BSC	Design Calculation or Analysis Cover Sheet *Complete only applicable items.*	1. QA: Q/A 2. Page 1 of 65

3. System Subsurface Facility	4. Document Identifier 800-KMC-MGR0-00200-000-00B
5. Title Closure and Sealing Design Calculation	
6. Group Subsurface Mining	
7. Document Status Designation ☐ Preliminary ☒ Committed ☐ Final ☐ Cancelled	

8. Notes/Comments

This calculation has been changed to committed per management instructions.

This calculation supercedes *Closure and Sealing Preliminary Design Calculation*, DI: 800-KMC-MGR0-00200-000-00A.

Attachment III was authored by John Case and checked by James Kam.

Attachments	Total Number of Pages
Attachment I	8
Attachment II	7
Attachment III	11

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. Approved/Accepted (Print/Sign/Date)
00A	Initial Issue of 800-30C-TUN0-00300-000-00A	17	17	N. Kramer	J. Sheridan	R. S. Saunders 3/13/03
00A	Initial issue supersedes 800-30C-TUN0-00300-000-00A. Document number corrected. Extensive revision to calculation adding details for License Application and affecting all pages.	40	40	N. Kramer R. Elayer	R. Elayer T. Lahnalampi	R. S. Saunders 1/7/04
00B TL 9/6/05	This is a complete revision of the calculation. The calculation status has been changed to "committed". It updates the design and location of the magma bulkhead. The document has been re-formatted in compliance with LP-3.12Q-BSC.	65	III- 11	T. Lahnalampi / Tapio Lahnalampi 8/26/05 J. Case John B. Case 8/26/05	J. Steinhoff for Robert S. Saunders 8-26-05 J. Kam James Kam 8/26/05	R. S. Saunders Robert S. Saunders 8/26/05

DISCLAIMER

The calculations contained in this document were developed by Subsurface Engineering and are intended solely for the use of the Subsurface Engineering in its work regarding Mining. Yucca Mountain Project personnel from the Subsurface Engineering should be consulted before use of the calculations for purposes other than those stated herein or use by individuals other than authorized personnel in Subsurface Engineering.

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FIGURES

TABLE

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ACRONYMS AND ABBREVIATIONS

ECRB	Enhanced Characterization of the Repository Block
TCw	Tiva Canyon welded tuff
PTn	Paintbrush nonwelded tuff
DTN	Data Tracking Number
CFR	Code of Federal Regulations
EIS	Environmental Impact Statement
SC	Safety Category
QARD	Quality Assurance Requirements and Description
DOE	U.S. Department of Energy
m	meter
YMP	Yucca Mountain Project
TSPA	Total System Performance Analysis
TDMS	Technical Data Management System
FTP	File Transfer Protocol

1. PURPOSE

The purpose of the *Closure and Sealing Design Calculation* is to illustrate closure and sealing methods for sealing shafts, ramps, and identify boreholes that require sealing in order to limit the potential of water infiltration. In addition, this calculation will provide a description of the magma that can reduce the consequences of an igneous event intersecting the repository. This calculation will also include a listing of the project requirements related to closure and sealing.

The scope of this calculation is to:

- summarize applicable project requirements and codes relating to backfilling nonemplacement openings, removal of uncommitted materials from the subsurface, installation of drip shields, and erecting monuments,
- compile an inventory of boreholes that are found in the area of the subsurface repository,
- describe the magma bulkhead feature and location, and
- include figures for the proposed shaft and ramp seals.

The objective of this calculation is to:

- categorize the boreholes for sealing by depth and proximity to the subsurface repository,
- develop drawing figures which show the location and geometry for the magma bulkhead
- include the shaft seal figures and a proposed construction sequence, and
- include the ramp seal figure and a proposed construction sequence.

The intent of this closure and sealing calculation is to support the License Application by providing a description of the closure and sealing methods for the Safety Analysis Report. The closure and sealing calculation will also provide input for Post Closure Activities by describing the location of the magma bulkhead.

This calculation is limited to describing the final configuration of the sealing and backfill systems for the underground area. The methods and procedures used to place the backfill and remove uncommitted materials (such as concrete) from the repository and detailed design of the magma bulkhead will be the subject of separate analyses or calculations. Post-closure monitoring will not be addressed in this calculation.

2. REFERENCES

2.1. DESIGN REFERENCES

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2.1.2 BSC (Bechtel SAIC Company) 2005. *Project Design Criteria Document*. 000-3DR-MGR0-00100-000 REV 004. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20050615.0019. [DIRS 173614]

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2.1.11 CRWMS M&O (Civilian Radioactive Waste Management System Management and Operating Contractor) 1996. *ESF Layout Calculation*. BABEAD000-01717-0200-00003 REV 04. Las Vegas, Nevada: CRWMS M&). ACC: MOL.19960930.0095. [DIRS 101536]

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2.1.13 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; through; MOL.20020524.0320. [DIRS 155970]

2.1.14 DOE 2002 *Yucca Mountain Science and Engineering Report*. DOE/RW-0539, Rev. 1. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20020404.0042. [DIRS 155943]

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2.1.16 BSC 2005. *Total System Performance Assessment Model/Analysis for the License Application, Volume II, IVRT Review Draft.* MDL-WIS-PA-000004 REV 01C. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20050802.0381 [DIRS 174838]

2.2. CODES, STANDARDS, REGULATIONS, AND PROCEDURES

2.2.1 10 CFR 63. 2005 *Energy: Disposal of High-Level Radioactive Wastes in a Geologic Repository at Yucca Mountain, Nevada.* ACC: MOL.20050405.0118 [DIRS 173273]

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2.3. SOURCE DATA, LISTED BY DATA TRACKING NUMBER (DTN)

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2.5. DESIGN INPUTS

2.5.1. Shaft Locations and Dimensions

Tables 1 and 2 are developed from the *Underground Layout Configuration* (Reference 2.1.9). Figure 1 shows the shaft locations.

Table 1. Shaft Locations

Panel	Shaft	Northing		Easting	
		Meters	Feet*	Meters	Feet*
4	Intake Shaft 1	234,474.453	769,271.6	170,560.873	559,581.8
3	Intake Shaft 2	235,903.432	773,959.8	171,805.963	563,666.7
2	Intake Shaft 3	233,260.252	765,288	171,322.497	562,080.6
1	Exhaust Raise 1	234,010	767,747.8	170,690	560,005.4
3	Exhaust Raise 2	234,580	769617.9	171,890	563,942.4
4	Exhaust Shaft 1	234,880.587	770,604.1	170,495.703	559,368
3	Exhaust Shaft 2	236,330.286	775,360.3	171,803.382	563,658.3
2	Exhaust Shaft 3	230,842.855	757,356.9	170,669.239	559,937.3
2	Exhaust Shaft ECRB+	233,029.534	764,531.1	170,378.507	558,983.5

Source: Reference 2.1.9, Table 7.
+Enhanced Characterization of the Repository Block
* Rounded to the nearest foot or meter.
Coordinate conversion from feet based on 1 foot = 12/39.37 meters (Reference 2.1.9, Section 3) for Tables 1 to 4.

Table 2. Shaft Details

Panel	Shaft	Excavated Diameter		Collar Elevation		Shaft Depth to Station	
		Meters	Feet+	Meters	Feet+	Meters*	Feet+*
4	Intake Shaft 1	8	26	1,450	4,757.208	378	1,240
3	Intake Shaft 2	8	26	1,410	4,625.975	350	1,150
2	Intake Shaft 3	8	26	1,325	4,347.104	248	814
1	Exhaust Raise 1	5	16	1,435	4,707.996	371	1,217
3	Exhaust Raise 2	5	16	1,340	4,396.317	279	915
4	Exhaust Shaft 1	8	26	1,470	4,822.825	405	1,329
3	Exhaust Shaft 2	8	26	1,450	4,757.208	428	1,403
2	Exhaust Shaft 3	8	26	1,400	4,593.167	292	958
2	Exhaust Shaft ECRB	8	26	1,475	4,839.229	398	1,307

Source: Collar elevations and depth information extracted from Reference 2.1.9, Table 7.
Diameter from Reference 2.1.9, Tables 3 to 6
* Rounded to the nearest foot or meter
+ Use conversion factor in Table 1.

2.5.2. Portal Locations and Dimensions

Table 3 is developed from the *Underground Layout Configuration* (Reference 2.1.9). Figure 1 shows the locations of all portals.

Table 3. Portal Locations and Elevations

Portal	Northing		Easting		Elevation	
	Meters	Feet*	Meters	Feet*	Meters	Feet*
North Ramp	233,279.97	765,352.7	173,679.768	569,814.4	1,122.56	3,682.932
South Ramp	230,614.635	756,608.2	172,900.776	567,258.6	1,160.069	3,805.993
North Construction Ramp	235,227.875	771,743.5	173,211.391	568,277.7	1,186.093	3,891.373

Source: Reference 2.1.9, Table 7.
*Use conversion factor in Table 1.

The North and South Ramp 7.62 meters (m) in diameter as documented in the *ESF Layout Calculation* (Reference 2.1.11, Section 4.2.4). The North Construction Ramp diameter is designed to be 7.62 m in diameter as documented in the *Underground Layout Configuration* (Reference 2.1.9, Section 8.3).

2.5.3. TCw/ PTn Contact Information

The *Yucca Mountain Science and Engineering Report* notes that TCw is highly permeable and the PTn has low permeability (Reference 2.1.14, Section 2.3.4.8.2). The approximate contact between the Tiva Canyon welded tuff (TCw) and the Paintbrush nonwelded tuff (PTn) thermo-mechanical units is at station 7+40 m on the North Ramp as determined from DTN: GS960908314224.020 (Reference 2.3.1). On the South Ramp the contact is at station 67+50 as determinted from DTN: GS970808314224.016 (Reference 2.3.2).

The contact between the TCw and PTn is at station 2+36m on the North Construction Ramp as measured from the North Construction Portal. The contact between the TCw and PTn units for each shaft is shown in Table 4. Table 4 and the North Construction Ramp contact is developed using the Vulcan software (Reference 2.4.1) and DTN: MO0110MWDGFM26.002 (Reference 2.3.5).

Table 4. Approximate Depth Below Surface for the TCw and PTn Unit Contact

Shaft	Meters	Feet*
Intake Shaft 1	103	338
Intake Shaft 2	73	240
Intake Shaft 3	79	259
Exhaust Raise 1	108	354
Exhaust Raise 2	91	299
Exhaust Shaft 1	101	331
Exhaust Shaft 2	79	259
Exhaust Shaft 3	92	302
Exhaust Shaft ECRB	128	420

* Rounded to the nearest foot or meter. Use conversion factor in Table 1.

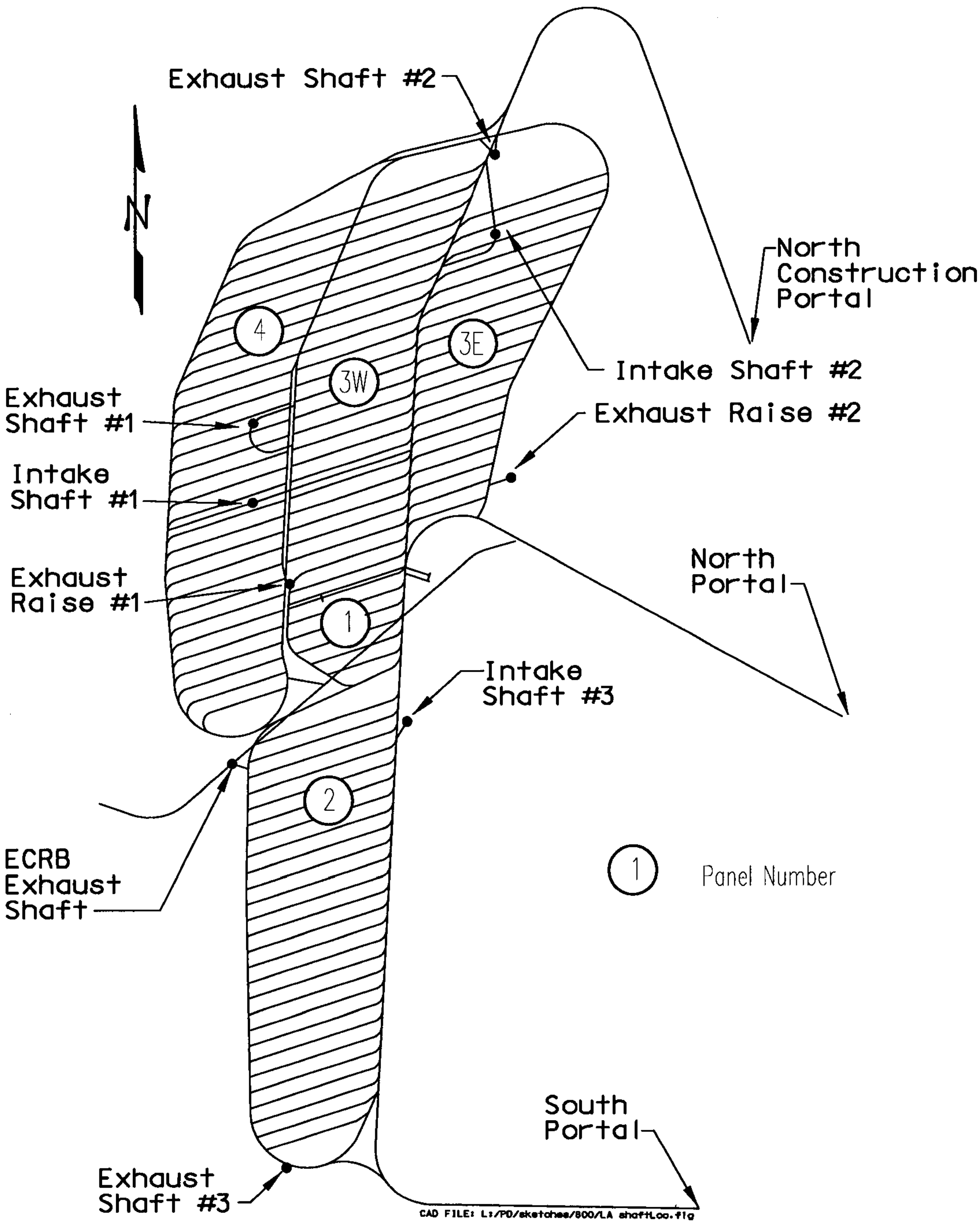


Figure 1. Locations of Shafts and Portals

Source: *Underground Layout Configuration*, Figures 5 and 10 (Reference 2.1.9)

2.5.4. Borehole Locations and Depths

Attachment II is a list of boreholes at various distances from the repository. Attachment II was developed using the Vulcan software (Reference 2.4.1).

2.5.5. Exhaust Main Dimensions

The exhaust main for Panel 1 is 5.5 m in diameter and all other exhaust mains in the repository are 7.6.2 m in diameter (Reference 2.1.9, Section 8.6).

2.5.6. Emplacement Drift Intersection With Exhaust Main

The *Underground Layout Configuration* (Reference 2.1.9, Figure 5) shows that the emplacement drift and the exhaust main have two types of intersections. A four-way intersection occurs in the exhaust main shared by Panel 3 and Panel 4 at the opposing emplacement drift pairs 3-1W and 4-1 through 3-9W and 4-9. All other emplacement drift intersections with an exhaust main form a three-way intersection.

2.5.7. Magma Bulkhead Parameters

Section 1.1 of *Magma Bulkhead Analysis* (Reference 2.1.4) says the bulkhead an inverted V-shaped keyway excavated in the tunnel roof and filled with a core of quartz sand sandwiched between the crushed tuff backfill.

Section 6.1 of the *Magma Bulkhead Analysis* (Reference 2.1.4) says the keyway can be located at designated locations in the turnouts and exhaust mains.

Section 6.1.1 of the *Magma Bulkhead Analysis* (Reference 2.1.4) says the magma flow will encounter the sand core in the keyway and the pressure of the magma against the sand will cause the sand to deform and dilate against the walls of the keyway. This will force the magma to infiltrate the fill where it will solidify in place due to the low permeability and the high heat transfer capacity of the fill.

Section 6.1.2 of the *Magma Bulkhead Analysis* (Reference 2.1.4) refines the keyway geometry indicating that one side ("front") should be at an angle relative to the horizontal that is smaller than the angle of repose of the sand. The other side ("back") should be at an angle relative to the horizontal such that the angle at the apex of the notch is less than 90 degrees. Figure 2 in the *Magma Bulkhead Analysis* (Reference 2.1.4) shows the typical magma bulkhead arrangement.

Section 6.1.2 of the *Magma Bulkhead Analysis* (Reference 2.1.4) notes the apex of the keyway is taken as 3.5 m above the crown of 5.5 and 7.62 m diameter tunnels and the turnout drift.

In Figure 3 of the *Magma Bulkhead Analysis* (Reference 2.1.4), a typical freestanding magma bulkhead arrangement is shown.

Case 2 in Section 6.2.2 of the *Magma Bulkhead Analysis* (Reference 2.1.4) describes the design applicable to the magma bulkhead that is the leading feature of a fully backfilled tunnel. The right side (or the "front", as noted above) of the bulkhead forms a passive berm, consisting of the crushed tuff.

Section 7.8.2 of the *Magma Bulkhead Analysis* (Reference 2.1.4) concludes that in a 7.62 m diameter tunnel, the minimum bulkhead lineal dimension, is approximately 40.2 m. Where the slope of the berm is 7.6 m, the berm is 20 m, the keyway is 7.6 m, and a minimum distance restricted for dike penetration is 5 m. In the 5.5 m diameter tunnel the minimum bulkhead lineal dimension is approximately 36 m. Where the slope of the berm is 5.5 m, the berm is 20 m, the keyway is 5.5 m, and a minimum distance restricted for dike penetration is 5 m.

2.5.8. Turnout Drift Dimensions and Geometry

As noted in the *Turnout Drift Operating Envelope Calculation* (Reference 2.1.8, Section 4.1.2), the turnout drift width is 8.0 m, the springline is at 3.0 m and the crown has a radius of 4.0 m. The turnout drift dimensions are used in Section B of Figure 7. The geometry of a representative turnout drift is shown in Figure 1 of the *Turnout Drift Operating Envelope Calculation* (Reference 2.1.8).

2.5.9. Location of Waste Package in Emplacement Drift

The *Underground Layout Configuration* notes that the minimum distance from the end of the waste package to the centerline of the exhaust main is 15 m (Reference 2.1.9, Section 6.3).

2.5.10. Length of Condensation Chamber at Exhaust Main

The length of drift provided to accumulate condensate at the exhaust main end of the emplacement drift is 15 m as used in the *In-Drift Natural Convection and Condensation* document (Reference 2.1.10, Section 6.3.5.2.1).

2.6. FORMULA USED IN CALCULATION

There are no formulas used in this calculation.

2.7. DESIGN OUTPUTS

The *Closure and Sealing Design Calculation* will support the License Application by providing description of the closure and sealing methods for the Safety Analysis Report. The calculation output will also support Post Closure Activities by describing the location of the magma bulkhead. The output will be used to develop a Mining drawing showing the proposed design and location of the magma bulkheads in the subsurface repository.

2.8. CODES AND STANDARDS

2.8.1. General Codes and Standards

There are no applicable codes/standards/industry guides (Reference 2.1.2, Section 4.11.2.1).

2.8.2. Code of Federal Regulations

The following Code of Federal Regulation (CFR) applies to closure and sealing. (Refer to 10 CFR 63 for the complete text.)

