# OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
# ANALYSIS/MODEL COVER SHEET
***Complete Only Applicable Items***

1. QA: QA



2. ☒ Analysis — Check all that apply

Type of Analysis:
- ☒ Engineering
- ☐ Performance Assessment
- ☐ Scientific

Intended Use of Analysis:
- ☒ Input to Calculation
- ☒ Input to another Analysis or Model
- ☒ Input to Technical Document
- ☒ Input to other Technical Products

Describe use:

Analyze and describe layout and ventilation system for lower-temperature operating mode design, perform parametric studies of the sensitivities and support the System Description Documents.

3. ☐ Model — Check all that apply

Type of Model:
- ☐ Conceptual Model
- ☐ Abstraction Model
- ☐ Mathematical Model
- ☐ System Model
- ☐ Process Model

Intended Use of Model:
- ☐ Input to Calculation
- ☐ Input to another Model or Analysis
- ☐ Input to Technical Document
- ☐ Input to other Technical Products

Describe use:

4. Title:

Lower- Temperature Subsurface Layout and Ventilation Concepts

5. Document Identifier (including Rev. No. and Change No., if applicable):

ANL-WER-MD-000002 REV 00

6. Total Attachments:

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Alan F. Linden provided all Vulcan design work used in this analysis.

Robert W. Elayer prepared new present day ground water table in Sections 4.1.1.2 and 6.1.2.2.1

Sections 1, 2, 3 were prepared as a joint effort between Christine L. Linden and Edward G. Thomas.

# OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
# ANALYSIS/MODEL REVISION RECORD
***Complete Only Applicable Items***



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## ACRONYMS

| | |
|---|---|
| ALARA | as low as reasonably achievable |
| AML | areal mass loading |
| AP | absorber plates |
| | |
| BSC | Bechtel SAIC Company, LLC |
| BWR | boiling water reactor |
| | |
| CFR | Code of Federal Regulations |
| CQ | Conventional Quality |
| CR | control rods |
| CSNF | commercial spent nuclear fuel |
| | |
| DHLW | Defense high-level waste |
| DOE | U.S. Department of Energy |
| | |
| ECRB | Enhanced Characterization of the Repository Block |
| EIS | environmental impact statement |
| ESF | Exploratory Studies Facility |
| | |
| HLW | high-level waste |
| | |
| IPWF | immobilized plutonium waste form |
| | |
| LT | low temperature |
| | |
| MCO | multi-canister overpacks |
| MGR | Monitored Geologic Repository |
| MTHM | metric tons heavy metal |
| | |
| NVP | natural ventilation pressure |
| | |
| OD | Test and Evaluation Facility Observation Drift |
| | |
| PCTD | Test and Evaluation Facility Postclosure Test Drift |
| PTn | Thermal/Mechanical Unit: Lower Tiva Canyon Member, Yucca Mountain and Pah Canyon Members, Upper Topopah Spring Member, non welded ashflows and bedded tuffs |
| PWR | pressurized water reactor |
| | |
| QA | quality affecting |
| QARD | *Quality Assurance Requirements and Description* |
| QL | Quality Level |
| | |
| RHH | repository host horizon |

## ACRONYMS (Continued)

| | |
|---|---|
| S&ER | *Yucca Mountain Science and Engineering Report* |
| SNF | spent nuclear fuel |
| SSC | systems, structures, and components |
| SSF | subsurface facility |
| TBD | to-be-determined |
| TBM | tunnel boring machine |
| TBV | to-be-verified |
| tptpll | Geologic/Lithologic Stratigraphy: lower lithophysal zone of the Topopah Spring Tuff |
| tptpln | Geologic/Lithologic Stratigraphy: lower nonlithophysal zone of the Topopah Spring Tuff |
| tptpmn | Geologic/Lithologic Stratigraphy: middle nonlithophysal zone of the Topopah Spring Tuff |
| tptpul | Geologic/Lithologic Stratigraphy: upper lithophysal zone of the Topopah Spring Tuff |
| TSw1 | Thermal/Mechanical Unit: Topopah Spring Member, welded, devitrified ashflows, lithophysal (alternating lithophysae-rich and lithophysae-poor ashflows) |
| TSw2 | Thermal/Mechanical Unit: Topopah Spring Member, welded, devitrified ashflows, nonlithophysal (sparsely distributed lithophysae) |
| TWP | technical work plan |
| WP | waste package |

# 1. PURPOSE

This analysis combines work scope identified as subsurface facility (SSF) low temperature (LT) Facilities System and SSF LT Ventilation System in the *Technical Work Plan for Subsurface Design Section FY 01 Work Activities* (CRWMS M&O 2001b, pp. 6 and 7, and pp. 13 and 14). In accordance with this technical work plan (TWP), this analysis is performed using AP-3.10Q, *Analyses and Models*. It also incorporates the procedure AP-SI.1Q, *Software Management*.

The purpose of this analysis is to develop an overall subsurface layout system and the overall ventilation system concepts that address a lower-temperature operating mode for the Monitored Geologic Repository (MGR).

The objective of this analysis is to provide a technical design product that supports the lower-temperature operating mode concept for the revision of the system description documents and to provide a basis for the system description document design descriptions.

The overall subsurface layout analysis develops and describes the overall subsurface layout, including performance confirmation facilities (also referred to as Test and Evaluation Facilities) for the Site Recommendation design. This analysis also incorporates current program directives for thermal management. The following activities were included as part of the scope of this analysis:

- A planning layout and a lower block expansion layout were developed in the *Site Recommendation Subsurface Layout* analysis (BSC 2001a, Figures 3 and 13 respectively) and are used as the basis for developing the conceptual layout for the lower-temperature operations. These layouts are illustrated in Section 4, Figure 1 and Figure 2, respectively.

- Provide the analytical bases and develop a layout configuration that supports the lower-temperature operations for the 70,000 metric tons heavy metal (MTHM) and 97,000 MTHM waste inventories. The potentiometric surface representing the present day ground water surface was updated as part of developing the layout configuration. This activity is included in the SSF LT Facilities System, site geology task as documented in the TWP (CRWMS M&O 2001b, p. 6).

- Perform parametric studies to evaluate the sensitivity of the layout configuration against operational and design options, including waste package (WP) spacing, smaller WP size and heat output, and emplacement drift spacing. A discussion of operational flexibility as this concept relates to the layout configuration is also discussed.

The overall ventilation system analysis is based on current program directives for thermal management and design concepts for the Site Recommendation design. This analysis examines and describes the overall ventilation system. As part of the scope of this analysis, the following activities were included:

- Evaluate the ventilation requirements for a 70,000 and a 97,000 MTHM waste inventory case study. Provide estimates of airflow requirements, overall system horsepower requirements, and ventilation shaft requirements necessary to support these subsurface layouts.

- Describe the overall ventilation system and update concepts that have changed as a result of the lower-temperature operating strategy, including an extended natural ventilation period.

- Discuss parametric sensitivities to evaluate the ventilation operating sensitivities, such as varying the ventilation rate and duration, for the lower-temperature operating mode concept.

## 2. QUALITY ASSURANCE

This technical product has been prepared in accordance with AP-3.10Q, *Analyses and Models*. The analysis has been determined to be quality affecting (QA) in accordance with the Activity Evaluation (CRWMS M&O 2001b, Addendum A, p. 1), since the information in this analysis affects the design of a Quality-Listed item. Therefore, this analysis is subject to the requirements of the *Quality Assurance Requirements and Description* (QARD) document (DOE 2000)

Systems, structures, and components (SSCs) discussed in the overall layout section of this report have been evaluated in the *Classification of the MGR Subsurface Facility System* (CRWMS M&O 1999a). The results of the QA classification (CRWMS M&O 1999a, Section 7.1, Table 1) are provided in Table 1.

Table 1. Subsurface Facility System QA Classification

| Subsurface Facility System | QL-1 | QL-2 | QL-3 | CQ |
|---|---|---|---|---|
| Access Mains | | | | X |
| Emplacement Drifts | X | | | |
| Mains and Raises | | | | X |
| Miscellaneous Support Openings | | | | X |
| Performance Confirmation Openings | | | | X |
| Portals and Access Ramps | | | | X |
| Ventilation Shafts | | | | X |

Source: CRWMS M&O 1999a, Table 1

The following classification categories are specified to meet the requirements of Section 2 of the QARD (DOE 2000) and have been defined in the *Classification of the MGR Subsurface Facility System* (CRWMS M&O 1999a, p. 6) as follows:

> "**Quality Level 1 (QL-1)**–Those SSCs whose failure could directly result in a condition adversely affecting public safety. These items have a high safety or waste isolation significance.
>
> **Quality Level 2 (QL-2)**–Those SSCs whose failure or malfunction could indirectly result in a condition adversely affecting public safety, or whose direct failure would result in consequences in excess of normal operational limits. These items have a low safety or waste isolation significance.
>
> **Quality Level 3 (QL-3)**–Those SSCs whose failure or malfunction would not significantly impact public or worker safety, including those defense-in-depth design features intended to keep doses as low as reasonably achievable (ALARA). These items have a minor impact on public and worker safety and waste isolation.
>
> **Conventional Quality (CQ)**–Those SSCs not meeting any of the criteria for Quality Levels 1, 2, or 3. Conventional quality items are not subject to the requirements of the QARD."

The control of the electronic management of information is in accordance with the *Technical Work Plan for Subsurface Design Section FY 01 Work Activities* (CRWMS M&O 2001b, pp. B8 and B9). Electronic data files describing the geology of the repository area (see Section 4.1.1.2) were retrieved from the Technical Data Management System. The files were loaded into VULCAN v3.4, and the transfer of the information was confirmed by comparing the files with the originating data.

In order to ensure accuracy and completeness of the information generated by this analysis, access to the information on the personal computer and UNIX™ workstation was controlled with password protection. The personal computer files were stored on the network 'H' drive, which was backed up daily by the Enterprise Server Team Department. The UNIX™ workstation files were stored on a local hard disk, which was backed up daily on a tape drive (identification number 116961), labeled and stored locally. The backups were stored for four weeks, then recycled through the backup system. When the work was complete, the files were transferred to floppy disk, appropriately labeled and verified by examining the file listing. The floppy disk was hand carried to the Records Processing Center. During the process of checking the document, accuracy and completeness of the data placed in the Records Processing Center was verified against the information contained in this analysis.

Both the Subsurface Development Area Ventilation and Subsurface Emplacement Ventilation Systems are classified as CQ (CRWMS M&O 1999f, p. 9).

## 3. COMPUTER SOFTWARE AND MODEL USAGE

The code VULCAN v3.4, STN: 10044-3.4-00 (CRWMS M&O 2001c), was used in the configuration of the subsurface layout within the three-dimensional geologic model of Yucca Mountain. The code was also used to re-evaluate the potentiometric surface that represents the present day ground water table. VULCAN v3.4 is a geology and mine engineering computer design system developed by Maptek/KRJA Systems, Inc.

The VULCAN v3.4 software was obtained from Software Configuration Management, was appropriate for the application, and was used only within the range of validation in accordance with AP-SI.1Q, *Software Management*. The VULCAN v3.4 is installed on a Silicon Graphics Octane workstation running the IRIX 6.5 operating system (central processing unit 116980).

The following models and files were used in the preparation of this analysis.

- The geologic model of Yucca Mountain, the VULCAN v3.4 Geological Framework Model (GFM) 3.1 Representation (DTN: MO0003MWDVUL03.002).
- The potentiometric surface contours from the unqualified ISM2.0 (DTN:MO9807MWDGFM02.000).
- Open File Report 95-159 *Water Levels in the Yucca Mountain Area, Nevada* (Tucci et al. 1996, DTN:GS950308312312.002).
- The ISM2000 (DTN:MO0012MWDGFM02.002) borehole data file *contacts00el.dat*.

Specific details of how the models and files were used are included in Section 4.1.1.2.

# 4. INPUTS

All technical product input and sources of the input used in the development of this analysis are documented in this section. The qualification status of the input is indicated, as well as the documentation for to-be-verified (TBV) or to-be-determined (TBD) data.

## 4.1 DATA AND PARAMETERS

Parameters are scientific data, performance assessment data, or technical engineering information that represent physical or chemical properties. A parameter consists of an assigned variable name and the parameter is generally represented by a value or a range of values. The following subsections will outline the parameters used in the preparation of this analysis.

### 4.1.1 Overall Subsurface Layout Data and Parameters

The data and parameters necessary to support the development of the subsurface layouts are documented in this section.

#### 4.1.1.1 Planning Layout and Lower Block Expansion Layout

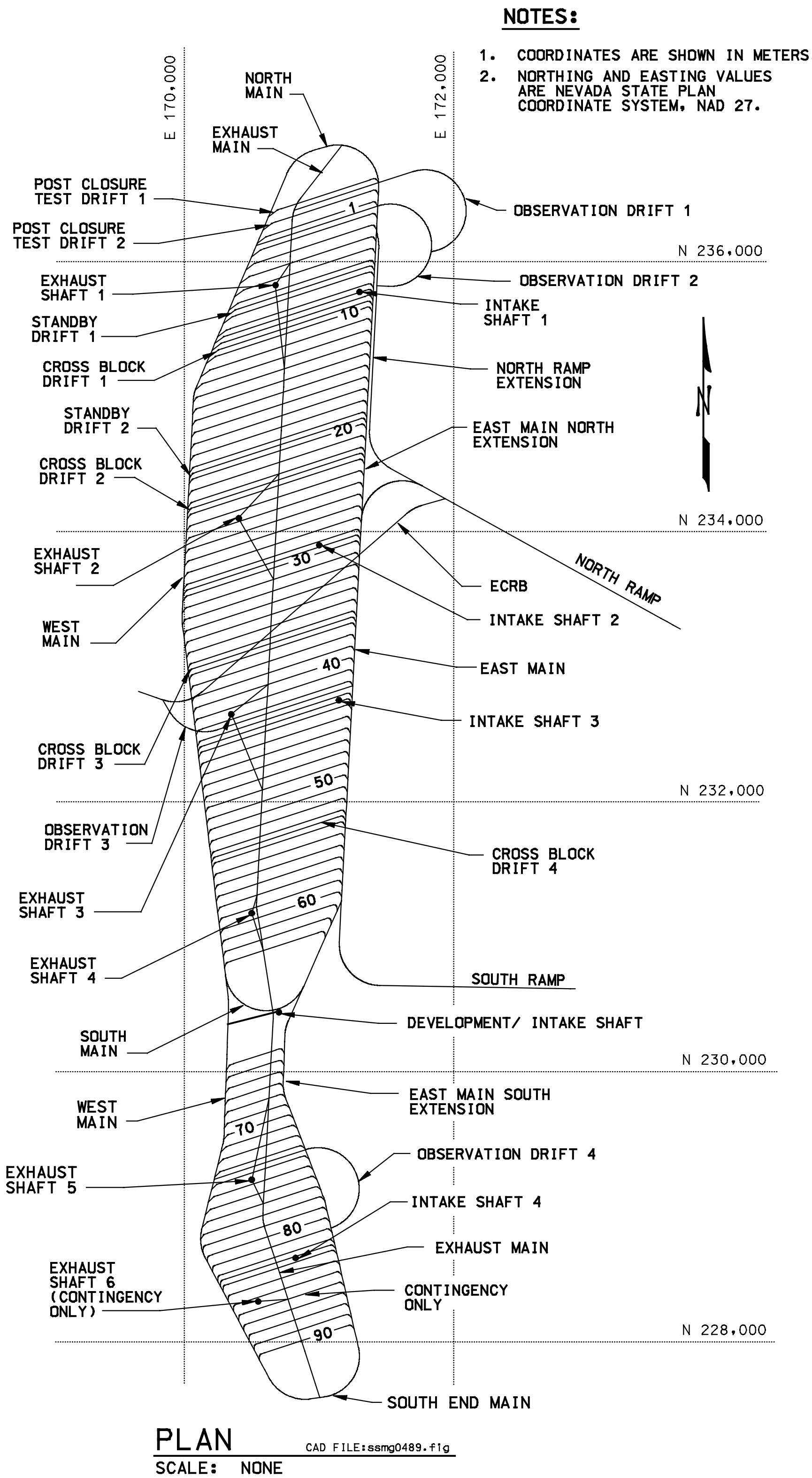
A planning layout and a lower block expansion layout were developed in the *Site Recommendation Subsurface Layout* analysis (BSC 2001a, Figures 3 and 13, and Sections 6.2 and 6.5). These layouts are illustrated in Figure 1 and Figure 2, respectively.

The layouts will maintain the emplacement area horizon, or the footprint as outlined in the *Site Recommendation Subsurface Layout* analysis (BSC 2001a, Sections 6.2 and 6.5), as well as maintain the specific locations of the emplacement drifts within that footprint.

The electronic files of the *Subsurface Facility Planning Layout in Support of ANL-SFS-MG-000001 REV 00* and the *Lower Block Layout in Support of ANL-SFS-MG-000001 REV 00* (CRWMS M&O 2000a and CRWMS M&O 2000b) were retrieved from the Records Processing Center. The files were loaded into VULCAN v3.4, and the content of the files was compared with the originating files (BSC 2001a) to ensure accurate file transfer.

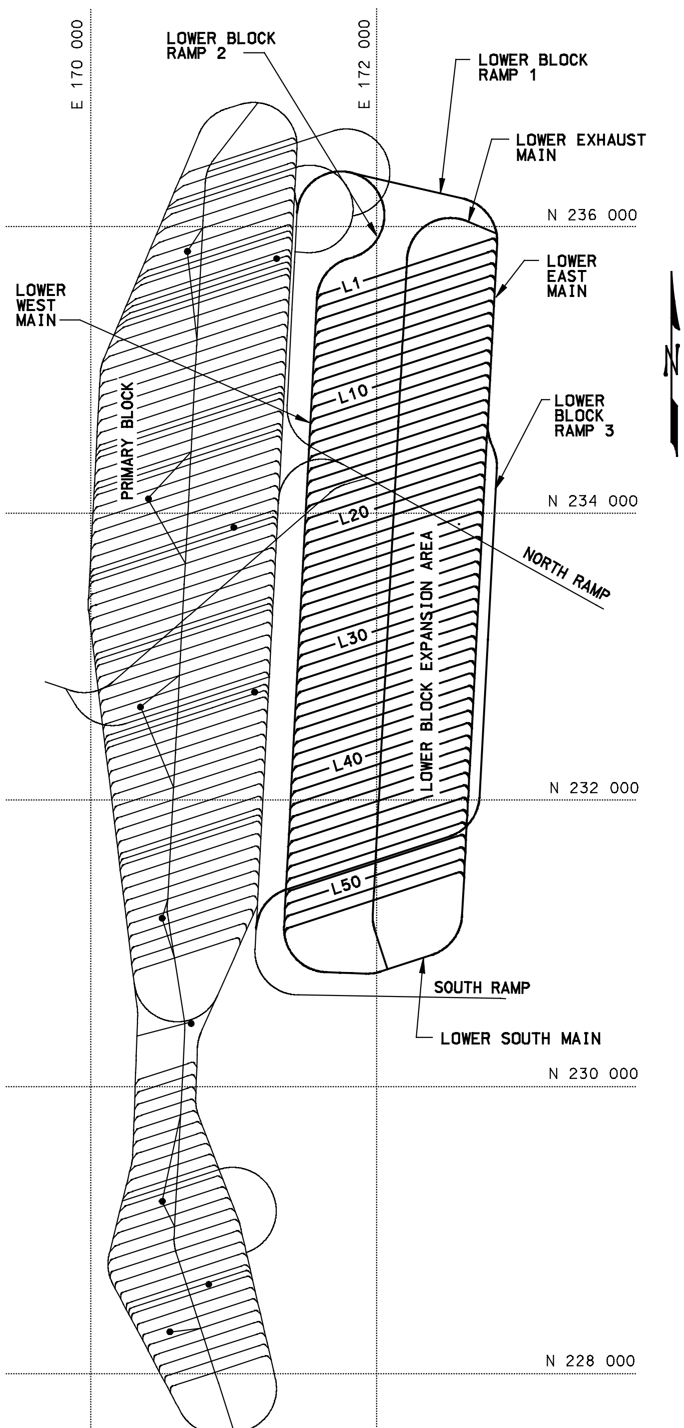
#### 4.1.1.2 Geology and Stratigraphy

The stratigraphy of Yucca Mountain and the characterized block were defined in the *Determination of Available Repository Siting Volume for the Site Recommendation* (CRWMS M&O 2000c, Section 8). The geologic model of Yucca Mountain, the VULCAN Geological Framework Model (GFM) 3.1 Representation (DTN: MO0003MWDVUL03.002) uses the Nevada State Plane coordinate system, NAD 27 as its basis (converted to metric). This geologic model (VULCAN v3.4) was compared with the *Determination of Available Repository Siting Volume for the Site Recommendation* (CRWMS M&O 2000c, Section 8) to ensure accurate file transfer.




Modified from Source: BSC 2001a, Figure 3

Figure 1. Planning Layout (Primary Block Only)




**NOTES:**

1. COORDINATES ARE SHOWN IN METERS.
2. NORTHING AND EASTING VALUES ARE NEVADA STATE PLANE COORDINATE SYSTEM, NAD 27.

PLAN CAD FILE:ssmg0488.flg
SCALE: NONE

Modified from Source: BSC 2001a, Figure 13

Figure 2. Primary Block and Lower Block Expansion Layout

The geology of Yucca Mountain was used to locate ancillary openings, and openings located about the emplacement area, within the repository host horizon (RHH).

To determine the vertical distance from the emplacement drift inverts to the potentiometric surface, a representative groundwater surface was developed based on the available data. This potentiometric surface was developed from multiple data sources as detailed below:

Potentiometric surface contours from the unqualified ISM2.0 (DTN:MO9807MWDGFM02.000) were used as corroborative data to give the general form of the surface. This potentiometric surface was originally developed based on RIB item DTN:MO9609RIB00038.000 with contours added to define the surface in the area of the Large Hydraulic Gradient (LHG) and Moderate Hydraulic Gradient (MHG). The potentiometric surface presented in ISM2.0 is the same surface used in the qualified GFM3.1 (DTN:MO9901MWDGFM31.000), as verified (Clayton 2000).

Potentiometric depth data for the boreholes used in the ISM2.0 map (DTN:MO9807MWDGFM02.000) were unqualified and not corrected for borehole deviation. The USGS developed qualified borehole depth-to-water measurements corrected for borehole deviation and presented them in the Open File Report 95-159 *Water Levels in the Yucca Mountain Area, Nevada* (Tucci et al. 1996, DTN:GS950308312312.002). A comparison of the uncorrected data from the RIB and the corrected data in the DTN shows agreement within one meter for all boreholes except three (WT-4, WT-17, and J-12), which were all within two meters. This difference is not considered significant. Therefore, the ISM2.0 potentiometric surface contours were used as a basis to develop the potentiometric surface and to determine the vertical distance from the potentiometric surface to the invert of the emplacement drifts to the top of the.

The ISM2.0 potentiometric surface map did not include data from two boreholes in the northern part of the area, G-2 and WT-24. Data from these two boreholes were added to the map and the contours were modified to reflect the new data. The data for G-2 and WT-24 were derived from the *Data Qualification Report: Water Level Altitude Data for Use on the Yucca Mountain Project* (CRWMS M&O 2000m, pp. 9 and 11). This report shows the qualified G-2 potentiometric surface at 1020-m elevation (CRWMS M&O 2000m, p. 9) and the qualified WT-24 potentiometric surface at 840-m elevation (CRWMS M&O 2000m, p. 11). The location for these boreholes was taken from the ISM2000 (DTN:MO0012MWDGFM02.002) borehole data file *contacts00el.dat*, which gives a collar elevation of 5098 ft (1554 m) for borehole G-2 and 4900 ft (1494 m) for borehole WT-24.

#### 4.1.1.3 Waste Inventory Information

The most recent information available for the WP inventories is contained in the input transmittal *De-rated Waste Package Quantities for BSC Scenario* (BSC 2001b, Item 1, p. 2) and outlined in Table 2. These values differ from those documented in the *Subsurface Facility System Description Document* (see Sections 4.2.1.1.1 and 4.2.1.1.2). Since the inventories outlined in Table 2 are the most recent information available, they will be used in this analysis as the basis of the emplacement capacity calculations. The 70,000 MTHM case contains 63,000 MTHM of commercial spent nuclear fuel (CSNF) and the 97,000 MTHM case contains 83,800 MTHM of CSNF.

Table 2. Waste Package Inventories

| Type of WP | 70,000 MTHM Case | | 97,000 MTHM Case | | WP Length (m) |
|---|---|---|---|---|---|
| | Nominal Quantity (WPs)[1] | Average Heat Output/Package (kW) | Nominal Quantity (WPs)[1] | Average Heat Output/Package (kW) | |
| 21 Pressurized Water Reactor (PWR) Absorber Plates (AP) | 4,299 | 11.530 | 5,690 | 11.330 | 5.165 |
| 21 PWR Control Rods (CR) | 95 | 3.110 | 106 | 3.260 | 5.165 |
| 12 PWR AP Long | 163 | 9.550 | 293 | 8.970 | 5.651 |
| 44 Boiling Water Reactor (BWR) AP | 2,831 | 7.380 | 3,732 | 7.000 | 5.165 |
| 24 BWR AP | 84 | 0.520 | 98 | 0.540 | 5.105 |
| *Total CSNF* | *7,472* | | *9,919* | | |
| 5 immobilized plutonium waste form (IPWF) | 95 | 3.530 | 127 | 3.530 | 3.590 |
| 5 Defense high-level waste (DHLW) Short/1 U.S. Department of Energy (DOE) Spent Nuclear Fuel (SNF) Short | 1,052 | 2.980 | 1,403 | 2.980 | 3.590 |
| 5 DHLW Long/1 DOE SNF Long | 1,406 | 0.407 | 1,874 | 0.407 | 5.217 |
| 2 multi-canister overpacks (MCO)/2 DHLW | 149 | 1.665 | 199 | 1.665 | 5.217 |
| 5 High-level waste (HLW) Long/ 1 DOE SNF Short | 126 | 0.407 | 167 | 0.407 | 5.217 |
| HLW Long Only | 584 | 0.282 | 780 | 0.282 | 5.217 |
| Naval Short | 200 | 3.070 | 200 | 3.070 | 5.430 |
| Naval Long | 100 | 3.070 | 100 | 3.070 | 6.065 |
| *Total DOE/HLW* | *3,712* | | *4,850* | | |
| **TOTAL** | **11,184** | | **14,769** | | |

Source: BSC 2001b, Item 1, p. 2

[1] Number of WPs

#### 4.1.1.4 Surface-Based Boreholes

The surface-based boreholes, also referred to as point features, of the Yucca Mountain Project are documented in the Technical Data Management System (DTN: MO0101COV00396.000). These boreholes are considered both qualified and non-qualified. All of the boreholes used are listed in Attachment V.

### 4.1.2 Overall Subsurface Ventilation Data and Parameters

The data and parameters necessary to support the development of the subsurface ventilation system are documented in this section.

#### 4.1.2.1 Exhaust Air Temperature

During the forced ventilation period, the peak exhaust air temperature at the ventilation raise is 50°C (CRWMS M&O 2000l, Table 6-2). This temperature reflects a 600-m emplacement drift split length at 1.0 kW/m line load, 50 years of forced ventilation, 15 $m^3/s$ airflow, and 25°C inlet air conditions. This information is used in Section 6.2.8.2. Note: This 50°C outlet temperature is based on an inlet temperature of 25°C that is derived from an assumption (CRWMS M&O 2000l, Section 3.2). The design inlet air temperature needs to be confirmed by thermal management analysis in the future.

#### 4.1.2.2 Airflow Design Values

Table 3 contains the design airflow volumes of the individual repository components as documented in the *Site Recommendation Subsurface Layout* (BSC 2001a). This information is used in Section 6.2.8.

Table 3. Airflow Design Values

| Component | Design Airflow Volume per split ($m^3/s$) | Reference Source |
|---|---|---|
| Emplacement Drift, Postclosure Test Drift (PCTD), Standby Drift | 15* | BSC 2001a, Section 6.2.3.4 |
| Observation Drift (OD), Cross-block Drift | 19.63 | BSC 2001a, p. IV-3 |

Note: *Airflow in drifts that may contain WPs is adjusted for thermal expansion (Section 6.2.8.2)

#### 4.1.2.3 Shaft Diameter

As documented in the *Site Recommendation Subsurface Layout* (BSC 2001a, p. IV-34) a shaft diameter of 8.0 meters (excavated) was calculated and is valid for this analysis.

#### 4.1.2.4 Airflow Opening Limitations

In order to estimate the number of shafts and determine the repository airflow allocations, the limitations of the intake and exhaust airflow openings are listed in Table 4. The nominal airflow rates were developed in the *Site Recommendation Subsurface Layout* (BSC 2001a, Attachment IV). This input is used in Section 6.2.8 and Attachment VIII.

Table 4. Repository Airflow Volumes

| Airflow Opening Description | Design Airflow Volume ($m^3/s$) | Reference Source |
|---|---|---|
| North Ramp, East Main and West Main | 217.02 | BSC 2001a, p. IV-3 |
| South Ramp [1] | 289.36 | BSC 2001a, p. IV-2 |
| Intake Shaft | 578.72 | BSC 2001a, p. IV-3 |
| Exhaust Shaft [2] | 733.51 | BSC 2001a, p. IV-33 |

Notes: [1] South Ramp air volume is higher than the North Ramp due to lack of transporter use.
[2] Volume was used to establish the 8-m excavated diameter shaft dimension in BSC 2001a.

#### 4.1.2.5 Conversion Factors

The following conversion factors are used for the ventilation work (Hartman et al. 1997, Table B.3) and are appropriate for the conceptual level of detail used in Section 6.2.8.

> 1 $m^3/s$ = 2,119 cfm (2,118.9 rounded)
> 1 hp = 0.7457 kW
> T (Kelvin) = t (°C) + 273.15

## 4.2 CRITERIA

### 4.2.1 Subsurface Facility System Criteria

The criteria necessary to support the development of the subsurface layouts are documented in this section.

#### 4.2.1.1 System Performance Criteria

4.2.1.1.1 The MGR shall be capable of accommodating the emplacement of 70,000 MTHM of the WP inventory (CRWMS M&O 2000d, Section 1.2.1.1). Because the Design Basis Waste Package Inventory criterion in the SDD does not reflect the latest information it will be revised to reflect the information presented in Table 2, Section 4.1.1.3. Table 2 information was used in lieu of that shown in the SDD.

4.2.1.1.2 The MGR shall provide the capability of accommodating the emplacement of 97,000 MTHM of the WP inventory (CRWMS M&O 2000d, Section 1.2.1.2). Because the Design Basis Waste Package Inventory criterion in the SDD does not reflect the latest information it will be revised to reflect the information presented in Table 2, Section 4.1.1.3. Table 2 information was used in lieu of that shown in the SDD.

4.2.1.1.3 Emplacement drifts shall have a nominal diameter of 5.5 meters (CRWMS M&O 2000d, Section 1.2.1.3).

4.2.1.1.4 The minimum emplacement space shall be a WP spacing of 10 centimeters (CRWMS M&O 2000d, Section 1.2.1.4). In order to provide the flexibility to allow a lower-temperature operating mode, WP spacing will be assigned values greater than 0.1 meters, but the minimum spacing requirement will be maintained.

4.2.1.1.5 Emplacement drifts will be spaced 81 meters center-to-center (CRWMS M&O 2000d, Section 1.2.1.5).

4.2.1.1.6 An upward grade of at least 1- percent for at least the first 10 meters of the entrance ramps from the surface will be provided (CRWMS M&O 2000d, Section 1.2.1.6).

4.2.1.1.7 Emplacement drifts shall be oriented at least 30 degrees from dominant rock joint orientations (CRWMS M&O 2000d, Section 1.2.1.7).

4.2.1.1.8 The drifts and alcoves for implementation of the Test and Evaluation Program shall have the characteristics shown in Table 5 (CRWMS M&O 2000d, Section 1.2.1.8). Table 5 contains TBV and TBD information.

Table 5. General Performance Characteristics–Test & Evaluation Facilities

| **General Performance Characteristics<br>Test & Evaluation Facilities** | |
|---|---|
| Quantity | **Performance Monitoring**:<br>Minimum of three (3) monitoring areas with one OD and a minimum of six (6) alcoves for each area.<br><br>**Postclosure Simulation**:<br>One Engineered Barrier System interaction test area and one Near Field Response test area, consisting of two (2) simulated emplacement drifts, one (1) OD and three (3) alcoves per area. Test areas may share the same OD.<br><br>**Specialized Test Areas**:<br>Ten (10) seepage alcoves<br>Two (2) seismic monitoring niches.<br>One (1) ramp-seal test alcove.<br>Two (2) shaft-seal test alcoves and one (1) connecting shaft.<br><br>**Other test alcoves:**<br>Quantity of test alcoves will be determined later. |
| Size | **All**:<br>Based on equipment / instrument envelope and ventilation duct requirements. |
| Grade | **Performance Monitoring**:<br>ODs are to be oriented parallel to emplacement drift horizon within 1% grade of target slope and sufficient to provide drainage. Alcoves sloped to provide drainage to ODs.<br><br>**Postclosure Simulation**:<br>OD(s) are to be oriented parallel to simulated drifts within 1-% grade of target slope and sufficient to provide drainage. Alcoves sloped to provide drainage to ODs.<br><br>**Specialized Test Areas**:<br>For seepage alcoves, grade sufficient to provide drainage.<br>For seismic monitoring niches, grade sufficient to provide drainage.<br>For ramp-seal test alcove, slope shall be representative of access mains.<br>For shaft-seal test area, alcove shall slope sufficient to provide drainage, and shaft shall be vertical.<br><br>**Other test alcoves**:<br>Sufficient to provide drainage. |

Table 5. General Performance Characteristics–Test & Evaluation Facilities (continued)

| General Performance Characteristics<br>Test & Evaluation Facilities | |
|---|---|
| Length | **Performance Monitoring**:<br>ODs for performance monitoring shall, at a minimum, span the width of the emplacement area where they are located. Alcoves shall be of sufficient length to extend from the OD and provide coverage of the area between adjacent emplacement drifts, and two drift diameters on outer sides of the emplacement drifts.<br><br>**Postclosure Simulation**:<br>Simulated Emplacement drifts shall be a minimum of 600 m long to provide for 2 segment tests and buffer areas. ODs shall provide access for monitoring along the entire length of the associated drift.<br><br>**Specialized Test Areas**:<br>For seepage alcoves, alcoves shall be a minimum of 20 m in length, and located outside the mechanical-hydrological zone of influence of adjacent excavations.<br><br>For seismic monitoring niches, niches shall be of sufficient depth to accommodate drilling of monitoring holes within niche without impact to traffic in other tunnels and drifts, and sufficient to house data acquisition system and associated electronics.<br><br>For ramp-seal test alcove, length shall be sufficient to contain representative seal and sufficient additional length to isolate seal test area from other tunnels and drift, and house related instrumentation and data acquisition systems.<br><br>Shaft-seal test alcove, test area shall be vertical and access alcoves of sufficient length to isolate seal test area from other tunnels and drifts and house related instrumentation and data acquisition systems.<br><br>**Other test alcoves**:<br>As required for testing. |
| Arrangement | **Performance Monitoring**:<br>ODs are to be located above or below repository horizon to not significantly impact the thermal-mechanical-hydrological response of the emplacement drifts. Location above or below the horizon shall be varied to provide both conditions over the range of ODs.<br><br>**Postclosure Simulation**:<br>Simulated emplacement drifts shall be at grades representative of emplacement drifts. ODs to be located below the simulated drifts to not significantly impact the thermal-mechanical-hydrological response of the simulated drifts. |

Table 5. General Performance Characteristics–Test & Evaluation Facilities (continued)

| **General Performance Characteristics<br>Test & Evaluation Facilities** | |
|---|---|
| Arrangement(continued) | **Specialized Test Areas**:<br>Seepage alcoves shall be located along access mains and performance monitoring ODs<br><br>Seismic monitoring alcoves/niches shall be arranged to be located off access mains at opposing ends of the repository configuration.<br><br>Ramp seal test area shall be arranged to be located off the south access main.<br><br>Shaft seal test area shall be arranged to be located off the south access main.<br><br>**Other test alcoves**:<br>Alcoves shall be arranged as required. |
| Location | **Performance Monitoring**:<br>One test area and associated OD shall be located so to monitor first emplacement drifts containing waste. Remaining ODs and test areas shall be located to provide access to varying rock mass conditions, including areas with differing rock stratigraphy, fracture density, and expected percolation rates. ODs shall provide flexibility in locating specific test areas.<br><br>**Postclosure Simulation**:<br>Test areas shall be located in rock conditions representative of the repository horizon. Test area may be located in areas outside the siting area designated as suitable for emplacement or as can be accommodated within the siting area.<br><br>**Specialized Test Areas**:<br>Seepage alcoves shall be located to provide access to varying rock mass conditions, including areas with differing rock stratigraphy, fracture density, and expected percolation rates.<br><br>Seismic monitoring alcoves/niches shall be located in areas with different rock mass characteristics at repository depth.<br><br>Ramp seals test shall be located in similar rock mass conditions as repository ramps.<br><br>Shaft seal test shall to be located in similar rock mass conditions as repository shafts.<br><br>**Other test alcoves**:<br>Will be determined later. |

Source: CRWMS M&O 2000d, Section 1.2.1.8

Table 5 will require modification. The *Performance Confirmation Plan* (CRWMS M&O 2000e, p. 5-22) indicates that only a single test drift will be employed for the postclosure simulations. This change has been incorporated into this analysis.

4.2.1.1.9 The system shall provide the capability of accommodating up to 115,000 MTHM or equivalent (CRWMS M&O 2000d, Section 1.2.1.9). Current predictions have indicated that as much as 119,000 MTHM or equivalent may need to be accommodated in the potential repository, if so authorized. For the purposes of flexibility, the 119,000 MTHM will be used to project emplacement capacity.

#### 4.2.1.2 Nuclear Safety Criteria

4.2.1.2.1 The system shall ensure subsurface areas requiring unrestricted access can be maintained at radiation levels less than or equal to 2.5 mrem/hr (CRWMS M&O 2000d, Section 1.2.2.1.1). Unrestricted access areas are the access mains and other areas, excluding the emplacement drift turnouts that require human access.

4.2.1.2.2 The system shall ensure subsurface areas requiring restricted access can be maintained at radiation levels less than or equal to 100 mrem/hr (CRWMS M&O 2000d, Section 1.2.2.1.2). Restricted access areas are the emplacement drift turnouts.

4.2.1.2.3 The system shall locate the entrance of all surface openings to the subsurface facility outside of the probable maximum flood areas as depicted in *Technical Basis Report for Surface Characteristics, Preclosure Hydrology, and Erosion*, (YMP 1995, Figure 2.6.2-1) (CRWMS M&O 2000d, Section 1.2.2.1.3). This criterion contains TBD information.

4.2.1.2.4 The system shall accommodate the minimum standoff distances identified in Table 6. Repository openings that are placed within these standoff distances shall be approved per site impact analysis (CRWMS M&O 2000d, Section 1.2.2.1.4). This criterion is considered TBV.

Table 6. Repository Opening Standoffs

| Geologic Areas | Standoff Distance |
|---|---|
| Top of the present day water table | 160 m from the closest edge of emplacement drifts |
| Main Trace of Type I fault zone | 60 m from the closest edge of repository openings |

4.2.1.2.5 The system shall accommodate a 15-meter standoff between WPs and Type I faults. If repository openings must be placed less than 60-m from a Type I fault, a 5-meter standoff between WPs and splays associated with Type I faults will be used. This is allowable only as approved per site impact analyses (CRWMS M&O 2000d, Section 1.2.2.1.5).

**Note**: Standoff distance requirements are used to establish usable drift length only. These distances do not specify final WP standoff distances.

4.2.1.2.6 The system shall allow at least a 5 meter standoff from the edge of the WPs to the perpendicular projection of the centerline of a surface-based borehole if the borehole intercepts the drift or comes within 5 meters of the edge of the drift (CRWMS M&O 2000d, Section 1.2.2.1.6).

4.2.1.2.7 The system shall provide a repository grade (i.e., non-emplacement drift openings) so overall water drainage and accumulation is away from emplacement areas (CRWMS M&O 2000d, Section 1.2.2.1.7).

4.2.1.2.8 The system shall limit the emplacement areas to within the lower part of the lithophysal zone of the TSw1 unit and the entire TSw2 unit, within the characterized block (CRWMS M&O 2000d, Section 1.2.2.1.8). The TSw1 unit is the Topopah Spring Member, welded, devitrified ashflows, lithophysal (alternating lithophysae-rich and lithophysae-poor ashflows) and the TSw2 unit is the Topopah Spring Member, welded, devitrified ashflows, nonlithophysal (sparsely distributed lithophsae). This volume of rock is known as the RHH.

4.2.1.2.9 The system shall locate the subsurface emplacement level at least 200 m below the directly overlying ground surface (CRWMS M&O 2000d, Section 1.2.2.1.9). This criterion is considered TBV.

### 4.2.1.3 Non-nuclear Safety Criteria

4.2.1.3.1 The system shall have two or more separate, properly maintained escapeways to the surface from the lowest levels, which are so positioned that damage to one shall not lessen the effectiveness of the others. A method of refuge shall be provided while a second opening to the surface is being developed (CRWMS M&O 2000d, Section 1.2.2.2.1).

4.2.1.3.2 A method of refuge shall be provided for employees who cannot reach the surface from their work place, through at least two separate escapeways, within a time limit of one hour when using the normal exit method (i.e., walking). These refuges must be positioned so that the employee can reach one of them within 30 minutes from the time the workplace is left (CRWMS M&O 2000d, Section 1.2.2.2.2).

4.2.1.3.3 Travel times for exiting or reaching a refuge shall be based on a maximum rate for personnel travel of 2,100 meters in 30 minutes (CRWMS M&O 2000d, Section 1.2.2.2.3). This criterion is considered TBV.

### 4.2.1.4 System Environmental Criteria

There are no applicable environmental criteria for this system.

### 4.2.1.5 System Interfacing Criteria

4.2.1.5.1 The system layout shall accommodate the Subsurface Ventilation System design criteria (CRWMS M&O 2000d, Section 1.2.4.1)

4.2.1.5.2 The system shall be designed so the grades of the South Ramp, emplacement drifts, and other openings providing rail transport do not exceed 2.7 percent, 1.0 percent, and 2.5 percent, respectively (CRWMS M&O 2000d, Section 1.2.4.2).

4.2.1.5.3 The system shall size the excavated openings, as a minimum, to accommodate the required operating envelopes while allowing for Ground Control System installation, variations in tunnel dimensions and alignment, and tunnel deformation, based on repository preclosure life (CRWMS M&O 2000d, Section 1.2.4.3).

**Note:** The diameter of the emplacement drifts is determined to be 5.5 m.

4.2.1.5.4 The system shall accommodate the Emplacement Drift System's temperature constraint for the zeolitized layer within the Calico Hills (CRWMS M&O 2000d, Section 1.2.4.4).

4.2.1.5.5 The system shall be designed to accommodate a limit on the temperature change, at 45 centimeters below the soil surface, to 2 degrees Celsius above the established naturally occurring pre-emplacement average annual ground surface temperature within the footprint of the MGR. The MGR footprint is defined as that area directly above emplaced WPs and extending 500 meters horizontally beyond the edge of emplaced packages (CRWMS M&O 2000d, Section 1.2.4.5). This criterion is considered TBV.

4.2.1.5.6 The system shall accommodate the Emplacement Drift System's temperature constraint for the PTn geologic unit, the Lower Tiva Canyon Member, Yucca Mountain and Pah Canyon Members, Upper Topopah Spring Member, non welded ashflows and bedded tuffs (CRWMS M&O 2000d, Section 1.2.4.6).

4.2.1.5.7 The system shall orient access drifts, mains, and ramps, etc., as needed to support Waste Emplacement/Retrieval System operations (CRWMS M&O 2000d, Section 1.2.4.7).

4.2.1.5.8 The system shall accommodate the Emplacement Drift System's uplift limit in the TSw1 thermomechanical unit (CRWMS M&O 2000d, Section 1.2.4.8).

4.2.1.5.9 The system shall interface with the Subsurface Excavation System for the location of construction openings (CRWMS M&O 2000d, Section 1.2.4.9), e.g., Tunnel Boring Machine (TBM) Assembly/Disassembly Chambers, etc.

4.2.1.5.10 The system shall operate within the Subsurface Emplacement Transportation System curvatures identified in Table 7. This criterion is considered TBV.

Table 7. Subsurface Waste Emplacement Transportation System Curvatures

| Location | Minimum Radius |
|---|---|
| Ramps and Mains | 305 meters |
| On the Surface and Within Emplacement Drift Turnouts | 20 meters |

Source: CRWMS M&O 2000f, Section 1.2.4.6

4.2.1.5.11 A difference in elevation of 0.8 meters between the bottom of the turnout and the bottom of the emplacement drift shall be accommodated (CRWMS M&O 2000f, Section 1.2.4.7). This is the result of the need to excavate a step in the launching chamber to allow TBM excavation of the emplacement drift. This criterion is needed to ensure the Waste Emplacement/Retrieval System is able to negotiate the change in elevation between the bottom of the turnout and the bottom of the emplacement drift, which is located at the emplacement drift dock.

#### 4.2.1.6 Operational Criteria

There are no defined operational criteria for the subsurface facility system. However, operational criteria are incorporated within the system performance criteria (see Section 4.2.1.1), nuclear criteria (see Section 4.2.1.2) and non-nuclear criteria (see Section 4.2.1.3).

### 4.2.2 Subsurface Ventilation System Criteria

The criteria necessary to support the subsurface ventilation analysis are documented in this section.

#### 4.2.2.1 System Performance Criteria

4.2.2.1.1 The system shall be capable of regulating airflow through each emplacement drift (CRWMS M&O 2000g, Section 1.2.1.2).

4.2.2.1.2 The system shall minimize the dry bulb temperatures in the subsurface for areas requiring human access while limiting the maximum dry bulb temperature to 48 degrees C. For subsurface areas requiring human access for a full shift (i.e., equal to or in excess of eight hours) without personnel heat stress protection, the system shall limit the maximum effective temperature to 25 degrees C (CRWMS M&O 2000g, Section 1.2.1.3). This criterion is considered TBV.

4.2.2.1.3 The system shall maintain underground air temperatures during repository remote access (remote equipment) modes to within the values specified in Table 8 (CRWMS M&O 2000g, Section 1.2.1.4).

Table 8. Remote Temperatures

| Location | Operations | Maximum Temperature |
|---|---|---|
| Emplacement Drift | Remote Access* | 50 degrees C Dry Bulb |
| Access Mains, Ramps, and Alcoves | Remote Access* | 50 degrees C Dry Bulb |
| Performance Confirmation Drifts | Remote Access* | 50 degrees C Dry Bulb |
| Exhaust Main | Remote Access* | 50 degrees C Dry Bulb |
| Turnouts | Remote Access* | 50 degrees C Dry Bulb |

*Includes emplacement, retrieval, recovery, backfill, and abnormal modes of operation.

4.2.2.1.4 The system shall provide ventilation for the development and emplacement areas by two separate and independent systems (CRWMS M&O 2000g, Section 1.2.1.6).

4.2.2.1.5 The system shall limit the maximum emplacement drift wall temperature to 96 degrees Celsius during the preclosure period (CRWMS M&O 2000g, Section 1.2.1.8). This criterion should be revised to allow for a higher drift wall temperature during abnormal events.

4.2.2.1.6 The system shall be designed to remove at least 70 percent of the heat generated by WPs within the emplacement drifts during the first 54 years after the initiation of WP emplacement (CRWMS M&O 2000g, Section 1.2.1.9).

4.2.2.1.7 The system shall have a maintainable service life up to 175 years (CRWMS M&O 2000g, Section 1.2.1.11). This criterion will support an extended forced ventilation period, but not the components required to support an extended natural ventilation period.

4.2.2.1.8 The system shall include provisions for upgrades and refurbishment designed to increase the system's operational life to support a deferral of closure for up to 300 years (CRWMS M&O 2000g, Section 1.2.1.12).

#### 4.2.2.2 Nuclear Safety Criteria

This system contains no nuclear safety criteria (CRWMS M&O 2000g, Section 1.2.2.1).

#### 4.2.2.3 Non-nuclear Safety Criteria

4.2.2.3.1 The system shall locate main intake airways a minimum of 100 m away from the surface exhaust airways (CRWMS M&O 2000g, Section 1.2.2.2.1). This criterion is considered TBV.

4.2.2.3.2 The system shall secure emplacement drift entrances to limit unauthorized personnel access to high radiation areas (CRWMS M&O 2000g, Section 1.2.2.2.3).

4.2.2.3.3 The system shall be designed to prevent reverse airflow in the emplacement drifts (i.e., from emplacement drifts to the turnouts) (CRWMS M&O 2000g, Section 1.2.2.2.4).

#### 4.2.2.4 System Environmental Criteria

4.2.2.4.1 The system shall be designed for line loading on WPs within individual emplacement drifts, defined as a maximum linear heat load of 1.5 kW/m of emplacement drift, averaged over a fully loaded emplacement drift at the time of completion of loading an entire emplacement drift (CRWMS M&O 2000g, Section 1.2.3.9).

#### 4.2.2.5 System Interfacing Criteria

4.2.2.5.1 The system shall accommodate the MGR Operations Monitoring and Control System in providing system measurements and equipment status as listed in Table 9 and Table 10, as a minimum. The type of monitoring capabilities (i.e., continuous versus intermittent) is dependent on the final system design and will be specified before system design is complete (CRWMS M&O 2000g, Section 1.2.4.1).

Table 9. Monitoring Parameters

| System Parameter | Location of Monitoring |
|---|---|
| Air Flow Rate (or Velocity)* | Main Intake, Exhaust, and Underground Working Areas |
| Air Pressure Differential* | Air Locks<br>Ventilation Fans |
| Air Temperature* | Main Intake, Exhaust, and Underground Working Areas |
| Relative Humidity of Airflow* | Main Intake, Exhaust, and Underground Working Areas |
| Concentration of Airborne Particulate* | Main Intake, Exhaust, and Underground Working Areas |
| Concentration of CO* | Main Intake, Exhaust, and Underground Working Areas |
| *Anticipated ranges for normal operation, for anticipated operational occurrences, and accident conditions will be provided for these parameters as part of final design. | |

Table 10. Equipment Status

| Equipment | Parameter Indicated |
|---|---|
| Valves (Dampers) | Open/Close Position |
| Fans | RPM, Voltage, Current, On-Off |
| Emplacement Doors | Open/Close Position |
| Air locks | Open/Close Position |

4.2.2.5.2 The System shall interface with the Subsurface Facility System to ensure that subsurface layout, arrangement, and opening sizes support ventilation (CRWMS M&O 2000g, Section 1.2.4.4).

4.2.2.5.3 The system shall interface with the Emplacement Drift System to ensure ventilation capacity and availability to support temperature constraints (CRWMS M&O 2000g, Section 1.2.4.5).

4.2.2.5.4 The system interfaces with the Backfill Emplacement System to accommodate ventilation needs for backfill operations (CRWMS M&O 2000g, Section 1.2.4.7).

4.2.2.5.5 The system interfaces with the Safeguards and Security System to accommodate for alarms and controls for the emplacement drift doors (CRWMS M&O 2000g, Section 1.2.4.8).

4.2.2.5.6 The system interfaces with the Site Radiological Monitoring System to accommodate the installation of radiation monitors (CRWMS M&O 2000g, Section 1.2.4.9).

#### 4.2.2.6 Operational Criteria

4.2.2.6.1 The repository system (in combination with appropriate shielding and ventilation) shall allow limited-time personnel access, in consideration of worker's radiation protection, into the emplacement drifts, only for the purpose of evaluating and remediating operational upset conditions after initiation of waste emplacement (CRWMS M&O 2001a, Section 5.3.2).

## 4.3 CODES AND STANDARDS

### 4.3.1 Overall Subsurface Layout Codes and Standards

4.3.1.1 The system shall comply with the applicable provisions of "Occupational Safety and Health Standards" (29 CFR 1910) CFR refers to the Code of Federal Regulations (CRWMS M&O 2000d, Section 1.2.6.1).

4.3.1.2 The system shall comply with the applicable provisions of "Safety and Health Regulations for Construction" (29 CFR 1926) (CRWMS M&O 2000d, Section 1.2.6.2).

4.3.1.3 The system shall comply with the applicable assumptions contained in the *Monitored Geologic Repository Project Description Document* (CRWMS M&O 2001a, CRWMS M&O 2000d, Section 1.2.6.3).

### 4.3.2 Overall Subsurface Ventilation Codes and Standards

4.3.2.1 The system shall comply with the applicable design provisions in Section 14.5 of "Radiation Protection in Uranium Mines" (ANSI N13.8-1973) to control concentrations of radon daughters in the potentially occupied areas of the repository (CRWMS M&O 2000g, Section 1.2.6.3).

4.3.2.2 The system shall be designed in accordance with the applicable sections of "Occupational Safety and Health Standards" (29 CFR 1910) (CRWMS M&O 2000g, Section 1.2.6.1)

4.3.2.3 The system shall comply with the applicable provisions of "Safety and Health Regulations for Construction" (29 CFR 1926) (CRWMS M&O 2000g, Section 1.2.6.2).

# 5. ASSUMPTIONS

An assumption is a statement or proposition that is taken to be true or representative in the absence of direct confirming data or evidence. The assumptions used in this analysis are identified and explained in this section.

## 5.1 OVERALL SUBSURFACE LAYOUT ASSUMPTIONS

The assumptions necessary to support the development of the subsurface layouts are documented in this section.

### 5.1.1 Controlled Project Assumptions

The *Monitored Geologic Repository Project Description Document* (CRWMS M&O 2001a, Section 6) does not contain any assumptions that are applicable to this analysis.

### 5.1.2 Other Assumptions

Other assumptions used in this analysis that are not documented in the *Monitored Geologic Repository Project Description Document* (CRWMS M&O 2001a, Section 6) are identified and explained in this section.

#### 5.1.2.1 Empty Emplacement Drifts During Emplacement

It is assumed that a certain number of special use drifts will be excavated within the pillar of two adjacent emplacement drifts and will be left empty during emplacement operations. These drifts are excavated within the pillar of adjacent emplacement drifts so as not to impact the required emplacement area. Some of the empty drifts will be cross-block drifts for ventilation, monitoring, emergency egress, and/or the Test and Evaluation program. These will be located to split the repository block into similarly sized areas. Other empty drifts will be standby emplacement drifts for possible temporary relocation of emplaced WPs. These drifts will be located within the first half of the emplacement drifts to be available early in the emplacement process. This assumption will not be considered TBV since the number of empty drifts excavated between adjacent emplacement drifts does not affect the total area required for emplacement of the specified WP inventories. The incorporation of standby and cross-block drifts is discussed in Section 6.1.2.1.2.

#### 5.1.2.2 Contingency Area

Two different allowances have been included in the layout. The required emplacement drift length will be calculated based on the nominal WP quantities plus a 5 percent contingency. This 5 percent contingency will be based on the nominal WP quantities. It is assumed that this contingency in the excavated emplacement drift length will be sufficient to allow possible variances in the WP inventory, and will be referred to as an excavation allowance.

It is also assumed that an additional 10 percent unexcavated contingency will be included in the conceptual layout. This contingency will be based on the required emplacement drift length. This contingency will only be excavated to allow for unexpected circumstances such as conditions found during development that would prevent the intended emplacement area from being used due to such things as unexpected ground conditions.

This assumption will not be considered TBV since the emplacement drift allocation and the repository footprint is not sensitive to the contingency allowance. The incorporation of the excavation allowance and the contingency area is discussed in Sections 6.1.3 and 6.1.4.

#### 5.1.2.3 Opening Separations

Vertical separation between crossing drifts is assumed a minimum of 10 meters from crown to invert. The minimum separation (centerline to centerline) for non-emplacement drifts running parallel are assumed as three diameters, based on the maximum diameter of the largest drifts. This assumption will not be considered TBV since the assignment of minimum separation does not affect the total area required for emplacement of the specified WP inventories. The incorporation of the opening separations in the layout is discussed in Section 6.1.2.1.1.

#### 5.1.2.4 Shaft Sumps

It is assumed that all ventilation shafts will be excavated with a 5-meter deep sump at the bottom. The sump provides a place for water entering the Subsurface Facility to collect for subsequent pumping to surface. This assumption in conjunction with the assigned drift spacing (see Section 4.2.1.1.5) does not impact the design of the emplacement area. Therefore, this assumption will not be considered TBV.

This assumption is used in Attachment IV.

#### 5.1.2.5 Smaller Waste Package Sizes and Decreased Heat Outputs

The repository footprint and emplacement area capacity will be evaluated for sensitivity in accommodating smaller WP sizes, at decreased average heat outputs.

The impact of changing the WP size to reduce the in-drift linear thermal power has been scoped in the past (Anderson 2000, Section 2.1). To assess the affect of smaller WPs on the repository layouts, 12 PWR and 24 BWR WPs were considered. Such WPs approximately double the inventories of WPs containing CSNF, which are the WPs with the highest heat generation rates. On the average, this brings the heat-generation rates at emplacement for these packages near the emplacement heat-generation rates for the other, cooler WPs.

It is assumed that a simple ratio will be sufficient to convert 21 PWR AP WPs to 12 PWR AP and 44 BWR AP WPs to 24 BWR AP (BSC 2001b, Item 1, p. 2) as outlined in Table 11.

Table 11. Conversion Factors for Decreasing Waste Package Size and Heat

| Required Conversions | | WP Quantity Factor | WP Average Heat Output Factor |
|---|---|---|---|
| From | To | | |
| 21 PWR AP | 12 PWR AP | $^{21}/_{12}$ = 1.750 | $^{12}/_{21}$ = 0.571 |
| 44 BWR AP | 24 BWR AP | $^{44}/_{24}$ = 1.833 | $^{24}/_{44}$ = 0.545 |

These conversion factors are used for the purposes of a parametric study only and if the project decides to go forward with the smaller WP concept, a new waste inventory will need to be defined in the technical baseline. At this time, smaller WP sizes and decreased heat outputs are not considered for the DOE SNF and HLW.

This assumption is used in Section 6.1.5.1 and Attachment VI.

#### 5.1.2.6 Standoff Distances

It is assumed that two standoff distances will reduce the useable length of the emplacement drifts. One is an operational standoff, the other a physical standoff.

The ventilation raises are located in each emplacement drift to channel exhaust air to the Exhaust Main. Since the exhaust main is located above the emplacement horizon (see Section 6.2.5.2), the ventilation raise will originate in the crown of the excavation. This presents two potential issues. First, the raise may provide a preferential pathway for water (drips) to enter the emplacement drift directly. Either a physical standoff distance between the raise and the WP should be incorporated, or an excavated alcove should be added to house the raise to prevent any of these potential drips from contacting the WP,. In addition, the raise could allow an object, ground fall, etc., to fall from a substantial height. A physical standoff distance or alcove concept would also prevent the design basis event fall height from increasing.

It is assumed that a physical standoff distance of 2 meters from the raise centerline to the WP will be provided. This distance is sufficient to provide protection for the WP from potential water entering the emplacement drift through the raise, or any potential objects that may fall from the raise.

An operational standoff distance of 1.5 meters will be required between the emplacement drift turnout interface and the closest placed WP in the emplacement drift. It is assumed that a standoff distance of 1.5 meters will be sufficient to ensure that the WP is not located at the edge of the 0.8 meter elevation difference between the turnout and the emplacement drift (see Section 4.2.1.5.11).

These assumptions are not considered TBV since the assignment of standoff distances does not significantly impact the repository footprint or emplacement drift allocations.

These assumptions are used in Attachment I.

#### 5.1.2.7 Maximum Drift Split Length

In the analysis *Site Recommendation Subsurface Layout* (BSC 2001a, Sections 5.2.4) the emplacement drift split was restricted to 600 meters.

It is assumed that the lower-temperature operating mode concept will produce somewhat lower temperatures within the emplacement drifts, and therefore allow emplacement within a longer emplacement drift split length. It is assumed that an emplacement drift split of 700 meters can be fully emplaced with waste. This assumption is preliminary and will require confirmation.

This assumption is used in Attachment I.

#### 5.1.2.8 Ventilation Raise Diameter

Ventilation raises connecting the emplacement drifts, ODs, stand-by drifts, etc. are assumed to have a nominal diameter of 2.0 meters. This assumed diameter provides a basis for excavation quantities only. This assumption is used in Sections 6.1.2.4, 6.1.3.2 and 6.1.4.2 and Attachment IV.

## 5.2 OVERALL SUBSURFACE VENTILATION ASSUMPTIONS

A number of assumptions are required to integrate the overall ventilation strategy with subsurface layout. These assumptions are listed in the following sub-sections.

### 5.2.1 Controlled Project Assumptions

There are no ventilation related Controlled Project Assumptions contained in the *Monitored Geologic Repository Project Description Document* (CRWMS M&O 2001a). Technical ventilation requirements have been incorporated into the repository design concept and are considered part of the technical baseline or are captured in the System Description Documents (CRWMS M&O 2001a, Section 5).

### 5.2.2 Other Assumptions

This section documents other assumptions used for the ventilation analysis.

#### 5.2.2.1 Fan Operating Efficiency

Vane-axial fans operate in the 70 percent to 85 percent efficiency range (Hartman et al. 1997, Table 9.3). For the purposes of this analysis, an efficiency of 75 percent has been selected. This assumption does not impact the design of the emplacement area. Therefore, this assumption will not be considered TBV. This assumption is used in Section 6.2.8.4.

#### 5.2.2.2 Fan Operating Pressure

For the purpose of this analysis, it is assumed that the repository ventilation system can be designed to operate at 10 inches of water gauge (wg) pressure. This assumption does not impact the design of the emplacement area. Therefore, this assumption will not be considered TBV. This assumption is used in Section 6.2.8.4.

#### 5.2.2.3 Natural Ventilation Monitoring Period

It is assumed a 25-year period is used for active monitoring at the start of the natural ventilation period. This period will be used for performance confirmation and airflow regulator installation or adjusting. This assumption does not impact the design of the emplacement area. Therefore, this assumption will not be considered TBV. This assumption is used in Sections 6.2 and 6.2.5.3.

# 6. ANALYSIS/MODEL

This analysis develops the subsurface layout (Section 6.1) and subsurface ventilation system (Section 6.2). The subsurface layout, footprint, and emplacement drift allocations are required to establish the overall subsurface ventilation system requirements, and these requirements in turn, feed back into the subsurface layout for location of the ancillary openings that support the ventilation system. This analysis does not provide estimates of any factors or potentially disruptive events, and therefore, is assigned a Level 3 importance in accordance with AP-3.15Q, *Managing Technical Product Inputs*.

## 6.1 OVERALL SUBSURFACE LAYOUT ANALYSIS

A lower-temperature operating mode, including a representative scenario and four other example scenarios has been defined that form the basis for a revision to the performance assessment models in the *Yucca Mountain Science and Engineering Report* (S&ER) (DOE 2001, Section 2.1.5.2, p. 2-24). This representative scenario provides a reasonable starting point for analysis and description of the lower-temperature operating mode. It preserves the ability to vary the design to bound the remaining scenarios. In the scenarios described below the text in parenthesis corresponds to the operational modes described in the S&ER (DOE 2001, Section 2.1.5.2, p. 2-24).

**Representative Scenario (Increased Waste Package Spacing and Extended Ventilation)** — The representative lower-temperature operating mode for the repository design achieves lower WP surface temperatures and drift wall temperatures by:

- spacing the reference WPs approximately 2.0 meters apart to create a 1 kW/m average thermal load in each drift at emplacement, and
- ventilating the emplacement drifts actively for 50 years after the last emplacement and then naturally for an additional 250 years.

**Alternative Scenario One (De-Rated or Smaller Waste Packages)** — Lower WP surface temperatures and drift wall temperatures would be achieved through an extended ventilation period, a minimal increase in the disposal area, and employment of lower heat output (i.e., smaller), tightly-spaced (0.1 meter) WPs. The ventilation period for this scenario would include 50 years of forced ventilation and 250 years of natural ventilation. Use of smaller WPs would require the manufacture of many more WPs. The variation of the smaller WPs size and the closer spacing can be reviewed as operating sensitivities to the representative lower-temperature operating mode layout.

**Alternative Scenario Two** — This scenario is not included in the example scenarios outlined in the S&ER. Alternative Scenario Two provides an example of varying the emplacement drift spacing that is potentially important to the LT design. Lower WP surface temperatures and drift wall temperatures would be achieved through an extended forced ventilation period, a minimal increase in the disposal area, and an increased drift spacing of 120 meters. This scenario requires the use of a forced ventilation system for a period of 300 years and emplacement of the reference design WP size and spacing (spacing of 0.1 meters). The variation of increased emplacement drift spacing can be reviewed parametrically as design sensitivity to the representative lower-temperature operating mode.

**Alternative Scenario Three (Increased Spacing and Duration of Forced Ventilation)** — Lower WP surface temperatures and drift wall temperatures would be achieved through an increase in the disposal area and by limiting the forced ventilation period (~125 years). This scenario would not include surface aging of the waste but would require an increased spacing between the reference WP (6 meters). This scenario is a variation in which the trade-off of additional repository drifting could be reviewed versus the reduced time for ventilation. This alternative is developed as an operational sensitivity. It also represents the extreme case for the emplacement drift excavation requirement.

**Alternative Scenario Four (Extended Surface Aging with Forced Ventilation)** — Lower WP surface temperatures and drift wall temperatures would be achieved through an increase in the disposal area, a limited forced ventilation period (~125 years), surface aging of the waste for up to 40,000 MTHM of spent fuel, and a limited increase in spacing between reference WPs (2 meters). This scenario would require extensive aging of a portion of the waste inventory. Aging is an option which will be used in conjunction with the recommended representative scenario to enable certain higher temperature wastes or variations in incoming waste streams to be handled. This scenario can be developed as an operational sensitivity to the representative lower-temperature operating mode.

A repository layout has been developed in Section 6.1.2 that will become the basis for discussing the recommended representative scenario for the lower-temperature operating mode. The representative scenario for the lower-temperature operating mode has been developed as case study for the 70,000 MTHM and 97,000 MTHM waste inventories in Sections 6.1.3 and 6.1.4. A number of parametric studies has been completed (see Section 6.1.5) to examine the flexibility of the repository layout to accommodate other operating scenarios, such as those outlined above.

The *Site Recommendation Subsurface Layout* analysis was based on a 0.1 m WP spacing, 50 years of forced ventilation, and 1.45 kW/m linear heat load (BSC 2001a, Section 6.2.3.2). This design corresponds to the *Yucca Mountain Science and Engineering Report* Higher Temperature Operating Mode (DOE 2001, Section 2.1.5.2, p. 2-24) and therefore, is not addressed here. Note that the S&ER Extended Natural Ventilation example scenario (DOE 2001, Section 2.1.5.2, p. 2-24) results in the same emplacement capacity as the S&ER Higher Temperature Operating Mode, and consequently, is not addressed in this analysis.

### 6.1.1 Design Methodology

The planning layout and the lower block expansion layout as described in Section 4.1.1.1, Figure 1, and Figure 2 were found to have sufficient capacity to support the representative lower-temperature operating mode layouts. The layouts also allow sufficient flexibility for performing the parametric studies presented in Sections 6.1.5.1 and 6.1.5.2.

### 6.1.2 Development of the Repository Layout

Specific locations of the emplacement drifts within that repository footprint are maintained by restricting the design activities to the modification of the ancillary openings supporting the subsurface ventilation system (see Section 6.2) and the Test and Evaluation Program (see Section 6.1.2.1.3). This approach does not adversely impact the repository footprint and hence, the available emplacement capacity.

### 6.1.2.1 Layout Description

The repository layout consists of various openings having different functions and different design considerations. The following sections provide a description of the repository layout, as it was developed three-dimensionally in VULCAN v3.4. For reference, the repository layout is illustrated in Figure 3 and details of the opening lengths and gradients are detailed in Attachment II. For this analysis, the following definitions will be used to differentiate between a layout, the footprint, and the characterized block.

**Layout** – The layout is a specific configuration of the subsurface openings that support the defined waste emplacement and retrieval operations.

**Footprint** – The areal extent, represented in a plan view of the emplacement area bounded by bounding coordinates as outlined in Attachment III. The footprint does not include areas occupied by support openings such as main drifts, ramps, and turnouts.

**Characterized Block** – A three-dimensional solid (volume) based on the following criteria as defined below and detailed in Section 4.2.1:

- Overburden minimum of 200 meters below the directly overlying ground surface (see Section 4.2.1.2.9).
- Stratigraphic requirements defined by the RHH (see Section 4.2.1.2.8).
- Standoff distance criteria for Type I faults and the ground water table (see Section 4.2.1.2.4).

For the lower-temperature operating mode, the Exhaust Main is placed above the repository horizon (see Section 6.2.5.2). This approach results in the following design modifications:

- Redesigning the Test and Evaluation Facility ODs. The Enhanced Characterization of the Repository Block drift (ECRB) is no longer available as an OD since it now intersects the exhaust main. The intersection between the two openings will be invert to invert. Consequently, the ODs have been relocated to below the repository horizon.

