)]	Annual Collective Dose for Task (k) (person-mrem/year)
1	Operations and Operations Support	1.54E+02	10	1.54E+03
2	Performance Confirmation Support	1.54E+02	10	1.54E+03
3	Ground Support Maintenance EXH Main Isolation Barrier ACC Main Isolation Barrier	1.80E+02	15	2.70E+03
4	Ventilation System & Mechanical Maintenance	2.04E+02	10	2.04E+03
5	Electrical Maintenance	1.20E+02	10	1.20E+03
6	Instrumentation and Controls Maintenance	2.04E+02	10	2.04E+03
7	Facility Access (Security and Safeguards)	1.00E+02	5	5.01E+02
8	Radiation Protection Health Physics	2.09E+02	10	2.09E+03
			Annual Collective Dose (ACD_{phase}):	1.37E+04

Attachment 1: File 800 00C SS00 0600 000 00A.xls, Sheet Table 20

a. Data Source: Table 16, Column 8.

b. Data Source: Table 5, Column 4. (Assumption 3.2.14)

ACD_{22} is equal to ACD_{phase} for the Operations-Emplacement/Concurrent Development Phase during the 22nd year of emplacement activities.

6.3.2 By Emplacement Year During Operations-Emplacement/Concurrent Development Phase

The collective annual external radiation dose in the subsurface facility during any year of emplacement with concurrent development is directly proportional to the number of active emplacement drifts in that emplacement year. (Assumption 3.2.23) Equation 13 is used in MS Excel 2000 to calculate the annual collective external dose for Subsurface Facility operations during any emplacement year (*t*) ($t = 1\ldots22$) during the Operations-Emplacement/Concurrent Development Phase.

$ACD_{22} = ACD_{phase} = 1.37E{+}04$ mrem/year is obtained from Table 20, Column 5. The number of emplacement drifts in service during any emplacement year 1 through 22 is listed in Table 2. (Assumptions 3.2.6, 3.2.7, and 3.2.8) The calculation input data and results for ACD_t during the Operations-Emplacement/Concurrent Development Phase are listed in Table 21.

Table 21: Emplacement Year Annual Collective External Dose By Year During Operations-Emplacement/Concurrent Development Phase

EMPLACEMENT YEAR (*t*)	NUMBER OF COMMISSIONED DRIFTS (ND_t)	ACD_t (mrem/year)	EMPLACEMENT YEAR (*t*)	NUMBER OF COMMISSIONED DRIFTS (ND_t)	ACD_t (mrem/year)
1	3	3.81E+02	12	58	7.36E+03
2	8	1.01E+03	13	63	7.99E+03
3	13	1.65E+03	14	68	8.63E+03
4	18	2.28E+03	15	73	9.26E+03
5	23	2.92E+03	16	78	9.89E+03
6	28	3.55E+03	17	83	1.05E+04
7	33	4.19E+03	18	88	1.12E+04
8	38	4.82E+03	19	93	1.18E+04
9	43	5.45E+03	20	98	1.24E+04
10	48	6.09E+03	21	103	1.31E+04
11	53	6.72E+03	22	108	1.37E+04

Attachment 1: File 800 00C SS00 0600 000 00A.xls, Sheet Table 21

The calculated annual collective external doses listed in Table 21 will apply to each year as indicated between one year (1) and less than twenty-two (22) years after emplacement operations begin.

6.3.3 Operations-Emplacement Phase (Development Complete) and Operations-Monitoring Phase

There are eight (8) tasks (*k*) performed in the Subsurface Facility during the Operations-Emplacement Phase and the Operations-Monitoring Phases. (Assumption 3.2.9) The staffing for the two phases under consideration becomes equal during the 22nd year of emplacement activities. (Assumption 3.2.14) Also, after the 22nd emplacement year, it is no longer necessary to move temporary isolation barriers in support of development activities because all (108) emplacement drifts are in service, resulting in less radiation exposure while staffing remains essential constant.

Equation 12 is used in MS Excel 2000 to calculate the annual collective external dose for Subsurface Facility operations during the last two years of the Operations-Emplacement Phase (emplacement years 23 and 24 after development is complete) and for each year during the Operations-Monitoring Phase (76 years duration) (Assumptions 3.2.2; 3.2.3; 3.2.4).