Section 10 CFR 63.51, *License amendment for permanent closure* (Reference 2.2.1) requires, in part, the following for permanent closure of the repository:

Part (3) A detailed description of the measures to be employed--such as land use controls, construction of monuments, and preservation of records--to regulate or prevent activities that could impair the long-term isolation of emplaced waste within the geologic repository and to assure that relevant information will be preserved for the use of future generations. As a minimum, these measures must include:

> (i) Identification of the site and geologic repository operations area by monuments that have been designed, fabricated, and emplaced to be as permanent as is practicable;
> (ii) Placement of records in the archives and land record systems of local, State, and Federal government agencies, and archives elsewhere in the world, that would be likely to be consulted by potential human intruders--such records to identify the location of the geologic repository operations area, including the underground facility, boreholes, shafts and ramps, and the boundaries of the site, and the nature and hazard of the waste; and
>
> (iii) A program for continued oversight, to prevent any activity at the site that poses an unreasonable risk of breaching the geologic repository's engineered barriers; or increasing the exposure of individual members of the public to radiation beyond allowable limits.

Part (5) The results of tests, experiments, and any other analyses relating to backfill of excavated areas, shaft, borehole, or ramp sealing, drip shields, waste packages, interactions between natural and engineered systems, and any other tests, experiments, or analyses pertinent to compliance with Sec. 63.113.

Section 10 CFR 63.113, *Performance objectives for the geologic repository after permanent closure* (Reference 2.2.1) requires, in part, for permanent closure of the repository:

> (a) The geologic repository must include multiple barriers, consisting of both natural barriers and an engineered barrier system.

2.9. CRITERIA AND REQUIREMENTS

2.9.1. Criteria

There are no closure and sealing criteria (Reference 2.1.2, Section 4.11.2).

2.9.2. Requirements

The *Subsurface Facility Description Document* (Reference 2.1.3) requirements are listed in Table 5. (Refer to the *Subsurface Facility Description Document* for the complete text.)

Table 5. Closure and Sealing Requirements

General Description of the Requirement	Requirement
1. All boreholes extending to the surface and located within the footprint of the emplacement panels, plus a 400-m buffer zone around the footprint perimeter, must be sealed in their lengths and capped at the surface. 2. All surface openings leading to the repository must be sealed, backfilled in their entire lengths, and capped at the surface. 3. Seal and closure components must be mechanically, chemically, geologically, and thermally compatible with the subsurface environment. 4. All boreholes outside of the buffer zone that could provide a preferential pathway to the emplacement area will be sealed.	3.1.1.3.4
Non-emplacement openings backfilled prior to closure to prevent magma intrusion into more than one emplacement drift	3.1.1.13.8
Remove non-committed materials from the repository	3.1.1.15.1
Land reclamation	3.1.1.15.3
Install drip shields	3.1.1.16.1 and 3.1.1.16.2
Provide equipment to install drip shields	3.1.1.16.3
Retain option to use emplacement drift backfill until closure	3.1.1.16.4
Backfill non-emplacement areas. Backfill properties: low permeability, chemical stability in repository environment, material longevity, availability, and similar hydraulic conductivity and permeability to surrounding rock mass.	3.1.1.16.5
Seal ramps and shafts to prevent unrestricted water flow	3.1.1.16.6
Seal boreholes to prevent water inflow	3.1.1.16.7
Place plugs and caps in surface penetrations leading into the repository	3.1.1.16.8
Erect site monuments and markers	3.1.1.16.9
Maintain construction records and complete as-built surveys	3.1.1.16.10

Source: Subsurface Facility Description Document (Reference 2.1.3)

Requirement 3.1.1.15.1 requires removal of non-committed materials that may impact the long-term performance of the repository. Non-committed materials inside the repository are to be removed at closure except for ground support. These items include bulkheads, rails, conduit, lighting, electrical equipment, piping, and electrical cable.

All concrete structures except those necessary for ground support, are to be removed (including inverts). Shaft concrete or shotcrete used to support the shafts will be removed as prescribed in the *Technical Management Review Board Meeting Minutes* (Reference 2.1.1, p. 2) and is an exception to retaining ground support materials. This *Technical Management Review Board* decision is noted to resolve the potential conflict between Requirement 3.1.1.15.1 and *Technical Management Review Board Meeting Minutes* (Reference 2.1.1, p. 2).

Requirement 3.1.1.13.8 stipulates that backfill will be used to prevent magma intrusion into an emplacement drift. Section 4.1.1.3.6.3 of the *Subsurface Facility Description Document* (Reference 2.1.3) proposes that a keyway located in the crown of a non-emplacement drift as the mechanism to prevent magma intrusion into an emplacement drift. The concept for the keyway is illustrated in Figure 4-12 in Section 4.1.1.3.6.3 (Reference 2.1.3).

3. ASSUMPTIONS

3.1. ASSUMPTIONS THAT REQUIRE VERIFICATION

None used.

3.2. BOUNDING ASSUMPTIONS

3.2.1. Condensation Chamber

Assumption: A condensation chamber will be located at both ends of the emplacement drift. The condensation chamber in the turnout drift will be at least 30 m long. (Refer to Section 2.5.10 for the condensation chamber length at the exhaust main end.)

Rationale: This assumption is based on the model results of seven emplacement drifts [DTN: SN0408T0509903.008 (Reference 2.3.6)] analyzed in the *In-Drift Natural Convection and Condensation Model* (Reference 2.1.10). In Attachment III, two of the seven emplacement drifts are selected for an impact evaluation in which the condensation rates were increased by a factor of two. The results are used to evaluate the *Total System Performance Analysis* (TSPA) (Reference 2.1.16) sensitivity to condensation effects. The conclusion of the comprehensive analysis determined that a 30 m condensation chamber would not likely result in condensation that would increase the probability weighted dose. Therefore, having a 30 m condensation chamber in the turnout drift is a conservative assumption suitable for its intended use in this calculation. This assumption is corroborated by using a qualified data source and applying a bounding condensation rate. The supporting documentation for this assumption is presented Attachment III.

This assumption is used in Section 6.5.

3.2.2. Preferential Pathways Boundary Constraint

Assumption: The limits used to identify boreholes that can be considered preferential pathways for water to enter the emplacement area excludes those boreholes that are less than 60 m in depth and outside the 400 m perimeter from the emplacement area, and all boreholes that are 1200 m away from the perimeter of emplacement area.

Rationale: The *Subsurface Facility Description Document* (Reference 2.1.3, Requirement 3.1.1.3.4) requires that boreholes outside the 400-m perimeter that are potential preferential pathways be identified. Engineering judgement was used to establish a boundary that would distinguish boreholes that may be preferential pathways. Shallow boreholes, less than 60-m in depth, outside the 400-m perimeter are not likely preferential pathways since they are relatively short. Boreholes that are 1200 m away from the perimeter of the emplacement area are not likely to be preferential pathways since they would be three times as far away from the emplacement area perimeter as the nominal requirement of 400 m. This assumption is used in Section 6.2.

4. METHODOLOGY

This calculation includes design material for closure and sealing consistent with the *Underground Layout Configuration* (Reference 2.1.9) and the requirements contained within the *Subsurface Facility Description Document* (Reference 2.1.3). The designs for shaft seals and ramp seals are presented in a qualitative manner. Similarly, the magma bulkhead is described in a qualitative manner and quantified to the extent where initial design dimensions have been made available in project calculations, models, requirements, and other documents. The borehole categorization was determined by comparing project requirements to the borehole parameters.

4.1. QUALITY ASSURANCE

The *Q-List* identifies *Closure* (magma bulkheads and backfill in access mains, exhaust mains, and turnouts) as Important to Waste Isolation and Safety Category (SC) (Reference 2.1.5, p. A-10). Therefore, this calculation is subject to *Quality Assurance Requirements and Description* (QARD) (Reference 2.1.15). This calculation has been prepared in accordance with LP-3.12Q-BSC, *Design Calculations and Analyses.*

4.2. USE OF SOFTWARE

4.2.1. General Software

This report was prepared with project standard software. Computations preformed in this calculation are reproducible in a manual check. Commercially available word processing (Microsoft Word 97), graphical design software (Microstation J) and software programs to support technical calculations (Microsoft EXCEL and Mathcad 2001i Professional) were used to produce this calculation. Subject to LP-SI.11Q-BSC, *Software Management*, Section 2.1, commercially available software are not required to be qualified.

4.2.2. Other Software

The qualified VULCAN V4.0NT (Reference 2.4.1) software system was used to sort the borehole information found in Attachment II and was used to determine the geologic contacts found in Section 2.5.3. The software was appropriate for this calculation, was obtained from Software Configuration Management in accordance with appropriate procedures, and was used within its range of validation. The software specifications are as follows:

- Software Name: VULCAN (Reference 2.4.1)
- Version/Revision Number: V4.0NT
- Status/Operating System: Qualified/ Personal Computer Microsoft Windows 2000
- Software Tracking Number: 10044-4.0NT-00
- Computer Type: DELL Precision 340
- CPU Number: 150455

Computer input files are from DTN: MO0110MWDGFM26.002 (Reference 2.3.5) and output files are listed in Attachment II and in Section 2.5.3.

5. LIST OF ATTACHMENTS

		Number of Pages
Attachment I	Seal Construction Sequence for Ramps and Shafts	8
Attachment II	Borehole Distances from Emplacement Block	7
Attachment III	Effects of Shortening the Intake Turnout on the Waste Package Condensation	11

6. BODY OF CALCULATION

6.1. BOREHOLES LOCATED INSIDE A 400-METER REPOSITORY PERIMETER

The *Subsurface Facility Description Document* (Reference 2.1.3) requires that boreholes located inside a 400 m perimeter of the footprint of the emplacement panels must be sealed and capped (refer to Section 2.9.2, Table 5, Requirements 3.1.1.3.4 and 3.1.1.16.7). Table 6 was developed by using the Vulcan software (Reference 2.4.1) to identify the location of all boreholes listed in Attachment II inside the 400 m perimeter requirement. The depth of the borehole is not a deciding factor in Table 6 since all boreholes located within 400 m of the repository perimeter must be sealed.

Table 6. Boreholes Inside a 400 m Repository Perimeter

Borehole	Easting		Northing	
	Meters	Feet*	Meters	Feet*
UZN #10	172,134.487	564,744.563	234,656.636	769,869.313
WT #18	172,168.034	564,854.625	235,052.248	771,167.250
G-1	170,993.466	561,001.063	234,849.365	770,501.625
G-4	171,627.661	563,081.751	233,418.593	765,807.501
H-1	171,416.339	562,388.439	234,774.137	770,254.814
H-5	170,355.633	558,908.439	233,670.549	766,634.126
NRG-7a	171,597.867	562,984.002	234,355.131	768,880.126
SD-12	171,177.737	561,605.625	232,244.825	761,956.563
SD-6	170,263.962	558,607.682	232,386.505	762,421.392
SD-6ST1	170,263.962	558,607.682	232,386.505	762,421.392
SD-7	171,066.371	561,240.252	231,328.385	758,949.876
SD-9	171,242.469	561,818.000	234,086.411	767,998.500
UZ-1	170,755.874	560,221.563	235,085.814	771,277.375
UZ-14	170,731.49	560,141.563	235,095.701	771,309.812
UZ-6	170,177.801	558,325.002	231,566.225	759,730.190
UZ-6s	170,094.19	558,050.688	231,620.822	759,909.314
UZ-7	171,575.807	562,911.627	231,903.582	760,837.002
UZ-7a	171,380.182	562,269.814	231,859.614	760,692.750
UZ-8	171,387.478	562,293.751	231,881.084	760,763.190
UZ-N24	171,314.536	562,054.440	234,088.583	768,005.626
UZ-N25	171,059.932	561,219.127	234,218.066	768,430.438
UZ-N26	171,000.229	561,023.251	234,317.717	768,757.377
UZ-N27	170,344.45	558,871.750	235,174.816	771,569.375
UZ-N31	171,527.134	562,751.939	232,942.533	764,245.627
UZ-N32	171,541.669	562,799.626	232,959.906	764,302.625
UZ-N33	171,051.721	561,192.188	234,717.844	770,070.127
UZ-N34	171,069.761	561,251.374	234,744.857	770,158.752
UZ-N35	171,392.412	562,309.938	232,338.532	762,264.000
UZ-N36	171,780.347	563,582.688	235,885.04	773,899.502
UZ-N42	171,559.652	562,858.625	233,394.704	765,729.125
UZ-N44	171,645.263	563,139.500	233,536.075	766,192.939
UZ-N46	170,611.513	559,747.939	235,385.986	772,262.189
UZ-N47	170,622.428	559,783.749	235,296.184	771,967.564
UZ-N48	171,424.073	562,413.813	231,903.258	760,835.939
UZ-N49	171,396.108	562,322.064	231,911.03	760,861.438
UZ-N50	171,575.902	562,911.938	231,885.275	760,776.940
UZ-N51	171,575.178	562,909.563	231,911.126	760,861.753
UZ-N52	171,574.988	562,908.940	231,921.241	760,894.938

Table 6. Boreholes Inside a 400 m Repository Perimeter (CONTINUED)

Borehole	Easting		Northing	
	Meters	Feet*	Meters	Feet*
UZ-N64	170,516.282	559,435.502	233,394.4	765,728.127
UZ-N66	171,261.881	561,881.688	231,171.108	758,433.877
UZ-N70	170,738.634	560,165.002	234,468.098	769,250.752
UZ-N71	170,202.471	558,405.940	231,961.094	761,025.689
UZ-N72	170,275.623	558,645.940	231,975.096	761,071.627
UZ-N73	170,366.948	558,945.562	231,969.4	761,052.940
UZ-N74	170,249.467	558,560.126	232,063.583	761,361.939
UZ-N75	170,406.706	559,076.001	232,094.158	761,462.250
UZ-N76	170,404.096	559,067.438	232,062.04	761,356.876
UZ-N93	170,176.581	558,320.999	231,521.685	759,584.062
UZ-N94	170,150.883	558,236.689	231,564.129	759,723.313
UZ-N95	170,131.357	558,172.627	231,617.603	759,898.753
UZ-N96	170,201.689	558,403.375	231,479.471	759,445.564
UZ-N98	171,323.47	562,083.751	234,085.802	767,996.502
WT-2	171,274.778	561,924.001	231,850.108	760,661.563

Source: Attachment II
Conversion based on 1 foot = 12/39.37 meters (Reference 2.1.9, Section 3).

6.2. BOREHOLES PROVIDING A PREFERENTIAL PATHWAY INTO THE REPOSITORY

The *Subsurface Facility Description Document* (Reference 2.1.3) requires that boreholes located outside the 400-m perimeter of the footprint of the emplacement panels that could provide a preferential pathway will be sealed and capped (refer to Section 2.9.2, Table 5, Requirement 3.1.1.3.4).

Table 7 was developed by using the Vulcan software (Reference 2.4.1) to identify all the boreholes listed in Attachment II that are outside the 400 m perimeter. (Note: not all boreholes more than 400 m from the repository are filled.)

Figure 2 was modified from the *Underground Layout Configuration* (Reference 2.1.9, Figure II-4) and the boreholes were selected from Attachment II, Table II-1 using the Vulcan software (Reference 2.4.1).

Engineering judgment was used to select a 60 m depth, and 1200 m distance from the perimeter, as suitable exclusion distances for the potential preferential pathway into the repository (refer to Section 3.2.2).

6.2.1. Identifying Boreholes That Are Potential Preferential Pathways

The *Yucca Mountain Science and Engineering Report* (Reference 2.1.14, Figure 1-10) shows the geologic formations near the repository dip to the east. Groundwater will tend to flow down and to the east due to the orientation of the bedding planes, unless it encounters a geologic feature (e.g., a joint, fault, bedding plane, fracture, etc.) that could divert the water. Therefore, boreholes that are located east of the repository and outside of the 400 m perimeter most likely will not serve as a preferential pathway for groundwater (refer to Section 3.2.2). For example, looking at Figure 2, boreholes east of E 172000, and outside the 400 m perimeter, can be excluded as potential preferential pathways because water entering these boreholes would tend to flow away from the repository.

The *Yucca Mountain Science and Engineering Report*, Figure 1-9 (Reference 2.1.14) shows the Solitario Canyon Fault (geologic feature) resides west of the repository and would likely divert water flowing toward the repository from the west. Therefore, boreholes that are located west of the Solitario Canyon Fault and outside of the 400 m perimeter likely will not serve as a preferential pathway for groundwater (refer to Section 3.2.2). For example, looking at Figure 2, all boreholes west E 170000 and outside the 400 m perimeter can be excluded as potential preferential pathways because of location and the water diversion.

Fifty-five boreholes where identified between E 170000 and E 172000 and located outside the 400 m repository perimeter by using the Vulcan software (Reference 2.4.1) in conjunction with all the boreholes listed in Attachment II and bounded by the aforementioned coordinate lines.

To further reduce the field of potential preferential pathways, shallow boreholes less than 60 m in depth are excluded (refer to Section 3.2.2). This reduces the field of potential preferential pathways to sixteen boreholes. A further reduction of the field of boreholes that are potential preferential pathways is achieved by excluding those boreholes that are at a distance greater than 1200 m away from the repository (refer to Section 3.2.2). The remaining five boreholes of concern are H-3, H-4, NRG-6, WT-24, and UZ-N54.

Figure 2 shows that boreholes H-4, NRG-6, and UZ-N54 are located to the east of E 172000 and are outside the 400-m perimeter of the emplacement panels. Therefore, these three boreholes can be excluded as preferential pathways for groundwater to enter the emplacement area.

Two remaining boreholes, H-3 and WT-24 situated west of the 400-m perimeter, are potential preferential pathways because of they are deep and located east of the Solitario Canyon Fault. Therefore water flowing east could enter either borehole and migrate into the repository.

Finally, boreholes A-4 and NRG-5, shown in Figure 2, are located close to the North Ramp and could provide a preferential pathway for water to enter the ramp.

Boreholes that could provide a preferential pathway into the repository are listed in Table 7. Table 7 shows the borehole depth, but this information is not qualified data. The exact depth of the borehole is not required for this calculation, because the depth is only shown to differentiate between shallow and deep boreholes.

Table 7. Locations and Depths of Preferential Pathway Boreholes

Borehole	Easting		Northing		Depth	
	Meters	Feet*	Meters	Feet*	Meters	Feet*
A-4	172,051.372	564,471.876	234,078.448	767,982.375	152.4	499.999
NRG-5	172,142.202	564.769.874	234,053.226	767,889.626	411.481	1350.001
H-3	170,216.472	558,451.875	230,594.463	756,542.001	1,219.202	4,036.575
WT-24	171,398.498	562,329.906	236,739.567	776,703.063	1,097.282	3,632.918

Source: Attachment II
Conversion based on 1 foot = 12/39.37 meters (Reference 2.1.9, Section 3).