- Locating the exhaust main above the repository horizon requires that the ventilation raises be offset from the centerline of the exhaust main. This change was made to simplify the potential raise furnishings, i.e.; the raise would not require a structural component at the collar to allow rail to be installed over the raise.

- Reducing the number of PCTD to one (see Section 4.2.1.1.8) to support the Test and Evaluation Facilities.

All the opening sizes presented are considered nominal values only. As a part of detailed design activities, opening sizes will include tolerance values for construction and operations.

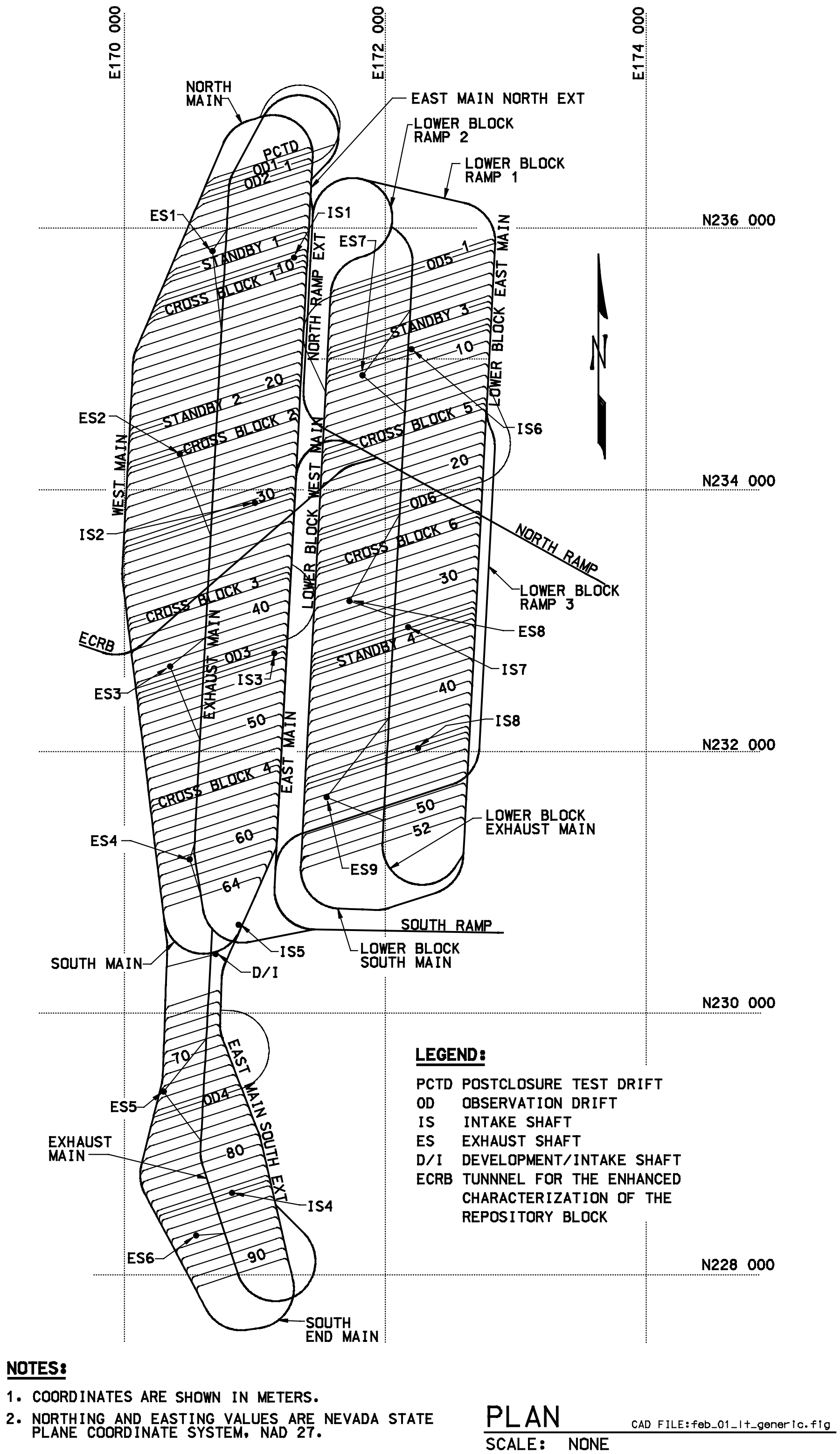



Figure 3. Repository Layout

(Layout of Potential Repository Development Areas as noted in the S&ER (DOE 2001, Fig. 2-10))

#### 6.1.2.1.1 Ramps and Mains

The ramps and mains, excluding the exhaust main remain unchanged from the *Site Recommendation Subsurface Layout* (BSC 2001a, Sections 6.2.1 and 6.5.1).

The East and West Mains, including those in the lower block and the East Main North and South Extensions will be used primarily for waste emplacement operations such as access to the emplacement drifts. The North, South, and South End Mains, including those in the lower block have been configured between the East and West Mains in order to provide access from one side of the repository block to the other. This type of access across the repository block will provide flexibility of movement for the WP transporter during waste emplacement operations. As such, these main drifts have been oriented with respect to each other to support waste emplacement and potential retrieval operations (see Section 4.2.1.5.7).

A North Ramp Extension is provided to the north end of the primary repository block as a bypass from the North Ramp to allow concurrent waste emplacement operations and continued Subsurface Facility development. The extension to the north end of the primary block is parallel to the East Main Extension. The two openings have a centerline-to-centerline plan distance of approximately 24.5 meters between the openings. This pillar size is in excess of the assumed stable pillar size of three diameters from centerline-to-centerline (see Section 5.1.2.3). Pillar stability will be further analyzed as part of ground control analyses for non-emplacement openings.

The access mains are configured such that any opening curvature radius within the mains and any transition from main to main are 305 meters. This opening radius dictates the curvature radius of the tracks and allows integration of the emplacement and retrieval equipment (see Section 4.2.1.5.10).

The Exhaust Mains receive the airflow from the subsurface openings and direct that flow to the surface through the exhaust shafts. The exhaust mains are situated approximately 10 meters above the repository elevation in both the primary and lower blocks (see Section 6.2.5.2) extending from the north end of each block to its extreme south end. A minimum pillar of 10 meters is allowed between the Exhaust Mains and the underlying openings. This pillar allowance provides ground between the Exhaust Main and the other repository openings (see Section 5.1.2.3).

The ramps and mains, excluding the South Ramp, have been configured such that the gradients do not exceed 2.5 percent. A gradient of 2.5 percent has been specified for all openings that require rail transportation (see Section 4.2.1.5.2). All gradients with the mains and ramps are documented in Attachment II. The steepest gradient within the ramps and mains, approximately 2.47 percent, occurs within the South End Main (see Table II-2). The South Ramp, which was excavated as part of the Exploratory Studies Facility (ESF), has a gradient of approximately 2.62 percent (CRWMS M&O 1996, p. 27). This gradient is in agreement with a South Ramp gradient restriction of 2.7 percent (see Section 4.2.1.5.2).

The ESF opening was excavated with a TBM to a nominal diameter of 7.62 meters in accordance with the *Exploratory Studies Facility Design Requirements* (YMP 1996, p. 3-69). This opening size considered waste emplacement operations allowing for ground control installation, variations in tunnel dimensions and alignment and tunnel deformations (see Section 4.2.1.5.3). The access mains for the repository layout will be excavated with a TBM to a nominal diameter of 7.62 meters to match the ESF openings.

6.1.2.1.2 Emplacement Area

The emplacement drifts will be excavated to connect with the East Mains and the West Mains and allow access into the emplacement drifts from either side during emplacement operations. Emplacement drifts are planned with an azimuth of 252 degrees (CRWMS M&O 1999b, p. 26). The drift orientation positions the emplacement drifts at least 30 degrees from the dominant joint orientations of the RHH (see Section 4.2.1.1.7).

The emplacement drifts are planned for excavation to a nominal diameter of 5.5 meters (see Section 4.2.1.1.3). The emplacement drifts are to be spaced at 81 meters centerline-to-centerline (see Section 4.2.1.1.5). With this drift spacing, the repository layout can accommodate 91 drifts in the primary block and 52 drifts in the lower block area. These drifts total 147,843 meters of available emplacement drift, excluding the Test and Evaluation PCTD (see Attachment I). The Test and Evaluation Facilities, including the use of the first drift in the emplacement area, are discussed in Section 6.1.2.1.3. Layouts other than the repository layout may provide more available emplacement drift length. A more detailed discussion of the area potentially available for waste emplacement is located in Section 6.1.2.2.

The emplacement area in the planning layout is bounded by a set of coordinates that represents an offset of 1.5 meters from each end of the emplacement drift (see Section 5.1.2.6). WPs will be emplaced within the emplacement area with no WP extending into the 1.5 meter WP free zone at each end of the drift. A list of these boundary coordinates for the emplacement area is located in Attachment III.

The gradients within the emplacement drifts can not exceed 1.0 percent (see Section 4.2.1.5.2). For drainage purposes, the emplacement drifts have been specified with a flat gradient (see Section 6.1.2.5).

**Acreage Available in the Primary Block Footprint**–The total emplacement drift length and the drift spacing can be used to calculate the total available acreage in the primary block footprint.

$$\text{Acreage} = \frac{L_a \text{ (meters)} \times \text{DS (meters)}}{43{,}560 \text{ ft}^2/\text{acre}} \times \frac{1}{0.0929 \text{ m}^2/\text{ft}^2}$$

Where: $L_a$ = available emplacement drift length (meters) and
DS = drift spacing (meters).

When: $L_a$ = 85,443.2 meters (see Attachment I, p. I-5) and

DS = 81.0 meters (see Section 4.2.1.1.5),

$$\text{Acreage} = \frac{85{,}443.2 \text{ meters} \times 81 \text{ meters}}{43{,}560 \ {ft^2}/{acre}} \times \frac{1}{0.0929 \ {m^2}/{ft^2}}$$

Acreage = 1,710.2 acres

**Acreage Available in the Lower Block Footprint**–The total emplacement drift length and the drift spacing can be used to calculate the total available acreage in the lower block footprint.

$$\text{Acreage} = \frac{L_a \text{ (meters)} \times \text{DS (meters)}}{43{,}560 \ {ft^2}/{acre}} \times \frac{1}{0.0929 \ {m^2}/{ft^2}}$$

Where: $L_a$ = available emplacement drift length (meters) and
DS = drift spacing (meters).

When: $L_a$ = 147,843.2 – 85,443.2 = 62,400 meters (see Attachment I, p. I-7)
DS = 81.0 meters (see Section 4.2.1.1.5),

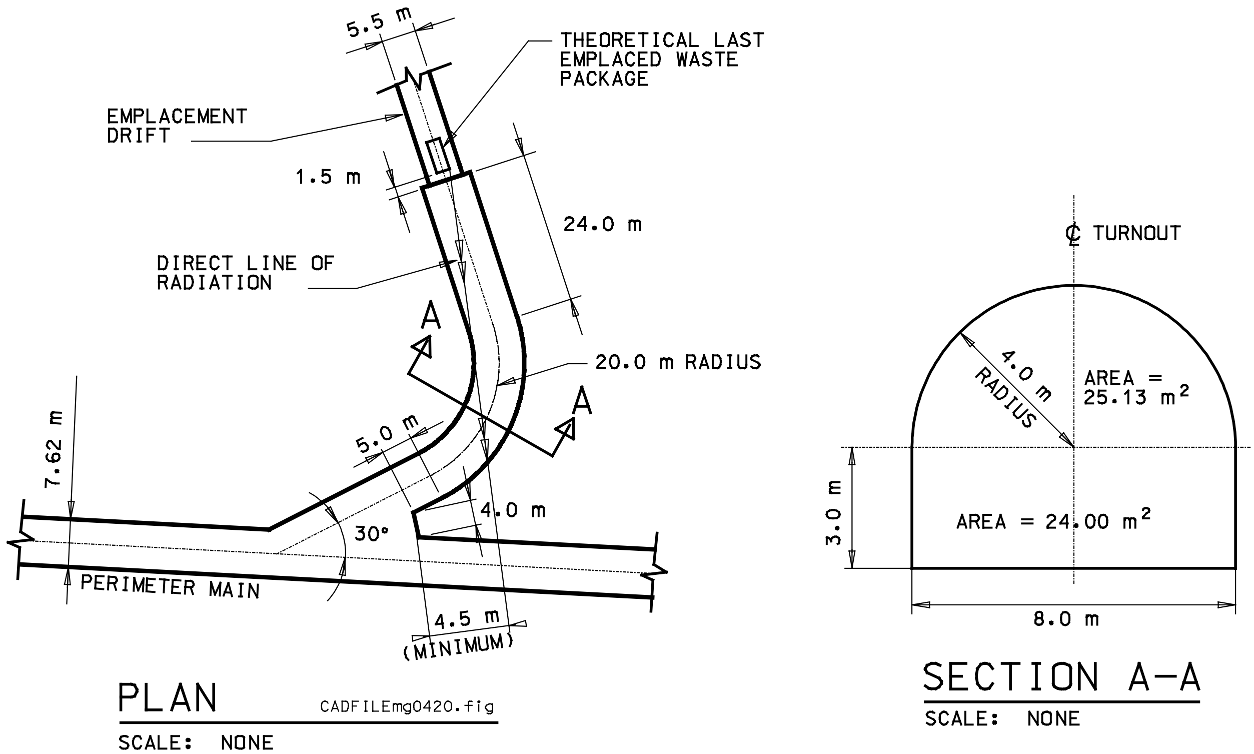
$$\text{Acreage} = \frac{62{,}400 \text{ meters} \times 81 \text{ meters}}{43{,}560 \ {ft^2}/{acre}} \times \frac{1}{0.0929 \ {m^2}/{ft^2}}$$

Acreage = 1,249.0 acres

The repository layout with 143 emplacement drifts, excluding the Test and Evaluation PCTD, has approximately 1,710 acres available within the primary block footprint and approximately 1,250 acres in the lower block footprint. A total of 2,960 acres is available within the footprints configured in the repository layout.

**Emplacement Drift Turnouts**–A transition from the East and West Mains into the emplacement drifts is required to support emplacement operations and accommodate the waste emplacement equipment. The emplacement drift turnouts will function as a transition from the Mains into the emplacement drifts. The turnouts will also support activities such as the TBM launch for emplacement drift excavation and WP transporter unloading and transfer of the WPs to the emplacement gantry.

The configuration of the turnout requires the integration of a number of activities and operations, and was developed in the *Site Recommendation Subsurface Layout* (BSC 2001a, Section 6.2.1.2). For reference, a typical turnout is illustrated in Figure 4.




Source: BSC 2001a, Section 6.2.1.2

Figure 4. Typical Turnout Configuration

The following factors have been integrated into the configuration of the turnouts:

- Provision of a stable intersection between the turnout and the main drift.
- Restriction of the direct-line-of-radiation from the last emplaced WP from entering the main drift.
- Accommodation to place ventilation doors at either end of the turnout, at the main drift and the entrance to the emplacement drift.
- Accommodation of the WP transporter within the turnout.

The profile of the emplacement drift turnout is 8 meters wide with an arch from spring-line to spring-line, and 7 meters high at the crown as illustrated in Figure 4.

The length of the turnout depends on the change in azimuth between the centerline of the perimeter main and the centerline of the emplacement drift. As the angle between the main and the emplacement drift gets larger, the turnout length increases. The lengths of the turnouts are discussed further in Attachment IV. The variances in the turnout gradients change with the turnout length, but are configured such that any water encountered within the turnout will drain out to the main away from the emplacement drift. The overall drainage scheme for the planning layout is further discussed in Section 6.1.2.5.

**Standby and Cross-Block Drifts** – These drifts are excavated in the pillar of adjacent emplacement drifts and will be left empty at closure but may be in use during emplacement operations (see Section 5.1.2.1). These drifts and their turnouts will be excavated to the same size as the emplacement drifts and turnouts. Standby and cross-block drifts will serve different purposes.

Standby drifts will be used for temporary relocation of WPs, if necessary. If, for some reason, the WPs must be removed from a loaded emplacement drift, the standby drifts will serve as receiving locations instead of removing the WPs back to the surface. Relocated WPs can remain in the standby drifts on a temporary basis. Any WPs in these drifts will be moved to a permanent location. Standby drifts, totaling four, will be excavated, between Emplacement Drifts 7 and 8, 20 and 21, L6 and L7, and L34 and L35 (see Figure 3).

Cross-block drifts will be left empty to facilitate ventilation, emergency egress, and assist in the Test and Evaluation program. The cross-block drifts will also serve as paths for cool, fresh air to get to the Exhaust Main service side (see Section 6.1.2.4). The Test and Evaluation program may also use the cross-block drifts to monitor the adjacent emplacement drifts. The cross-block drifts, totaling six are currently placed between Emplacement Drifts 10 and 11, between Emplacement Drifts 23 and 24, between Emplacement Drifts 37 and 38, between Emplacement Drifts 54 and 55, between Emplacement Drifts L15 and L16, and between Emplacement Drifts L25 and L26 (see Figure 3).

#### 6.1.2.1.3 Test and Evaluation Program

A Test and Evaluation program will be conducted within the Subsurface Facility (see Section 4.2.1.1.8). This Test and Evaluation program, part of the Performance Confirmation Plan, will operate during both construction and operations to confirm that the design objective, i.e., the long-term isolation of waste in the Subsurface Facility, is accomplished. The Test and Evaluation program will require a number of facilities for performance monitoring, postclosure simulations, and specialized test areas. The location of the Test and Evaluation Facilities within the repository layout is illustrated in Figure 3. Only major facilities (ODs and the test drift) are shown. Smaller facilities, such as alcoves, are not designed at this time.

The performance monitoring facility will require a minimum of three monitoring areas with one OD, OD1, and a minimum of six alcoves for each area (see Section 4.2.1.1.8). The performance monitoring ODs are labeled OD2, OD3, OD4, OD5, and OD6 in Figure 3. These monitoring areas allow performance to be monitored throughout the primary area, with a separate monitoring area in the south end of the primary block footprint, and two additional monitoring areas within the lower block footprint.

These performance monitoring ODs are located below the repository horizon and will provide access for monitoring of preclosure conditions in the near-field environment. Along with each of the ODs, a number of testing alcoves will be required. The locations of these alcoves will be specified in future analyses.

A postclosure simulation facility will be located within the primary area (see Section 4.2.1.1.8). The first drift within the emplacement block will be designated as the simulation drift. The postclosure simulation drift must be a minimum of 600 meters in length to provide for two segment tests and buffer areas (see Section 4.2.1.1.8). Therefore, only the east side of the reserved drift will be used. An OD to monitor the postclosure simulation drift is located below the repository horizon. Along with the OD, a number of testing alcoves will be required. The locations of these alcoves will be specified in future analyses.

The test and evaluation facilities will be excavated with a nominal diameter of 5.5 meters, similar to the emplacement drifts.

Additional specialized test areas will be required within the Subsurface Facility (see Section 4.2.1.1.8). These test areas include seepage measurement alcoves, seismic monitoring alcoves, ramp-seal test alcoves, and shaft-seal test alcoves. These specialized alcoves will require specific testing locations that will provide the varying conditions needed for the test. Since the locations of these alcoves do not affect the conceptual Subsurface Facility layout, they will be addressed in future analyses.

#### 6.1.2.2 Geological and Hydrological Constraints

The geology and hydrology play a large role in the siting and configuration of the potential repository. The site geology, surface topography and the ground water table define the physical three-dimensional spatial boundaries of the Subsurface Facility. The geological model, GFM 3.1 (see Section 4.1.1.2) was used as input to VULCAN v3.4. The VULCAN v3.4 software was then used to extract geologic information with respect to the repository layout from the *Electronic Files in Support of ANL-WER-MD-000002 REV 00* (BSC 2001aa).

The repository siting volume is a complex three-dimensional solid that may be difficult to visualize for some and equally difficult to illustrate. The repository siting volume when input to VULCAN v3.4 can be superimposed on the repository footprint to define the limits of the characterized block and the footprint. The limits of the characterized block for the primary and lower blocks are illustrated in Figure 5 and Figure 6, respectively. The characterized block limits outlined in these figures are representative only at the specific elevations of the repository footprint in that block.

As can be noted from Figure 5 and Figure 6, not all of the characterized block for the primary and lower blocks is incorporated into the repository layout. If additional emplacement drift capacity is required, the layout can be reconfigured within the characterized block to accommodate future design changes. This concept is described below.

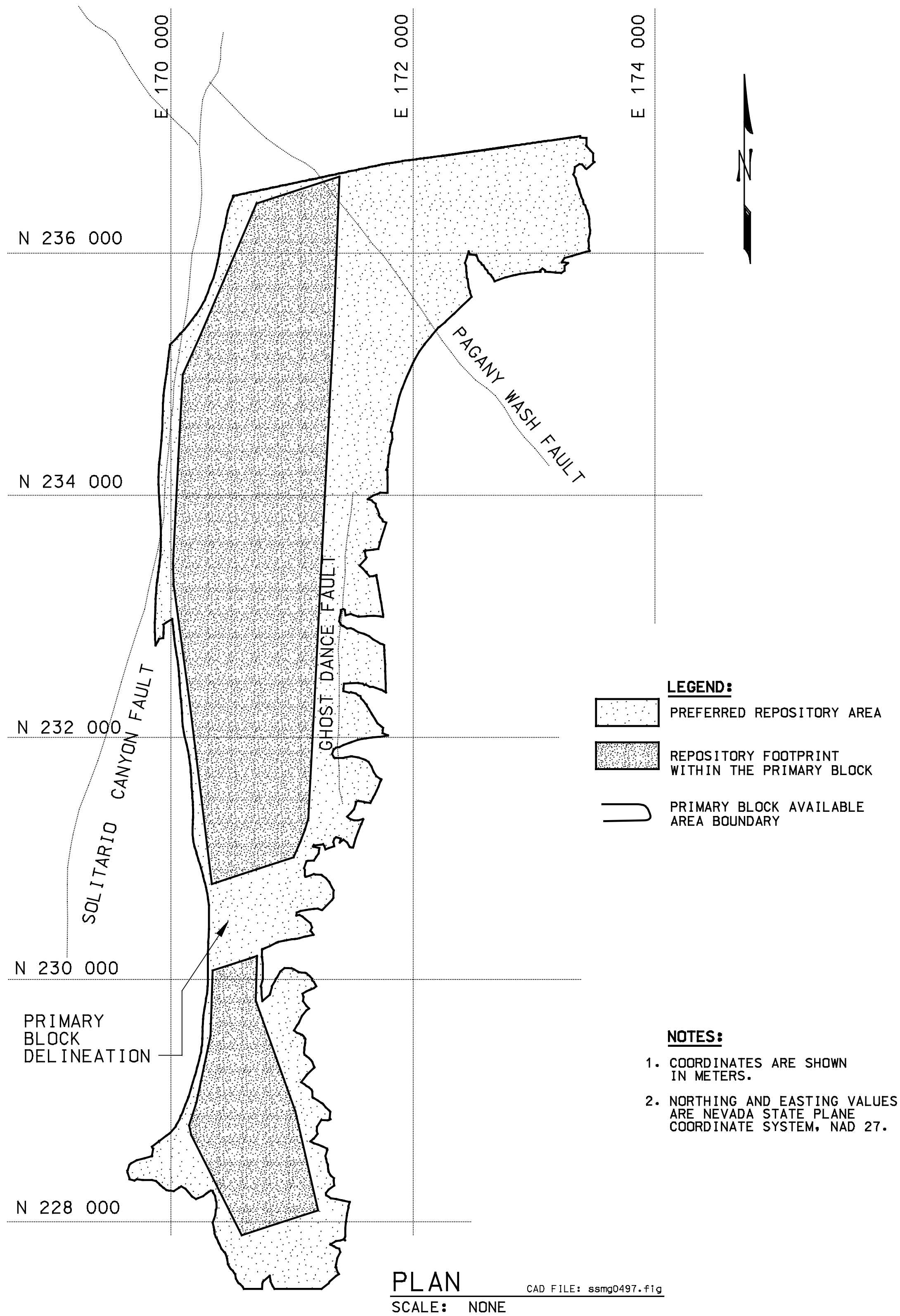



Figure 5. Primary Block Repository Footprint (EL. 1,030 – 1,116 meters)

Characterized area limit outlined in this figure is representative only at the specific elevations of the repository footprint.

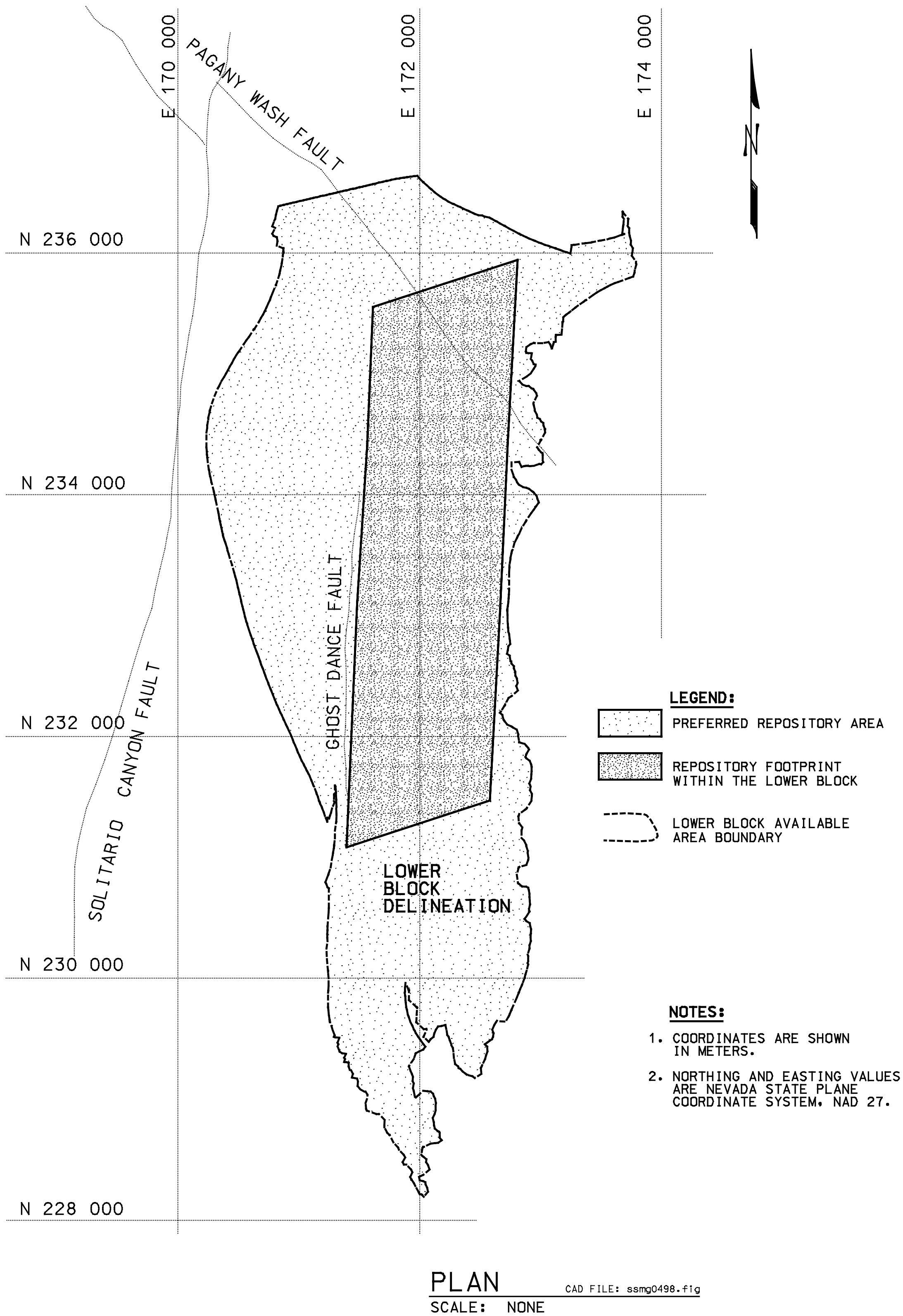



Figure 6. Lower Block Repository Footprint (EL. 974 – 1,004 meters)

Characterized area limit outlined in this figure is representative only at the specific elevations of the repository footprint.

In order to determine a maximum potential area within the characterized block, the three-dimensional representation of the geology was used to project a plan view of the characterized block within Yucca Mountain, using the VULCAN v3.4 software. This outline bounds areas that are at varying elevations within the mountain. This method only reflects a single-tier repository concept where one emplacement area can not be placed directly above another emplacement area.

Additional layout work could produce a different layout configuration that provides a more effective use of the characterized block, and would still incorporate the current design requirements for the subsurface facility.

Due to design considerations and the irregularities of the boundary described as the maximum potential area within the characterized block, it is estimated that only 40 to 50 percent of this area would actually be available and useable for emplacement. The following factors have been considered when restricting the useable area within the maximum potential area of the characterized block:

- The maximum area consists of areas available at different elevations within the mountain. This creates a three-dimensional layout configuration constraint where efficient and optimal use of the space creates small areas that cannot accommodate emplacement operations.
- There may be a need to allocate openings other than emplacement drifts within this boundary.
- Certain design constraints such as the minimum opening curvature limit of 305 meters may restrict usage of the area, specifically along the boundaries.
- The irregularities of the boundary itself will restrict usage of the full area.

An estimate of the total potential available emplacement length can be back calculated from the square meters of the potential useable area and the factor of 40 to 50 percent. The maximum potential area of the characterized block, as calculated with VULCAN v3.4, is approximately 37 million square meters. Applying a factor of 40 to 50 percent indicates that from 14.8 to 18.5 million square meters should be available for emplacement drift allocation. This equates to 3,660 to 4,560 acres (see calculation method in Section 6.1.2.1.2), or between 183 and 228 kilometers of emplacement drift (this is determined by dividing the area by the emplacement drift spacing of 81 meters). This potential expansion capability within the characterized block of Yucca Mountain will be used in conjunction with the parametric studies presented in Section 6.1.5.

The layout configuration is based on the current geological model of Yucca Mountain as documented in Section 4.1.1.2. The GFM 3.1 provides a baseline representation of the locations and distributions of rock layers and faults in the subsurface of the Yucca Mountain area for use in geoscientific modeling and repository design. The input data from the geologic map and boreholes provide controls at the ground surface and to the total depths of the boreholes; however, most of the modeled volume is unsampled. For this reason, there are inherent uncertainties associated with this geologic model.

Uncertainties in the GFM 3.1 model are described in the *Geologic Framework Model (GFM3.1) Analysis Model Report* (CRWMS M&O 1999h, Section 7). The uncertainty discussion from the *Geologic Framework Model (GFM3.1) Analysis Model Report* is included here to relate these uncertainties to possible uncertainties in the configuration of the layout.

> "Elevation uncertainty in the geologic model increases with distance from the data and is also a function of geologic processes like deposition, faulting, and erosion. Thickness uncertainty of individual units is a contributing factor to elevation uncertainty and is strongly influenced by the thickness range of a unit and the geologic process that formed it. Uncertainty in the model is mitigated by the application of established geologic principles.
>
> The most uncertain areas in the model are the four corners, the less constrained areas, and the volume deeper than the borehole penetrations."

If additional detailed mapping of the Yucca Mountain area results in additional fault restrictions such as those outlined in Section 4.2.1.2.4 or any changes to the stratigraphic boundaries, the impacts to the layout configuration will need to be determined. This means that the configuration of the layout as presented in Figure 3 could require modification.

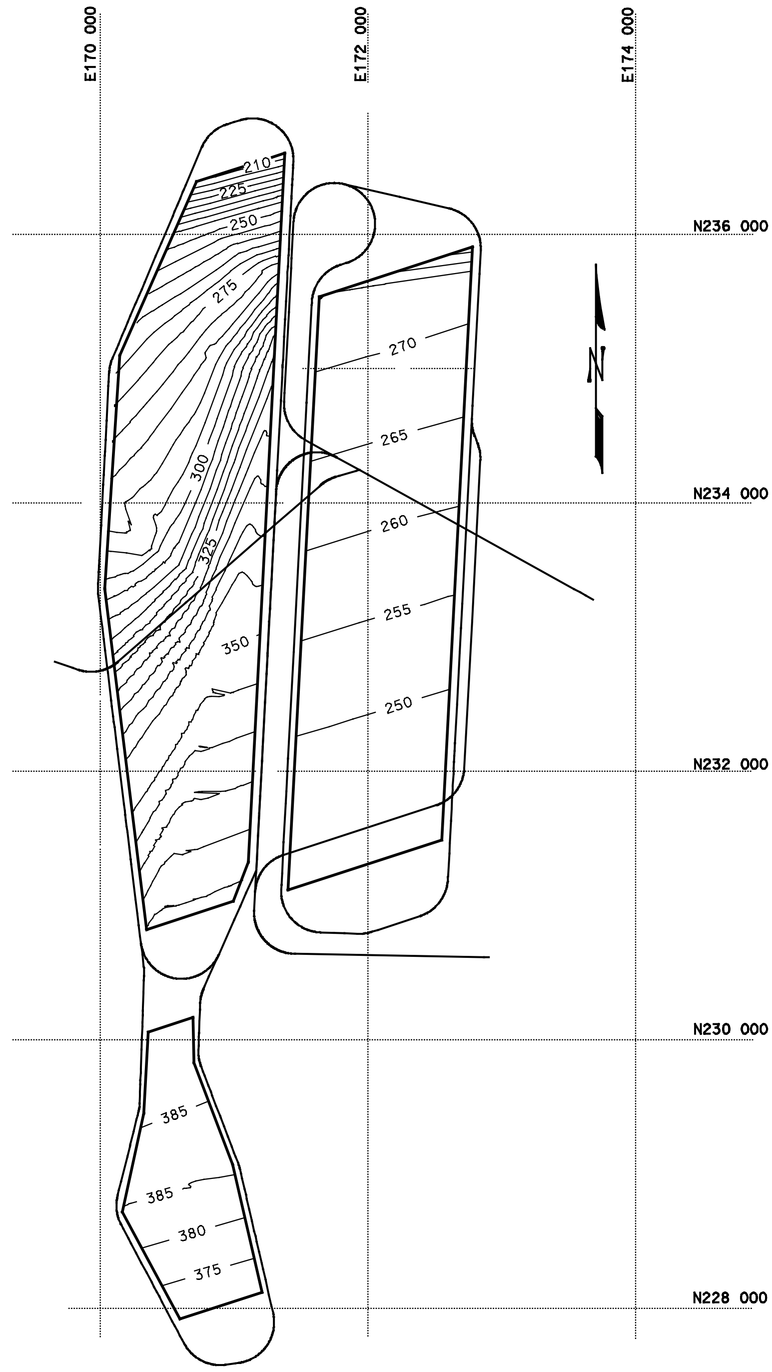
6.1.2.2.1 Hydrology

Figure 7 illustrates vertical separation between the repository and the present day ground water table. The values indicated in the figure represent the difference in elevation between the emplacement drift inverts and the top surface of the ground water table for the primary and lower blocks.

A revised set of contours was developed using VULCAN v3.4 for the present day ground water table. The contours were then triangulated to form a triangulation surface defining the top of the potentiometric groundwater surface.

To develop the thickness contour map for the rock interval between the invert of the emplacement drifts and the top of the potentiometric groundwater surface, the following procedure steps were taken:

1. Triangulated surfaces of the emplacement drift inverts for each of the two emplacement areas were developed to define the limits of the emplacement areas.
2. The triangulated surface for the potentiometric groundwater level was subtracted from the triangulated surfaces defining the three emplacement areas. The resulting triangulated surface represented a thickness of the rock units between invert of the emplacement drifts and the top of the potentiometric groundwater surface.
3. The resulting triangulated thickness was contoured for each of the three emplacement areas. This is illustrated in Figure 7.




**NOTES:**

1. COORDINATES ARE SHOWN IN METERS.
2. NORTHING AND EASTING VALUES ARE NEVADA STATE PLANE COORDINATE SYSTEM, NAD 27.
3. CONTOUR INTERVAL 5 m.
4. CONTOURS REPRESENT THE DEPTH OF THE WATER TABLE BELOW THE EMPLACEMENT DRIFTS.

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Figure 7. Ground Water Contours Relative to Emplacement Horizon

Showing depth of the groundwater table

Below the emplacement drift invert.

As shown in Figure 7, the repository layout is located such that the closest edge of the emplacement drifts is placed a minimum of 160 meters from the top of the present day ground water table (see Section 4.2.1.2.4). This allowance assists both the engineered and natural barriers to work in combination to limit the possible annual dose released from the repository by providing a standoff from the water table.

6.1.2.2.2 Geology

Geologic criteria relating to the repository layout in a plan view are shown in Figure 8 and Figure 9. The emplacement area is located at least 200 meters below the directly overlying ground surface (see Section 4.2.1.2.9). The figures show where the overburden contour (200 meter standoff) limits the extent of the repository layout. The figure also shows a representation, as depicted by VULCAN v3.4, of the rock units in which the three-dimensional planning layout will be situated. Other identified limits for repository siting include limiting the emplacement areas to within the characterized block (see Section 4.2.1.2.8), and providing minimum standoffs from the main trace of Type I faults (see Section 4.2.1.2.4). The identification and classification of Type I faults are discussed in more detail later in this section.

**Rock Units** — The repository footprint is located within the lower part of the TSw1 unit and the entire TSw2 unit of the characterized block (see Section 4.2.1.2.8). The excavation percentages of the potential repository in each of the geologic rock units are listed in Table 12. The rock units within the Topopah Spring Tuff are defined as follows:

- The tptpul rock unit is the upper lithophysal zone.
- The tptpmn rock unit is the middle nonlithophysal zone.
- The tptpll rock unit is the lower lithophysal zone.
- The tptpln rock unit is the lower nonlithophysal zone.

The excavation volumes outlined in Table 12 were extracted from the *Electronic Files in Support of ANL-WER-MD-000002 REV 00* (BSC 2001aa). This was accomplished using VULCAN v3.4. The excavation percentages were then calculated based on the extracted volumes.

Table 12. Percentage of Excavation in Various Rock Units

| Area | tptpul | | tptpmn | | tptpll | | tptpln | | TOTAL | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Volume ($m^3$) | % | Volume ($m^3$) | % | Volume ($m^3$) | % | Volume ($m^3$) | % | Volume ($m^3$) | % |
| Primary Block | 0 | 0.0 | 2,562,522 | 6.5 | 28,826,255 | 73.3 | 7,920,025 | 20.1 | 39,308,801 | 100.0 |
| Lower Block | 2,305,316 | 8.4 | 7,245,859 | 26.5 | 16,079,556 | 58.8 | 1,727,424 | 6.3 | 27,358,155 | 100.0 |
| Total | 2,305,316 | 3.5 | 9,808,381 | 14.7 | 44,905,811 | 67.4 | 9,647,449 | 14.5 | 66,666,956 | 100.0 |

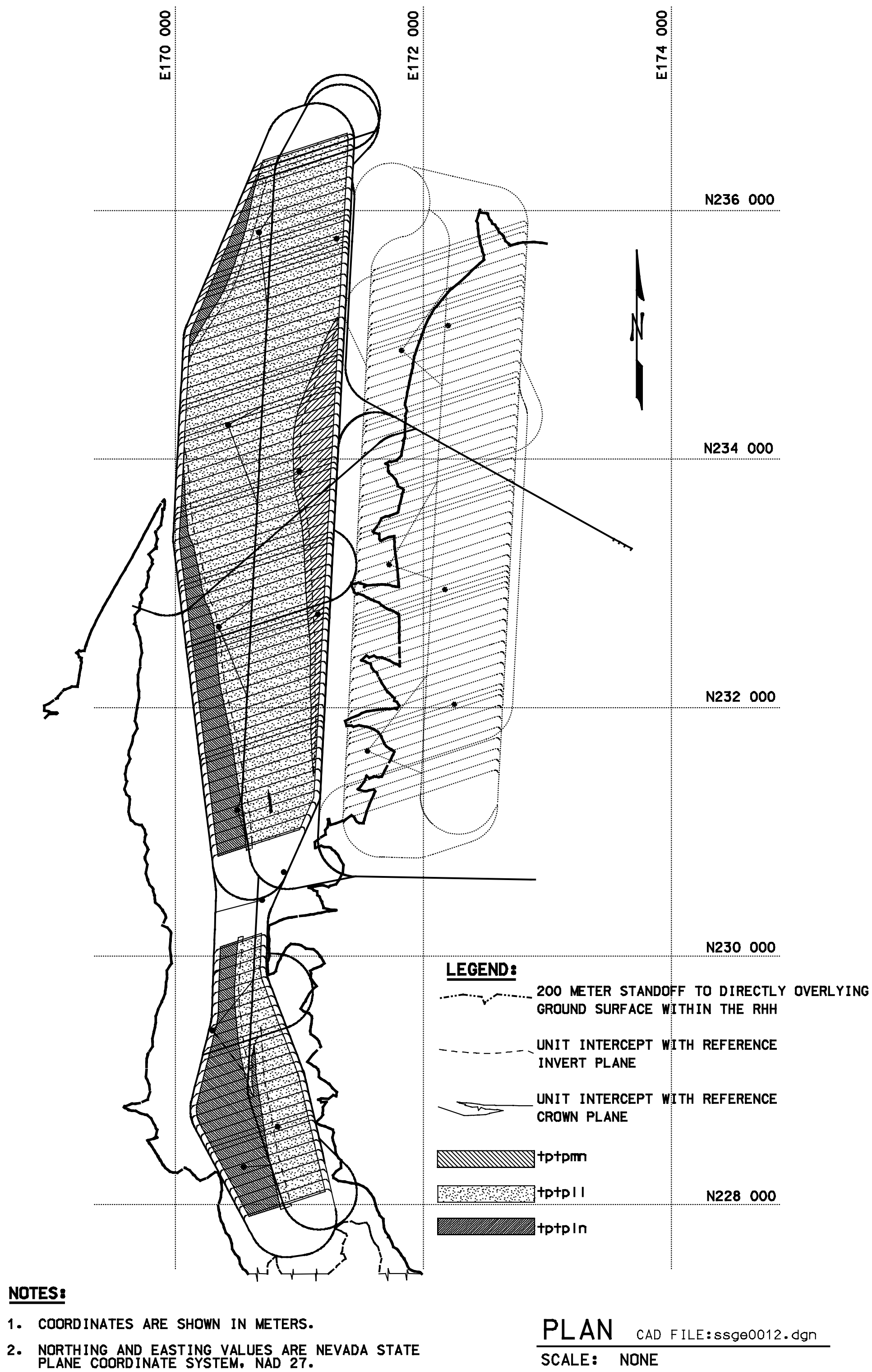



Figure 8. Geologic Criteria within the Primary Block

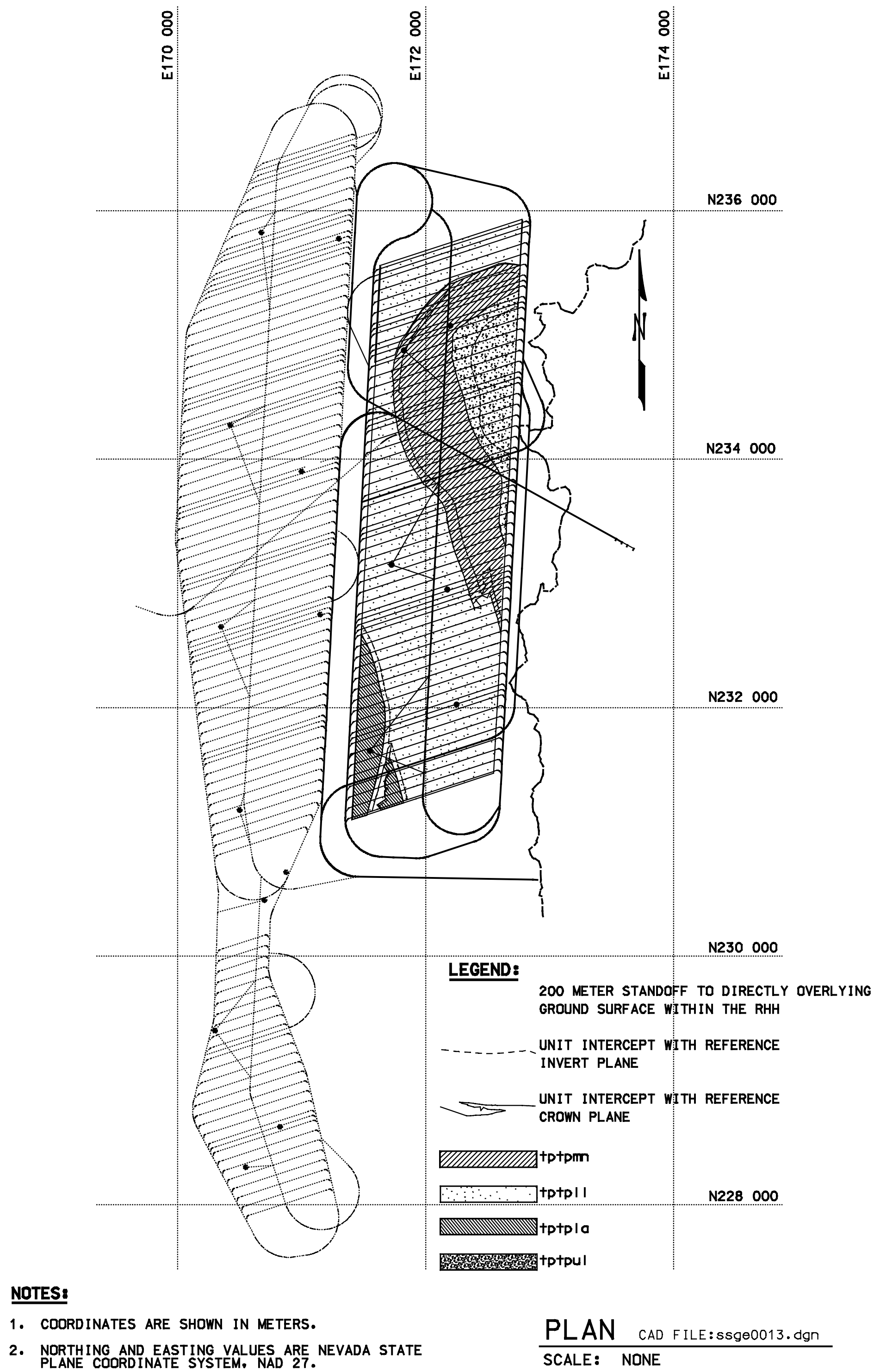



Figure 9. Geologic Criteria within the Lower Block

**Faults** — The report NUREG-1451, *Staff Technical Position on Investigations to Identify Fault Displacement Hazards and Seismic Hazards at a Geologic Repository* (McConnell et al. 1992, p. 5) defines a Type I fault:

> "Faults or fault zones that are subject to displacement and of sufficient length and located such that they may affect repository design and/or performance. As such, they should be investigated in detail. Only faults that are determined to be Type I are of regulatory concern, because it is those faults, both inside and outside the controlled area, that may require consideration in repository design, or could have an effect on repository performance, or could provide significant input into models used to assess repository performance."

Fault displacement hazard results have indicated two faults, Bow Ridge and Solitario Canyon, that have a higher hazard of fault displacement, as indicated in Table 13 (CRWMS M&O 1998b, pp. 4-7 to 4-9). Additional evaluations have also indicated that Bow Ridge and Solitario Canyon faults have a higher hazard of fault displacement (Wong et al. 1998, Table 8-1).

Table 13. Calculated Fault Displacements

| Fault | Displacement for $10^{-4}$ Annual Probability | Displacement for $10^{-5}$ Annual Probability | Type I Fault |
|---|---|---|---|
| Bow Ridge | < 1 cm | 12 cm | Yes |
| Solitario Canyon | < 1 cm | 30 cm | Yes |
| Drill Hole Wash | < 1 cm | < 1 cm | No |
| Ghost Dance | < 1 cm | < 1 cm | No |
| Sundance | < 1 cm | < 1 cm | No |

Source: CRWMS M&O 1998b, pp. 4-7 to 4-9

The only Type I fault identified in the immediate area of the repository is the Solitario Canyon fault, which defines the western edge of the repository, based on a 60-meter standoff (see Section 4.2.1.2.4). The Bow Ridge fault is not in the immediate area of the repository and, therefore, will not impact the subsurface layout. Although the Drill Hole Wash, Ghost Dance, and Sundance faults are at or near the Subsurface Facility, these faults have not been identified as a Type I fault. Abandon Wash fault has not been evaluated for fault displacement and is therefore not considered a Type I fault. Thus, geologic standoff-distances to emplaced WPs (see Section 4.2.1.2.5) will not be required.

#### 6.1.2.3 Thermal Design Constraints

The layout configuration must accommodate temperature limits and uplift limits specified for the Emplacement Drift System. Evaluation of the criteria listed below are outside the scope of the layout analysis, but will be addressed in a thermal management analysis.

- Accommodate the Emplacement Drift System's temperature constraint for the zeolotized layer within the Calico Hills (see Section 4.2.1.5.4).

- Accommodate a limit on the temperature change, at 45 centimeters below the soil surface, to 2 degrees Celsius above the established naturally occurring pre-emplacement average annual ground surface temperature within the footprint of the MGR (see Section 4.2.1.5.5).

- Accommodate the Emplacement Drift System's temperature constraint for the PTn geologic unit (see Section 4.2.1.5.6).
- Accommodate the Emplacement Drift System's uplift limit in the TSw1 thermomechnical unit (see Section 4.2.1.5.8).

#### 6.1.2.4 Ventilation Design Interface

The overall ventilation strategy influences and is influenced by the ventilation airway sizes in the Subsurface Facility. This section will discuss the ventilation system interfaces with the subsurface layout as detailed in Section 6.2.

In order to support the 15 $m^3/s$ (see Section 6.2.9.1) airflow volume to each emplacement drift split, eight intake shafts (see Section 6.2.9.2), one Development/Intake Shaft (see Section 6.2.9.2), and nine exhaust shafts (see Section 6.2.9.2) are required in the repository layout (see Figure 3). The intake shafts and the Development/Intake Shaft are required in addition to the air supplied by the North and South Ramps.

Intake shafts and exhaust shafts are located in the Emplacement Area within the pillar between adjacent emplacement drifts. Intake shafts are connected to the East and West Mains via an intake shaft access drift to distribute the ventilation air to each end of the emplacement drifts. The intake shaft accesses will be excavated to a nominal diameter of 7.62 meters. Their turnouts will be excavated 8 meters wide with an arch from spring-line to spring-line and 8.5 meters from invert to crown.

Each exhaust shaft is connected to the Exhaust Main via two exhaust shaft accesses. These exhaust shaft accesses have the same dimensions as the intake shaft access turnouts.

A Development/Intake Shaft is located in the vicinity of the South Main and is connected to the South Main and West Main via two access drifts. One of the shaft accesses will be excavated to a nominal 7.62-meter diameter, and the other 8 meters in width with an arch from spring-line to spring-line and 8.5 meters from invert to crown.

The shafts have been located at the coordinates listed in Table 14 such that the shaft collars are outside the probable maximum flood areas (see Section 4.2.1.2.3). The shaft collars have been located to avoid steep terrain that would require extensive earth moving for pad and road construction. A more detailed shaft siting analysis will be required to confirm the shaft collar locations.

The shafts have been sized at an excavated diameter of 8 meters (see Section 4.1.2.3) to accommodate the required airflow volumes for the subsurface operations. The repository ventilation system analysis is addressed in Section 6.2.

Table 14. Shaft Coordinates

| Description | Northing (m) | Easting (m) |
|---|---|---|
| Intake Shaft 1 | 235,775 | 171,300 |
| Intake Shaft 2 | 233,900 | 171,000 |
| Intake Shaft 3 | 232,750 | 171,150 |
| Intake Shaft 4 | 228,625 | 170,825 |
| Intake Shaft 5 | 230,675 | 172,875 |
| Development/Intake Shaft | 230,450 | 170,700 |
| Intake Shaft 6(L) | 235,075 | 172,200 |
| Intake Shaft 7(L) | 232,950 | 172,175 |
| Intake Shaft 8(L) | 232,025 | 172,250 |
| Exhaust Shaft 1 | 235,825 | 170,675 |
| Exhaust Shaft 2 | 234,275 | 170,425 |
| Exhaust Shaft 3 | 232,650 | 170,350 |
| Exhaust Shaft 4 | 231,175 | 170,500 |
| Exhaust Shaft 5 | 229,400 | 170,300 |
| Exhaust Shaft 6 | 228,300 | 170,550 |
| Exhaust Shaft 7(L) | 234,875 | 171,825 |
| Exhaust Shaft 8(L) | 233,150 | 171,725 |
| Exhaust Shaft 9(L) | 231,650 | 171,550 |

Source: BSC 2001aa

Ventilation raises located in the emplacement drifts, cross-block drifts, standby drifts, and Test and Evaluation Facility headings, will connect the headings to the Exhaust Main above the repository. A raise bore machine will be used to excavate the raises to a diameter of 2 meters (see Section 5.1.2.8) from the crown of the lower headings to the Exhaust Main. The raises serve as ventilation airways for emplacement operations and for Test and Evaluation Program activities.

#### 6.1.2.5 Drainage Control

A number of factors affecting the overall drainage pattern of the Subsurface Facility must be incorporated into the repository layout. These factors are:

- The ramps providing access to the Subsurface Facility must have an initial upward grade of at least one percent for at least the first 10 meters of the entranceway (see Section 4.2.1.1.6). This is required to limit water inflow into the ramp and, subsequently, into the Subsurface Facility.

- The entrance to all surface openings to the Subsurface Facility must be located outside the probable maximum flood areas (see Section 4.2.1.2.3).

- The overall grading of the Subsurface Facility openings must provide drainage control such that any accumulation of water is away from the emplacement areas (see Section 4.2.1.2.7).

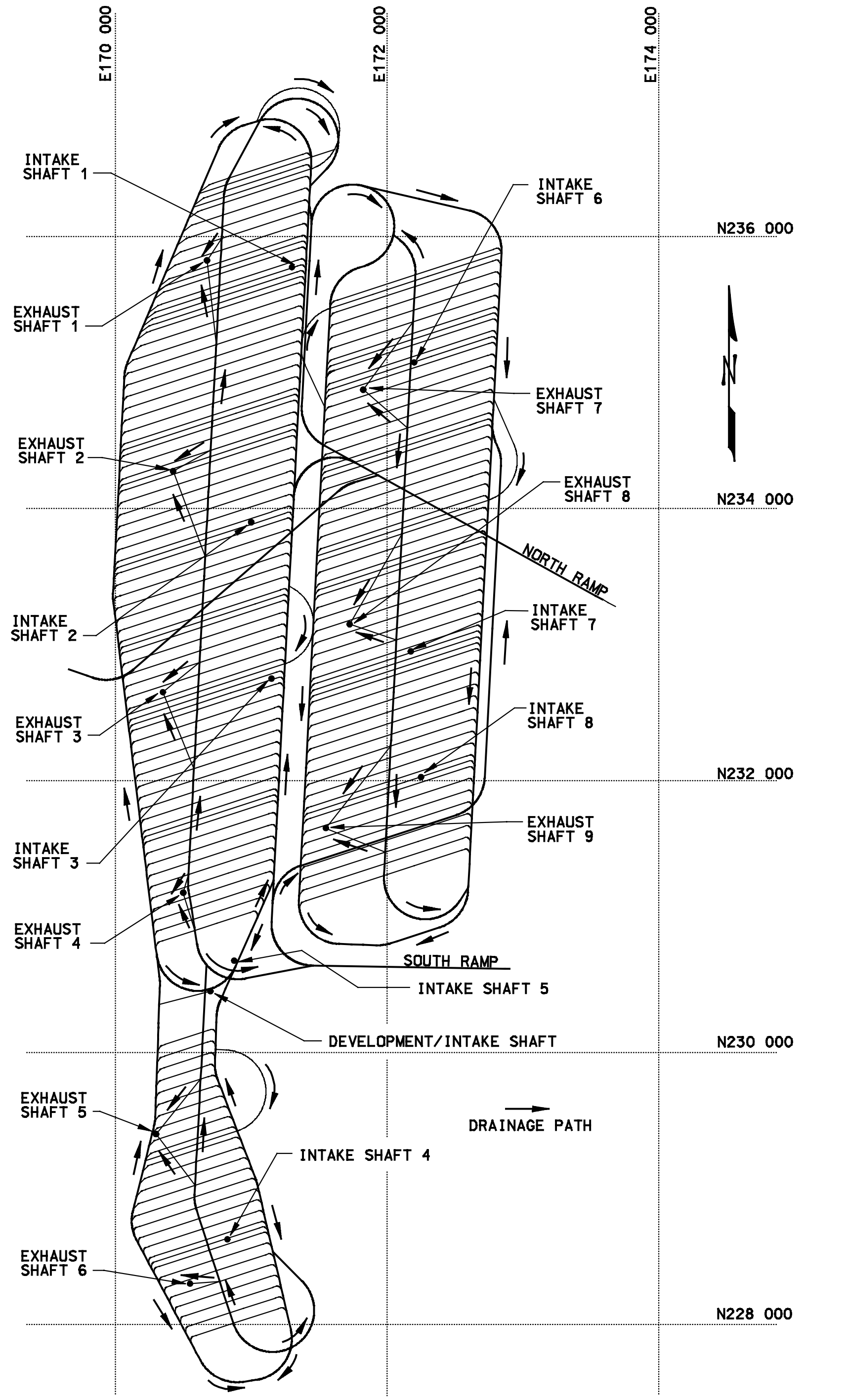
The first two factors preclude surface floodwater entering the Subsurface Facility. Currently the existing North and South Ramps are the only ramp accesses to the Subsurface Facility. The South Ramp has been designed and excavated to provide an initial 2 percent gradient up for a minimum of 10 meters (33 feet) inside the tunnel. This was done to prevent the introduction of Probable Maximum Flood storm water to the subsurface (CRWMS M&O 1996, p. I-3). The

North Ramp starter tunnel has been excavated at a flat grade and a step up of 0.432 meters. Although the North Ramp starter tunnel does not physically have a minimum grade of one percent, the invert and finishing work in the tunnel can accommodate this requirement. The locations of future surface openings, namely the ventilation shafts are discussed in Section 6.1.2.4.

The overall grading of the Subsurface Facility, excluding the emplacement drifts, diverts any water entering the Facility away from the emplacement drifts. During the preclosure period, the water is directed to central sumps located at the north and south ends of the repository, then to the surface, as shown in Figure 10. For areas that will require special drainage such as the shafts and ODs, there will be separate sumps located in each heading. The ODs now require separate drainage from the overall system as they are now located below the emplacement area elevation and cannot be simply connected to the overall system. The shafts and shaft access drifts drain to sumps located at the shaft bottoms. These headings are isolated from the overall drainage system for the emplacement area to limit water inflow from the surface directly into the subsurface facility.

The gradients in all sections of the mains and ramps have also been configured to allow rail transportation within the opening (see Section 4.2.1.5.2). The actual grades within the subsurface openings are documented in Attachment II. The 0.8-meter step at the transition of the emplacement drift and the turnout (see Section 4.2.1.5.11) also prevents water inflow into the emplacement drifts.

The emplacement drifts are excavated at a zero percent gradient to allow water to drain directly into the host rock (BSC 2001a, Section 6.2.5, p. 70).




**NOTES:**

1. COORDINATES ARE SHOWN IN METERS.
2. NORTHING AND EASTING VALUES ARE NEVADA STATE PLANE COORDINATE SYSTEM, NAD 27.

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SCALE: NONE

Figure 10. Drainage Control

#### 6.1.2.6 Surface Based Boreholes

There are 34 surface-based boreholes near the repository layout (see Attachment V). The design of the layout must allow at least a 5-meter standoff from the edge of the WPs to the perpendicular projection of the centerline of a surface-based borehole. This standoff is incorporated if the borehole intercepts the drift or comes within 5 meters of the edge of the drift (see Section 4.2.1.2.6). In order to determine the perpendicular projection of the borehole at the repository elevation, deviation surveys for these boreholes are required. Since these deviation surveys are not available at this time, this requirement cannot be fully addressed in this analysis. The maximum impact this criterion could have on the emplacement area is a reduction of the useable emplacement drift length by an estimated 340 meters (34 boreholes with 5-meter standoffs to two WPs). This equates to approximately 0.23 percent of the 147,843.2 meters (see Section 6.1.2.1.2) of available emplacement drift length in the repository layout (340 meters divided by 147,843.2 meters, multiplied by 100). Future analyses using the borehole deviation surveys will determine the actual impact of this criterion on the Subsurface Facility design.

#### 6.1.2.7 Radiological Safety

Radiological safety is one of the most important aspects of the repository and the MGR must comply with the applicable provisions of the *Standards for Protection Against Radiation* (10 CFR 20). Since personnel will be frequently travelling in the mains, potential radiological exposure will be kept ALARA. Since individual WPs will only provide sufficient shielding to protect the WP materials from radiation enhanced corrosion (CRWMS M&O 2001a, Section 5.2.23), the turnouts have been configured to aid in increasing radiological protection in the mains. The turnout configuration has been designed to eliminate the direct line of radiation from entering the main (see Figure 4, Section 6.1.2.1.2). The length of the turnout also provides an increase in radiological protection, as distance is one of the best sources of protection. A typical turnout is illustrated in Figure 4, showing the design configuration and elimination of the direct line of radiation entering the main. The system description document criteria need to address the incorporation of ALARA principles, such as the turnout configuration, for the subsurface design.

Emplacement drift doors are also located within the emplacement drift turnouts (see Figure 4, Section 6.1.2.1.2). These doors serve to limit personnel access to the emplacement drifts after waste has been emplaced in a drift.

The unrestricted radiation level (see Section 4.2.1.2.1) and the restricted-access radiation level (see Section 4.2.1.2.2) have not yet been determined for this layout configuration, but will be calculated in future analyses. It is not anticipated that these calculations will adversely impact the design of the Subsurface Facility.

#### 6.1.2.8 Non-Nuclear Safety

The design, construction, and development of the Subsurface Facility is governed by two occupational health and safety standards, the "Occupational Safety and Health Standard" (29 CFR 1910) and the "Safety and Health Regulations for Construction" (29 CFR 1926); see Section 4.3.1. The applicability of, and adherence to, these standards will be addressed in future analyses.

The layout of the Subsurface Facility is required to provide two or more separate, properly maintained escapeways to the surface from the lowest levels. The escapeways should be positioned such that damage to one escapeway will not lessen the effectiveness of the others (see Section 4.2.1.3.1). The existing North and South Ramps provide the minimum required escape routes from the primary area to the surface.

Within the Subsurface Facility, personnel refuge chambers will also be required (see Section 4.2.1.3.2). Personnel refuge chambers can serve multiple personnel functions other than emergency refuge, such as first aid stations, temporary offices, and lunchrooms. The personnel refuge chambers will be located at a maximum of 2,100 meters from an adjacent personnel refuge chamber or the nearest escapeway such that personnel can reach a refuge chamber within 30 minutes (see Section 4.2.1.3.3). The location and specifics of the personnel refuge chamber design and locations within the Subsurface Facility do not affect the design of the overall Subsurface Facility and will be addressed in future analyses.

#### 6.1.2.9 Constructibility

The layout is influenced by practical limitations imposed by the operating requirements and performance characteristics of the equipment and methods selected for construction of the repository. The size, configuration, and operating requirements of the construction equipment will provide restrictions on the size and shape of the excavated openings and the general arrangements possible for the layout (see Section 4.2.1.5.9).

The construction methods and equipment, construction sequence, and equipment productivity must be considered to ensure the overall constructibility of the planned layout. The layout configuration seeks to minimize the number and size of the openings needed to accommodate waste emplacement operations and to utilize completed drifts in an efficient manner to help the construction process. This section discusses the planned construction approach and its influence on the repository layout.

The excavation methods for developing the Subsurface Facilities are outlined in the Summary of the *Subsurface Excavation System Description Document* (CRWMS M&O 1999c, p. 5). The excavation methods include mechanical excavation (using TBMs, roadheaders, raise-borers, and drills), although drilling and blasting methods may be used for special applications. The main ESF openings, the North Ramp, Main Drift, and South Ramp were excavated by a 7.62-meter diameter TBM (see Section 6.1.2.1.1). Both the 7.62-meter and the 5.5-meter TBMs will be designed for transportation through completed tunnels.

Excavated chambers are required to assemble, launch, recover, and disassemble TBMs. The 7.62-meter TBM will excavate the ramps and mains, and the 5.5 meter TBM which will excavate the emplacement drifts, standby drifts, cross-block drifts, and Test and Evaluation drifts. For the ramps and mains, the assembly and disassembly chambers are located as needed to support the desired construction sequence. The emplacement drift turnouts that are required for the waste emplacement operations would serve as the launch chambers on the east side and recovery chambers on the west side for the 5.5-meter TBM. For the Test and Evaluation drifts located above and below the repository block, assembly chambers will be excavated as needed. The 5.5-meter TBM will be designed to back out of a completed Test and Evaluation drift so disassembly chambers will not be required. The locations and sizes of the assembly and disassembly chambers will be presented in future analyses. The specifics of these chambers do not affect the layout of the Subsurface Facility.

The TBM assembly and disassembly chambers, the emplacement drift turnouts, and other miscellaneous access drifts will be excavated by either roadheader or drill and blast methods. Roadheader productivity is low compared to that of a TBM and, for that reason, the use of these machines for repository excavation will be limited to short openings. The crawler-mounted roadheaders have the advantage over TBMs of greater mobility and the capability to excavate openings with non-circular cross-sections making them better suited to excavating turnouts and similar openings.

Typical drill and blast operations use several pieces of equipment, in sequence, to excavate. Normal operations include drilling holes for explosives, loading the blast holes, detonating them, ventilating the blast zone, removing muck, and installing rock support. Drill and blast operations are flexible, do not require the extensive set-up periods, and may be associated with mechanical excavation methods. Drill and blast operations can be conducted concurrently with other subsurface activities and would be a favorable construction method when schedule concerns exist. In addition, these types of operations are not generally sensitive to the final size of an excavated opening. Although controlled drill and blast operations would be utilized, this operation has the potential of disturbing the rock surrounding the opening. Drill and blast operations will not be used where mechanical excavation methods are more applicable.

#### 6.1.2.9.1 Construction Sequence

Construction and development of the repository will be accomplished in two general phases. The construction phase will prepare for the beginning of waste emplacement operations. The development phase will occur concurrently with waste emplacement operations. The construction sequence and schedule for the Subsurface Facility are currently planned for the years 2005 to 2009 to ensure that the facility will be ready to begin waste emplacement in 2010. The remaining development of the repository will occur in stages but concurrently with emplacement, from 2010 to completion of the facility.

The construction phase will include partial excavation of the mains on the north end of the repository block and excavation of the ventilation shafts required for the first panel of several emplacement drifts. The construction phase will also support continued development. Isolation airlocks will be erected after the first panel of emplacement drifts is finished to allow simultaneous emplacement and development operations to proceed. Emplacement operations will use the first panel of emplacement drifts on the north side of the isolation airlocks. Concurrently, the next panel of emplacement drifts, ventilation raises and the supporting main drift excavation is under development on the south side of the airlocks. As a panel of emplacement drifts is completed, a new set of isolation airlocks will be erected, the completed panel turned over to emplacement operations, and the previous set of isolation airlocks dismantled. As each new panel is being developed, only sufficient excavation is completed to support turnover of the next emplacement panel. This will also facilitate the start of operations concurrently with subsequent construction stages.