The individual annual external dose in person-mrem per year for a task (*k*) during this phase is obtained from Table 17, column 7. Annual staffing per task (*k*) (S_k) is listed in Table 5. (Assumption 3.2.14) The calculation input data and results for *ACD* during the Operations-Emplacement Phase (Development Complete) and Operations-Monitoring Phase are listed in Table 22.

Table 22: Annual Collective External Dose Calculation Results for the Operations-Emplacement Phase (Development Complete) and Operations-Monitoring Phase

Task No. (k)	Task Description	Annual Individual Dose for Task (k) (mrem/year) [(a)]	Annual Staffing for Task (k) (#-persons) [(b)]	Annual Collective Dose for Task (k) (person-mrem/year)
1	Operations and Operations Support	1.54E+02	10	1.54E+03
2	Performance Confirmation Support	1.54E+02	10	1.54E+03
3	Ground Support Maintenance	1.20E+02	15	1.80E+03
4	Ventilation System & Mechanical Maintenance	2.04E+02	10	2.04E+03
5	Electrical Maintenance	1.20E+02	10	1.20E+03
6	Instrumentation and Controls Maintenance	2.04E+02	10	2.04E+03
7	Facility Access (Security and Safeguards)	1.00E+02	5	5.01E+02
8	Radiation Protection Health Physics	2.03E+02	10	2.03E+03
			Annual Collective Dose (ACD_{phase}):	1.27E+04

Attachment 1: File 800 00C SS00 0600 000 00A.xls, Sheet Table 22

a. Data Source: Table 17, Column 7.

b. Data Source: Table 5, Column 4. (Assumption 3.2.14)

The calculated annual collective external dose listed in Table 22 will apply to any year greater than or equal to twenty-three (23) years and less than or equal to (100) years after emplacement operations begin.

The application of these results to each year of the Operations-Monitoring Phase is very conservative because radioactive decay is not taken into account. All waste packages will be emplaced by the 24th year of operation. Thus, the source term in the Subsurface Facility will steadily decrease due to decay, and if radioactive decay is taken into account, then the annual collective external dose calculation results for the Operations-Monitoring Phase would begin at 1.27E+04 mrem/year in the 24th operational year and steadily decrease each year until it reaches a minimum in the 100th operational year at the end of the Operations-Monitoring Phase.

6.3.4 Operations-Closure Phase

The Operations-Closure Phase begins after the Operations-Monitoring Phase. The Operations-Closure Phase will be ten (10) years in duration. (Assumption 3.2.5)

Equation 12 is used in MS Excel 2000 to calculate the annual collective external dose for Subsurface Facility operations during the Operations-Closure Phase.

The individual annual external dose in person-mrem per year for a task (k) during this phase is obtained from Table 18, column 8. Annual staffing per task (k) (S_k) is listed in Table 7. (Assumption 3.2.17) The calculation input data and results for ACD during the Operations-Closure Phase are listed in Table 23.

Table 23: Annual Collective External Dose Calculation Results for the Operations-Closure Phase

Task No. (k)	Task Description	Annual Individual Dose for Task (k) (mrem/year) [(a)]	Annual Staffing for Task (k) (#-persons) [(b)]	Annual Collective Dose for Task (k) (person-mrem/year)
1	Install Drip Shields/Shielding in Drifts	9.75E+00	10	9.75E+01
2	Remove Non-committed Materials	2.66E+01	20	5.32E+02
3	Install Backfill In Exhaust Mains Install Backfill In Ramps/Shafts Install Backfill in Access Mains/Turnouts	3.94E+01	180	7.09E+03
4	Facility Access (Security and Safeguards)	8.74E+00	10	8.74E+01
5	Radiation Protection/Health Physics	2.02E+01	10	2.02E+02
			Annual Collective Dose (ACD_{phase}):	8.01E+03

Attachment 1: File 800 00C SS00 0600 000 00A.xls, Sheet Table 23

a. Data Source: Table 18, Column 8.

b. Data Source: Table 7, Column 4 (Assumption 3.2.17).