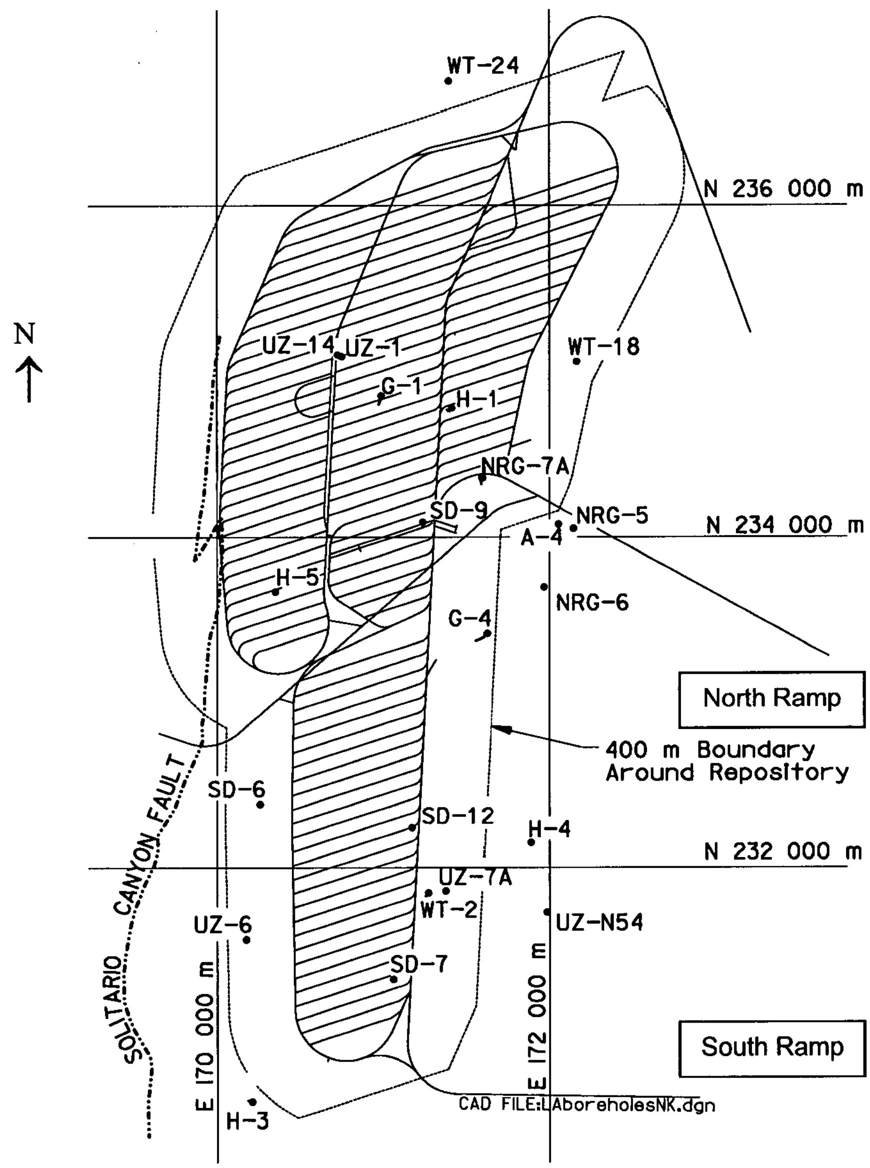


Figure 2. Select Boreholes Located Near the Emplacement Area

Source: Modified from *Underground Layout Configuration*, Figure II-4 (Reference 2.1.9) and *Yucca Mountain Science and Engineering Report,* Figure 1-9 (Reference 2.1.14)
Note: Only boreholes from Table 7 or those with a depth greater than 200m are shown for clarity.

6.3. CLOSURE STRATEGY OVERVIEW

Closure of the repository will be conducted in phases. The general approach to repository closure is backfilling operations will commence at the outer boundaries of a panel and retreat in the direction of the portals. Sealing the boreholes and the installation of drip shields in emplacement drifts can be performed independently and prior to backfilling the mains and ramps. Boreholes that intersect the repository (refer to Figure 2) may be sealed in conjunction with construction to prevent water intrusion during the early part of repository life.

Backfilling of the ramps and mains can be accomplished with conventional construction equipment as shown in the *Yucca Mountain Science and Engineering Report*, Figure 2-61 (Reference 2.1.14). Backfilling the shafts can be accomplished using conventional mining equipment as shown in the *Yucca Mountain Science and Engineering Report*, Figure 2-62 (Reference 2.1.14). By design, backfilling the emplacement drifts will be possible if required (Table 5, Requirement 3.1.1.16.4) and is discussed in detail in the *Backfill Strategy and Preliminary Design Analysis* (Reference 2.1.12).

Removal of non-committed items from the repository (Table 5, Requirement 3.1.1.15.1) needs to be accomplished prior to backfilling. Most ground support items will stay in place because it would be unsafe to remove them. This means that some concrete may remain in the repository after closure.

The construction of the magma bulkhead can be performed either during the repository development or during the preclosure period after waste emplacement. In general, if the keyway component is constructed during the repository development, there are impacts to the development schedule and the ground support may require augmentation to satisfy project requirements pertaining to the ground support. Conversely, if the magma bulkheads are constructed during the preclosure period after waste emplacement, the excavation method becomes more complicated due to the proximity of the waste packages.

The access mains will provide good working conditions throughout the pre-closure period and during closure and ensure a viable staging point for backfill operations in the turnouts. However, conditions in the exhaust air main at time of closure will require that work crew utilize equipment with special features to operate in the environment. Crews and equipment will have to contend with high temperatures, possible radioactive contamination, and direct radiation shine at the emplacement drift intersections. Many of the operations must therefore rely on remote control. At closure, the exhaust air main will provide the access for the back-filling operations, which will commence at the emplacement drift in the panel furthest from the point of entry and retreat out. To cool the exhaust main, the first step will be to eliminate hot exhaust air from the emplacement drifts by shutting down the surface exhaust fans, closing the louvers in the turnout ventilation doors, and if necessary installing the magma bulkheads in the turnout as the first step. A ducted ventilation system will carry chilled fresh air directly to the back-fill operations. The ventilation system must also deal with dusty conditions created by the backfill stowing operations. To protect against radiation crews must install shielding at each emplacement drift as they advance from their point of entry to the first emplacement drift. Utilities will also be carried in at the same time. The shielding and utilities will be removed for use elsewhere as the work-crews retreat. A trackless transportation system will be needed for men and materials. To reduce the number of steps needed for installing the magma plugs in the exhaust main at time of closure the magma keyways can be excavated at time of initial construction.

6.4. CLOSURE SEALS FOR RAMPS, SHAFTS AND PORTALS

An example of a ramp seal is shown in Figure 3, and Figure 4 shows an example of a shaft seal as documented in the *Yucca Mountain Science and Engineering Report* (Reference 2.1.14, Figures 2-63 & 2-64). The TCw is highly permeable and the PTn has low permeability (refer to Section 2.5.3) therefore seals located at the boundary of the TCw and PTn thermo-mechanical units will divert water into the TCw.

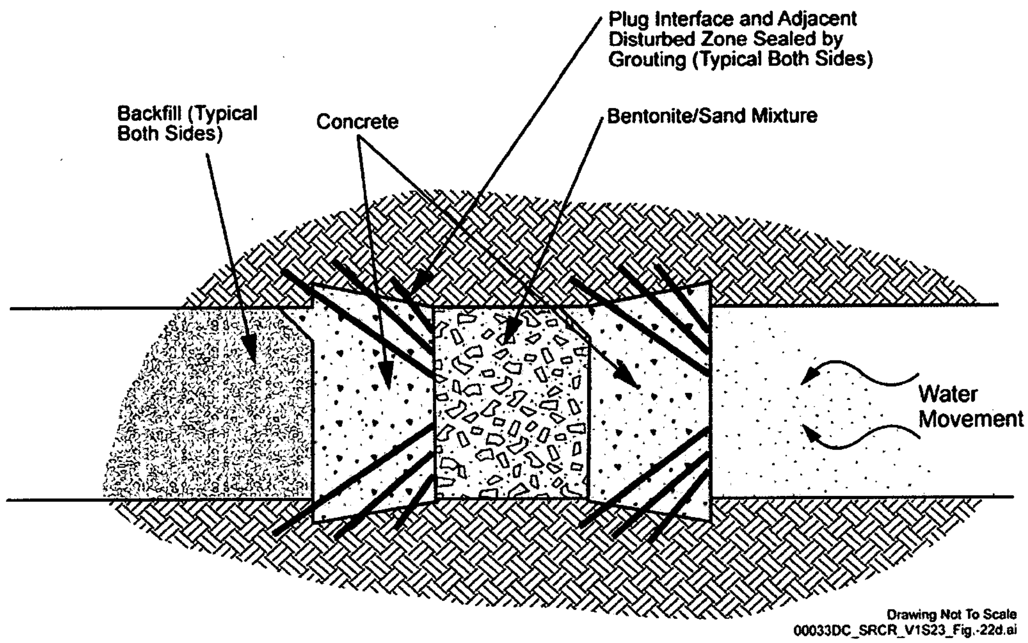


Figure 3. Ramp Seal

Source: Modified from *Yucca Mountain Science and Engineering Report*, Figure 2-63 (Reference 2.1.14)

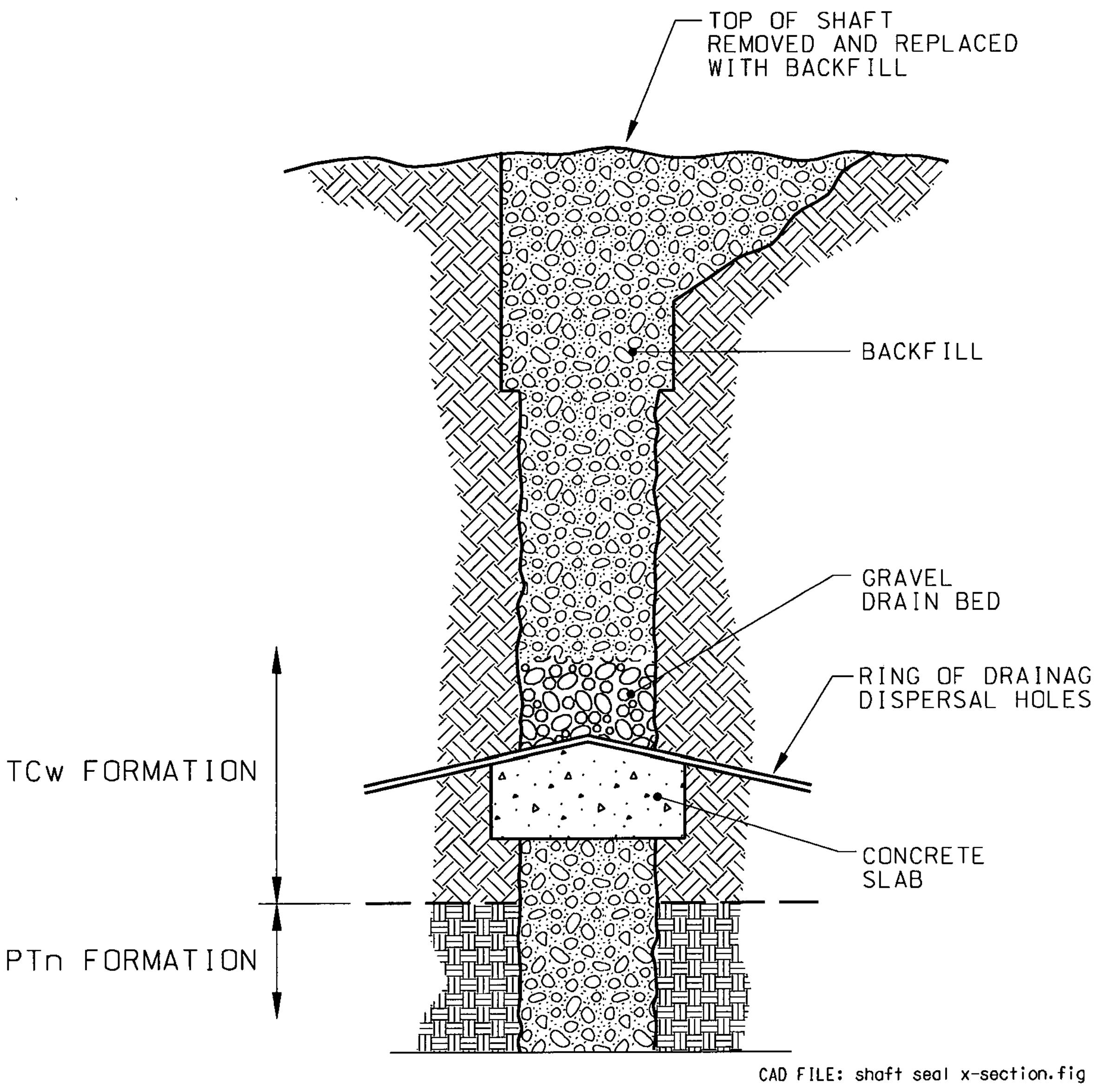


Figure 4. Shaft Seal

Source: Modified from *Yucca Mountain Science and Engineering Report*, Figure 2-64 (Reference 2.1.14)
Note: Concrete slab location modified from Figure 2-63 (Reference 2.1.14) and upper portion of the shaft modified from Figures 3 and 4 (Reference 2.1.6).

A bentonite/sand mixture and grouting have been chosen as part of the ramp seal material to provide a low permeability plug for water intrusion. Concrete has been chosen as part of the ramp seal to ensure that the plug will not be breached easily from the surface. The construction of the ramp seals could be accomplished as shown in Attachment I, Figures I-1 to I-9. Figure 3 has been modified from *Yucca Mountain Science and Engineering Report,* Figure 2-64 (Reference 2.1.14) with small wedges of concrete included at the top of each plug conforming to the backfill material angle of repose.

Figure 4 has been modified from *Yucca Mountain Science and Engineering Report,* Figure 2-63 (Reference 2.1.14) to locate the seal near the interface between the TCw and PTn units (Reference 2.1.14, Section 2.3.4.8.2). The upper portion of Figure 4 also incorporates the current shaft collar design described in the *Shafts Preliminary Design Calculation* (Reference 2.1.6). Construction of the shaft seals could be accomplished as shown in Attachment I, Figures I-10 to I-13. The underlying requirement for Figures 3 and 4 are from Table 5, Requirements 3.1.1.16.6 and 3.1.1.16.8.

The nine shafts will have their collars removed and the surface area will be restored in compliance with the EIS (Reference 2.1.13, p. 2-40) and the *Subsurface Facility Description Document* (Table 5, Requirement 3.1.1.16.6). The wording of the reference also indicates that the shaft pads will be removed.

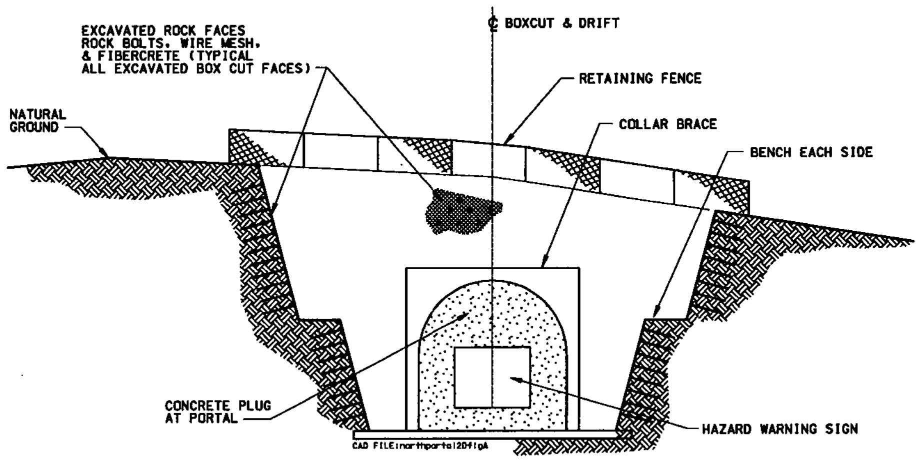
Boreholes will be filled and sealed (Table 5, Requirement 3.1.1.3.4 & 3.1.1.16.7) with bentonitic grout as described in the *Yucca Mountain Science and Engineering Report,* Table 2-21 (Reference 2.1.14). Some boreholes may have already been filled using other methods (such as drill cuttings). However this is beyond the scope of this calculation to determined if these other methods of filling boreholes are sufficient to reduce water intrusion into the repository.

Access mains, ramps, alcoves, and performance confirmation drifts will be backfilled (Table 5, Requirement 3.1.1.16.5). The aforementioned nonemplacement opening can be completely filled using a pneumatic delivery system to place the backfill against the drift crown. Shafts will also be backfilled (Table 5, Requirement 3.1.1.16.5) and the concrete shaft liner will be removed (Section 2.9.3, Reference 2.1.1, p. 2) prior to backfill.

The backfill will be an engineered material having a specific gradation, size, and maximum fine particle content. Backfill will be engineered, because it is a good construction practice to define or specify any item important to repository closure. The backfill may have water diversion properties (Table 5, Requirement 3.1.1.16.5).

The drip shields will be installed within the emplacement drifts prior to closure (Table 5, Requirements 3.1.1.16.1 and 3.1.1.16.2). Specialized equipment will be supplied to install the drip shields (Table 5, Requirement 3.1.1.16.3). Backfill may be installed in place of or in addition to the drip shields (Table 5, Requirement 3.1.1.16.4).

The portals will be sealed against human intrusion (Table 5, Requirement 3.1.1.16.8). This seal is in addition to the seal which is located underground on the ramp. Backfill will be placed up to the portal and a seal or cap will be installed at the entrance to inhibit human intrusion. A conceptual design of a portal closure arrangement developed in the *Portals Preliminary Design Calculation* (Reference 2.1.7, Figure 8) is shown in Figure 5. After the cap is installed, the area around the portal will be reclaimed as discussed in Section 6.6.



NorthPortal.PPT

Figure 5. Portal Seal

Source: *Portals Preliminary Design Calculation* (Reference 2.1.7, Figure 8)

6.5. MAGMA BULKHEAD

The *Subsurface Facility Description Document* stipulates that nonemplacement openings are backfilled before the repository closure to prevent magma intrusion into more than one emplacement drift (refer to Table 5, Requirement 3.1.1.13.8). A magma bulkhead is a feature that will satisfy the requirement (refer to Section 2.9.2).

The *Magma Bulkhead Analysis* (Reference 2.1.4) describes the magma bulkhead as a v-shaped keyway that extends above the crown of the nonemepalcement drift. The keyway pitch is asymmetrical. The magma bulkhead has a sand core and a berm that acts as a reaction mass to a potential magma intrusion. The berm extends out from the sand core and is composed of unconsolidated crushed tuff. Conventional backfilling using crushed tuff is performed moving away from the magma bulkhead.

The turnout drift and the exhaust main are suitable non-emplacement drifts in which to construct a magma bulkhead (refer to Section 2.5.7). Construction the magma bulkhead in these locations serves to isolate the individual emplacement drifts from adjacent drifts with respect to potential magma intrusion. The magma bulkhead also delineates the condensation chambers at either end of the emplacement drift (refer to Section 3.2.1).

6.5.1. Typical Magma Bulkhead in Turnout Drift

The magma bulkhead will be located such that a portion of the turnout drift adjacent to the emplacement drift will not be backfilled (refer to Figure 6). The unfilled length of turnout drift is referred to as a condensation chamber. The condensation chamber in the turnout drift will be at least 30 m long (refer to Section 3.2.1).

The elevation views of the typical magma bulkhead, located in the turnout drift, are illustrated in Figure 7. As noted, the magma bulkhead is situated such that a 30 m long condensation chamber is created. The magma bulkhead has a v-shaped keyway that extends 3.5 m above the crown of the turnout drift (refer to Section 2.5.7). The keyway pitch is asymmetrical with one side having a slope less than the angle of repose and the opposing side sloped greater than the angle of repose. The apex angle is less than 90 degrees. The shallow pitch is facing out from the emplacement area and the steep pitch is oriented towards the emplacement area. The width of the keyway is less than the width of the turnout drift due to effective drilling angles and clearance requirements for the drilling equipment.

The magma bulkhead has a sand core in the keyway. The sand core functions to resist the pressure of the magma will deform and dilate against the walls of the keyway. This will force the magma to infiltrate the fill where it will solidify in place due to the low permeability and the high heat transfer capacity of the fill (refer to Section 2.5.7).

The berm acts as a reaction mass to a potential magma intrusion. The berm, composed of unconsolidated crushed tuff, is located in front of the sand core and extends approximately 28 m (refer to Section 2.5.7). Conventional backfilling with crushed tuff is carried out retreating away from the magma bulkhead out into the access main.