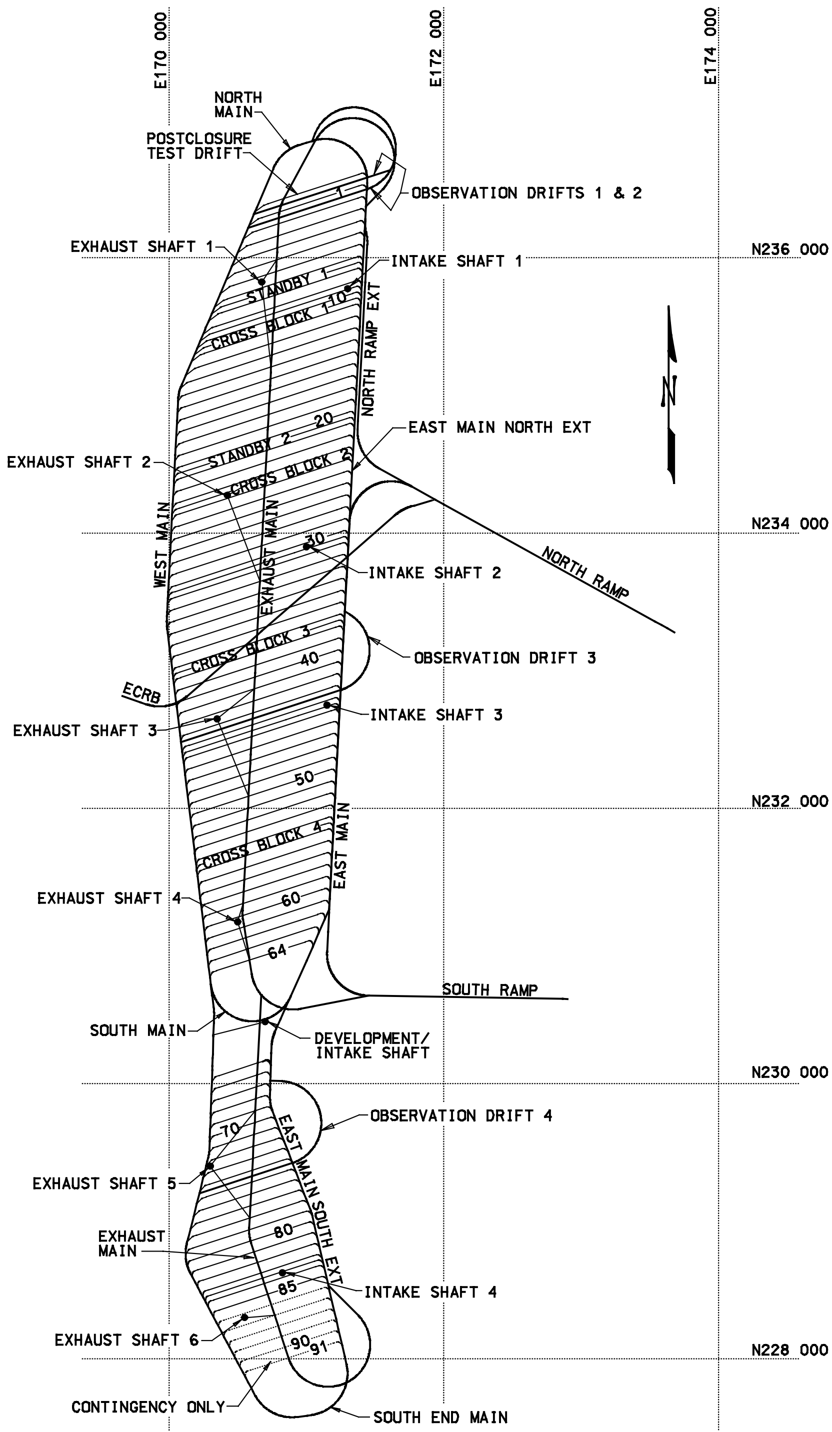
### 6.1.3 70,000 MTHM LT Case Study

The potential repository must be capable of accommodating the emplacement of a WP inventory of 70,000 MTHM (see Section 4.2.1.1.1). The 70,000 MTHM layout is based on the repository layout as described in Section 6.1.2. For reference, the 70,000 MTHM Layout is illustrated in Figure 11.

The 70,000 MTHM Layout will occupy the majority of the primary block emplacement area. This area extends from the extreme north of the repository block to the South End Main. The required emplacement area calculations and details for the 70,000 MTHM case can be found in Section 6.1.3.1. The main drift excavation for this layout includes the North Main, North Ramp Extension, East Main North Extension, South Main, East Main South Extension and the South End Main. Details of the main drifts and the configuration concepts have been outlined in Section 6.1.2.1.1

The emplacement area will consist of 85 emplacement drifts for emplacement of the required WP inventory. The required inventory includes a five percent excavated contingency, based on WP quantities. To accommodate possible variances in the WP inventory (see Section 5.1.2.2). Also included in the layout is an unexcavated contingency area. Emplacement Drifts 85 through 91 will provide approximately 5.0 percent of unexcavated contingency. These drifts will only be excavated if portions of the intended emplacement area cannot be used due to unexpected ground conditions (see Section 5.1.2.2). In the event that additional space beyond these combined contingencies is required to accommodate the 70,000 MTHM inventory, portions of the lower block could be developed. Details of the emplacement drifts and the configuration concepts have been outlined in Section 6.1.2.1.2.

The required emplacement length calculated to accommodate the WP inventory, including the five- percent WP allowance, is approximately 81 kilometers. This results in approximately 1,630 acres at an areal mass loading (AML) of approximately 40 MTHM/acre, as calculated in Section 6.1.3.1.




**NOTES:**

1. COORDINATES ARE SHOWN IN METERS.
2. NORTHING AND EASTING VALUES ARE NEVADA STATE PLANE COORDINATE SYSTEM, NAD 27.

PLAN CAD FILE:feb-2001_lt_70kmtu

SCALE: NONE

Figure 11. 70,000 MTHM LT Layout

Within the emplacement area, six standby and cross-block drifts will be excavated in this scenario. Two standby drifts will be excavated, one between Emplacement Drifts 7 and 8 and the other between Emplacement Drifts 20 and 21. Four cross-block drifts will be required. They are located between Emplacement Drifts 10 and 11, between Emplacement Drifts 23 and 24, between Emplacement Drifts 37 and 38, and between Emplacement Drifts 54 and 55. The details of the configuration concepts for the standby and cross-block drifts have been outlined in Section 6.1.2.1.2.

The Test and Evaluation Facility for the 70,000 MTHM layout will consist of a single PCTD on the north end of the repository with an OD, and the performance monitoring ODs 2, 3, and 4. Details and functions of the Test and Evaluation Facilities have been outlined in Section 6.1.2.1.3.

Four intake shafts are required to supply the necessary ventilation flow rates to the Subsurface Facility for the 70,000 MTHM Case, in addition to the North and South Ramps (see Section 6.2.10). The locations of the intake shafts are listed in Table 15.

Table 15. Intake Shaft Locations for the 70,000 MTHM LT Case

| Intake Shaft Number | Northing (m) | Easting (m) | Collar Elevations (m) |
|---|---|---|---|
| 1 | 235,775 | 171,300 | 1,435 |
| 2 | 233,900 | 171,000 | 1,390 |
| 3 | 232,750 | 171,150 | 1,365 |
| 4 | 228,625 | 170,825 | 1,435 |

Source: BSC 2001aa

The Development Shaft, located near the South Main, provides intake airflow for the construction operation in the Subsurface Facility (see Section 6.2.10). Later the shaft will be converted to an intake shaft for emplacement operations. The Development Shaft is located at 230,450 meters north and 170,700 meters east, with a collar elevation of 1,380 meters.

Six exhaust shafts are required to exhaust emplacement side air from the Subsurface Facility for the 70,000 MTHM Case (see Section 6.2.10). The locations of the exhaust shafts are listed in Table 16.

Table 16. Exhaust Shaft Locations for the 70,000 MTHM LT Case

| Exhaust Shaft Number | Northing (m) | Easting (m) | Collar Elevation (m) |
|---|---|---|---|
| 1 | 235,825 | 170,675 | 1,465 |
| 2 | 234,275 | 170,425 | 1,475 |
| 3 | 232,650 | 170,350 | 1,485 |
| 4 | 231,175 | 170,500 | 1,435 |
| 5 | 229,400 | 170,300 | 1,470 |
| 6 | 228,300 | 170,550 | 1,405 |

Source: BSC 2001aa

#### 6.1.3.1 Emplacement Area Determination

The current WP inventory as listed in Table 2 (see Section 4.1.1.3) will be used for defining the emplacement area for the 70,000 MTHM case. The WPs will be loaded in the drift to create a 1 kW/m average thermal load in each drift at emplacement (see Section 6.1) and this will dictate the method of calculating the required emplacement length.

The average WP spacing for a maximum Lineal Thermal Load of 1.0 kW/m is 1.9 meters (see Attachment VI, Table VI-1). The average end-to-end WP spacing creates the overall average across the repository. The actual end-to-end WP spacing will range from 10 centimeters to several meters, depending on the type and heat output of the WP being emplaced. This variation in spacing, with an overall average end-to-end WP spacing is used to produce as even a line load as possible within the emplacement drifts.

Based on the average WP spacing of 1.9 meters, 81,347.9 meters of emplacement drift is required to emplace the 70,000 MTHM waste inventory (see Attachment VI, Table VI-1).

By examining the available area in the planning layout as outlined in Attachment I, Table I-1, it can be seen that 85 emplacement drifts will be required for emplacement of 70,000 MTHM of waste as illustrated in Figure 11. This does not include the single drift designated for use as the postclosure simulation drift (see Section 6.1.2.1.3),

A 10 percent contingency area (see Section 5.1.2.2) cannot be accommodated within the primary block alone. Only a 5 percent unexcavated contingency is available within the primary block area (see calculation below), additional contingency area is available within the lower block area if required.

$$\text{Available Contingency} = \frac{\text{Available Length} - \text{Required Length}}{\text{Required Length}} \quad \text{x} \quad 100\%$$

*Where*: Available Length within the Primary Area = 85,443.2 meters (see Attachment I, Table I - 1)
Required Length of Emplacement Drift = 81,347.9 meters (see Table VI - 1)

$$\text{Available Contingency} = \frac{85{,}443.2 \text{ meters} - 81{,}347.9 \text{ meters}}{81{,}347.9 \text{ meters}} \quad \text{x} \quad 100\%$$

$$= 5.0\%$$

The required emplacement drift length and the drift spacing can be used to calculate the total available acreage in the layout:

$$\text{Acreage} = \frac{L_r\ (\text{m}) \quad \text{x} \quad \text{DS (m)}}{43{,}560\ \text{ft}^2/\text{acre}} \quad \text{x} \quad \frac{1}{0.0929\ \text{m}^2/\text{ft}^2}$$

Where: $L_r$ = required emplacement drift length (m) and

DS = drift spacing (m).

When: $L_r$ = 81,347.9 meters (see Attachment VI, Table VI-1) and
DS = 81.0 meters (see Section 4.2.1.1.5),

$$\text{Acreage} = \frac{81{,}347.9 \text{ meters} \quad x \quad 81 \text{ meters}}{43{,}560 \ \text{ft}^2/\text{acre}} \quad x \quad \frac{1}{0.0929 \ \text{m}^2/\text{ft}^2}$$

$$\text{Acreage} = 1{,}628.3 \text{ acres}$$

The layout supporting the 70,000 MTHM will require approximately 1,630 acres to accommodate the waste inventory.

The AML is calculated with the amount of MTHM from CSNF only. The AML of the repository layout is calculated as:

$$\text{AML} = \frac{\text{CSNF (MTHM)}}{\text{Acreage}}$$

Where: CSNF = 63,000 MTHM (see Section 4.1.1.3)
Acreage = 1,630 acres

$$\text{AML} = \frac{63{,}000 \text{ MTHM}}{1{,}630 \text{ acres}}$$

$$\text{AML} = 38.7 \ \text{MTHM}/\text{acre}$$

The repository layout to support the 70,000 MTHM waste stream has an AML of approximately 40 MTHM/acre.

#### 6.1.3.2 Excavation Lengths

The detailed excavation lengths and volume calculations for the 70,000 MTHM Case are outlined in Attachment IV, Section IV.1. Table 17 summarizes the detailed excavation lengths by excavation types. Table 18 summarizes the detailed excavation lengths by excavation size.

Table 17. 70,000 MTHM LT Case Excavation Length Summary by Excavation Type

| Heading Description | Excavated Length | Comments |
|---|---|---|
| **Main Drifts** | | |
| Access Mains and Ramps | 19,879 m | 7.62 meter diameter |
| Exhaust Main | 12,435 m | 7.62 meter diameter |
| *Subtotal* | *32,314 m* | |
| **Emplacement Area** | | |
| Emplacement Drifts | 81,954 m | 5.5 meter diameter |
| Emplacement Drift Turnouts | 13,497 m | 7.0 meters high x 8 meter wide horseshoe |
| Emplacement Drift Raises | 1,552 m | 2.0 meter diameter |
| Emplacement Drift Raise Alcoves | 425 m | 5.0 meters high x 5.0 meter wide horseshoe |
| *Subtotal* | *97,427 m* | |
| **Shafts** | | |
| Intake Shafts | 1,293 m | 8.0 meter diameter |
| Intake Shaft Accesses | 4,221 m | 7.62 meter diameter |
| Intake Shaft Access Turnouts | 612 m | 8.0 meter high x 8.5 meter wide horseshoe |
| Development Shaft | 288 m | 8.0 meter diameter |
| Development Shaft Access | 406 m | 8.0 meter high x 8.5 meter wide horseshoe |
| Exhaust Shafts | 2,116 m | 8.0 meter diameter |
| Exhaust Shaft Accesses | 4,399 m | 8.0 meter high x 8.5 meter wide horseshoe |
| *Subtotal* | *13,334 m* | |
| **Standby and Crossblock Drifts** | | |
| Standby Drifts | 2,261 m | 5.5 meter diameter |
| Standby Drift Turnouts | 346 m | 7.0 meters high x 8 meter wide horseshoe |
| Standby Drift Raises | 34 m | 2.0 meter diameter |
| Standby Drift Raise Alcoves | 10 m | 5.0 meters high x 5.0 meter wide horseshoe |
| Crossblock Drifts | 4,507 m | 5.5 meter diameter |
| Crossblock Drift Turnouts | 650 m | 7.0 meters high x 8 meter wide horseshoe |
| Crossblock Drift Raises | 67 m | 2.0 meter diameter |
| Crossblock Drift Raise Alcoves | 20 m | 5.0 meters high x 5.0 meter wide horseshoe |
| *Subtotal* | *7,895 m* | |
| **Test and Evaluation Facilities** | | |
| PCTDs | 697 m | 5.5 meter diameter |
| PCTD Turnouts | 188 m | 7.0 meters high x 8 meter wide horseshoe |
| PCTD Raises | 10 m | 2.0 meter diameter |
| PCTD Raise Alcoves | 5 m | 5.0 meters high x 5.0 meter wide horseshoe |
| ODs | 6,835 m | 5.5 meter diameter |
| OD Raises | 211 m | 2.0 meter diameter |
| OD Raise Alcoves | 45 m | 5.0 meters high x 5.0 meter wide horseshoe |
| *Subtotal* | *7,991 m* | |
| **Total Repository Openings** | **158,961 m** | Does not include length of the ESF |

Table 18. 70,000 MTHM LT Case Excavation Length Summary by Excavation Size

| Excavation Description | Excavation Length | Comments |
|---|---|---|
| Total 7.62 meter diameter TBM | 36,535 m | Does not include length of the ESF |
| Total 5.5 meter diameter TBM | 96,254 m | |
| Total Shaft Excavation, 8.0 meter diameter | 3,696 m | |
| Total 7.0 meter high x 8.0 meter wide | 14,681 m | |
| Total 8.0 meter high x 8.5 meter wide | 5,417 m | |
| Total Raising, 2.0 meter diameter | 1,873 m | |
| Total Raise Alcoves | 505 m | |
| **Total Repository Openings** | **158,961 m** | Does not include length of the ESF |

### 6.1.4 97,000 MTHM LT Case Study

The potential repository must not preclude the capability of accommodating the emplacement of 97,000 MTHM (see Section 4.2.1.1.2). The 97,000 MTHM layout (see Figure 12) is based on the repository layout as described in Section 6.1.2. It will occupy all of the primary block emplacement area and a portion of the lower block emplacement area. Emplacement area calculations and details for the 97,000 MTHM case can be found in Section 6.1.4.1.

The 97,000 MTHM waste inventory will fill a total of 110 emplacement drifts. This allows a five percent-excavated contingency based on WP quantities to accommodate possible variances in the WP inventory (see Section 5.1.2.2). Also included in the layout is an unexcavated contingency area of 10 percent. These drifts will only be excavated in this area if portions of the defined emplacement area cannot receive waste due to unexpected conditions, or (see Section 5.1.2.2).

The required emplacement length calculated to accommodate the WP inventory, including the five-percent WP allowance, is approximately 107 kilometers. This results in approximately 2,150 acres in total, 1,710 acres in the primary block and 440 acres in the lower block. An AML of approximately 40 MTHM/acre results, as calculated in Section 6.1.4.1.

Within the emplacement area, eight standby and cross-block drifts will be excavated in this scenario. Three standby drifts will be excavated, one between Emplacement Drifts 7 and 8, another between Emplacement Drifts 20 and 21, and the last between Emplacement Drifts L6 and L7. Five cross-block drifts will be required. They are located between Emplacement Drifts 10 and 11, between Emplacement Drifts 23 and 24, between Emplacement Drifts 37 and 38, between Emplacement Drifts 54 and 55, and between Emplacement Drifts L15 and L16. The details of the configuration concepts for the standby and cross-block drifts have been outlined in Section 6.1.2.1.2.

The Test and Evaluation Facility for the 97,000 MTHM layout will consist of a single PCTD on the north end of the repository with an OD, and the performance monitoring ODs 2, 3, 4, and 5. OD 5 is located in the lower block area. Details and functions of the Test and Evaluation Facilities have been outlined in Section 6.1.2.1.3.

Six intake shafts are required to supply the necessary ventilation flow rates to the Subsurface Facility for the 97,000 MTHM Case, in addition to the North and South Ramps (see Section 6.2.11). The locations of the intake shafts are listed in Table 19.

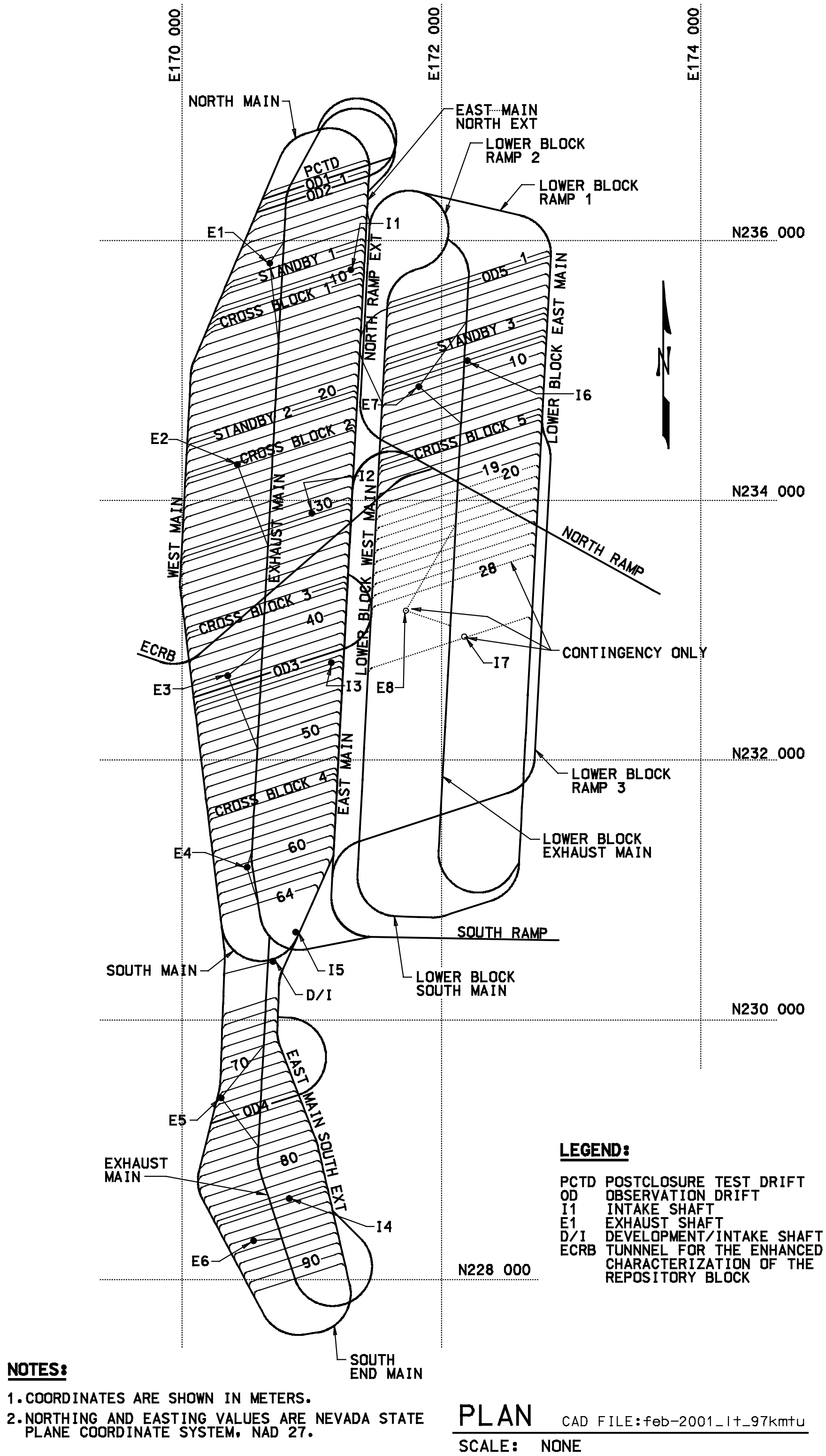



Figure 12. 97,000 MTHM LT Layout

Table 19. Intake Shaft Locations for the 97,000 MTHM LT Case

| Intake Shaft Number | Northing (m) | Easting (m) | Collar Elevations (m) |
|---|---|---|---|
| 1 | 235,775 | 171,300 | 1,435 |
| 2 | 233,900 | 171,000 | 1,390 |
| 3 | 232,750 | 171,150 | 1,365 |
| 4 | 228,625 | 170,825 | 1,435 |
| 5 | 230,675 | 170,875 | 1,390 |
| 6 (L) | 235,075 | 172,200 | 1,335 |

Source: BSC 2001aa

The Development Shaft, located near the South Main, provides intake airflow for the construction and development operations in the Subsurface Facility (see Section 6.2.11). This shaft will be converted to an intake shaft for emplacement operations. The Development Shaft is located at 230,450 meters north and 170,700 meters east, with a collar elevation of 1,380 meters (BSC 2001aa).

Eight exhaust shafts are required to exhaust emplacement side air from the Subsurface Facility for the 97,000 MTHM Case (see Section 6.2.11). The locations of the exhaust shafts are listed in Table 20.

Table 20. Exhaust Shaft Locations for the 97,000 MTHM LT Case

| Exhaust Shaft Number | Northing (m) | Easting (m) | Collar Elevation (m) |
|---|---|---|---|
| 1 | 235,825 | 170,675 | 1,465 |
| 2 | 234,275 | 170,425 | 1,475 |
| 3 | 232,650 | 170,350 | 1,485 |
| 4 | 231,175 | 170,500 | 1,435 |
| 5 | 229,400 | 170,300 | 1,470 |
| 6 | 228,300 | 170,550 | 1,405 |
| 7 (L) | 234,875 | 171,825 | 1,360 |
| 8 (L) | 233,150 | 171,725 | 1,340 |

Source: BSC 2001aa

#### 6.1.4.1 Emplacement Area Determination

The current WP inventory as listed in Table 2 (see Section 4.1.1.3) will be used for defining the emplacement area for the 97,000 MTHM case. The WPs will be loaded in the drift to create a 1 kW/m average thermal load in each drift at emplacement (see Section 6.1) and this will dictate the method of calculating the required emplacement length.

Based on an average WP spacing of 1.9 meters, 107,405.3 meters of emplacement drift is required to accommodate the 97,000 MTHM waste inventory (see Attachment VI, Table VI-2).

By examining the available area in the planning layout as outlined in Attachment I, it can be seen that all emplacement drifts and up to emplacement drift L19, will be required for emplacement of 97,000 MTHM of waste as illustrated in Figure 11 (see Attachment I, Table I-1). This does not include the single drift designated for use as the postclosure simulation drift (see Section 6.1.2.1.3)

A 10 percent contingency area (see Section 5.1.2.2) can be accommodated within the lower block. The contingency is calculated as 10 percent of the required emplacement drift length, an additional 10,740.5 meters. The contingency area will encompass emplacement drifts L20 through L28 for a total of 119,043.2 meters of available emplacement drift (see Attachment I).

The required emplacement drift length and the drift spacing can be used to calculate the total available acreage in the layout:

$$\text{Acreage} = \frac{L_r\,(\text{m}) \times \text{DS}\,(\text{m})}{43{,}560\ \text{ft}^2/\text{acre}} \times \frac{1}{0.0929\ \text{m}^2/\text{ft}^2}$$

Where: $L_r$ = required emplacement drift length (m) and
DS = drift spacing (m).

When: $L_r$ = 107,405.3 meters (see Attachment VI, Table VI-2) and
DS = 81.0 meters (see Section 4.2.1.1.5),

$$\text{Acreage} = \frac{107{,}405.3\ \text{meters} \times 81\ \text{meters}}{43{,}560\ \text{ft}^2/\text{acre}} \times \frac{1}{0.0929\ \text{m}^2/\text{ft}^2}$$

$$\text{Acreage} = 2{,}149.8\ \text{acres}$$

The layout supporting the 97,000 MTHM will require approximately 2,150 acres to accommodate the waste inventory, 1,710 acres in the primary block (see Section 6.1.2.1.2) and 440 acres in the lower block (2,150 acres – 1,710 acres).

The AML is calculated with the amount of MTHM from CSNF only. The AML of the repository layout can then be calculated as:

$$\text{AML} = \frac{\text{CSNF (MTHM)}}{\text{Acreage}}$$

Where: CSNF = 83,800 MTHM (see Section 4.1.1.3)
Acreage = 2,150 acres

$$\text{AML} = \frac{83{,}800\ \text{MTHM}}{2{,}150\ \text{acres}}$$

$$\text{AML} = 39.0\ \text{MTHM}/\text{acre}$$

The repository layout to support the 97,000 MTHM waste stream has an AML of approximately 40 MTHM/acre.

### 6.1.4.2 Excavation Lengths

The detailed excavation lengths and volume calculations for the 97,000 MTHM Case are estimated in Attachment IV, Section IV.2. Table 21 summarizes the detailed excavation lengths by excavation types. Table 22 summarizes the detailed excavation lengths by excavation size.

Table 21. 97,000 MTHM LT Case Excavation Length Summary by Excavation Type

| Heading Description | Excavated Length | Comments |
|---|---|---|
| **Main Drifts** | | |
| Access Mains and Ramps | 38,103 m | 7.62 meter diameter |
| Exhaust Main | 18,119 m | 7.62 meter diameter |
| *Subtotal* | *56,222 m* | |
| **Emplacement Area** | | |
| Emplacement Drifts | 109,006 m | 5.5 meter diameter |
| Emplacement Drift Turnouts | 17,344 m | 7.0 meters high x 8 meter wide horseshoe |
| Emplacement Drift Raises | 1,924 m | 2.0 meter diameter |
| Emplacement Drift Raise Alcoves | 550 m | 5.0 meters high x 5.0 meter wide horseshoe |
| *Subtotal* | *128,825 m* | |
| **Shafts** | | |
| Intake Shafts | 1,921 m | 8.0 meter diameter |
| Intake Shaft Accesses | 5,455 m | 7.62 meter diameter |
| Intake Shaft Access Turnouts | 767 m | 8.0 meter high x 8.5 meter wide horseshoe |
| Development Shaft | 288 m | 8.0 meter diameter |
| Development Shaft Access | 406 m | 8.0 meter high x 8.5 meter wide horseshoe |
| Exhaust Shafts | 2,808 m | 8.0 meter diameter |
| Exhaust Shaft Accesses | 6,576 m | 8.0 meter high x 8.5 meter wide horseshoe |
| *Subtotal* | *18,220 m* | |
| **Standby and Crossblock Drifts** | | |
| Standby Drifts | 3,468 m | 5.5 meter diameter |
| Standby Drift Turnouts | 501 m | 7.0 meters high x 8 meter wide horseshoe |
| Standby Drift Raises | 44 m | 2.0 meter diameter |
| Standby Drift Raise Alcoves | 15 m | 5.0 meters high x 5.0 meter wide horseshoe |
| Crossblock Drifts | 5,714 m | 5.5 meter diameter |
| Crossblock Drift Turnouts | 805 m | 7.0 meters high x 8 meter wide horseshoe |
| Crossblock Drift Raises | 77 m | 2.0 meter diameter |
| Crossblock Drift Raise Alcoves | 25 m | 5.0 meters high x 5.0 meter wide horseshoe |
| *Subtotal* | *10,649 m* | |
| **Performance Confirmation Facilities** | | |
| PCTDs | 697 m | 5.5 meter diameter |
| PCTD Turnouts | 188 m | 7.0 meters high x 8 meter wide horseshoe |
| PCTD Raises | 10 m | 2.0 meter diameter |
| PCTD Raise Alcoves | 5 m | 5.0 meters high x 5.0 meter wide horseshoe |
| ODs | 9,019 m | 5.5 meter diameter |
| OD Raises | 252 m | 2.0 meter diameter |
| OD Raise Alcoves | 55 m | 5.0 meters high x 5.0 meter wide horseshoe |
| *Subtotal* | 10,226 m | |
| **Total Repository Openings** | **224,143 m** | Does not include length of the ESF |

Table 22. 97,000 MTHM LT Case Excavation Length Summary by Excavation Size

| Excavation Description | Excavation Length | Comments |
|---|---|---|
| Total 7.62 meter diameter TBM | 61,677 m | Does not include length of the ESF |
| Total 5.5 meter diameter TBM | 127,905 m | |
| Total Shaft Excavation, 8.0 meter diameter | 5,017 m | |
| Total 7.0 meter high x 8.0 meter wide | 18,838 m | |
| Total 8.0 meter high x 8.5 meter wide | 7,749 m | |
| Total Raising, 2.0 meter diameter | 2,307 m | |
| Total Raise Alcoves | 650 m | |
| **Total Repository Openings** | **224,143 m** | Does not include length of the ESF |

### 6.1.5 Parametric Studies

The configuration of the subsurface facility and the methods used to operate and maintain this facility is distinct but interrelated in their developmental and evolutionary processes. Flexibility in the layout configuration allows this evolutionary process to continue, and takes advantage of the relationship between the configuration and the operating mode.

Because the specific thermal criteria (e.g., the WP and drift wall temperature limits) that will be imposed on future design enhancements have not been finalized, the repository configuration must be sufficiently flexible to allow operation under a wide range of potential thermal conditions. The operating mode of a potential repository at Yucca Mountain has evolved as more has been learned about the site and the performance contribution of the design and operational performance objectives (see Section 6.1.6).

The layout configuration (see Figure 3) can be operated to support a range of thermal operating modes. As outlined in the four alternative scenarios presented in Section 6.1, a number of variations of both operational and design features can be made to allow the repository to operate under similar thermal conditions. This same flexibility of operational and design features to choose a lower-temperature operating mode could also be applied to higher-temperature operating modes as well. The following sections outline potential operational and design flexibility associated with the repository layout.

#### 6.1.5.1 Operational Sensitivities

Drift wall temperatures, WP temperatures, and relative humidity are a function of the thermal energy (integrated heat) transferred to the mountain and can be managed by altering several operational features of the design:

- Varying the thermal load to the repository by managing the thermal output of the WPs.
- Varying the distance between WPs in emplacement drifts.
- Varying the ventilation rate and duration (see Section 6.2.14).

**Thermal Output of the WPs** — The major contributor of thermal energy in the repository is CSNF, which will likely have a wide range of thermal powers at emplacement, in a waste stream that is subject to uncertainty arising from contractual conditions. The characteristics of the CSNF assemblies received at the repository are dependent on waste forms generated by the utilities and which is predictable based on records and projections of future power productions. However, which assemblies individual utilities will ship to the repository is dependent on factors that cannot be defined at this time. Therefore, the design and operations of the repository must be flexible enough to allow receipt, packaging, and emplacement of assemblies with a wide range of characteristics. The total thermal energy is directly related to the amount of thermal energy contained in the fuel emplaced in it. The thermal energy contained in the fuel, in turn, is directly related to its age and the amount of burn-up. The age and burn-up of SNF received for emplacement in a repository will vary considerably. Therefore, the current operational plan for the repository specifies that the DOE will manage the commercial WP heat output by one or more of the following features:

- Thermal blending whereby low heat output fuel is placed with high heat output fuel within a WP.
- Decreasing or limiting the number of SNF assemblies to fewer than the WP design capacity.
- Placing high thermal power fuel in smaller WPs that have fewer assemblies.
- Aging or placing younger, hotter fuel into the fuel blending inventories to be emplaced later.
- Sequencing of the HLW and CSNF in the individual emplacement drifts.

Managing the average thermal output of WPs through any of these means can control the temperature of the drift and allow for a cooler repository.

**Distance Between WPs** — The distance between WPs in emplacement drifts is another design feature that can be modified to manage the temperature in the repository. As WPs are spaced farther apart, the linear thermal density in the drift (measured in kilowatts of heat output per meter of drift length) decreases, delivering less heat per unit volume of the host rock when drift-to-drift spacing remains fixed.

By varying these operational features, the capacity of the potential repository would be impacted. The capacity of the potential repository is determined by the quantity of each type of WP, their respective WP lengths and the average WP spacing.

The first sensitivity to be evaluated is the WP spacing. This WP spacing represents an overall average WP spacing. The average spacing represents a variable spacing that will be needed during the emplacement operations to compensate for the differences in the thermal powers of the individual WPs. Figure 13 illustrates the operational flexibility of the repository layout with respect to the WP spacing, basing the waste inventory on that defined in Section 4.1.1.3. The bases and calculations for the sensitivity chart are outlined in Attachment VI.

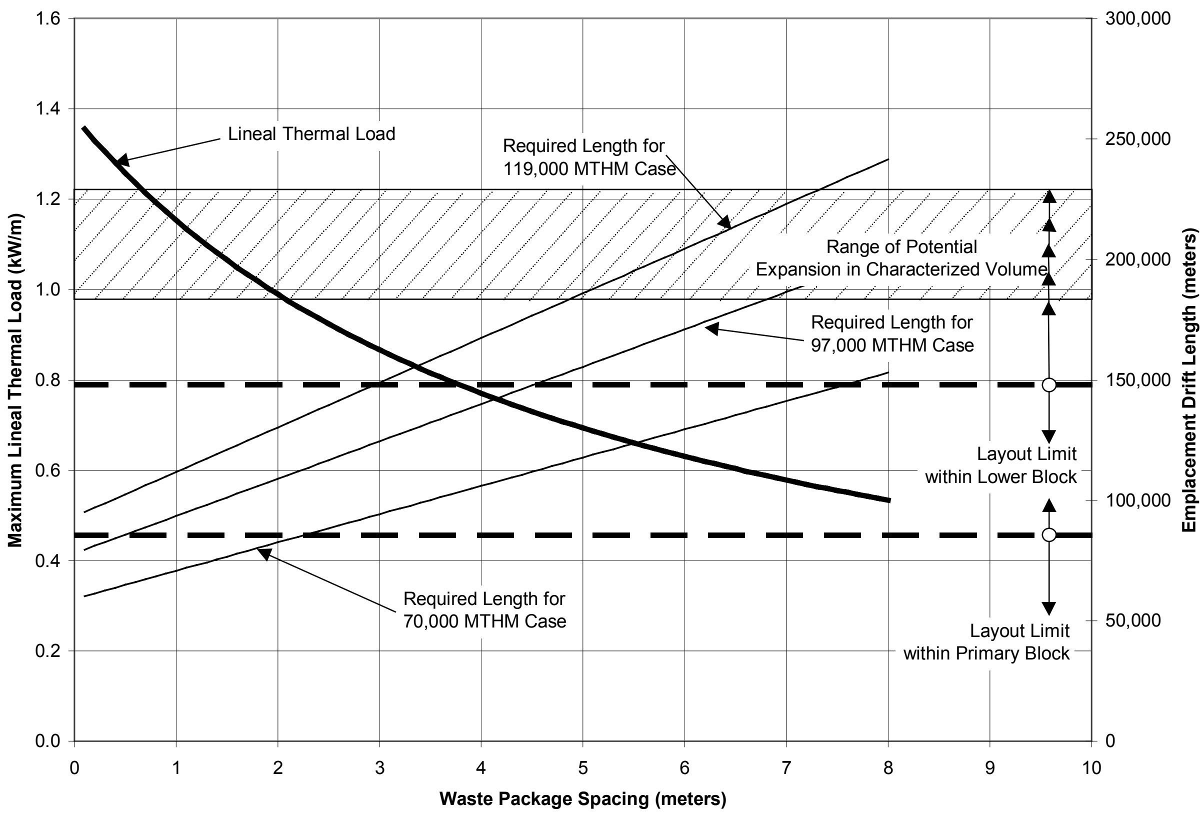



Figure 13. Operational Flexibility, 81 meter Drift Spacing

Table 23 outlines a brief summary of the data used to create the parametric chart outlined in Figure 13. The lightly shaded areas of Table 23 indicate that the capacity of the current layout configuration is exceeded, but capacity is still within the potential expansion capabilities of the characterized block (see Section 6.1.2.2) for the specific scenario indicated. The darker shaded areas of Table 23 indicate that the capacity the potential expansion capabilities of the characterized block (see Section 6.1.2.2) would probably be exceeded for the specific scenario indicated.

Table 23. Summary of Operational Flexibility Data, 81 meter Drift Spacing

| WP Spacing (m) | kW/m Based on 70,000 MTHM Case | AML Based on 70,000 MTHM Case (MTHM/acre) | 70,000 MTHM Case | | 97,000 MTHM Case | | 119,000 MTHM Case | |
|---|---|---|---|---|---|---|---|---|
| | | | Required Drift Length (meters) | Last Drift Required | Required Drift Length (meters) | Last Drift Required | Required Drift Length (meters) | Last Drift Required |
| 0.1 | 1.36 | 52.3 | 60,227 | P54 | 79,511 | P83 | 95,062 | L9 |
| 0.5 | 1.26 | 48.5 | 64,920 | P59 | 85,710 | L1 | 102,476 | L15 |
| 1.0 | 1.15 | 44.5 | 70,787 | P70 | 93,458 | L7 | 111,744 | L22 |
| 1.5 | 1.07 | 41.1 | 76,654 | P80 | 101,207 | L14 | 121,011 | L30 |
| 1.9 | 1.00 | 38.7 | 81,348 | P85 | 107,405 | L19 | 128,425 | L36 |
| 2.0 | 0.99 | 38.1 | 82,521 | P87 | 108,955 | L20 | 130,279 | L38 |
| 2.5 | 0.92 | 35.6 | 88,388 | L3 | 116,704 | L27 | 139,546 | L46 |
| 3.0 | 0.87 | 33.4 | 94,255 | L8 | 124,452 | L33 | 148,814 | -- |
| 3.5 | 0.82 | 31.4 | 100,122 | L13 | 132,201 | L39 | 158,081 | -- |
| 4.0 | 0.77 | 29.7 | 105,989 | L18 | 139,949 | L46 | 167,349 | -- |
| 4.5 | 0.73 | 28.1 | 111,856 | L23 | 147,698 | L52 | 176,616 | -- |
| 5.0 | 0.69 | 26.7 | 117,723 | L27 | 155,446 | -- | 185,884 | -- |
| 5.5 | 0.66 | 25.5 | 123,590 | L32 | 163,195 | -- | 195,151 | -- |
| 6.0 | 0.63 | 24.3 | 129,457 | L37 | 170,943 | -- | 204,419 | -- |
| 6.5 | 0.60 | 23.3 | 135,324 | L42 | 178,692 | -- | 213,686 | -- |
| 7.0 | 0.58 | 22.3 | 141,191 | L47 | 186,440 | -- | 222,953 | -- |
| 7.5 | 0.56 | 21.4 | 147,058 | L52 | 194,189 | -- | 232,221 | -- |
| 8.0 | 0.53 | 20.6 | 152,925 | -- | 201,937 | -- | 241,488 | -- |

Notes: Lightly shaded areas indicate where current layout configuration is exceeded
Darker shaded areas indicate where capacity of potential expansion areas may be exceeded.

The flexibility of the repository layout (see Figure 3) can be illustrated with a couple of examples using the defined alternative scenarios in Section 6.1. The first example uses alternative scenario three (see Section 6.1). Alternative scenario three involves lowering the WP surface temperatures and drift wall temperatures by increasing the disposal area (using a WP spacing of 6.0 meters) and using forced ventilation for 125 years.

As illustrated in Figure 14, if a vertical line is drawn at the 6 meter WP spacing, and horizontal lines are drawn at the intercept of this vertical line and the various curves, the emplacement capacity requirements and the maximum lineal thermal load for this scenario can be determined. Specifically, a 6.0-meter WP spacing would result in a maximum lineal thermal load of 0.63 kW/m, and the required emplacement length for the 70,000 MTHM case would be 129,457 meters. This scenario would require the majority of the capacity available in both the primary and lower blocks of the repository layout to accommodate the 70,000 MTHM Case. The required emplacement lengths for 97,000 and estimated 119,000 MTHM Cases would exceed the capacity available within the current footprint configuration.

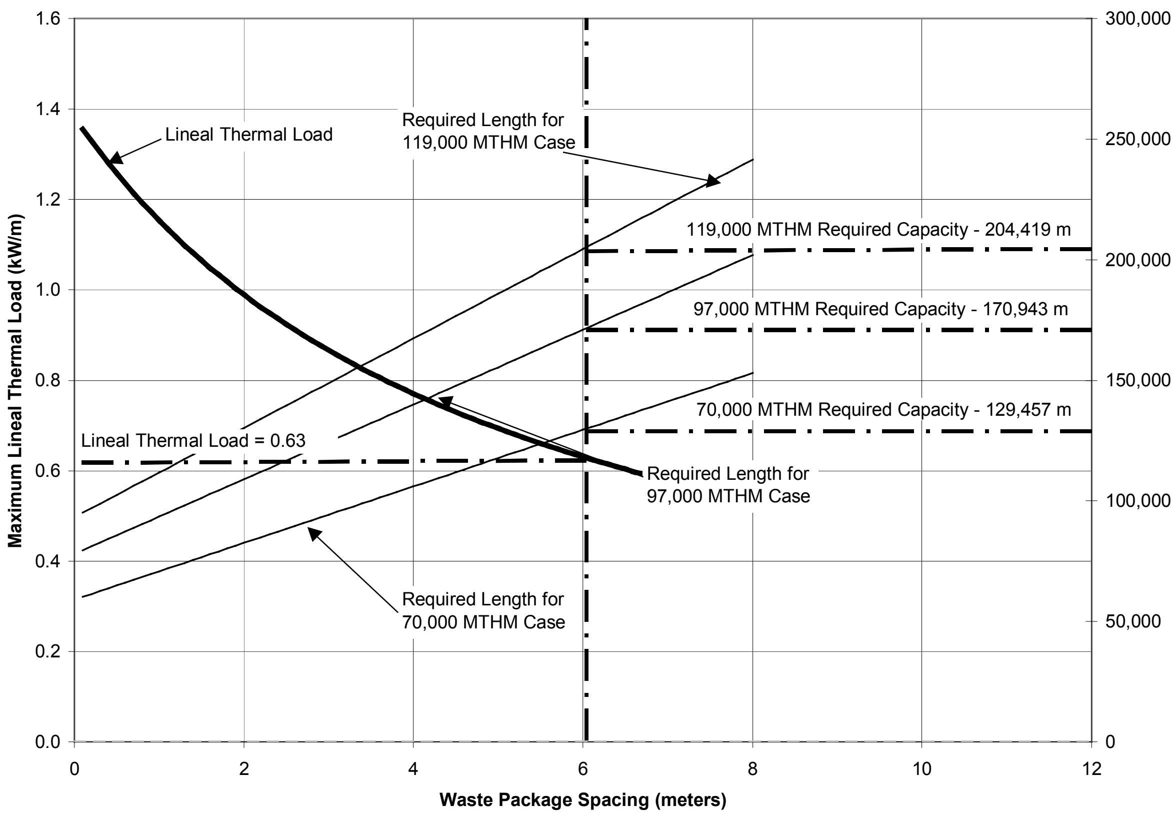



Figure 14. Example for Alternative Scenario Three, 81 meter Drift Spacing

The second example uses alternative scenario four (see Section 6.1). Alternative scenario four involves lowering the WP surface temperatures and drift wall temperatures by a slight increase in the disposal area (using a WP spacing of 2.0 meters), using forced ventilation for 125 years, and surface aging of the waste for up to 40,000 MTHM of spent fuel.

As illustrated in Figure 15 if a vertical line is drawn at the 2.0 meter WP spacing, and horizontal lines are drawn at the intercept of this vertical line and the various curves, the emplacement capacity requirements and the maximum lineal thermal load for this scenario can be determined. Specifically, a 2.0 meter WP spacing would result in a maximum lineal thermal load of 0.99 kW/m (this value does not account for the aging of the waste, and the actual thermal load is expected to be lower), and the required emplacement length for the 70,000 MTHM case would be 82,526 meters. This scenario would require all the space available in the primary block of the repository layout to accommodate the 70,000 MTHM Case. Both the 97,000 and estimated 119,000 MTHM Cases could be accommodated within the capacity available in both the primary and lower blocks of the repository layout.

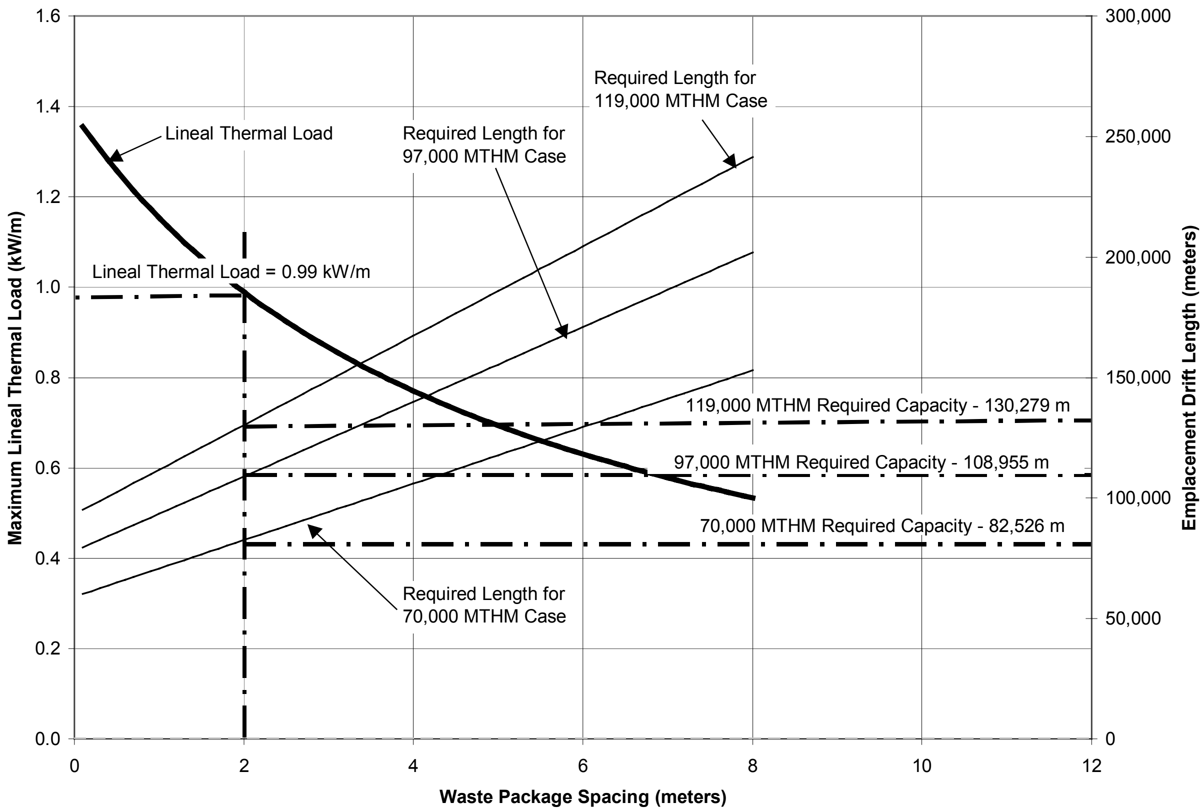



Figure 15. Example for Alternative Scenario Four

By decreasing the size of the higher heat output WPs (see Section 5.1.2.5), the quantity of CSNF WPs increase by approximately 75 percent (see Attachment VI). Figure 16 illustrates the operational flexibility of the repository layout with respect to the decreased WP sizes and heat outputs. Table 24 provides a summary of the data presented in Figure 16. The lightly shaded areas of Table 24 indicate that the capacity of the current layout configuration is exceeded, but capacity is still within the potential expansion capabilities of the characterized block (see Section 6.1.2.2) for the specific scenario indicated. The darker shaded areas of Table 24 indicate that the capacity the potential expansion capabilities of the characterized block (see Section 6.1.2.2) would probably be exceeded for the specific scenario indicated. The bases and calculations for this sensitivity evaluation are outlined in Attachment VI.

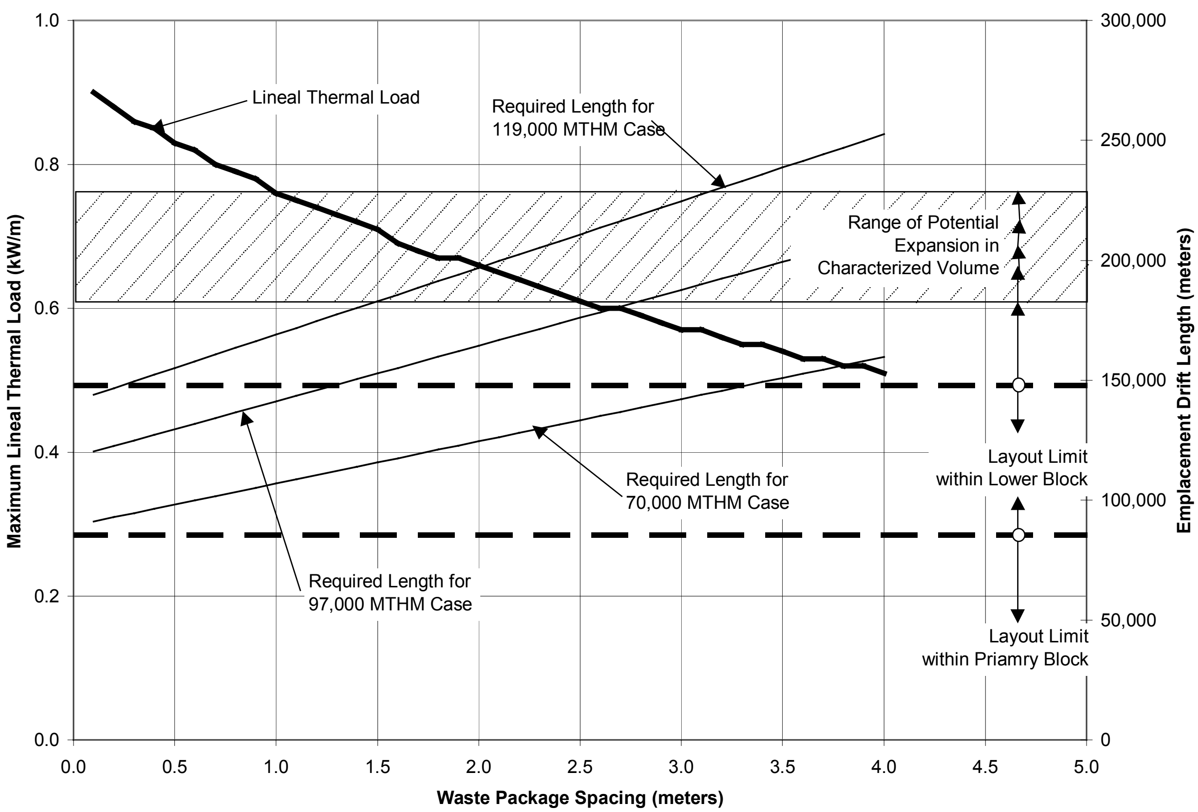



Figure 16. Operational Flexibility, 81 meter Drift Spacing, Smaller Waste Packages

Table 24. Summary of Operational Flexibility Data, 81 meter Drift Spacing, Smaller Waste Packages

| WP Spacing (m) | kW/m Based on 70,000 MTHM Case | AML Based on 70,000 MTHM Case (MTHM/acre) | 70,000 MTHM Case | | 97,000 MTHM Case | | 119,000 MTHM Case | |
|---|---|---|---|---|---|---|---|---|
| | | | Required Drift Length (meters) | Last Drift Required | Required Drift Length (meters) | Last Drift Required | Required Drift Length (meters) | Last Drift Required |
| 0.1 | 0.9 | 34.5 | 91,106 | L5 | 120,299 | L30 | 144,006 | L49 |
| 0.5 | 0.8 | 32.1 | 98,146 | L11 | 129,596 | L37 | 155,138 | -- |
| 1.0 | 0.8 | 29.4 | 106,945 | L18 | 141,218 | L47 | 169,053 | -- |
| 1.5 | 0.7 | 27.2 | 115,745 | L26 | 152,840 | -- | 182,969 | -- |
| 2.0 | 0.7 | 25.3 | 124,544 | L33 | 164,462 | -- | 196,884 | -- |
| 2.5 | 0.6 | 23.6 | 133,344 | L40 | 176,084 | -- | 210,800 | -- |
| 3.0 | 0.6 | 22.1 | 142,143 | L48 | 187,706 | -- | 224,715 | -- |
| 3.5 | 0.5 | 20.9 | 150,943 | -- | 199,328 | -- | 238,631 | -- |
| 4.0 | 0.5 | 19.7 | 159,742 | -- | 210,950 | -- | 252,546 | -- |

Notes: Lightly shaded areas indicate where current layout configuration is exceeded
Darker shaded areas indicate where capacity of potential expansion areas may be exceeded.

The defined alternatives in Section 6.1 will be used again to show an example of how to use the chart in Figure 16. This example uses alternative scenario one (see Section 6.1). Alternative scenario one involves lowering the WP surface temperatures and drift wall temperatures by an extended ventilation period, a minimal increase in the disposal area, and lower heat output (smaller), tightly spaced (0.1 meter spacing) WPs.

As illustrated in Figure 17 if a vertical line is drawn at the 0.1 meter WP spacing, and horizontal lines are drawn at the intercept of this vertical line and the various curves, the emplacement capacity requirements and the maximum lineal thermal load for this scenario can be determined. Specifically, a 0.10 meter WP spacing, with smaller WPs, would result in a maximum lineal thermal load of 0.90 kW/m, and the required emplacement length for the 70,000 MTHM case would be 91,072 meters. This scenario would require all of the capacity available in the primary block and would require the first five drifts of the lower block to be excavated (see Attachment VI) to accommodate the 70,000 MTHM Case. Both the 97,000 and estimated 119,000 MTHM Cases could be accommodated within the capacity available in both the primary and lower blocks of the repository layout.

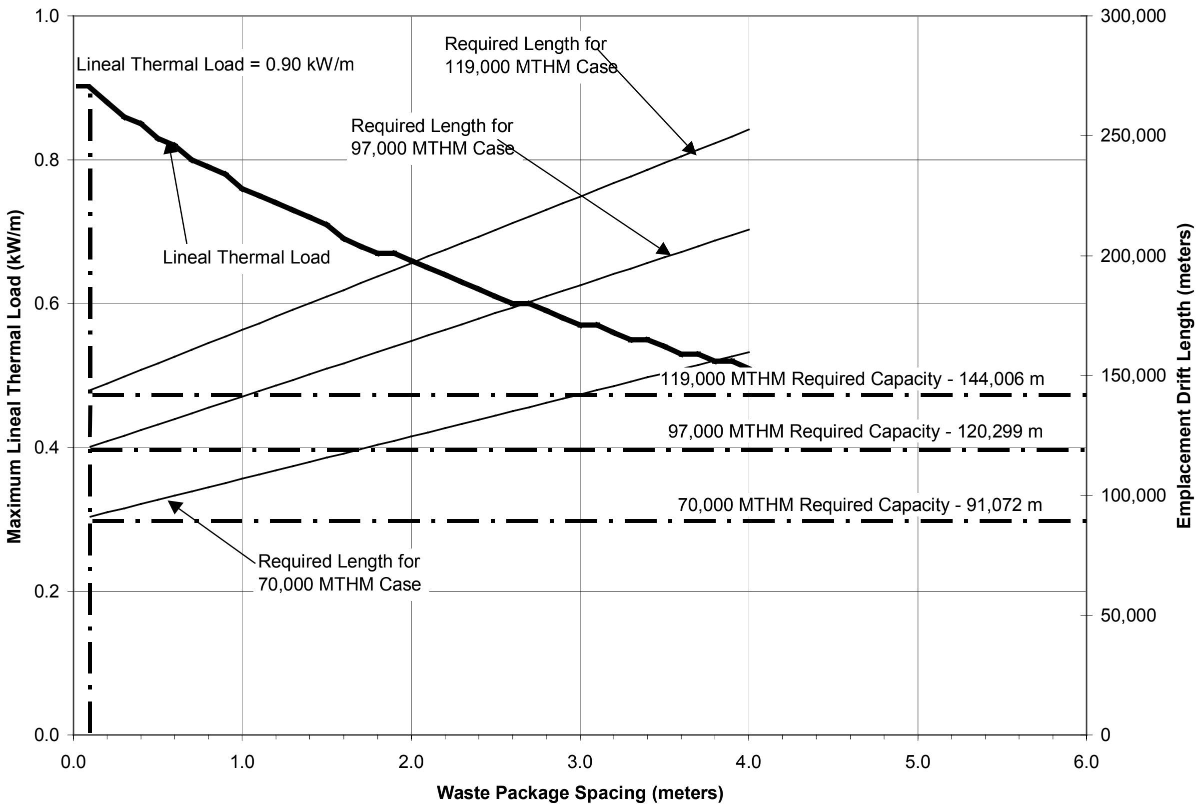



Figure 17. Example for Alternative Scenario One

### 6.1.5.2 Design Sensitivities

The layout configuration can be modified to incorporate a change in the drift spacing. This type of design change would need to be decided before construction of the individual emplacement drift begins. There are implications of changing the drift spacing, specifically when it is decreased. The current repository layout is configured with the cross-block drifts, standby drifts and intake shaft access drifts located in the pillar between emplacement drifts (see Figure 3). As the drift spacing is decreased, a point will be reached where it is no longer practical or technically feasible to place openings in the pillars between adjacent emplacement drifts. Future layout configuration work will need to determine the minimum drift spacing that will allow positioning of these openings within the pillar or determine whether an emplacement drift would need to be reallocated as either a standby or cross-block drift, or redesigned as an intake shaft access drift.

In order to evaluate this type of design sensitivity, a simple calculation is used to convert the available emplacement drift length in the repository layout (at an 81 meter drift spacing) to other emplacement drift spacing both increased and decreased (see Attachment VII). Figure 18 illustrates the concept that as the drift spacing decreases the length of emplacement drift available increases substantially. Figure 18 also plots the required emplacement drift length for the three inventory cases against the WP spacing. As can be seen by visual inspection, a wide range of operating conditions can be accommodated by simply changing the spacing of the emplacement drifts.

Additionally, the AML of the potential repository would change as the emplacement drift spacing is varied. This is illustrated in Figure 19. Specific drift spacing could be chosen to reflect a specific AML or a range of AMLs. Since the AML is also a function of the WP spacing, the AMLs are given with respect to a specific WP spacing.

The maximum drift and WP spacing combinations for each waste inventory that can be accommodated within the current layout configuration are outlined Table 25.

Table 25. Maximum Constraints on Current Layout Configuration

| Waste Inventory (MTHM) | Emplacement Drift Spacing (meters) | WP Spacing (meters) |
|---|---|---|
| 70,000 | 90 | 5.9 |
| 97,000 | 76 | 4.8 |
| Estimated 119,000 | 67 | 4.3 |

The 67 meter emplacement drift spacing, 4.3 meter WP spacing case outlined in Table 25 should be checked for thermal performance to determine the limit or bounds for the optimal development of the current primary/lower block areas.

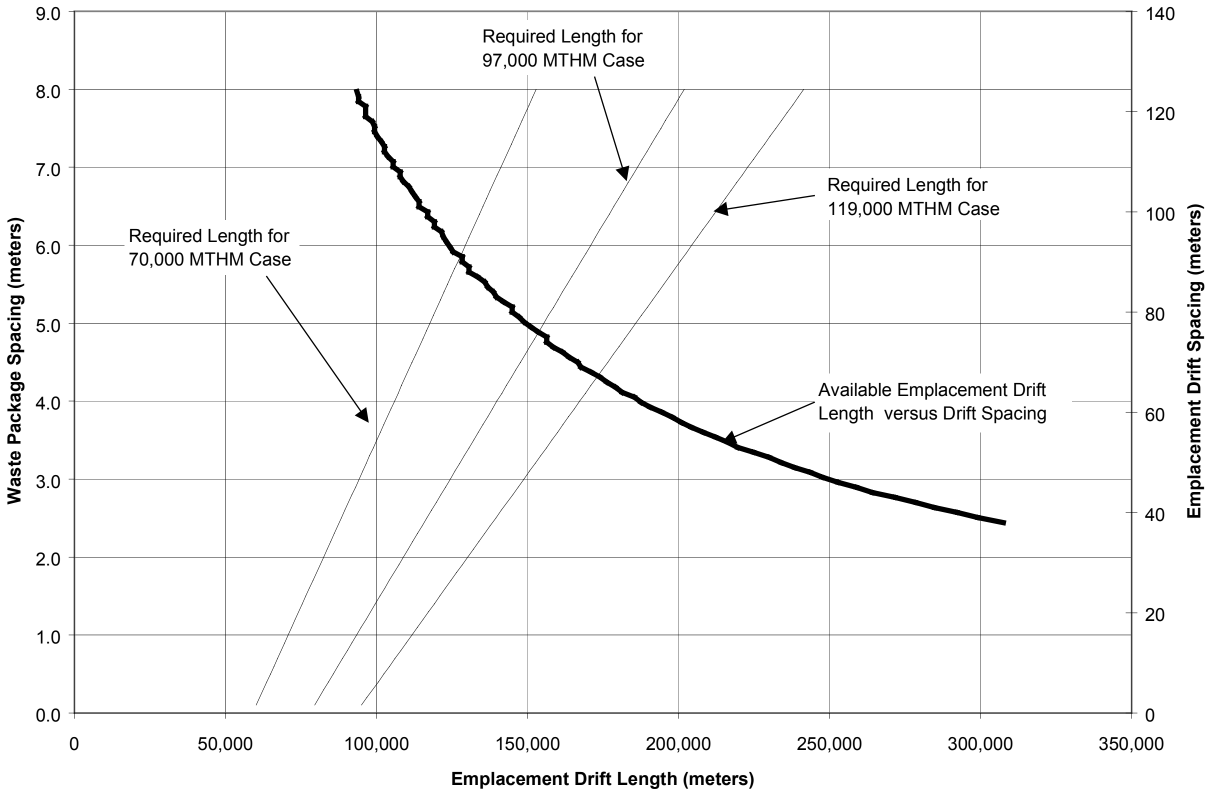



Figure 18. Available Emplacement Drift Length for Various Drift Spacing

For example, looking at Figure 18, it can be determined that complete development of the primary and lower blocks with a drift spacing of approximately 67 meters may allow for a generous average WP spacing of 4.3 meters or less. If the thermal response for these conditions is determined to be favorable, then sensitivity analyses could be completed for tighter WP spacing until a lower limit WP spacing is determined for the 67 meter drift spacing. This type of sensitivity analyses would help define a more realistic limit to the "knobs" that can be turned with a flexible approach the operating mode of the repository, within the limits of the current layout configuration.

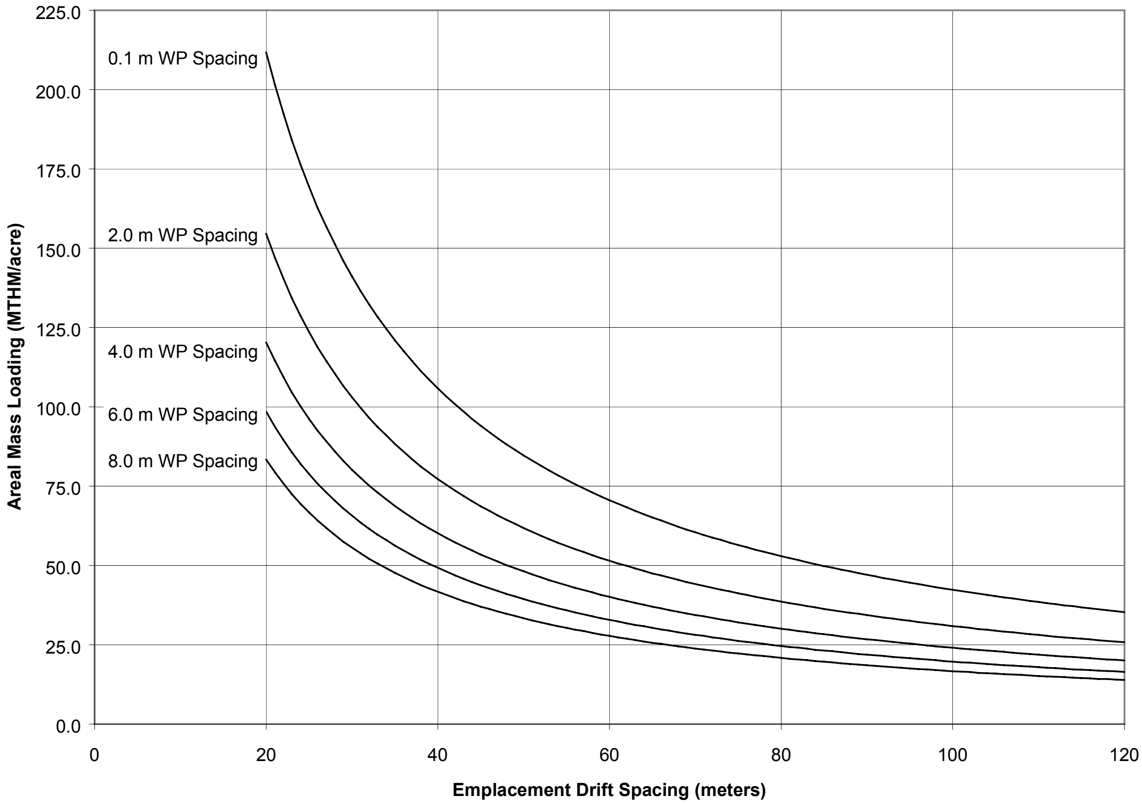



Figure 19. Areal Mass Loading Versus Emplacement Drift Spacing

As an example, alternative scenario two (see Section 6.1) will be illustrated. Alternative scenario two involves lowering the WP surface temperatures and drift wall temperatures by an extended ventilation period, a minimal increase in the disposal area (0.1 meter WP spacing), and an increased drift spacing of 120 meters.

As illustrated in Figure 20 if a horizontal line is drawn at the 120 meter drift spacing, and a vertical line is drawn to the intercept the 119,000 MTHM Case curve, the WP spacing can be determined that will accommodate all waste inventories within the current repository layout configuration. Specifically, a 120-meter drift spacing, would result in a WP spacing of 0.1 meters to accommodate the 119,000 MTHM Case. The liner thermal load for this example, 1.36 kW/m, can be determined by examining the maximum lineal thermal load curve in Figure 13.

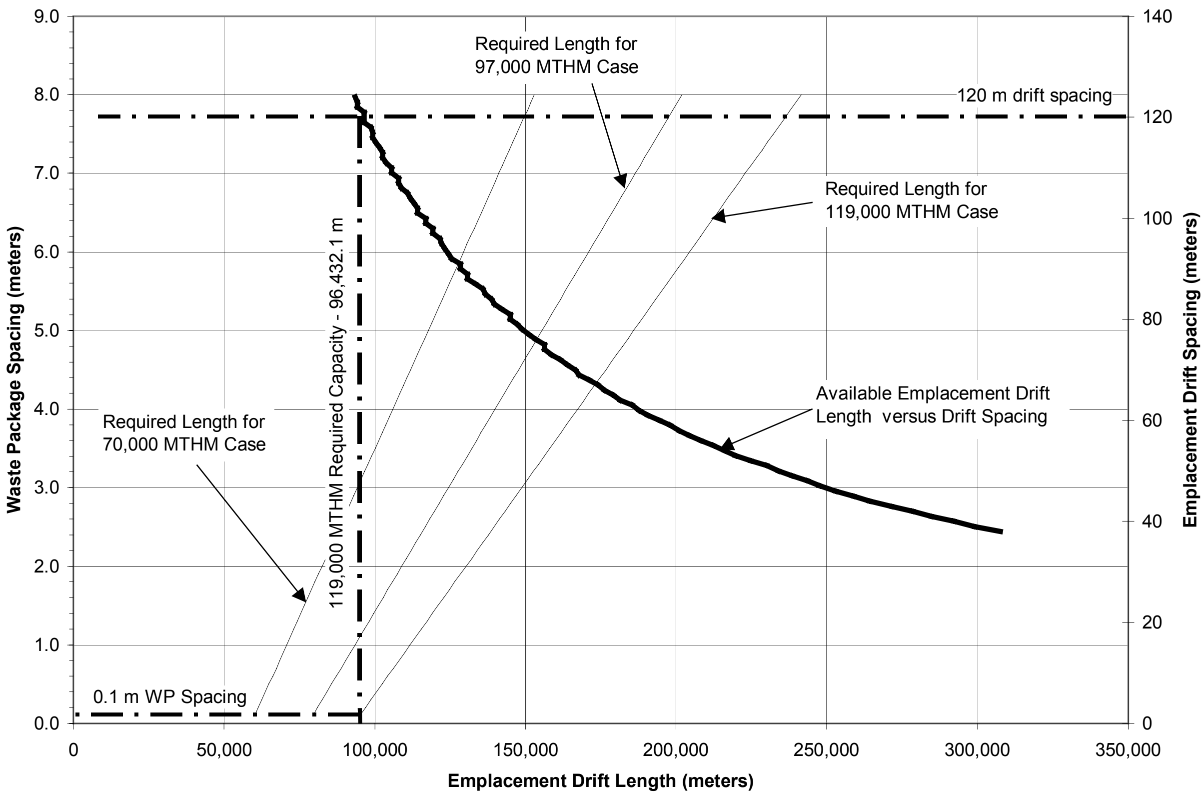



Figure 20. Example for Alternative Scenario Two – Available Drift Length

To determine the AML for alternative scenario two, a vertical line is drawn at the 120 meter drift spacing to intercept the 0.1 meter WP spacing curve as illustrated in Figure 21. Specifically, this scenario would result in an AML of 35.3 MTHM/acre.