The calculated annual collective external dose in Table 23 will apply to any year greater than (100) years and less than or equal (110) years after emplacement operations.

The application of these results to each year of Operations-Closure Phase is conservative because radioactive decay is not taken into account during this phase. Further, as backfill is installed, dose rates will decrease due to shielding effects and the limiting of access to certain areas. Thus, dose rates in the Subsurface Facility will steadily decrease due to decay and backfilling, and if radioactive decay and backfilling is taken into account, then the annual collective external dose calculation results for the Operations-Closure Phase would begin at 8.01E+03 mrem/year and steadily decrease each year until it reaches a minimum in the 110th operational year at the end of the Operations-Closure Phase.

6.3.5 Summary of Annual Collective External Dose Calculation Results

Table 24 summarizes the annual collective dose calculations performed in section 6.3. It lists the estimated annual collective dose from year one (1) of repository operations through year (110) when closure is complete.

Table 24: Summary of Annual Collective External Dose Calculation Results

Operational Year	Annual Collective External Dose (person-mrem/year)	Operational Year	Annual Collective External Dose (person-mrem/year)
1	3.81E+02	13	7.99E+03
2	1.01E+03	14	8.63E+03
3	1.65E+03	15	9.26E+03
4	2.28E+03	16	9.89E+03
5	2.92E+03	17	1.05E+04
6	3.55E+03	18	1.12E+04
7	4.19E+03	19	1.18E+04
8	4.82E+03	20	1.24E+04
9	5.45E+03	21	1.31E+04
10	6.09E+03	22	1.37E+04
11	6.72E+03	23 Through 100	1.27E+04
12	7.36E+03	101 Through 110	8.01E+03

Notes: 1. Data in this table is taken from Tables 21, 22 and 23 as appropriate.
2. To convert person-mrem/year to person-rem/year, divide person-mrem/year by 1000 mrem/rem.

7.0 RESULTS AND CONCLUSIONS

The numerical results of this dose assessment are summarized in Section 6.2.4, Table 19 and Section 6.3.5, Table 24. The dose assessment method used in this calculation is consistent with the method for such assessments described in the applicable ALARA regulatory guide (Ref. 2.1.4, Ref. 2.2.7, Section 4.10.3.1). The results of this calculation can be used to support on-going ALARA design reviews in the Subsurface Facility as design progresses and to provide Subsurface Facility occupational dose estimate inputs for the license application.

Individual and collective dose results are based on dose rates calculated from commercial pressurized water reactor spent nuclear fuel waste packages (21-PWR; conservative) containing an average source term (radionuclide inventory). Use of this conservative average source term is appropriate for estimating individual and collective doses over the operational life of the repository. Use of other than an average source term would significantly over-estimate the individual and collective external radiation doses associated with Subsurface Facility operations.

7.1 ANNUAL INDIVIDUAL AND ANNUAL COLLECTIVE DOSE DURING OPERATIONS-EMPLACEMENT PHASE AND THE OPERATIONS-MONITORING PHASES

The estimated maximum annual dose for an individual working in the Subsurface Facility during the Operations-Emplacement Phase and the Operations-Monitoring Phase is 2.09E+02 mrem per year. (Section 6.2.4, Table 19) This is due to external radiation dose only. Internal radiation dose is not a credible concern during routine operations in the Subsurface Facility and is considered equal to zero dose for purposes of this assessment. Radon dose is not considered in this calculation and analysis. Dose from naturally occurring radioactive materials in background and the environment is also not considered in this dose assessment.

The estimated annual collective dose in the Subsurface Facility during the Operations-Emplacement Phase and the Operations-Monitoring Phase is approximately 3.81E+02 mrem per year for emplacement year one (1). The estimated annual collective dose steadily increases each year as emplacement drifts are placed in service, until it peaks at 1.37E+04 mrem per year in the 22nd emplacement year. Through the remainder of the Operations-Emplacement Phase and the Operations-Monitoring Phase (years 23 through 100), the estimated annual collective dose remains steady at 1.27E+04 mrem per year. (Section 6.3.5, Table 24)

The dose rate models used during the Operations-Emplacement Phase with concurrent development are conservative. The model assumes that each emplacement drift is fully loaded with waste packages. This will not be the case until emplacement activities are complete. Therefore, average dose rates during this operational phase will be lower than those calculated in this assessment.