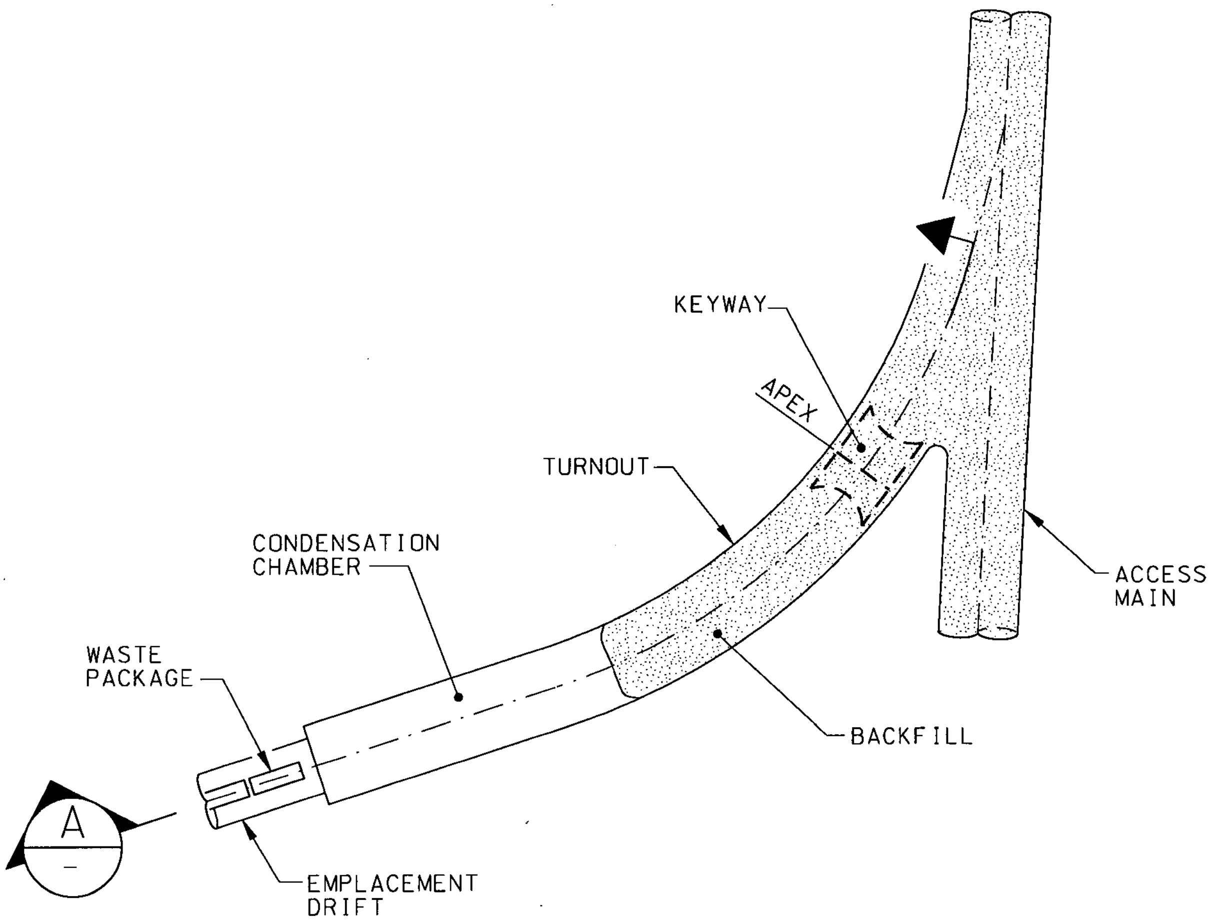
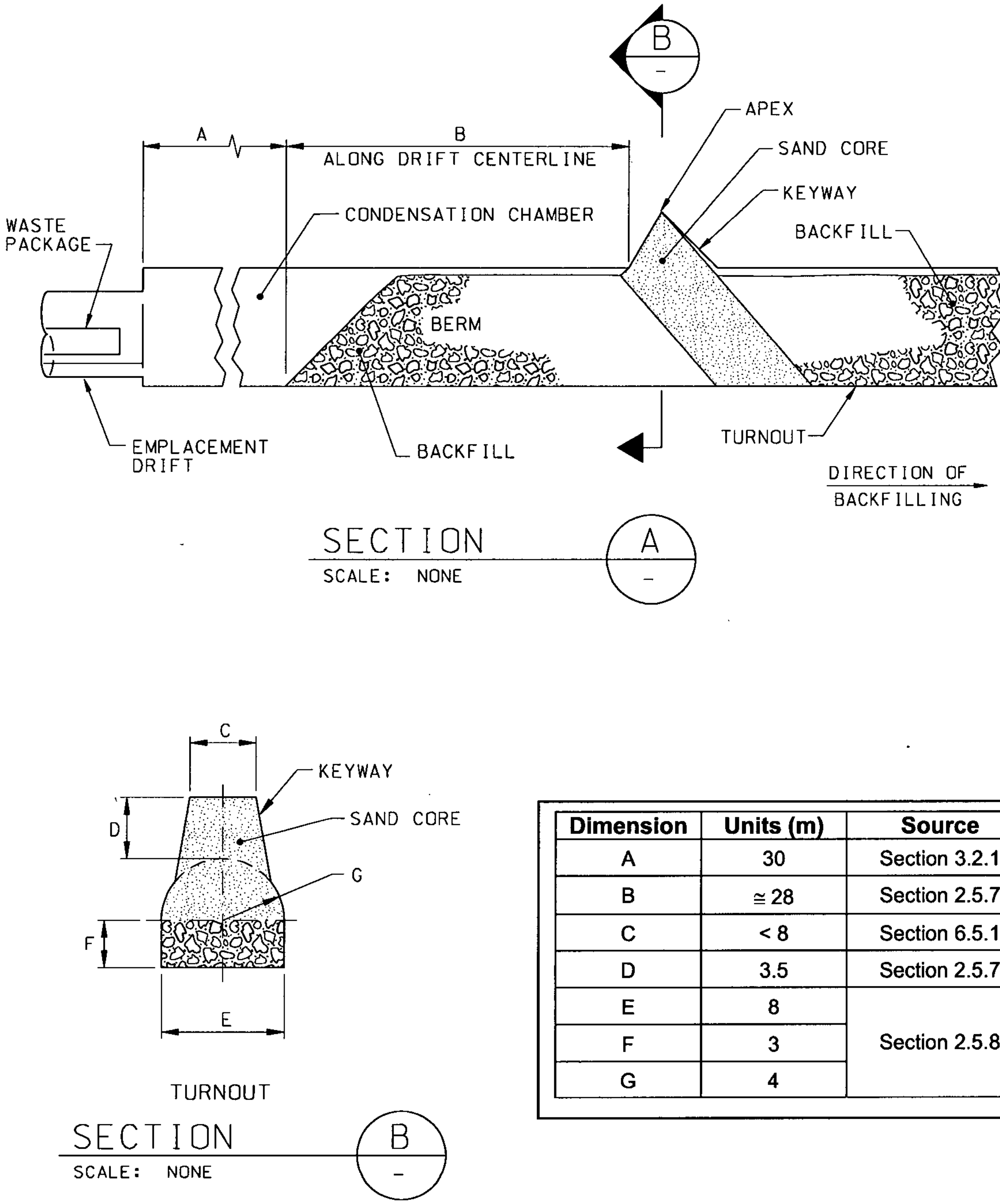


Figure 6. Typical Magma Bulkhead Located in Turnout (Plan Views)

Note: Typical Turnout Drift geometry from *Turnout Drift Operating Envelope Calculation* (Reference 2.1.8, Figure 1)



Dimension	Units (m)	Source
A	30	Section 3.2.1
B	≅ 28	Section 2.5.7
C	< 8	Section 6.5.1
D	3.5	Section 2.5.7
E	8	Section 2.5.8
F	3	
G	4	

Figure 7. Typical Magma Bulkhead Keyway Located in Turnout (Elevation Views)

6.5.2. Typical Magma Bulkhead in Exhaust Main

The typical magma bulkhead in the exhaust main that forms a three-way intersection with the emplacement drift (refer to Section 2.5.6) is freestanding (refer to Section 2.5.7). The three-way intersection configuration does not provide sufficient room to satisfy the 15 m waste package stand off distance (refer to Section 2.5.9) and accommodate the lineal dimensions of the magma bulkhead (refer to Section 2.5.7).

For example, in the 7.82 m diameter exhaust main the magma bulkhead requires about 8 m for the keyway and a minimum 5 m restriction for dike penetration to either side of the keyway. In addition, there is the 15 m condensation chamber at the end of each emplacement drift resulting in a workable dimension of about 48 m for the magma bulkhead. Therefore, the magma bulkhead is situated in the exhaust main, positioned between the intersections formed by the emplacement drifts with the exhaust main as shown in Figure 8. It has the same basic geometry as the magma bulkhead in the turnout drift. The magma bulkhead location is appropriate since the emplacement drift is aligned with the exhaust main at a sharp angle (comparatively, the turnout drift and the emplacement drift are in direct alignment).

The magma bulkhead will be positioned such that the section of the emplacement drift from the waste package to the adjoining exhaust main will not be backfilled. The unfilled length of turnout drift is referred to as a condensation chamber. To achieve the condensation chamber length of at least 15 m (Refer to Section 2.5.10), the exhaust main section in front of the emplacement drift will not be backfilled as well.

The magma bulkhead is characterized by the v-shaped keyway that extends 3.5 m above the crown of the 5.5 and 7.62 m diameter tunnels (refer to Section 2.5.7) and has a sand core. The keyway pitch is asymmetrical with one side having a slope less than the angle of repose of the sand and the opposing side sloped greater than the angle of repose of the sand.

As noted above, providing a condensation chamber establishes an unfilled section of exhaust main adjoining the emplacement drift. Therefore, the magma bulkhead in the exhaust main effectively has a berm to either side of the keyway. The minimum dimension, for the berm is approximately 28 m (refer to Section 2.5.7). However taking into consideration that the exhaust main will be backfilled (refer to Table 5, Requirement 3.1.1.13.8), the actual length of the berm can be greater than 28 m to one side of the keyway. Therefore, the berm can be located measuring from the midpoint between the intersections of the exhaust main and emplacement drifts such that the length of the berm can be the same on both sides. The typical magma bulkhead arrangement in the exhaust main with equal length berms, denoted by the letter "T", is shown in Figures 8 and 9.

The magma bulkhead has a sand core and a berm that acts as a reaction mass to a potential magma intrusion. The reaction mass berm is located in front of the sand core and is composed of unconsolidated crushed tuff. Conventional crushed tuff backfilling is carried out away from the magma bulkhead.

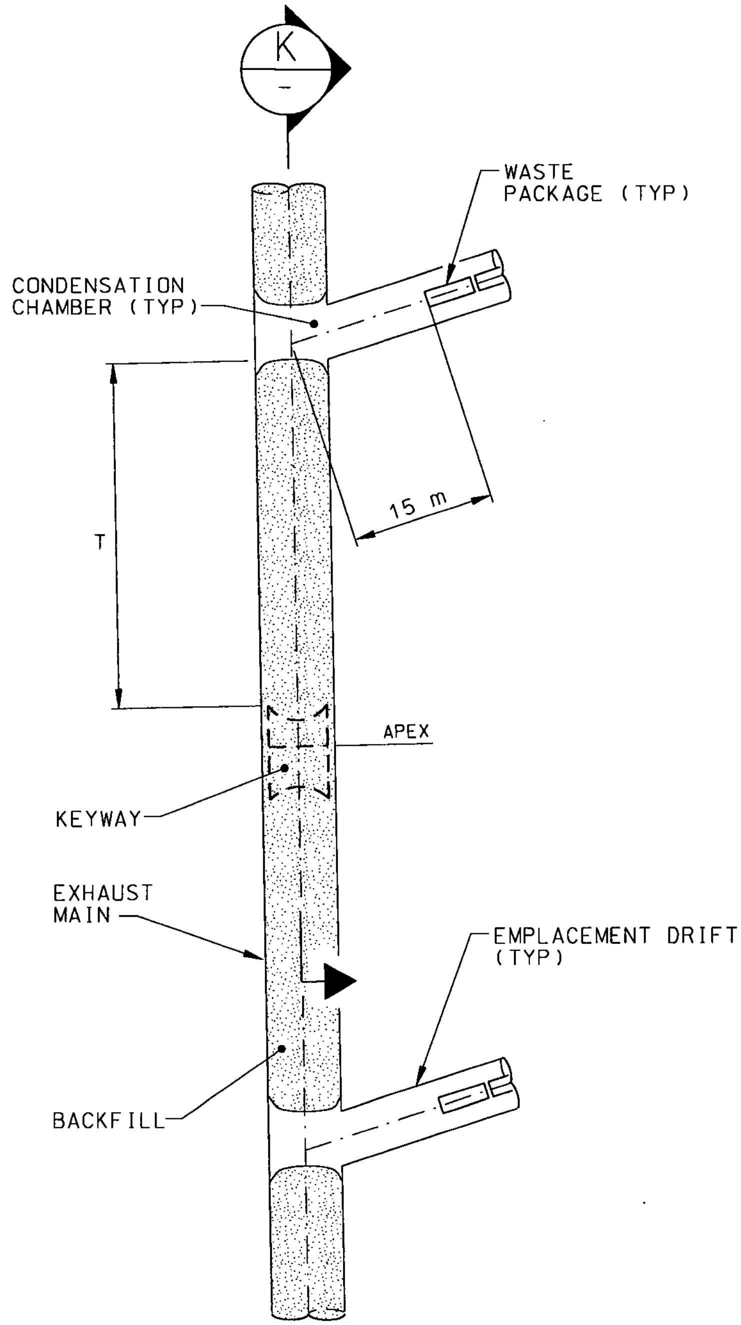
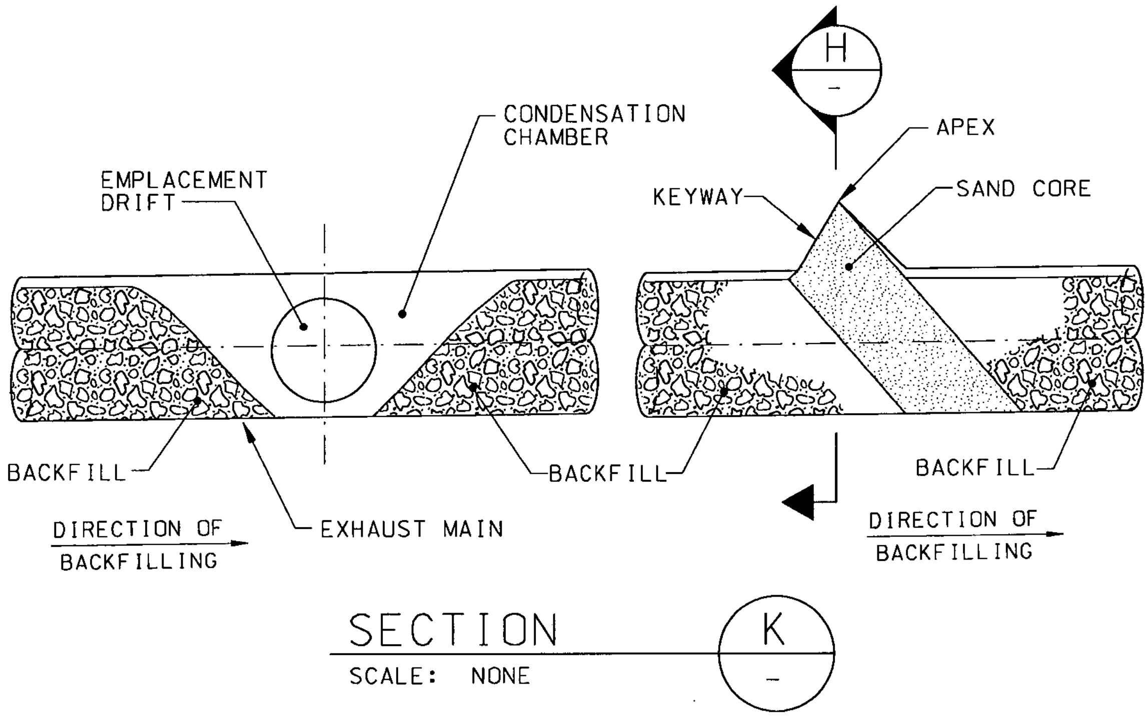
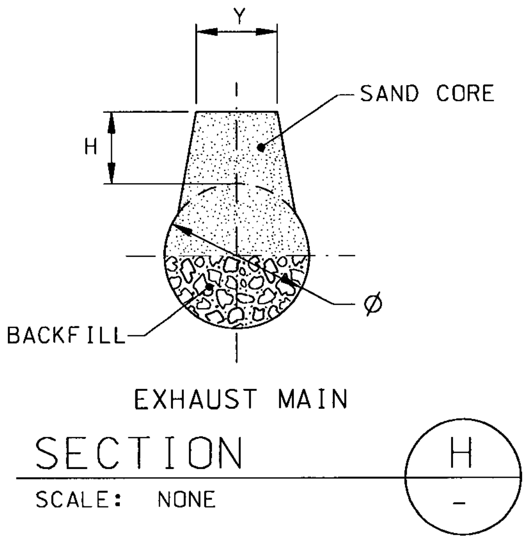


Figure 8. Typical Magma Bulkhead - Exhaust Main (Plan Views)

Note: Typical Exhaust Main geometry developed from the exhaust main for Panel 2 shown in the *Underground Layout Configuration* (Reference 2.1.9, Figure 5)





Dimension	Units (m)	Source
Y	< Ø	Section 6.5.1
H	3.5	Section 2.5.7
Ø [1]	5.5	Section 2.5.5
Ø [2]	7.62	

1 Exhaust Main Panel 1
2 Exhaust Main Panel 2, 3 and 4

CAD FILE: drift keyways metric.fig

Figure 9. Typical Magma Bulkhead Keyway - Exhaust Main (Elevation Views)

6.5.3. Typical Magma Bulkhead in Exhaust Main With Opposing Emplacement Drifts

In the subsurface repository, a unique set of emplacement drifts dictates a modified design to accommodate the magma bulkhead. In the exhaust main, common to Panel 3W and Panel 4 there are nine, four-way intersections formed by directly opposing emplacement drifts (refer to Figure 1). The opposing pairs of emplacement drifts that form intersections in the common exhaust main are 3-1W and 4-1 through opposing pairs' 3-9W and 4-9 (refer to Section 2.5.6).

The opposing emplacement drift configuration is not suitable to construct a magma bulkhead that would isolate an opposing emplacement drift from a magma intrusion originating from its counterpart across the exhaust main. The available length for construction is equivalent to twice the length of the waste package offset of 15 m (refer to Section 2.5.9) to the centerline of the exhaust main, or 30 meters. Essentially, there is only sufficient room to construct a single magma bulkhead without the berm needed as a reaction mass and no condensation chamber. An alternative design is provided.

The design shown in Figures 10 and 11 does isolate the opposing emplacement drifts from each other. Note that it is beyond the scope of this calculation to determine the final design dimensions for the magma bulkhead in the common exhaust main and aforementioned figures are used for illustrative purposes only.

In the design, the emplacement drift would stop short of intercepting the common exhaust main by a minimum pillar dimension. The minimum pillar dimension would be equivalent to the longest rockbolt that might be used for ground support plus an additional allowance to account for over-drilling or material spalling off the exhaust main wall during installation of the ground support. The maximum pillar dimension would be less than the sum of the required waste package standoff and the clearance requirements for the waste package gantry over travel beyond the point-of-emplacement.