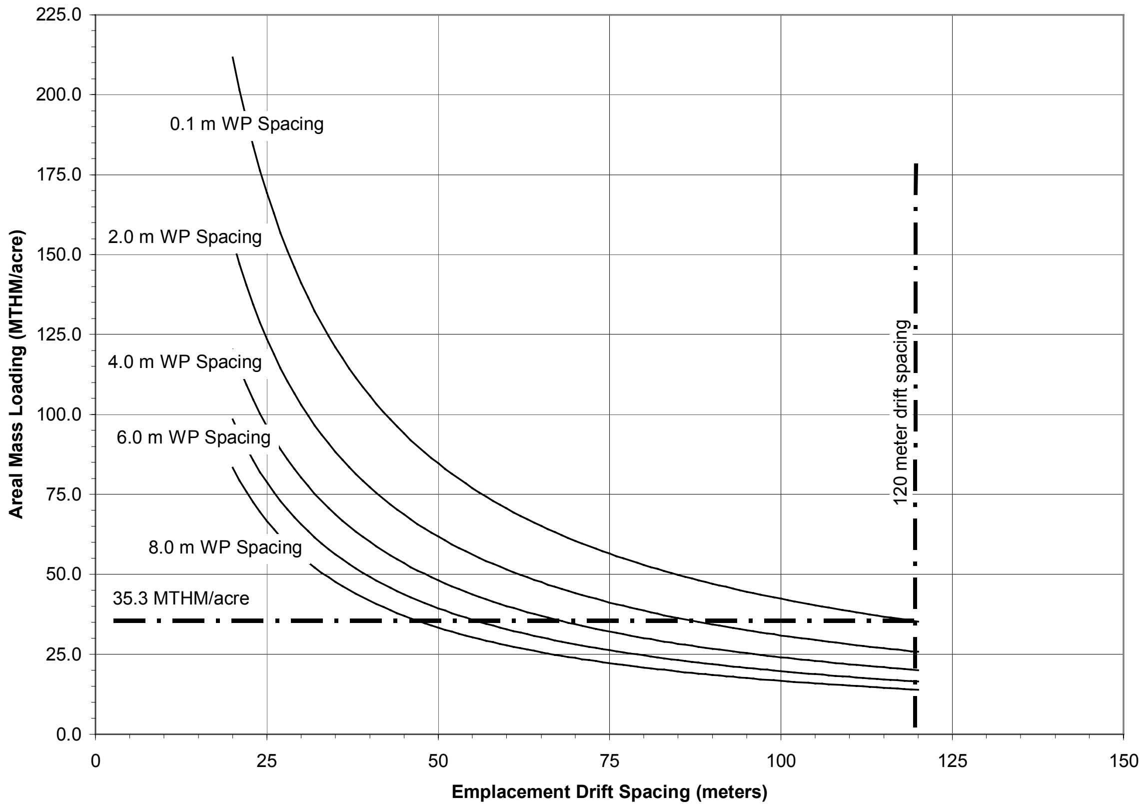



Figure 21. Example for Alternative Scenario Two – Areal Mass Loading

### 6.1.6 Operational Flexibility

Operational flexibility refers to the ability to change various operational parameters in order to control the amount of energy transmitted to the mountain. Selection of specific values to assign to these operational parameters is a function of both the characteristics of the incoming waste stream and policy decisions, not all of which can be accurately predicted at this time. A number of parameter combinations can provide the desired thermal response, and thus the desired repository performance. Therefore, it is desirable to establish allowable operating ranges for parameters that can provide operational flexibility within the allowable design envelop.

Two factors that drive the need for operational flexibility are outlined below:

**Maximizing Performance while Reducing Uncertainties** - As the design of the repository has evolved, more knowledge of the mountain's thermal response, and the project's ability to accurately model the response, have led to the acceptance of various thermal goals (i.e., 50 percent of the drift pillar below the boiling point of water, maximum 96 degrees Celsius drift wall temperature, maximum 85 degrees Celsius WP surface temperature, etc.). The repository design work proceeds using a flexible approach allowing operation of the repository over a range of thermal operating modes. Testing and modeling over time can reduce uncertainties, improve performance and provide optimal thermal goals. This approach allows continued feedback from the ongoing testing and analyses work.

**Accommodating Variations in Incoming Waste Stream** - The characteristics of the CSNF assemblies received at the repository are dependent on waste forms generated by the utilities and the fuel assemblies each utility selects for shipment. The characteristics of the fuel discharged from each reactor are predictable based on records and projections of future power productions. However, which assemblies individual utilities will ship to the repository is dependent on factors that cannot be defined at this time. Therefore, the design and operations of the repository must be flexible enough to allow receipt, packaging, and emplacement of assemblies with a wide range of characteristics.

#### 6.1.6.1 Various Repository Operating Modes

The operational flexibility of a potential repository can be evaluated by examining and correlating the various operating modes since the publication of the *Viability Assessment of a Repository at Yucca Mountain* (DOE 1998c) in December of 1998.

Previous DOE studies have investigated repository operating mode, layout, and performance considerations for a range of thermal conditions. The *Total System Performance Assessmen*t. Volume 3 of *Viability Assessment of a Repository at Yucca Mountain* (DOE 1998b, pp. 3-30 to 3-31) utilized a mode of operations where the emplacement drift ventilation rate was limited to 0.1 $m^3/s$ after waste emplacement. This low ventilation rate permitted monitoring for radiation leaks in the air stream exhausting the drifts, but did not contribute significantly to removal of heat from the emplacement drifts. This low ventilation rate could result in rock temperatures of approximately 200 degrees Celsius at the drift wall (DOE 1998a, pp. 5-27).

Subsequent direction (Wilkins and Heath 1999, Enclosure 2) during the License Application Design Selection (CRWMS M&O 1999d, Overview, pp. O-21 to O-26) and Enhanced Design Alternative II studies (CRWMS M&O 1999e, Executive Summary) lead to evaluations that defined thermal goals for a moderate temperature repository design. This concept is referred to in this report as the higher-temperature operating mode. Goals included prevention of the boiling fronts from coalescing in the rock pillars between the emplacement drifts. To achieve this goal a portion of the pillars are maintained at temperatures below the boiling point of water at the elevation of the emplacement horizon.

Current project efforts provide the bases for a lower-temperature operating mode that achieves lower drift wall and WP surface temperatures (see Section 6.1). These evaluations provide the bases for the discussion of operating and design flexibility (see Section 6.1.5).

For the various operating modes, four distinct groups of analyses have been performed for the Yucca Mountain Project. These analyses can be grouped as: as the engineering analysis, the performance assessment of the potential repository, the total system life cycle cost reports, and the evaluation of the environmental impacts. Each analysis considered scenarios to provide information that could operate the design in a given manner. Attachment IX provides a history of the various operating modes evaluated to date. As additional evaluations are performed, each evaluation can utilize improved models with an increased understanding of the natural and engineered processes that affect performance and uncertainties. Future analyses can incorporate the latest test results from the ongoing test program. Section 6.1.6.2 discusses the differences in design bases used for the various evaluations.

### 6.1.6.2 Design Bases for the Case Studies

Table 26 provides a summary of the various operating modes outlined in Attachment VII. When examining this summary with the associated design bases and parameters used to achieve that mode it is noted that not all of the cases use a consistent design basis for their evaluations. The following sections will discuss and explain the mode variations in Table 26.

#### 6.1.6.2.1 Waste Inventories

The cited requirements indicate that the subsurface facility system must provide sufficient emplacement capacity to allow the capability of accommodating a waste inventory of as much as 119,000 MTHM (see Section 4.2.1.1.9). In addition, specific waste inventories of 70,000 and 97,000 MTHM (see Section 4.2.1.1.1 and Section 4.2.1.1.2) have been provided.

The 70,000 MTHM waste inventory is the operational limit of the first repository until a second repository is in operation as defined in the Nuclear Waste Policy Act of 1982, Section 114(d). For this reason, the 70,000 MTHM waste inventory is used as the design basis for the engineering analyses, performance assessment and the environmental impact statement (EIS) evaluations.

The 97,000 MTHM waste inventory, including 83,800 MTHM of CSNF, is the current repository inventory requirement (see Section 4.2.1.1.2). This inventory is equal to the 1999 projection of SNF discharges, which was fully consistent with the reference Energy Information Administration (EIA) nuclear-electric projection for 1999 (Williams 2001, p. 1 and CRWMS M&O 1999j, p. 5). This inventory has been used in the engineering analysis to provide a layout configuration to support the total system life cycle cost reports. The total system life cycle cost report bounds the total system costs of the potential repository by using the 97,000 MTHM waste inventory.

The EIS evaluation includes additional waste inventories. These inventories consist of the base case 70,000 MTHM waste inventory plus the remainder of the total projected inventory of CSNF, high-level radioactive waste, and DOE SNF. In addition, commercial Greater-Than-Class-C low level radioactive waste and DOE Special–Performance-Assessment-Required waste are also considered candidate materials for disposal in a MGR (DOE 1999, Appendix A, p. A-1). The largest inventory, approximately 119,000 MTHM, consists of 105,000 MTHM of CSNF plus the other fuel type inventories. The EIS evaluations are required to bound the higher and lower-ends of a design concept. Deviations from the 70,000 MTHM design basis for this purpose is acceptable for purposes of this analysis.

Table 26. Summary of the Various Operating Modes

| Case Study | Waste Inventory (MTHM) | Total WP Quantity | Average WP Spacing (meters) | Emplacement Drift Spacing (meters) | Linear Thermal Load (kW/m) | Forced Ventilation Rate ($m^3/s$) | Forced Ventilation Efficiency (%) | Years of Forced Ventilation from start of Emplacement | Years of Natural Ventilation after Forced Ventilation Period | AML (MTHM/acre) | Area Required (acres) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Viability Assessment | | | | | | | | | | | |
| Engineering/PA/Total System Life Cycle Cost | 70,000 | 10,500 | ~3.9 end-to-end | 28 | N/A | 0.1 | N/A | 100 | 0 | 85 | ~ 740 [B] |
| Environmental Impact Statement | | | | | | | | | | | |
| Base Case - VA Design | 70,000 | 10,500 | ~3.9 end-to-end | 28 | N/A | 0.1 | N/A | 100 | 0 | 85 | ~ 740 [A] |
| Alternative Base Case - Intermediate Thermal Loading | 70,000 | 10,500 | ~3.9 end-to-end | 40 [A] | N/A | 0.1 | N/A | 100 | 0 | 60 [A] | 1,050 [A] |
| Alternative Base Case - Low Thermal Loading | 70,000 | 10,500 | 35 meters center to center for CSNF [H] | 38 [A] | N/A | 0.1 | N/A | 100 | 0 | 25 [A] | 2,520 [A] |
| Larger Inventory Case - High Thermal Loading | ~ 119,000 | 17,435 | ~3.9 end-to-end | 28 | N/A | 0.1 | N/A | 100 | 0 | 85 | 1,240 [A] |
| Alternative Larger Inventory Case - Intermediate Thermal Loading | ~ 119,000 | 17,435 | ~3.9 end-to-end | 40 [A] | N/A | 0.1 | N/A | 100 | 0 | 60 [A] | 1,750 [A] |
| Alternative Larger Inventory Case - Low Thermal Loading | ~ 119,000 | 17,435 | 35 meters center to center for CSNF [H] | 38 [A] | N/A | 0.1 | N/A | 100 | 0 | 25 [A] | 4,200 [A] |
| Higher-Temperature Operating Mode | | | | | | | | | | | |
| Engineering | 70,000 and 97,000 | 11,184 and 14,769 | 0.1 end-to-end [I] | 81 | 1.45 | 15 | 70 | ~ 50 | 0 | ~ 60 | ~ 1,150 and 1,485 [D] |
| Performance Assessment | 70,000 | 9,972 | 0.1 end-to-end [I] | 81 | 1.35 | 15 | 70 | ~ 50 [F] | 0 | ~ 60 [E] | 1,050 [F] |
| Total System Life Cycle Cost | 97,000 | 14,769 | 0.1 end-to-end [I] | 81 | 1.45 | 15 | 70 | 63 [C] | 0 | 56 | 1,485 [D] |
| EIS | 70,000 | 11,301 | 0.1 end-to-end [I] | 81 | 1.45 | 15 | 70 | ~ 50 | 0 | 56 | 1,125 [E] |

Table 26. Summary of the Various Operating Modes (continued)

| Case Study | Waste Inventory (MTHM) | Total WP Quantity | Average WP Spacing (meters) | Emplacement Drift Spacing (meters) | Linear Thermal Load (kW/m) | Forced Ventilation Rate ($m^3/s$) | Forced Ventilation Efficiency (%) | Years of Forced Ventilation from start of Emplacement | Years of Natural Ventilation after Forced Ventilation Period | AML (MTHM/acre) | Area Required (acres) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Lower-Temperature Operating Mode | | | | | | | | | | | |
| Engineering | 70,000 and 97,000 | 11,184 and 14,769 | ~ 2.0 end-to-end | 81 | 1.00 | 15 | ~ 70 | 75 | 250 | 40 | ~ 1,650 and 2,150 |
| Performance Assessment | 70,000 | 11,184 | ~ 1.1 end-to-end | 81 | 1.13 | > 15 | 80 | 300 | N/A | 45 | ~ 1,400 [G] |
| Total System Life Cycle Cost | 97,000 | 14,769 | ~ 2.0 end-to-end | 81 | 1.00 | 15 | ~ 70 | 75 | 250 | 40 | 2,150 |
| EIS | 70,000 | 11,301 | ~ 2.0 end-to-end | 81 | 1.00 | 15 | ~ 70 | 75 | 250 | 40 | ~ 1,650 |

[A] CRWMS M&O 1999i, p. 3-3
[B] DOE 1998a, p. 4-45
[C] CRWMS M&O 2000p, p. 2
[D] BSC 2001a, pp. 110 – 111
[E] CRWMS M&O 2000n, p. 3-2
[F] CRWMS M&O 2000o, p. 1-47
[G] Value is back calculated from the AML (MTHM/acre) and the CSNF waste inventory
[H] CRWMS M&O 1999i, p. 5-4
[I] These values represent true end-to-end spacing, not average

#### 6.1.6.2.2 Waste Package Quantities

The assumptions used to manipulate the waste inventories listed in Section 6.1.6.2.1 have resulted in different WP quantity estimates for the following assessments:

**Viability Assessment** - The Viability Assessment evaluations, engineering, performance assessment, total system life cycle costs, and the EIS evaluations consist of 10,500 WPs for the 70,000 MTHM waste inventory (DOE 1998a, p. 4-45, DOE 1998b, p. 3-81, CRWMS M&O 1999i, p. 3-3). The EIS evaluation uses 17,435 WPs to represent the larger waste inventory of approximately 119,000 MTHM (CRWMS M&O 1999i, p. 3-3). The larger WP inventory is considered a bounding case that includes the total projected inventory of commercial pent nuclear fuel, high-level radioactive waste, and DOE SNF. In addition, commercial Greater-Than-Class-C low-level radioactive waste and DOE Special-Performance-Assessment-Required waste, also considered candidate materials for disposal in a MGR, are included in the WP inventory.

**Higher Temperature Operating Mode** - During the License Application Design Selection process, a waste inventory consisting of 9,972 WPs was specified for the Enhanced Design Alternative II evaluation (CRWMS M&O 1999e, p. 5-3). This change was based on using a blending process to restrict the average initial heat output per PWR WP to 9.8 kW, with a maximum of 11.8 kW (CRWMS M&O 1999e, p. 5-6). The higher-temperature operating mode evaluation, (EDA II) cited in the Total System Performance for the Site Recommendation, used this inventory as its basis (CRWMS M&O 2000o, p. 1-48).

Subsequent refinements to the WP inventory resulted in an update to the WP quantities and these new quantities were used as the design bases for the engineering analyses and the total system life cycle costs. The 70,000 MTHM inventory consisted of 11,184 WPs and the 97,000 MTHM inventory consisted of 14,769 WPs (BSC 2001a, p. 18).

The EIS evaluations uses a more restrictive set of assumptions for developing a blended WP inventory. This resulted in a bounding set of WP quantities, 11,301 WPs for the 70,000 MTHM waste inventory, and 17,232 WPs for the larger waste inventory (CRWMS M&O 2000n, p. 3-2).

**Lower-Temperature Operating Mode** – The waste inventories used in the lower-temperature operating mode are the same as those for the higher-temperature operating mode. Consequently, the performance assessment evaluations for the range of thermal operating modes is now using the 11,184 WP quantity described above as its design basis.

The current total system life cycle cost evaluation uses the same WP quantities as those for the higher-temperature operation mode total system life cycle cost evaluation.

For bounding purposes, the EIS evaluations use the 11,301 WPs for the 70,000 MTHM waste inventory, and 17,232 WPs for the larger waste inventory. This deviation for the purposes of bounding the EIS evaluations is acceptable.

6.1.6.2.3 Other Parameter Specifications

Other parameters, such as the WP spacing, emplacement drift spacing, and ventilation rate, duration, method, and heat removal efficiency have been specified for each case study. This provides a design that achieves the overall thermal goals for a specific case study. The AML and the area that is required to support the case study can be calculated and determined from the layout configuration, the WP inventory and quantities, as well as the other parameter specifications.

Different combinations of these parameters can produce a similar thermal response in the mountain. Therefore, the use of different case studies for evaluation of lower-temperature operating modes is acceptable at this time. This concept is addressed in Section 6.1 with the discussion of the alternative lower-temperature operating mode scenarios.

In order to provide timely evaluation of the lower-temperature operating mode concept, the performance assessment evaluation limited the footprint of the repository to current model limits. As result, the performance assessment evaluation spreads the 70,000 MTHM waste inventory through the first 64 drifts of the layout for the potential repository development areas (see Figure 3). This results in a lineal thermal load of 1.13 kW/m, as compared to the lineal thermal load for the engineering evaluation of 1 kW/m. In order to achieve a similar thermal response as that presented in the engineering analysis, the performance assessment evaluation incorporated a longer forced ventilation period (300 years), with an increased ventilation heat removal efficiency (80 percent).

### 6.1.6.3 Correlation of the Operating Modes

The engineering analysis feeds information into the performance assessment, total system life cycle cost, and EIS evaluations. Performance assessment evaluates the layout configuration provided through the engineering analyses along with any sensitivity and then provides appropriate feedback to engineering.

Flexibility in the layout configuration allows an evolutionary development process and takes advantage of the relationship between the configuration and the operating mode. The parametric studies described in Section 6.1.5 illustrate the flexibility inherent in the current layout configuration. The layout configuration presented in Figure 3 can be shown to accommodate the waste inventories emplaced in accordance with the operating modes presented in Attachment VII.

Bounding inventory scenarios at very low AML, such as the EIS evaluation Alternative Larger Inventory Case – Low Thermal Loading listed in Table 26, may require additional layout configuration work within the characterized block. The Alternative Larger Inventory Case – Low Thermal Loading scenario requires 4,200 acres. It is anticipated that with additional layout configuration work as much as 4,500 acres may be available within the current characterized block at Yucca Mountain (see Section 6.1.2.2). This additional layout area could require a configuration that could still allow operational flexibility.

## 6.2 OVERALL SUBSURFACE VENTILATION ANALYSIS

This section describes changes to the conceptual ventilation design that have resulted from the lower-temperature operating requirements. Ventilation design principles and results documented in the *Site Recommendation Subsurface Layout* (BSC 2001a) and *Overall Subsurface Ventilation System* (CRWMS M&O 2000h) are valid and are used as the supporting basis for this analysis. The lower-temperature operating mode does not change the basic ventilation design concept and methodology presented in the *Overall Subsurface Ventilation System* (CRWMS M&O 2000h, Section 6.1). The additional emplacement drifts required as a result of the increased WP spacing will require an increase in the total air volumes and corresponding ventilation components. Ventilation concepts that have not changed are identified and appropriate documents are referenced.

For the Recommended Representative Scenario (Section 6.1) the waste emplacement period is followed by a forced ventilation period of 50 years followed by a natural ventilation period of 250 years. At the start of the natural ventilation period there is a 25-year monitoring period used to verify the system performance (see Section 5.2.2.3).

### 6.2.1 Construction Ventilation Phase

The Construction Ventilation Phase follows methods described in the *Overall Subsurface Ventilation System* (CRWMS M&O 2000h, Section 6.3). Concepts documented in the *Ventilation Needs During Construction* (CRWMS M&O 1998a) and *Overall Development and Emplacement Ventilation Systems* (CRWMS M&O 1997a) reports are valid for this analysis and not duplicated herein.

In summary, the existing airflow pattern through ESF ventilation system will be used, i.e., fresh air intake through the North Ramp and exhaust out the South Ramp. The ESF flow-though air volume will be capable of providing airflow for multiple work faces. The ventilation concept defined in *Ventilation Needs During Construction* (CRWMS M&O 1998a, Section 3) was described as two parts. One part defined local ventilation and the other, global ventilation (see Figure 22). Local ventilation provides ventilation from the Main Drift through to the working face. For example, the ventilation system between a TBM excavating an emplacement drift and the intersection of the emplacement drift and the main drift is a local system. The other ventilation system is termed "global ventilation," in which ventilation is provided in the Main Drifts. An example of the global ventilation system would be the system between the emplacement drift/main drift intersection and the surface. The working drift begins at the intersection of the main drift and the drift where excavation is taking place and contains the working face. The working face is where a mechanical excavator is extending the length of a drift. Excavation methods can be either mechanical (TBM) or conventional (drill and blast). Each local ventilation system will interact with the global system to provide proper working face conditions.

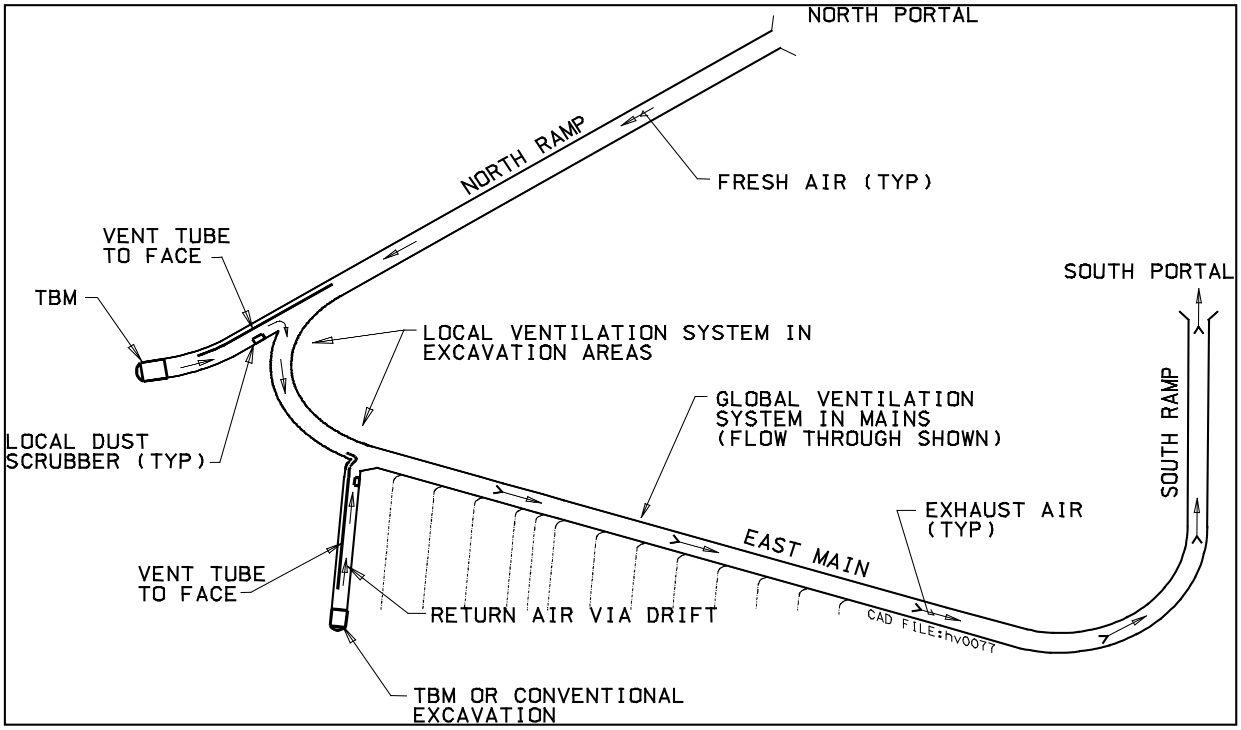



Figure 22. Examples of Local/Global Ventilation Concept

Shaft excavations during the early construction phase would be ventilated by a local ventilation system that would intake fresh air from the surface.

### 6.2.2 Construction/Emplacement Ventilation Phase

The number of drifts does not change the ventilation concept for concurrent construction/development effort with emplacement operations as presented in the *Overall Development and Emplacement Ventilation System* (CRWMS M&O 1997a, Section 7.8) and *Ventilation Needs During Construction* (CRWMS M&O 1998a, Section 7.1). The repository is developed in a series of "panels" isolated from the emplacement area by the isolation airlocks. The isolation barriers create two independent ventilation systems (see Section 4.2.2.1.4). Isolation barriers will exist at all emplacement/ development interfaces on both the emplacement and exhaust levels. When each panel of emplacement drifts is complete, the isolation barriers are relocated and that panel is released for emplacement. Subsequently, the next panel is developed. This sequence continues until all emplacement drifts in the repository are complete.

The construction/development ventilation air is supplied through a positive pressure system with the fan installed at the Development/Intake Shaft collar. The emplacement ventilation system operates in an exhaust mode with fans at the exhaust shaft collars. This combined system maintains a pressure differential across the isolation barriers ensuring that any leakage between the two systems is from the development side toward the emplacement side.

Once the Development Shaft is no longer required for development use, it is converted to emplacement side intake use during the forced ventilation period.

### 6.2.3 Emplacement Ventilation Phase

The basic ventilation concepts for the forced ventilation period are described in this section as documented in the *Overall Subsurface Ventilation System* (CRWMS M&O 2000h, Section 6.1). There are no major changes to the ventilation concepts described in this report.

Fresh air enters through an intake shaft, or the ramps, and is distributed to the East and/or West Mains. The intake shafts are connected to the East and West Mains by a shaft access drift. From the mains, air enters emplacement, postclosure test, or empty drifts and travels to centrally located exhaust raises. The exhaust raises carry the airflow to the Exhaust Main, where it is then carried to the surface through the exhaust shafts. The exhaust raise effectively divides each respective drift in half, hereafter referred to as a "split". Each split receives a design air volume. The Exhaust Main will be a single drift with a center divider wall that will isolate (BSC 2001a, p. IV-5) the warmer emplacement side air stream allowing unrestricted human access to controls and regulator valves satisfying the criterion listed in Section 4.2.2.1.2. Air entering an OD, cross-block drift, or empty emplacement drift (cooler air) is directed to the Service Side of the Exhaust Main, and air flowing through emplacement drifts containing WPs (warm air) is directed to the Exhaust Side of the Exhaust Main (BSC 2001a, p. IV-5). As an option, some or all of the cooler air contained in the Service Side can be redirected to the warm airflow stream in the Exhaust Side to cool that air stream. The exhaust shafts are connected to the Exhaust Main by shaft access drifts.

Two fans located on each exhaust shaft and operating in parallel provide the motivational force for the subsurface repository airflow. The fans are designed to have enough power to exhaust the maximum amount of air that will be required during the emplacement, monitoring, and closure phases, and include a contingency for abnormal events. The airflow volume produced by the fans is variable such that as the thermal requirements of the repository change with time, the air volume can also be adjusted (see Section 4.2.2.5.3). Air distribution within the repository is controlled by regulators located at each emplacement drift, OD, cross-block drift, standby drift, and at each exhaust raise (see Section 4.2.2.1.1). The exhaust shaft fan installations create a negative air pressure on the Exhaust Main level that is a greater negative air pressure than on the emplacement level. This pressure differential prevents recirculation from inside the emplacement drifts out to the main drifts (see Section 4.2.2.3.3).

If a major power outage were to result in all fans being off, the natural ventilation pressure (NVP) would maintain a small airflow out the exhaust shafts until backup power supplies can restore some limited fan capacity (see Section 6.2.5). A spare fan(s) would be kept available in storage for change out should the need arise. This would be more cost effective than a three-fan surface installation at each shaft. With multiple ventilation shafts, a single fan down being down for maintenance would not have a major impact on the overall repository air volume.

Activities in the emplacement drifts vary as does the demand for airflow. During emplacement, airflow is required to provide an acceptable environment for equipment operation. After the waste has been emplaced, an airflow of 15 $m^3/s$ removes heat that is generated by the WPs during preclosure (see Sections 4.1.2.2, 4.2.2.1.5, and 4.2.2.1.6). The emplacement drift airflow can be adjusted for retrieval, drip shield installation, backfill placement, or to react to operational upset events that may occur (see Sections 4.2.2.5.4 and 4.2.2.6.1). Determination of the timing of drip shield emplacement will depend on future studies and design analyses. The installation of regulators at the entrances and/or exits of the emplacement drifts provide the method to vary airflow volumes.

The current concept allows for an air lock (dual doors) to provide ventilation control at the emplacement drift entry. The doors provide a physical barrier against unauthorized entry into an emplacement drift (see Section 4.2.2.3.2).

Historically, a 47 $m^3/s$ supplemental airflow quantity has been included in the ventilation design to accommodate blast cooling (CRWMS M&O 2000h, Section 6.1.4) that was necessary to reduce the air temperature below 50° C for remote access (see Section 4.2.2.1.3). Since the maximum air temperature at the center of an emplacement drift peaks at 50° C during the preclosure period, the need for blast cooling is no longer a primary concern. As WPs would be retrieved during an abnormal event, the air temperature in the emplacement drifts would also decrease due to removal of the primary heat source. For those reasons, a blast cooling air volume is not included in this analysis.

### 6.2.4 Ventilation Monitoring Phase

There are no ventilation design concept changes to the Monitoring Phase brought on by the lower-temperature operating mode. The monitoring phase refers to activities during the forced ventilation period. The concepts documented in the *Overall Subsurface Ventilation System* (CRWMS M&O 2000h, Section 6.5) are valid and not duplicated herein. In summary of this concept, the Subsurface Ventilation Monitoring System is a component of the Repository Operations Monitoring and Control System. The ventilation-related monitoring requirements include pressure, humidity, temperature, flow rate, carbon monoxide, door status, fan status, and louver status for assorted locations including main intake, main exhaust drifts, and the working areas (see Sections 4.2.2.5.1 and 4.2.2.5.5). Select monitoring of radioactive and non-radioactive particulate is also required (see Section 4.2.2.5.6). The ventilation related monitoring components supply data into the Subsurface Monitoring and Control System. Some monitoring points relay data such as temperatures, humidity, status and airflow rates, while other monitoring points, such as emplacement drift louvers, isolation doors and main fans, include some supervisory control functions.

The monitoring instruments required would increase due to the additional emplacement drifts. The natural ventilation phase will require personnel access to the subsurface as necessary for maintenance and check/balance of airflow during the initial natural ventilation phase. Pending an operational strategy, the surface fans would likely remain in place during the natural ventilation monitoring phase. This would make it possible to provide adequate forced ventilation to support activities such as drift repair. The monitoring operations and costs would increase accordingly during the natural ventilation phase and continue as long as deemed necessary.

### 6.2.5 Natural Ventilation Phase

This section describes the NVP concepts incorporated in the proposed layout. The ventilation system must be capable of supporting any operational concept strategy required to support the longer life of a naturally ventilated repository. The primary change attributed to the NVP in this layout is the Exhaust Main is moved to above the emplacement horizon. The *Natural Ventilation Study: Demonstration of Concept* (CRWMS M&O 2000i) report provides additional information concerning natural ventilation as an alternative to forced ventilation.

#### 6.2.5.1 Characteristics of Natural Ventilation

Natural ventilation will commonly occur in underground mines. "Natural ventilation depends on the difference in elevation of the surface and mine workings and the difference in air temperature inside and outside the mine" (Hartman et al. 1997, p. 293). This is similar to airflow through a chimney where warm air rises and creates airflow from the inside to outside. Though there is a slight elevation difference between the intake and exhaust shafts, the WPs provide the thermal driving force to heat the air – an energy source that is lacking in underground mines.

Air density is inversely proportional to its temperature and therefore, warmer air is less dense than cooler air. As the air flows across the WPs, it is heated and expands (see Section 6.2.8.2), and therefore, less dense. This difference in densities creates a natural pressure difference between the intake side and exhaust side of the repository. The cooler, denser intake air will displace the warm exhaust air, thereby creating a natural airflow sufficient to overcome frictional and shock losses. Consequently, airflow is induced and maintained by the thermal energy added by the WPs.

Since the NVP is dependent, in part, on the temperature difference (density) between the intake and exhaust columns of air, it will fluctuate daily, or seasonally, depending upon surface air temperature variations. As long as the repository is warmer than the intake air temperature, the airflow will continue in the desired direction. During the forced ventilation period, the natural ventilation would assist the forced airflow and provide a reduction in power consumption. With the WPs continually generating heat, it is unlikely the natural ventilation airflow would stop or reverse its direction. On very hot days, the airflow may be reduced, but it would continue. Also, since the heat generated by the WPs decreases with time, the driving force for the natural ventilation will decrease over time.

#### 6.2.5.2 Exhaust Main Relocation

Moving the Exhaust Main above the repository horizon provides possible NVP benefits to the repository. Intuitively, moving the Exhaust Main above the emplacement drift provides increased stability by eliminating the downcast leg as the air exits the emplacement drift as in the Planning Layout (CRWMS M&O 2000h, Figure 2). Figure 23 shows a conceptual comparison between the planning layout and lower-temperature layout ventilation raise.

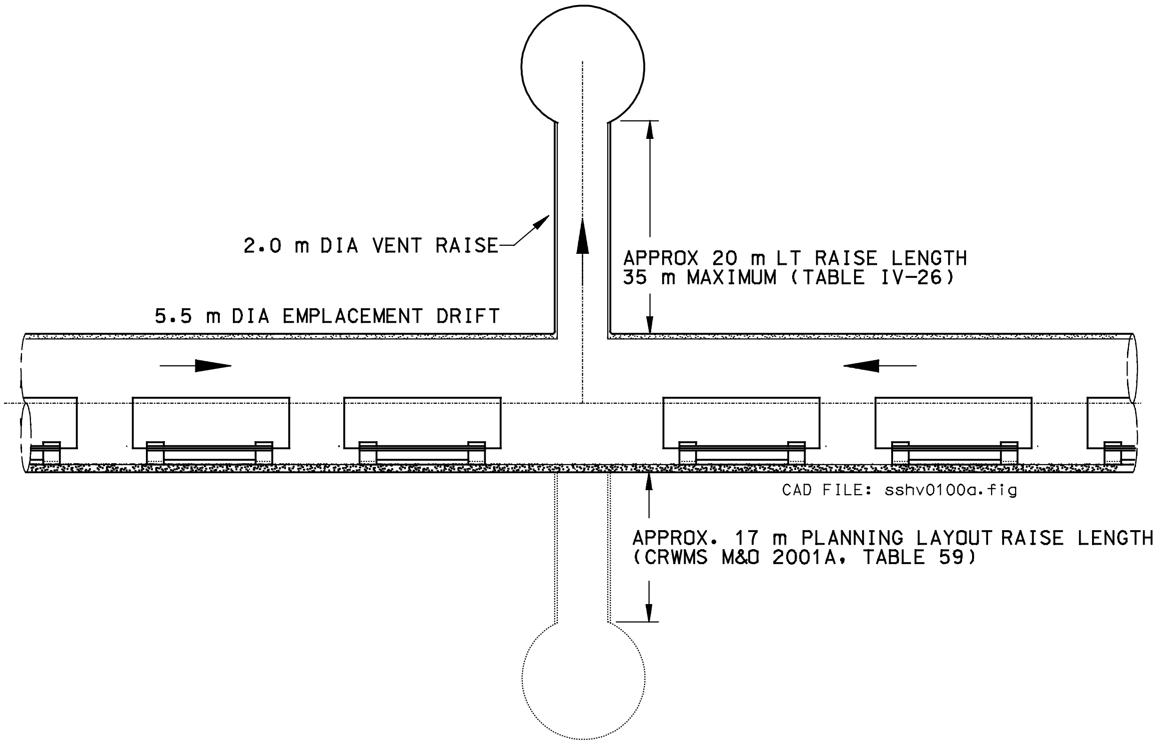



Figure 23. Comparison of Planning Layout and Lower-temperature Operating Mode Concept Ventilation Raises

By moving the Exhaust Main above the emplacement horizon the following marginal gains are realized within the airflow system:

- The Exhaust Shafts would be shorter thereby reducing the resistance of these components.
- The shortened exhaust column will cool less due to the adiabatic expansion as the air rises.

Though not a benefit to the airflow system, locating the Exhaust Main above the emplacement drifts provides an operational benefit by allowing a continuous emplacement track that permits easier WP retrieval. With the prior design, the ventilation raise prevented continuous rail and access for WP retrieval was limited to either end of the drift unless a temporary crossing was installed at the raise.

#### 6.2.5.3 Operations Concept

As air moves through the underground openings it will gain or lose heat to the rock. The naturally occurring thermal gradient of the rock will provide an intake air temperature of approximately 25°C (see Section 4.1.2.1) at the emplacement drift entry. As shown in Figure 24, during the forced ventilation period thermal energy will be transferred from the WPs to the exhaust airways and shafts via the warmed air. The WPs also heat the emplacement drift wall rock to a temperature above the naturally occurring thermal gradient. This heated rock on the exhaust side of the ventilation system will help establish and maintain the direction of the natural ventilation air movement. No analysis has been done to quantify the heat transfer to the exhaust airways and shafts.

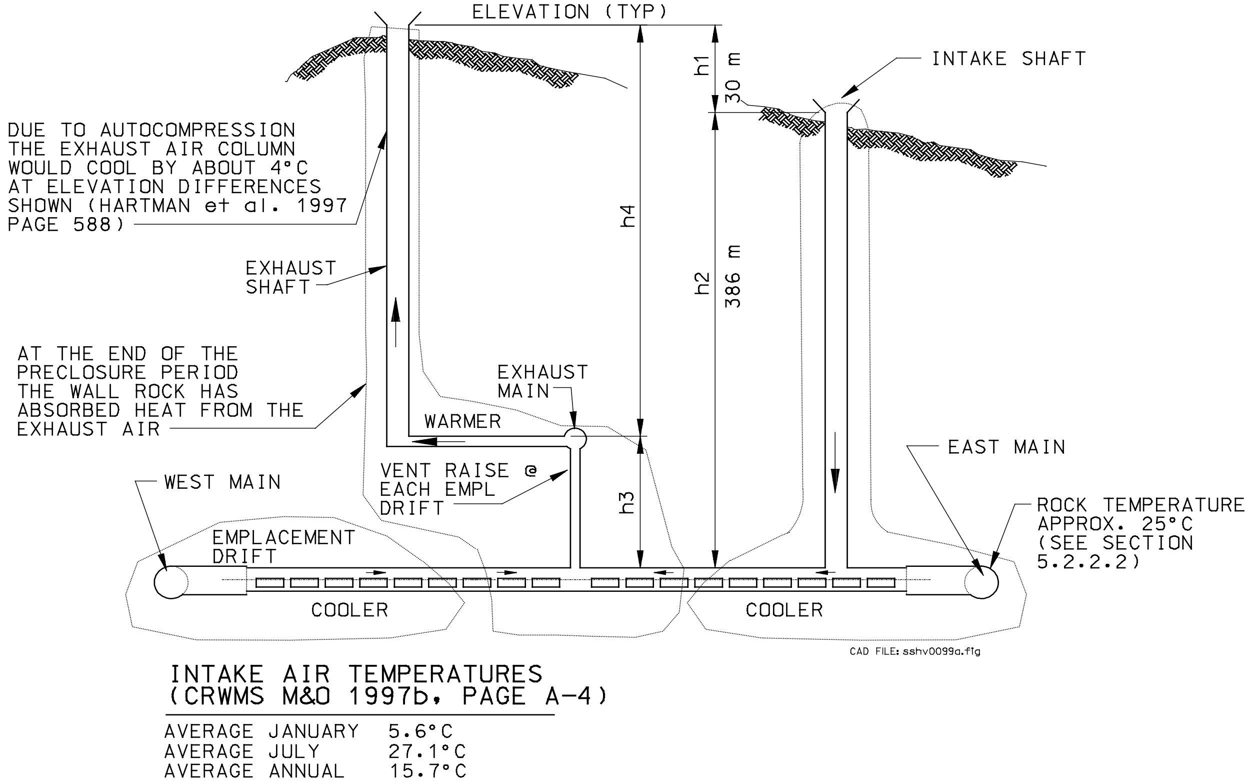



Figure 24. Conceptual Diagram of Heat Transfer During Forced Ventilation

At the end of the forced ventilation period, the main fans would be turned off and the repository would be allowed to naturally ventilate for approximately 250 years (see Section 6.1). The natural ventilation airflow distribution in the repository would be similar to the forced ventilation airflow distribution in which the intake/exhaust shaft pairs provide airflow to a general area (Attachment VIII). A 25-year active subsurface monitoring period would be anticipated during the initial phase of the natural ventilation (see Section 5.2.2.3). During this period, the monitoring and performance activities would verify the natural ventilation system and additional regulators could be installed in the main or emplacement drifts to further isolate and balance the airflow. Since the observation and cross-block drifts do not contain a heat source to generate natural airflow, these areas would need to be isolated or supplied with localized ventilation systems to allow personnel access.

If a decision were made to restrict subsurface access after the initial natural ventilation monitoring phase, periodic maintenance of the subsurface facilities would discontinue. Airflow regulation devices would no longer be maintained. Since the subsurface instruments would degrade without maintenance, the instruments would become unreliable and the remote subsurface monitoring would cease. At that time, limited surface monitoring would be possible from the intake and exhaust shafts. The main fans could be salvaged at this time.

### 6.2.6 Closure Ventilation Phase

There are no ventilation concept changes to the Closure Phase brought on by the lower-temperature operating mode. The concepts documented in the *Overall Subsurface Ventilation System* (CRWMS M&O 2000h, Section 6.3.4) are valid. As discussed in Section 6.2.3, the ventilation system components can be adjusted to accommodate ventilation requirements during drip shield placement. The ventilation system interacts with the Backfill Emplacement System to ensure backfill is placed in a manner to control contaminants and afford strategic withdrawal from the repository (see Section 4.2.2.5.4). Future generations would determine how the main drifts would be backfilled at the end of the natural ventilation phase and if fans need to be reinstalled on the shafts to support backfilling operations. The main fan installations with variable speed drives would be capable of providing a reduced, controlled airflow both during and after backfill placement in the main drifts. Temporary, localized ventilation systems could be established as necessary to support the backfilling operations in the shafts and ramps.

### 6.2.7 Contaminants

There are no ventilation concept changes to the dust and radon control concepts described in the *Overall Subsurface Ventilation System* (CRWMS M&O 2000h, Section 6.4).

#### 6.2.7.1 Dust

The dust control strategy will follow the concepts and guidelines documented in the *Overall Subsurface Ventilation System* (CRWMS M&O 2000h, Sections 6.3.4.1 and 6.4.1) and the *Overall Development and Emplacement Ventilation System Report* (CRWMS M&O 1997a, Section 7.5). Repository changes brought on by the lower-temperature operating mode concept do not require changes to the comprehensive dust program established in the VA Design. Though additional drifts and shafts may be developed, the dust control process for individual activities is unchanged (see Section 4.3.2).

The ventilation system could be capable of providing a reduced, controlled airflow both during and after backfill emplacement. The localized airflow during backfill placement will carry dust away from stowing equipment and personnel working in the main drifts. The contaminated air can be filtered with equipment to prevent downstream contamination.

#### 6.2.7.2 Radon

Radon gas is liberated in proportion to the exposed area of rock (McPherson 1993, Section 13.4.1, p. 470) and can be controlled to acceptable limits by dilution (Hartman et al. 1997, Section 3.5, p. 55; and McPherson 1993, Section 13.6.1, p. 478). The radon control strategy will follow the concepts documented in the *Overall Subsurface Ventilation System* (CRWMS M&O 2000h, Section 6.4.2). Since radon gas is liberated in relation to the exposed rock area, the shortest airflow path will contain the minimum rock surface area and the air traversing this shortest path will contain the lowest possible radon working level concentration. Keeping the air residence time to a minimum is made possible by designing airway paths to be as short as possible. In the airflow allocation process (Attachment VIII), airflow are typically distributed from the closest intake shaft to the closest exhaust shaft, thereby keeping air travel paths to a minimum. A development heading can be designed to control the theoretical length that will maintain radon exposures within applicable design requirements (see Section 4.3.2). The increased number of drifts in the repository (exposed rock) will result in an overall increase of the radon that is released, however, designing the airflow paths within the repository to be as short as possible will provide the best dilution.

The *Subsurface Radon Calculations* document (CRWMS M&O 2000j, Section 6.1, Table 5) indicates the working level concentrations for potentially occupied areas are below the applicable ANSI requirements (see Section 4.3.2). The *Subsurface Radon Calculations* document looked at radon concentrations and working levels for a representative layout ventilation network during the monitoring phase of the repository (CRWMS M&O 2000j, Section 1).

Though no work has been done to analyze the radon at the natural ventilation airflow, a previous radon calculation indicated the radon flux rate decreases with a reduction in the negative pressure in the system (CRWMS M&O 2000k, Section 6.1). That is to say, during the forced ventilation period, the main fans exert a higher negative pressure in the repository than would be present during the natural ventilation period when the airflow is generated by the air density differences. During the natural ventilation period when airflow volumes are lower, the radon flux would also be lower. The lower airflow volumes will decrease the air speed, thereby increasing the airflow residence time in the mountain. This will allow for increased production of radon daughters. The effect of the reduction in radon flux (pressure reduction) combined with the increase due to retention time remains to be fully analyzed.

Though the current emplacement ventilation concept utilizes a negative pressure ventilation system with main fans located on the exhaust shafts, the ventilation system could be designed as a positive pressure system if required for radon control. In a positive pressure ventilation system, the main fans would be located at the intake shafts and ramps. The ramps would use intake fans to maintain fresh air in the primary escape routes. During the Construction/Emplacement Ventilation phase development side main fans would be operated at a higher pressure than the emplacement side fans to maintain the pressure differential across the isolation barriers.

### 6.2.8 Repository Ventilation Design Methodology

This section provides detail as to how the repository air volume requirements, ventilation shaft requirements, and system horsepower are determined. This process, documented in the *Overall Subsurface Ventilation System* (CRWMS M&O 2000h, Section 6.2), is valid for this analysis.

#### 6.2.8.1 Repository Air Volume Requirements

The air volume of each repository component is determined by multiplying the number of drifts times the airflow split of the component, times two (two splits per drift), or

$$\text{(air volume)} \times \text{(drift quantity)} \times (2) = \text{m}^3\text{/s per component} \qquad \text{(Equation 1)}$$

The total repository design air volume is the sum of the emplacement, postclosure test, observation, cross-block and standby drift components (see Section 4.1.2.2). The repository air volume is used to provide a basis for cost estimates external to this analysis and is not intended for construction or procurement use. During final design, a contingency may be added to provide additional system flexibility. The fans will be sized accordingly. The methodology used to determine the overall air volume is valid for repository layouts that may contain different quantities of emplacement, postclosure test, or empty drifts.

#### 6.2.8.2 Thermal Expansion of the Airflow

The design intake airflow rate for an emplacement, postclosure test, or standby drift is 15 $m^3/s$ (see Section 4.1.2.2), or an instantaneous volume of 15 $m^3$. These drifts may contain WPs and as the 15 $m^3$ air volume flows across the WPs it is heated and expands. For the purposes of this analysis, the air volume of 15 $m^3$ is expanded thermally for the airflow allocation process (see Attachment VII). Charles' Law applies to a constant pressure system and is used to calculate the thermal expansion of the 15 $m^3$ air volume as it traverses a drift. Though Charles' Law applies to an ideal gas, it is sufficiently accurate for normal air in routine air conditioning calculations (Hartman et al. 1997, p. 22). This application is intended to provide an order of magnitude air volume for the allocation process and not perform a thermal analysis, or a mass and momentum balance of airflow. That is beyond the scope of this document.

The ventilation system is designed to deliver a mass of air to the emplacement drift at a density consistent with the conditions at the entrance of the emplacement drift. It is designed to remove the same mass of air from the emplacement drift at a density consistent with the conditions at the exit of the emplacement drift. Neglecting the change in air pressure caused by resistance losses in the drift, the change in volume of the mass of air is proportional to the ratio of the temperature of the intake and exhaust air (Charles' Law). Charles' Law states $v1/v2=T1/T2$ at a constant pressure, where temperatures are absolute ($T = t\ (^\circ C) + 273.15$) (Hartman et al. 1997, p. 22), or

$$v2 = (v1/T1) \times T2 \qquad \text{(Equation 2)}$$

where

$v1$ = initial volume ($m^3$)
$v2$ = final volume ($m^3$)
T1 = initial temperature (absolute)
T2 = final temperature (absolute)

Using the 15 $m^3$ emplacement air volume, an inlet temperature of 25°C (298 K) (see Section 4.1.2.1), an outlet temperature of 50°C (323 K) (see Section 4.1.2.1), and applying Equation 2 to calculate an expanded air volume of 16.26 $m^3$ is estimated as follows:

$$v2 = [(15\ m^3) \div (298)] \times 323$$
$$v2 = 16.26\ m^3$$

The 16.26 $m^3$ expanded air volume is an airflow rate of 16.26 $m^3/s$ for the allocation process. Though not all the WPs reach the maximum temperature at the same time, a conservative estimate is obtained by applying the expanded air volume to all drifts containing WPs. Note:

The 50°C outlet temperature is based on an inlet temperature of 25°C that is derived from an assumption (CRWMS M&O 2000l, Section 3.2). The design inlet air temperature needs to be confirmed by thermal management analysis in the future.

#### 6.2.8.3 Ventilation Shaft Requirements

The number of intake shafts is estimated by reducing the total repository intake volume by the North Ramp and South Ramp airflow volumes (217.02 + 289.36 $m^3/s$ respectively, 506.38 $m^3/s$ total) and then dividing by the intake shaft design airflow volume of 578.72 $m^3/s$ (see Section 4.1.2.4). The difference between the allocated airflow volume and the maximum airflow volume is considered extra capacity. Attachment VIII documents the airflow allocations for the intake shafts.

Once the Development Shaft is no longer required for development use, it is considered available for use as an intake shaft (see Section 6.2.2). Airflow distribution from the Development/Intake Shaft is taken into account during the airflow allocation process (Attachment VIII).

By inspection of Figure 3, the intake and exhaust shafts are separated by a minimum distance of 100-m (see Section 4.2.2.3.1).

Airflow volumes are allocated to each exhaust shaft and the Exhaust Main to support the exhaust airflow from specific headings within the facility (see Section 6.2.12). The airflow allocation tables in Attachment VIII document how the number of exhaust shafts is determined. The exhaust shaft allocations consider a maximum airflow volume of 733.51 $m^3/s$ (see Section 4.1.2.4).

#### 6.2.8.4 System Horsepower Requirements

The ventilation system horsepower estimate is provided for use external to this analysis. Using Equation 3, the air horsepower is calculated using the total exhaust air volume (cfm) at a total pressure of 10 inches wg. (see Section 5.2.2.2), and 75 percent efficiency (see Section 5.2.2.1) horsepower as follows:

$$Pa = HQ/6346 \text{ hp} \quad \text{(Hartman et al. 1997, p. 165)} \qquad \text{(Equation 3)}$$

where

Pa = air horsepower
H = total pressure (in wg)
Q = air quantity (cfm)
1 $m^3/s$ = 2,119 cfm (Section 4.1.2.5)
1 hp = 0.7457 kW (Section 4.1.2.5)

### 6.2.9 Ventilation Requirements for the Repository Layout

Applying the methodology described in Section 6.2.8 the ventilation requirements for the repository layout are documented in the following subsections.

#### 6.2.9.1 Repository Layout Air Volume Estimate

Table 27 details the air volume requirements for the repository layout.

Table 27. Repository Layout Airflow Quantity

| Component | Number of Drifts (Section 6.1.2.1) | Intake Air Volume | | Exhaust Air Volume | |
|---|---|---|---|---|---|
| | | Design Airflow ($m^3/s$) | Total Airflow[c] ($m^3/s$) | Design Airflow ($m^3/s$) | Total Airflow[c] ($m^3/s$) |
| Emplacement Drift | 143 | 15 [a] | 4,290 | 16.26 [b] | 4,650 |
| Standby Drift | 4 | 15 [a] | 120 | 16.26 [b] | 130 |
| Cross-block Drift | 6 | 19.63 [a] | 236 | 19.63 [a] | 236 |
| OD | 6 | 19.63 [a] | 236 | 19.63 [a] | 236 |
| PCTD | 1 | 15 [a] | 30 | 16.26 [b] | 33 |
| Total Volume | | | 4,912 | | 5,285 |

Notes: [a] see Section 4.1.2.2
[b] see Section 6.2.8.2
[c] see Equation 1

#### 6.2.9.2 Ventilation Shaft Requirements

Using the total air volumes from Table 27 above, and the intake shaft design air volume from Section 4.1.2.4, there are eight intake shafts estimated, not including the Development/Intake Shaft:

Intake Shafts = (4,912 – 506.38m³/s)/(578.72 m³/s per shaft)
= 7.6 intake shafts required (rounded to 8)

As documented in Attachment VIII, there are nine exhaust shafts required to support the airflow.

#### 6.2.9.3 System Horsepower Estimate

Using Equation 3 and a volume of 5,285 m³/s (11,198,915 cfm), a system horsepower of 23,529 hp is calculated as follows:

Pa = [(10 in wg.)(5,285 m³/s)(2,119 m³/s per cfm)]÷6,346
Pa = 17,647 hp
At 75 percent efficiency, hp = 23,529 hp (17,546 kW)

### 6.2.10 Ventilation Requirements for the 70,000 MTHM Case

Applying the methodology described in Section 6.2.8, the ventilation requirements for the 70,000 MTHM Case are documented in the following subsections.

#### 6.2.10.1 Air Volume Estimate

Table 28 details the air volume requirements for the 70,000 MTHM repository layout.

Table 28. 70,000 MTHM Case Airflow Quantity

| Component | Number of Drifts (Section 6.1.3) | Intake Air Volume | | Exhaust Air Volume | |
|---|---|---|---|---|---|
| | | Design Airflow ($m^3/s$) | Total Airflow [c] ($m^3/s$) | Design Airflow ($m^3/s$) | Total Airflow [c] ($m^3/s$) |
| Emplacement Drift | 85 | 15 [a] | 2,550 | 16.26 [b] | 2,764 |
| Standby Drift | 2 | 15 [a] | 60 | 16.26 [b] | 65 |
| Cross-block Drift | 4 | 19.63 [a] | 157 | 19.63 [a] | 157 |
| OD | 4 | 19.63 [a] | 157 | 19.63 [a] | 157 |
| PCTD | 1 | 15 [a] | 30 | 16.26 [b] | 33 |
| Total Volume | | | 2,954 | | 3,176 |

Notes: [a] see Section 4.1.2.2
[b] see Section 6.2.8.2
[c] see Equation 1

#### 6.2.10.2 Ventilation Shaft Requirements

Using the total air volumes from Table 28, and the intake shaft design air volume from Section 4.1.2.4, there are four intake shafts estimated, not including the Development/Intake Shaft:

Intake Shafts = (2,954 – 506.38 $m^3/s$)/(578.72 $m^3/s$ per shaft)
= 4.2 intake shafts required

As documented in Attachment VIII, there are six exhaust shafts required to support the airflow allocated for the 70,000 MTHM layout.

#### 6.2.10.3 System Horsepower Estimate

Using Equation 3 and a volume of 3,176 $m^3/s$ (6,729,944 cfm), a system horsepower of 14,140 hp is calculated as follows:

Pa = [(10 in wg.)(3,176 $m^3/s$)(2,119 $m^3/s$ per cfm)]÷6,346
Pa = 10,605 hp
At 75 percent efficiency, hp = 14,140 hp (10,544 kW)

### 6.2.11 Ventilation Requirements for the 97,000 MTHM Case

Applying the methodology described in Section 6.2.8 the ventilation requirements for the 97,000 MTHM Case are documented in the following subsections.

#### 6.2.11.1 Air Volume Estimate

Table 29 details the air volume requirements for the 97,000 MTHM repository layout.

Table 29. 97,000 MTHM Case Airflow Quantity

| Component | Number of Drifts (Section 6.1.4) | Intake Air Volume | | Exhaust Air Volume | |
|---|---|---|---|---|---|
| | | Design Airflow ($m^3/s$) | Total Airflow[c] ($m^3/s$) | Design Airflow ($m^3/s$) | Total Airflow[c] ($m^3/s$) |
| Emplacement Drift | 110 | 15[a] | 3,300 | 16.26[b] | 3,577 |
| Standby Drift | 3 | 15[a] | 90 | 16.26[b] | 98 |
| Cross-block Drift | 5 | 19.63[a] | 196 | 19.63[a] | 196 |
| OD | 5 | 19.63[a] | 196 | 19.63[a] | 196 |
| PCTD | 1 | 15[a] | 30 | 16.26[b] | 33 |
| Total Volume | | | 3,812 | | 4,100 |

Notes: [a] see Section 4.1.2.2
[b] see Section 6.2.8.2
[c] see Equation 1

#### 6.2.11.2 Ventilation Shaft Requirements

Using the total air volumes from Table 29, and the intake shaft design air volume from Section 4.1.2.4, there are six intake shafts estimated, not including the Development/Intake Shaft:

Intake Shafts = (3,812 – 506.38 $m^3/s$)/(578.72 $m^3/s$ per shaft)
= 5.7 intake shafts required (rounded to 6)

As documented in Attachment VIII, there are eight exhaust shafts required to support the airflow allocated for the 97,000 MTHM layout.

#### 6.2.11.3 System Horsepower Estimate

Using Equation 3 and a volume of 4,100 $m^3/s$ (8,687,900 cfm), a system horsepower of 18,253 hp is calculated as follows:

Pa = [(10 in wg.)(4,100 $m^3/s$)(2,119 $m^3/s$ per cfm)]÷6,346
Pa = 13,690 hp
at 75 percent efficiency, hp = 18,253 hp (13,612 kW)

### 6.2.12 Airflow Allocation Process

The airflow allocation process documented in the *Site Recommendation Subsurface Layout* (BSC 2001a, Attachment IV) is valid for this report and is not duplicated herein. In summary, the allocation process involves distributing the ramp and shaft airflow volumes to specific headings within the subsurface facility without violating the airflow opening limitations listed in Section 4.1.2.4. These allocations are used for planning purposes only.

Airflow allocation tables and figures for the repository layout is contained in Attachment VIII. Airflow allocations for the 70,000 MTHM, 97,000 MTHM, or other inventory layout cases would be similar.

### 6.2.13 Long Term Ventilation Operating Strategies

The repository's operating strategy variations affect the ventilation system. Flexibility can be maintained in ventilation system components, such as main fans and air doors. They can be maintained in operable condition by maintenance, refurbishment, and replacement for the life of the facility (see Sections 4.2.2.1.7 and 4.2.2.1.8). Main fans, air doors, and related components could be modular in design and replaceable. The ability to regulate the airflow volume at each emplacement drift and the ability to vary the total volumes at the surface fans can make it possible to meet changing conditions or design requirements.

During the initial natural ventilation phase the main fans could be shut down but maintained in a standby mode. Future forced ventilation may not need high volume capacity fans. Small capacity fan(s) could be installed for standby use.

If repository access is required for monitoring, regulating controls, retrieval, or ground support maintenance, one or more of the main fans could be operated. For abnormal events, localized ventilation could be established for use in lieu of operating surface fans.

At closure of the subsurface facilities, it may be necessary to operate some of the surface fans while placing drip shields or while placing, fill material in the mains, ramps, etc.

### 6.2.14 Parametric Sensitivities

The ventilation system has the ability to respond to various operational parameters without altering the basic airflow concepts. Any changes to the ventilation operating parameters could mostly impact the ventilation system horsepower requirements.

The 70,000 MTHM and 97,000 MTHM Case Studies both utilize a 1.0 kW/m line load (Sections 6.1.3.1 and 6.1.4.1 respectively). This is below the maximum design value of 1.5 kW/m line load (see Section 4.2.2.4.1). Any increase in the spacing between WPs would reduce this line load. A WP spacing as close as 0.1 m (BSC 2001a, Section 6.2.3.2) also satisfied the 1.5 kW/m heat load requirement.

#### 6.2.14.1 Operating Sensitivities

The ventilation system has the flexibility to respond to various layout parameters without altering the basic airflow concepts. A variation in the emplacement drift spacing would not change the airflow patterns, only the airflow system resistance. The airflow resistance for a segment of tunnel is a based on its length (Hartman et al. 1997, p.152), therefore, wider drift spacing would result in a corresponding increase in the system's resistance and fan horsepower requirements. Similarly, narrower drift spacing would reduce the airflow network's resistance and fan horsepower requirements.

#### 6.2.14.2 Design Sensitivities

The airflow louvers, regulators and variable speed main fans can provide ventilation system flexibility in response to temperature control scenarios that may include variations to the linear heat loading, WP spacing, or smaller WPs.

The described scenarios in Section 6.1 may require extended periods of forced ventilation. These long periods of operation may be possible through a maintenance, repair and refurbishment program. Major ventilation systems can be operated for up to 300 years (see Section 4.2.2.1.8).

The natural ventilation is driven primarily by WPs adding heat to the airflow system as detailed in Section 6.2.5.1. Variations due to smaller WPs, increased WP spacing, or any method that reduces the linear thermal output would impact the natural ventilation airflow.

Previous work demonstrated that varying the emplacement drift airflow would provide a range of thermal responses. For example, *ANSYS Calculations in Support of Natural Ventilation Parametric Study for SR* (CRWMS M&O 2000l, Section 6) documented the thermal effects of variations in the forced ventilation periods, linear heat loads, natural ventilation airflow rates, and drift spacing. The *ANSYS Thermal Calculations in Support of Waste Quantity, Mix and Throughput Study* documented the thermal effects at varying linear heat loads (1.2, 1.4, 1.6, 1.8, and 2.0 kW/m) and varying airflow rates (10 and 15 $m^3/s$) (CRWMS M&O 1999g, Section 6.0, Table 6-1).

The number of emplacement drifts is a primary driver for the ventilation system capacity (see Sections 4.2.2.5.3 and 6.2.8.1). The total emplacement drift excavation varies dependant upon WP spacing and the number of WPs. Since the ventilation system's capacity is based on an airflow rate per drift, any increase in the number of emplacement drifts will also increase the total airflow volume and related operating costs.

Surface aging of the waste would reduce the heat that would be removed by the ventilation system and possibly reduce the forced ventilation period. However, this may also extend the emplacement period. An increase in the emplacement period would require the main fans be operated for that same extension of time.

# 7. CONCLUSIONS

Since the subsurface layout is essential to the development of the ventilation system, and vice versa, this analysis combines the subsurface conceptual layout and subsurface ventilation system concepts. This indicates that the repository footprint and emplacement drift allocations are required to establish the overall subsurface ventilation system requirements. Those requirements in turn, feed back into the subsurface layout for locating the ancillary openings that support the ventilation system.

## 7.1 OVERALL SUBSURFACE LAYOUT ANALYSIS

The Planning Layout and the Lower Block Expansion Layout (see Figure 1 and Figure 2) were evaluated for use as the basis for developing the subsurface layouts. Sufficient capacity exists within these configured areas to support the representative lower-temperature operating mode layouts and allows sufficient flexibility for performing various parametric studies. The current layout configuration (see Figure 3) can accommodate emplacement scenarios requiring up to 148 kilometers (see Attachment I, Table I-1). This layout configuration is contained in the output file *Electronic Files in Support of ANL-WER-MD-000002, Revision 00* (BSC 2001aa). There is a maximum drift and WP spacing combination for any given waste inventory that can be accommodated within the current layout configuration (see Section 6.1.5.2).

A representative scenario was defined in Section 6.1. This representative lower-temperature operating mode achieves lower temperatures by using the following operational features:

- Spacing the reference WPs approximately 2.0 meters apart to create a 1 kW/m average thermal load in each drift at emplacement, and
- Ventilating the emplacement drifts actively for 50 years after the last emplacement and then naturally for an additional 250 years.

The repository layout shown in Figure 3 was used for specifying specific layouts for the 70,000 MTHM and 97,000 MTHM waste inventories. This repository layout demonstrates the layout configuration flexibility.

Design considerations in the emplacement drift turnouts have been incorporated to address radiological exposure in the mains (see Section 6.1.2.7).

The layout is influenced by practical limitations imposed by the operating requirements and performance characteristics of the equipment and by methods of repository construction. The size, configuration, and operating requirements of the subsurface construction equipment were considered in restricting the size and shape of the excavated openings and the general arrangements possible for the layout (see Section 6.1.2.9).

The layouts for both the 70,000 MTHM and 97,000 MTHM waste inventories are located within the available site volume as defined by current geologic information (see Section 6.1.2.2). If the available site volume were to be changed, impacts to the layouts would be redefined and modification to the layouts would be done to accommodate the changes.

The North Ramp provides access to the emplacement side of the subsurface repository, and the South Ramp provides access for the development side. The ESF Main Drift becomes the East Main. All other subsurface repository openings will be developed from these existing ESF openings.

The layouts facilitate preclosure and postclosure water drainage away from the emplacement drifts. Access mains and other subsurface openings are sloped away from the emplacement area to central drainage areas located at the north and south ends of the repository (see Section 6.1.2.5). The emplacement drifts themselves have been designed with flat gradients to allow any water entering the emplacement drifts to drain directly into the surrounding rock without traveling along the drift inverts. The emplacement drift - turnout step-up prevents water from flowing into the emplacement drifts.

The repository layout supports a range of thermal operating modes. These variations of both operational and design features can be made to allow the potential repository to operate with similar thermal conditions. This same flexibility to choose a lower-temperature operating mode could also be applied to other operating modes (see Section 6.1.5).

This document must be considered in conjunction with a thermal management analysis of the lower-temperature operating concept to determine the viability of any specific combination of operating parameters.

#### 7.1.1 70,000 MTHM Layout Case Study

The repository is required to be capable of emplacing 70,000 MTHM waste. The 70,000 MTHM Layout is shown capable of accommodating this waste inventory (see Section 6.1.3.1). The 70,000 MTHM Layout (see Figure 11) will require 85 emplacement drifts.

The emplacement length required to accommodate WPs for the 70,000 MTHM Layout is approximately 81 kilometers and the area is approximately 1,630 acres giving an AML of approximately 40 MTHM/acre (see Section 6.1.3.1).

Along with the emplacement drifts, six standby and cross-block drifts will be excavated. The two standby drifts will be located within the first half of the emplacement drifts to be available for early relocation of WPs. The four cross-block drifts serve for ventilation, monitoring, emergency egress, and/or Test and Evaluation program functions.

The Test and Evaluation Facility for the 70,000 MTHM layout consists of a single PCTD on the north end of the repository with an OD, and performance monitoring ODs 2, 3, and 4 in the remainder.

The Subsurface Ventilation System was analyzed in parallel with the layouts to determine the number of openings and respective sizes required to support the continuous ventilation rate of

15 $m^3/s$ (see Section 6.2). In addition to the North and South Ramps, four intake shafts are required to supply the needed ventilation flow rates to the Subsurface Facility. The Development Shaft, located near the South Main, provides intake airflow for the construction and development operations in the Subsurface Facility. This shaft will be converted to an intake shaft for emplacement operations. Six exhaust shafts are required to exhaust air from the Subsurface Facility for the 70,000 MTHM case.

### 7.1.2 97,000 MTHM Layout

The repository is also required to design for a WP inventory of 97,000 MTHM of SNF/HLW, if authorized, for disposal in the repository (see Section 6.1.4.1). The 97,000 MTHM Layout will occupy all of the primary block emplacement area and a portion of the lower block emplacement area (see Figure 12).

Approximately 107 kilometers emplacement drift length accommodates the 97,000 MTHM waste inventory. This emplacement length uses approximately 2,150 acres giving an AML of approximately 40 MTHM/acre (see Section 6.1.4.1).

Within the emplacement areas, eight standby and cross-block drifts will be excavated between emplacement drifts (see Section 6.1.4). Three standby drifts and five cross-block drifts are located in the primary block and the lower block.

The Test and Evaluation Facility for the 97,000 MTHM layout will consist of single PCTD on the north end of the repository with an OD, and the performance monitoring ODs 2, 3, 4, and 5.

The Subsurface Ventilation System was analyzed to parallel the layout and to determine the number of openings and respective sizes required to support the continuous ventilation rate of 15 $m^3/s$ (see Section 6.2). In addition to the North and South Ramps, six intake shafts are required to supply the needed ventilation flow rates to the Subsurface Facility for the 97,000 MTHM case (see Section 6.1.4). The Development/Intake Shaft, located near the South Main, provides intake airflow for the construction and development operations in the Subsurface Facility and will be required as an intake shaft after construction and development is complete. Eight exhaust shafts are required to exhaust air from the Subsurface Facility for the 97,000 MTHM case.