The dose models used during Operations-Emplacement Phase and Operations-Monitoring Phase are conservative. They do not take radioactive decay into account. Once a waste package is emplaced, dose rates will decrease due to radioactive decay. The overall duration of the Operations-Emplacement Phase and Operations-Monitoring Phase (100 years) allows for a significant amount of radioactive decay after emplacement. Therefore, average dose rates during these operational phases will be lower than those calculated in this assessment.

7.2 ANNUAL INDIVIDUAL AND ANNUAL COLLECTIVE DOSE DURING OPERATIONS-CLOSURE PHASE

The estimated maximum annual dose for an individual working in the Subsurface Facility during the Operations-Closure Phase is 3.94E+01 mrem per year. (Section 6.2.4, Table 19) This is due to external radiation dose only. Internal radiation dose is not a credible concern during routine operations in the Subsurface Facility. Radon dose is not considered in this calculation and analysis.

This assessment assumes two (2) tenth-value layers of temporary radiation shielding will be installed in front of, and as near as possible to, the last waste package at the exhaust main end of emplacement drifts to reduce radiation levels prior to commencing backfill operations in the exhaust main. The state of current technology supports the completely remote installation and removal of such shielding.

The estimated annual collective dose in the Subsurface Facility during the Operations-Closure Phase is 8.01E+03 mrem per year. (Section 6.3.5, Table 24) It will remain at 8.01E+03 mrem/year throughout the ten (10) year closure phase.

The Operations-Closure Phase dose rate model is conservative. The model does not take radioactive decay into account during the ten (10) year closure period. The model does not account for the fact that dose rates will decrease due to shielding effects and access limitations as backfill is placed. Average dose rates during this operational phase will be lower than those calculated and used in this assessment.

7.3 CONCLUSIONS

7.3.1 Regulation

Reference 2.2.7 Section 4.10.1. 2, *General Radiation Dose Criteria for Occupationally Exposed Personnel*, states as follows:

> "The repository surface and subsurface facility design shall meet the following general dose criteria for occupationally exposed personnel.
>
> - Maximum individual total effective dose equivalent (TEDE) is limited to less than or equal to 5 rem/yr.
> - Maximum sum of deep-dose equivalent and committed dose equivalent to any organ or tissue other than the lens of the eye is limited to less than or equal to 50 rem/yr.
> - Maximum lens dose equivalent is limited to less than or equal to 15 rem/yr.
> - Maximum shallow-dose equivalent to the skin or any extremity is limited to less than or equal to 50 rem/yr.
>
> [The general radiation dose criteria are required to meet the occupational dose requirements in 10 CFR 20.1201 [DIRS 176618]. The YMP ALARA design goals are specified in Section 4.10.3. The dose criteria for the general public are addressed separately in the BOD [DIRS 177636] Chapter 2, Section 2.2.3.1.]" (Ref. 2.2.7, section 4.10.1.2)

Internal radiation dose is not a credible concern during routine operations in the Subsurface Facility. Section 6.2.4, Table 19 lists estimated maximum annual individual dose results for the Subsurface Facility by operational phase. These results demonstrate that planned Subsurface Facility design and operation support applicable regulatory requirements for occupational radiation dose.

7.3.2 ALARA Design Goals

ALARA design goals (Ref. 2.2.7 Section 4.10.3.3.1) for occupational workers ensure that individual annual doses are maintained at ALARA levels during normal operations or during potential Category 1 event sequences. The following ALARA design goal is established for the design process.

(1) Individual Dose:

"The ALARA design goal for individual radiation worker doses is to minimize the number of individuals that have the potential of receiving more than 500 mrem/yr total effective dose equivalent (TEDE). That goal is 10 percent of the annual TEDE limit in 10 CFR 20.1201, and includes internal and external exposures."

Internal radiation dose is not a credible concern during routine operations in the Subsurface Facility. Section 6.2.4, Table 19 lists estimated maximum annual individual dose results for the Subsurface Facility by operational phase. These results demonstrate that the planned Subsurface Facility design and operation support project ALARA design goals.

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