The 3 m x 3 m condensation chamber in the design would be a sufficient size to satisfy the repository ventilation requirements and construction/excavation and muck haulage equipment. The drifts would be offset laterally a sufficient distance from the correspondingly opposed emplacement drifts, to accommodate the excavation of the magma bulkhead keyway without compromising the exhaust main ground stability.

Dimensions "K" and "M" are design solutions developed with the commercially available graphical design software (refer to Section 4.2.1). They accommodate the pillar dimension constraint based on the waste package standoff and the ground support while conforming to the dike a minimum 5 m restriction for dike penetration.

Figures 10 and 11 are dimensioned to illustrate the spatial relationship amongst the emplacement drift, the exhaust main and the condensation chamber. Dimension "N" represents a minimum 5 m restriction for dike penetration (refer to Section 2.5.7) applicable to a keyway located between the condensation chamber drifts. Dimension "P" is greater than or equal to the minimum 5 m restriction for dike penetration applicable to the keyway located between two adjacent emplacement drifts.

Dimension	Units (m)	Source
K	12	Section 6.5.3
M	25	
N	> 5	Section 2.5.8
P	> 5	

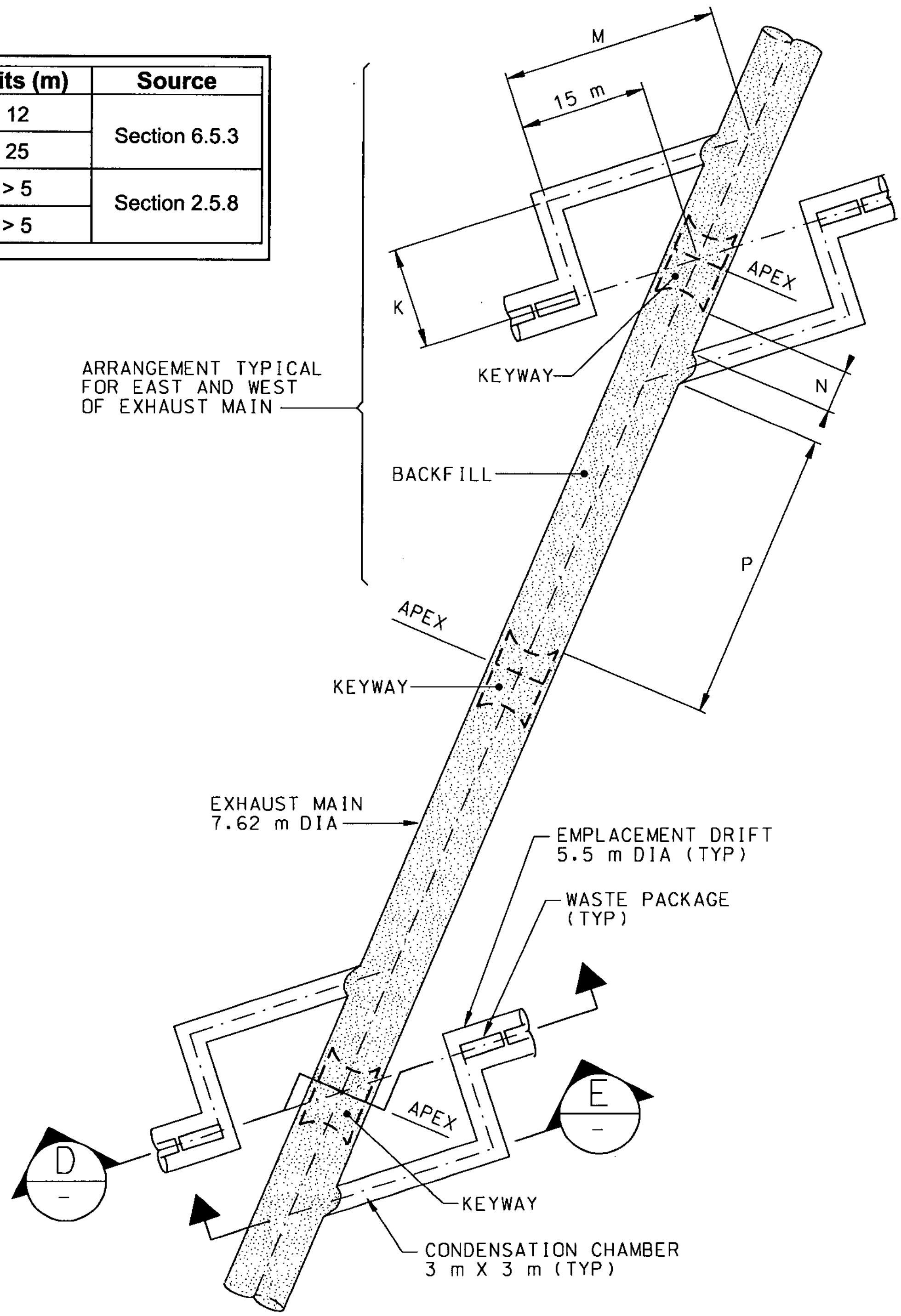
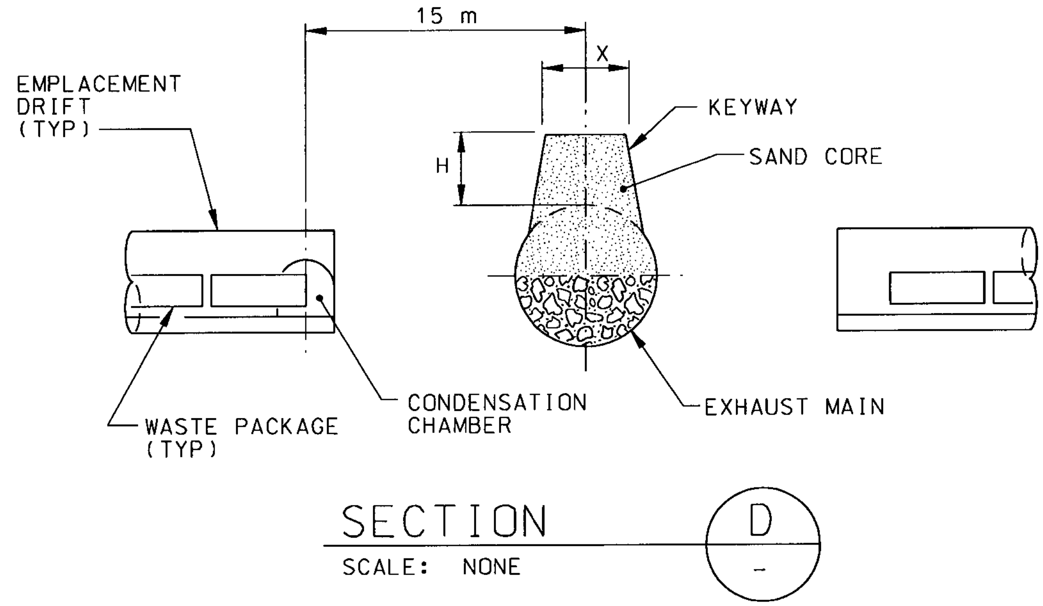


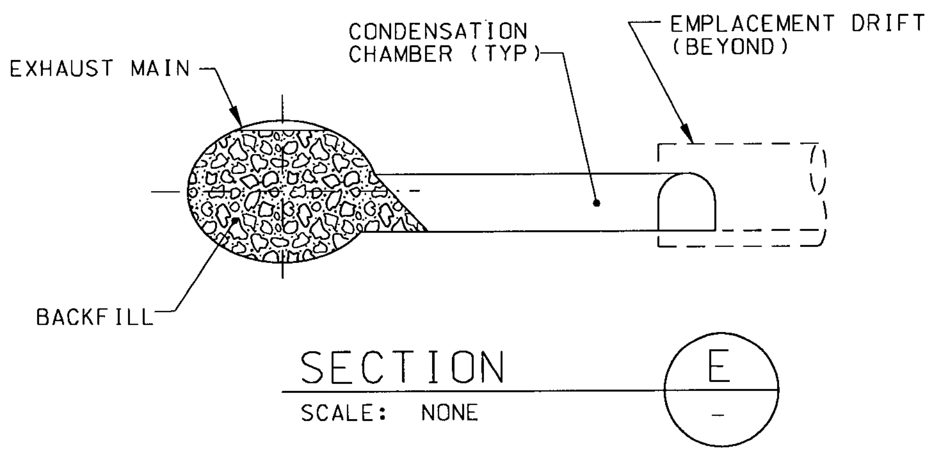
Figure 10. Typical Magma Bulkhead Keyway – Common Exhaust Main (Plan Views)

Note: Exhaust Main geometry developed from the common exhaust main for Panels 3 and 4 shown in the *Underground Layout Configuration* (Reference 2.1.9, Figure 5)



Dimension	Units (m)	Source
X[1]	< 7.62	Section 2.5.5
H	3.5	Section 2.5.7

1 Exhaust Main Common to Panel 3W and Panel 4



CAD FILE: drift keyways metric.fig

Figure 11. Typical Magma Bulkhead Keyway – Common Exhaust Main (Elevation Views)

6.6. CLOSURE DETAILS

The EIS (Reference 2.1.13, p. 2-40) requires the site to be reclaimed to a condition as close to preconstruction condition as practicable. This will involve the removal of all shaft surface facilities (head frames and ventilation fans), removal of much of the portal structure, removal of the surface facilities, and re-grading of the pads near the portals.

Surface monuments and markers will be constructed (Table 5, Requirements 3.1.1.16.9). The markers should be at the minimum, erected at the three portals and nine shaft locations. The markers should be of sufficient size and construction that they can not be easily destroyed by human intervention or the passage of time. The markers should have signage that notifies future generations of the radiological danger present by intrusion into the repository. The signage should be in several languages and in pictograph format to provide the greatest possibility that the warning will be understood far into the future.

As-built surveys of the subsurface area will be provided (Table 5, Requirements 3.1.1.16.10). In addition to submittal of these surveys to state and local governments, a copy be stored under each monument to increase the possibility that future generations will have this knowledge available.

7. RESULTS AND CONCLUSIONS

The repository boreholes located in areas UE-25 and USW are listed in Attachment II, Table II-1. They have been categorized according to the *Subsurface Facility Description Document* requirements 3.1.1.3.4 and 3.1.1.16.7 (refer to Section Section 2.9.2, Table 5) which invokes a 400 m perimeter around the repository where all boreholes are sealed. Table 6 lists all the boreholes that are governed by these requirements. In addition, Requirement 3.1.1.3.4 states that boreholes that reside outside the 400 m perimeter that are potential preferential pathways to the emplacement area will be sealed. Table 7 lists the borehole identified as potential preferential pathways.

In compliance with the *Subsurface Facility Description Document* requirement 3.1.1.3.4 (refer to Section 2.9.2, Table 5) all surface openings leading into the repository are sealed and capped at surface. The shafts are to be sealed between the Tiva Canyon welded tuff (TCw) and Paintbrush nonwelded tuff (PTn) formations with a plug similar to that shown in Figure 4. All ramps are to be sealed between the TCw and PTn formations with a plug similar to that shown in Figure 3. Finally, all portals are to be sealed with a structure similar to that shown in Figure 5.

A magma bulkhead design has been developed to satisfy the *Subsurface Facility Description Document* requirement 3.1.1.13.8 (refer to Section 2.9.2, Table 5) that require backfilling nonemplacement openings to prevent magma intrusion. The typical magma bulkhead has a v-shaped keyway that extends above the crown of the nonemepalcement drift. The keyway pitch is asymmetrical. The magma bulkhead has a sand core and a berm that acts as a reaction mass to a potential magma intrusion. The berm extends out from the sand core and is composed of unconsolidated crushed tuff. Conventional backfilling using crushed tuff is carried out moving away from the magma bulkhead (refer to Section 6.5). A magma bulkhead will be constructed in the every turnout drift and in the exhaust main at a location that will isolate the individual emplacement drift.

Three typical locations in the repository account for all the magma bulkhead configurations. The turnout drift is one such location. The typical magma bulkhead in the turnout is illustrated in Figures 6 and 7. The typical magma bulkhead that is constructed in the exhaust main that forms a three-way intersection with the emplacement drift is illustrated in Figures 8 and 9. The typical magma bulkhead that is constructed in the exhaust main that forms a four-way intersection with the opposing emplacement drift is illustrated in Figures 10 and 11. The nine, four-way intersections of opposing pairs of emplacement drifts that form intersections in the common exhaust main are 3-1W and 4-1 through opposing pairs 3-9W and 4-9.

All non-committed materials will be removed in compliance with the *Subsurface Facility Description Document* requirement 3.1.1.15.1 (refer to Section 2.9.2, Table 5) as noted in Section 6.3. Drip shields will be installed over waste packages in the emplacement drifts in compliance with the *Subsurface Facility Description Document* requirements 3.1.1.16.1 and 3.1.1.16.5 and 3.1.1.16.3 (refer to Section 2.9.2, Table 5). Backfill may be installed in place of or in addition to the drip shields (refer to Section 2.9.2, Table 5, Requirement 3.1.1.16.4). The surface area will be reclaimed at closure. Monuments and markers will be erected at closure to warn future generations of the radiological danger of intrusion into the repository (refer to Section 2.9.2, Table 5, Requirement 3.1.1.16.8).

ATTACHMENT I
SEAL CONSTRUCTION SEQUENCE FOR RAMPS AND SHAFTS

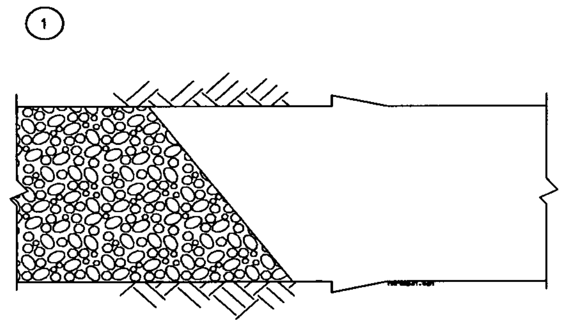


Figure I-1. Ramp Seal Sequence 1

Backfill the ramp and stop short of the seal location. Excavate a wedge shaped, circular slot around the ramp circumference.

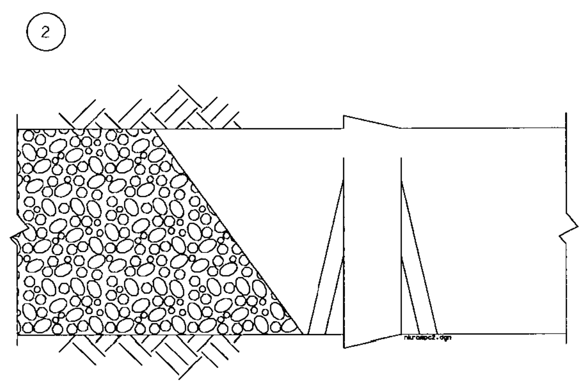


Figure I-2. Ramp Seal Sequence 2

Form most of the circular plug and leave a space at the top for access to the backside of the plug.

(3)

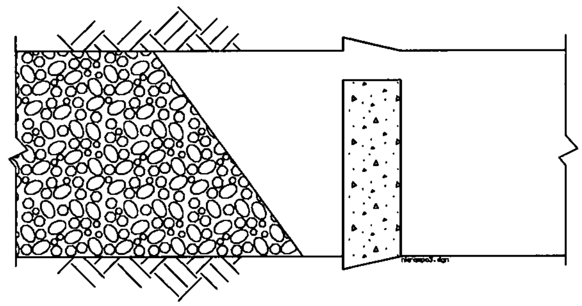


Figure I-3. Ramp Seal Sequence 3

Place concrete for most of the plug. Remove forms from both sides of the plug.

(4)

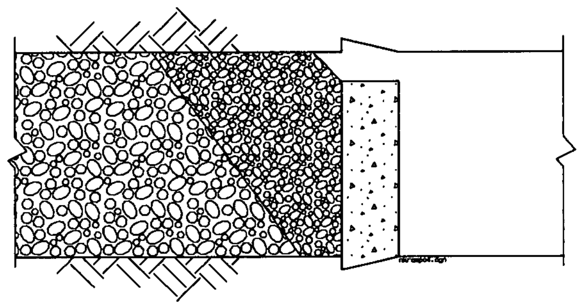


Figure I-4. Ramp Seal Sequence 4

Place granular backfill behind the plug using pneumatic placement techniques.

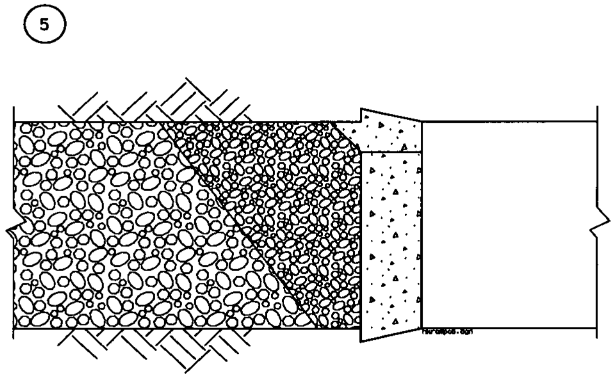


Figure I-5. Ramp Seal Sequence 5

Form and place the last part of the concrete plug.

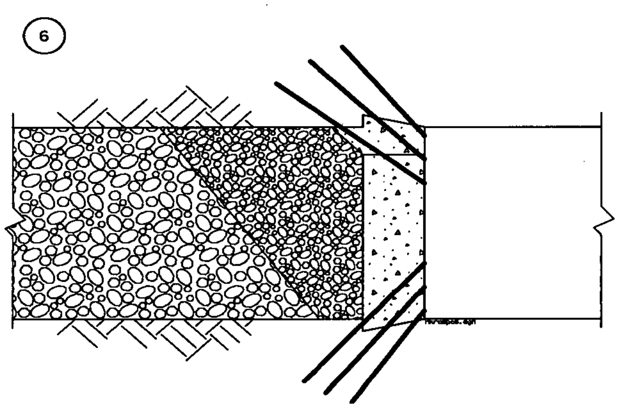


Figure I-6. Ramp Seal Sequence 6

Drill holes in a fan pattern around the circular plug and inject grout to fill cracks or voids in the surrounding rock mass.

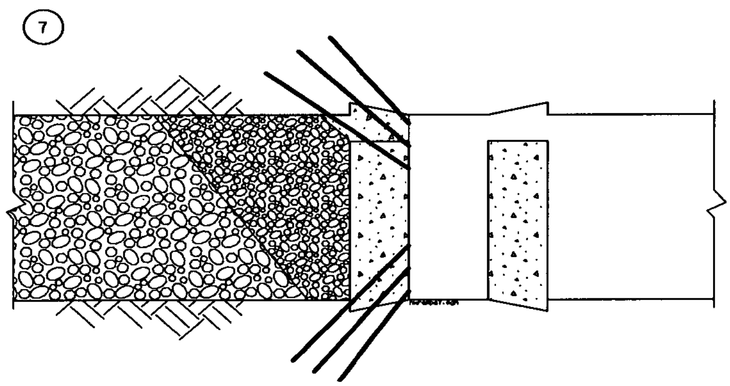


Figure I-7. Ramp Seal Sequence 7

Construct another plug using the same construction techniques as the first plug.

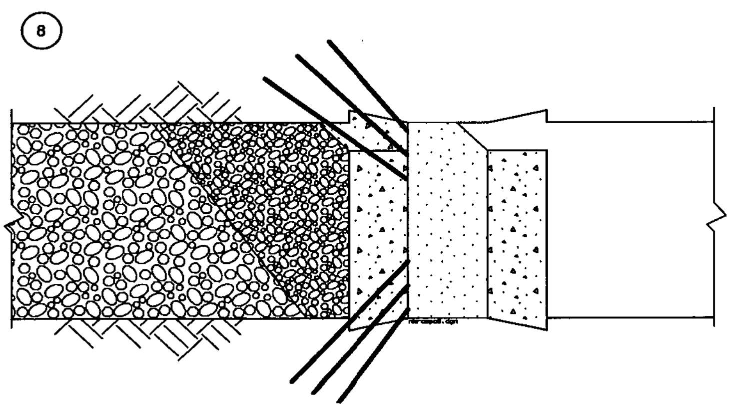


Figure I-8. Ramp Seal Sequence 8

Fill the space between the plugs with a bentonite/ sand mixture using an auger to emplace the mixture. The mixture may be placed slightly moist to improve its handling characteristics and to cut down on dust. The mixture should be placed in lifts with compaction between each lift.