### 7.1.3 Criterion Compliance

Various design criteria were used in the process of completing the layout portion of this analysis. Other criteria, which have been discussed in the analysis, may not have been fully addressed. A list of the criteria discussed in this analysis is presented in Table 30 with indications of where the discussion is located as well as whether the criteria were fully met.

Table 30. Subsurface Facility Criteria Compliance

| Criterion | Description | Criterion Documentation in Section | Criterion Discussion Located in Section | Adherence to Criteria |
|---|---|---|---|---|
| CRWMS M&O 2000d, Section 1.2.1.1 | Waste Inventory Requirement | 4.2.1.1.1 | 6.1.3 | The waste inventories outlined in this criterion need to be updated. |
| CRWMS M&O 2000d, Section 1.2.1.2 | WP Quantities and Lengths | 4.2.1.1.2 | 6.1.4 | The waste inventories outlined in this criterion need to be updated. |
| CRWMS M&O 2000d, Section 1.2.1.3 | Emplacement Drift Diameter | 4.2.1.1.3 | 6.1.2.1.2 | Criterion has been met. |
| CRWMS M&O 2000d, Section 1.2.1.4 | WP Spacing | 4.2.1.1.4 | 6.1.3 and 6.1.4 | Criterion has been met. |
| CRWMS M&O 2000d, Section 1.2.1.5 | Emplacement Drift Spacing | 4.2.1.1.5 | 6.1.2.1.2 | Criterion has been met. |
| CRWMS M&O 2000d, Section 1.2.1.6 | Limit Water Inflow in Ramps | 4.2.1.1.6 | 6.1.2.5 | Criterion has been met. |
| CRWMS M&O 2000d, Section 1.2.1.7 | Orientation of Emplacement Drifts | 4.2.1.1.7 | 6.1.2.1.2 | Criterion has been met. |
| CRWMS M&O 2000d, Section 1.2.1.8 | Test and Evaluation Program | 4.2.1.1.8 | 6.1.2.1.3 | Criterion has been met for major facilities. Details of minor facilities have not yet been included in the layout. Criterion needs to be modified to reflect the requirement for a single PCTD. |
| CRWMS M&O 2000d, Section 1.2.1.9 | Capability of Accommodating 115,000 MTHM Inventory | 4.2.1.1.9 | 6.1.5 | This requirement must be update to reflect the increased maximum waste inventory. |
| CRWMS M&O 2000d, Section 1.2.2.1.1 | Unrestricted Access Radiation Level Limit | 4.2.1.2.1 | 6.1.2.7 | This criterion has not been evaluated at this time, however it is not anticipated that this calculation will adversely impact the design of the Subsurface Facility. |
| CRWMS M&O 2000d, Section 1.2.2.1.2 | Restricted Access Radiation Level Limit | 4.2.1.2.2 | 6.1.2.7 | This criterion has not been evaluated at this time. It is not anticipated that this calculation will adversely impact the design of the Subsurface Facility. It will be revisited when full operational aspects of the repository are available. |
| CRWMS M&O 2000d, Section 1.2.2.1.3 | Locating surface Openings | 4.2.1.2.3 | 6.1.2.4 | Criterion has been met. |
| CRWMS M&O 2000d, Section 1.2.2.1.4 | Minimum Geologic Standoffs to Repository Openings | 4.2.1.2.4 | 6.1.2.2 | Criterion has been met. |

Table 30. Subsurface Facility Criteria Compliance (continued)

| Criterion | Description | Criterion Documentation in Section | Criterion Discussion Located in Section | Adherence to Criteria |
|---|---|---|---|---|
| CRWMS M&O 2000d, Section 1.2.2.1.5 | Geologic Standoff Distances for WPs | 4.2.1.2.5 | 6.1.2.2 | Criterion has been met. |
| CRWMS M&O 2000d, Section 1.2.2.1.6 | Standoff Distance to Surface Drilled Boreholes | 4.2.1.2.6 | 6.1.2.6 and Attachment V | This criterion has not been evaluated at this time because it requires knowledge of specific borehole locations. Potential impacts associated with applying this criterion have been discussed and contingency emplacement space provided. |
| CRWMS M&O 2000d, Section 1.2.2.1.7 | Overall Water Drainage | 4.2.1.2.7 | 6.1.2.5 | Criterion has been met. |
| CRWMS M&O 2000d, Section 1.2.2.1.8 | Characterized block | 4.2.1.2.8 | 6.1.2.2 | Criterion has been met. |
| CRWMS M&O 2000d, Section 1.2.2.1.9 | Overlying Ground Surface Limit | 4.2.1.2.9 | 6.1.2.2 | Criterion has been met. |
| CRWMS M&O 2000d, Section 1.2.2.2.1 | Escapeways | 4.2.1.3.1 | 6.1.2.8 | This criterion has not been evaluated at this time, however it is not anticipated that this calculation will adversely impact the design of the Subsurface Facility. |
| CRWMS M&O 2000d, Section 1.2.2.2.2 | Method of Refuge | 4.2.1.3.2 | 6.1.2.8 | This criterion has not been evaluated at this time, however it is not anticipated that this calculation will adversely impact the design of the Subsurface Facility. |
| CRWMS M&O 2000d, Section 1.2.2.2.3 | Travel Times for Reaching Refuge | 4.2.1.3.3 | 6.1.2.8 | This criterion has not been evaluated at this time, however it is not anticipated that this calculation will adversely impact the design of the Subsurface Facility. |
| CRWMS M&O 2000d, Section 1.2.4.1 | Interface with Subsurface Ventilation System | 4.2.1.5.1 | 6.1.2.4 | Criterion has been met. |
| CRWMS M&O 2000d, Section 1.2.4.2 | Gradients | 4.2.1.5.2 | 6.1.2.1 | Criterion has been met. |
| CRWMS M&O 2000d, Section 1.2.4.3 | Opening Envelopes | 4.2.1.5.3 | 6.1.2.1 | Criterion has been met. |
| CRWMS M&O 2000d, Section 1.2.4.4 | Temperature Constraint on Zeolites | 4.2.1.5.4 | 6.1.2.3 | Criterion is not addressed in this analysis. |
| CRWMS M&O 2000d, Section 1.2.4.5 | Temperature Constraint at Soil Surface | 4.2.1.5.5 | 6.1.2.3 | Criterion is not addressed in this analysis. |

Table 30. Subsurface Facility Criteria Compliance (continued)

| Criterion | Description | Criterion Documentation in Section | Criterion Discussion Located in Section | Adherence to Criteria |
|---|---|---|---|---|
| CRWMS M&O 2000d, Section 1.2.4.6 | Temperature Constraint on PTn unit | 4.2.1.5.6 | 6.1.2.3 | Criterion is not addressed in this analysis. |
| CRWMS M&O 2000d, Section 1.2.4.7 | Opening Orientations | 4.2.1.5.7 | 6.1.2.1 | Criterion has been met. |
| CRWMS M&O 2000d, Section 1.2.4.8 | Uplift Limit of the TSw1 Unit | 4.2.1.5.8 | 6.1.2.3 | Criterion has been met. |
| CRWMS M&O 2000d, Section 1.2.4.9 | Interface with the Subsurface Excavation System | 4.2.1.5.9 | 6.1.2.9 | Criterion has been met. |
| CRWMS M&O 2000f, Section 1.2.4.7 | Emplacement Drift and Turnout Interface | 4.2.1.5.11 | 6.1.2.1.2 | Criterion has been met. |
| CRWMS M&O 2000f, Section 1.2.4.6 | Opening Curvatures | 4.2.1.5.10 | 6.1.2.1 | Criterion has been met. |
| CRWMS M&O 2000d, Section 1.2.6.1 | Occupational Safety and Health Standards | 4.3.1.1 | 6.1.2.8 | This criterion has not been evaluated. Analyses to verify that the layouts will meet this criterion will be conducted in the future. |
| CRWMS M&O 2000d, Section 1.2.6.2 | Safety and Health Regulations for Construction | 4.3.1.2 | 6.1.2.8 | This criterion has not been evaluated. Analyses to verify that the layouts will meet this criterion will be conducted in the future. |
| CRWMS M&O 2000d, Section 1.2.6.3 | MGR Project Description Document | 4.3.1.3 | 5.1.1 | Criterion has been met. |

## 7.2 OVERALL SUBSURFACE VENTILATION ANALYSIS

The ventilation system has the flexibility to respond to various layout parameters without altering the basic airflow concepts as shown by the ability to regulate the airflow volume at each emplacement drift and to vary the total volume at the surface fans.

Ventilation system components, such as main fans and air doors can remain in an operable condition for the operating life of the facility through maintenance, refurbishment, and replacement. Since the ventilation system's capacity is based on an airflow rate per drift, any increase in the number of emplacement drifts increases the total system airflow volume, horsepower, and related operating costs. Table 31 provides a summary of the ventilation information.

Table 31. Summary of Ventilation Components

| Layout | Number of Intake Shafts | Development / Intake Shaft | Number of Exhaust Shafts | Exhaust Airflow Volume Estimate m³/s (cfm) | System Horsepower hp, and (kW) |
|---|---|---|---|---|---|
| Repository Layout (see Figure 3) | 8 | 1 | 9 | 5,285 m³/s (11,198,915 cfm) | 23,529 hp (17,546 kW) |
| 70,000 MTHM Case (see Figure 11) | 4 | 1 | 6 | 3,176 m³/s (6,729,944 cfm) | 14,140 hp(10,544 kW) |
| 97,000 MTHM Case (see Figure 12) | 6 | 1 | 8 | 4,100 m³/s (8,687,900 cfm) | 18,253 hp (13,612 kW) |

### 7.2.1 Criterion Compliance

A list of the ventilation criteria discussed in this analysis is presented in Table 32 with indications of where the discussion is located as well as whether the criteria was fully met.

Table 32. Ventilation System Criteria Compliance

| Criterion | Description | Criterion Documentation in Section | Criterion Discussion Located in Section | Adherence to Criteria |
|---|---|---|---|---|
| CRWMS M&O 2000g, Section 1.2.1.2 | Regulate airflow through emplacement drift | 4.2.2.1.1 | 6.2.3 | Criterion has been met. |
| CRWMS M&O 2000g, Section 1.2.1.3 | Maximum dry bulb 48° for human access | 4.2.2.1.2 | 6.2.3 | Conceptually criterion can be met. |
| CRWMS M&O 2000g, Section 1.2.1.4 | Remote temperatures 50°C | 4.2.2.1.3 | 6.2.3 | Criterion has been met. |
| CRWMS M&O 2000g, Section 1.2.1.6 | Separate systems for emplacement/development | 4.2.2.1.4 | 6.2.2 | Criterion has been met. |
| CRWMS M&O 2000g, Section 1.2.1.8 | Maximum drift wall temperature of 96°C | 4.2.2.1.5 | 6.2.3 | Criterion has been met. |
| CRWMS M&O 2000g, Section 1.2.1.9 | 70 percent heat removal | 4.2.2.1.6 | 6.2.3 | Criterion has been met for the preclosure period. |
| CRWMS M&O 2000g, Section 1.2.1.11 | Serviceable life of 175 years | 4.2.2.1.7 | 6.2.3, 6.2.13 | Can be met for the forced ventilation period, may need to be revised to accommodate natural ventilation. |
| CRWMS M&O 2000g, Section 1.2.1.12 | Operational life for up to 300 years | 4.2.2.1.8 | 6.2.13, 6.2.14.2 | Criterion has been met. |

Table 32. Ventilation System Criteria Compliance (continued)

| Criterion | Description | Criterion Documentation in Section | Criterion Discussion Located in Section | Adherence to Criteria |
|---|---|---|---|---|
| CRWMS M&O 2000g, Section 1.2.2.2.1 | 100m separation between intake and exhaust | 4.2.2.3.1 | 6.2.8.3 | Criterion has been met for the ventilation shafts. |
| CRWMS M&O 2000g, Section 1.2.2.2.3 | Emplacement drifts secured against unauthorized access | 4.2.2.3.2 | 6.2.3 | Criterion has been met. |
| CRWMS M&O 2000g, Section 1.2.2.2.4 | Reverse airflow in the emplacement drifts | 4.2.2.3.3 | 6.2.3 | Criterion has been met. |
| CRWMS M&O 2000g, Section 1.2.3.9 | Maximum WP linear heat load of 1.5 kW/m | 4.2.2.4.1 | 6.1.3.1, 6.1.4.1 | Criterion has been met. |
| CRWMS M&O 2000g Section 1.2.4.1 | Monitoring capabilities and parameters | 4.2.2.5.1 | 6.2.4 | Criterion has been met. |
| CRWMS M&O 2000g, Section 1.2.4.4 | Subsurface Facility Interface | 4.2.2.5.2 | 6.1.2.4 | Criterion has been met. |
| CRWMS M&O 2000g, Section 1.2.4.5 | Emplacement drift system interface | 4.2.2.5.3 | 6.2.3 | Criterion has been met. |
| CRWMS M&O 2000g, Section 1.2.4.7 | Backfill System interface | 4.2.2.5.4 | 6.2.3, 6.2.6 | Criterion has been met. |
| CRWMS M&O 2000g, Section 1.2.4.8 | Safeguards and Security System interface | 4.2.2.5.5 | 6.2.4 | Criterion has been met. |
| CRWMS M&O 2000g, Section 1.2.4.9 | Site Radiological Monitoring System interface | 4.2.2.5.6 | 6.2.4 | Criterion has been met. |
| CRWMS M&O 2001a Section 5.3.2 | Limited time access for operational upsets | 4.2.2.6.1 | 6.2.3 | Criterion has been met. |
| CRWMS M&O 2000g, Section 1.2.6.3 | Compliance with Radon control requirements | 4.3.2.1 | 6.2.7.2 | Requires additional design detail. Conceptually will be complied with. |
| CRWMS M&O 2000g, Section 1.2.6.1 | Compliance with 29 CFR 1910 (S&H) | 4.3.2.2 | 6.2.7.1 | Requires additional design detail. Conceptually will be complied with. |
| CRWMS M&O 2000g, Section 1.2.6.2 | Compliance with 29 CFR 1926 (S&H Construction) | 4.3.2.3 | 6.2.7.1 | Requires additional design detail. Conceptually will be complied with. |

This document may be affected by technical product input information that requires confirmation. Any changes to the document that may occur as a result of completing the confirmation activities will be reflected in subsequent revisions. The status of the technical product input information quality may be confirmed by review of the DIRS database.

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# ATTACHMENT I

# EMPLACEMENT DRIFT LENGTH FOR REPOSITORY FOOTPRINT

## ATTACHMENT I

## EMPLACEMENT DRIFT LENGTH FOR REPOSITORY FOOTPRINT

In order to determine the capacity of the emplacement area, the available emplacement drift length within the designed repository footprint must be determined. Table I-1 summarizes the excavated and available length of each emplacement drift as well as cumulative totals for the entire repository footprint.

The excavated length of the emplacement drifts represented in Table I-1 were taken from the *Site Recommendation Subsurface Layout* analysis (BSC 2001a, Attachment I, pp. I-3 to I-5 and Attachment VI, pp. VI-3 to VI-4). Only a single PCTD is required (see Section 6.1.2.1.3) to support the Test and Evaluation facilities. A second PCTD was identified in the *Site Recommendation Subsurface Layout* analysis (BSC 2001a, Attachment I, p. I-3). The second PCTD has been designated as an emplacement drift, and the emplacement drifts were then relabeled accordingly.

The excavated length represents the drift length from the door of the emplacement drift on the east side of the repository block to the door of the emplacement drift on the west side of the repository block. The operational standoff distance is the distance from the door of the emplacement drift to the closest WP emplaced in the drift, 1.5 meters on each end of the emplacement drift (see Section 5.1.2.6). A total operational standoff of 3.0 meters is therefore applied to each emplacement drift.

A physical standoff distance, of 2 meters, is established from the centerline of the ventilation raise to the nearest emplaced WP. This physical standoff will minimize the preferential pathway for water to directly contact the WP and to prevent any object from possibly dropping down the raise and contacting a WP (see Section 5.1.2.6).

Other unusable lengths are lengths that exceeds the maximum emplacement drift split and cannot be used (see Section 5.1.2.3) or length is reserved for the PCTD.

Drift length available for emplacement is the usable length of each emplacement drift. The usable length is calculated as the excavation length of each drift less the total standoff lengths. (see Table I-1). The cumulative excavated and usable emplacement lengths are shown in Table I-1. The 91 emplacement drifts in the primary block provide 85,443 meters of available emplacement drift length. The 52 emplacement drifts in the lower block provide 62,400 meters of available emplacement drift length. The entire repository footprint provides 147,843 meters of emplacement drift length.

Table I-1. Available Emplacement Drift Length in Repository Footprint

| Drift Number | Excavated Length (m) | Cumulative Excavated Length (m) | WP Standoff[a] (m) | Vent Standoff[b] (m) | Other Unusable Length[c] (m) | Available Emplacement Drift Length (m) | Cumulative Available Emplacement Drift Length (m) |
|---|---|---|---|---|---|---|---|
| PC 1 | 697.2 | 0.0 | 0.0 | 0.0 | 697.2 | 0.0 | 0.0 |
| | | | | | | | |
| P 1 | 741.7 | 741.7 | 3.0 | 4.0 | 0.0 | 734.7 | 734.7 |
| P 2 | 781.1 | 1,522.8 | 3.0 | 4.0 | 0.0 | 774.1 | 1,508.8 |
| P 3 | 820.4 | 2,343.2 | 3.0 | 4.0 | 0.0 | 813.4 | 2,322.2 |
| P 4 | 859.7 | 3,202.9 | 3.0 | 4.0 | 0.0 | 852.7 | 3,174.9 |
| P 5 | 899.0 | 4,101.9 | 3.0 | 4.0 | 0.0 | 892.0 | 4,066.9 |
| P 6 | 938.3 | 5,040.2 | 3.0 | 4.0 | 0.0 | 931.3 | 4,998.2 |
| P 7 | 977.7 | 6,017.9 | 3.0 | 4.0 | 0.0 | 970.7 | 5,968.9 |
| P 8 | 1,017.0 | 7,034.9 | 3.0 | 4.0 | 0.0 | 1,010.0 | 6,978.9 |
| P 9 | 1,056.3 | 8,091.2 | 3.0 | 4.0 | 0.0 | 1,049.3 | 8,028.2 |
| P 10 | 1,095.6 | 9,186.8 | 3.0 | 4.0 | 0.0 | 1,088.6 | 9,116.8 |
| | | | | | | | |
| P 11 | 1,134.9 | 10,321.7 | 3.0 | 4.0 | 0.0 | 1,127.9 | 10,244.7 |
| P 12 | 1,174.3 | 11,496.0 | 3.0 | 4.0 | 0.0 | 1,167.3 | 11,412.0 |
| P 13 | 1,230.0 | 12,726.0 | 3.0 | 4.0 | 0.0 | 1,223.0 | 12,635.0 |
| P 14 | 1,263.5 | 13,989.5 | 3.0 | 4.0 | 0.0 | 1,256.5 | 13,891.5 |
| P 15 | 1,263.5 | 15,253.0 | 3.0 | 4.0 | 0.0 | 1,256.5 | 15,148.0 |
| P 16 | 1,263.5 | 16,516.5 | 3.0 | 4.0 | 0.0 | 1,256.5 | 16,404.5 |
| P 17 | 1,263.5 | 17,780.0 | 3.0 | 4.0 | 0.0 | 1,256.5 | 17,661.0 |
| P 18 | 1,263.5 | 19,043.5 | 3.0 | 4.0 | 0.0 | 1,256.5 | 18,917.5 |
| P 19 | 1,263.5 | 20,307.0 | 3.0 | 4.0 | 0.0 | 1,256.5 | 20,174.0 |
| P 20 | 1,263.5 | 21,570.5 | 3.0 | 4.0 | 0.0 | 1,256.5 | 21,430.5 |
| | | | | | | | |
| P 21 | 1,263.5 | 22,834.0 | 3.0 | 4.0 | 0.0 | 1,256.5 | 22,687.0 |
| P 22 | 1,263.5 | 24,097.5 | 3.0 | 4.0 | 0.0 | 1,256.5 | 23,943.5 |
| P 23 | 1,263.5 | 25,361.0 | 3.0 | 4.0 | 0.0 | 1,256.5 | 25,200.0 |
| P 24 | 1,263.5 | 26,624.5 | 3.0 | 4.0 | 0.0 | 1,256.5 | 26,456.5 |
| P 25 | 1,263.5 | 27,888.0 | 3.0 | 4.0 | 0.0 | 1,256.5 | 27,713.0 |
| P 26 | 1,263.5 | 29,151.5 | 3.0 | 4.0 | 0.0 | 1,256.5 | 28,969.5 |
| P 27 | 1,263.5 | 30,415.0 | 3.0 | 4.0 | 0.0 | 1,256.5 | 30,226.0 |
| P 28 | 1,263.5 | 31,678.5 | 3.0 | 4.0 | 0.0 | 1,256.5 | 31,482.5 |
| P 29 | 1,263.5 | 32,942.0 | 3.0 | 4.0 | 0.0 | 1,256.5 | 32,739.0 |
| P 30 | 1,263.5 | 34,205.5 | 3.0 | 4.0 | 0.0 | 1,256.5 | 33,995.5 |
| Subtotal | 34,205.5 | | 90.0 | 120.0 | 697.2 | 33,995.5 | |

Table I-1. Available Emplacement Drift Length in Repository Footprint (continued)

| Drift Number | Excavated Length (m) | Cumulative Excavated Length (m) | WP Standoff[a] (m) | Vent Standoff[b] (m) | Other Unusable Length[c] (m) | Available Emplacement Drift Length (m) | Cumulative Available Emplacement Drift Length (m) |
|---|---|---|---|---|---|---|---|
| P 31 | 1,263.5 | 35,469.0 | 3.0 | 4.0 | 0.0 | 1,256.5 | 35,252.0 |
| P 32 | 1,263.5 | 36,732.5 | 3.0 | 4.0 | 0.0 | 1,256.5 | 36,508.5 |
| P 33 | 1,263.8 | 37,996.3 | 3.0 | 4.0 | 0.0 | 1,256.8 | 37,765.3 |
| P 34 | 1,248.5 | 39,244.8 | 3.0 | 4.0 | 0.0 | 1,241.5 | 39,006.8 |
| P 35 | 1,233.1 | 40,477.9 | 3.0 | 4.0 | 0.0 | 1,226.1 | 40,232.9 |
| P 36 | 1,217.8 | 41,695.7 | 3.0 | 4.0 | 0.0 | 1,210.8 | 41,443.7 |
| P 37 | 1,202.4 | 42,898.1 | 3.0 | 4.0 | 0.0 | 1,195.4 | 42,639.1 |
| P 38 | 1,187.1 | 44,085.2 | 3.0 | 4.0 | 0.0 | 1,180.1 | 43,819.2 |
| P 39 | 1,171.7 | 45,256.9 | 3.0 | 4.0 | 0.0 | 1,164.7 | 44,983.9 |
| P 40 | 1,156.4 | 46,413.3 | 3.0 | 4.0 | 0.0 | 1,149.4 | 46,133.3 |
| | | | | | | | |
| P 41 | 1,141.1 | 47,554.4 | 3.0 | 4.0 | 0.0 | 1,134.1 | 47,267.4 |
| P 42 | 1,125.7 | 48,680.1 | 3.0 | 4.0 | 0.0 | 1,118.7 | 48,386.1 |
| P 43 | 1,110.4 | 49,790.5 | 3.0 | 4.0 | 0.0 | 1,103.4 | 49,489.5 |
| P 44 | 1,095.0 | 50,885.5 | 3.0 | 4.0 | 0.0 | 1,088.0 | 50,577.5 |
| P 45 | 1,079.7 | 51,965.2 | 3.0 | 4.0 | 0.0 | 1,072.7 | 51,650.2 |
| P 46 | 1,064.3 | 53,029.5 | 3.0 | 4.0 | 0.0 | 1,057.3 | 52,707.5 |
| P 47 | 1,049.0 | 54,078.5 | 3.0 | 4.0 | 0.0 | 1,042.0 | 53,749.5 |
| P 48 | 1,033.6 | 55,112.1 | 3.0 | 4.0 | 0.0 | 1,026.6 | 54,776.1 |
| P 49 | 1,018.3 | 56,130.4 | 3.0 | 4.0 | 0.0 | 1,011.3 | 55,787.4 |
| P 50 | 1,002.9 | 57,133.3 | 3.0 | 4.0 | 0.0 | 995.9 | 56,783.3 |
| | | | | | | | |
| P 51 | 987.6 | 58,120.9 | 3.0 | 4.0 | 0.0 | 980.6 | 57,763.9 |
| P 52 | 972.2 | 59,093.1 | 3.0 | 4.0 | 0.0 | 965.2 | 58,729.1 |
| P 53 | 956.9 | 60,050.0 | 3.0 | 4.0 | 0.0 | 949.9 | 59,679.0 |
| P 54 | 941.5 | 60,991.5 | 3.0 | 4.0 | 0.0 | 934.5 | 60,613.5 |
| P 55 | 926.2 | 61,917.7 | 3.0 | 4.0 | 0.0 | 919.2 | 61,532.7 |
| P 56 | 910.8 | 62,828.5 | 3.0 | 4.0 | 0.0 | 903.8 | 62,436.5 |
| P 57 | 895.5 | 63,724.0 | 3.0 | 4.0 | 0.0 | 888.5 | 63,325.0 |
| P 58 | 880.1 | 64,604.1 | 3.0 | 4.0 | 0.0 | 873.1 | 64,198.1 |
| P 59 | 864.8 | 65,468.9 | 3.0 | 4.0 | 0.0 | 857.8 | 65,055.9 |
| P 60 | 849.4 | 66,318.3 | 3.0 | 4.0 | 0.0 | 842.4 | 65,898.3 |
| Subtotal | 66,318.3 | | 180.0 | 240.0 | 697.2 | 65,898.3 | |

Table I-1. Available Emplacement Drift Length in Repository Footprint (continued)

| Drift Number | Excavated Length (m) | Cumulative Excavated Length (m) | WP Standoff[a] (m) | Vent Standoff[b] (m) | Other Unusable Length[c] (m) | Available Emplacement Drift Length (m) | Cumulative Available Emplacement Drift Length (m) |
|---|---|---|---|---|---|---|---|
| P 61 | 834.1 | 67,152.4 | 3.0 | 4.0 | 0.0 | 827.1 | 66,725.4 |
| P 62 | 796.2 | 67,948.6 | 3.0 | 4.0 | 0.0 | 789.2 | 67,514.6 |
| P 63 | 739.0 | 68,687.6 | 3.0 | 4.0 | 0.0 | 732.0 | 68,246.6 |
| P 64 | 681.8 | 69,369.4 | 3.0 | 4.0 | 0.0 | 674.8 | 68,921.4 |
| P 65 | 333.5 | 69,702.9 | 3.0 | 4.0 | 0.0 | 326.5 | 69,247.9 |
| P 66 | 333.5 | 70,036.4 | 3.0 | 4.0 | 0.0 | 326.5 | 69,574.4 |
| P 67 | 333.5 | 70,369.9 | 3.0 | 4.0 | 0.0 | 326.5 | 69,900.9 |
| P 68 | 335.4 | 70,705.3 | 3.0 | 4.0 | 0.0 | 328.4 | 70,229.3 |
| P 69 | 352.8 | 71,058.1 | 3.0 | 4.0 | 0.0 | 345.8 | 70,575.1 |
| P 70 | 384.7 | 71,442.8 | 3.0 | 4.0 | 0.0 | 377.7 | 70,952.8 |
| | | | | | | | |
| P 71 | 415.4 | 71,858.2 | 3.0 | 4.0 | 0.0 | 408.4 | 71,361.2 |
| P 72 | 458.5 | 72,316.7 | 3.0 | 4.0 | 0.0 | 451.5 | 71,812.7 |
| P 73 | 513.4 | 72,830.1 | 3.0 | 4.0 | 0.0 | 506.4 | 72,319.1 |
| P 74 | 568.3 | 73,398.4 | 3.0 | 4.0 | 0.0 | 561.3 | 72,880.4 |
| P 75 | 623.1 | 74,021.5 | 3.0 | 4.0 | 0.0 | 616.1 | 73,496.5 |
| P 76 | 678.0 | 74,699.5 | 3.0 | 4.0 | 0.0 | 671.0 | 74,167.5 |
| P 77 | 732.8 | 75,432.3 | 3.0 | 4.0 | 0.0 | 725.8 | 74,893.3 |
| P 78 | 787.7 | 76,220.0 | 3.0 | 4.0 | 0.0 | 780.7 | 75,674.0 |
| P 79 | 845.4 | 77,065.4 | 3.0 | 4.0 | 0.0 | 838.4 | 76,512.4 |
| P 80 | 861.4 | 77,926.8 | 3.0 | 4.0 | 0.0 | 854.4 | 77,366.8 |
| | | | | | | | |
| P 81 | 848.1 | 78,774.9 | 3.0 | 4.0 | 0.0 | 841.1 | 78,207.9 |
| P 82 | 826.7 | 79,601.6 | 3.0 | 4.0 | 0.0 | 819.7 | 79,027.6 |
| P 83 | 805.3 | 80,406.9 | 3.0 | 4.0 | 0.0 | 798.3 | 79,825.9 |
| P 84 | 784.0 | 81,190.9 | 3.0 | 4.0 | 0.0 | 777.0 | 80,602.9 |
| P 85 | 762.6 | 81,953.5 | 3.0 | 4.0 | 0.0 | 755.6 | 81,358.5 |
| P 86 | 741.2 | 82,694.7 | 3.0 | 4.0 | 0.0 | 734.2 | 82,092.7 |
| P 87 | 719.8 | 83,414.5 | 3.0 | 4.0 | 0.0 | 712.8 | 82,805.5 |
| P 88 | 698.5 | 84,113.0 | 3.0 | 4.0 | 0.0 | 691.5 | 83,497.0 |
| P 89 | 677.1 | 84,790.1 | 3.0 | 4.0 | 0.0 | 670.1 | 84,167.1 |
| P 90 | 655.7 | 85,445.8 | 3.0 | 4.0 | 0.0 | 648.7 | 84,815.8 |
| | | | | | | | |
| P 91 | 634.4 | 86,080.2 | 3.0 | 4.0 | 0.0 | 627.4 | 85,443.2 |
| Subtotal | 86,080.2 | | 273.0 | 364.0 | 697.2 | 85,443.2 | |

Table I-1. Available Emplacement Drift Length in Repository Footprint (continued)

| Drift Number | Excavated Length (m) | Cumulative Excavated Length (m) | WP Standoff[a] (m) | Vent Standoff[b] (m) | Other Unusable Length[c] (m) | Available Emplacement Drift Length (m) | Cumulative Available Emplacement Drift Length (m) |
|---|---|---|---|---|---|---|---|
| L 1 | 1,207.0 | 87,287.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 86,643.2 |
| L 2 | 1,207.0 | 88,494.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 87,843.2 |
| L 3 | 1,207.0 | 89,701.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 89,043.2 |
| L 4 | 1,207.0 | 90,908.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 90,243.2 |
| L 5 | 1,207.0 | 92,115.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 91,443.2 |
| L 6 | 1,207.0 | 93,322.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 92,643.2 |
| L 7 | 1,207.0 | 94,529.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 93,843.2 |
| L 8 | 1,207.0 | 95,736.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 95,043.2 |
| L 9 | 1,207.0 | 96,943.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 96,243.2 |
| L 10 | 1,207.0 | 98,150.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 97,443.2 |
| | | | | | | | |
| L 11 | 1,207.0 | 99,357.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 98,643.2 |
| L 12 | 1,207.0 | 100,564.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 99,843.2 |
| L 13 | 1,207.0 | 101,771.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 101,043.2 |
| L 14 | 1,207.0 | 102,978.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 102,243.2 |
| L 15 | 1,207.0 | 104,185.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 103,443.2 |
| L 16 | 1,207.0 | 105,392.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 104,643.2 |
| L 17 | 1,207.0 | 106,599.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 105,843.2 |
| L 18 | 1,207.0 | 107,806.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 107,043.2 |
| L 19 | 1,207.0 | 109,013.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 108,243.2 |
| L 20 | 1,207.0 | 110,220.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 109,443.2 |
| | | | | | | | |
| L 21 | 1,207.0 | 111,427.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 110,643.2 |
| L 22 | 1,207.0 | 112,634.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 111,843.2 |
| L 23 | 1,207.0 | 113,841.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 113,043.2 |
| L 24 | 1,207.0 | 115,048.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 114,243.2 |
| L 25 | 1,207.0 | 116,255.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 115,443.2 |
| L 26 | 1,207.0 | 117,462.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 116,643.2 |
| L 27 | 1,207.0 | 118,669.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 117,843.2 |
| L 28 | 1,207.0 | 119,876.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 119,043.2 |
| L 29 | 1,207.0 | 121,083.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 120,243.2 |
| L 30 | 1,207.0 | 122,290.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 121,443.2 |
| Subtotal | 122,290.2 | | 363.0 | 484.0 | 697.2 | 121,443.2 | |

Table I-1. Available Emplacement Drift Length in Repository Footprint (continued)

| Drift Number | Excavated Length (m) | Cumulative Excavated Length (m) | WP Standoff[a] (m) | Vent Standoff[b] (m) | Other Unusable Length[c] (m) | Available Emplacement Drift Length (m) | Cumulative Available Emplacement Drift Length (m) |
|---|---|---|---|---|---|---|---|
| L 31 | 1,207.0 | 123,497.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 122,643.2 |
| L 32 | 1,207.0 | 124,704.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 123,843.2 |
| L 33 | 1,207.0 | 125,911.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 125,043.2 |
| L 34 | 1,207.0 | 127,118.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 126,243.2 |
| L 35 | 1,207.0 | 128,325.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 127,443.2 |
| L 36 | 1,207.0 | 129,532.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 128,643.2 |
| L 37 | 1,207.0 | 130,739.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 129,843.2 |
| L 38 | 1,207.0 | 131,946.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 131,043.2 |
| L 39 | 1,207.0 | 133,153.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 132,243.2 |
| L 40 | 1,207.0 | 134,360.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 133,443.2 |
| | | | | | | | |
| L 41 | 1,207.0 | 135,567.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 134,643.2 |
| L 42 | 1,207.0 | 136,774.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 135,843.2 |
| L 43 | 1,207.0 | 137,981.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 137,043.2 |
| L 44 | 1,207.0 | 139,188.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 138,243.2 |
| L 45 | 1,207.0 | 140,395.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 139,443.2 |
| L 46 | 1,207.0 | 141,602.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 140,643.2 |
| L 47 | 1,207.0 | 142,809.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 141,843.2 |
| L 48 | 1,207.0 | 144,016.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 143,043.2 |
| L 49 | 1,207.0 | 145,223.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 144,243.2 |
| L 50 | 1,207.0 | 146,430.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 145,443.2 |
| | | | | | | | |
| L 51 | 1,207.0 | 147,637.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 146,643.2 |
| L 52 | 1,207.0 | 148,844.2 | 3.0 | 4.0 | 0.0 | 1,200.0 | 147,843.2 |
| Subtotal | 148,844.2 | | 429.0 | 572.0 | 697.2 | 147,843.2 | |

[a] A total operational standoff of 3 meters is used (see Section 5.1.2.6).
[b] A total physical standoff of 4 meters about the ventilation raise is used (see Section 5.1.2.6).
[c] The maximum length of drift split is restricted to 700 meters (see Section 5.1.2.7)

# ATTACHMENT II

# REPOSITORY LAYOUT DETAILS

# ATTACHMENT II

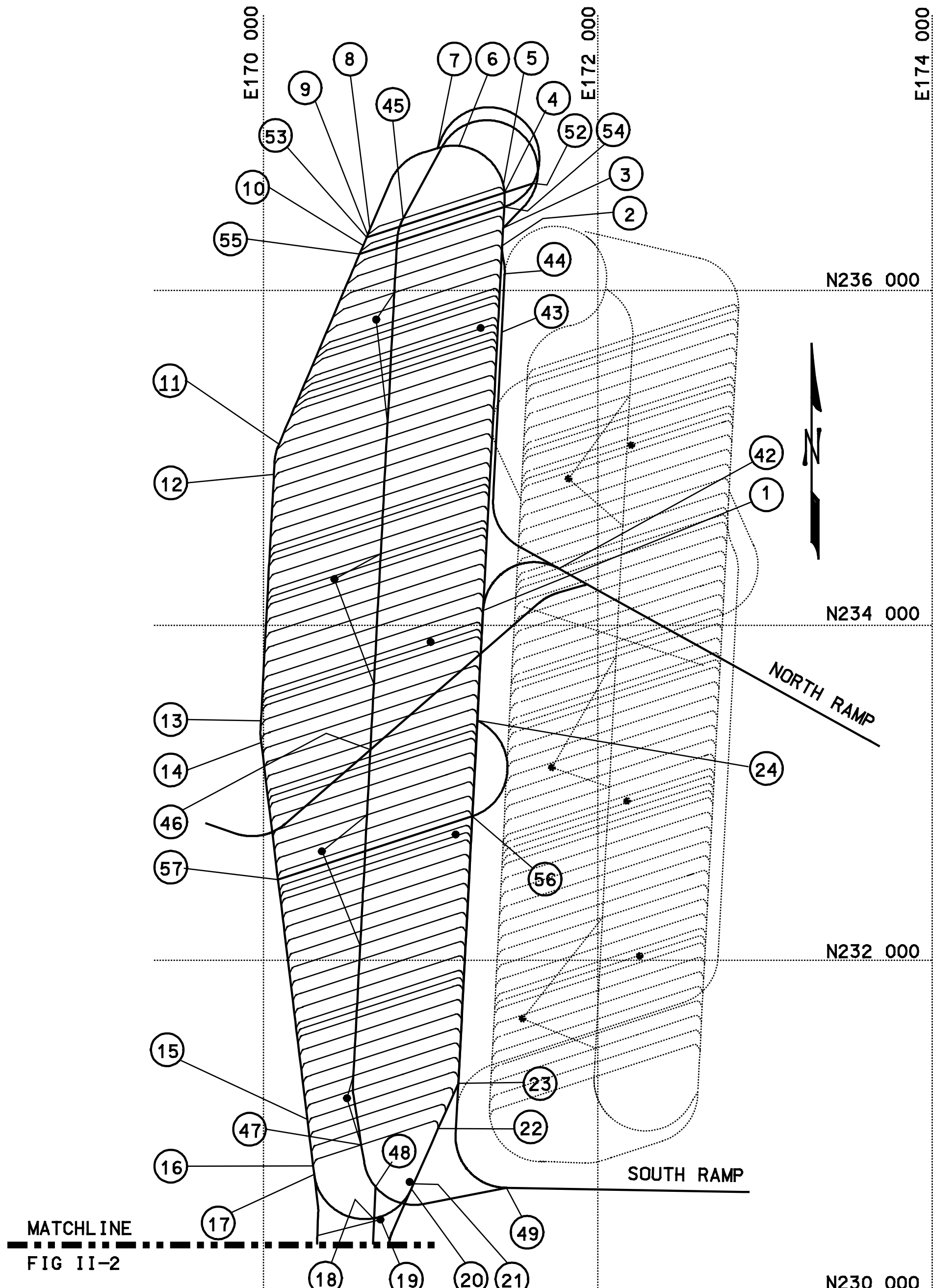
## REPOSITORY LAYOUT DETAILS

The information in this attachment was extracted from the *Electronic Files in Support of ANL-WER-MD-000002 REV 00* (BSC 2001aa) using VULCAN v3.4.

The VULCAN v3.4 software program provides a three dimensional design of the subsurface layout. In order to provide specific information about the layout as illustrated in Figure 3, key reference points within the layout are used to describe the lengths and grades of the various subsurface openings. The coordinates are located on the centerline of the opening and the elevation corresponds to the elevation of the invert. The coordinates are northing and easting metric values of coordinates converted from the Nevada State Plane Coordinate System, NAD 27 (see Section 4.1.1.2).

Figure II-1 presents a set of reference points within the layout. The definitions of these reference points are listed in Table II-1, complete with the coordinates and elevations.

The details of the opening lengths and grades, corresponding to the reference points presented in Figure II-1 and outlined in Table II-1, are presented in Table II-2.



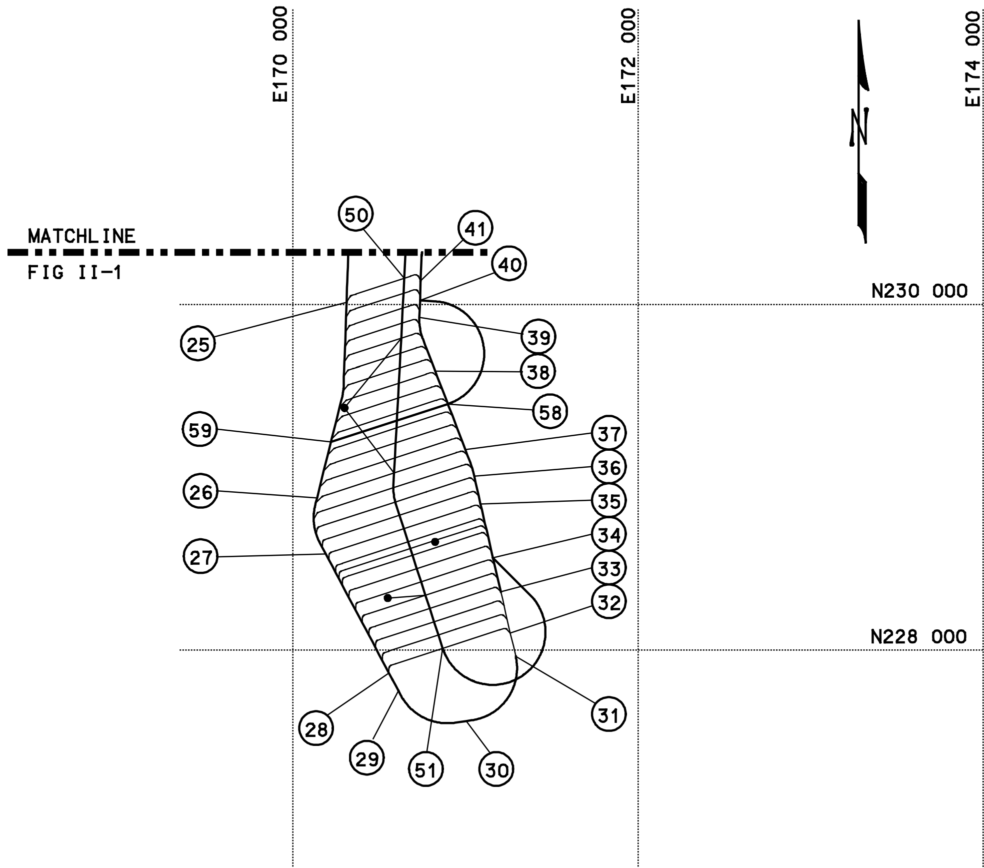

**NOTES:**

1. COORDINATES ARE SHOWN IN METERS.
2. NORTHING AND EASTING VALUES ARE NEVADA STATE PLANE COORDINATE SYSTEM, NAD 27.
3. POINT DESIGNATION DEFINITIONS PROVIDED IN TABLE II-1.

PLAN CAD FILE:feb_01_lt_splitlayout.fig

SCALE: NONE

Figure II-1. Details for the Repository Layout, Primary Block – Part I




**NOTES:**

1. COORDINATES ARE SHOWN IN METERS.
2. NORTHING AND EASTING VALUES ARE NEVADA STATE PLANE COORDINATE SYSTEM, NAD 27.
3. POINT DESIGNATION DEFINITIONS PROVIDED IN TABLE II-1.

PLAN CAD FILE:feb_01_lt_splitlayout.fig

SCALE: NONE

Figure II-2. Details for the Repository Layout, Primary Block – Part II

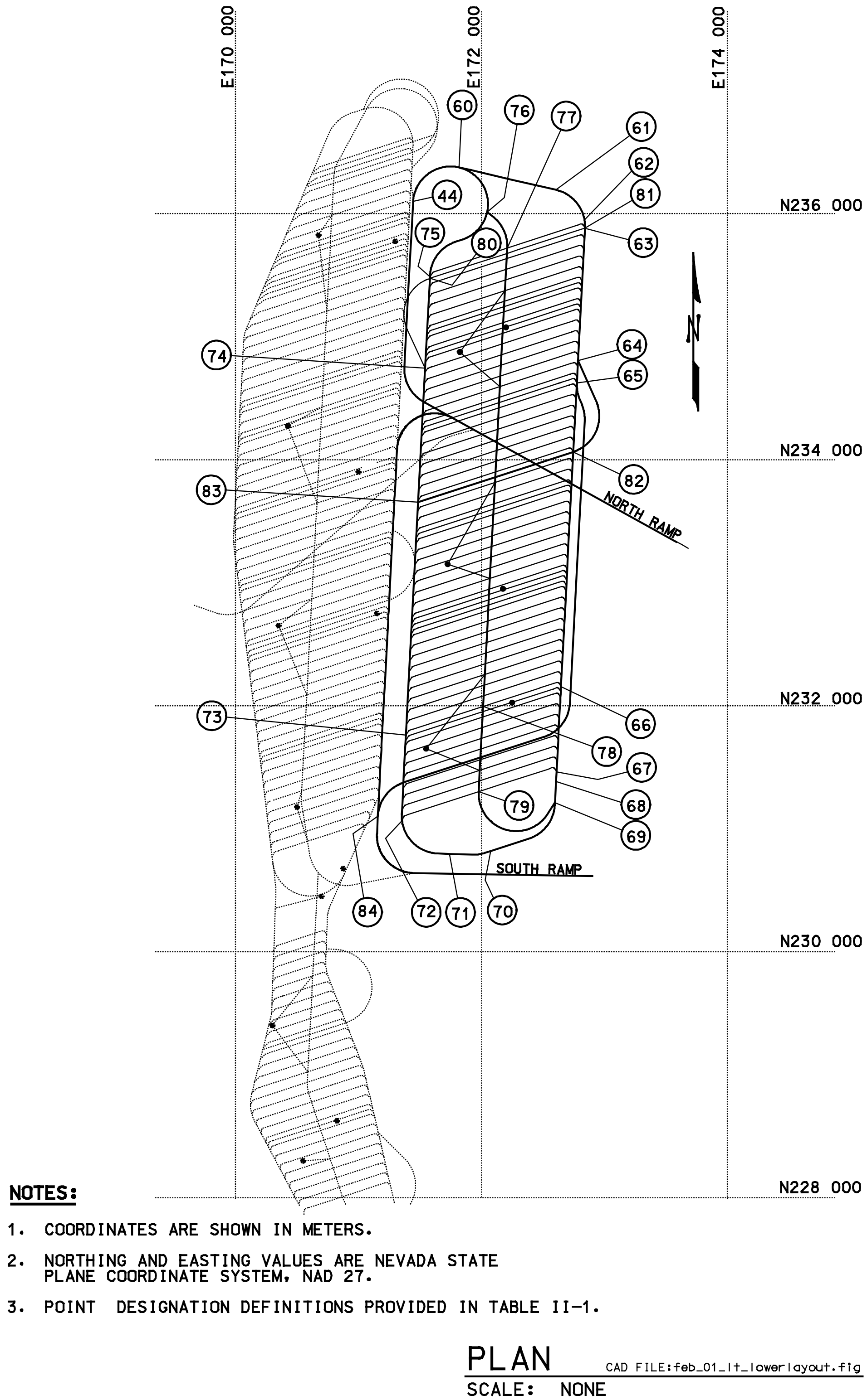



Figure II-3. Details for the Repository Layout, Lower Block

Table II-1. Point Designation Definitions

| Point Designation | Reference Point [1] | Description | Northing [2] (m) | Easting [2] (m) | Elevation (m) |
|---|---|---|---|---|---|
| 1 | 1 | Bottom of northern curve of the ESF loop | 234,087.742 | 171,313.778 | 1,065.000 |
| 2 | 2 | Intersection of the East Main North Extension and the North Ramp Extension | 236,265.995 | 171,427.935 | 1,035.553 |
| 3 | NEW | Intersection of the East Main North Extension and the Exhaust Main | 236,372.220 | 171,433.502 | 1,034.117 |
| 4 | 3 | Intersection of the centerline of the east turnout of PCTD and the East Main North Extension | 236,584.156 | 171,441.857 | 1,031.253 |
| 5 | 4 | Grade break in the North Main | 236,624.569 | 171,435.799 | 1,030.700 |
| 6 | 5 | Grade break in the North Main | 236,862.588 | 171,169.724 | 1,022.806 |
| 7 | NEW | Intersection of the North Main and OD #1 and OD #2 Entrance | 236,848.658 | 171,041.293 | 1,024.092 |
| 8 | 6 | Grade break in the North Main | 236,365.524 | 170,638.542 | 1,030.700 |
| 9 | 7 | Intersection of the centerline of the west turnout of PCTD and the West Main | 236,332.334 | 170,624.454 | 1,031.079 |
| 10 | 8 | Grade break in the West Main | 236,266.730 | 170,596.606 | 1,031.828 |
| 11 | 9 | Grade break in the West Main | 235,081.200 | 170,093.379 | 1,045.884 |
| 12 | 10 | Grade break in the West Main | 234,900.977 | 170,062.952 | 1,048.226 |
| 13 | 11 | Grade break in the West Main | 233,428.032 | 169,985.759 | 1,068.139 |
| 14 | 12 | Grade break in the West Main | 233,300.734 | 169,987.157 | 1,069.896 |
| 15 | 13 | Grade break in the West Main | 231,048.457 | 170,263.702 | 1,102.106 |
| 16 | 14 | Intersection of the centerline of the west turnout for Emplacement Drift # 64 and the West Main | 230,771.546 | 170,297.702 | 1,105.592 |
| 17 | 15 | Intersection of the South Main and the West Main | 230,720.853 | 170,303.926 | 1,106.230 |
| 18 | 16 | Grade break in the South Main | 230,456.966 | 170,655.489 | 1,096.782 |

Table II-1. Point Designation Definitions (continued)

| Point Designation | Reference Point [1] | Description | Northing [2] (m) | Easting [2] (m) | Elevation (m) |
|---|---|---|---|---|---|
| 19 | 17 | Intersection of access to the Development/Intake Shaft and the South Main | 230,466.350 | 170,695.826 | 1,097.404 |
| 20 | 18 | Intersection of the East Main South Extension and the South Main | 230,633.968 | 170,885.284 | 1,101.316 |
| 21 | NEW | Intersection of the South Main and the access for Intake Shaft #5 | 230,664.391 | 170,898.829 | 1,101.704 |
| 22 | 19 | Intersection of the centerline of the east turnout for Emplacement Drift # 64 and the East Main South Extension | 230,993.486 | 171,045.352 | 1,105.895 |
| 23 | 20 | Intersection of the East Main and East Main South Extension | 231,263.998 | 171,165.792 | 1,103.173 |
| 24 | NEW | Intersection of the East Main and OD #3 Entrance | 233,431.267 | 171,279.373 | 1,073.875 |
| 25 | 21 | Intersection of the West Main and the centerline of the west turnout of Emplacement Drift # 65 | 230,011.802 | 170,311.217 | 1,110.757 |
| 26 | 22 | Grade break in the West Main | 228,879.123 | 170,140.217 | 1,116.515 |
| 27 | 23 | Grade break in the West Main | 228,554.967 | 170,191.053 | 1,112.270 |
| 28 | 24 | Intersection of the West Main and the centerline of the west turnout of Emplacement Drift #91 | 227,866.605 | 170,557.062 | 1,099.796 |
| 29 | 25 | Grade break in the South End Main | 227,763.800 | 170,611.724 | 1,097.933 |
| 30 | 26 | Grade break in the South End Main | 227,587.993 | 171,005.323 | 1,086.317 |
| 31 | 27 | Grade break in the South End Main | 227,963.024 | 171,291.286 | 1,097.711 |
| 32 | 28 | Intersection of the East Main South Extension and the centerline of the east turnout of Emplacement Drift # 91 | 228,097.714 | 171,260.190 | 1,099.908 |
| 33 | 29 | Grade break in the East Main South Extension | 228,335.390 | 171,205.318 | 1,103.785 |

Table II-1. Point Designation Definitions (continued)

| Point Designation | Reference Point [1] | Description | Northing [2] (m) | Easting [2] (m) | Elevation (m) |
|---|---|---|---|---|---|
| 34 | NEW | Intersection of the Exhaust Main South Extension and the East Main South Extension | 228,533.302 | 171,159.627 | 1,107.073 |
| 35 | 30 | Grade break in the East Main South Extension | 228,843.773 | 171,087.949 | 1,112.230 |
| 36 | 31 | Grade break in the East Main South Extension | 229,004.654 | 171,050.806 | 1,114.526 |
| 37 | 32 | Grade break in the East Main South Extension | 229,158.348 | 170,999.582 | 1,116.515 |
| 38 | 33 | Grade break in the East Main South Extension | 229,612.690 | 170,825.177 | 1,113.650 |
| 39 | 34 | Grade break in the East Main South Extension | 229,923.676 | 170,733.806 | 1,111.898 |
| 40 | NEW | Intersection of the East Main South Extension and OD #4 Entrance | 230,022.349 | 170,737.252 | 1,111.405 |
| 41 | 35 | Intersection of the East Main South Extension and the centerline of the east turnout of Emplacement Drift # 65 | 230,135.984 | 170,741.220 | 1,110.836 |
| 42 | 36 | Top of northern curve of the ESF loop | 234,338.604 | 171,766.109 | 1,078.265 |
| 43 | 37 | Point on the North Ramp Extension | 235,749.672 | 171,425.374 | 1,045.061 |
| 44 | 39 | Grade break in the North Ramp Extension | 236,099.254 | 171,443.648 | 1,037.877 |
| 45 | NEW | Grade break in the Exhaust Main | 236,429.966 | 170,836.872 | 1,047.937 |
| 46 | NEW | Intersection of the Exhaust Main and the ECRB | 233,257.262 | 170,640.477 | 1,106.329 |
| 47 | NEW | Grade break in the Exhaust Main | 230,897.576 | 170,585.703 | 1,129.251 |
| 48 | NEW | Intersection of the Exhaust Main and the Exhaust Main South Extension | 230,644.517 | 170,671.992 | 1,127.892 |
| 49 | NEW | Intersection of the Exhaust Main and the South Ramp | 230,639.896 | 171,453.607 | 1,123.780 |

Table II-1. Point Designation Definitions (continued)

| Point Designation | Reference Point [1] | Description | Northing [2] (m) | Easting [2] (m) | Elevation (m) |
|---|---|---|---|---|---|
| 50 | NEW | Grade break in the Exhaust Main South Extension | 230,150.688 | 170,646.112 | 1,130.364 |
| 51 | NEW | Grade break in the Exhaust Main South Extension | 228,008.617 | 170,868.645 | 1,141.306 |
| 52 | NEW | Intersection of OD #2 and the entrance to OD #1 | 236,639.213 | 171,611.931 | 1,010.537 |
| 53 | NEW | End of OD #1 | 236,316.127 | 170,617.574 | 1,015.764 |
| 54 | NEW | Point in OD #2 where it crosses under the East Main North Extension | 236,498.215 | 171,440.105 | 1,011.813 |
| 55 | NEW | End of OD #2 | 236,217.333 | 170,575.638 | 1,016.914 |
| 56 | NEW | Point in OD #3 where it crosses under the East Main | 232,859.174 | 171,249.391 | 1,066.108 |
| 57 | NEW | End of OD #3 | 232,481.724 | 170,087.719 | 1,060.001 |
| 58 | NEW | Point in OD #4 where it crosses under the East Main | 229,423.381 | 170,897.846 | 1,099.344 |
| 59 | NEW | End of OD 34 | 229,203.490 | 170,221.090 | 1,095.786 |
| 60 | L2 | Intersection of Ramp 1 to the lower block and Ramp 2 to the lower block | 236,375.084 | 171,816.918 | 1,026.506 |
| 61 | L3 | Grade Break in Ramp 1 to the lower block | 236,192.885 | 172,606.110 | 1,009.104 |
| 62 | L4 | Grade Break in Ramp 1 to the lower block | 235,948.791 | 172,837.843 | 1,004.825 |
| 63 | L5 | Intersection of the lower block East Main and the lower block Emplacement Drift 1 | 235,879.740 | 172,842.082 | 1,003.993 |
| 64 | NEW | Intersection of the lower block East Main and OD #6 | 234,804.773 | 172,785.746 | 995.920 |
| 65 | L6 | Intersection of the lower block East Main and Ramp 3 to the lower block | 234,623.404 | 172,776.240 | 994.558 |
| 66 | L7 | Grade Break in lower block East Main | 232,154.055 | 172,646.827 | 976.012 |
| 67 | L8 | Intersection of the lower block East Main and the lower block Emplacement Drift 52 | 231,460.904 | 172,610.501 | 974.277 |
| 68 | L9 | Grade Break in the lower block South Main | 231,386.033 | 172,606.577 | 974.090 |

Table II-1. Point Designation Definitions (continued)

| Point Designation | Reference Point [1] | Description | Northing [2] (m) | Easting [2] (m) | Elevation (m) |
|---|---|---|---|---|---|
| 69 | NEW | Intersection of the lower block South Main and the lower block Exhaust Main | 231,211.072 | 172,597.408 | 972.473 |
| 70 | L10 | Grade Break in the lower block South Main | 230,818.486 | 172,075.218 | 965.904 |
| 71 | L11 | Grade Break in the lower block South Main | 230,795.195 | 171,741.019 | 972.894 |
| 72 | L12 | Transition point between the lower block South Main and the lower block West Main | 231,065.180 | 171,353.958 | 974.207 |
| 73 | L13 | Grade Break in the lower block West Main | 231,760.456 | 171,385.575 | 975.948 |
| 74 | NEW | Intersection of the lower block West Main and OD #5 | 234,745.338 | 171,542.006 | 998.365 |
| 75 | L14 | Intersection of the lower block West Main and Ramp 2 to the lower block | 235,486.141 | 171,580.830 | 1,003.929 |
| 76 | NEW | Intersection of Ramp 2 to the lower block and the lower block Exhaust Main | 236,012.276 | 172,046.153 | 1,017.736 |
| 77 | NEW | Grade break in the lower block Exhaust Main | 235,720.063 | 172,208.917 | 1,020.691 |
| 78 | NEW | Grade break in the lower block Exhaust Main | 231,994.378 | 172,013.663 | 992.710 |
| 79 | NEW | Grade break in the lower block Exhaust Main | 231,301.227 | 171,977.336 | 990.975 |
| 80 | NEW | Point in OD #5 where it crosses under the East Main | 235,473.180 | 171,580.151 | 988.332 |
| 81 | NEW | End of OD #5 | 235,883.305 | 172,842.238 | 981.696 |
| 82 | NEW | Point in OD #6 where it crosses under the East Main | 234,063.746 | 172,746.910 | 974.855 |
| 83 | NEW | End of OD #6 | 233,653.659 | 171,484.794 | 968.219 |
| 84 | L15 | Start of Ramp 3 to the lower block | 231,101.269 | 171,157.263 | 1,107.156 |

1 "Reference Point" refers to the key reference points defined in BSC 2001a, Attachment II and Attachment VI. Any new reference points defined for the first time in this analysis are listed as NEW.

2 The coordinates are northing and easting metric values of coordinates converted from the Nevada State Plane Coordinate System, NAD 27 (see Section 4.1.1.2).

Table II-2. Repository Layout Details

| From Point | To Point | Slope Length (m) | Grade (%) |
|---|---|---|---|
| 1 | 2 | 2,181.4 | -1.35 |
| 2 | 3 | 106.4 | -1.35 |
| 3 | 4 | 212.2 | -1.35 |
| 4 | 5 | 40.9 | -1.35 |
| 5 | 6 | 381.4 | -2.07 |
| 6 | 7 | 130.2 | 0.99 |
| 7 | 8 | 668.7 | 0.99 |
| 8 | 9 | 36.1 | 1.05 |
| 9 | 10 | 70.3 | 1.05 |
| 10 | 11 | 1,287.9 | 1.09 |
| 11 | 12 | 184.2 | 1.27 |
| 12 | 13 | 1,475.1 | 1.35 |
| 13 | 14 | 127.6 | 1.38 |
| 14 | 15 | 2,269.4 | 1.42 |
| 15 | 16 | 279.0 | 1.25 |
| 16 | 17 | 51.1 | 1.25 |
| 17 | 18 | 491.0 | -1.92 |
| 18 | 19 | 41.5 | 1.50 |
| 19 | 20 | 260.9 | 1.50 |
| 20 | 21 | 33.3 | 1.16 |
| 21 | 22 | 360.3 | 1.16 |
| 22 | 23 | 296.1 | -0.92 |
| 17 | 25 | 710.8 | 0.64 |
| 25 | 26 | 1,151.5 | 0.50 |
| 26 | 27 | 340.7 | -1.25 |
| 27 | 28 | 779.7 | -1.60 |
| 28 | 29 | 116.4 | -1.60 |
| 29 | 30 | 471.2 | -2.47 |
| 30 | 31 | 537.4 | 2.12 |
| 31 | 32 | 138.2 | 1.59 |
| 32 | 33 | 244.0 | 1.59 |
| 33 | 34 | 203.1 | 1.62 |
| 34 | 35 | 318.7 | 1.62 |
| 35 | 36 | 165.1 | 1.39 |
| 36 | 37 | 162.3 | 1.23 |
| 37 | 38 | 486.7 | -0.59 |
| 38 | 39 | 326.7 | -0.54 |
| 39 | 40 | 98.7 | -0.50 |
| 40 | 41 | 113.7 | -0.50 |
| 41 | 20 | 525.9 | -1.81 |
| 42 | 43 | 1,610.0 | -2.06 |
| 43 | 44 | 344.8 | -2.06 |
| 44 | 2 | 48.9 | -1.35 |
| 3 | 45 | 1,701.7 | 0.81 |
| 45 | 46 | 3,183.7 | 1.83 |
| 46 | 47 | 2,366.4 | 0.97 |
| 47 | 48 | 272.0 | -0.50 |
| 48 | 49 | 822.3 | -0.50 |
| 48 | 50 | 494.5 | 0.50 |
| 50 | 51 | 2,188.4 | 0.50 |
| 51 | 34 | 1,405.0 | -2.44 |
| 7 | 52 | 1,055.0 | -1.28 |
| 52 | 53 | 1,045.5 | 0.50 |
| 52 | 54 | 227.5 | 0.56 |

Table II-2. Repository Layout Details (continued)

| From Point | To Point | Slope Length (m) | Grade (%) |
|---|---|---|---|
| 54 | 55 | 909.0 | 0.56 |
| 24 | 56 | 736.1 | -1.06 |
| 56 | 57 | 1,221.5 | -0.50 |
| 40 | 58 | 928.9 | -1.30 |
| 58 | 59 | 711.6 | -0.50 |
| 44 | 60 | 532.8 | -2.15 |
| 60 | 61 | 810.1 | -2.15 |
| 61 | 62 | 356.6 | -1.20 |
| 62 | 63 | 69.3 | -1.20 |
| 63 | 64 | 1,076.5 | -0.75 |
| 64 | 65 | 181.6 | -0.75 |
| 65 | 66 | 2,472.8 | -0.75 |
| 66 | 67 | 694.1 | -0.25 |
| 67 | 68 | 75.0 | -0.25 |
| 68 | 69 | 175.2 | -0.92 |
| 69 | 70 | 711.7 | -0.92 |
| 70 | 71 | 338.3 | 2.07 |
| 71 | 72 | 525.4 | 0.25 |
| 72 | 73 | 696.3 | 0.25 |
| 73 | 74 | 2,989.1 | 0.75 |
| 74 | 75 | 741.8 | 0.75 |
| 75 | 76 | 749.6 | 1.84 |
| 76 | 60 | 476.1 | 1.84 |
| 76 | 77 | 351.1 | 0.84 |
| 77 | 78 | 3,730.8 | -0.75 |
| 78 | 79 | 694.1 | -0.25 |
| 79 | 69 | 908.3 | -2.04 |
| 84 | 65 | 4,551.5 | -2.47 |
| 74 | 80 | 857.2 | -1.17 |
| 80 | 81 | 1,327.1 | -0.50 |
| 64 | 82 | 869.1 | -2.42 |
| 82 | 83 | 1,327.1 | -0.50 |

# ATTACHMENT III

# BOUNDING COORDINATES OF EMPLACEMENT AREA

## ATTACHMENT III

## BOUNDING COORDINATES OF EMPLACEMENT AREA

The emplacement area in the planning layout is bounded by a set of coordinates that represent the theoretically last emplaced WP in the drift. Emplaced WPs on either end of the emplacement drift are assumed to be 1.5 meters from either end of the emplacement drift as illustrated in Figure III-1 (see Section 5.1.2.6). Table III-1 lists the boundary coordinates for the emplacement area of the repository layout, primary and lower block. The coordinates are northing and easting metric values of coordinates converted from the Nevada State Plane Coordinate System, NAD 27 (see Section 4.1.1.2).

Coordinates, listed in Table III-1, were taken from the *Site Recommendation Subsurface Layout* analysis (BSC 2001a, Attachment V, pp. V-3 to V-5 and Attachment VI, pp. V1-12 to VI-13). Only a single PCTD is required (see Section 6.1.2.1.3) to support the Test and Evaluation facilities. A second PCTD was identified in the *Site Recommendation Subsurface Layout* analysis (BSC 2001a, Attachment V, p. V-3). In this analysis, this second PCTD has been designated as an emplacement drift, and the emplacement drifts were then relabeled accordingly.

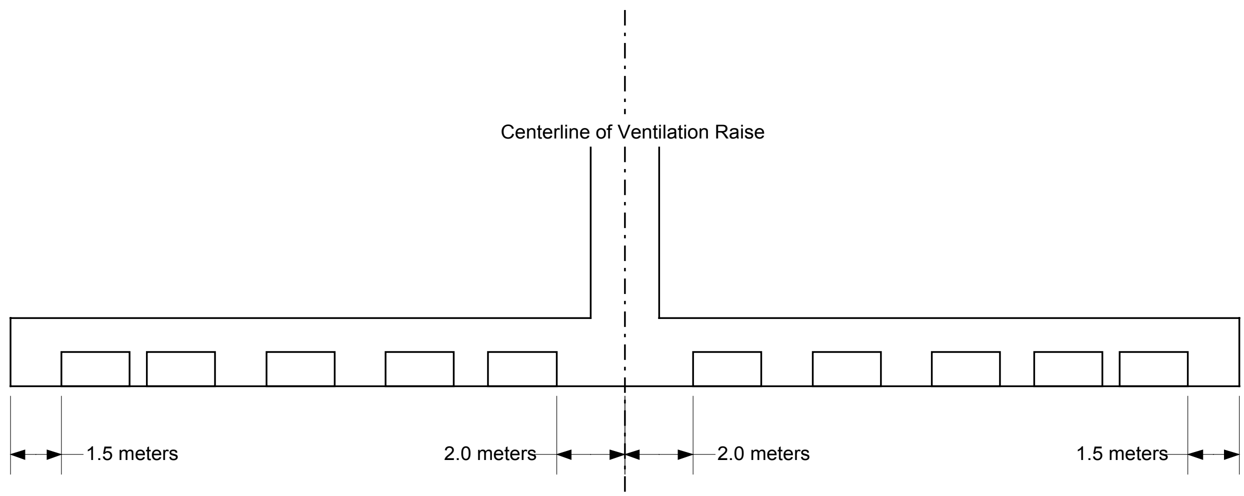



Figure III-1. Typical Drift

Table III-1. Bounding Coordinates for the Emplacement Area by Emplacement Drift

| Drift Number | East Side of Emplacement Drift | | | West Side of Emplacement Drift | | |
|---|---|---|---|---|---|---|
| | Northing[1] (m) | Easting[1] (m) | Elevation (m) | Northing[1] (m) | Easting[1] (m) | Elevation (m) |
| PC1 | 236,606.073 | 171,378.875 | 1,032.437 | 236,391.550 | 170,718.641 | 1,032.437 |
| 1 | 236,521.040 | 171,379.292 | 1,033.659 | 236,292.756 | 170,676.706 | 1,033.659 |
| 2 | 236,434.396 | 171,374.751 | 1,034.831 | 236,193.962 | 170,634.770 | 1,034.831 |
| 3 | 236,347.752 | 171,370.210 | 1,036.002 | 236,095.168 | 170,592.834 | 1,036.002 |
| 4 | 236,261.109 | 171,365.669 | 1,037.173 | 235,996.374 | 170,550.899 | 1,037.173 |
| 5 | 236,174.465 | 171,361.129 | 1,038.345 | 235,897.579 | 170,508.963 | 1,038.345 |
| 6 | 236,087.821 | 171,356.588 | 1,039.516 | 235,798.785 | 170,467.027 | 1,039.516 |
| 7 | 236,001.177 | 171,352.047 | 1,040.687 | 235,699.991 | 170,425.092 | 1,040.687 |
| 8 | 235,914.533 | 171,347.506 | 1,041.858 | 235,601.197 | 170,383.156 | 1,041.858 |
| 9 | 235,827.889 | 171,342.965 | 1,043.030 | 235,502.403 | 170,341.221 | 1,043.030 |
| 10 | 235,741.245 | 171,338.424 | 1,044.201 | 235,403.608 | 170,299.285 | 1,044.201 |
| 11 | 235,654.601 | 171,333.884 | 1,045.372 | 235,304.814 | 170,257.349 | 1,045.372 |
| 12 | 235,567.957 | 171,329.343 | 1,046.544 | 235,206.020 | 170,215.414 | 1,046.544 |
| 13 | 235,481.314 | 171,324.802 | 1,047.715 | 235,102.137 | 170,157.816 | 1,047.715 |
| 14 | 235,394.670 | 171,320.261 | 1,048.886 | 235,005.154 | 170,121.454 | 1,048.886 |
| 15 | 235,308.026 | 171,315.720 | 1,050.058 | 234,918.510 | 170,116.913 | 1,050.058 |
| 16 | 235,221.382 | 171,311.180 | 1,051.229 | 234,831.866 | 170,112.372 | 1,051.229 |
| 17 | 235,134.738 | 171,306.639 | 1,052.400 | 234,745.222 | 170,107.831 | 1,052.400 |
| 18 | 235,048.094 | 171,302.098 | 1,053.571 | 234,658.578 | 170,103.290 | 1,053.571 |
| 19 | 234,961.450 | 171,297.557 | 1,054.743 | 234,571.935 | 170,098.749 | 1,054.743 |
| 20 | 234,874.806 | 171,293.016 | 1,055.914 | 234,485.291 | 170,094.209 | 1,055.914 |
| 21 | 234,788.163 | 171,288.475 | 1,057.085 | 234,398.647 | 170,089.668 | 1,057.085 |
| 22 | 234,701.519 | 171,283.935 | 1,058.257 | 234,312.003 | 170,085.127 | 1,058.257 |
| 23 | 234,614.875 | 171,279.394 | 1,059.428 | 234,225.359 | 170,080.586 | 1,059.428 |
| 24 | 234,528.231 | 171,274.853 | 1,060.599 | 234,138.715 | 170,076.045 | 1,060.599 |
| 25 | 234,441.587 | 171,270.312 | 1,061.770 | 234,052.071 | 170,071.505 | 1,061.770 |
| 26 | 234,354.943 | 171,265.771 | 1,062.942 | 233,965.427 | 170,066.964 | 1,062.942 |
| 27 | 234,268.299 | 171,261.231 | 1,064.113 | 233,878.784 | 170,062.423 | 1,064.113 |
| 28 | 234,181.655 | 171,256.690 | 1,065.284 | 233,792.140 | 170,057.882 | 1,065.284 |
| 29 | 234,095.012 | 171,252.149 | 1,066.456 | 233,705.496 | 170,053.341 | 1,066.456 |
| 30 | 234,008.368 | 171,247.608 | 1,067.627 | 233,618.852 | 170,048.801 | 1,067.627 |
| 31 | 233,921.724 | 171,243.067 | 1,068.798 | 233,532.208 | 170,044.260 | 1,068.798 |

Table III-1. Bounding Coordinates for the Emplacement Area by Emplacement Drift (Continued)

| Drift Number | East Side of Emplacement Drift | | | West Side of Emplacement Drift | | |
|---|---|---|---|---|---|---|
| | Northing[1] (m) | Easting[1] (m) | Elevation (m) | Northing[1] (m) | Easting[1] (m) | Elevation (m) |
| 32 | 233,835.080 | 171,238.527 | 1,069.969 | 233,445.564 | 170,039.719 | 1,069.969 |
| 33 | 233,748.436 | 171,233.986 | 1,071.141 | 233,358.817 | 170,034.860 | 1,071.141 |
| 34 | 233,661.792 | 171,229.445 | 1,072.312 | 233,276.916 | 170,044.916 | 1,072.312 |
| 35 | 233,575.148 | 171,224.904 | 1,073.483 | 233,195.015 | 170,054.972 | 1,073.483 |
| 36 | 233,488.504 | 171,220.363 | 1,074.655 | 233,113.114 | 170,065.029 | 1,074.655 |
| 37 | 233,401.861 | 171,215.822 | 1,075.826 | 233,031.213 | 170,075.085 | 1,075.826 |
| 38 | 233,315.217 | 171,211.282 | 1,076.997 | 232,949.312 | 170,085.141 | 1,076.997 |
| 39 | 233,228.573 | 171,206.741 | 1,078.169 | 232,867.411 | 170,095.197 | 1,078.169 |
| 40 | 233,141.929 | 171,202.200 | 1,079.340 | 232,785.510 | 170,105.253 | 1,079.340 |
| 41 | 233,055.285 | 171,197.659 | 1,080.511 | 232,703.609 | 170,115.309 | 1,080.511 |
| 42 | 232,968.641 | 171,193.118 | 1,081.682 | 232,621.708 | 170,125.366 | 1,081.682 |
| 43 | 232,881.997 | 171,188.578 | 1,082.854 | 232,539.807 | 170,135.422 | 1,082.854 |
| 44 | 232,795.353 | 171,184.037 | 1,084.025 | 232,457.906 | 170,145.478 | 1,084.025 |
| 45 | 232,708.710 | 171,179.496 | 1,085.196 | 232,376.005 | 170,155.534 | 1,085.196 |
| 46 | 232,622.066 | 171,174.955 | 1,086.368 | 232,294.104 | 170,165.590 | 1,086.368 |
| 47 | 232,535.422 | 171,170.414 | 1,087.539 | 232,212.203 | 170,175.647 | 1,087.539 |
| 48 | 232,448.778 | 171,165.874 | 1,088.710 | 232,130.301 | 170,185.703 | 1,088.710 |
| 49 | 232,362.134 | 171,161.333 | 1,089.881 | 232,048.400 | 170,195.759 | 1,089.881 |
| 50 | 232,275.490 | 171,156.792 | 1,091.053 | 231,966.499 | 170,205.815 | 1,091.053 |
| 51 | 232,188.846 | 171,152.251 | 1,092.224 | 231,884.598 | 170,215.871 | 1,092.224 |
| 52 | 232,102.202 | 171,147.710 | 1,093.395 | 231,802.697 | 170,225.927 | 1,093.395 |
| 53 | 232,015.558 | 171,143.169 | 1,094.567 | 231,720.796 | 170,235.984 | 1,094.567 |
| 54 | 231,928.915 | 171,138.629 | 1,095.738 | 231,638.895 | 170,246.040 | 1,095.738 |
| 55 | 231,842.271 | 171,134.088 | 1,096.909 | 231,556.994 | 170,256.096 | 1,096.909 |
| 56 | 231,755.627 | 171,129.547 | 1,098.081 | 231,475.093 | 170,266.152 | 1,098.081 |
| 57 | 231,668.983 | 171,125.006 | 1,099.252 | 231,393.192 | 170,276.208 | 1,099.252 |
| 58 | 231,582.339 | 171,120.465 | 1,100.423 | 231,311.291 | 170,286.265 | 1,100.423 |
| 59 | 231,495.695 | 171,115.925 | 1,101.594 | 231,229.390 | 170,296.321 | 1,101.594 |
| 60 | 231,409.051 | 171,111.384 | 1,102.766 | 231,147.489 | 170,306.377 | 1,102.766 |
| 61 | 231,322.407 | 171,106.843 | 1,103.937 | 231,065.588 | 170,316.433 | 1,103.937 |

Table III-1. Bounding Coordinates for the Emplacement Area by Emplacement Drift (Continued)

| Drift Number | East Side of Emplacement Drift | | | West Side of Emplacement Drift | | |
|---|---|---|---|---|---|---|
| | Northing[1] (m) | Easting[1] (m) | Elevation (m) | Northing[1] (m) | Easting[1] (m) | Elevation (m) |
| 62 | 231,228.794 | 171,080.845 | 1,105.126 | 230,983.689 | 170,326.489 | 1,105.126 |
| 63 | 231,129.221 | 171,036.512 | 1,106.128 | 230,901.788 | 170,336.545 | 1,106.128 |
| 64 | 231,029.648 | 170,992.179 | 1,107.130 | 230,819.887 | 170,346.601 | 1,107.130 |
| 65 | 230,161.806 | 170,680.331 | 1,112.032 | 230,059.664 | 170,365.970 | 1,112.032 |
| 66 | 230,075.660 | 170,677.322 | 1,112.463 | 229,973.518 | 170,362.962 | 1,112.463 |
| 67 | 229,989.514 | 170,674.314 | 1,112.894 | 229,887.373 | 170,359.954 | 1,112.894 |
| 68 | 229,903.957 | 170,673.116 | 1,113.279 | 229,801.227 | 170,356.946 | 1,113.279 |
| 69 | 229,823.182 | 170,686.637 | 1,113.667 | 229,715.081 | 170,353.937 | 1,113.667 |
| 70 | 229,746.888 | 170,713.951 | 1,114.115 | 229,628.935 | 170,350.929 | 1,114.115 |
| 71 | 229,671.164 | 170,743.018 | 1,114.549 | 229,543.716 | 170,350.774 | 1,114.549 |
| 72 | 229,595.440 | 170,772.086 | 1,115.001 | 229,454.670 | 170,338.840 | 1,115.001 |
| 73 | 229,519.716 | 170,801.154 | 1,115.479 | 229,361.994 | 170,315.734 | 1,115.479 |
| 74 | 229,443.993 | 170,830.221 | 1,115.957 | 229,269.318 | 170,292.627 | 1,115.957 |
| 75 | 229,368.269 | 170,859.289 | 1,116.434 | 229,176.641 | 170,269.520 | 1,116.434 |
| 76 | 229,292.545 | 170,888.357 | 1,116.912 | 229,083.965 | 170,246.413 | 1,116.912 |
| 77 | 229,216.821 | 170,917.424 | 1,117.389 | 228,991.289 | 170,223.306 | 1,117.389 |
| 78 | 229,141.098 | 170,946.492 | 1,117.275 | 228,898.612 | 170,200.200 | 1,117.275 |
| 79 | 229,065.285 | 170,975.285 | 1,116.251 | 228,804.965 | 170,174.104 | 1,116.251 |
| 80 | 228,986.633 | 170,995.342 | 1,115.190 | 228,721.372 | 170,178.952 | 1,115.190 |
| 81 | 228,907.407 | 171,013.632 | 1,114.059 | 228,646.270 | 170,209.934 | 1,114.059 |
| 82 | 228,828.182 | 171,031.923 | 1,112.851 | 228,573.648 | 170,248.548 | 1,112.851 |
| 83 | 228,748.957 | 171,050.214 | 1,111.535 | 228,501.026 | 170,287.162 | 1,111.535 |
| 84 | 228,669.731 | 171,068.504 | 1,110.219 | 228,428.404 | 170,325.776 | 1,110.219 |
| 85 | 228,590.506 | 171,086.795 | 1,108.903 | 228,355.782 | 170,364.389 | 1,108.903 |
| 86 | 228,511.280 | 171,105.085 | 1,107.587 | 228,283.160 | 170,403.003 | 1,107.587 |
| 87 | 228,432.055 | 171,123.376 | 1,106.271 | 228,210.538 | 170,441.617 | 1,106.271 |
| 88 | 228,352.829 | 171,141.667 | 1,104.955 | 228,137.916 | 170,480.231 | 1,104.955 |
| 89 | 228,273.604 | 171,159.957 | 1,103.663 | 228,065.294 | 170,518.845 | 1,103.663 |
| 90 | 228,194.378 | 171,178.248 | 1,102.370 | 227,992.672 | 170,557.459 | 1,102.370 |
| 91 | 228,115.153 | 171,196.539 | 1,101.078 | 227,920.050 | 170,596.072 | 1,101.078 |

1 The coordinates are northing and easting metric values of coordinates converted from the Nevada State Plane Coordinate System, NAD 27 (see Section 4.1.1.2).

## ATTACHMENT IV

## EXCAVATION QUANTITIES

## ATTACHMENT IV

## EXCAVATION QUANTITIES

Excavation quantities extracted from the *Electronic files in support of ANL-WER-MD-000002 REV 00* (BSC 2001aa) using VULCAN v3.4 for subsurface headings are discussed in the following sections.

Heading lengths are expressed in slope length. The slope length of a heading refers to the actual length excavated at the specified gradient of the heading.

Opening profile areas are outlined in Table IV-1. Circular openings have been calculated as $\pi r^2$, where r is the radius of the opening. Horseshoe profile openings have been calculated based on 1/2 the circular area for the top portion plus the rectangular area on the bottom portion.

All opening sizes presented are considered nominal values only. As a part of future detailed design, opening sizes will include tolerance values for construction and operations.

Table IV-1. Excavated Opening Areas

| Opening Profile | Nominal Opening Size (meters) | | | | Area ($m^2$) |
|---|---|---|---|---|---|
| | Diameter | Radius | Width | Height | |
| Circular | 7.62 | 3.81 | -- | -- | 45.60 |
| Circular | 5.5 | 2.75 | -- | -- | 23.76 |
| Circular | 8.0 | 4.0 | -- | -- | 50.27 |
| Circular | 2.0 | 1.0 | -- | -- | 3.14 |
| Horseshoe | -- | 4.0 | 8.0 | 7.0 | 49.13 |
| Horseshoe | -- | 4.0 | 8.0 | 8.5 | 61.13 |

### IV.1 70,000 MTHM Case

**Access Mains** — The access mains and the Exhaust Main are excavated at a diameter of 7.62 meters (see Section 6.1.2.1.1). The excavated circular cross-sectional area of these headings is 45.60 $m^2$. The lengths of the access mains and the Exhaust Main, as well as the excavated volumes, are outlined in Table IV-2.

Table IV-2. Access Mains Excavated Length and Volume for 70,000 MTHM Case

| Heading Designation | Description[a] | | Excavation Length (m) | Shape Of Opening | Profile (m) | Area ($m^2$) | Volume ($m^3$) |
|---|---|---|---|---|---|---|---|
| | From Point | To Point | | | | | |
| North Ramp | | | Existing | Circular | 7.62 | 45.60 | Existing |
| East Main | | | Existing | Circular | 7.62 | 45.60 | Existing |
| South Ramp | | | Existing | Circular | 7.62 | 45.60 | Existing |
| North Ramp Extension | 42 | 2 | 2003.7 | Circular | 7.62 | 45.60 | 91,368.7 |
| East Main North Extension | 1 | 4 | 2,500.0 | Circular | 7.62 | 45.60 | 114,000.0 |
| North Main | 4 | 9 | 1,256.8 | Circular | 7.62 | 45.60 | 57,310.1 |
| West Main | 9 | 28 | 8,727.3 | Circular | 7.62 | 45.60 | 397,964.9 |
| South Main | 17 | 20 | 793.4 | Circular | 7.62 | 45.60 | 36,179.0 |
| Exhaust Main | 3 | 34 | 12,435.0 | Circular | 7.62 | 45.60 | 567,036.0 |
| East Main South Extension | 32 | 23 | 3,334.6 | Circular | 7.62 | 45.60 | 152,057.8 |
| South End Main | 28 | 32 | 1,263.2 | Circular | 7.62 | 45.60 | 57,601.9 |
| Total | | | 32,314.0 | | | | 1,473,518.4 |

[a] Points refer to key reference points defined in Attachment II, Table II-1

**Emplacement Drifts** — The emplacement drifts are excavated at a diameter of 5.5 meters (see Section 4.2.1.1.3). The excavated circular cross-sectional area of these headings is 23.76 $m^2$. The lengths of the emplacement drifts, as well as the excavated volumes, are outlined in Table IV-3.

The emplacement drift turnouts will be excavated with a horseshoe-shaped profile of 8 meters wide and 7 meters high (see Section 6.1.2.1.2). The cross-sectional area of the turnouts is 49.13 $m^2$. The lengths of the turnouts, as well as the excavated volumes, are outlined in Table IV-4.

Table IV-3. Emplacement Drifts Excavated Length and Volume for 70,000 MTHM Case

| Drift Number | Length (m) | Volume ($m^3$) | | Drift Number | Length (m) | Volume ($m^3$) | | Drift Number | Length (m) | Volume ($m^3$) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 741.7 | 17,622.8 | | 32 | 1,263.5 | 30,020.8 | | 63 | 739.0 | 17,558.6 |
| 2 | 781.1 | 18,558.9 | | 33 | 1,263.8 | 30,027.9 | | 64 | 681.8 | 16,199.6 |
| 3 | 820.4 | 19,492.7 | | 34 | 1,248.5 | 29,664.4 | | 65 | 333.5 | 7,924.0 |
| 4 | 859.7 | 20,426.5 | | 35 | 1,233.1 | 29,298.5 | | 66 | 333.5 | 7,924.0 |
| 5 | 899.0 | 21,360.2 | | 36 | 1,217.8 | 28,934.9 | | 67 | 333.5 | 7,924.0 |
| 6 | 938.3 | 22,294.0 | | 37 | 1,202.4 | 28,569.0 | | 68 | 335.4 | 7,969.1 |
| 7 | 977.7 | 23,230.2 | | 38 | 1,187.1 | 28,205.5 | | 69 | 352.8 | 8,382.5 |
| 8 | 1,017.0 | 24,163.9 | | 39 | 1,171.7 | 27,839.6 | | 70 | 384.7 | 9,140.5 |
| 9 | 1,056.3 | 25,097.7 | | 40 | 1,156.4 | 27,476.1 | | 71 | 415.4 | 9,869.9 |
| 10 | 1,095.6 | 26,031.5 | | 41 | 1,141.1 | 27,112.5 | | 72 | 458.5 | 10,894.0 |
| 11 | 1,134.9 | 26,965.2 | | 42 | 1,125.7 | 26,746.6 | | 73 | 513.4 | 12,198.4 |
| 12 | 1,174.3 | 27,901.4 | | 43 | 1,110.4 | 26,383.1 | | 74 | 568.3 | 13,502.8 |
| 13 | 1,230.0 | 29,224.8 | | 44 | 1,095.0 | 26,017.2 | | 75 | 623.1 | 14,804.9 |
| 14 | 1,263.5 | 30,020.8 | | 45 | 1,079.7 | 25,653.7 | | 76 | 678 | 16,109.3 |
| 15 | 1,263.5 | 30,020.8 | | 46 | 1,064.3 | 25,287.8 | | 77 | 732.8 | 17,411.3 |
| 16 | 1,263.5 | 30,020.8 | | 47 | 1,049.0 | 24,924.2 | | 78 | 787.7 | 18,715.8 |
| 17 | 1,263.5 | 30,020.8 | | 48 | 1,033.6 | 24,558.3 | | 79 | 845.4 | 20,086.7 |
| 18 | 1,263.5 | 30,020.8 | | 49 | 1,018.3 | 24,194.8 | | 80 | 861.4 | 20,466.9 |
| 19 | 1,263.5 | 30,020.8 | | 50 | 1,002.9 | 23,828.9 | | 81 | 848.1 | 20,150.9 |
| 20 | 1,263.5 | 30,020.8 | | 51 | 987.6 | 23,465.4 | | 82 | 826.7 | 19,642.4 |
| 21 | 1,263.5 | 30,020.8 | | 52 | 972.2 | 23,099.5 | | 83 | 805.3 | 19,133.9 |
| 22 | 1,263.5 | 30,020.8 | | 53 | 956.9 | 22,735.9 | | 84 | 784.0 | 18,627.8 |
| 23 | 1,263.5 | 30,020.8 | | 54 | 941.5 | 22,370.0 | | 85 | 762.6 | 18,119.4 |
| 24 | 1,263.5 | 30,020.8 | | 55 | 926.2 | 22,006.5 | | | | |
| 25 | 1,263.5 | 30,020.8 | | 56 | 910.8 | 21,640.6 | | | | |
| 26 | 1,263.5 | 30,020.8 | | 57 | 895.5 | 21,277.1 | | | | |
| 27 | 1,263.5 | 30,020.8 | | 58 | 880.1 | 20,911.2 | | | | |
| 28 | 1,263.5 | 30,020.8 | | 59 | 864.8 | 20,547.6 | | | | |
| 29 | 1,263.5 | 30,020.8 | | 60 | 849.4 | 20,181.7 | | | | |
| 30 | 1,263.5 | 30,020.8 | | 61 | 834.1 | 19,818.2 | | | | |
| 31 | 1,263.5 | 30,020.8 | | 62 | 796.2 | 18,917.7 | | | | |
| Subtotal | 35,469.0 | 842,743.4 | | Subtotal | 32,479.6 | 771,715.3 | | Subtotal | 14,004.9 | 332756.4 |

| | | |
|---|---|---|
| Total Length | 81,953.5 | m |
| Total Volume | 1,947,215.2 | $m^3$ |

Table IV-4. Emplacement Drift Turnouts Excavated Length and Volume for 70,000 MTHM Case

| Turnout Description | Quantity | Centerline Length (m) | Total Length (m) | Excavation Volume ($m^3$) | Total Volume ($m^3$) |
|---|---|---|---|---|---|
| East Main Turnouts | | | | | |
| Turnouts 1 through 61 | 61 | 79.5 | 4,849.5 | 3,905.8 | 238,255.9 |
| Turnouts 62 through 64 | 3 | 86.9 | 260.7 | 4,269.4 | 12,808.2 |
| Turnouts 65 through 67 | 3 | 79.2 | 237.6 | 3,891.1 | 11,673.3 |
| Turnout 68 | 1 | 74.1 | 74.1 | 3,640.5 | 3,640.5 |
| Turnout 69 | 1 | 70.3 | 70.3 | 3,453.8 | 3,453.8 |
| Turnouts 70 through 78 | 9 | 71.9 | 647.1 | 3,532.4 | 31,792.0 |
| Turnouts 79 through 85 | 7 | 74.4 | 520.8 | 3,655.3 | 25,586.9 |
| West Main Turnouts | | | | | |
| Turnouts 1 through 12 | 12 | 110.9 | 1,330.8 | 5,448.5 | 65,382.2 |
| Turnout 13 | 1 | 93.2 | 93.2 | 4,578.9 | 4,578.9 |
| Turnouts 14 through 32 | 19 | 75.6 | 1,436.4 | 3,714.2 | 70,570.3 |
| Turnouts 33 through 64 | 32 | 72.9 | 2,332.8 | 3,581.6 | 114,610.5 |
| Turnouts 65 through 70 | 6 | 75.2 | 451.2 | 3,694.6 | 22,167.5 |
| Turnout 71 | 1 | 76.3 | 76.3 | 3,748.6 | 3,748.6 |
| Turnouts 72 through 78 | 7 | 84.1 | 588.7 | 4,131.8 | 28,922.8 |
| Turnout 79 | 1 | 75.6 | 75.6 | 3,714.2 | 3,714.2 |
| Turnout 80 | 1 | 73.2 | 73.2 | 3,596.3 | 3,596.3 |
| Turnouts 81 through 85 | 5 | 75.7 | 378.5 | 3,719.1 | 18,595.7 |
| Total | 170 | | 13,496.8 | | 663,097.8 |

**Intake Shafts** — The intake shafts will be excavated with a diameter of 8 meters, and a circular cross-sectional area of 50.27 $m^2$. The intake shafts will be excavated from the surface to the repository elevation, and will include a sump at the bottom, excavated 5 meters deep with an 8-meter diameter (see Section 5.1.2.4). The intake shaft accesses will be excavated at a diameter of 7.62 meters (see Section 6.1.2.4), and a circular cross-sectional area of 45.60 $m^2$. The intake shaft access turnouts will be excavated with a horseshoe-shaped profile of 8 meters wide and 8.5 meters high, similar to the exhaust shaft accesses (see Section 6.1.2.4), with a cross-sectional area of 61.13 $m^2$. The depths of the intake shafts and the associated heading lengths with the excavated volume are outlined in Table IV-5 and Table IV-6.

Table IV-5. Intake Shafts Excavated Depth and Volume for 70,000 MTHM Case

| Shaft Number | Shaft Depth (m) | Shaft Sump Depth (m) | Total Shaft Depth (m) | Shaft Volume ($m^3$) |
|---|---|---|---|---|
| 1 | 386.4 | 5.0 | 391.4 | 19,675.7 |
| 2 | 321.9 | 5.0 | 326.9 | 16,433.3 |
| 3 | 275.4 | 5.0 | 280.4 | 14,095.7 |
| 4 | 289.2 | 5.0 | 294.2 | 14,789.4 |
| Totals | 1,272.9 | 20.0 | 1,292.9 | 64,994.1 |

Table IV-6. Intake Shaft Accesses and Turnouts Excavated Length and Volume for 70,000 MTHM Case

| Shaft Number | Access Length (m) | Volume ($m^3$) | East Turnout | | West Turnout | |
|---|---|---|---|---|---|---|
| | | | Length (m) | Volume ($m^3$) | Length (m) | Volume ($m^3$) |
| 1 | 1,076.0 | 49,065.6 | 79.5 | 4,859.8 | 75.6 | 4,621.4 |
| 2 | 1,263.5 | 57,615.6 | 79.5 | 4,859.8 | 75.6 | 4,621.4 |
| 3 | 1,087.3 | 49,580.9 | 79.5 | 4,859.8 | 72.9 | 4,456.4 |
| 4 | 794.6 | 36,233.8 | 74.0 | 4,523.6 | 75.7 | 4,627.5 |
| Totals | 4,221.4 | 192,495.8 | 312.5 | 19,103.1 | 299.8 | 18,326.8 |

**Development/Intake Shaft** — The Development/Intake Shaft will be excavated to a diameter of 8 meters and a circular cross-sectional area of 50.27 $m^2$. The shaft will be excavated from the surface to the repository elevation, and will include a 5-meter deep sump at the bottom, (see Section 5.1.2.4). The Development Shaft provides intake airflow for the construction and development operations in the Subsurface Facility (see Section 6.1.2.4). The Access 1 of the Development/Intake Shaft will be excavated to a horseshoe-shaped profile of 8 meters wide and 8.5 meters high (see Section 6.1.2.4), with a cross-sectional area of 61.13 $m^2$. The Access 2 of the Development/Intake Shaft will be excavated to a diameter of 7.62 meters (see Section 6.1.2.4), and a circular cross-sectional area of 45.60 $m^2$. The depth of the Development Shaft and associated heading lengths, including the excavated volume, are outlined in Table IV-7 and Table IV-8.

Table IV-7. Development/Intake Shaft Excavated Depth and Volume for 70,000 MTHM Case

| Shaft Depth (m) | Shaft Sump Depth (m) | Total Shaft Depth (m) | Shaft Volume ($m^3$) |
|---|---|---|---|
| 282.7 | 5.0 | 287.7 | 14,462.7 |

Table IV-8. Development Shaft Accesses Excavated Lengths and Volumes for 70,000 MTHM Case

| Access Number | Access Length (m) | Volume ($m^3$) |
|---|---|---|
| 1 | 16.9 | 1,033.1 |
| 2 | 389.0 | 17,738.4 |
| Totals | 405.9 | 18,771.5 |

**Exhaust Shafts** — The exhaust shafts will be excavated to a diameter of 8 meters, and a circular cross-sectional area of 50.27 $m^2$. The shafts will be excavated from the surface to the repository elevation, and will include a 5-meter deep sump at the bottom (see Section 5.1.2.4). The exhaust shaft accesses will be excavated in a horseshoe-shaped profile of 8 meters wide and 8.5 meters high (see Section 6.1.2.4), with a cross-sectional area of 61.13 $m^2$. The depths of the exhaust shafts and the associated heading lengths, including the excavated volume, are outlined in Table IV-9 and Table IV-10.

Table IV-9. Exhaust Shafts Excavated Depth and Volume for 70,000 MTHM Case

| Shaft Number | Shaft Depth (m) | Shaft Sump Depth(m) | Total Shaft Depth (m) | Shaft Volume ($m^3$) |
|---|---|---|---|---|
| 1 | 404.8 | 5.0 | 409.8 | 20,600.6 |
| 2 | 391.7 | 5.0 | 396.7 | 19,942.1 |
| 3 | 371.6 | 5.0 | 376.6 | 18,931.7 |
| 4 | 315.5 | 5.0 | 320.5 | 16,111.5 |
| 5 | 340.5 | 5.0 | 345.5 | 17,368.3 |
| 6 | 261.4 | 5.0 | 266.4 | 13,391.9 |
| Total | 2,085.5 | 30.0 | 2,115.5 | 106,346.2 |

Table IV-10. Exhaust Shaft Accesses Excavated Length and Volume for 70,000 MTHM Case

| Shaft Number | Access #1 Length (m) | Access #1 Volume ($m^3$) | Access #2 Length (m) | Access #2 Volume ($m^3$) |
|---|---|---|---|---|
| 1 | 194.8 | 11,908.1 | 621.9 | 38,016.7 |
| 2 | 315.9 | 19,311.0 | 670.7 | 40,999.9 |
| 3 | 346.8 | 21,199.9 | 607.2 | 37,118.1 |
| 4 | 138.4 | 8,460.4 | 290.4 | 17,752.2 |
| 5 | 520.4 | 31,812.1 | 472.9 | 28,908.4 |
| 6 | 219.2 | 13,399.7 | 0.0 | 0.0 |
| Total | 1,735.5 | 106,091.1 | 2,663.1 | 162,795.3 |

**Emplacement Drift Ventilation Raises** — The emplacement drift ventilation raises channel the exhaust air from each emplacement drifts to the Exhaust Main service side where ductwork directs the airflow to the exhaust side (see Section 6.1.2.4). The raises will be excavated to a diameter of 2 meters (see Section 6.1.2.4), and a circular cross-sectional area of 3.14 $m^2$. The lengths of the ventilation raises, including the excavated volume, are outlined in Table IV-11.

Table IV-11. Ventilation Raises Excavated Length and Volume for 70,000 MTHM Case

| Drift Number | Length (m) | Volume ($m^3$) | | Drift Number | Length (m) | Volume ($m^3$) | | Drift Number | Length (m) | Volume ($m^3$) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 10.6 | 33.3 | | 32 | 23.7 | 74.4 | | 63 | 16.8 | 52.8 |
| 2 | 11.1 | 34.9 | | 33 | 24.1 | 75.7 | | 64 | 16.6 | 52.2 |
| 3 | 11.5 | 36.1 | | 34 | 24.5 | 77.0 | | 65 | 12.8 | 40.3 |
| 4 | 11.9 | 37.4 | | 35 | 25.0 | 78.4 | | 66 | 12.8 | 40.3 |
| 5 | 12.3 | 38.8 | | 36 | 25.4 | 79.7 | | 67 | 12.8 | 40.3 |
| 6 | 12.8 | 40.1 | | 37 | 25.4 | 79.8 | | 68 | 12.9 | 40.5 |
| 7 | 13.2 | 41.4 | | 38 | 25.1 | 78.8 | | 69 | 12.9 | 40.6 |
| 8 | 13.6 | 42.7 | | 39 | 24.8 | 77.7 | | 70 | 12.9 | 40.6 |
| 9 | 14.0 | 44.0 | | 40 | 24.4 | 76.7 | | 71 | 12.9 | 40.6 |
| 10 | 14.4 | 45.4 | | 41 | 24.1 | 75.7 | | 72 | 12.9 | 40.5 |
| 11 | 14.9 | 46.7 | | 42 | 23.8 | 74.6 | | 73 | 12.9 | 40.4 |
| 12 | 15.3 | 48.0 | | 43 | 23.4 | 73.6 | | 74 | 12.8 | 40.2 |
| 13 | 15.7 | 49.3 | | 44 | 23.1 | 72.5 | | 75 | 12.8 | 40.1 |
| 14 | 16.1 | 50.6 | | 45 | 22.8 | 71.5 | | 76 | 12.7 | 40.0 |
| 15 | 16.5 | 52.0 | | 46 | 22.4 | 70.5 | | 77 | 12.7 | 39.8 |
| 16 | 17.0 | 53.3 | | 47 | 22.1 | 69.4 | | 78 | 13.2 | 41.5 |
| 17 | 17.4 | 54.6 | | 48 | 21.8 | 68.4 | | 79 | 14.7 | 46.1 |
| 18 | 17.8 | 55.9 | | 49 | 21.5 | 67.4 | | 80 | 16.2 | 50.7 |
| 19 | 18.2 | 57.2 | | 50 | 21.1 | 66.3 | | 81 | 17.7 | 55.6 |
| 20 | 18.6 | 58.6 | | 51 | 20.8 | 65.3 | | 82 | 19.3 | 60.6 |
| 21 | 19.1 | 59.9 | | 52 | 20.5 | 64.2 | | 83 | 21.0 | 66.0 |
| 22 | 19.5 | 61.2 | | 53 | 20.1 | 63.2 | | 84 | 22.8 | 71.4 |
| 23 | 19.9 | 62.5 | | 54 | 19.8 | 62.2 | | 85 | 24.5 | 76.8 |
| 24 | 20.3 | 63.8 | | 55 | 19.5 | 61.1 | | | | |
| 25 | 20.8 | 65.2 | | 56 | 19.1 | 60.1 | | | | |
| 26 | 21.2 | 66.5 | | 57 | 18.8 | 59.0 | | | | |
| 27 | 21.6 | 67.8 | | 58 | 18.5 | 58.0 | | | | |
| 28 | 22.0 | 69.1 | | 59 | 18.1 | 57.0 | | | | |
| 29 | 22.4 | 70.4 | | 60 | 17.8 | 56.0 | | | | |
| 30 | 22.9 | 71.8 | | 61 | 17.4 | 54.7 | | | | |
| 31 | 23.3 | 73.1 | | 62 | 17.0 | 53.5 | | | | |
| Subtotal | 526.0 | 1,651.5 | | Subtotal | 675.9 | 2,122.5 | | Subtotal | 349.7 | 1,098.0 |

Total Length 1,551.6 m
Total Volume 4,872.0 $m^3$

**Ventilation Raise Alcoves —**

Number of Emplacement Drifts 85
Length of Each Alcove 5.0 m
Volume of Each Alcove 127.8 $m^3$ As calculated by VULCAN v3.4 (see Figure IV-1)

Total Length of Alcoves 425.0 m
Total Volume of Alcoves 10,863.0 $m^3$

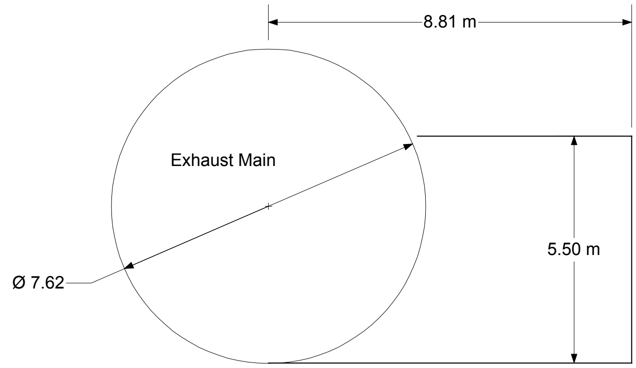



Figure IV-1. Ventilation Raise Alcove Arrangement

**Standby Drifts** — The standby drifts are excavated at a diameter of 5.5 meters (see Section 6.1.2.1.2). The excavated circular cross-sectional area of these headings is 23.76 $m^2$. The standby drift turnouts will be excavated in a horseshoe-shaped profile of 8 meters wide and 7 meters high, similar to the emplacement drift turnouts (see Section 6.1.2.1.2), with a cross-sectional area of 49.13 $m^2$. The standby drifts also require ventilation raises to exhaust air to the Exhaust Main, exhaust side. These raises will be excavated to a diameter of 2 meters (see Section 6.1.2.4), similar to the emplacement drift raise, and a circular cross-sectional area of 3.14 $m^2$. The lengths of the standby drifts and the associated headings, including the excavated volumes, are outlined in Table IV-12.

Table IV-12. Standby Drifts Excavated Length and Volume for 70,000 MTHM Case

| Drift Number | Drift Length (m) | Volume ($m^3$) | East Turnout | | West Turnout | |
|---|---|---|---|---|---|---|
| | | | Length (m) | Volume ($m^3$) | Length (m) | Volume ($m^3$) |
| 1 | 997.3 | 23,695.8 | 79.5 | 3,905.8 | 110.9 | 5,448.5 |
| 2 | 1,263.5 | 30,020.8 | 79.5 | 3,905.8 | 75.6 | 3,714.2 |
| Totals | 2,260.8 | 53,716.6 | 159.0 | 7,811.7 | 186.5 | 9,162.7 |

| Drift Number | Raise Length (m) | Raise Volume ($m^3$) | Raise Alcove Length (m) | Raise Alcove Volume ($m^3$) |
|---|---|---|---|---|
| 1 | 17.2 | 54.0 | 5.0 | 127.8 |
| 2 | 17.0 | 53.4 | 5.0 | 127.8 |
| Totals | 34.2 | 107.4 | 10.0 | 255.6 |

**Crossblock Drifts** — The cross-block drifts are excavated at a diameter of 5.5 meters (see Section 6.1.2.1.2). The excavated circular cross-sectional area of these headings is 23.76 $m^2$. The cross-block drift turnouts will be excavated in a horseshoe-shaped profile of 8 meters wide and 7 meters high, similar to the emplacement drift turnouts (see Section 6.1.2.1.2), with a cross-sectional area of 49.13 $m^2$. The cross-block drifts also require ventilation raises to exhaust air to the Exhaust Main, service side. These raises will be excavated to a diameter of 2 meters (see Section 6.1.2.4), similar to the emplacement drift raise, and a circular cross-sectional area of 3.14 $m^2$. The lengths of the cross-block drifts and associated headings, including the excavated volume, are outlined in Table IV-13.

Table IV-13. Crossblock Drifts Excavated Length and Volume for 70,000 MTHM Case

| Drift Number | Drift Length (m) | Volume ($m^3$) | East Turnout | | West Turnout | |
|---|---|---|---|---|---|---|
| | | | Length (m) | Volume ($m^3$) | Length (m) | Volume ($m^3$) |
| 1 | 1,115.3 | 26,499.5 | 79.5 | 3,905.8 | 110.9 | 5,448.5 |
| 2 | 1,263.5 | 30,020.8 | 79.5 | 3,905.8 | 75.6 | 3,714.2 |
| 3 | 1,194.8 | 28,388.4 | 79.5 | 3,905.8 | 72.9 | 3,581.6 |
| 4 | 933.8 | 22,187.1 | 79.5 | 3,905.8 | 72.9 | 3,581.6 |
| Totals | 4,507.4 | 107,095.8 | 318.0 | 15,623.3 | 332.3 | 16,325.9 |

| Drift Number | Raise Length (m) | Raise Volume ($m^3$) | Raise Alcove Length (m) | Raise Alcove Volume ($m^3$) |
|---|---|---|---|---|
| 1 | 17.2 | 54.0 | 5.0 | 127.8 |
| 2 | 17.0 | 53.4 | 5.0 | 127.8 |
| 3 | 16.7 | 52.4 | 5.0 | 127.8 |
| 4 | 15.7 | 49.3 | 5.0 | 127.8 |
| Totals | 66.6 | 209.1 | 20.0 | 511.2 |

**Test and Evaluation Facility Drifts** — The PCTDs will be excavated to a diameter of 5.5 meters (see Section 6.1.2.1.3), and a circular cross-sectional area of 23.76 $m^2$. The PCTD turnouts will be excavated in a horseshoe-shaped profile of 8 meters wide and 7 meters high, similar to the emplacement drift turnouts (see Section 6.1.2.1.3), with a cross-sectional area of 49.13 $m^2$. The cross-block drifts also require ventilation raises to exhaust air to the Exhaust Main, exhaust side. These raises will be excavated to a diameter of 2 meters (see

Section 6.1.2.4), similar to the emplacement drift raise, and a circular cross-sectional area of 3.14 $m^2$. The lengths of the PCTDs and the associated headings, including the excavated volume, are outlined in Table IV-14.

The ODs will be excavated to a diameter of 5.5 meters (see Section 6.1.2.1.3), and a circular cross-sectional area of 23.76 $m^2$. The ODs also requires ventilation raises to exhaust air to the Exhaust Main, service side. These raises will be excavated to a diameter of 2 meters (see Section 6.1.2.4), similar to the emplacement drift raise, and a circular cross-sectional area of 3.14 $m^2$. The lengths of the ODs and the associated headings, including the excavated volume, are outlined in Table IV-15 and Table IV-16.

Table IV-14. Postclosure Test Drift Excavated Length and Volume for 70,000 MTHM Case

| Drift Number | Drift Length (m) | Volume ($m^3$) | East Turnout | | West Turnout | |
|---|---|---|---|---|---|---|
| | | | Length (m) | Volume ($m^3$) | Length (m) | Volume ($m^3$) |
| 1 | 697.2 | 16,565.5 | 77.0 | 3,783.0 | 110.9 | 5,448.5 |
| Totals | 697.2 | 16,565.5 | 77.0 | 3,783.0 | 110.9 | 5,448.5 |

| Drift Number | Raise Length (m) | Raise Volume ($m^3$) | Raise Alcove Length (m) | Raise Alcove Volume ($m^3$) |
|---|---|---|---|---|
| 1 | 10.0 | 31.4 | 5.0 | 127.8 |
| Totals | 10.0 | 31.4 | 5.0 | 127.8 |

Table IV-15. Observation Drifts Excavated Length and Volume for 70,000 MTHM Case

| Drift Number | Drift Length (m) | Volume ($m^3$) |
|---|---|---|
| 1 | 2,191.5 | 52,070.0 |
| 2 | 1,045.5 | 24,841.1 |
| 3 | 1,957.6 | 46,512.6 |
| 4 | 1,640.5 | 38,978.3 |
| Total | 6,835.1 | 162,402.0 |

Table IV-16. Observation Drift Raises Excavated Length and Volume for 70,000 MTHM Case

| Description | | Raise Length (m) | Raise Volume ($m^3$) | Raise Alcove Length (m) | Raise Alcove Volume ($m^3$) |
|---|---|---|---|---|---|
| From | To | | | | |
| ECRB | West Main | 28.0 | 87.8 | 5.0 | 127.8 |
| OD 1 | West Main | 10.0 | 31.4 | 5.0 | 127.8 |
| OD 1 | Exhaust Main | 28.7 | 90.1 | 5.0 | 127.8 |
| OD 2 | West Main | 10.0 | 31.4 | 5.0 | 127.8 |
| OD 2 | Exhaust Main | 29.5 | 92.7 | 5.0 | 127.8 |
| OD 3 | West Main | 16.1 | 50.6 | 5.0 | 127.8 |
| OD 3 | Exhaust Main | 44.0 | 138.1 | 5.0 | 127.8 |
| OD 4 | West Main | 13.6 | 42.6 | 5.0 | 127.8 |
| OD 4 | Exhaust Main | 31.2 | 97.9 | 5.0 | 127.8 |
| Total | | 211.1 | 662.8 | 45.0 | 1,150.2 |

## IV.2 97,000 MTHM Case

**Access Mains** — The access mains and theExhaust Main are excavated at a diameter of 7.62 meters (see Section 6.1.2.1.1). The excavated circular cross-sectional area of these headings is 45.60 $m^2$. The lengths of the access mains and the Exhaust Main, as well as the excavated volumes, are outlined in Table IV-17.

Table IV-17. Access Main Excavated Length and Volume for 97,000 MTHM Case

| Heading Designation | Description[a] | | Excavation Length (m) | Shape Of Opening | Profile (m) | Area ($m^2$) | Volume ($m^3$) |
|---|---|---|---|---|---|---|---|
| | From Point | To Point | | | | | |
| North Ramp | | | Existing | Circular | 7.62 | 45.60 | Existing |
| East Main | | | Existing | Circular | 7.62 | 45.60 | Existing |
| South Ramp | | | Existing | Circular | 7.62 | 45.60 | Existing |
| North Ramp Extension | 42 | 2 | 2003.7 | Circular | 7.62 | 45.60 | 91,368.7 |
| East Main North Extension | 1 | 4 | 2,500.0 | Circular | 7.62 | 45.60 | 114,000.0 |
| North Main | 4 | 9 | 1,256.8 | Circular | 7.62 | 45.60 | 57,310.1 |
| West Main | 9 | 28 | 8,727.3 | Circular | 7.62 | 45.60 | 397,964.9 |
| South Main | 17 | 20 | 793.4 | Circular | 7.62 | 45.60 | 36,179.0 |
| Exhaust Main | 3 | 34 | 12,435.0 | Circular | 7.62 | 45.60 | 567,036.0 |
| East Main South Extension | 32 | 23 | 3,334.6 | Circular | 7.62 | 45.60 | 152,057.8 |
| South End Main | 28 | 32 | 1,263.2 | Circular | 7.62 | 45.60 | 57,601.9 |
| Lower Block Ramp 1 | 44 | 63 | 1,768.8 | Circular | 7.62 | 45.60 | 80,657.3 |
| Lower Block Ramp 2 | 60 | 75 | 1,225.7 | Circular | 7.62 | 45.60 | 55,891.9 |
| Lower Block Ramp 3 | 84 | 65 | 4,551.5 | Circular | 7.62 | 45.60 | 207,548.4 |
| Lower East Main | 63 | 67 | 4,425.0 | Circular | 7.62 | 45.60 | 201,780.0 |
| Lower West Main | 72 | 75 | 4,427.2 | Circular | 7.62 | 45.60 | 201,880.3 |
| Lower South Main | 67 | 72 | 1,825.6 | Circular | 7.62 | 45.60 | 83,247.4 |
| Lower Exhaust Main | 76 | 69 | 5,684.3 | Circular | 7.62 | 45.60 | 259,204.1 |
| Total | | | 56,222.1 | | | | 2,563,727.8 |

[a] Points refer to key reference points defined in Attachment II, Table II-1

**Emplacement Drifts** — The emplacement drifts are excavated at a diameter of 5.5 meters (see Section 4.2.1.1.3). The excavated circular cross-sectional area of these headings is 23.76 $m^2$. The lengths of the emplacement drifts, as well as the excavated volumes, are outlined in Table IV-18.

The emplacement drift turnouts will be excavated with a horseshoe-shaped profile of 8 meters wide and 7 meters high (see Section 6.1.2.1.2). The cross-sectional area of the turnouts is 49.13 $m^2$ (see Figure 4). The lengths of the turnouts, as well as the excavated volumes, are outlined in Table IV-19.

Table IV-18. Emplacement Drifts Excavated Length and Volume for 97,000 MTHM Case

| Drift Number | Length (m) | Volume ($m^3$) | | Drift Number | Length (m) | Volume ($m^3$) |
|---|---|---|---|---|---|---|
| 1 | 734.7 | 17,456.5 | | 32 | 1,263.5 | 30,020.8 |
| 2 | 781.1 | 18,558.9 | | 33 | 1,263.8 | 30,027.9 |
| 3 | 820.4 | 19,492.7 | | 34 | 1,248.5 | 29,664.4 |
| 4 | 859.7 | 20,426.5 | | 35 | 1,233.1 | 29,298.5 |
| 5 | 899.0 | 21,360.2 | | 36 | 1,217.8 | 28,934.9 |
| 6 | 938.3 | 22,294.0 | | 37 | 1,202.4 | 28,569.0 |
| 7 | 977.7 | 23,230.2 | | 38 | 1,187.1 | 28,205.5 |
| 8 | 1,017.0 | 24,163.9 | | 39 | 1,171.7 | 27,839.6 |
| 9 | 1,056.3 | 25,097.7 | | 40 | 1,156.4 | 27,476.1 |
| 10 | 1,095.6 | 26,031.5 | | 41 | 1,141.1 | 27,112.5 |
| 11 | 1,134.9 | 26,965.2 | | 42 | 1,125.7 | 26,746.6 |
| 12 | 1,174.3 | 27,901.4 | | 43 | 1,110.4 | 26,383.1 |
| 13 | 1,230.0 | 29,224.8 | | 44 | 1,095.0 | 26,017.2 |
| 14 | 1,263.5 | 30,020.8 | | 45 | 1,079.7 | 25,653.7 |
| 15 | 1,263.5 | 30,020.8 | | 46 | 1,064.3 | 25,287.8 |
| 16 | 1,263.5 | 30,020.8 | | 47 | 1,049.0 | 24,924.2 |
| 17 | 1,263.5 | 30,020.8 | | 48 | 1,033.6 | 24,558.3 |
| 18 | 1,263.5 | 30,020.8 | | 49 | 1,018.3 | 24,194.8 |
| 19 | 1,263.5 | 30,020.8 | | 50 | 1,002.9 | 23,828.9 |
| 20 | 1,263.5 | 30,020.8 | | 51 | 987.6 | 23,465.4 |
| 21 | 1,263.5 | 30,020.8 | | 52 | 972.2 | 23,099.5 |
| 22 | 1,263.5 | 30,020.8 | | 53 | 956.9 | 22,735.9 |
| 23 | 1,263.5 | 30,020.8 | | 54 | 941.5 | 22,370.0 |
| 24 | 1,263.5 | 30,020.8 | | 55 | 926.2 | 22,006.5 |
| 25 | 1,263.5 | 30,020.8 | | 56 | 910.8 | 21,640.6 |
| 26 | 1,263.5 | 30,020.8 | | 57 | 895.5 | 21,277.1 |
| 27 | 1,263.5 | 30,020.8 | | 58 | 880.1 | 20,911.2 |
| 28 | 1,263.5 | 30,020.8 | | 59 | 864.8 | 20,547.6 |
| 29 | 1,263.5 | 30,020.8 | | 60 | 849.4 | 20,181.7 |
| 30 | 1,263.5 | 30,020.8 | | 61 | 834.1 | 19,818.2 |
| 31 | 1,263.5 | 30,020.8 | | 62 | 796.2 | 18,917.7 |
| Subtotal | 35,462.0 | 842,577.1 | | Subtotal | 32,479.6 | 771,715.3 |

Table IV-18. Emplacement Drifts Excavated Length and Volume for 97,000 MTHM Case (continued)

| Drift Number | Length (m) | Volume ($m^3$) | | Drift Number | Length (m) | Volume ($m^3$) |
|---|---|---|---|---|---|---|
| 63 | 739.0 | 17,558.6 | | L3 | 1,207.0 | 28,678.3 |
| 64 | 681.8 | 16,199.6 | | L4 | 1,207.0 | 28,678.3 |
| 65 | 333.5 | 7,924.0 | | L5 | 1,207.0 | 28,678.3 |
| 66 | 333.5 | 7,924.0 | | L6 | 1,207.0 | 28,678.3 |
| 67 | 333.5 | 7,924.0 | | L7 | 1,207.0 | 28,678.3 |
| 68 | 335.4 | 7,969.1 | | L8 | 1,207.0 | 28,678.3 |
| 69 | 352.8 | 8,382.5 | | L9 | 1,207.0 | 28,678.3 |
| 70 | 384.7 | 9,140.5 | | L10 | 1,207.0 | 28,678.3 |
| 71 | 415.4 | 9,869.9 | | L11 | 1,207.0 | 28,678.3 |
| 72 | 458.5 | 10,894.0 | | L12 | 1,207.0 | 28,678.3 |
| 73 | 513.4 | 12,198.4 | | L13 | 1,207.0 | 28,678.3 |
| 74 | 568.3 | 13,502.8 | | L14 | 1,207.0 | 28,678.3 |
| 75 | 623.1 | 14,804.9 | | L15 | 1,207.0 | 28,678.3 |
| 76 | 678 | 16,109.3 | | L16 | 1,207.0 | 28,678.3 |
| 77 | 732.8 | 17,411.3 | | L17 | 1,207.0 | 28,678.3 |
| 78 | 787.7 | 18,715.8 | | L18 | 1,207.0 | 28,678.3 |
| 79 | 845.4 | 20,086.7 | | L19 | 1,207.0 | 28,678.3 |
| 80 | 861.4 | 20,466.9 | | | | |
| 81 | 848.1 | 20,150.9 | | | | |
| 82 | 826.7 | 19,642.4 | | | | |
| 83 | 805.3 | 19,133.9 | | | | |
| 84 | 784.0 | 18,627.8 | | | | |
| 85 | 762.6 | 18,119.4 | | | | |
| 86 | 741.2 | 17,610.9 | | | | |
| 87 | 719.8 | 17,102.4 | | | | |
| 88 | 698.5 | 16,596.4 | | | | |
| 89 | 677.1 | 16,087.9 | | | | |
| 90 | 655.7 | 15,579.4 | | | | |
| 91 | 634.4 | 15,073.3 | | | | |
| L1 | 1,207.0 | 28,678.3 | | | | |
| L2 | 1,207.0 | 28,678.3 | | | | |
| Subtotal | 20,545.6 | 488,163.5 | | Subtotal | 20,519.0 | 487,531.4 |

| | | |
|---|---|---|
| Total Length | 109,006.2 | m |
| Total Volume | 2,589,987.3 | $m^3$ |

Table IV-19. Emplacement Drift Turnouts Excavated Length and Volume for 97,000 MTHM Case

| Turnout Description | Quantity | Centerline Length (m) | Total Length (m) | Excavation Volume ($m^3$) | Total Volume ($m^3$) |
|---|---|---|---|---|---|
| East Main Turnouts | | | | | |
| Turnouts 1 through 61 | 61 | 79.5 | 4,849.5 | 3,905.8 | 238,255.9 |
| Turnouts 62 through 64 | 3 | 86.9 | 260.7 | 4,269.4 | 12,808.2 |
| Turnouts 65 through 67 | 3. | 79.2 | 237.6 | 3,891.1 | 11,673.3 |
| Turnout 68 | 1 | 74.1 | 74.1 | 3,640.5 | 3,640.5 |
| Turnout 69 | 1 | 70.3 | 70.3 | 3,453.8 | 3,453.8 |
| Turnouts 70 through 78 | 9 | 71.9 | 647.1 | 3,532.4 | 31,792.0 |
| Turnouts 79 through 91 | 13 | 74.4 | 967.2 | 3,655.3 | 47,518.5 |
| Turnouts L1 through L19 | 19 | 79.5 | 1,510.5 | 3,905.8 | 74,210.9 |
| West Main Turnouts | | | | | |
| Turnouts 1 through 12 | 12 | 110.9 | 1,330.8 | 5,448.5 | 65,382.2 |
| Turnout 13 | 1 | 93.2 | 93.2 | 4,578.9 | 4,578.9 |
| Turnouts 14 through 32 | 19 | 75.6 | 1,436.4 | 3,714.2 | 70,570.3 |
| Turnouts 33 through 64 | 32 | 72.9 | 2,332.8 | 3,581.6 | 114,610.5 |
| Turnouts 65 through 70 | 6 | 75.2 | 451.2 | 3,694.6 | 22,167.5 |
| Turnout 71 | 1 | 76.3 | 76.3 | 3,748.6 | 3,748.6 |
| Turnouts 72 through 78 | 7 | 84.1 | 588.7 | 4,131.8 | 28,922.8 |
| Turnout 79 | 1 | 75.6 | 75.6 | 3,714.2 | 3,714.2 |
| Turnout 80 | 1 | 73.2 | 73.2 | 3,596.3 | 3,596.3 |
| Turnouts 81 through 91 | 11 | 75.7 | 832.7 | 3,719.1 | 40,910.6 |
| Turnouts L1 through L19 | 19 | 75.6 | 1,436.4 | 3,714.2 | 70,570.3 |
| Total | 220 | | 17,344.3 | | 852,125.5 |

**Intake Shafts** — The intake shafts will be excavated with a diameter of 8 meters, and a circular cross-sectional area of 50.27 $m^2$. The shafts will be excavated from the surface to the repository elevation, and will include a sump at the bottom, excavated 5 meters deep (see Section 5.1.2.4). The intake shaft accesses will be excavated at a diameter of 7.62 meters (see Section 6.1.2.4), and a circular cross-sectional area of 45.60 $m^2$. The intake shaft access turnouts will be excavated with a horseshoe-shaped profile of 8 meters wide and 8.5 meters high, similar to the exhaust shaft accesses (see Section 6.1.2.4), with a cross-sectional area of 61.13 $m^2$. The depths of the intake shafts and the associated heading lengths with the excavated volume are outlined in Table IV-20 and Table IV-21.

Table IV-20. Intake Shafts Excavated Depth and Volume for 97,000 MTHM Case

| Shaft Number | Shaft Depth (m) | Shaft Sump Depth (m) | Total Shaft Depth (m) | Shaft Volume ($m^3$) |
|---|---|---|---|---|
| 1 | 386.4 | 5.0 | 391.4 | 19,675.7 |
| 2 | 321.9 | 5.0 | 326.9 | 16,433.3 |
| 3 | 275.4 | 5.0 | 280.4 | 14,095.7 |
| 4 | 289.2 | 5.0 | 294.2 | 14,789.4 |
| 5 | 283.4 | 5.0 | 288.4 | 14,497.9 |
| 6 (L) | 334.7 | 5.0 | 339.7 | 17,076.7 |
| Totals | 1,891.0 | 30.0 | 1,921.0 | 96,568.7 |

Table IV-21. Intake Shaft Accesses and Turnouts Excavated Length and Volume for 97,000 MTHM Case

| Shaft Number | Access Length (m) | Volume ($m^3$) | East Turnout | | West Turnout | |
|---|---|---|---|---|---|---|
| | | | Length (m) | Volume ($m^3$) | Length (m) | Volume ($m^3$) |
| 1 | 1,076.0 | 49,065.6 | 79.5 | 4,859.8 | 75.6 | 4,621.4 |
| 2 | 1,263.5 | 57,615.6 | 79.5 | 4,859.8 | 75.6 | 4,621.4 |
| 3 | 1,087.3 | 49,580.9 | 79.5 | 4,859.8 | 72.9 | 4,456.4 |
| 4 | 794.6 | 36,233.8 | 74.0 | 4,523.6 | 75.7 | 4,627.5 |
| 5 | 26.1 | 1,190.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 (L) | 1,207.0 | 55,039.2 | 79.5 | 4,859.8 | 75.6 | 4,621.4 |
| Totals | 5,454.5 | 248,725.2 | 392.0 | 23,963.0 | 375.4 | 22,948.2 |

**Development/Intake Shaft** — The Development/Intake Shaft will be excavated to a diameter of 8 meters and a circular cross-sectional area of 50.27 $m^2$. The shaft will be excavated from the surface to the repository elevation, and will include a 5-meter deep sump at the bottom, (see Section 5.1.2.4). The Development Shaft provides intake airflow for the construction and development operations in the Subsurface Facility (see Section 6.1.2.4). The Access 1 of the Development/Intake Shaft will be excavated to a horseshoe-shaped profile of 8 meters wide and 8.5 meters high (see Section 6.1.2.4), with a cross-sectional area of 61.13 $m^2$. The Access 2 of the Development/Intake Shaft will be excavated to a diameter of 7.62 meters (see Section 6.1.2.4), and a circular cross-sectional area of 45.60 $m^2$. The depth of the Development Shaft and associated heading lengths, including the excavated volume, are outlined in Table IV-22 and Table IV-23.

Table IV-22. Development/Intake Shaft Excavated Depth and Volume for 97,000 MTHM Case

| Shaft Depth (m) | Shaft Sump Depth (m) | Total Shaft Depth (m) | Shaft Volume ($m^3$) |
|---|---|---|---|
| 282.7 | 5.0 | 287.7 | 14,462.7 |

Table IV-23. Development Shaft Accesses Excavated Length and Volume for 97,000 MTHM Case

| Access Number | Access Length (m) | Volume ($m^3$) |
|---|---|---|
| 1 | 16.9 | 1,033.1 |
| 2 | 389.0 | 17,738.4 |
| Totals | 405.9 | 18,771.5 |

**Exhaust Shafts** — The exhaust shafts will be excavated to a diameter of 8 meters, and a circular cross-sectional area of 50.27 $m^2$. The shafts will be excavated from the surface to the repository elevation, and will include a 5-meter deep sump at the bottom (see Section 5.1.2.4). The exhaust shaft accesses will be excavated in a horseshoe-shaped profile of 8 meters wide and 8.5 meters high (see Section 6.1.2.4), with a cross-sectional area of 61.13 $m^2$. The depths of the exhaust shafts and the associated heading lengths, including the excavated volume, are outlined in Table IV-24 and Table IV-25.

Table IV-24. Exhaust Shafts Excavated Depth and Volume for 97,000 MTHM Case

| Shaft Number | Shaft Depth (m) | Shaft Sump Depth (m) | Total Shaft Depth (m) | Shaft Volume ($m^3$) |
|---|---|---|---|---|
| 1 | 404.8 | 5.0 | 409.8 | 20,600.6 |
| 2 | 391.7 | 5.0 | 396.7 | 19,942.1 |
| 3 | 371.6 | 5.0 | 376.6 | 18,931.7 |
| 4 | 315.5 | 5.0 | 320.5 | 16,111.5 |
| 5 | 340.5 | 5.0 | 345.5 | 17,368.3 |
| 6 | 261.4 | 5.0 | 266.4 | 13,391.9 |
| 7 (L) | 345.0 | 5.0 | 350.0 | 17,594.5 |
| 8 (L) | 337.5 | 5.0 | 342.5 | 17,217.5 |
| Total | 2,768.0 | 40.0 | 2,808.0 | 141,158.2 |

Table IV-25. Exhaust Shaft Accesses Excavated Length and Volume for 97,000 MTHM Case

| Shaft Number | Access #1 Length (m) | Access #1 Volume ($m^3$) | Access #2 Length (m) | Access #2 Volume ($m^3$) |
|---|---|---|---|---|
| 1 | 194.8 | 11,908.1 | 621.9 | 38,016.7 |
| 2 | 315.9 | 19,311.0 | 670.7 | 40,999.9 |
| 3 | 346.8 | 21,199.9 | 607.2 | 37,118.1 |
| 4 | 138.4 | 8,460.4 | 290.4 | 17,752.2 |
| 5 | 520.4 | 31,812.1 | 472.9 | 28,908.4 |
| 6 | 219.2 | 13,399.7 | 0.0 | 0.0 |
| 7 (L) | 618.3 | 37,796.7 | 429.8 | 26,273.7 |
| 8 (L) | 767.0 | 46,886.7 | 362.2 | 22,141.3 |
| Total | 3,120.8 | 190,774.5 | 3,455.1 | 211,210.3 |

**Emplacement Drift Ventilation Raises** — The emplacement drift ventilation raises channel the exhaust air from each emplacement drifts to the Exhaust Main, service side where ductwork directs the airflow to the exhaust side (see Section 6.1.2.4). The raises will be excavated to a diameter of 2 meters (see Section 6.1.2.4), and a circular cross-sectional area of 3.14 $m^2$. The lengths of the ventilation raises, including the excavated volume, are outlined in Table IV-26.

Table IV-26. Ventilation Raises Excavated Length and Volume for 97,000 MTHM Case

| Drift Number | Length (m) | Volume ($m^3$) | | Drift Number | Length (m) | Volume ($m^3$) |
|---|---|---|---|---|---|---|
| 1 | 10.6 | 33.3 | | 32 | 23.7 | 74.4 |
| 2 | 11.1 | 34.9 | | 33 | 24.1 | 75.7 |
| 3 | 11.5 | 36.1 | | 34 | 24.5 | 77.0 |
| 4 | 11.9 | 37.4 | | 35 | 25.0 | 78.4 |
| 5 | 12.3 | 38.8 | | 36 | 25.4 | 79.7 |
| 6 | 12.8 | 40.1 | | 37 | 25.4 | 79.8 |
| 7 | 13.2 | 41.4 | | 38 | 25.1 | 78.8 |
| 8 | 13.6 | 42.7 | | 39 | 24.8 | 77.7 |
| 9 | 14.0 | 44.0 | | 40 | 24.4 | 76.7 |
| 10 | 14.4 | 45.4 | | 41 | 24.1 | 75.7 |
| 11 | 14.9 | 46.7 | | 42 | 23.8 | 74.6 |
| 12 | 15.3 | 48.0 | | 43 | 23.4 | 73.6 |
| 13 | 15.7 | 49.3 | | 44 | 23.1 | 72.5 |
| 14 | 16.1 | 50.6 | | 45 | 22.8 | 71.5 |
| 15 | 16.5 | 52.0 | | 46 | 22.4 | 70.5 |
| 16 | 17.0 | 53.3 | | 47 | 22.1 | 69.4 |
| 17 | 17.4 | 54.6 | | 48 | 21.8 | 68.4 |
| 18 | 17.8 | 55.9 | | 49 | 21.5 | 67.4 |
| 19 | 18.2 | 57.2 | | 50 | 21.1 | 66.3 |
| 20 | 18.6 | 58.6 | | 51 | 20.8 | 65.3 |
| 21 | 19.1 | 59.9 | | 52 | 20.5 | 64.2 |
| 22 | 19.5 | 61.2 | | 53 | 20.1 | 63.2 |
| 23 | 19.9 | 62.5 | | 54 | 19.8 | 62.2 |
| 24 | 20.3 | 63.8 | | 55 | 19.5 | 61.1 |
| 25 | 20.8 | 65.2 | | 56 | 19.1 | 60.1 |
| 26 | 21.2 | 66.5 | | 57 | 18.8 | 59.0 |
| 27 | 21.6 | 67.8 | | 58 | 18.5 | 58.0 |
| 28 | 22.0 | 69.1 | | 59 | 18.1 | 57.0 |
| 29 | 22.4 | 70.4 | | 60 | 17.8 | 56.0 |
| 30 | 22.9 | 71.8 | | 61 | 17.4 | 54.7 |
| 31 | 23.3 | 73.1 | | 62 | 17.0 | 53.5 |
| Subtotal | 526.0 | 1,651.5 | | Subtotal | 675.9 | 2,122.5 |

Table IV-26. Ventilation Raises Excavated Length and Volume for 97,000 MTHM Case (continued)

| Drift Number | Length (m) | Volume ($m^3$) | | Drift Number | Length (m) | Volume ($m^3$) |
|---|---|---|---|---|---|---|
| 63 | 16.8 | 52.8 | | L3 | 10.0 | 31.4 |
| 64 | 16.6 | 52.2 | | L4 | 10.0 | 31.4 |
| 65 | 12.8 | 40.3 | | L5 | 10.0 | 31.4 |
| 66 | 12.8 | 40.3 | | L6 | 10.0 | 31.4 |
| 67 | 12.8 | 40.3 | | L7 | 10.0 | 31.4 |
| 68 | 12.9 | 40.5 | | L8 | 10.0 | 31.4 |
| 69 | 12.9 | 40.6 | | L9 | 10.0 | 31.4 |
| 70 | 12.9 | 40.6 | | L10 | 10.0 | 31.4 |
| 71 | 12.9 | 40.6 | | L11 | 10.0 | 31.4 |
| 72 | 12.9 | 40.5 | | L12 | 10.0 | 31.4 |
| 73 | 12.9 | 40.4 | | L13 | 10.0 | 31.4 |
| 74 | 12.8 | 40.2 | | L14 | 10.0 | 31.4 |
| 75 | 12.8 | 40.1 | | L15 | 10.0 | 31.4 |
| 76 | 12.7 | 40.0 | | L16 | 10.0 | 31.4 |
| 77 | 12.7 | 39.8 | | L17 | 10.0 | 31.4 |
| 78 | 13.2 | 41.5 | | L18 | 10.0 | 31.4 |
| 79 | 14.7 | 46.1 | | L19 | 10.0 | 31.4 |
| 80 | 16.2 | 50.7 | | | | |
| 81 | 17.7 | 55.6 | | | | |
| 82 | 19.3 | 60.6 | | | | |
| 83 | 21.0 | 66.0 | | | | |
| 84 | 22.8 | 71.4 | | | | |
| 85 | 24.5 | 76.8 | | | | |
| 86 | 26.2 | 82.2 | | | | |
| 87 | 27.9 | 87.7 | | | | |
| 88 | 29.6 | 93.1 | | | | |
| 89 | 31.3 | 98.4 | | | | |
| 90 | 33.0 | 103.7 | | | | |
| 91 | 34.7 | 109.0 | | | | |
| L1 | 10.0 | 31.4 | | | | |
| L2 | 10.0 | 31.4 | | | | |
| Subtotal | 552.5 | 1,734.9 | | Subtotal | 170.0 | 533.8 |

| | | |
|---|---|---|
| Total Length | 1,944.4 | m |
| Total Volume | 6,042.7 | $m^3$ |

**Ventilation Raise Alcoves** —

| | | |
|---|---|---|
| Number of Emplacement Drifts | 110 | |
| Length of Each Alcove | 5.0 m | |
| Volume of Each Alcove | 127.8 $m^3$ | As calculated by VULCAN v3.4 |
| Total Length of Alcoves | 550.0 m | |
| Total Volume of Alcoves | 14,058.0 $m^3$ | |

**Standby Drifts** — The standby drifts are excavated at a diameter of 5.5 meters (see Section 6.1.2.1.2). The excavated circular cross-sectional area of these headings is 23.76 $m^2$. The standby drift turnouts will be excavated in a horseshoe-shaped profile of 8 meters wide and 7 meters high, similar to the emplacement drift turnouts (see Section 6.1.2.1.2), with a cross-sectional area of 49.13 $m^2$. The standby drifts also require ventilation raises to exhaust air to the Exhaust Main, exhaust side. These raises will be excavated to a diameter of 2 meters (see Section 6.1.2.4), similar to the emplacement drift raise, and a circular cross-sectional area of 3.14 $m^2$. The lengths of the standby drifts and the associated headings, including the excavated volumes, are outlined in Table IV-27.