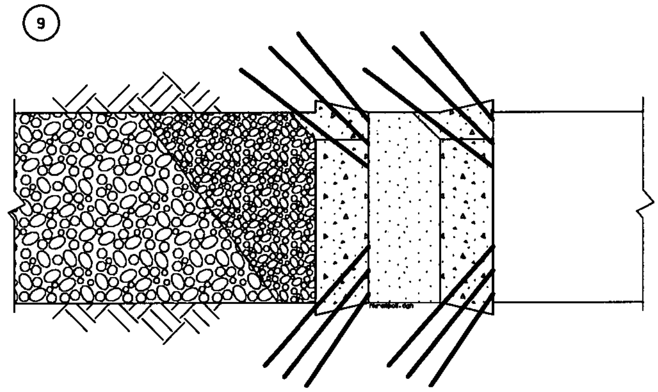


Figure I-9. Ramp Seal Sequence 9

Complete concrete plug construction. Drill holes and inject with grout to complete the seal. Compare this figure to Figure 3.

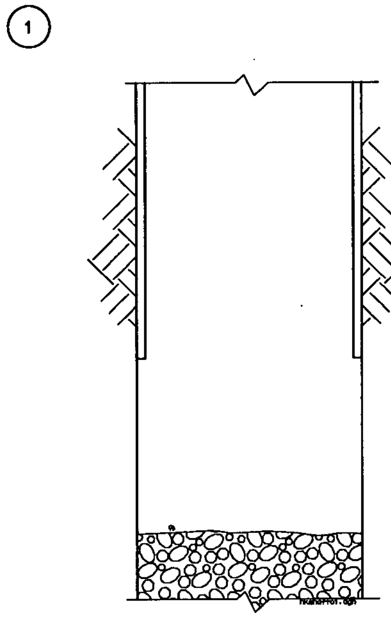


Figure I-10. Shaft Seal Sequence 1

Remove shaft liner. Place backfill as the liner is removed to support the ground.

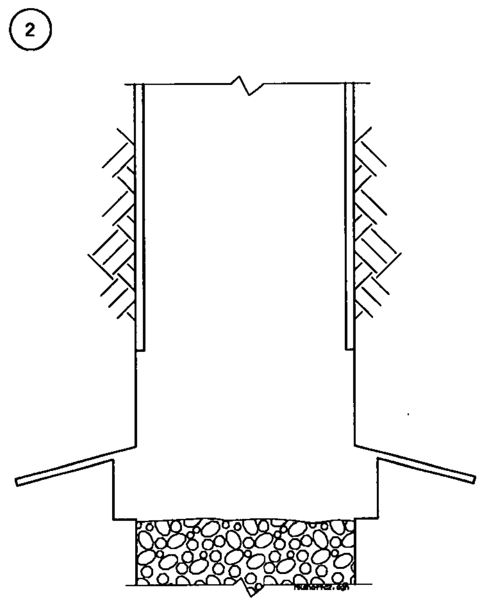


Figure I-11. Shaft Seal Sequence 2

Cut a circular slot around the shaft. Drainage dispersion holes are drilled in a fan pattern around the shaft.

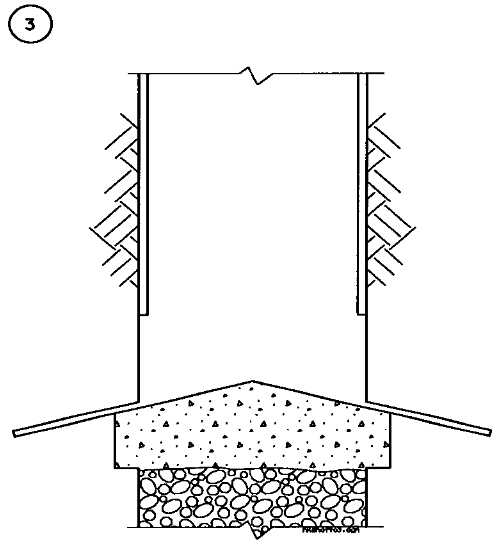


Figure I-12. Shaft Seal Sequence 3

Place concrete for the plug. Slope the top of the concrete towards the drainage dispersion holes. The backfill under the plug may settle over time, creating a gap between the concrete and the backfill. The concrete should be reinforced at the bottom to prevent cracking of the plug.

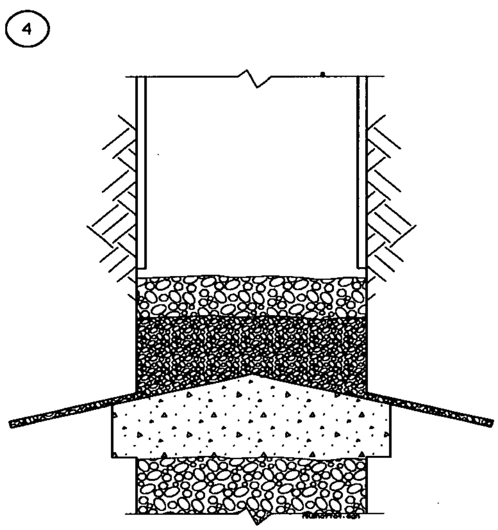


Figure I-13. Shaft Seal Sequence 4

Remove the shaft liner above the plug and place a gravel drain bed over the concrete plug. The drainage dispersion holes should be filled with gravel to ensure they remain functional. Continue with the liner removal/ backfilling operation to the surface. Compare this figure to Figure 4

ATTACHMENT II
BOREHOLE DISTANCES FROM EMPLACEMENT BLOCK

Table II-1. Boreholes Located Within the Vicinity of the Repository Layout
(All boreholes in areas UE-25 and USW, All measurements are in meters.)

Table II-1 was developed using Vulcan software (Reference 2.4.1) to extract borehole data from DTN: MO0101COV00396.000 (Reference 2.3.3), DTN: MO0103COV01031.000 (Reference 2.3.4), and DTN: MO0110MWDGFM26.002 (Reference 2.3.5)

BOREHOLES LOCATED WITHIN 400M OF EMPLACEMENT DRIFT BLOCKS

Borehole Identification (BHL ID)	Area	Easting	Northing	Collar Elevation (Elev)	Total Depth (T. Depth)
UE-25 UZN #10	UE-25	172134.487	234656.636	1231.001	30.175
UE-25 WT #18	UE-25	172168.034	235052.248	1336.246	622.708
USW G-1	USW	170993.466	234849.365	1325.928	1828.804
USW G-4	USW	171627.661	233418.593	1269.839	914.707
USW H-1	USW	171416.339	234774.137	1302.776	182.88
USW H-5	USW	170355.633	233670.549	1478.694	1219.202
USW NRG-7a	USW	171597.867	234355.131	1282.348	461.163
USW SD-12	USW	171177.737	232244.825	1323.694	660.29
USW SD-6	USW	170263.962	232386.505	1495.145	774.498
USW SD-6ST1	USW	170263.962	232386.505	1495.145	10
USW SD-7	USW	171066.371	231328.385	1363.068	815.372
USW SD-9	USW	171242.469	234086.411	1302.303	677.572
USW UZ-1	USW	170755.874	235085.814	1348.66	387.097
USW UZ-14	USW	170731.49	235095.701	1348.865	672.695
USW UZ-6	USW	170177.801	231566.225	1501.195	575.159
USW UZ-6s	USW	170094.19	231620.822	1508.507	158.192
USW UZ-7	USW	171575.807	231903.582	1270.753	63.094
USW UZ-7a	USW	171380.182	231859.614	1288.782	234.696
USW UZ-8	USW	171387.478	231881.084	1288.31	17.374
USW UZ-N24	USW	171314.536	234088.583	1288.246	22.86
USW UZ-N25	USW	171059.932	234218.066	1321.003	17.983
USW UZ-N26	USW	171000.229	234317.717	1336.188	10.668
USW UZ-N27	USW	170344.45	235174.816	1480.499	61.698
USW UZ-N31	USW	171527.134	232942.533	1265.483	58.705
USW UZ-N32	USW	171541.669	232959.906	1266.806	63.216
USW UZ-N33	USW	171051.721	234717.844	1319.531	22.86
USW UZ-N34	USW	171069.761	234744.857	1317.08	25.634
USW UZ-N35	USW	171392.412	232338.532	1293.991	53.34
USW UZ-N36	USW	171780.347	235885.04	1414.388	18.233
USW UZ-N42	USW	171559.652	233394.704	1273.853	12.192
USW UZ-N44	USW	171645.263	233536.075	1268.489	10.973
USW UZ-N46	USW	170611.513	235385.986	1371.804	30.175
USW UZ-N47	USW	170622.428	235296.184	1365.632	26.213
USW UZ-N48	USW	171424.073	231903.258	1283.54	10.668
USW UZ-N49	USW	171396.108	231911.03	1288.773	10.973
USW UZ-N50	USW	171575.902	231885.275	1271.863	6.096
USW UZ-N51	USW	171575.178	231911.126	1270.598	6.096
USW UZ-N52	USW	171574.988	231921.241	1271.582	7.62
USW UZ-N64	USW	170516.282	233394.4	1459.806	18.3
USW UZ-N65	USW	171461.811	231230.067	1332.686	15.24
USW UZ-N66	USW	171261.881	231171.108	1328.303	15.24
USW UZ-N70	USW	170738.634	234468.098	1384.35	10.668

BOREHOLES LOCATED WITHIN 400M OF EMPLACEMENT DRIFT BLOCKS (Continued)

Borehole Identification (BHL ID)	Area	Easting	Northing	Collar Elevation (Elev)	Total Depth (T. Depth)
USW UZ-N71	USW	170202.471	231961.094	1501.039	15.85
USW UZ-N72	USW	170275.623	231975.096	1482.672	9.144
USW UZ-N73	USW	170366.948	231969.4	1457.441	9.144
USW UZ-N74	USW	170249.467	232063.583	1494.523	11.278
USW UZ-N75	USW	170406.706	232094.158	1462.631	11.278
USW UZ-N76	USW	170404.096	232062.04	1461.68	12.192
USW UZ-N93	USW	170176.581	231521.685	1500.847	12.192
USW UZ-N94	USW	170150.883	231564.129	1501.405	9.144
USW UZ-N95	USW	170131.357	231617.603	1502.271	6.096
USW UZ-N96	USW	170201.689	231479.471	1491.414	10.668
USW UZ-N98	USW	171323.47	234085.802	1287.392	22.86
USW WT-2	USW	171274.778	231850.108	1300.959	627.889

BOREHOLES LOCATED WITHIN 400-800M OF EMPLACEMENT DRIFT BLOCKS

Borehole Identification (BHL ID)	Area	Easting	Northing	Collar Elevation (Elev)	Total Depth (T. Depth)
UE-25 a #4	UE-25	172051.372	234078.448	1250.304	152.4
UE-25 a #5	UE-25	172137.726	233768.79	1237.664	148.438
UE-25 a #6	UE-25	172060.211	233446.749	1235.439	152.4
UE-25 NRG #5	UE-25	172142.202	234053.226	1251.712	411.481
UE-25 UZN #1	UE-25	172280.753	234492.177	1217.81	15.24
USW H-3	USW	170216.472	230594.463	1483.303	1219.202
USW H-4	USW	171880.531	232149.708	1248.515	1220.422
USW NRG-6	USW	171964.542	233698.705	1247.281	335.281
USW UZ-N37	USW	171820.219	233934.201	1256.12	82.702
USW UZ-N38	USW	171707.557	233924.2	1263.975	27.249
USW UZ-N40	USW	171975.038	233530.969	1243.495	10.668
USW UZ-N41	USW	171761.563	233436.957	1255.111	11.278
USW UZ-N43	USW	171683.096	233476.505	1264.77	13.716
USW UZ-N45	USW	171733.579	233470.333	1258.887	13.716
USW UZ-N53	USW	171979.858	231677.801	1235.619	71.537
USW UZ-N55	USW	171983.211	231801.74	1240.721	77.816
USW UZ-N57	USW	170941.269	230174.6	1275.182	36.241
USW UZ-N58	USW	170951.137	230197.727	1273.832	36.21
USW UZ-N59	USW	170959.119	230222.378	1273.369	36.21
USW UZ-N61	USW	170960.814	230239.047	1274.728	36.241
USW UZ-N62	USW	170171	230772.219	1488.021	18.288
USW UZ-N80	USW	169835.319	230927.61	1320.162	15.85
USW WT-24	USW	171398.498	236739.567	1493.608	1097.282

BOREHOLES LOCATED WITHIN 800-1200M OF EMPLACEMENT DRIFT BLOCKS

Borehole Identification (BHL ID)	Area	Easting	Northing	Collar Elevation (Elev)	Total Depth (T. Depth)
UE-25 a #7	UE-25	172355.086	233553.467	1220.903	305.41
UE-25 NRG #4	UE-25	172767.082	233806.509	1249.524	221.285
UE-25 UZ #16	UE-25	172168.911	231811.57	1219.349	517.003
UE-25 UZ #4	UE-25	172559.855	234305.011	1200.93	125.273
UE-25 UZ #5	UE-25	172558.636	234267.653	1204.825	123.444

BOREHOLES LOCATED WITHIN 800-1200M OF EMPLACEMENT DRIFT BLOCKS (Continued)					
Borehole Identification (BHL ID)	Area	Easting	Northing	Collar Elevation (Elev)	Total Depth (T. Depth)
UE-25 UZN #12	UE-25	172729.039	234285.446	1191.237	15.24
UE-25 UZN #18	UE-25	172287.516	233621.381	1224.963	18.593
UE-25 UZN #19	UE-25	172081.528	232773.044	1226.972	12.192
UE-25 UZN #2	UE-25	172551.797	234271.692	1203.069	15.24
UE-25 UZN #20	UE-25	172084.157	232794.704	1227.542	12.497
UE-25 UZN #21	UE-25	172087.796	232808.782	1227.731	12.802
UE-25 UZN #22	UE-25	172091.91	232831.414	1228.133	28.956
UE-25 UZN #23	UE-25	172073.87	232859.665	1232.541	10.668
UE-25 UZN #28	UE-25	172309.824	232590.926	1206.681	7.925
UE-25 UZN #29	UE-25	172265.17	232445.155	1211.083	10.668
UE-25 UZN #3	UE-25	172553.55	234279.331	1201.164	4.572
UE-25 UZN #30	UE-25	172283.325	232272.753	1206.867	10.668
UE-25 UZN #4	UE-25	172555.893	234289.37	1201.679	9.144
UE-25 UZN #5	UE-25	172558.046	234297.238	1201.99	15.24
UE-25 UZN #56	UE-25	172358.687	231768.765	1207.087	18.288
UE-25 UZN #6	UE-25	172558.846	234302.21	1200.539	13.716
UE-25 UZN #63	UE-25	172568.847	234342.063	1201.588	18.288
UE-25 UZN #7	UE-25	172560.236	234307.83	1200.875	13.716
UE-25 UZN #8	UE-25	172561.837	234313.583	1200.408	13.716
UE-25 UZN #9	UE-25	172564.713	234325.337	1201.259	12.192
UE-25 UZN #97	UE-25	172310.071	232591.688	1206.715	18.288
US-25 #1	US-25	172341.199	232450.242	1297.993	16.154
USW Seismic-14	USW	170914.123	237251.689	1547.198	60.96
USW Seismic-15	USW	170942.564	237198.597	1543.483	60.96
USW Seismic-16	USW	170971.463	237145.009	1539.658	60.96
USW Seismic-17	USW	171000.439	237091.174	1536.055	60.96
USW Seismic-18	USW	171029.109	237037.719	1532.419	60.96
USW Seismic-19	USW	171057.646	236983.808	1528.395	60.96
USW SRS-208.5a	USW	169702.007	230904.445	1293.574	10
USW SRS-208.5b	USW	169702.007	230904.445	1293.574	10
USW SRS-211a	USW	169370.384	232305.919	1267.971	10
USW SRS-211b	USW	169370.384	232305.919	1267.971	10
USW SRS-302a	USW	169370.384	232305.919	1267.971	10
USW SRS-302b	USW	169370.384	232305.919	1267.971	10
USW UZ-N15	USW	170551.715	237162.478	1556.864	18.258
USW UZ-N16	USW	170574.346	237180.842	1559.049	18.288
USW UZ-N17	USW	170686.856	237203.188	1562.332	18.233
USW UZ-N54	USW	171987.459	231731.35	1232.635	74.591
USW UZ-N78	USW	169549.207	230904.274	1274.682	9.144
USW UZ-N79	USW	169570.981	230957.69	1266.267	9.754
USW UZ-N81	USW	169345.809	230980.207	1238.835	21.336
USW UZ-N83	USW	169575.591	231838.945	1267.135	21.336
USW UZ-N84	USW	169435.001	231867.025	1253.179	13.716
USW UZ-N86	USW	169609.5	231836.03	1271.717	9.144
USW UZ-N87	USW	169434.773	231866.167	1253.163	13.716
USW UZ-N88	USW	169637.16	231891.676	1280.665	9.144

BOREHOLES LOCATED WITHIN 800-1200M OF EMPLACEMENT DRIFT BLOCKS (Continued)					
Borehole Identification (BHL ID)	Area	Easting	Northing	Collar Elevation (Elev)	Total Depth (T. Depth)
USW UZ-N89	USW	169343.79	231834.773	1246.47	13.716
USW UZ-N90	USW	169343.39	231834.163	1246.433	13.716