Table IV-27. Standby Drifts Excavated Length and Volume for 97,000 MTHM Case

| Drift Number | Drift Length (m) | Volume ($m^3$) | East Turnout | | West Turnout | |
|---|---|---|---|---|---|---|
| | | | Length (m) | Volume ($m^3$) | Length (m) | Volume ($m^3$) |
| 1 | 997.3 | 23,695.8 | 79.5 | 3,905.8 | 110.9 | 5,448.5 |
| 2 | 1,263.5 | 30,020.8 | 79.5 | 3,905.8 | 75.6 | 3,714.2 |
| 3 | 1,207.0 | 28,678.3 | 79.5 | 3,905.8 | 75.6 | 3,714.2 |
| Totals | 3,467.8 | 82,394.9 | 238.5 | 11,717.5 | 262.1 | 12,877.0 |

| Drift Number | Raise Length (m) | Raise Volume ($m^3$) | Raise Alcove Length (m) | Raise Alcove Volume ($m^3$) |
|---|---|---|---|---|
| 1 | 17.2 | 54.0 | 5.0 | 127.8 |
| 2 | 17.0 | 53.4 | 5.0 | 127.8 |
| 3 | 10.0 | 31.4 | 5.0 | 127.8 |
| Totals | 44.2 | 138.8 | 15.0 | 383.4 |

**Crossblock Drifts** — The cross-block drifts are excavated at a diameter of 5.5 meters (see Section 6.1.2.1.2). The excavated circular cross-sectional area of these headings is 23.76 $m^2$. The cross-block drift turnouts will be excavated in a horseshoe-shaped profile of 8 meters wide and 7 meters high, similar to the emplacement drift turnouts (see Section 6.1.2.1.2), with a cross-sectional area of 49.13 $m^2$. The cross-block drifts also require ventilation raises to exhaust air to the Exhaust Main, service side. These raises will be excavated to a diameter of 2 meters (see Section 6.1.2.4), similar to the emplacement drift raise, and a circular cross-sectional area of 3.14 $m^2$. The lengths of the cross-block drifts and associated headings, including the excavated volume, are outlined in Table IV-28.

Table IV-28. Crossblock Drifts Excavated Length and Volume for 97,000 MTHM Case

| Drift Number | Drift Length (m) | Volume ($m^3$) | East Turnout | | West Turnout | |
|---|---|---|---|---|---|---|
| | | | Length (m) | Volume ($m^3$) | Length (m) | Volume ($m^3$) |
| 1 | 1,115.3 | 26,499.5 | 79.5 | 3,905.8 | 110.9 | 5,448.5 |
| 2 | 1,263.5 | 30,020.8 | 79.5 | 3,905.8 | 75.6 | 3,714.2 |
| 3 | 1,194.8 | 28,388.4 | 79.5 | 3,905.8 | 72.9 | 3,581.6 |
| 4 | 933.8 | 22,187.1 | 79.5 | 3,905.8 | 72.9 | 3,581.6 |
| 5 | 1,207.0 | 28,678.3 | 79.5 | 3,905.8 | 75.6 | 3,714.2 |
| Totals | 5,714.4 | 135,774.1 | 397.5 | 19,529.2 | 407.9 | 20,040.1 |

| Drift Number | Raise Length (m) | Raise Volume ($m^3$) | Raise Alcove Length (m) | Raise Alcove Volume ($m^3$) |
|---|---|---|---|---|
| 1 | 17.2 | 54.0 | 5.0 | 127.8 |
| 2 | 17.0 | 53.4 | 5.0 | 127.8 |
| 3 | 16.7 | 52.4 | 5.0 | 127.8 |
| 4 | 15.7 | 49.3 | 5.0 | 127.8 |
| 5 | 10.0 | 31.4 | 5.0 | 127.8 |
| Totals | 76.6 | 240.5 | 25.0 | 639.0 |

**Test and Evaluation Facility Drifts** — The PCTDs will be excavated to a diameter of 5.5 meters (see Section 6.1.2.1.3), and a circular cross-sectional area of 23.76 $m^2$. The PCTD turnouts will be excavated in a horseshoe-shaped profile of 8 meters wide and 7 meters high, similar to the emplacement drift turnouts (see Section 6.1.2.1.3), with a cross-sectional area of 49.13 $m^2$. The cross-block drifts also require ventilation raises to exhaust air to the Exhaust Main, exhaust side. These raises will be excavated to a diameter of 2 meters (see Section 6.1.2.4), similar to the emplacement drift raise, and a circular cross-sectional area of 3.14 $m^2$. The lengths of the PCTDs and the associated headings, including the excavated volume, are outlined in Table IV-29.

The ODs will be excavated to a diameter of 5.5 meters (see Section 6.1.2.1.3), and a circular cross-sectional area of 23.76 $m^2$. The ODs also requires ventilation raises to exhaust air to the Exhaust Main, service side. These raises will be excavated to a diameter of 2 meters (see Section 6.1.2.4), similar to the emplacement drift raise, and a circular cross-sectional area of 3.14 $m^2$. The lengths of the ODs and the associated headings, including the excavated volume, are outlined in Table IV-30 and Table IV-31.

Table IV-29. Postclosure Test Drift Excavated Length and Volume for 97,000 MTHM Case

| Drift Number | Drift Length (m) | Volume ($m^3$) | East Turnout | | West Turnout | |
|---|---|---|---|---|---|---|
| | | | Length (m) | Volume ($m^3$) | Length (m) | Volume ($m^3$) |
| 1 | 697.2 | 16,565.5 | 77.0 | 3,783.0 | 110.9 | 5,448.5 |
| Totals | 697.2 | 16,565.5 | 77.0 | 3,783.0 | 110.9 | 5,448.5 |

| Drift Number | Raise Length (m) | Raise Volume ($m^3$) | Raise Alcove Length (m) | Raise Alcove Volume ($m^3$) |
|---|---|---|---|---|
| 1 | 10.0 | 31.4 | 5.0 | 127.8 |
| Totals | 10.0 | 31.4 | 5.0 | 127.8 |

Table IV-30. Observation Drifts Excavated Length and Volume for 97,000 MTHM Case

| Drift Number | Drift Length (m) | Volume ($m^3$) |
|---|---|---|
| 1 | 2,191.5 | 52,070.0 |
| 2 | 1,045.5 | 24,841.1 |
| 3 | 1,957.6 | 46,512.6 |
| 4 | 1,640.5 | 38,978.3 |
| 5 | 2,184.3 | 51,899.0 |
| Total | 9,019.4 | 214,300.9 |

Table IV-31. Observation Drift Raises Excavated Length and Volume for 97,000 MTHM Case

| Description | | Raise Length (m) | Raise Volume ($m^3$) | Raise Alcove Length (m) | Raise Alcove Volume ($m^3$) |
|---|---|---|---|---|---|
| From | To | | | | |
| ECRB | West Main | 28.0 | 87.8 | 5.0 | 127.8 |
| OD 1 | West Main | 10.0 | 31.4 | 5.0 | 127.8 |
| OD 1 | Exhaust Main | 28.7 | 90.1 | 5.0 | 127.8 |
| OD 2 | West Main | 10.0 | 31.4 | 5.0 | 127.8 |
| OD 2 | Exhaust Main | 29.5 | 92.7 | 5.0 | 127.8 |
| OD 3 | West Main | 16.1 | 50.6 | 5.0 | 127.8 |
| OD 3 | Exhaust Main | 44.0 | 138.1 | 5.0 | 127.8 |
| OD 4 | West Main | 13.6 | 42.6 | 5.0 | 127.8 |
| OD 4 | Exhaust Main | 31.2 | 97.9 | 5.0 | 127.8 |
| OD 5 | Lower East Main | 10.0 | 31.4 | 5.0 | 127.8 |
| OD 5 | Lower Exhaust Main | 30.8 | 96.7 | 5.0 | 127.8 |
| Total | | 251.8 | 790.7 | 55.0 | 1,405.8 |

## ATTACHMENT V

## SURFACE-BASED BOREHOLES

## ATTACHMENT V

## SURFACE-BASED BOREHOLES

The Subsurface Facility must allow at least a 5-meter standoff from the edge of the WPs to the perpendicular projection of the centerline of a surface-based borehole if the borehole intercepts the drift or comes within 5 meters of the edge of the drift (see Section 4.2.1.2.6).

The point features of the Yucca Mountain Project boreholes are documented in the Technical Data Management System as indicated in Section 4.1.1.4. These boreholes include holes that are considered qualified and some that are considered non-qualified. The boreholes are listed in Table V-1. The coordinates of the boreholes are expressed in Nevada State Plane Coordinate System, in feet (NAD 27), the collar elevation is expressed in feet above sea level, and the total depth is expressed in feet from the collar elevation. Where data is not currently available, or the borehole is planned and not actually drilled, -9,999.000 feet has been recorded for the depth.

In order to determine which boreholes may affect the subsurface layout, the boreholes listed in Table V-1 must be converted to Nevada State Plane Meters, meters above sea level, and depth in meters. This conversion is easily accomplished knowing that 3.2808 feet equals 1 meter. The boreholes can then be sorted to determine which fall within the Northing and Easting boundaries of the planning layout, as well as pass through the plane of the repository itself.

The repository layout as illustrated in Figure 3 can be bounded by 227,750 meters north, 236,900 meters north, 169,950 meters east, and 171,500 meters east. These Northing and Easting boundaries are used to eliminate any boreholes that are not within these bounds.

The repository horizon in the primary area lies within a lower elevation of 1,022 meters and an upper elevation of 1,120 meters. The highest elevation of 1,120 meters will be used as a discriminator to eliminate those boreholes that do not pass through the repository horizon. These elevations were determined from examining Table II-1 in Attachment II.

The boreholes listed in Table V-2 have been determined to be within the vicinity of the Subsurface Facility and to pass through the repository horizon using the discriminators listed above.

Table V-1. Surface-Based Boreholes

| Bores3 Identifier | Borehole Identifier | Elevation (feet) | Depth (feet) | Easting (feet) | Northing (feet) | Qualification Status |
|---|---|---|---|---|---|---|
| 1 | U-5 Seismic #1 | 3,868.36 | 140.00 | 668,101.062 | 749,607.375 | Q |
| 2 | U-5 Seismic #2 | 3,867.05 | 140.00 | 668,123.188 | 749,624.438 | Q |
| 3 | USW Seismic-1 | 5,101.78 | 200.00 | 560,432.562 | 778,958.812 | Q |
| 4 | USW Seismic-2 | 5,106.74 | 200.00 | 560,362.625 | 779,090.562 | Q |
| 5 | USW Seismic-3 | 5,111.46 | 200.00 | 560,268.312 | 779,266.625 | Q |
| 6 | USW Seismic-4 | 5,114.02 | 200.00 | 560,173.000 | 779,442.625 | Q |
| 7 | USW Seismic-5 | 5,121.31 | 200.00 | 560,079.500 | 779,619.125 | Q |
| 8 | USW Seismic-7 | 5,141.70 | 200.00 | 559,891.312 | 779,972.000 | Q |
| 9 | USW Seismic-8 | 5,153.02 | 200.00 | 559,796.438 | 780,147.625 | Q |
| 10 | USW Seismic-9 | 5,161.69 | 200.00 | 559,702.125 | 780,320.500 | Q |
| 11 | USW Seismic-10 | 5,171.21 | 200.00 | 559,604.688 | 780,502.250 | Q |
| 12 | USW Seismic-11 | 5,179.40 | 200.00 | 559,513.500 | 780,677.312 | Q |
| 13 | USW Seismic-12 | 5,185.20 | 200.00 | 559,419.688 | 780,851.438 | Q |
| 14 | USW Seismic-13 | 5,085.57 | 200.00 | 560,645.812 | 778,560.750 | Q |
| 15 | USW Seismic-14 | 5,076.10 | 200.00 | 560,740.750 | 778,383.250 | Q |
| 16 | USW Seismic-15 | 5,063.91 | 200.00 | 560,834.062 | 778,209.062 | Q |
| 17 | USW Seismic-16 | 5,051.36 | 200.00 | 560,928.875 | 778,033.250 | Q |
| 18 | USW Seismic-17 | 5,039.54 | 200.00 | 561,023.938 | 777,856.625 | Q |
| 19 | USW Seismic-18 | 5,027.61 | 200.00 | 561,118.000 | 777,681.250 | Q |
| 20 | USW Seismic-19 | 5,014.41 | 200.00 | 561,211.625 | 777,504.375 | Q |
| 21 | U-25 Seismic #20 | 3,357.00 | 140.00 | 593,171.938 | 747,172.875 | Q |
| 22 | U-25 Seismic #21 | 3,524.58 | 140.00 | 569,427.625 | 746,906.312 | Q |
| 23 | U-25 Seismic #22 | 2,947.37 | 140.00 | 581,268.500 | 718,335.000 | Q |
| 24 | U-25 Seismic #23 | 3,215.66 | 140.00 | 580,246.688 | 741,126.062 | Q |
| 25 | U-25 Seismic #24 | 3,554.12 | 140.00 | 580,907.250 | 769,057.312 | Q |
| 26 | U-25 TC #1 | 3,753.74 | 30.00 | 612,897.750 | 756,483.875 | Q |
| 27 | U-25 TC #2 | 3,753.79 | 30.00 | 612,899.125 | 756,486.312 | Q |
| 28 | U-25 TCi #1 | 3,790.12 | 5.00 | 613,452.750 | 756,777.062 | Q |
| 29 | U-25 TCi #2 | 3,790.11 | 5.00 | 613,451.125 | 756,779.250 | Q |
| 30 | U-25 TCi #3 | 3,790.05 | 5.00 | 613,436.438 | 756,783.000 | Q |
| 31 | U-25 TCi #4 | 3,790.11 | 5.00 | 613,438.750 | 756,784.375 | Q |
| 32 | U-26 Seismic #1 | 3,847.75 | 140.00 | 629,834.125 | 746,151.312 | Q |
| 33 | U-29 Seismic #1 | 3,877.83 | 142.00 | 585,139.938 | 791,869.125 | Q |
| 34 | U-30 Seismic #1 | 4,754.40 | 142.00 | 604,819.938 | 837,368.812 | Q |
| 35 | U-30 Seismic #2 | 4,751.88 | 140.00 | 604,800.625 | 837,375.375 | Q |
| 36 | UE-1 m | 4,478.13 | 514.00 | 657,843.125 | 825,408.688 | Q |
| 37 | UE-1 n | 4,483.23 | 5.00 | 657,761.875 | 825,330.250 | Q |
| 38 | UE-1 o | 4,480.07 | 5.00 | 657,757.000 | 825,418.688 | Q |
| 39 | UE-1 p | 4,231.96 | 782.00 | 662,294.250 | 826,268.812 | Q |
| 40 | UE-16 c | 4,726.53 | 144.00 | 644,558.875 | 844,957.688 | Q |
| 41 | UE-16 d | 4,685.82 | 2,321.00 | 646,567.812 | 844,877.312 | Q |
| 42 | UE-16 f | 4,651.45 | 1,479.00 | 648,842.125 | 832,352.938 | Q |
| 43 | UE-17 a | 4,696.63 | 1,214.00 | 645,992.500 | 846,138.062 | Q |
| 44 | UE-17 b | 4,783.34 | 256.50 | 646,471.500 | 849,216.250 | Q |
| 45 | UE-17 c | 4,833.45 | 586.00 | 650,048.000 | 857,444.438 | Q |
| 46 | UE-17 d | 4,680.73 | 398.00 | 647,789.188 | 847,189.000 | Q |
| 47 | UE-17 e | 4,934.25 | 3,000.00 | 646,448.812 | 853,205.000 | Q |
| 48 | UE-17 f | 4,929.90 | 100.00 | 646,032.375 | 853,321.625 | Q |
| 49 | UE-17 g | 4,929.75 | 104.00 | 646,515.312 | 853,291.750 | Q |
| 50 | UE-17 SI #1 | 4,931.86 | 110.00 | 646,487.750 | 853,331.250 | Q |

Table V-1. Surface-Based Boreholes (Continued)

| Bores3 Identifier | Borehole Identifier | Elevation (feet) | Depth (feet) | Easting (feet) | Northing (feet) | Qualification Status |
|---|---|---|---|---|---|---|
| 51 | UE-17 SI #2 | 4,931.88 | 92.50 | 646,488.125 | 853,333.125 | Q |
| 52 | UE-17 SI #3 | 4,931.84 | 115.00 | 646,489.750 | 853,330.812 | Q |
| 53 | UE-17 SI #4 | 4,931.89 | 92.50 | 646,485.812 | 853,331.438 | Q |
| 54 | UE-17 SI #5 | 4,931.88 | 83.50 | 646,488.438 | 853,335.062 | Q |
| 55 | UE-17 SI #6 | 4,931.87 | 80.00 | 646,491.750 | 853,330.438 | Q |
| 56 | UE-17 SI #7 | 4,931.85 | 82.50 | 646,487.062 | 853,327.188 | Q |
| 57 | UE-17 SI #8 | 4,931.88 | 77.50 | 646,484.500 | 853,328.938 | Q |
| 58 | UE-17 SI #8a | 4,931.87 | 60.00 | 646,478.812 | 853,324.812 | Q |
| 59 | UE-17 SI #9 | 4,931.88 | 80.00 | 646,483.812 | 853,331.812 | Q |
| 60 | UE-17 SI #10 | 4,931.88 | 84.50 | 646,489.062 | 853,338.000 | Q |
| 61 | UE-17 SI #11 | 4,931.84 | 82.50 | 646,486.562 | 853,324.188 | Q |
| 62 | UE-17 SI #11a | 4,931.79 | 60.00 | 646,485.875 | 853,320.312 | Q |
| 63 | UE-17 SI #12 | 4,931.88 | 77.50 | 646,480.938 | 853,332.312 | Q |
| 64 | UE-17 SI #13 | 4,931.88 | 84.50 | 646,489.688 | 853,342.000 | Q |
| 65 | UE-17 SI #14 | 4,931.89 | 80.00 | 646,498.562 | 853,329.188 | Q |
| 66 | UE-17 SI #15 | 4,931.89 | 77.50 | 646,476.812 | 853,333.062 | Q |
| 67 | UE-17 SI #16 | 4,931.29 | 84.00 | 646,495.438 | 853,374.438 | Q |
| 68 | UE-17 TH #1 | 4,931.98 | 80.00 | 646,479.188 | 853,343.438 | Q |
| 69 | UE-17 TH #2 | 4,931.98 | 80.00 | 646,477.938 | 853,345.188 | Q |
| 70 | UE-17 TH #3 | 4,931.84 | 80.00 | 646,478.812 | 853,349.188 | Q |
| 71 | UE-17 TH #4 | 4,931.77 | 80.00 | 646,491.750 | 853,352.625 | Q |
| 72 | UE-17 TH #5 | 4,931.80 | 80.00 | 646,492.000 | 853,354.562 | Q |
| 73 | UE-22 ARMY #1 | 3,153.35 | 1,945.00 | 684,772.938 | 670,903.125 | Q |
| 74 | UE-25 a #1 | 3,935.35 | 2,501.00 | 566,349.875 | 764,901.000 | Q |
| 75 | UE-25 a #3 | 4,548.90 | 2,530.00 | 602,940.688 | 769,318.938 | Q |
| 76 | UE-25 a #4 | 4,102.04 | 500.00 | 564,471.875 | 767,972.375 | Q |
| 77 | UE-25 a #5 | 4,060.57 | 487.00 | 564,755.188 | 766,956.438 | Q |
| 78 | UE-25 a #6 | 4,053.27 | 500.00 | 564,500.875 | 765,899.875 | Q |
| 79 | UE-25 a #7 | 4,005.58 | 1,002.00 | 565,468.312 | 766,250.000 | Q |
| 80 | UE-25 b #1 | 3,939.28 | 4,003.00 | 566,416.188 | 765,244.312 | Q |
| 81 | UE-25 c #1 | 3,708.49 | 3,000.00 | 569,680.562 | 757,096.750 | Q |
| 82 | UE-25 c #2 | 3,714.09 | 3,000.00 | 569,633.938 | 756,849.625 | Q |
| 83 | UE-25 c #3 | 3,714.41 | 3,000.00 | 569,554.938 | 756,910.875 | Q |
| 84 | UE-25 h #1 | 3,407.59 | 400.00 | 574,462.312 | 748,352.688 | Q |
| 85 | UE-25 J-11 | 3,443.06 | 1,329.00 | 611,768.000 | 740,968.750 | Q |
| 86 | UE-25 J-11Prime | 3,441.94 | 220.00 | 611,821.812 | 740,890.938 | Q |
| 87 | UE-25 J-12 | 3,129.84 | 1,139.00 | 581,012.062 | 733,508.250 | Q |
| 88 | UE-25 J-13 | 3,317.40 | 3,498.00 | 579,647.938 | 749,202.000 | Q |
| 89 | UE-25 JF #3 | 3,098.42 | 1,298.00 | 581,179.438 | 730,875.375 | Q |
| 90 | UE-25 NRG #2 | 3,800.37 | 294.00 | 569,162.438 | 765,763.750 | Q |
| 91 | UE-25 NRG #2a | 3,780.55 | 266.00 | 569,001.062 | 765,699.938 | Q |
| 92 | UE-25 NRG #2b | 3,801.40 | 330.00 | 569,214.562 | 765,765.250 | Q |
| 93 | UE-25 NRG #2c | 3,801.17 | 151.00 | 569,189.750 | 765,771.688 | Q |
| 94 | UE-25 NRG #2d | 3,792.05 | 170.20 | 569,132.312 | 765,825.125 | Q |
| 95 | UE-25 NRG #3 | 3,823.33 | 330.00 | 568,316.125 | 766,250.625 | Q |
| 96 | UE-25 NRG #4 | 4,099.48 | 726.00 | 566,820.000 | 767,080.188 | Q |
| 97 | UE-25 NRG #5 | 4,106.66 | 1,350.00 | 564,769.875 | 767,889.625 | Q |
| 98 | UE-25 ONC #1 | 3,815.11 | 1,540.00 | 568,092.875 | 759,257.250 | Q |
| 99 | UE-25 p #1 | 3,654.53 | 5,923.00 | 571,484.438 | 756,172.562 | Q |
| 100 | UE-25 RF #1 | 3,688.60 | 145.00 | 570,890.125 | 762,190.562 | Q |

Table V-1. Surface-Based Boreholes (Continued)

| Bores3 Identifier | Borehole Identifier | Elevation (feet) | Depth (feet) | Easting (feet) | Northing (feet) | Qualification Status |
|---|---|---|---|---|---|---|
| 101 | UE-25 RF #2 | 3,657.85 | 52.00 | 570,335.125 | 758,800.812 | Q |
| 102 | UE-25 RF #3b | 3,661.37 | 111.00 | 571,066.062 | 765,695.750 | Q |
| 103 | UE-25 RF #4 | 3,637.06 | 306.00 | 572,063.312 | 762,091.625 | Q |
| 104 | UE-25 RF #7 | 3,756.08 | 150.00 | 571,171.062 | 768,804.750 | Q |
| 105 | UE-25 RF #7a | 3,756.50 | 153.00 | 570,268.812 | 768,768.750 | Q |
| 106 | UE-25 RF #8 | 3,785.70 | 128.00 | 568,790.188 | 765,631.375 | Q |
| 107 | USW SR-1 | 3,051.31 | -9,999.00 | 559,339.062 | 721,817.875 | Q |
| 108 | USW SR-2 | 3,051.15 | -9,999.00 | 559,333.312 | 721,809.688 | Q |
| 109 | USW SR-3 | 3,046.65 | -9,999.00 | 559,246.625 | 721,823.000 | Q |
| 110 | UE-25 UZ #4 | 3,940.05 | 411.00 | 566,140.125 | 768,715.688 | Q |
| 111 | UE-25 UZ #5 | 3,952.83 | 405.00 | 566,136.125 | 768,593.125 | Q |
| 112 | UE-25 UZ #16 | 4,000.48 | 1,696.20 | 564,857.500 | 760,535.125 | Q |
| 113 | UE-25 UZN #1 | 3,995.43 | 50.00 | 565,224.438 | 769,329.750 | Q |
| 114 | UE-25 UZN #2 | 3,947.07 | 50.00 | 566,113.688 | 768,606.375 | Q |
| 115 | UE-25 UZN #3 | 3,940.82 | 15.00 | 566,119.438 | 768,631.438 | Q |
| 116 | UE-25 UZN #4 | 3,942.51 | 30.00 | 566,127.125 | 768,664.375 | Q |
| 117 | UE-25 UZN #5 | 3,943.53 | 50.00 | 566,134.188 | 768,690.188 | Q |
| 118 | UE-25 UZN #6 | 3,938.77 | 45.00 | 566,136.812 | 768,706.500 | Q |
| 119 | UE-25 UZN #7 | 3,939.87 | 45.00 | 566,141.375 | 768,724.938 | Q |
| 120 | UE-25 UZN #8 | 3,938.34 | 45.00 | 566,146.625 | 768,743.812 | Q |
| 121 | UE-25 UZN #9 | 3,941.13 | 40.00 | 566,156.062 | 768,782.375 | Q |
| 122 | UE-25 UZN #10 | 4,038.71 | 99.00 | 564,744.562 | 769,869.312 | Q |
| 123 | UE-25 UZN #12 | 3,908.25 | 50.00 | 566,695.188 | 768,651.500 | Q |
| 124 | UE-25 UZN #13 | 3,821.47 | 65.00 | 568,255.188 | 768,025.438 | Q |
| 125 | UE-25 UZN #14 | 3,824.38 | 55.00 | 568,233.062 | 767,968.000 | Q |
| 126 | UE-25 UZN #18 | 4,018.90 | 61.00 | 565,246.625 | 766,472.812 | Q |
| 127 | UE-25 UZN #19 | 4,025.49 | 40.00 | 564,570.812 | 763,689.562 | Q |
| 128 | UE-25 UZN #20 | 4,027.36 | 41.00 | 564,579.438 | 763,760.625 | Q |
| 129 | UE-25 UZN #21 | 4,027.98 | 42.00 | 564,591.375 | 763,806.812 | Q |
| 130 | UE-25 UZN #22 | 4,029.30 | 95.00 | 564,604.875 | 763,881.062 | Q |
| 131 | UE-25 UZN #23 | 4,043.76 | 35.00 | 564,545.688 | 763,973.750 | Q |
| 132 | UE-25 UZN #28 | 3,958.92 | 26.00 | 565,319.812 | 763,092.062 | Q |
| 133 | UE-25 UZN #29 | 3,973.36 | 35.00 | 565,173.312 | 762,613.812 | Q |
| 134 | UE-25 UZN #30 | 3,959.53 | 35.00 | 565,232.875 | 762,048.188 | Q |
| 135 | UE-25 UZN #56 | 3,960.25 | 60.00 | 565,480.125 | 760,394.688 | Q |
| 136 | UE-25 UZN #60 | 3,893.04 | 35.00 | 566,567.125 | 759,757.938 | Q |
| 137 | UE-25 UZN #63 | 3,942.21 | 60.00 | 566,169.625 | 768,837.250 | Q |
| 138 | UE-25 UZN #85 | 3,337.06 | 80.00 | 577,568.250 | 750,715.812 | Q |
| 139 | UE-25 UZN #97 | 3,959.03 | 60.00 | 565,320.625 | 763,094.562 | Q |
| 140 | UE-25 UZNC #1 | 3,928.61 | 5.00 | 566,159.000 | 764,671.500 | Q |
| 141 | UE-25 UZNC #2 | 3,928.71 | 5.00 | 566,157.312 | 764,669.562 | Q |
| 142 | UE-25 WT #3 | 3,379.23 | 1,142.00 | 573,385.188 | 745,995.562 | Q |
| 143 | UE-25 WT #4 | 3,835.68 | 1,580.00 | 568,038.312 | 768,511.938 | Q |
| 144 | UE-25 WT #5 | 3,558.03 | 1,330.00 | 574,249.750 | 761,826.688 | Q |
| 145 | UE-25 WT #6 | 4,313.27 | 1,258.00 | 564,523.625 | 780,576.125 | Q |
| 146 | UE-25 WT #12 | 3,525.76 | 1,308.00 | 567,011.812 | 739,726.688 | Q |
| 147 | UE-25 WT #13 | 3,385.86 | 1,154.00 | 578,842.250 | 756,885.188 | Q |
| 148 | UE-25 WT #14 | 3,529.67 | 1,310.00 | 575,210.188 | 761,651.375 | Q |
| 149 | UE-25 WT #15 | 3,552.56 | 1,360.00 | 579,806.250 | 766,117.000 | Q |
| 150 | UE-25 WT #16 | 3,971.26 | 1,709.00 | 570,395.125 | 774,420.188 | Q |

Table V-1. Surface-Based Boreholes (Continued)

| Bores3 Identifier | Borehole Identifier | Elevation (feet) | Depth (feet) | Easting (feet) | Northing (feet) | Qualification Status |
|---|---|---|---|---|---|---|
| 151 | UE-25 WT #17 | 3,687.09 | 1,450.00 | 566,212.000 | 748,421.500 | Q |
| 152 | UE-25 WT #18 | 4,384.00 | 2,043.00 | 564,854.625 | 771,167.250 | Q |
| 153 | UE-29 UZN #91 | 3,949.34 | 94.00 | 585,341.375 | 797,275.812 | Q |
| 154 | UE-29 UZN #92 | 3,670.68 | 120.00 | 583,559.000 | 778,010.125 | Q |
| 155 | UE-29 a #1 | 3,984.20 | 215.00 | 585,575.250 | 797,730.000 | Q |
| 156 | UE-29 a #2 | 3,984.64 | 1,383.00 | 585,547.500 | 797,745.750 | Q |
| 157 | US-25 #4 | 3,800.04 | 50.00 | 567,853.438 | 762,458.312 | Q |
| 158 | US-25 #5 | 3,799.21 | 52.00 | 567,853.438 | 762,433.000 | Q |
| 159 | US-25 #6 | 3,782.77 | 52.00 | 568,551.750 | 762,378.562 | Q |
| 160 | US-25 #7 | 3,782.82 | 52.00 | 568,551.250 | 762,355.125 | Q |
| 161 | US-25 #8 | 3,756.33 | 52.00 | 569,332.188 | 762,317.438 | Q |
| 162 | US-25 #9 | 3,757.87 | 50.00 | 569,328.625 | 762,284.250 | Q |
| 163 | US-25 #10 | 3,722.99 | 50.00 | 570,113.438 | 762,251.000 | Q |
| 164 | US-25 #11 | 3,722.91 | 52.00 | 570,109.188 | 762,227.375 | Q |
| 165 | US-25 #12 | 3,687.79 | 52.00 | 570,894.250 | 762,189.312 | Q |
| 166 | US-25 #13 | 3,686.99 | 52.00 | 570,891.312 | 762,168.312 | Q |
| 167 | US-25 #14 | 3,653.10 | 50.00 | 571,675.000 | 762,137.250 | Q |
| 168 | US-25 #15 | 3,653.87 | 50.00 | 571,671.875 | 762,106.125 | Q |
| 169 | US-25 #16 | 3,619.34 | 50.00 | 572,452.812 | 762,048.688 | Q |
| 170 | US-25 #17 | 3,575.27 | 50.00 | 573,629.375 | 761,985.562 | Q |
| 171 | US-25 #19 | 3,498.60 | 50.00 | 576,242.625 | 761,747.125 | Q |
| 172 | US-25 #21 | 3,842.00 | 50.00 | 578,542.938 | 761,629.125 | Q |
| 173 | U-25 TC #3 | 3,763.62 | 45.00 | 613,080.188 | 756,807.188 | Q |
| 174 | U-25 TC #4 | 3,764.70 | 45.00 | 613,095.625 | 756,861.188 | Q |
| 175 | U-25 TC #5 | 3,762.79 | -9,999.00 | 613,077.750 | 756,795.250 | Q |
| 176 | USW G-1 | 4,350.15 | 6,000.00 | 561,001.062 | 770,501.625 | Q |
| 177 | USW G-2 | 5,097.27 | 6,602.00 | 560,503.938 | 778,825.938 | Q |
| 178 | USW G-3 | 4,856.09 | 5,031.00 | 558,483.312 | 752,779.625 | Q |
| 179 | USW G-4 | 4,166.13 | 3,001.00 | 563,081.750 | 765,807.500 | Q |
| 180 | USW GA-1 | 5,186.95 | 551.00 | 559,246.812 | 779,367.188 | Q |
| 181 | USW GU-3 | 4,856.70 | 5,031.00 | 558,501.625 | 752,690.000 | Q |
| 182 | USW H-1 | 4,274.19 | 600.00 | 562,388.438 | 770,254.812 | Q |
| 183 | USW H-3 | 4,866.47 | 4,000.00 | 558,451.875 | 756,542.000 | Q |
| 184 | USW H-4 | 4,096.17 | 4,004.00 | 563,911.375 | 761,644.500 | Q |
| 185 | USW H-5 | 4,851.35 | 4,000.00 | 558,908.438 | 766,634.125 | Q |
| 186 | USW H-6 | 4,270.79 | 4,002.00 | 554,074.938 | 763,299.438 | Q |
| 187 | USW NRG-6 | 4,092.12 | 1,100.00 | 564,187.000 | 766,726.500 | Q |
| 188 | USW NRG-7a | 4,207.17 | 1,513.00 | 562,984.000 | 768,880.125 | Q |
| 189 | USW SD-7 | 4,472.00 | 2,675.10 | 561,240.250 | 758,949.875 | Q |
| 190 | USW SD-9 | 4,272.64 | 2,223.00 | 561,818.000 | 767,998.500 | Q |
| 191 | USW SD-12 | 4,342.82 | 2,166.30 | 561,605.625 | 761,956.562 | Q |
| 192 | USW UZ-1 | 4,424.73 | 1,270.00 | 560,221.562 | 771,277.375 | Q |
| 193 | USW UZ-6 | 4,925.17 | 1,887.00 | 558,325.000 | 759,730.188 | Q |
| 194 | USW UZ-6s | 4,949.16 | 519.00 | 558,050.688 | 759,909.312 | Q |
| 195 | USW UZ-7 | 4,169.13 | 207.00 | 562,911.625 | 760,837.000 | Q |
| 196 | USW UZ-7a | 4,228.28 | 770.00 | 562,269.812 | 760,692.750 | Q |
| 197 | USW UZ-8 | 4,226.73 | 57.00 | 562,293.750 | 760,763.188 | Q |
| 198 | USW UZ-13 | 4,816.11 | 430.00 | 558,489.312 | 751,953.062 | Q |
| 199 | USW UZ-14 | 4,425.40 | 2,207.00 | 560,141.562 | 771,309.812 | Q |
| 200 | USW UZ-N11 | 5,221.79 | 84.40 | 559,020.938 | 780,573.938 | Q |

Table V-1. Surface-Based Boreholes (Continued)

| Bores3 Identifier | Borehole Identifier | Elevation (feet) | Depth (feet) | Easting (feet) | Northing (feet) | Qualification Status |
|---|---|---|---|---|---|---|
| 201 | USW UZ-N15 | 5,107.81 | 59.90 | 559,551.750 | 778,090.562 | Q |
| 202 | USW UZ-N16 | 5,114.98 | 60.00 | 559,626.000 | 778,150.812 | Q |
| 203 | USW UZ-N17 | 5,125.75 | 59.82 | 559,995.125 | 778,224.125 | Q |
| 204 | USW UZ-N24 | 4,226.52 | 75.00 | 562,054.438 | 768,005.625 | Q |
| 205 | USW UZ-N25 | 4,333.99 | 59.00 | 561,219.125 | 768,430.438 | Q |
| 206 | USW UZ-N26 | 4,383.81 | 35.00 | 561,023.250 | 768,757.375 | Q |
| 207 | USW UZ-N27 | 4,857.27 | 202.42 | 558,871.750 | 771,569.375 | Q |
| 208 | USW UZ-N31 | 4,151.84 | 192.60 | 562,751.938 | 764,245.625 | Q |
| 209 | USW UZ-N32 | 4,156.18 | 207.40 | 562,799.625 | 764,302.625 | Q |
| 210 | USW UZ-N33 | 4,329.16 | 75.00 | 561,192.188 | 770,070.125 | Q |
| 211 | USW UZ-N34 | 4,321.12 | 84.10 | 561,251.375 | 770,158.750 | Q |
| 212 | USW UZ-N35 | 4,245.37 | 175.00 | 562,309.938 | 762,264.000 | Q |
| 213 | USW UZ-N36 | 4,640.37 | 59.82 | 563,582.688 | 773,899.500 | Q |
| 214 | USW UZ-N37 | 4,121.12 | 271.33 | 563,713.500 | 767,499.125 | Q |
| 215 | USW UZ-N38 | 4,146.89 | 89.40 | 563,343.875 | 767,466.312 | Q |
| 216 | UE-25 UZN #39 | 3,768.22 | 125.00 | 617,277.750 | 755,133.062 | Q |
| 217 | USW UZ-N40 | 4,079.70 | 35.00 | 564,221.438 | 766,176.188 | Q |
| 218 | USW UZ-N41 | 4,117.81 | 37.00 | 563,521.062 | 765,867.750 | Q |
| 219 | USW UZ-N42 | 4,179.30 | 40.00 | 562,858.625 | 765,729.125 | Q |
| 220 | USW UZ-N43 | 4,149.50 | 45.00 | 563,263.625 | 765,997.500 | Q |
| 221 | USW UZ-N44 | 4,161.70 | 36.00 | 563,139.500 | 766,192.938 | Q |
| 222 | USW UZ-N45 | 4,130.20 | 45.00 | 563,429.250 | 765,977.250 | Q |
| 223 | USW UZ-N46 | 4,500.66 | 99.00 | 559,747.938 | 772,262.188 | Q |
| 224 | USW UZ-N47 | 4,480.41 | 86.00 | 559,783.750 | 771,967.562 | Q |
| 225 | USW UZ-N48 | 4,211.08 | 35.00 | 562,413.812 | 760,835.938 | Q |
| 226 | USW UZ-N49 | 4,228.25 | 36.00 | 562,322.062 | 760,861.438 | Q |
| 227 | USW UZ-N50 | 4,172.77 | 20.00 | 562,911.938 | 760,776.938 | Q |
| 228 | USW UZ-N51 | 4,168.62 | 20.00 | 562,909.562 | 760,861.750 | Q |
| 229 | USW UZ-N52 | 4,171.85 | 25.00 | 562,908.938 | 760,894.938 | Q |
| 230 | USW UZ-N53 | 4,053.86 | 234.70 | 564,237.250 | 760,096.250 | Q |
| 231 | USW UZ-N54 | 4,044.07 | 244.72 | 564,262.188 | 760,271.938 | Q |
| 232 | USW UZ-N55 | 4,070.60 | 255.30 | 564,248.250 | 760,502.875 | Q |
| 233 | USW UZ-N57 | 4,183.66 | 118.90 | 560,829.812 | 755,164.500 | Q |
| 234 | USW UZ-N58 | 4,179.23 | 118.80 | 560,862.188 | 755,240.375 | Q |
| 235 | USW UZ-N59 | 4,177.71 | 118.80 | 560,888.375 | 755,321.250 | Q |
| 236 | USW UZ-N61 | 4,182.17 | 118.90 | 560,893.938 | 755,375.938 | Q |
| 237 | USW UZ-N62 | 4,881.95 | 60.00 | 558,302.688 | 757,125.188 | Q |
| 238 | USW UZ-N64 | 4,789.38 | 60.04 | 559,435.500 | 765,728.125 | Q |
| 239 | USW UZ-N65 | 4,372.32 | 50.00 | 562,537.625 | 758,627.312 | Q |
| 240 | USW UZ-N66 | 4,357.94 | 50.00 | 561,881.688 | 758,433.875 | Q |
| 241 | USW UZ-N67 | 3,918.22 | 25.00 | 563,799.250 | 753,635.562 | Q |
| 242 | USW UZ-N68 | 3,923.25 | 55.00 | 564,006.125 | 753,963.688 | Q |
| 243 | USW UZ-N69 | 3,916.96 | 35.00 | 564,402.000 | 754,462.500 | Q |
| 244 | USW UZ-N70 | 4,541.82 | 35.00 | 560,165.000 | 769,250.750 | Q |
| 245 | USW UZ-N71 | 4,924.66 | 52.00 | 558,405.938 | 761,025.688 | Q |
| 246 | USW UZ-N72 | 4,864.40 | 30.00 | 558,645.938 | 761,071.625 | Q |
| 247 | USW UZ-N73 | 4,781.62 | 30.00 | 558,945.562 | 761,052.938 | Q |
| 248 | USW UZ-N74 | 4,903.28 | 37.00 | 558,560.125 | 761,361.938 | Q |
| 249 | USW UZ-N75 | 4,798.65 | 37.00 | 559,076.000 | 761,462.250 | Q |
| 250 | USW UZ-N76 | 4,795.53 | 40.00 | 559,067.438 | 761,356.875 | Q |

Table V-1. Surface-Based Boreholes (Continued)

| Bores3 Identifier | Borehole Identifier | Elevation (feet) | Depth (feet) | Easting (feet) | Northing (feet) | Qualification Status |
|---|---|---|---|---|---|---|
| 251 | USW UZ-N77 | 3,902.95 | 50.00 | 554,397.312 | 755,526.875 | Q |
| 252 | USW UZ-N78 | 4,182.02 | 30.00 | 556,262.688 | 757,558.438 | Q |
| 253 | USW UZ-N79 | 4,154.41 | 32.00 | 556,334.125 | 757,733.688 | Q |
| 254 | USW UZ-N80 | 4,331.23 | 52.00 | 557,201.375 | 757,635.000 | Q |
| 255 | USW UZ-N81 | 4,064.41 | 70.00 | 555,595.375 | 757,807.562 | Q |
| 256 | USW UZ-N82 | 3,974.22 | 40.00 | 554,689.938 | 757,498.750 | Q |
| 257 | USW UZ-N83 | 4,157.26 | 70.00 | 556,349.250 | 760,624.938 | Q |
| 258 | USW UZ-N84 | 4,111.47 | 45.00 | 555,888.000 | 760,717.062 | Q |
| 259 | USW UZ-N86 | 4,172.29 | 30.00 | 556,460.500 | 760,615.375 | Q |
| 260 | USW UZ-N87 | 4,111.42 | 45.00 | 555,887.250 | 760,714.250 | Q |
| 261 | USW UZ-N88 | 4,201.65 | 30.00 | 556,551.250 | 760,797.938 | Q |
| 262 | USW UZ-N89 | 4,089.46 | 45.00 | 555,588.750 | 760,611.250 | Q |
| 263 | USW UZ-N90 | 4,089.34 | 45.00 | 555,587.438 | 760,609.250 | Q |
| 264 | USW UZ-N93 | 4,924.03 | 40.00 | 558,321.000 | 759,584.062 | Q |
| 265 | USW UZ-N94 | 4,925.86 | 30.00 | 558,236.688 | 759,723.312 | Q |
| 266 | USW UZ-N95 | 4,928.70 | 20.00 | 558,172.625 | 759,898.750 | Q |
| 267 | USW UZ-N96 | 4,893.08 | 35.00 | 558,403.375 | 759,445.562 | Q |
| 268 | USW UZ-N98 | 4,223.72 | 75.00 | 562,083.750 | 767,996.500 | Q |
| 269 | USW VH-1 | 3,160.05 | 2,501.00 | 533,625.000 | 743,356.375 | Q |
| 270 | USW VH-2 | 3,197.08 | 4,000.00 | 526,264.500 | 748,321.062 | Q |
| 271 | USW WT-1 | 3,939.75 | 1,689.00 | 563,739.188 | 753,942.125 | Q |
| 272 | USW WT-2 | 4,268.23 | 2,060.00 | 561,924.000 | 760,661.562 | Q |
| 273 | USW WT-7 | 3,926.24 | 1,610.00 | 553,891.625 | 755,570.562 | Q |
| 274 | USW WT-10 | 3,685.77 | 1,412.00 | 553,302.312 | 748,771.562 | Q |
| 275 | USW WT-11 | 3,589.10 | 1,446.00 | 558,376.688 | 739,071.312 | Q |
| 276 | UE-25 SPT #1 | 3,945.90 | -9,999.00 | 566,219.312 | 765,089.875 | Q |
| 277 | USW UNK-2 | 3,925.91 | -9,999.00 | 553,793.812 | 755,580.062 | Q |
| 278 | USW SRS-13 | 3,062.31 | -9,999.00 | 528,364.688 | 740,508.500 | Q |
| 279 | USW SRS-11 | 2,998.00 | 202.30 | 522,693.000 | 737,205.000 | Q |
| 280 | USW SRS-201 | 3,173.00 | 200.00 | 534,016.000 | 743,815.000 | Q |
| 281 | USW SRS-203 | 3,364.00 | 152.00 | 539,831.000 | 747,042.000 | Q |
| 282 | USW SRS-207 | 3,782.00 | 194.20 | 550,960.000 | 753,855.000 | Q |
| 283 | USW SRS-208.5a | 4,244.00 | -9,999.00 | 556,764.000 | 757,559.000 | Q |
| 284 | USW SRS-208.5b | 4,244.00 | -9,999.00 | 556,764.000 | 757,559.000 | Q |
| 285 | USW SRS-211a | 4,160.00 | -9,999.00 | 555,676.000 | 762,157.000 | Q |
| 286 | USW SRS-211b | 4,160.00 | -9,999.00 | 555,676.000 | 762,157.000 | Q |
| 287 | USW SRS-300 | 3,703.00 | 201.70 | 538,298.000 | 766,510.000 | Q |
| 288 | USW SRS-302a | 4,160.00 | -9,999.00 | 555,676.000 | 762,157.000 | Q |
| 289 | USW SRS-302b | 4,160.00 | -9,999.00 | 555,676.000 | 762,157.000 | Q |
| 290 | UE-25 SRS #307r | 3,661.00 | -9,999.00 | 570,958.000 | 756,207.000 | Q |
| 291 | UE-25 SRS #311 | 3,356.00 | -9,999.00 | 577,865.000 | 755,087.000 | Q |
| 292 | US-25 #3 | 3,620.00 | 52.00 | 572,455.000 | 762,075.000 | Q |
| 293 | USW SRS-1 | 2,663.00 | 201.30 | 498,514.000 | 717,226.000 | Q |
| 294 | USW SRS-3 | 2,670.00 | 202.40 | 503,010.000 | 721,851.000 | Q |
| 295 | USW SRS-5 | 2,736.00 | 200.00 | 507,380.000 | 726,590.000 | Q |
| 296 | USW SRS-7 | 2,954.00 | -9,999.00 | 511,921.000 | 730,880.000 | Q |
| 297 | USW SRS-9 | 2,939.00 | -9,999.00 | 517,012.000 | 733,911.000 | Q |
| 298 | UE-25 RF #9 | 3,671.70 | 106.00 | 570,642.688 | 765,945.625 | NQ |
| 299 | UE-25 RF #10 | 3,669.70 | 60.00 | 570,229.062 | 765,307.125 | NQ |
| 300 | US-25 #1 | 4,258.50 | 53.00 | 565,422.750 | 762,630.500 | NQ |

Table V-1. Surface-Based Boreholes (Continued)

| Bores3 Identifier | Borehole Identifier | Elevation (feet) | Depth (feet) | Easting (feet) | Northing (feet) | Qualification Status |
|---|---|---|---|---|---|---|
| 301 | US-25 #2 | 4,316.20 | 53.00 | 566,430.125 | 762,402.375 | NQ |
| 302 | US-25 #18 | 3,545.00 | 50.00 | 574,709.250 | 761,895.500 | NQ |
| 303 | US-25 #20 | 3,485.00 | 50.00 | 577,174.688 | 761,613.375 | NQ |
| 304 | UE-25 RF #11 | 3,665.40 | 78.00 | 570,433.625 | 765,621.500 | NQ |
| 306 | UE-25 G #7 | -9,999.00 | -9,999.00 | 566,090.688 | 724,585.375 | NQ |
| 307 | USW G-5 | -9,999.00 | -9,999.00 | 563,008.438 | 781,929.750 | NQ |
| 308 | USW G-6 | -9,999.00 | -9,999.00 | 548,924.062 | 778,721.312 | NQ |
| 309 | UE-25 PH #1a | -9,999.00 | -9,999.00 | 569,303.250 | 766,000.562 | NQ |
| 310 | UE-25 PH #1b | -9,999.00 | -9,999.00 | 569,303.250 | 766,000.562 | NQ |
| 311 | USW V-1 | -9,999.00 | -9,999.00 | 518,001.469 | 729,600.125 | NQ |
| 312 | USW V-2 | -9,999.00 | -9,999.00 | 578,906.938 | 683,721.312 | NQ |
| 313 | USW V-3 | -9,999.00 | -9,999.00 | 549,338.438 | 656,876.438 | NQ |
| 314 | USW V-4 | -9,999.00 | -9,999.00 | 546,412.875 | 654,950.938 | NQ |
| 315 | USW SD-11 | -9,999.00 | -9,999.00 | 558,315.188 | 758,175.000 | NQ |
| 316 | USW SD-10 | -9,999.00 | -9,999.00 | 561,799.938 | 765,499.688 | NQ |
| 317 | UE-25 SD #8 | -9,999.00 | -9,999.00 | 564,603.062 | 762,799.438 | NQ |
| 319 | UE-25 SD #5 | -9,999.00 | -9,999.00 | 564,969.438 | 764,630.625 | NQ |
| 320 | USW SD-4 | -9,999.00 | -9,999.00 | 562,800.500 | 764,264.562 | NQ |
| 321 | USW SD-3 | -9,999.00 | -9,999.00 | 559,174.562 | 764,609.438 | NQ |
| 322 | USW SD-2 | -9,999.00 | -9,999.00 | 559,799.688 | 767,700.688 | NQ |
| 323 | USW SD-1 | -9,999.00 | -9,999.00 | 561,298.500 | 769,199.562 | NQ |
| 326 | USW SRG-1 | -9,999.00 | -9,999.00 | 567,189.688 | 756,609.000 | NQ |
| 327 | USW SRG-2 | -9,999.00 | -9,999.00 | 564,934.250 | 756,699.500 | NQ |
| 328 | USW SRG-3 | -9,999.00 | -9,999.00 | 563,301.000 | 757,165.125 | NQ |
| 329 | USW SRG-4 | -9,999.00 | -9,999.00 | 561,799.375 | 757,675.625 | NQ |
| 330 | USW SRG-5 | -9,999.00 | -9,999.00 | 558,315.188 | 758,175.000 | NQ |
| 331 | USW UZ-10 | -9,999.00 | -9,999.00 | 561,123.688 | 750,138.938 | NQ |
| 332 | UE-25 WT #19 | -9,999.00 | -9,999.00 | 589,972.688 | 747,978.125 | NQ |
| 333 | UE-25 WT #20 | -9,999.00 | -9,999.00 | 565,140.938 | 728,303.500 | NQ |
| 335 | UE-25 UZ #9 | -9,999.00 | -9,999.00 | 564,751.062 | 760,600.000 | NQ |
| 336 | UE-25 UZP #1/2 | -9,999.00 | -9,999.00 | 569,199.188 | 730,400.438 | NQ |
| 337 | USW H-7 | -9,999.00 | -9,999.00 | 558,652.625 | 762,290.500 | NQ |
| 338 | USW UZ-11 | -9,999.00 | -9,999.00 | 556,613.188 | 757,399.375 | NQ |
| 339 | USW UZ-12 | -9,999.00 | -9,999.00 | 556,055.000 | 757,399.625 | NQ |
| 340 | USW UZ-2 | -9,999.00 | -9,999.00 | 558,180.125 | 759,769.000 | NQ |
| 341 | USW UZ-3 | -9,999.00 | -9,999.00 | 558,220.625 | 759,624.625 | NQ |
| 342 | USW WT-21 | -9,999.00 | -9,999.00 | 550,327.500 | 760,085.688 | NQ |
| 343 | USW WT-22 | -9,999.00 | -9,999.00 | 528,373.312 | 778,858.125 | NQ |
| 344 | UE-25 FM #1 | -9,999.00 | -9,999.00 | 581,694.688 | 766,450.688 | NQ |
| 345 | USW WT-9 | -9,999.00 | -9,999.00 | 557,642.188 | 769,476.500 | NQ |
| 346 | USW WT-23 | -9,999.00 | -9,999.00 | 559,597.375 | 772,549.688 | NQ |
| 347 | USW WT-8 | -9,999.00 | -9,999.00 | 557,052.000 | 762,283.062 | NQ |
| 348 | UE-25 FM #2 | -9,999.00 | -9,999.00 | 583,497.750 | 782,300.188 | NQ |
| 349 | UE-25 UZ #15 | -9,999.00 | -9,999.00 | 558,327.562 | 759,731.812 | NQ |
| 350 | UE-25 UZ #9b | -9,999.00 | -9,999.00 | 564,849.312 | 760,600.250 | NQ |
| 351 | UE-25 UZ #9a | -9,999.00 | -9,999.00 | 564,800.188 | 760,600.125 | NQ |
| 352 | UE-25 FM #3 | -9,999.00 | -9,999.00 | 572,400.062 | 776,000.438 | NQ |
| 353 | UE-25 RF #3 | 3,657.70 | 151.00 | 571,098.938 | 765,574.562 | NQ |
| 354 | UE-25 RF #5 | 3,813.70 | 122.00 | 568,096.625 | 759,198.375 | NQ |
| 355 | USW G-8 | -9,999.00 | -9,999.00 | 589,974.938 | 747,979.562 | NQ |

Table V-1. Surface-Based Boreholes (Continued)

| Bores3 Identifier | Borehole Identifier | Elevation (feet) | Depth (feet) | Easting (feet) | Northing (feet) | Qualification Status |
|---|---|---|---|---|---|---|
| 356 | USW sei-101 | -9,999.00 | -9,999.00 | 518,361.188 | 750,233.750 | NQ |
| 357 | USW sei-102 | -9,999.00 | -9,999.00 | 520,948.406 | 748,899.625 | NQ |
| 358 | USW sei-103 | -9,999.00 | -9,999.00 | 523,975.906 | 747,567.500 | NQ |
| 359 | USW sei-104 | -9,999.00 | -9,999.00 | 527,001.375 | 746,285.688 | NQ |
| 360 | USW sei-105 | -9,999.00 | -9,999.00 | 530,036.062 | 745,034.750 | NQ |
| 361 | USW sei-106 | -9,999.00 | -9,999.00 | 533,185.125 | 743,644.062 | NQ |
| 362 | USW sei-202 | -9,999.00 | -9,999.00 | 536,933.438 | 745,458.250 | NQ |
| 363 | USW sei-203 | -9,999.00 | -9,999.00 | 539,792.500 | 747,100.812 | NQ |
| 364 | USW sei-204 | -9,999.00 | -9,999.00 | 542,720.750 | 748,600.812 | NQ |
| 365 | USW sei-205 | -9,999.00 | -9,999.00 | 545,424.688 | 750,475.688 | NQ |
| 366 | USW sei-206 | -9,999.00 | -9,999.00 | 548,208.812 | 752,281.500 | NQ |
| 367 | USW sei-207 | -9,999.00 | -9,999.00 | 551,012.875 | 753,964.000 | NQ |
| 368 | USW sei-208 | -9,999.00 | -9,999.00 | 553,910.688 | 755,506.750 | NQ |
| 369 | USW sei-210 | -9,999.00 | -9,999.00 | 560,492.375 | 759,085.062 | NQ |
| 370 | USW sei-211 | -9,999.00 | -9,999.00 | 563,782.562 | 760,396.438 | NQ |
| 371 | UE-25 sei #212 | -9,999.00 | -9,999.00 | 567,096.312 | 762,001.188 | NQ |
| 372 | USW sei-300 | -9,999.00 | -9,999.00 | 538,287.062 | 766,675.500 | NQ |
| 373 | USW sei-301 | -9,999.00 | -9,999.00 | 553,789.688 | 763,838.875 | NQ |
| 374 | USW sei-302 | -9,999.00 | -9,999.00 | 555,748.188 | 762,326.250 | NQ |
| 375 | USW sei-303 | -9,999.00 | -9,999.00 | 557,884.562 | 760,191.938 | NQ |
| 376 | USW sei-304 | -9,999.00 | -9,999.00 | 560,492.375 | 759,085.062 | NQ |
| 377 | USW sei-305 | -9,999.00 | -9,999.00 | 563,074.062 | 757,796.500 | NQ |
| 378 | UE-25 sei #306 | -9,999.00 | -9,999.00 | 568,612.125 | 757,474.875 | NQ |
| 379 | UE-25 sei #307 | -9,999.00 | -9,999.00 | 570,935.812 | 755,094.812 | NQ |
| 380 | UE-25 sei #308 | -9,999.00 | -9,999.00 | 573,436.125 | 756,183.062 | NQ |
| 381 | UE-25 sei #401 | -9,999.00 | -9,999.00 | 570,170.500 | 753,062.562 | NQ |
| 382 | UE-25 sei #402 | -9,999.00 | -9,999.00 | 570,930.750 | 756,197.438 | NQ |
| 383 | UE-25 sei #403 | -9,999.00 | -9,999.00 | 573,078.812 | 758,763.812 | NQ |
| 384 | UE-25 sei #404 | -9,999.00 | -9,999.00 | 574,640.312 | 761,791.188 | NQ |
| 385 | UE-25 sei #405 | -9,999.00 | -9,999.00 | 576,541.062 | 762,269.875 | NQ |
| 386 | UE-25 sei #406 | -9,999.00 | -9,999.00 | 578,474.000 | 764,783.312 | NQ |
| 387 | UE-25 sei #407 | -9,999.00 | -9,999.00 | 580,117.812 | 767,598.750 | NQ |
| 388 | UE-25 sei #501 | -9,999.00 | -9,999.00 | 575,152.500 | 746,480.438 | NQ |
| 389 | UE-25 sei #502 | -9,999.00 | -9,999.00 | 576,372.750 | 749,508.375 | NQ |
| 390 | UE-25 sei #503 | -9,999.00 | -9,999.00 | 577,438.562 | 752,573.438 | NQ |
| 391 | UE-25 sei #504 | -9,999.00 | -9,999.00 | 578,119.562 | 755,831.938 | NQ |
| 392 | UE-25 sei #505 | -9,999.00 | -9,999.00 | 578,432.938 | 759,524.062 | NQ |
| 393 | UE-25 sei #506 | -9,999.00 | -9,999.00 | 576,538.875 | 762,268.500 | NQ |
| 394 | UE-25 sei #507 | -9,999.00 | -9,999.00 | 574,469.250 | 764,843.188 | NQ |
| 395 | UE-25 sei #510 | -9,999.00 | -9,999.00 | 570,335.562 | 773,559.312 | NQ |
| 396 | UE-25 sei #511 | -9,999.00 | -9,999.00 | 569,026.875 | 776,679.312 | NQ |
| 397 | UE-25 sei #512 | -9,999.00 | -9,999.00 | 566,600.500 | 778,941.188 | NQ |
| 398 | USW sei-513 | -9,999.00 | -9,999.00 | 563,990.125 | 780,902.938 | NQ |
| 399 | USW sei-514 | -9,999.00 | -9,999.00 | 561,459.875 | 783,083.125 | NQ |
| 400 | USW sei-515 | -9,999.00 | -9,999.00 | 559,068.438 | 785,222.188 | NQ |
| 401 | USW sei-516 | -9,999.00 | -9,999.00 | 557,528.375 | 786,778.562 | NQ |
| 402 | UE-25 UZ #4a | -9,999.00 | -9,999.00 | 566,138.375 | 768,716.250 | NQ |
| 403 | UE-25 UZ #5a | -9,999.00 | -9,999.00 | 566,134.188 | 768,591.250 | NQ |
| 404 | USW UZ-8a | -9,999.00 | -9,999.00 | 562,292.625 | 760,762.438 | NQ |
| 405 | UE-25 PTH #2 | 3,641.73 | -9,999.00 | 571,147.438 | 764,947.000 | NQ |

Table V-1. Surface-Based Boreholes (Continued)

| Bores3 Identifier | Borehole Identifier | Elevation (feet) | Depth (feet) | Easting (feet) | Northing (feet) | Qualification Status |
|---|---|---|---|---|---|---|
| 406 | UE-25 PTH #3 | 3,642.28 | -9,999.00 | 571,098.312 | 764,946.875 | NQ |
| 407 | USW WT-25 | -9,999.00 | -9,999.00 | 553,603.562 | 788,691.375 | NQ |
| 408 | USW WT-26 | -9,999.00 | -9,999.00 | 553,673.438 | 752,287.250 | NQ |
| 409 | USW WT-27 | -9,999.00 | -9,999.00 | 524,360.500 | 800,774.188 | NQ |
| 410 | UE-25 PTH #1 | 3,640.27 | -9,999.00 | 571,198.750 | 764,947.125 | NQ |
| 411 | UE-25 PTH #4 | 3,639.61 | -9,999.00 | 571,096.375 | 764,845.500 | NQ |
| 412 | UE-25 PTH #5 | 3,639.56 | -9,999.00 | 571,147.688 | 764,847.000 | NQ |
| 413 | UE-25 PTH #6 | 3,638.23 | -9,999.00 | 571,199.000 | 764,847.125 | NQ |
| 414 | UE-25 PSF #7 | 3,641.01 | -9,999.00 | 571,152.000 | 764,895.625 | NQ |
| 415 | USW NRG-5a | -9,999.00 | -9,999.00 | 564,769.875 | 767,889.500 | NQ |
| 416 | USW NRG-7 | 4,209.40 | -9,999.00 | 563,006.688 | 768,846.500 | NQ |
| 417 | USW NRG-8c | -9,999.00 | -9,999.00 | 568,704.938 | 766,032.438 | NQ |
| 418 | USW NRG-8b | -9,999.00 | -9,999.00 | 568,801.062 | 765,978.500 | NQ |
| 419 | USW NRG-8a | -9,999.00 | -9,999.00 | 568,988.688 | 765,927.625 | NQ |
| 420 | UE-25 NRG #2e | -9,999.00 | -9,999.00 | 569,102.812 | 765,822.312 | NQ |
| 421 | USW SRS-102 | -9,999.00 | -9,999.00 | 520,948.406 | 748,899.625 | NQ |
| 422 | USW SRS-104 | -9,999.00 | -9,999.00 | 527,001.375 | 746,285.688 | NQ |
| 423 | USW SRS-106 | -9,999.00 | -9,999.00 | 533,185.125 | 743,642.688 | NQ |
| 424 | USW SRS-205 | -9,999.00 | -9,999.00 | 525,425.062 | 750,475.375 | NQ |
| 425 | USW SRS-205a | -9,999.00 | -9,999.00 | 525,425.062 | 750,475.375 | NQ |
| 426 | USW SRS-205b | -9,999.00 | -9,999.00 | 525,425.062 | 750,475.375 | NQ |
| 427 | USW SRS-211 | -9,999.00 | -9,999.00 | 563,474.188 | 760,540.125 | NQ |
| 428 | USW SRS-302 | -9,999.00 | -9,999.00 | 555,748.188 | 762,327.625 | NQ |
| 429 | USW SRS-305 | -9,999.00 | -9,999.00 | 563,203.750 | 757,705.125 | NQ |
| 430 | USW SRG-3a | -9,999.00 | -9,999.00 | 563,350.125 | 757,165.250 | NQ |
| 431 | USW SRS-305a | -9,999.00 | -9,999.00 | 563,176.938 | 757,705.062 | NQ |
| 432 | USW SRS-305b | -9,999.00 | -9,999.00 | 563,230.562 | 757,705.188 | NQ |
| 433 | UE-25 BS #1 | -9,999.00 | -9,999.00 | 570,441.875 | 765,016.062 | NQ |
| 434 | UE-25 BS #2 | -9,999.00 | -9,999.00 | 570,450.875 | 764,989.688 | NQ |
| 435 | UE-25 BS #3 | -9,999.00 | -9,999.00 | 570,372.625 | 765,032.562 | NQ |
| 436 | UE-25 BS #4 | -9,999.00 | -9,999.00 | 570,319.000 | 765,061.562 | NQ |
| 437 | UE-25 PL #1 | -9,999.00 | -9,999.00 | 571,487.000 | 763,092.500 | NQ |
| 438 | UE-25 PL #2 | -9,999.00 | -9,999.00 | 571,513.750 | 763,106.500 | NQ |
| 439 | UE-25 PL #3 | -9,999.00 | -9,999.00 | 571,473.500 | 763,142.500 | NQ |
| 440 | UE-25 PL #4 | -9,999.00 | -9,999.00 | 570,966.625 | 764,060.562 | NQ |
| 441 | UE-25 PL #5 | -9,999.00 | -9,999.00 | 570,955.438 | 764,082.750 | NQ |
| 442 | UE-25 PL #6 | -9,999.00 | -9,999.00 | 570,942.000 | 764,104.938 | NQ |
| 443 | UE-25 PL #7 | -9,999.00 | -9,999.00 | 570,894.875 | 764,192.312 | NQ |
| 444 | UE-25 PL #8 | -9,999.00 | -9,999.00 | 570,881.438 | 764,214.500 | NQ |
| 445 | UE-25 PL #9 | -9,999.00 | -9,999.00 | 570,868.000 | 764,236.625 | NQ |
| 446 | UE-25 PL #10 | -9,999.00 | -9,999.00 | 570,441.875 | 765,016.062 | NQ |
| 447 | UE-25 PL #11 | -9,999.00 | -9,999.00 | 570,450.875 | 764,989.688 | NQ |
| 448 | UE-25 PL #12 | -9,999.00 | -9,999.00 | 570,435.250 | 764,998.000 | NQ |
| 449 | UE-25 PL #13 | -9,999.00 | -9,999.00 | 570,372.625 | 765,032.562 | NQ |
| 450 | UE-25 PL #14 | -9,999.00 | -9,999.00 | 570,348.062 | 765,046.375 | NQ |
| 451 | UE-25 PL #15 | -9,999.00 | -9,999.00 | 570,319.000 | 765,061.562 | NQ |
| 452 | NA | -9,999.00 | -9,999.00 | 562,368.688 | 760,709.312 | NQ |
| 453 | USW sei-201 | -9,999.00 | -9,999.00 | 534,039.688 | 743,907.375 | NQ |
| 454 | USW SP-5a | 3,368.90 | -9,999.00 | 538,653.375 | 751,454.875 | NQ |
| 455 | USW SP-5b | 3,366.10 | -9,999.00 | 538,763.875 | 751,426.875 | NQ |

Table V-1. Surface-Based Boreholes (Continued)

| Bores3 Identifier | Borehole Identifier | Elevation (feet) | Depth (feet) | Easting (feet) | Northing (feet) | Qualification Status |
|---|---|---|---|---|---|---|
| 456 | U-12 g | 6,114.00 | -9,999.00 | 637,708.000 | 881,027.000 | NQ |
| 457 | USW SD-13 | -9,999.00 | -9,999.00 | 560,872.000 | 773,837.000 | NQ |
| 458 | UE-20 PM #2 | 5,586.00 | 8,782.00 | 528,664.812 | 944,583.250 | NQ |
| 459 | UE-20 PM #1 | 6,558.00 | 7,858.00 | 575,885.625 | 921,109.250 | NQ |
| 460 | UE-12 DOL | -9,999.00 | -9,999.00 | 638,611.375 | 886,664.875 | NQ |
| 461 | U-15 k | 5,168.00 | 857.00 | 677,459.000 | 903,088.000 | NQ |
| 462 | UE-3 TWE | 4,934.00 | 3,000.00 | 695,991.375 | 839,984.625 | NQ |
| 463 | UE-27 TWF | 4,143.00 | 3,400.00 | 661,206.938 | 731,855.750 | NQ |
| 464 | USW TW-3 | 3,477.00 | 1,860.00 | 736,937.000 | 750,189.000 | NQ |
| 465 | USW TW-5 | 3,050.00 | 926.00 | 607,632.000 | 687,231.000 | NQ |
| 466 | USW TW-4 | -9,999.00 | 1,500.00 | 755,786.000 | 669,497.000 | NQ |
| 467 | UE-16 b | 4,894.06 | 361.00 | 646,345.000 | 839,498.000 | Q |
| 468 | UE-20 c | 6,283.00 | 4,800.00 | 556,763.000 | 903,204.000 | NQ |
| 469 | UE-18 t | 5,201.00 | 2,600.00 | 598,394.000 | 865,793.000 | NQ |
| 472 | USW WT-24 | 4,900.28 | -9,999.00 | 562,329.905 | 776,703.061 | Q |
| 1 | U-20 f | 6,117.00 | 4,202.00 | 551,857.000 | 917,825.000 | NQ |
| 2 | UE-15 d | 4,586.00 | 6,001.00 | 682,084.000 | 895,709.000 | NQ |
| 3 | UE-19 c | 7,033.00 | 8,489.00 | 601,027.000 | 917,000.000 | NQ |
| 4 | UE-2 WW #2 | 4,470.00 | 3,422.00 | 668,720.000 | 880,000.000 | NQ |
| 5 | UE-5 WW #5a | 3,093.00 | 910.00 | 707,514.000 | 738,361.000 | NQ |
| 6 | UE-5 WW #5b | 3,092.00 | 900.00 | 704,263.000 | 747,359.000 | NQ |
| 7 | UE-5 WW #5c | 3,081.00 | 1,200.00 | 705,888.000 | 742,860.000 | NQ |
| 8 | UE-18 WW #8 | 5,695.00 | 5,499.00 | 609,999.000 | 879,468.000 | NQ |
| 9 | UE-6 WW c | 3,921.00 | 1,701.00 | 692,061.000 | 790,082.000 | NQ |
| 10 | UE-6 WW c #1 | 3,921.00 | 1,707.00 | 692,132.000 | 790,011.000 | NQ |
| 318 | USW SD-6 | 4,905.32 | 2,541.00 | 558,607.680 | 762,421.390 | Q |
| 305 | UE-25 NRG #1 | 3,754.60 | 150.00 | 569,803.350 | 765,359.030 | Q |
| 473 | UE-20f | 6,116.00 | -9,999.00 | 552,007.000 | 917,825.000 | NQ |
| 324 | UE-25 RF #12 | -9,999.00 | -9,999.00 | 569,905.062 | 764,563.375 | NQ |
| 325 | UE-25 RF #6 | -9,999.00 | -9,999.00 | 570,051.438 | 764,934.500 | NQ |
| 470 | UE-25 RF #13 | 3,671.03 | -9,999.00 | 570,720.119 | 765,500.041 | Q |
| 459 | UE-25 RF #14 | 3,651.52 | -9,999.00 | 571,065.440 | 765,308.730 | Q |
| 460 | UE-25 RF #15 | 3,680.98 | -9,999.00 | 570,224.850 | 765,773.640 | Q |
| 461 | UE-25 RF #16 | 3,672.03 | -9,999.00 | 570,472.650 | 765,055.540 | Q |
| 462 | UE-25 RF #17 | 3,672.38 | -9,999.00 | 571,041.880 | 766,075.860 | Q |
| 463 | UE-25 RF #18 | 3,640.34 | -9,999.00 | 570,626.930 | 764,522.340 | Q |
| 464 | UE-25 RF #19 | 3,661.81 | -9,999.00 | 571,383.730 | 765,880.410 | Q |
| 465 | UE-25 RF #20 | 3,671.26 | -9,999.00 | 570,796.820 | 765,637.360 | Q |
| 466 | UE-25 RF #21 | 3,673.02 | -9,999.00 | 570,739.180 | 765,898.910 | Q |
| 467 | UE-25 RF #22 | 3,679.17 | -9,999.00 | 570,793.480 | 766,206.200 | Q |
| 468 | UE-25 RF #23 | 3,673.98 | -9,999.00 | 570,465.030 | 765,311.430 | Q |
| 469 | UE-25 RF #24 | 3,684.48 | -9,999.00 | 570,542.260 | 766,344.310 | Q |
| 470 | UE-25 RF #25 | 3,676.54 | -9,999.00 | 570,626.380 | 765,968.150 | Q |
| 471 | UE-25 RF #26 | 3,670.79 | -9,999.00 | 570,579.710 | 765,247.950 | Q |
| 472 | UE-25 RF #28 | 3,680.63 | -9,999.00 | 570,104.870 | 765,510.210 | Q |
| 473 | UE-25 RF #29 | 3,672.71 | -9,999.00 | 570,836.040 | 766,018.460 | Q |
| 474 | USW SD-6ST1 | 4,905.32 | -9,999.00 | 558,607.680 | 762,421.390 | NQ |