BOREHOLES LOCATED GREATER THAN 1200M FROM EMPLACEMENT DRIFT BLOCKS					
Borehole Identification (BHL ID)	Area	Easting	Northing	Collar Elevation (Elev)	Total Depth (T. Depth)
UE-25 a #1	UE-25	172623.787	233142.291	1199.497	762.306
UE-25 a #3	UE-25	183776.689	234488.882	1386.507	771.146
UE-25 b #1	UE-25	172644	233246.933	1200.695	1220.117
UE-25 c #1	UE-25	173638.983	230763.551	1130.35	914.402
UE-25 c #2	UE-25	173624.772	230688.227	1132.057	914.402
UE-25 c #3	UE-25	173600.693	230706.896	1132.154	914.402
UE-25 h #1	UE-25	175096.463	228098.356	1038.636	121.92
UE-25 J-11	UE-25	186467.26	225847.727	1049.447	405.08
UE-25 J-11Prime	UE-25	186483.662	225824.01	1049.105	67.056
UE-25 J-12	UE-25	177092.831	223573.762	953.977	347.168
UE-25 J-13	UE-25	176677.045	228357.227	1011.146	1066.193
UE-25 JF #3	UE-25	177143.847	222771.26	944.4	395.631
UE-25 NRG #1	UE-25	173676.409	233281.899	1144.404	45.72
UE-25 NRG #2	UE-25	173481.058	233405.258	1158.355	89.611
UE-25 NRG #2a	UE-25	173431.871	233385.808	1152.314	81.077
UE-25 NRG #2b	UE-25	173496.946	233405.715	1158.669	100.584
UE-25 NRG #2c	UE-25	173489.383	233407.678	1158.599	46.025
UE-25 NRG #2d	UE-25	173471.876	233423.965	1155.819	51.877
UE-25 NRG #3	UE-25	173223.102	233553.658	1165.353	100.584
UE-25 ONC #1	UE-25	173155.055	231422.073	1162.848	469.393
UE-25 p #1	UE-25	174188.805	230481.858	1113.903	1805.334
UE-25 PSF #7	UE-25	174087.478	233140.653	1109.782	10
UE-25 PTH #1	UE-25	174101.727	233156.35	1109.557	10
UE-25 PTH #2	UE-25	174086.088	233156.312	1110.002	10
UE-25 PTH #3	UE-25	174071.114	233156.274	1110.169	10
UE-25 PTH #4	UE-25	174070.523	233125.375	1109.355	10
UE-25 PTH #5	UE-25	174086.164	233125.832	1109.34	10
UE-25 PTH #6	UE-25	174101.804	233125.87	1108.935	10
UE-25 RF #1	UE-25	174007.658	232316.148	1124.288	44.196
UE-25 RF #10	UE-25	173806.166	233266.079	1118.527	18.288
UE-25 RF #11	UE-25	173868.517	233361.9	1117.216	23.774
UE-25 RF #13	UE-25	173955.84	233324.879	1118.932	93.513
UE-25 RF #14	UE-25	174061.094	233266.568	1112.986	167.64
UE-25 RF #15	UE-25	173804.882	233408.273	1121.965	100.584
UE-25 RF #16	UE-25	173880.412	233189.395	1119.237	137.922
UE-25 RF #17	UE-25	174053.913	233500.389	1119.344	203.302
UE-25 RF #18	UE-25	173927.436	233026.876	1109.578	91.44
UE-25 RF #19	UE-25	174158.109	233440.816	1116.122	198.12
UE-25 RF #2	UE-25	173838.494	231282.95	1114.915	15.85
UE-25 RF #20	UE-25	173979.219	233366.734	1119.002	91.44
UE-25 RF #21	UE-25	173961.65	233446.455	1119.539	91.44

BOREHOLES LOCATED GREATER THAN 1200M FROM EMPLACEMENT DRIFT BLOCKS Continued)					
Borehole Identification (BHL ID)	Area	Easting	Northing	Collar Elevation (Elev)	Total Depth (T. Depth)
UE-25 RF #22	UE-25	173978.201	233540.117	1121.413	60.96
UE-25 RF #23	UE-25	173878.089	233267.391	1119.831	48.494
UE-25 RF #24	UE-25	173901.629	233582.213	1123.032	38.1
UE-25 RF #25	UE-25	173927.269	233467.559	1120.612	60.96
UE-25 RF #26	UE-25	173913.044	233248.042	1118.859	80.742
UE-25 RF #28	UE-25	173768.312	233327.979	1121.858	30.419
UE-25 RF #29	UE-25	173991.173	233482.894	1119.444	131.064
UE-25 RF #3	UE-25	174071.305	233347.593	1114.869	46.025
UE-25 RF #3b	UE-25	174061.284	233384.532	1115.988	33.833
UE-25 RF #4	UE-25	174365.246	232285.992	1108.578	93.269
UE-25 RF #5	UE-25	173156.198	231404.128	1162.418	37.186
UE-25 RF #7	UE-25	174093.288	234332.157	1144.855	45.72
UE-25 RF #7a	UE-25	173818.282	234321.184	1144.983	46.634
UE-25 RF #8	UE-25	173367.596	233364.91	1153.884	39.014
UE-25 RF #9	UE-25	173932.239	233460.694	1119.136	32.309
UE-25 SPT #1	UE-25	172583.992	233199.861	1202.713	10
UE-25 SRS #307r	UE-25	174028.347	230492.355	1115.875	10
UE-25 SRS #311	UE-25	176133.604	230150.978	1022.911	10
UE-25 UZN #13	UE-25	173204.528	234094.622	1164.786	19.812
UE-25 UZN #14	UE-25	173197.784	234077.115	1165.673	16.764
UE-25 UZN #39	UE-25	188146.635	230165.018	1148.556	38.1
UE-25 UZN #60	UE-25	172690.005	231574.683	1186.601	10.668
UE-25 UZN #85	UE-25	176043.155	228818.637	1017.138	24.384
UE-25 UZNC #1	UE-25	172565.609	233072.34	1197.443	1.524
UE-25 UZNC #2	UE-25	172565.094	233071.749	1197.473	1.524
UE-25 WT #12	UE-25	172825.546	225469.146	1074.654	398.679
UE-25 WT #13	UE-25	176431.471	230699.067	1032.012	351.74
UE-25 WT #14	UE-25	175324.416	232151.804	1075.846	399.289
UE-25 WT #15	UE-25	176725.299	233512.929	1082.822	414.529
UE-25 WT #16	UE-25	173856.782	236043.746	1210.442	520.904
UE-25 WT #17	UE-25	172581.763	228119.33	1123.827	441.961
UE-25 WT #3	UE-25	174768.155	227379.902	1029.991	348.082
UE-25 WT #4	UE-25	173138.424	234242.907	1169.118	481.585
UE-25 WT #5	UE-25	175031.674	232205.239	1084.49	405.385
UE-25 WT #6	UE-25	172067.145	237920.079	1314.687	383.439
USW G-2	USW	170841.942	237386.621	1553.651	2012.294
USW G-3	USW	170226.054	229447.689	1480.139	1533.452
USW GA-1	USW	170458.769	237551.594	1580.986	167.945
USW GU-3	USW	170231.636	229420.371	1480.325	1533.452
USW H-6	USW	168882.379	232654.134	1301.739	1219.812
USW Seismic-1	USW	170820.187	237427.121	1555.026	60.96
USW Seismic-10	USW	170567.85	237897.562	1576.188	60.96
USW Seismic-11	USW	170540.056	237950.921	1578.684	60.96
USW Seismic-12	USW	170511.462	238003.995	1580.452	60.96
USW Seismic-13	USW	170885.185	237305.792	1550.085	60.96
USW Seismic-2	USW	170798.87	237467.279	1556.537	60.96

BOREHOLES LOCATED GREATER THAN 1200M FROM EMPLACEMENT DRIFT BLOCKS (Continued)					
Borehole Identification (BHL ID)	Area	Easting	Northing	Collar Elevation (Elev)	Total Depth (T. Depth)
USW Seismic-3	USW	170770.123	237520.943	1557.976	60.96
USW Seismic-4	USW	170741.072	237574.588	1558.756	60.96
USW Seismic-5	USW	170712.573	237628.385	1560.978	60.96
USW Seismic-7	USW	170655.213	237735.941	1567.193	60.96
USW Seismic-8	USW	170626.296	237789.472	1570.644	60.96
USW Seismic-9	USW	170597.549	237842.164	1573.286	60.96
USW SP-5a	USW	164181.877	229043.904	1026.843	10
USW SP-5b	USW	164215.558	229035.37	1025.989	10
USW SR-1	USW	170486.887	220010.529	930.041	10
USW SR-2	USW	170485.135	220008.033	929.992	10
USW SR-3	USW	170458.712	220012.091	928.621	10
USW SRS-1	USW	151947.371	218610.922	811.684	61.356
USW SRS-11	USW	159317.145	224700.534	913.792	61.661
USW SRS-13	USW	161045.879	225707.443	933.394	10
USW SRS-201	USW	162768.403	226715.266	967.132	60.96
USW SRS-203	USW	164540.818	227698.857	1025.349	46.33
USW SRS-207	USW	167932.944	229775.464	1152.756	59.192
USW SRS-3	USW	153317.755	220020.625	813.818	61.692
USW SRS-300	USW	164073.559	233632.716	1128.677	61.478
USW SRS-5	USW	154649.734	221465.075	833.934	60.96
USW SRS-7	USW	156033.833	222772.67	900.381	10
USW SRS-9	USW	157585.573	223696.52	895.809	10
USW TW-3	USW	224618.847	228658.065	1059.792	566.929
USW TW-5	USW	185206.604	209468.428	929.642	282.245
USW UNK-2	USW	168796.692	230301.264	1196.62	10
USW UZ-13	USW	170227.883	229195.752	1467.953	131.064
USW UZ-N11	USW	170389.923	237919.412	1591.605	25.725
USW UZ-N67	USW	171846.355	229708.579	1194.276	7.62
USW UZ-N68	USW	171909.411	229808.592	1195.809	16.764
USW UZ-N69	USW	172030.074	229960.63	1193.892	10.668
USW UZ-N77	USW	168980.639	230285.052	1189.622	15.24
USW UZ-N82	USW	169069.831	230886.081	1211.345	12.192
USW VH-1	USW	162649.226	226575.477	963.185	762.306
USW VH-2	USW	160405.741	228088.716	974.472	1219.202
USW WT-1	USW	171828.048	229802.02	1200.838	514.808
USW WT-10	USW	168646.882	228226.029	1123.425	430.378
USW WT-11	USW	170193.555	225269.387	1093.96	440.742
USW WT-7	USW	168826.505	230298.368	1196.72	490.729

Source: DTN: MO0101COV00396.000 (Reference 2.3.3), DTN: MO0103COV01031.000 (Reference 2.3.4), and DTN: MO0110MWDGFM26.002 (Reference 2.3.5)

ATTACHMENT III
EFFECTS OF SHORTENING THE INTAKE TURNOUT ON WASTE PACKAGE CONDENSATION

THE EFFECTS OF SHORTENING THE INTAKE TURNOUT ON WASTE PACKAGE CONDENSATION

The Yucca Mountain Project (YMP) is currently considering reducing the length of the open-end turnout (condensation chamber) in the intake portion of the emplacement drift through the construction of magma plugs. *The In-Drift Natural Convection and Condensation Model* (Reference 2.1.10) analyzed seven emplacement drifts located throughout the repository (named Choices 1 through 7) (Figure III-1), and considered the intake turnout extended linearly 60 m from the edge of the last waste package. The design modification would reduce this length to 30 m. The purpose of this appendix is to:

(1) present model results from the *In-Drift Natural Convection and Condensation Model* (Reference 2.1.10) in this zone,

(2) summarize the results of *Total System Performance Analysis* (TSPA) (Reference 2.1.16) calculations in which the condensation rates were increased by a factor of two, and

(3) describe TSPA sensitivity to condensation effects.

The *In-Drift Natural Convection and Condensation Model* (Reference 2.1.10) analyzed for the seven drift choices at 10,000 years emplacement with combinations of low and high invert evaporation and low and high axial dispersion. The original results presented the drift wall condensation in the portion of the emplacement drift that was loaded with waste packages. Figures III-2 through III-5 present results of the condensation rate for the high invert evaporation case for Choices 3 and 7 for low and high axial dispersion extending out into the unheated portion of the emplacement drifts. The two drifts consist of a 400 m long drift on the edge of the repository where temperatures are lower, and a 700 m drift in the south central portion of the repository that is more representative of the general repository conditions. The results show that at 10,000 years (time selected by TSPA for postclosure condensation analysis) that a general condensation pattern forms within the drift and a larger condensation rate in the unheated turnout section of the drift (the cold trap effect).

The *In-Drift Natural Convection and Condensation Model* (Reference 2.1.10) presents a discussion of the uncertainties associated with the calculation of these condensation rates. A major uncertainty is the axial dispersion down the drift. The axial dispersion is affected by:

(1) hot/cold package arrangement in the drift that creates package-scale axial flow patterns.

(2) axial temperature profile that creates drift-scale flow patterns,

(3) barometric pumping that creates drift-scale flow patterns, and

(4) natural circulation that creates drift-scale and repository-scale flow patterns. The progressive inclusion of these flow field contributors results in progressively larger

calculated values of the axial dispersion coefficient, and based upon results would increase condensation rates in the unheated portions of the repository and reduce condensation in the heated portion of the drifts.

As noted in the *In-Drift Natural Convection and Condensation Model* (Reference 2.1.10), the energy deposited in the unheated regions of the drifts will heat the surrounding rock just like the waste packages heat the rock that surrounds them. The equivalent average line power of the condensate (W/m) was also tabulated in Tables 6.3.7-8 through 6.3.7-15 of the *In-Drift Natural Convection and Condensation Model* (Reference 2.1.10). In that analysis, it was found that the equivalent source strength due to the movement of condensate was actually higher than the line source strength in the emplacement region in isolated areas and at specific times. These equivalent line average power values were thought to be overestimated because the length of unheated drift available for condensation was greater than the length represented in the model as discussed in the *In-Drift Natural Convection and Condensation Model* (Reference 2.1.10, Section 6.3.7.2.4).

The effect of backfilling or plugging on the temperature distribution has not been explicitly evaluated in this analysis. However, two impacts of axial transport of vapor were discussed in the *In-Drift Natural Convection and Condensation Model* (Reference 2.1.10, Section 6.3.7.2.4) have some relevance to this issue. These included the flattening of the axial temperature profiles, and the decrease in the temperature differences that drive the evaporation and condensation processes. The first impact will tend to increase the condensation rate in the emplacement region. The second impact was thought to decrease the temperature differences that drive the evaporation and condensation processes; this will tend to decrease the condensation rate in the emplacement region.

The net impact of the redistribution of energy due to backfilling or plugging of the ends of the drift cannot be quantitatively determined based on the existing calculations. Qualitatively, the effect of backfilling or plugging the ends of the drift with a backfill or plug with a lower thermal conductivity would result in somewhat higher temperatures in the unheated section of the drift, and possibly in the emplacement drift itself. However, it is not thought that such temperature variations would be that significant since the overall temperature environment depends dominantly on heat transfer by conduction through the surrounding rock mass.

Further, as articulated in the *In-Drift Natural Convection and Condensation Model* (Reference 2.1.10, Section 6.3.7.2.4), the temperature is a function of the entire power history rather than the instantaneous value when condensation occurs. Therefore, the fractional change in condensation rate within the emplacement region is still likely to be less than the fraction of the decay heat that is transported to the access and exhaust regions. This is within the uncertainty bounds of the current evaluation.

Table III-1 presents the integrated condensation rates on the drift wall for a case within the emplacment drift in which the vapor pressure across the drip shields are equalized (the well mixed case), in the intake turnout extending 60 m, and 30 m in the intake turnout furthest away from the heated portions of the emplacement drift at a time of

10,000 years for the case of high invert evaporation. The tabulated results are obtained from DTN: SN0408T0509903.008 (Reference 2.3.6) and are accessed in the following manner. The DTN is accessed in the Technical Data Management System (TDMS). The link to the System Performance Assessment Dataset is then accessed. If the Download Files Button is pressed, the TDMS navigates to the File Transfer Protocol (FTP) site: ftp://sol.ymp.gov/pub11/SN0408T0509903.008/InDrift_Condensation_Corrected/. The FTP directory contains one compressed file entitled ColdtrapHandbook_V.zip. The software WinZip can be used to extract the compressed MathCad Files and EXCEL files that are organized into a series of input files and output folders. In the extracted set of files and directories, the folder Mixed_HighInvertTransport is located. This folder contains the MathCad and EXCEL output files for the case of a well-ventilated drip shield with high invert evaporation. The MathCad files Choice3Figures.mcd and Choice7Figures.mcd contain the driftwall condensation rates plotted as a function of drift position for these two drift choices. These results are used to perform spatial integrations over the emplacement drift and the turnout.

The integrated condensation rates from the analysis show that the condensation rates range from 1010 to 5670 kg/yr over the intake turnout length of 60 m for the shorter Choice 3 drift, and 1270 to 6800 kg/yr for the longer Choice 7 drift at 10,000 years. For the 30 m extending away in the condensation chamber, the condensation rates range from 110 to 780 kg/yr for the shorter Choice 3 drift, and 330 to 2100 kg/yr for the longer Choice 7 drift at 10,000 years.

The integrated condensation rates for the cases shown generally show that the integrated condensation rate in the intake turnout is approximately one-half to three quarters the integrated condensation rate in the emplacement drift. For the one case of Choice 7 with a high axial dispersion, and a low percolation rate, the intake turnout integrated condensation rate (4610 kg/yr) is much larger than the value within the emplacement drift (160 kg/yr). However, in this case if all of this condensation were forced into the emplacement drift by shortening the condensation chamber, the value would not exceed the highest integrated condensation rate for several of the low dispersion cases evaluated (Compare 6410 kg/yr and 12700 kg/yr in the emplacement drift for the low dispersion case for medium and high percolation in Table III-1 with the value of 4610 kg/yr). The integrated condensation rates in the 30m portion of the condensation chamber furthest away from the emplacement drift ranges from one-tenth to one third of the amount of condensation in the 60-m length.

After completion of the *In-Drift Natural Convection and Condensation Model,* the TSPA evaluated issues regarding the estimates of indrift condensation by performing an impact analysis in the *Total System Performance Assessment Model/Analysis for the License Application, Volume II* (Reference 2.1.16, Section 7.5.3.2). The impact analysis identified such issues as the estimates of driftwall condensation versus invert condensation; the effects of barometric pumping and repository natural convection; the amount of axial heat transfer by movement of water vapor or radiant heat transfer between packages; and the partitioning of water at the invert surface. To address these issues, and to evaluate the impact of condensation on mean annual dose, the condensation flux was increased by a factor of two and applied to all locations within the entire repository.

The impact analysis shows that there is no significant difference between the base-case for the seismic model and the case with increased condensation flux. This is because the increase in driftwall condensation will not contact the waste packages, and will flow into the invert and the increase in moisture content will increase diffusion rates within the invert. The contribution to waste isolation in the invert is small, and is not significantly impacted by this condensate.

The evaluation of condensation rates in the condensation chamber and the impact analysis results presented above show that shortening the turnout drift by 30 m would not likely result in condensation that would increase the probability weighted dose.

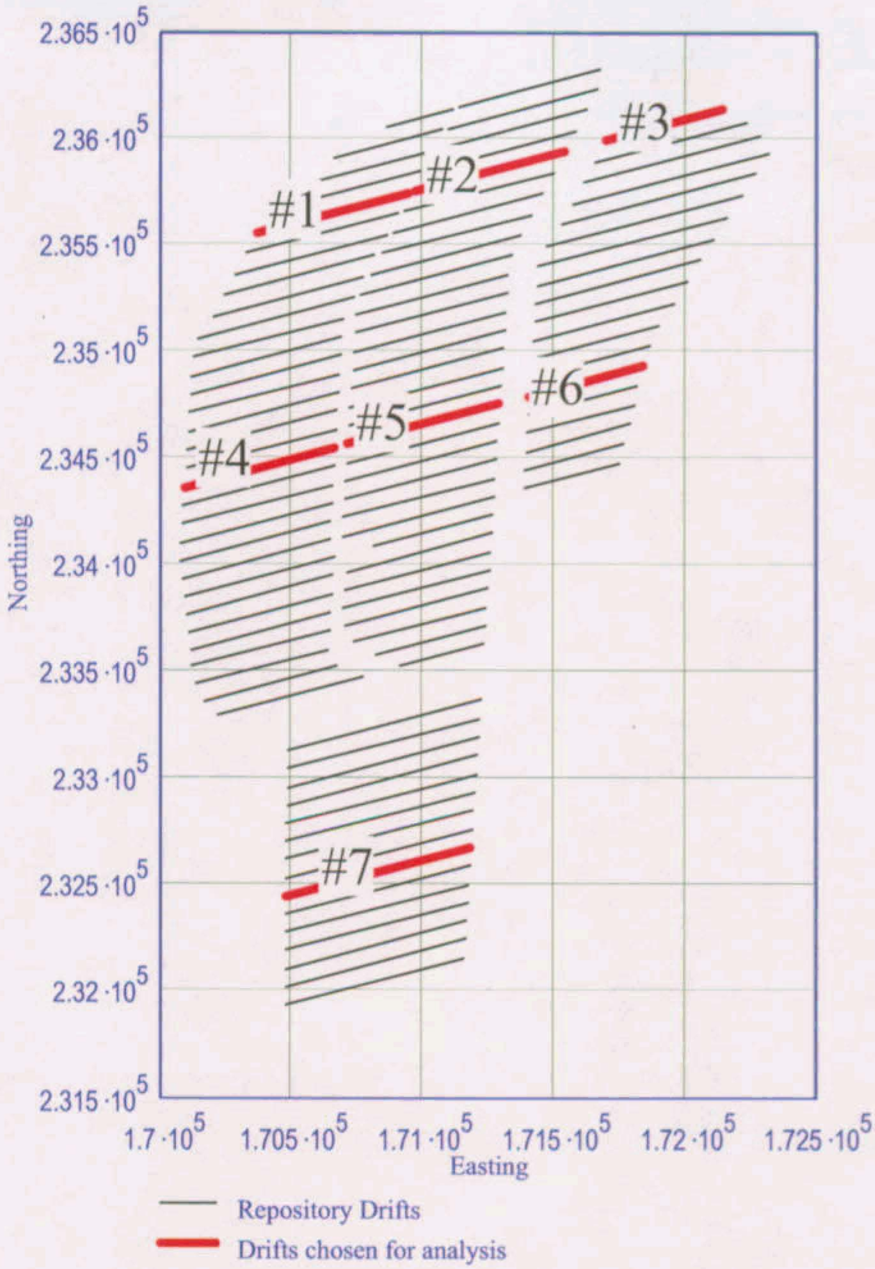


Figure III-1 Locations of Storage Drifts Chosen for Analysis

Source: DTN: SN0408T0509903.008 (Reference 2.3.6) Compressed File: ColdtrapHandbook_V.zip , Coordinates replotted on figure as obtained from File: Repository Temperature Field 3.mcd)

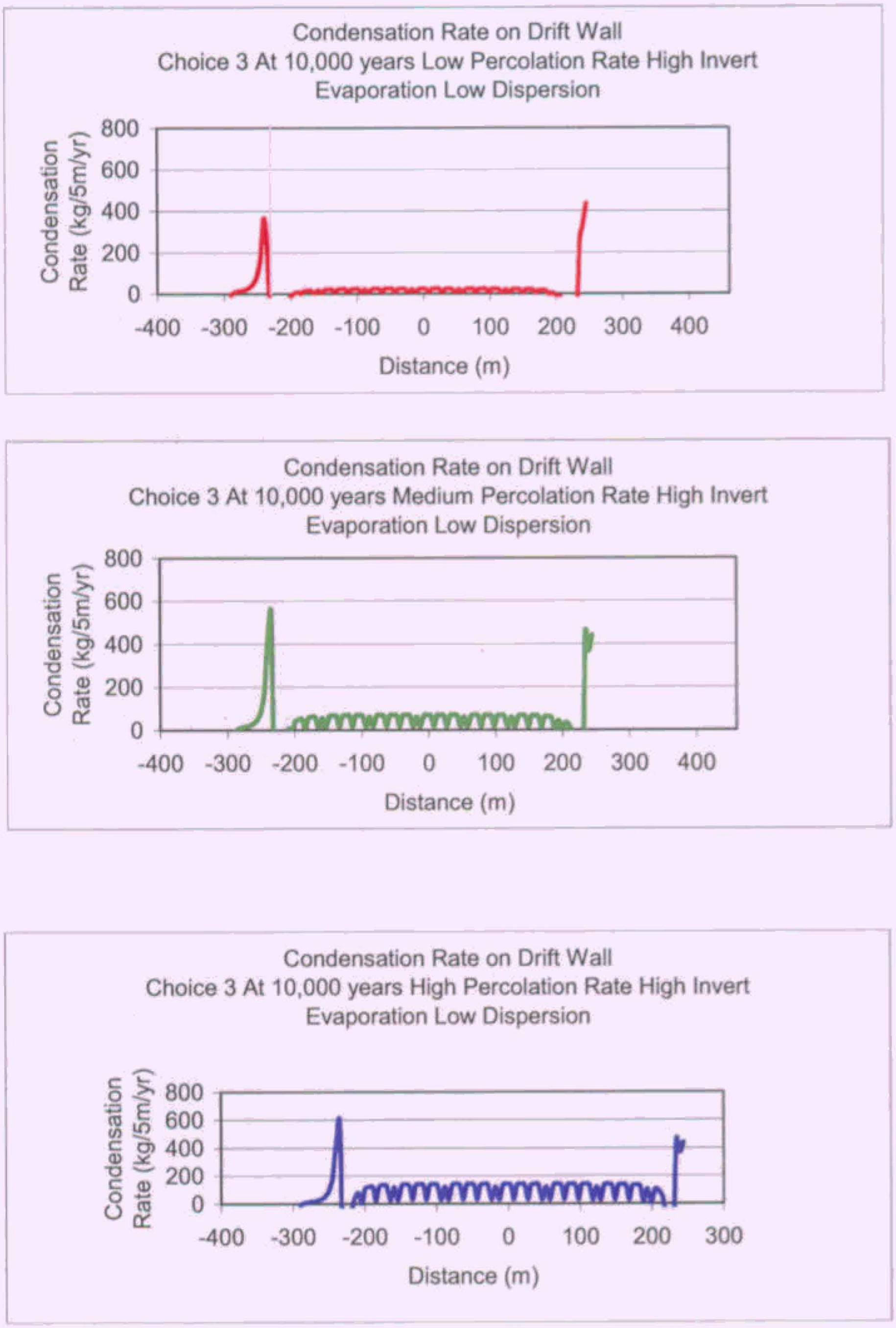


Figure III-2. Condensation Rates for the Choice 3 Drift with High Invert Evaporation and Low Axial Dispersion After 10000 years

Source: DTN: SN0408T0509903.008 (Reference 2.3.6) Compressed File: ColdtrapHandbook_V.zip Folder: Mixed_HighInvertTransport Files: Choice3Figures.mcd.
Note that zero is the center of the drift and that the intake turnout is on the left side.

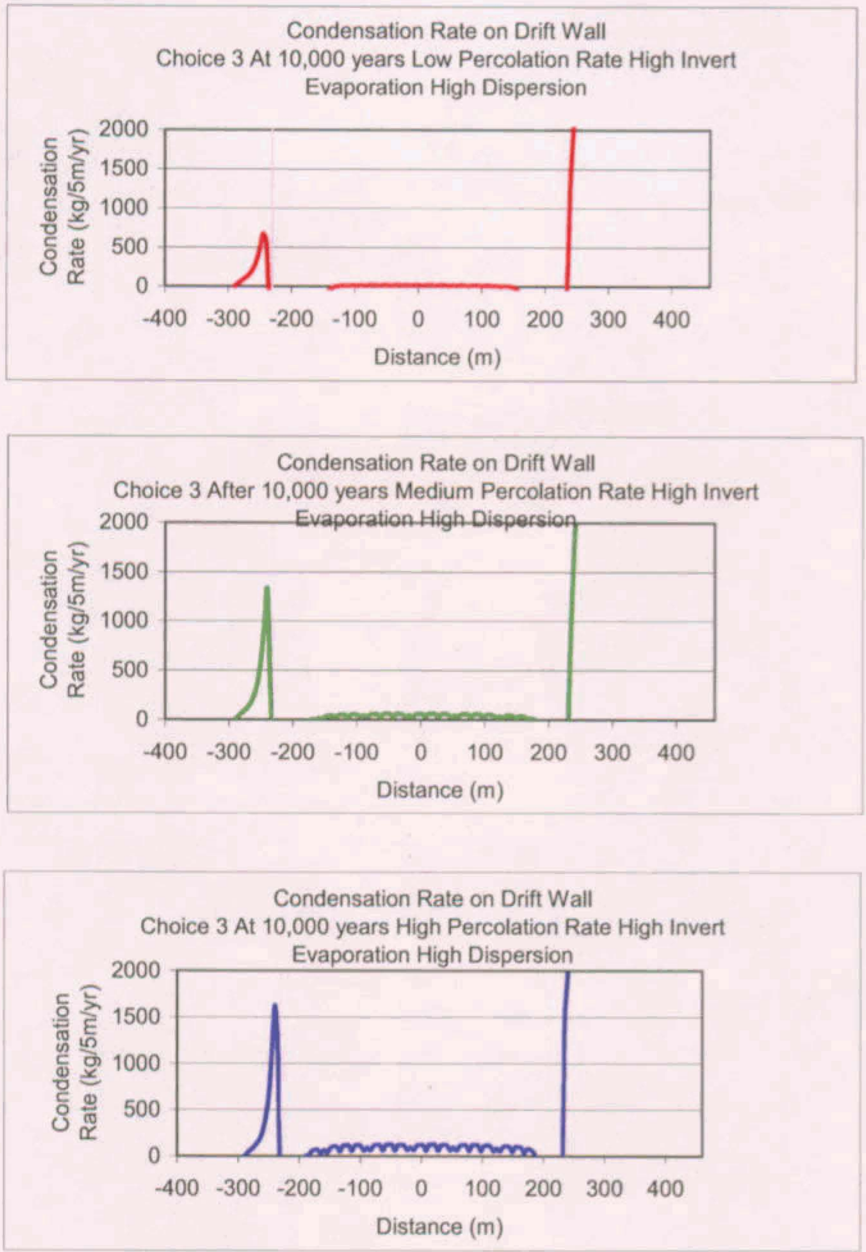
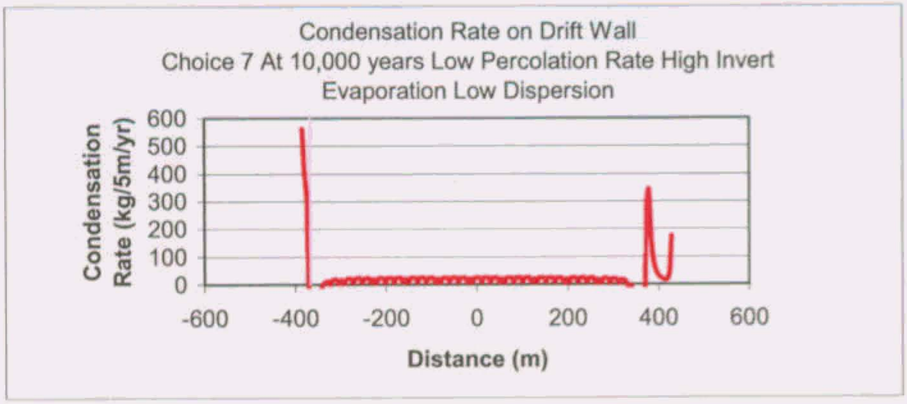
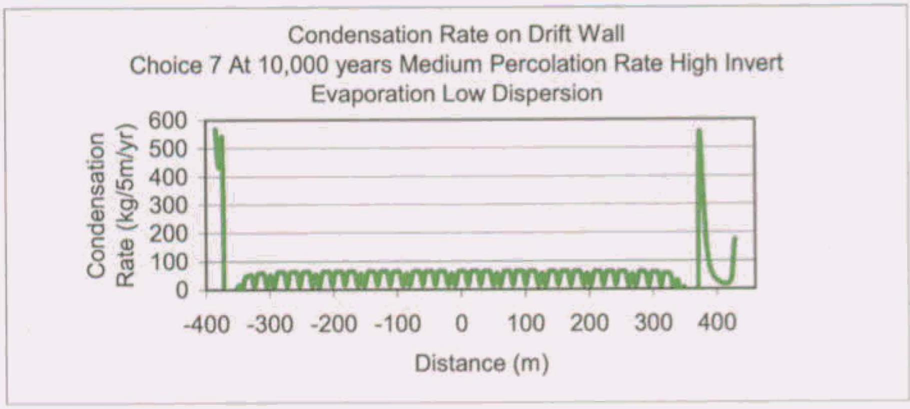


Figure III- 3. Condensation Rates for the Choice 3 Drift with High Invert Evaporation and High Axial Dispersion After 10000 years

Source: DTN SN0408T0509903.008 (Reference 2.3.6) Compressed File: ColdtrapHandbook_V.zip Folder: Mixed_HighInvertTransport Files: Choice3Figures.mcd. Note that zero is the center of the drift and that the intake turnout is on the left side.





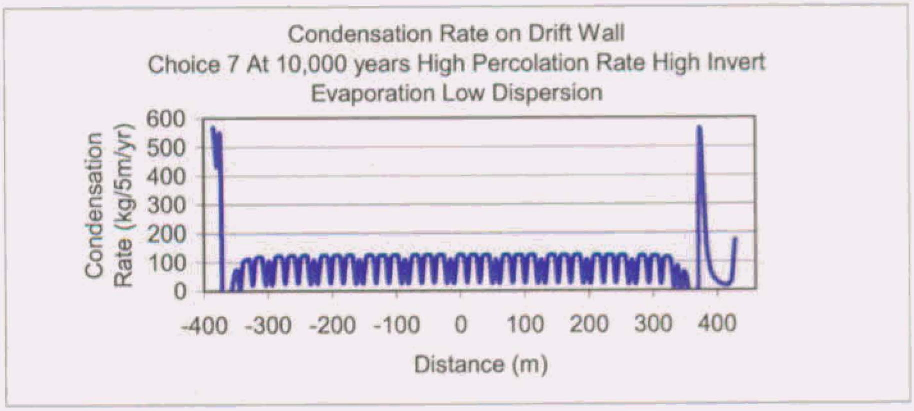


Figure III-4. Condensation Rates for the Choice 7 Drift with High Invert Evaporation and Low Axial Dispersion After 10000 years

Source: DTN SN0408T0509903.008 (Reference 2.3.6) Compressed File: ColdtrapHandbook_V.zip Folder: Mixed_HighInvertTransport Files: Choice7Figures.mcd). Note that zero is the center of the drift and that the intake turnout is on the right side.

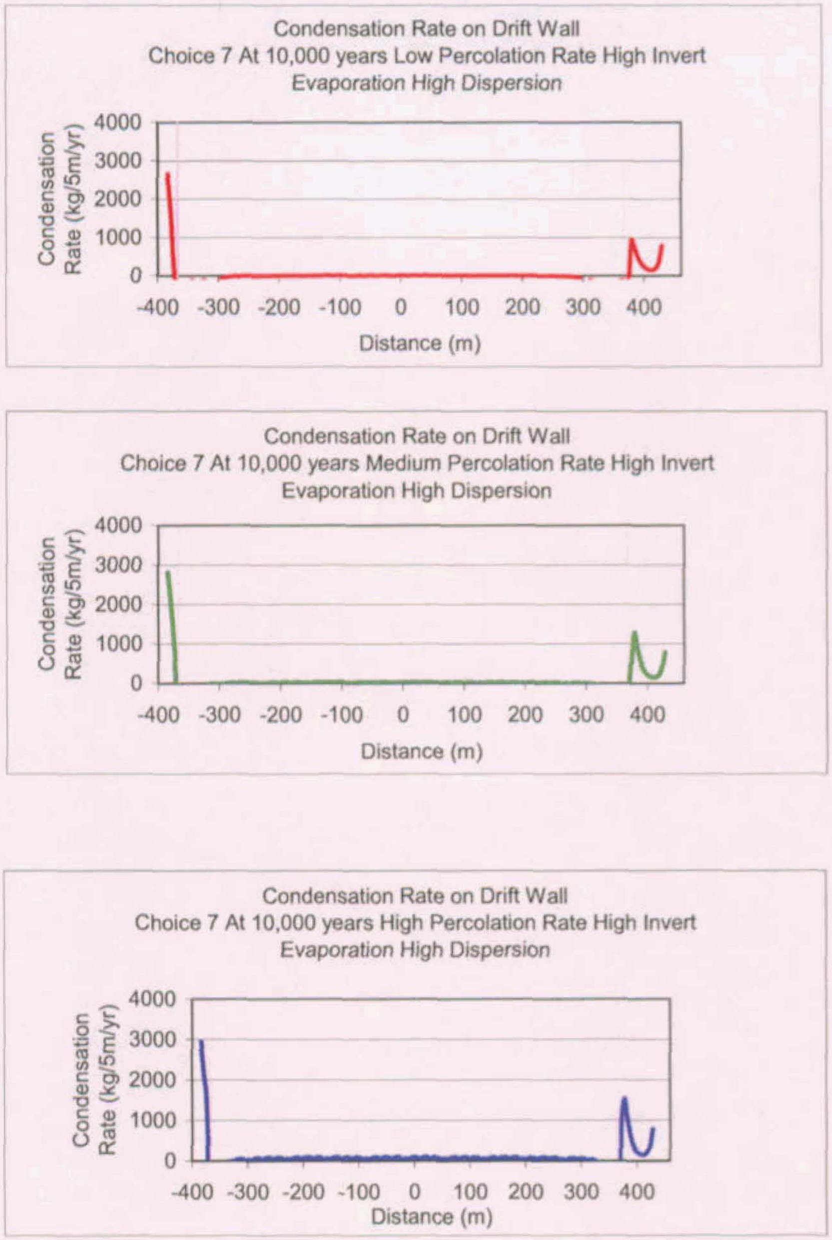


Figure III- 5. Condensation Rates for the Choice 7 Drift with High Invert Evaporation and High Axial Dispersion After 10000 years

Source: DTN SN0408T0509903.008 (Reference 2.3.6) Compressed File: ColdtrapHandbook_V.zip Folder: Mixed_HighInvertTransport Files: Choice7Figures.mcd). Note that zero is the center of the drift and that the intake turnout is on the right side.

Table III-1. Integrated Condensation Rates for the Well Mixed Case[1]

Choice	Axial Dispersion	Percolation	Spatially Integrated Condensation Rate (kg/yr)		
			Emplacement Drift[2]	Intake Turnout (60 m)[3]	Intake Turnout to be Backfilled (30 m)[4]
3	Low	Low	1310	1010	110
		Medium	4100	1480	120
		High	8450	1720	120
	High	Low	690	2830	730
		Medium	2920	4350	770
		High	6810	5670	780
7	Low	Low	2360	1270	330
		Medium	6410	1560	330
		High	12700	1570	330
	High	Low	160	4610	2070
		Medium	3270	5750	2090
		High	8950	6800	2100

[1]The spatially integrated condensation rates are determined by adding the condensation rates (kg/5m/yr) shown in Figures III-2 through III-5 over length of the heated emplacement drift, the 60 m intake turnout, and the 30 m of the intake turnout furthest away from the heated emplacment drift. The figures show the spatial condensation rates for the various cases of drift choice, low and high axial dispersion, and low, medium and high percolation rates.

[2]The condensation rates for the emplacement drift are presented in DTN SN0408T0509903.008 (Reference 2.3.6) Compressed File: ColdtrapHandbook_V.zip Folder: Mixed_HighInvertTransport Files: Choice3Figures.mcd and Choice7Figures.mcd) at 10,000 years. The Mathcad files summarize the emplacment drift condensation profile over the heated portion of the emplacment drift. Note that in Figure Figures III-2 through III-5, the ends of the heated portion of the emplacment drift are shown as two red lines.

[3]The condensation rates for the 60 meter intake turnout was obtained from DTN SN0408T0509903.008 (Reference 2.3.6) Compressed File: ColdtrapHandbook_V.zip Folder: Mixed_HighInvertTransport Files: Choice3Figures.mcd and Choice7Figures.mcd) at 10,000 years. The MathCad files show plots in the emplacement drift that excluded the condensation rate in the 60 meter turnout through the use of a Boolean operator. This operator was eliminated, and the condensation rates in the 60-meter intake turnout are shown in Figures III-2 through III-5. The spatially integrated condensation rate (kg/yr) was determined by summing the condensation rates in the 60-meter turnout.

[4]The condensation rate for the 30 meter intake turnout furthest away from the heated emplacement drift is determined in the same manner with the same data as for the 60 m intake turnout.