Source: MO0101COV00396.000

Table V-2. Surface-Based boreholes in the Vicinity of the Repository Layout

| Bores3 Identifier | Borehole Identifier | Elevation | | Depth | | Borehole Bottom Elevation (meters) | Easting | | Northing | | Q Status |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | feet | meters | feet | meters | | feet | meters | feet | meters | |
| 74 | UE-25 a #1 | 3,935.35 | 1,199.5 | 2,501.00 | 762.3 | 437.2 | 566,349.875 | 172,625.5 | 764,901.000 | 233,144.7 | Q |
| 76 | UE-25 a #4 | 4,102.04 | 1,250.3 | 500.00 | 152.4 | 1,097.9 | 564,471.875 | 172,053.1 | 767,972.375 | 234,080.8 | Q |
| 77 | UE-25 a #5 | 4,060.57 | 1,237.7 | 487.00 | 148.4 | 1,089.3 | 564,755.188 | 172,139.5 | 766,956.438 | 233,771.2 | Q |
| 78 | UE-25 a #6 | 4,053.27 | 1,235.5 | 500.00 | 152.4 | 1,083.1 | 564,500.875 | 172,062.0 | 765,899.875 | 233,449.1 | Q |
| 79 | UE-25 a #7 | 4,005.58 | 1,220.9 | 1,002.00 | 305.4 | 915.5 | 565,468.312 | 172,356.8 | 766,250.000 | 233,555.8 | Q |
| 80 | UE-25 b #1 | 3,939.28 | 1,200.7 | 4,003.00 | 1,220.1 | -19.4 | 566,416.188 | 172,645.8 | 765,244.312 | 233,249.3 | Q |
| 96 | UE-25 NRG #4 | 4,099.48 | 1,249.5 | 726.00 | 221.3 | 1,028.2 | 566,820.000 | 172,768.8 | 767,080.188 | 233,808.9 | Q |
| 97 | UE-25 NRG #5 | 4,106.66 | 1,251.7 | 1,350.00 | 411.5 | 840.2 | 564,769.875 | 172,144.0 | 767,889.625 | 234,055.6 | Q |
| 110 | UE-25 UZ #4 | 3,940.05 | 1,200.9 | 411.00 | 125.3 | 1,075.6 | 566,140.125 | 172,561.6 | 768,715.688 | 234,307.4 | Q |
| 111 | UE-25 UZ #5 | 3,952.83 | 1,204.8 | 405.00 | 123.4 | 1,081.4 | 566,136.125 | 172,560.4 | 768,593.125 | 234,270.0 | Q |
| 112 | UE-25 UZ #16 | 4,000.48 | 1,219.4 | 1,696.20 | 517.0 | 702.4 | 564,857.500 | 172,170.7 | 760,535.125 | 231,813.9 | Q |
| 151 | UE-25 WT #17 | 3,687.09 | 1,123.8 | 1,450.00 | 442.0 | 681.8 | 566,212.000 | 172,583.5 | 748,421.500 | 228,121.6 | Q |
| 152 | UE-25 WT #18 | 4,384.00 | 1,336.3 | 2,043.00 | 622.7 | 713.6 | 564,854.625 | 172,169.8 | 771,167.250 | 235,054.6 | Q |
| 176 | USW G-1 | 4,350.15 | 1,325.9 | 6,000.00 | 1,828.8 | -502.9 | 561,001.062 | 170,995.2 | 770,501.625 | 234,851.8 | Q |
| 178 | USW G-3 | 4,856.09 | 1,480.2 | 5,031.00 | 1,533.5 | -53.3 | 558,483.312 | 170,227.8 | 752,779.625 | 229,450.0 | Q |
| 179 | USW G-4 | 4,166.13 | 1,269.9 | 3,001.00 | 914.7 | 355.2 | 563,081.750 | 171,629.4 | 765,807.500 | 233,421.0 | Q |
| 181 | USW GU-3 | 4,856.70 | 1,480.3 | 5,031.00 | 1,533.5 | -53.2 | 558,501.625 | 170,233.4 | 752,690.000 | 229,422.7 | Q |
| 182 | USW H-1 | 4,274.19 | 1,302.8 | 600.00 | 182.9 | 1,119.9 | 562,388.438 | 171,418.1 | 770,254.812 | 234,776.5 | Q |
| 183 | USW H-3 | 4,866.47 | 1,483.3 | 4,000.00 | 1,219.2 | 264.1 | 558,451.875 | 170,218.2 | 756,542.000 | 230,596.8 | Q |
| 184 | USW H-4 | 4,096.17 | 1,248.5 | 4,004.00 | 1,220.4 | 28.1 | 563,911.375 | 171,882.3 | 761,644.500 | 232,152.1 | Q |
| 185 | USW H-5 | 4,851.35 | 1,478.7 | 4,000.00 | 1,219.2 | 259.5 | 558,908.438 | 170,357.4 | 766,634.125 | 233,672.9 | Q |
| 187 | USW NRG-6 | 4,092.12 | 1,247.3 | 1,100.00 | 335.3 | 912.0 | 564,187.000 | 171,966.3 | 766,726.500 | 233,701.1 | Q |
| 188 | USW NRG-7a | 4,207.17 | 1,282.4 | 1,513.00 | 461.2 | 821.2 | 562,984.000 | 171,599.6 | 768,880.125 | 234,357.5 | Q |
| 189 | USW SD-7 | 4,472.00 | 1,363.1 | 2,675.10 | 815.4 | 547.7 | 561,240.250 | 171,068.1 | 758,949.875 | 231,330.7 | Q |
| 190 | USW SD-9 | 4,272.64 | 1,302.3 | 2,223.00 | 677.6 | 624.7 | 561,818.000 | 171,244.2 | 767,998.500 | 234,088.8 | Q |
| 191 | USW SD-12 | 4,342.82 | 1,323.7 | 2,166.30 | 660.3 | 663.4 | 561,605.625 | 171,179.5 | 761,956.562 | 232,247.2 | Q |
| 192 | USW UZ-1 | 4,424.73 | 1,348.7 | 1,270.00 | 387.1 | 961.6 | 560,221.562 | 170,757.6 | 771,277.375 | 235,088.2 | Q |
| 193 | USW UZ-6 | 4,925.17 | 1,501.2 | 1,887.00 | 575.2 | 926.0 | 558,325.000 | 170,179.5 | 759,730.188 | 231,568.6 | Q |
| 196 | USW UZ-7a | 4,228.28 | 1,288.8 | 770.00 | 234.7 | 1,054.1 | 562,269.812 | 171,381.9 | 760,692.750 | 231,862.0 | Q |
| 199 | USW UZ-14 | 4,425.40 | 1,348.9 | 2,207.00 | 672.7 | 676.2 | 560,141.562 | 170,733.2 | 771,309.812 | 235,098.1 | Q |
| 231 | USW UZ-N54 | 4,044.07 | 1,232.6 | 244.72 | 74.6 | 1,158.0 | 564,262.188 | 171,989.2 | 760,271.938 | 231,733.7 | Q |
| 271 | USW WT-1 | 3,939.75 | 1,200.9 | 1,689.00 | 514.8 | 686.1 | 563,739.188 | 171,829.8 | 753,942.125 | 229,804.4 | Q |
| 272 | USW WT-2 | 4,268.23 | 1,301.0 | 2,060.00 | 627.9 | 673.1 | 561,924.000 | 171,276.5 | 760,661.562 | 231,852.5 | Q |
| 318 | USW SD-6 | 4,905.32 | 1,495.2 | 2,541.00 | 774.5 | 720.7 | 558,607.680 | 170,265.7 | 762,421.390 | 232,388.9 | Q |

# ATTACHMENT VI

# MAXIMUM LINEAL THERMAL LOAD CALCULATIONS

## ATTACHMENT VI

## MAXIMUM LINEAL THERMAL LOAD CALCULATION

The current WP inventory as listed in Table 2 of Section 4.1.1.3 will be used for defining the lower-temperature operating mode emplacement area for the 70,000 MTHM case. The WPs will be loaded in the drift to create a 1 kW/m average thermal load in each drift at emplacement (see Section 6.1) and this will dictate the method of calculating the required emplacement length.

Based on the maximum lineal thermal load of 1 kW/m, an average WP spacing is determined by an iterative process using an average spacing to calculate an emplacement drift length. Then the total heat output of the total inventory is divided by the total required emplacement drift length.

The required emplacement drift length for each WP type is determined by multiplying the total number of WPs, by type, with the length of the WP plus the WP spacing. The cumulative required emplacement drift length for each WP type is summed to get the total required emplacement drift length. Similarly, the heat output per WP type is determined by multiplying the total number of WP by type with the average initial heat output per WP type.

The average WP spacing for a maximum lineal thermal load of 1.0 kW/m is 1.9 meters (see Table VI-1). The average end-to-end WP spacing is an overall average across the repository. The actual end-to-end WP spacing will most likely range from 10 centimeters to several meters, depending on the type and heat output of the WP being emplaced. This variation in spacing, with an overall average end-to-end WP spacing is used to produce as even a line load as possible within the emplacement drifts.

Table VI-1. Maximum Lineal Thermal Load Calculation

| WP Description | | Number of WPs by WP Type (see Table 2) | Number of WPs Plus 5 Percent | WP Outer Length (m) (see Table 2) | Average Initial Heat Output kW (see Table 2) | Drift Length Required (m) | Total Heat Output (kW) | Heat Output per Meter |
|---|---|---|---|---|---|---|---|---|
| 21 PWR | APs | 4,299 | 4,514 | 5.165 | 11.530 | 31,891.4 | 52,046.4 | 1.63 |
| | CRs | 95 | 100 | 5.165 | 3.110 | 706.5 | 311.0 | 0.44 |
| 12 PWR | APs Long | 163 | 172 | 5.651 | 9.550 | 1,298.8 | 1,642.6 | 1.26 |
| 44 BWR | APs | 2,831 | 2,973 | 5.165 | 7.380 | 21,004.2 | 21,940.7 | 1.04 |
| 24 BWR | APs | 84 | 89 | 5.105 | 0.520 | 623.4 | 46.3 | 0.07 |
| *CSNF Subtotal* | | *7,472* | *7,848* | | | *55,524.3* | *75,987.0* | |
| 5 IPWF | | 95 | 100 | 3.590 | 3.530 | 549.0 | 353.0 | 0.64 |
| 5 DHLW Short/1 DOE SNF Short | | 1,052 | 1,105 | 3.590 | 2.980 | 6,066.5 | 3,292.9 | 0.54 |
| 5 DHLW Long/1 DOE SNF Long | | 1,406 | 1,477 | 5.217 | 0.407 | 10,511.8 | 601.1 | 0.06 |
| 2 MCO/2 DHLW | | 149 | 157 | 5.217 | 1.665 | 1,117.4 | 261.4 | 0.23 |
| 5 HLW Long/1 DOE SNF Short | | 126 | 133 | 5.217 | 0.407 | 946.6 | 54.1 | 0.06 |
| HLW Long Only | | 584 | 614 | 5.217 | 0.282 | 4,369.8 | 173.1 | 0.04 |
| Naval | Short | 200 | 200 | 5.430 | 3.070 | 1,466.0 | 614.0 | 0.42 |
| | Long | 100 | 100 | 6.065 | 3.070 | 796.5 | 307.0 | 0.39 |
| *DOE/HLW Subtotal* | | *3,712* | *3,886* | | | *25,823.6* | *5,656.6* | |
| **TOTAL** | | **11,184** | **11,734** | | | **81,347.9** | **81,643.6** | **1.00** |

Based on these calculations, applying a 1.9 meter average WP end-to-endspacing to the 97,000 MTHM inventory results in a required emplacement drift length of 107,405.3 meters.

Table VI-2. 97,000 MTHM Case Required Emplacement Drift Length Calculation

| WP Description | | Number of WPs by WP Type (see Table 2) | Number of WPs Plus 5 Percent | WP Outer Length (m) (see Table 2) | Drift Length Required (m) |
|---|---|---|---|---|---|
| 21 PWR | APs | 5,690 | 5,975 | 5.165 | 42,213.4 |
| | CRs | 106 | 112 | 5.165 | 791.3 |
| 12 PWR | APs Long | 293 | 308 | 5.651 | 2,325.7 |
| 44 BWR | APs | 3,732 | 3,919 | 5.165 | 27,687.7 |
| 24 BWR | APs | 98 | 103 | 5.105 | 721.5 |
| *CSNF Subtotal* | | *9,919* | *10,417* | | *73,739.6* |
| 5 IPWF | | 127 | 134 | 3.590 | 735.7 |
| 5 DHLW Short/1 DOE SNF Short | | 1,403 | 1,474 | 3.590 | 8,092.3 |
| 5 DHLW Long/1 DOE SNF Long | | 1,874 | 1968 | 5.217 | 14,006.3 |
| 2 MCO/2 DHLW | | 199 | 209 | 5.217 | 1,487.5 |
| 5 HLW Long/1 DOE SNF Short | | 167 | 176 | 5.217 | 1,252.6 |
| HLW Long Only | | 780 | 819 | 5.217 | 5,828.8 |
| Naval | Short | 200 | 200 | 5.430 | 1,466.0 |
| | Long | 100 | 100 | 6.065 | 796.5 |
| *DOE/HLW Subtotal* | | *4,850* | *5,080* | | *33,665.7* |
| **TOTAL** | | **14,769** | **15,497** | | **107,405.3** |

In addition, the flexibility of accommodating an expanded waste inventory of up to 119,000 MTHM has been considered. For the purposes of this analysis, a factor 1.2 is used to scale the 97,000 MTHM inventory up to 119,000 MTHM (119,000 divided by 97,000 equals approximately 1.2). The estimated inventory for the 119,000 MTHM Case is outlined in Table VI-3.

Table VI-3. Estimated Waste Inventory for 119,000 MTHM

| WP Description | | 97,000 MTHM Case Number of WPs by WP Type (see Table 2) | 119,000 MTHM Case Estimated Number of WPs by WP Type | 119,000 MTHM Case Number of WPs Plus 5 Percent |
|---|---|---|---|---|
| 21 PWR | APs | 5,690 | 6,828 | 7,170 |
| | CRs | 106 | 127 | 134 |
| 12 PWR | APs Long | 293 | 352 | 370 |
| 44 BWR | APs | 3,732 | 4,478 | 4,702 |
| 24 BWR | APs | 98 | 118 | 124 |
| *CSNF Subtotal* | | *9,919* | *11,903* | *12,500* |
| 5 IPWF | | 127 | 152 | 160 |
| 5 DHLW Short/1 DOE SNF Short | | 1,403 | 1,684 | 1,769 |
| 5 DHLW Long/1 DOE SNF Long | | 1,874 | 2,249 | 2,362 |
| 2 MCO/2 DHLW | | 199 | 239 | 251 |
| 5 HLW Long/1 DOE SNF Short | | 167 | 200 | 210 |
| HLW Long Only | | 780 | 936 | 983 |
| Naval | Short | 200 | 200 | 5.430 |
| | Long | 100 | 100 | 6.065 |
| *DOE/HLW Subtotal* | | *4,850* | *5,760* | *6,035* |
| **TOTAL** | | **14,769** | **17,663** | **18,535** |

Table VI-4. Estimated 119,000 MTHM Case Required Emplacement Drift Length Calculation

| **WP Description** | | **Number of WPs by WP Type (see Table VI-3)** | **Number of WPs Plus 5 Percent** | **WP Outer Length (m) (see Table 2)** | **Drift Length Required (m)** |
|---|---|---|---|---|---|
| 21 PWR | APs | 6,828 | 7,170 | 5.165 | 50,656.1 |
| | CRs | 127 | 134 | 5.165 | 946.7 |
| 12 PWR | APs Long | 352 | 370 | 5.651 | 2,793.9 |
| 44 BWR | APs | 4,478 | 4,702 | 5.165 | 33,219.6 |
| 24 BWR | APs | 118 | 124 | 5.105 | 868.6 |
| *CSNF Subtotal* | | *11,903* | *12,500* | | *88,484.9* |
| 5 IPWF | | 152 | 160 | 3.590 | 878.4 |
| 5 DHLW Short/1 DOE SNF Short | | 1,684 | 1,769 | 3.590 | 9,711.8 |
| 5 DHLW Long/1 DOE SNF Long | | 2,249 | 2,362 | 5.217 | 16,810.4 |
| 2 MCO/2 DHLW | | 239 | 251 | 5.217 | 1,786.4 |
| 5 HLW Long/1 DOE SNF Short | | 200 | 210 | 5.217 | 1,494.6 |
| HLW Long Only | | 936 | 983 | 5.217 | 6,996.0 |
| Naval | Short | 200 | 200 | 5.430 | 1,466.0 |
| | Long | 100 | 100 | 6.065 | 796.5 |
| *DOE/HLW Subtotal* | | *5,760* | *6,035* | | *39,940.1* |
| **TOTAL** | | **17,663** | **18,535** | | **128,425.0** |

The calculations outlined in Table VI-1, Table VI-2, and Table VI-4 can be repeated for a range of WP spacing, from 0.1 meters to 8.0 meters. These additional calculations are used to demonstrate the operational flexibility of the repository layout (see Table VI-5). The last required emplacement drift is determined by examining Table I-1.

Table VI-5. Linear Thermal Density Calculations, 81 meter Drift Spacing

| WP Spacing (m) | kW/m Based on 70,000 MTHM Case | AML Based on 70,000 MTHM Case (MTHM/acre) | 70,000 MTHM Case | | 97,000 MTHM Case | | 119,000 MTHM Case | |
|---|---|---|---|---|---|---|---|---|
| | | | Required Drift Length (meters) | Last Drift Required (see Table I-1) | Required Drift Length (meters) | Last Drift Required (see Table I-1) | Required Drift Length (meters) | Last Drift Required (see Table I-1) |
| 0.1 | 1.36 | 52.3 | 60,226.7 | P54 | 79,510.7 | P83 | 95,062.0 | L9 |
| 0.2 | 1.33 | 51.3 | 61,400.1 | P55 | 81,060.4 | P85 | 96,915.5 | L10 |
| 0.3 | 1.30 | 50.3 | 62,573.5 | P57 | 82,610.1 | P87 | 98,769.0 | L12 |
| 0.4 | 1.28 | 49.4 | 63,746.9 | P58 | 84,159.8 | P89 | 100,622.5 | L13 |
| 0.5 | 1.26 | 48.5 | 64,920.3 | P59 | 85,709.5 | L1 | 102,476.0 | L15 |
| 0.6 | 1.24 | 47.6 | 66,093.7 | P61 | 87,259.2 | L2 | 104,329.5 | L16 |
| 0.7 | 1.21 | 46.8 | 67,267.1 | P62 | 88,808.9 | L3 | 106,183.0 | L18 |
| 0.8 | 1.19 | 46.0 | 68,440.5 | P64 | 90,358.6 | L5 | 108,036.5 | L19 |
| 0.9 | 1.17 | 45.2 | 69,613.9 | P67 | 91,908.3 | L6 | 109,890.0 | L21 |
| 1.0 | 1.15 | 44.5 | 70,787.3 | P70 | 93,458.0 | L7 | 111,743.5 | L22 |
| 1.1 | 1.13 | 43.7 | 71,960.7 | P73 | 95,007.7 | L8 | 113,597.0 | L24 |
| 1.2 | 1.12 | 43.0 | 73,134.1 | P75 | 96,557.4 | L10 | 115,450.5 | L26 |
| 1.3 | 1.10 | 42.4 | 74,307.5 | P77 | 98,107.1 | L11 | 117,304.0 | L27 |
| 1.4 | 1.08 | 41.7 | 75,480.9 | P78 | 99,656.8 | L12 | 119,157.5 | L29 |
| 1.5 | 1.07 | 41.1 | 76,654.3 | P80 | 101,206.5 | L14 | 121,011.0 | L30 |
| 1.6 | 1.05 | 40.4 | 77,827.7 | P81 | 102,756.2 | L15 | 122,864.5 | L32 |
| 1.7 | 1.03 | 39.8 | 79,001.1 | P82 | 104,305.9 | L16 | 124,718.0 | L33 |
| 1.8 | 1.02 | 39.3 | 80,174.5 | P84 | 105,855.6 | L18 | 126,571.5 | L35 |
| 1.9 | 1.00 | 38.7 | 81,347.9 | P85 | 107,405.3 | L19 | 128,425.0 | L36 |
| 2.0 | 0.99 | 38.1 | 82,521.3 | P87 | 108,955.0 | L20 | 130,278.5 | L38 |
| 2.1 | 0.98 | 37.6 | 83,694.7 | P89 | 110,504.7 | L21 | 132,132.0 | L39 |
| 2.2 | 0.96 | 37.1 | 84,868.1 | P91 | 112,054.4 | L23 | 133,985.5 | L41 |
| 2.3 | 0.95 | 36.6 | 86,041.5 | L1 | 113,604.1 | L24 | 135,839.0 | L42 |
| 2.4 | 0.94 | 36.1 | 87,214.9 | L2 | 115,153.8 | L25 | 137,692.5 | L44 |
| 2.5 | 0.92 | 35.6 | 88,388.3 | L3 | 116,703.5 | L27 | 139,546.0 | L46 |
| 2.6 | 0.91 | 35.1 | 89,561.7 | L4 | 118,253.2 | L28 | 141,399.5 | L47 |
| 2.7 | 0.90 | 34.7 | 90,735.1 | L5 | 119,802.9 | L29 | 143,253.0 | L49 |
| 2.8 | 0.89 | 34.2 | 91,908.5 | L6 | 121,352.6 | L30 | 145,106.5 | L50 |
| 2.9 | 0.88 | 33.8 | 93,081.9 | L7 | 122,902.3 | L32 | 146,960.0 | L52 |
| 3.0 | 0.87 | 33.4 | 94,255.3 | L8 | 124,452.0 | L33 | 148,813.5 | -- |
| 3.1 | 0.86 | 33.0 | 95,428.7 | L9 | 126,001.7 | L34 | 150,667.0 | -- |
| 3.2 | 0.85 | 32.6 | 96,602.1 | L10 | 127,551.4 | L36 | 152,520.5 | -- |
| 3.3 | 0.84 | 32.2 | 97,775.5 | L11 | 129,101.1 | L37 | 154,374.0 | -- |
| 3.4 | 0.83 | 31.8 | 98,948.9 | L12 | 130,650.8 | L38 | 156,227.5 | -- |
| 3.5 | 0.82 | 31.4 | 100,122.3 | L13 | 132,200.5 | L39 | 158,081.0 | -- |
| 3.6 | 0.81 | 31.1 | 101,295.7 | L14 | 133,750.2 | L41 | 159,934.5 | -- |
| 3.7 | 0.80 | 30.7 | 102,469.1 | L15 | 135,299.9 | L42 | 161,788.0 | -- |
| 3.8 | 0.79 | 30.4 | 103,642.5 | L16 | 136,849.6 | L43 | 163,641.5 | -- |
| 3.9 | 0.78 | 30.0 | 104,815.9 | L17 | 138,399.3 | L45 | 165,495.0 | -- |
| 4.0 | 0.77 | 29.7 | 105,989.3 | L18 | 139,949.0 | L46 | 167,348.5 | -- |
| 4.1 | 0.76 | 29.4 | 107,162.7 | L19 | 141,498.7 | L47 | 169,202.0 | -- |
| 4.2 | 0.75 | 29.1 | 108,336.1 | L20 | 143,048.4 | L49 | 171,055.5 | -- |
| 4.3 | 0.75 | 28.7 | 109,509.5 | L21 | 144,598.1 | L50 | 172,909.0 | -- |
| 4.4 | 0.74 | 28.4 | 110,682.9 | L22 | 146,147.8 | L51 | 174,762.5 | -- |
| 4.5 | 0.73 | 28.1 | 111,856.3 | L23 | 147,697.5 | L52 | 176,616.0 | -- |
| 4.6 | 0.72 | 27.8 | 113,029.7 | L23 | 149,247.2 | -- | 178,469.5 | -- |
| 4.7 | 0.71 | 27.6 | 114,203.1 | L24 | 150,796.9 | -- | 180,323.0 | -- |
| 4.8 | 0.71 | 27.3 | 115,376.5 | L25 | 152,346.6 | -- | 182,176.5 | -- |
| 4.9 | 0.70 | 27.0 | 116,549.9 | L26 | 153,896.2 | -- | 184,029.9 | -- |
| 5.0 | 0.69 | 26.7 | 117,723.3 | L27 | 155,446.0 | -- | 185,883.5 | -- |
| 5.1 | 0.69 | 26.5 | 118,896.7 | L28 | 156,995.7 | -- | 187,737.0 | -- |

Table VI-5. Linear Thermal Density Calculations, 81 meter Drift Spacing (continued)

| WP Spacing (m) | kW/m Based on 70,000 MTHM Case | AML Based on 70,000 MTHM Case (MTHM/acre) | 70,000 MTHM Case | | 97,000 MTHM Case | | 119,000 MTHM Case | |
|---|---|---|---|---|---|---|---|---|
| | | | Required Drift Length (meters) | Last Drift Required (see Table I-1) | Required Drift Length (meters) | Last Drift Required (see Table I-1) | Required Drift Length (meters) | Last Drift Required (see Table I-1) |
| 5.2 | 0.68 | 26.2 | 120,070.1 | L29 | 158,545.4 | -- | 189,590.5 | -- |
| 5.3 | 0.67 | 26.0 | 121,243.5 | L30 | 160,095.1 | -- | 191,444.0 | -- |
| 5.4 | 0.67 | 25.7 | 122,416.9 | L31 | 161,644.8 | -- | 193,297.5 | -- |
| 5.5 | 0.66 | 25.5 | 123,590.3 | L32 | 163,194.5 | -- | 195,151.0 | -- |
| 5.6 | 0.65 | 25.2 | 124,763.7 | L33 | 164,744.2 | -- | 197,004.5 | -- |
| 5.7 | 0.65 | 25.0 | 125,937.1 | L34 | 166,293.9 | -- | 198,858.0 | -- |
| 5.8 | 0.64 | 24.8 | 127,110.5 | L35 | 167,843.6 | -- | 200,711.5 | -- |
| 5.9 | 0.64 | 24.5 | 128,283.9 | L36 | 169,393.3 | -- | 202,565.0 | -- |
| 6.0 | 0.63 | 24.3 | 129,457.3 | L37 | 170,943.0 | -- | 204,418.5 | -- |
| 6.1 | 0.62 | 24.1 | 130,630.7 | L38 | 172,492.7 | -- | 206,272.0 | -- |
| 6.2 | 0.62 | 23.9 | 131,804.1 | L39 | 174,042.4 | -- | 208,125.5 | -- |
| 6.3 | 0.61 | 23.7 | 132,977.5 | L40 | 175,592.1 | -- | 209,978.9 | -- |
| 6.4 | 0.61 | 23.5 | 134,150.9 | L41 | 177,141.8 | -- | 211,832.5 | -- |
| 6.5 | 0.60 | 23.3 | 135,324.3 | L42 | 178,691.5 | -- | 213,685.9 | -- |
| 6.6 | 0.60 | 23.1 | 136,497.7 | L43 | 180,241.2 | -- | 215,539.5 | -- |
| 6.7 | 0.59 | 22.9 | 137,671.1 | L44 | 181,790.9 | -- | 217,392.9 | -- |
| 6.8 | 0.59 | 22.7 | 138,844.5 | L45 | 183,340.6 | -- | 219,246.4 | -- |
| 6.9 | 0.58 | 22.5 | 140,017.9 | L46 | 184,890.3 | -- | 221,099.9 | -- |
| 7.0 | 0.58 | 22.3 | 141,191.3 | L47 | 186,440.0 | -- | 222,953.4 | -- |
| 7.1 | 0.57 | 22.1 | 142,364.7 | L48 | 187,989.7 | -- | 224,806.9 | -- |
| 7.2 | 0.57 | 21.9 | 143,538.1 | L49 | 189,539.4 | -- | 226,660.4 | -- |
| 7.3 | 0.56 | 21.8 | 144,711.5 | L50 | 191,089.1 | -- | 228,513.9 | -- |
| 7.4 | 0.56 | 21.6 | 145,884.9 | L51 | 192,638.8 | -- | 230,367.4 | -- |
| 7.5 | 0.56 | 21.4 | 147,058.3 | L52 | 194,188.5 | -- | 232,220.9 | -- |
| 7.6 | 0.55 | 21.2 | 148,231.7 | -- | 195,738.2 | -- | 234,074.4 | -- |
| 7.7 | 0.55 | 21.1 | 149,405.1 | -- | 197,287.9 | -- | 235,927.9 | -- |
| 7.8 | 0.54 | 20.9 | 150,578.5 | -- | 198,837.6 | -- | 237,781.4 | -- |
| 7.9 | 0.54 | 20.7 | 151,751.9 | -- | 200,387.3 | -- | 239,634.9 | -- |
| 8.0 | 0.53 | 20.6 | 152,925.3 | -- | 201,937.0 | -- | 241,488.4 | -- |

These calculations can also be repeated for a smaller WP scenario. The WP quantities are increased based on a simple ratio (see Section 5.1.2.5) to convert 21 PWR AP WPs to 12 PWR AP and 44 BWR WPs to 24 BWR for these purposes as outlined in Table VI-6.

Table VI-6. Conversion Factors for Decreasing Waste Package Size and Heat

| Required Conversions | | WP Quantity Factor | WP Average Heat Output Factor |
|---|---|---|---|
| From | To | | |
| 21 PWR AP | 12 PWR AP | $^{21}/_{12}$ = 1.750 | $^{12}/_{21}$ = 0.571 |
| 44 BWR AP | 24 BWR AP | $^{44}/_{24}$ = 1.833 | $^{24}/_{44}$ = 0.545 |

Based on these conversion factors, Table VI-7 outlines the estimated increased WP quantities that will be used to demonstrate the flexibility of the repository layout.

Table VI-7. Estimated Increased Waste Package Quantities

| **WP Description** | | **70,000 MTHM Case** | | **97,000 MTHM Case** | | **Estimated 119,000 MTHM Case** | |
|---|---|---|---|---|---|---|---|
| | | **Number of WPs by WP Type** | **Convert to Increased WPs** | **Number of WPs by WP Type** | **Convert to Increased WPs** | **Number of WPs by WP Type** | **Convert to Increased WPs** |
| 21 PWR | APs | 4,299 | 7,524 | 5,690 | 9,958 | 6,828 | 11,949 |
| | CRs | 95 | 95 | 106 | 106 | 127 | 127 |
| 12 PWR | APs Long | 163 | 163 | 293 | 293 | 352 | 352 |
| 44 BWR | APs | 2,831 | 5,191 | 3,732 | 6,842 | 4,478 | 8,210 |
| 24 BWR | APs | 84 | 84 | 98 | 98 | 118 | 118 |
| *CSNF Subtotal* | | *7,472* | *13,057* | *9,919* | *17,297* | *11,903* | *20,756* |
| 5 IPWF | | 95 | 95 | 127 | 127 | 152 | 152 |
| 5 DHLW Short/1 DOE SNF Short | | 1,052 | 1,052 | 1,403 | 1,403 | 1,684 | 1,684 |
| 5 DHLW Long/1 DOE SNF Long | | 1,406 | 1,406 | 1874 | 1,874 | 2,249 | 2,249 |
| 2 MCO/2 DHLW | | 149 | 149 | 199 | 199 | 239 | 239 |
| 5 HLW Long/1 DOE SNF Short | | 126 | 126 | 167 | 167 | 200 | 200 |
| HLW Long Only | | 584 | 584 | 780 | 780 | 936 | 936 |
| Naval | Short | 200 | 200 | 200 | 200 | 200 | 200 |
| | Long | 100 | 100 | 100 | 100 | 100 | 100 |
| *DOE/HLW Subtotal* | | *3,712* | *3,712* | *4,850* | *4,850* | *5,760* | *5,760* |
| **TOTAL** | | **11,184** | **16,769** | **14,769** | **22,147** | **17,663** | **26,516** |

By decreasing the higher heat output WPs, the quantity of CSNF packages increase by approximately 75 percent. This is shown in the calculations below.

For the 70,000 MTHM Case

$$\text{Percentage Increase} = \frac{13{,}057\text{ WPs} - 7{,}472\text{ WPs}}{7{,}472\text{ WPs}}$$
$$= \frac{5{,}585\text{ WPs}}{7{,}472\text{ WPs}}$$
$$= 0.747\text{ percent}$$

For the 97,000 MTHM Case

$$\text{Percentage Increase} = \frac{17{,}297\text{ WPs} - 9{,}919\text{ WPs}}{9{,}919\text{ WPs}}$$
$$= \frac{7{,}378\text{ WPs}}{9{,}919\text{ WPs}}$$
$$= 0.744\text{ percent}$$

For the estimated 119,000 MTHM Case

$$\text{Percentage Increase} = \frac{20{,}756\ \text{WPs} - 11{,}903\ \text{WPs}}{11{,}903\ \text{WPs}}$$

$$= \frac{8{,}853\ \text{WPs}}{11{,}903\ \text{WPs}}$$

$$= 0.744\ \text{percent}$$

In addition to adjusting the WP quantities for decreasing the size of the WPs, the heat outputs must also be decreased. The calculations shown in Table VI-8 are based on the conversion factors outlined in Table VI-6.

Table VI-8. Decreased Heat Outputs for 70,000 MTHM Case

| WP Description | | Average Initial Heat Output kW | Decreased Heat Output kW |
|---|---|---|---|
| 21 PWR | APs | 11.530 | 6.589 |
| | CRs | 3.110 | 3.110 |
| 12 PWR | APs Long | 9.550 | 9.550 |
| 44 BWR | APs | 7.380 | 4.025 |
| 24 BWR | APs | 0.520 | 0.520 |
| 5 IPWF | | 3.530 | 3.530 |
| 5 DHLW Short/1 DOE SNF Short | | 2.980 | 2.980 |
| 5 DHLW Long/1 DOE SNF Long | | 0.407 | 0.407 |
| 2 MCO/2 DHLW | | 1.665 | 1.665 |
| 5 HLW Long/1 DOE SNF Short | | 0.407 | 0.407 |
| HLW Long Only | | 0.282 | 0.282 |
| Naval | Short | 3.070 | 3.070 |
| | Long | 3.070 | 3.070 |

Source: BSC 2001b, Item 1, p. 2

Similar to the calculations provided for the reference WP quantities, the maximum Lineal Thermal Load calculation and the required drift length calculations for the 70,000 MTHM, 97,000 MTHM, and 119,000 MTHM Cases can be evaluated. Sample calculations have been provided in using an end-to-end WP spacing of 0.1 meters.

Table VI-9. Maximum Lineal Thermal Load Calculation – Smaller WP Case

| WP Description | | Number of WPs by WP Type (see Table V I-7) | Number of WPs Plus 5 Percent | WP Outer Length (m) (see Table 2) | Average Initial Heat Output kW (see Table VI-8) | Drift Length Required (m) | Total Heat Output (kW) | Heat Output per Meter |
|---|---|---|---|---|---|---|---|---|
| 21 PWR | APs | 7,524 | 7,901 | 5.165 | 6.589 | 41,598.8 | 52,059.7 | 1.25 |
| | CRs | 95 | 100 | 5.165 | 3.110 | 526.5 | 311.0 | 0.59 |
| 12 PWR | APs Long | 163 | 172 | 5.651 | 9.550 | 989.2 | 1,642.6 | 1.66 |
| 44 BWR | APs | 5,191 | 5,451 | 5.165 | 4.025 | 28,699.5 | 21,940.3 | 0.76 |
| 24 BWR | APs | 84 | 89 | 5.105 | 0.520 | 463.2 | 46.3 | 0.10 |
| *CSNF Subtotal* | | *13,057* | *13,713* | | | *72,277.2* | *75,999.9* | |
| 5 IPWF | | 95 | 100 | 3.590 | 3.530 | 369.0 | 353.0 | 0.96 |
| 5 DHLW Short/1 DOE SNF Short | | 1,052 | 1,105 | 3.590 | 2.980 | 4,077.5 | 3,292.9 | 0.81 |
| 5 DHLW Long/1 DOE SNF Long | | 1,406 | 1,477 | 5.217 | 0.407 | 7,853.2 | 601.1 | 0.08 |
| 2 MCO/2 DHLW | | 149 | 157 | 5.217 | 1.665 | 834.8 | 261.4 | 0.31 |
| 5 HLW Long/1 DOE SNF Short | | 126 | 133 | 5.217 | 0.407 | 707.2 | 54.1 | 0.08 |
| HLW Long Only | | 584 | 614 | 5.217 | 0.282 | 3,264.6 | 173.1 | 0.05 |
| Naval | Short | 200 | 200 | 5.430 | 3.070 | 1,106 | 614.0 | 0.56 |
| | Long | 100 | 100 | 6.065 | 3.070 | 616.5 | 307.0 | 0.50 |
| *DOE/HLW Subtotal* | | *3,712* | *3,886* | | | *18,828.8* | *5,656.6* | |
| **TOTAL** | | **16,769** | **17,599** | | | **91,106.0** | **81,656.5** | **0.90** |

Based on these calculations, applying a 0.1 meter average WP spacing to the 97,000 MTHM smaller WP inventory results in a required emplacement drift length of 120,298.6 meters. This calculation is shown in Table VI-10.

Table VI-10. 97,000 MTHM Smaller WP Case Required Emplacement Drift Length Calculation

| WP Description | | Number of WPs by WP Type (see Table VI-7) | Number of WPs Plus 5 Percent | WP Outer Length (m) (see Table 2) | Drift Length Required (m) |
|---|---|---|---|---|---|
| 21 PWR | APs | 9,958 | 10,456 | 5.165 | 55,050.8 |
| | CRs | 106 | 112 | 5.165 | 589.7 |
| 12 PWR | APs Long | 293 | 308 | 5.651 | 1,771.3 |
| 44 BWR | APs | 6,842 | 7,185 | 5.165 | 37,829.0 |
| 24 BWR | APs | 98 | 103 | 5.105 | 536.1 |
| *CSNF Subtotal* | | *17,297* | *18,164* | | *95,776.9* |
| 5 IPWF | | 127 | 134 | 3.590 | 494.5 |
| 5 DHLW Short/1 DOE SNF Short | | 1,403 | 1,474 | 3.590 | 5,439.1 |
| 5 DHLW Long/1 DOE SNF Long | | 1,874 | 1,968 | 5.217 | 10,463.9 |
| 2 MCO/2 DHLW | | 199 | 209 | 5.217 | 1,111.3 |
| 5 HLW Long/1 DOE SNF Short | | 167 | 176 | 5.217 | 935.8 |
| HLW Long Only | | 780 | 819 | 5.217 | 4,354.6 |
| Naval | Short | 200 | 200 | 5.430 | 1,106.0 |
| | Long | 100 | 100 | 6.065 | 616.5 |
| *DOE/HLW Subtotal* | | *4,850* | *5,080* | | *24,521.7* |
| **TOTAL** | | **22,147** | **23,244** | | **120,298.6** |

Based on these calculations, applying a 0.1 meter average WP spacing to the estimated 119,000 MTHM smaller WP inventory results in a required emplacement drift length of 144,005.5 meters. This calculation is shown in Table VI-11.

Table VI-11. Estimated 119,000 MTHM Smaller WP Case Required Emplacement Drift Length Calculation

| WP Description | | Number of WPs by WP Type (see Table VI-7) | Number of WPs Plus 5 Percent | WP Outer Length (m) (see Table 2) | Drift Length Required (m) |
|---|---|---|---|---|---|
| 21 PWR | APs | 11,949 | 12,547 | 5.165 | 66,060.0 |
| | CRs | 127 | 134 | 5.165 | 705.5 |
| 12 PWR | APs Long | 352 | 370 | 5.651 | 2,127.9 |
| 44 BWR | APs | 8,210 | 8,621 | 5.165 | 45,389.6 |
| 24 BWR | APs | 118 | 124 | 5.105 | 645.4 |
| *CSNF Subtotal* | | *20,756* | *21,796* | | *114,928.4* |
| 5 IPWF | | 152 | 160 | 3.590 | 590.4 |
| 5 DHLW Short/1 DOE SNF Short | | 1,684 | 1,769 | 3.590 | 6,527.6 |
| 5 DHLW Long/1 DOE SNF Long | | 2,249 | 2,362 | 5.217 | 12,558.8 |
| 2 MCO/2 DHLW | | 239 | 251 | 5.217 | 1,334.6 |
| 5 HLW Long/1 DOE SNF Short | | 200 | 210 | 5.217 | 1,116.6 |
| HLW Long Only | | 936 | 983 | 5.217 | 5,226.6 |
| Naval | Short | 200 | 200 | 5.430 | 1,106.0 |
| | Long | 100 | 100 | 6.065 | 616.5 |
| *DOE/HLW Subtotal* | | *5,760* | *6,035* | | *29,077.1* |
| **TOTAL** | | **26,516** | **27,831** | | **144,005.5** |

The calculations outlined in Table VI-9, Table VI-10, and Table VI-11 can be repeated for a range of WP spacing, from 0.1 meters to 4.0 meters using the smaller WP quantities and heat outputs. Again, these calculations are used to demonstrate the operational flexibility of the repository layout (see Table VI-12). The last required emplacement drift is determined by examining Table I-1.

Table VI-12. Linear Thermal Density Calculations – Smaller WPs, 81 meter Drift Spacing

| WP Spacing (m) | kW/m Based on 70,000 MTHM Case | AML Based on 70,000 MTHM Case (MTHM/acre) | 70,000 MTHM Case | | 97,000 MTHM Case | | 119,000 MTHM Case | |
|---|---|---|---|---|---|---|---|---|
| | | | Required Drift Length (meters) | Last Drift Required | Required Drift Length (meters) | Last Drift Required | Required Drift Length (meters) | Last Drift Required |
| 0.1 | 0.9 | 34.5 | 91,106.0 | L5 | 120,298.6 | L30 | 144,005.5 | L49 |
| 0.2 | 0.9 | 33.9 | 92,865.9 | L7 | 122,623.0 | L31 | 146,788.6 | L52 |
| 0.3 | 0.9 | 33.3 | 94,625.8 | L8 | 124,947.4 | L33 | 149,571.7 | -- |
| 0.4 | 0.9 | 32.7 | 96,385.7 | L10 | 127,271.8 | L35 | 152,354.8 | -- |
| 0.5 | 0.8 | 32.1 | 98,145.6 | L11 | 129,596.2 | L37 | 155,137.9 | -- |
| 0.6 | 0.8 | 31.5 | 99,905.5 | L13 | 131,920.6 | L39 | 157,921.0 | -- |
| 0.7 | 0.8 | 31.0 | 101,665.4 | L14 | 134,245.0 | L41 | 160,704.1 | -- |
| 0.8 | 0.8 | 30.4 | 103,425.3 | L15 | 136,569.4 | L43 | 163,487.2 | -- |
| 0.9 | 0.8 | 29.9 | 105,185.2 | L17 | 138,893.8 | L45 | 166,270.3 | -- |
| 1.0 | 0.8 | 29.4 | 106,945.1 | L18 | 141,218.2 | L47 | 169,053.4 | -- |
| 1.1 | 0.8 | 29.0 | 108,705.0 | L20 | 143,542.6 | L49 | 171,836.5 | -- |
| 1.2 | 0.7 | 28.5 | 110,464.9 | L21 | 145,867.0 | L51 | 174,619.6 | -- |
| 1.3 | 0.7 | 28.0 | 112,224.8 | L23 | 148,191.4 | -- | 177,402.7 | -- |
| 1.4 | 0.7 | 27.6 | 113,984.7 | L24 | 150,515.8 | -- | 180,185.8 | -- |
| 1.5 | 0.7 | 27.2 | 115,744.6 | L26 | 152,840.2 | -- | 182,968.9 | -- |
| 1.6 | 0.7 | 26.8 | 117,504.5 | L27 | 155,164.6 | -- | 185,752.0 | -- |
| 1.7 | 0.7 | 26.4 | 119,264.4 | L29 | 157,489.0 | -- | 188,535.1 | -- |
| 1.8 | 0.7 | 26.0 | 121,024.3 | L30 | 159,813.4 | -- | 191,318.2 | -- |
| 1.9 | 0.7 | 25.6 | 122,784.2 | L32 | 162,137.8 | -- | 194,101.3 | -- |
| 2.0 | 0.7 | 25.3 | 124,544.1 | L33 | 164,462.2 | -- | 196,884.4 | -- |
| 2.1 | 0.7 | 24.9 | 126,304.0 | L35 | 166,786.6 | -- | 199,667.5 | -- |
| 2.2 | 0.6 | 24.6 | 128,063.9 | L36 | 169,111.0 | -- | 202,450.6 | -- |
| 2.3 | 0.6 | 24.2 | 129,823.8 | L37 | 171,435.4 | -- | 205,233.7 | -- |
| 2.4 | 0.6 | 23.9 | 131,583.7 | L39 | 173,759.8 | -- | 208,016.8 | -- |
| 2.5 | 0.6 | 23.6 | 133,343.6 | L40 | 176,084.2 | -- | 210,799.9 | -- |
| 2.6 | 0.6 | 23.3 | 135,103.5 | L42 | 178,408.6 | -- | 213,583.0 | -- |
| 2.7 | 0.6 | 23.0 | 136,863.4 | L43 | 180,733.0 | -- | 216,366.1 | -- |
| 2.8 | 0.6 | 22.7 | 138,623.3 | L45 | 183,057.4 | -- | 219,149.2 | -- |
| 2.9 | 0.6 | 22.4 | 140,383.2 | L46 | 185,381.8 | -- | 221,932.3 | -- |
| 3.0 | 0.6 | 22.1 | 142,143.1 | L48 | 187,706.2 | -- | 224,715.4 | -- |
| 3.1 | 0.6 | 21.9 | 143,903.0 | L49 | 190,030.6 | -- | 227,498.5 | -- |
| 3.2 | 0.6 | 21.6 | 145,662.9 | L51 | 192,355.0 | -- | 230,281.6 | -- |
| 3.3 | 0.6 | 21.4 | 147,422.8 | L52 | 194,679.4 | -- | 233,064.7 | -- |
| 3.4 | 0.6 | 21.1 | 149,182.7 | -- | 197,003.8 | -- | 235,847.8 | -- |
| 3.5 | 0.5 | 20.9 | 150,942.6 | -- | 199,328.2 | -- | 238,630.9 | -- |
| 3.6 | 0.5 | 20.6 | 152,702.5 | -- | 201,652.6 | -- | 241,414.0 | -- |
| 3.7 | 0.5 | 20.4 | 154,462.4 | -- | 203,977.0 | -- | 244,197.1 | -- |
| 3.8 | 0.5 | 20.1 | 156,222.3 | -- | 206,301.4 | -- | 246,980.2 | -- |
| 3.9 | 0.5 | 19.9 | 157,982.2 | -- | 208,625.8 | -- | 249,763.3 | -- |
| 4.0 | 0.5 | 19.7 | 159,742.1 | -- | 210,950.2 | -- | 252,546.4 | -- |

# ATTACHMENT VII

# DESIGN SENSITIVITY CALCULATIONS

## ATTACHMENT VII

## DESIGN SENSITIVITY CALCULATIONS

In order to evaluate changes in the drift spacing, a calculation converts the available emplacement drift length in the repository layout (at an 81 meter drift spacing) to alternative emplacement drift spacing.

In order provide a basis for calculating the drift spacing sensitivities, the repository layout can be reduced to the length of the emplacement block along the Exhaust Main, and an average drift length available for emplacement. This basis is outlined in Table VII-1

Table VII-1. Basis for Calculating Drift Spacing Sensitivities

| Emplacement Area | Number of Drifts at 81 meter spacing (See Figure 3) | Length of Emplacement Block, Along Exhaust Main (# Drifts - 1) x 81 meters | Average Drift Length Available (see note) |
|---|---|---|---|
| Primary Block - Main (excludes the PCTD) | 64 | 5,103.0 | 1,076.9 |
| Primary Block - South End | 27 | 2,106.0 | 611.9 |
| Lower Block - All | 52 | 4,131.0 | 1,200.0 |

Note: see calculations below or average drift length available.

The following calculations document the method for determining the average drift length available for each emplacement area defined in Table VII-1. The cumulative available emplacement drift length for these calculations were taken from Table I-1.

**For Primary Block – Main (excludes the PCTD):**

$$\text{Avg. Drift Length Avail.} = \frac{\text{Cum. Avail. Empl. Length @P64}}{\text{64 Drifts}}$$

$$= \frac{\text{68,921.4 meters}}{\text{64 drifts}}$$

$$= \text{1,076.9 meters / drift}$$

**For the Primary Block – South End:**

$$\text{Avg. Drift Length Avail.} = \frac{\text{(Cum. Avail. Empl. Length @P91) - (Cum. Avail. Empl. Length @P64)}}{\text{(91 - 64) Drifts}}$$

$$= \frac{85{,}443.2 - 68{,}921.4 \text{ meters}}{27 \text{ drifts}}$$

$$= 611.9 \text{ meters / drift}$$

**For the Lower Block – All:**

$$\text{Avg. Drift Length Avail.} = \frac{\text{(Cum. Avail. Empl. Length @L52) - (Cum. Avail. Empl. Length @P91)}}{\text{52 Drifts}}$$

$$= \frac{147{,}843.2 - 85{,}443.2 \text{ meters}}{52 \text{ drifts}}$$

$$= 1{,}200.0 \text{ meters / drift}$$

From the information in Table VII-1, the number of drifts and available emplacement drift length can be estimated for different emplacement drift spacings.

For example, the following method is used to estimate the number of drifts in the primary block main area for drift spacing of 38 meters. The length of the emplacement block along the exhaust main from Table VII-1 (5,103.0 meters) is divided by the new drift spacing (38 meters). This value, 134.3 drifts is rounded down to 134 drifts. To estimate the available emplacement drift length for the same 38 meter spacing, the estimate number of emplacement drifts (134 drifts) is multiplied by the average drift length available (1,076.9 meters) from Table VII-1. This results in an estimated available emplacement drift length of 144,304.6 meters within the primary block main area.

This type of calculation method can be used to estimate the number of drifts and available drift length for the other emplacement areas. Table VII-2 outlines calculations completed using this described methodology for various emplacement drift spacings.

Table VII-2. Drift Spacing Evaluation Calculations

| Drift Spacing (meters) | Primary Block Main Area | | Primary Block South End | | Lower Block All | | Total | |
|---|---|---|---|---|---|---|---|---|
| | Number of Drifts | Estimated Available Drift Length (meters) | Number of Drifts | Estimated Available Drift Length (meters) | Number of Drifts | Estimated Available Drift Length (meters) | Number of Drifts | Estimated Available Drift Length (meters) |
| 20 | 255 | 274,609.5 | 105 | 64,249.5 | 206 | 247,200.0 | 566 | 586,059.0 |
| 21 | 243 | 261,686.7 | 100 | 61,190.0 | 196 | 235,200.0 | 539 | 558,076.7 |
| 22 | 231 | 248,763.9 | 95 | 58,130.5 | 187 | 224,400.0 | 513 | 531,294.4 |
| 23 | 221 | 237,994.9 | 91 | 55,682.9 | 179 | 214,800.0 | 491 | 508,477.8 |
| 24 | 212 | 228,302.8 | 87 | 53,235.3 | 172 | 206,400.0 | 471 | 487,938.1 |
| 25 | 204 | 219,687.6 | 84 | 51,399.6 | 165 | 198,000.0 | 453 | 469,087.2 |
| 26 | 196 | 211,072.4 | 81 | 49,563.9 | 158 | 189,600.0 | 435 | 450,236.3 |
| 27 | 189 | 203,534.1 | 78 | 47,728.2 | 153 | 183,600.0 | 420 | 434,862.3 |
| 28 | 182 | 195,995.8 | 75 | 45,892.5 | 147 | 176,400.0 | 404 | 418,288.3 |
| 29 | 175 | 188,457.5 | 72 | 44,056.8 | 142 | 170,400.0 | 389 | 402,914.3 |
| 30 | 170 | 183,073.0 | 70 | 42,833.0 | 137 | 164,400.0 | 377 | 390,306.0 |
| 31 | 164 | 176,611.6 | 67 | 40,997.3 | 133 | 159,600.0 | 364 | 377,208.9 |
| 32 | 159 | 171,227.1 | 65 | 39,773.5 | 129 | 154,800.0 | 353 | 365,800.6 |
| 33 | 154 | 165,842.6 | 63 | 38,549.7 | 125 | 150,000.0 | 342 | 354,392.3 |
| 34 | 150 | 161,535.0 | 61 | 37,325.9 | 121 | 145,200.0 | 332 | 344,060.9 |
| 35 | 145 | 156,150.5 | 60 | 36,714.0 | 118 | 141,600.0 | 323 | 334,464.5 |
| 36 | 141 | 151,842.9 | 58 | 35,490.2 | 114 | 136,800.0 | 313 | 324,133.1 |
| 37 | 137 | 147,535.3 | 56 | 34,266.4 | 111 | 133,200.0 | 304 | 315,001.7 |
| 38 | 134 | 144,304.6 | 55 | 33,654.5 | 108 | 129,600.0 | 297 | 307,559.1 |
| 39 | 130 | 139,997.0 | 54 | 33,042.6 | 105 | 126,000.0 | 289 | 299,039.6 |
| 40 | 127 | 136,766.3 | 52 | 31,818.8 | 103 | 123,600.0 | 282 | 292,185.1 |
| 41 | 124 | 133,535.6 | 51 | 31,206.9 | 100 | 120,000.0 | 275 | 284,742.5 |
| 42 | 121 | 130,304.9 | 50 | 30,595.0 | 98 | 117,600.0 | 269 | 278,499.9 |
| 43 | 118 | 127,074.2 | 48 | 29,371.2 | 96 | 115,200.0 | 262 | 271,645.4 |
| 44 | 115 | 123,843.5 | 47 | 28,759.3 | 93 | 111,600.0 | 255 | 264,202.8 |
| 45 | 113 | 121,689.7 | 46 | 28,147.4 | 91 | 109,200.0 | 250 | 259,037.1 |
| 46 | 110 | 118,459.0 | 45 | 27,535.5 | 89 | 106,800.0 | 244 | 252,794.5 |
| 47 | 108 | 116,305.2 | 44 | 26,923.6 | 87 | 104,400.0 | 239 | 247,628.8 |
| 48 | 106 | 114,151.4 | 43 | 26,311.7 | 86 | 103,200.0 | 235 | 243,663.1 |
| 49 | 104 | 111,997.6 | 42 | 25,699.8 | 84 | 100,800.0 | 230 | 238,497.4 |
| 50 | 102 | 109,843.8 | 42 | 25,699.8 | 82 | 98,400.0 | 226 | 233,943.6 |
| 51 | 100 | 107,690.0 | 41 | 25,087.9 | 81 | 97,200.0 | 222 | 229,977.9 |
| 52 | 98 | 105,536.2 | 40 | 24,476.0 | 79 | 94,800.0 | 217 | 224,812.2 |
| 53 | 96 | 103,382.4 | 39 | 23,864.1 | 77 | 92,400.0 | 212 | 219,646.5 |
| 54 | 94 | 101,228.6 | 39 | 23,864.1 | 76 | 91,200.0 | 209 | 216,292.7 |
| 55 | 92 | 99,074.8 | 38 | 23,252.2 | 75 | 90,000.0 | 205 | 212,327.0 |
| 56 | 91 | 97,997.9 | 37 | 22,640.3 | 73 | 87,600.0 | 201 | 208,238.2 |
| 57 | 89 | 95,844.1 | 36 | 22,028.4 | 72 | 86,400.0 | 197 | 204,272.5 |
| 58 | 87 | 93,690.3 | 36 | 22,028.4 | 71 | 85,200.0 | 194 | 200,918.7 |
| 59 | 86 | 92,613.4 | 35 | 21,416.5 | 70 | 84,000.0 | 191 | 198,029.9 |
| 60 | 85 | 91,536.5 | 35 | 21,416.5 | 68 | 81,600.0 | 188 | 194,553.0 |
| 61 | 83 | 89,382.7 | 34 | 20,804.6 | 67 | 80,400.0 | 184 | 190,587.3 |
| 62 | 82 | 88,305.8 | 33 | 20,192.7 | 66 | 79,200.0 | 181 | 187,698.5 |
| 63 | 81 | 87,228.9 | 33 | 20,192.7 | 65 | 78,000.0 | 179 | 185,421.6 |
| 64 | 79 | 85,075.1 | 32 | 19,580.8 | 64 | 76,800.0 | 175 | 181,455.9 |
| 65 | 78 | 83,998.2 | 32 | 19,580.8 | 63 | 75,600.0 | 173 | 179,179.0 |
| 66 | 77 | 82,921.3 | 31 | 18,968.9 | 62 | 74,400.0 | 170 | 176,290.2 |
| 67 | 76 | 81,844.4 | 31 | 18,968.9 | 61 | 73,200.0 | 168 | 174,013.3 |

Table VII-2. Drift Spacing Evaluation Calculations(continued)

| Drift Spacing (meters) | Primary Block Main Area | | Primary Block South End | | Lower Block All | | Total | |
|---|---|---|---|---|---|---|---|---|
| | Number of Drifts | Estimated Available Drift Length (meters) | Number of Drifts | Estimated Available Drift Length (meters) | Number of Drifts | Estimated Available Drift Length (meters) | Number of Drifts | Estimated Available Drift Length (meters) |
| 68 | 75 | 80,767.5 | 30 | 18,357.0 | 60 | 72,000.0 | 165 | 171,124.5 |
| 69 | 73 | 78,613.7 | 30 | 18,357.0 | 59 | 70,800.0 | 162 | 167,770.7 |
| 70 | 72 | 77,536.8 | 30 | 18,357.0 | 59 | 70,800.0 | 161 | 166,693.8 |
| 71 | 71 | 76,459.9 | 29 | 17,745.1 | 58 | 69,600.0 | 158 | 163,805.0 |
| 72 | 70 | 75,383.0 | 29 | 17,745.1 | 57 | 68,400.0 | 156 | 161,528.1 |
| 73 | 69 | 74,306.1 | 28 | 17,133.2 | 56 | 67,200.0 | 153 | 158,639.3 |
| 74 | 68 | 73,229.2 | 28 | 17,133.2 | 55 | 66,000.0 | 151 | 156,362.4 |
| 75 | 68 | 73,229.2 | 28 | 17,133.2 | 55 | 66,000.0 | 151 | 156,362.4 |
| 76 | 67 | 72,152.3 | 27 | 16,521.3 | 54 | 64,800.0 | 148 | 153,473.6 |
| 77 | 66 | 71,075.4 | 27 | 16,521.3 | 53 | 63,600.0 | 146 | 151,196.7 |
| 78 | 65 | 69,998.5 | 27 | 16,521.3 | 52 | 62,400.0 | 144 | 148,919.8 |
| 79 | 64 | 68,921.6 | 26 | 15,909.4 | 52 | 62,400.0 | 142 | 147,231.0 |
| 80 | 63 | 67,844.7 | 26 | 15,909.4 | 51 | 61,200.0 | 140 | 144,954.1 |
| 81 | 63 | 67,844.7 | 26 | 15,909.4 | 51 | 61,200.0 | 140 | 144,954.1 |
| 82 | 62 | 66,767.8 | 25 | 15,297.5 | 50 | 60,000.0 | 137 | 142,065.3 |
| 83 | 61 | 65,690.9 | 25 | 15,297.5 | 49 | 58,800.0 | 135 | 139,788.4 |
| 84 | 60 | 64,614.0 | 25 | 15,297.5 | 49 | 58,800.0 | 134 | 138,711.5 |
| 85 | 60 | 64,614.0 | 24 | 14,685.6 | 48 | 57,600.0 | 132 | 136,899.6 |
| 86 | 59 | 63,537.1 | 24 | 14,685.6 | 48 | 57,600.0 | 131 | 135,822.7 |
| 87 | 58 | 62,460.2 | 24 | 14,685.6 | 47 | 56,400.0 | 129 | 133,545.8 |
| 88 | 57 | 61,383.3 | 23 | 14,073.7 | 46 | 55,200.0 | 126 | 130,657.0 |
| 89 | 57 | 61,383.3 | 23 | 14,073.7 | 46 | 55,200.0 | 126 | 130,657.0 |
| 90 | 56 | 60,306.4 | 23 | 14,073.7 | 45 | 54,000.0 | 124 | 128,380.1 |
| 91 | 56 | 60,306.4 | 23 | 14,073.7 | 45 | 54,000.0 | 124 | 128,380.1 |
| 92 | 55 | 59,229.5 | 22 | 13,461.8 | 44 | 52,800.0 | 121 | 125,491.3 |
| 93 | 54 | 58,152.6 | 22 | 13,461.8 | 44 | 52,800.0 | 120 | 124,414.4 |
| 94 | 54 | 58,152.6 | 22 | 13,461.8 | 43 | 51,600.0 | 119 | 123,214.4 |
| 95 | 53 | 57,075.7 | 22 | 13,461.8 | 43 | 51,600.0 | 118 | 122,137.5 |
| 96 | 53 | 57,075.7 | 21 | 12,849.9 | 43 | 51,600.0 | 117 | 121,525.6 |
| 97 | 52 | 55,998.8 | 21 | 12,849.9 | 42 | 50,400.0 | 115 | 119,248.7 |
| 98 | 52 | 55,998.8 | 21 | 12,849.9 | 42 | 50,400.0 | 115 | 119,248.7 |
| 99 | 51 | 54,921.9 | 21 | 12,849.9 | 41 | 49,200.0 | 113 | 116,971.8 |
| 100 | 51 | 54,921.9 | 21 | 12,849.9 | 41 | 49,200.0 | 113 | 116,971.8 |
| 101 | 50 | 53,845.0 | 20 | 12,238.0 | 40 | 48,000.0 | 110 | 114,083.0 |
| 102 | 50 | 53,845.0 | 20 | 12,238.0 | 40 | 48,000.0 | 110 | 114,083.0 |
| 103 | 49 | 52,768.1 | 20 | 12,238.0 | 40 | 48,000.0 | 109 | 113,006.1 |
| 104 | 49 | 52,768.1 | 20 | 12,238.0 | 39 | 46,800.0 | 108 | 111,806.1 |
| 105 | 48 | 51,691.2 | 20 | 12,238.0 | 39 | 46,800.0 | 107 | 110,729.2 |
| 106 | 48 | 51,691.2 | 19 | 11,626.1 | 38 | 45,600.0 | 105 | 108,917.3 |
| 107 | 47 | 50,614.3 | 19 | 11,626.1 | 38 | 45,600.0 | 104 | 107,840.4 |
| 108 | 47 | 50,614.3 | 19 | 11,626.1 | 38 | 45,600.0 | 104 | 107,840.4 |
| 109 | 46 | 49,537.4 | 19 | 11,626.1 | 37 | 44,400.0 | 102 | 105,563.5 |
| 110 | 46 | 49,537.4 | 19 | 11,626.1 | 37 | 44,400.0 | 102 | 105,563.5 |
| 111 | 45 | 48,460.5 | 18 | 11,014.2 | 37 | 44,400.0 | 100 | 103,874.7 |
| 112 | 45 | 48,460.5 | 18 | 11,014.2 | 36 | 43,200.0 | 99 | 102,674.7 |
| 113 | 45 | 48,460.5 | 18 | 11,014.2 | 36 | 43,200.0 | 99 | 102,674.7 |
| 114 | 44 | 47,383.6 | 18 | 11,014.2 | 36 | 43,200.0 | 98 | 101,597.8 |
| 115 | 44 | 47,383.6 | 18 | 11,014.2 | 35 | 42,000.0 | 97 | 100,397.8 |

Table VII-2. Drift Spacing Evaluation Calculations(continued)

| Drift Spacing (meters) | Primary Block Main Area | | Primary Block South End | | Lower Block All | | Total | |
|---|---|---|---|---|---|---|---|---|
| | Number of Drifts | Estimated Available Drift Length (meters) | Number of Drifts | Estimated Available Drift Length (meters) | Number of Drifts | Estimated Available Drift Length (meters) | Number of Drifts | Estimated Available Drift Length (meters) |
| 116 | 43 | 46,306.7 | 18 | 11,014.2 | 35 | 42,000.0 | 96 | 99,320.9 |
| 117 | 43 | 46,306.7 | 18 | 11,014.2 | 35 | 42,000.0 | 96 | 99,320.9 |
| 118 | 43 | 46,306.7 | 17 | 10,402.3 | 35 | 42,000.0 | 95 | 98,709.0 |
| 119 | 42 | 45,229.8 | 17 | 10,402.3 | 34 | 40,800.0 | 93 | 96,432.1 |
| 120 | 42 | 45,229.8 | 17 | 10,402.3 | 34 | 40,800.0 | 93 | 96,432.1 |
| 121 | 42 | 45,229.8 | 17 | 10,402.3 | 34 | 40,800.0 | 93 | 96,432.1 |
| 122 | 41 | 44,152.9 | 17 | 10,402.3 | 33 | 39,600.0 | 91 | 94,155.2 |
| 123 | 41 | 44,152.9 | 17 | 10,402.3 | 33 | 39,600.0 | 91 | 94,155.2 |
| 124 | 41 | 44,152.9 | 16 | 9,790.4 | 33 | 39,600.0 | 90 | 93,543.3 |

In addition to these calculations, the AML at various emplacement drift spacings and WP spacings can be calculated. In order to calculate the AML of a specific scenario, the required emplacement drift lengths are needed. These values are listed in Table VII- 3.

Table VII- 3. Required Emplacement Drift Length at Various Waste Package Spacings

| WP Spacing Meters | 70,000 MTHM Required Drift Length from Table VI-5 |
|---|---|
| 0.1 | 60,226.7 |
| 1.0 | 70,787.3 |
| 2.0 | 82,521.3 |
| 3.0 | 94,255.3 |
| 4.0 | 105,989.3 |
| 5.0 | 117,723.3 |
| 6.0 | 129,457.3 |
| 7.0 | 141,191.3 |
| 8.0 | 152,925.3 |

The AML is then calculated as outlined previously in Section 6.1.3.1. For example, the AML can be calculated for a drift spacing of 38 meters and a WP spacing of 0.1 meters.

The required emplacement drift length and the drift spacing can be used to calculate the total available acreage in the layout:

$$\text{Acreage} = \frac{L_r\ (\text{m}) \quad \text{x} \quad \text{DS}\ (\text{m})}{43{,}560\ \text{ft}^2/\text{acre}} \quad \text{x} \quad \frac{1}{0.0929\ \text{m}^2/\text{ft}^2}$$

Where: $L_r$ = required emplacement drift length (m) and
DS = drift spacing (m).

When: $L_r$ = 60,226.7 meters (see Table VII- 3) and
DS = 38.0 meters,

$$\text{Acreage} = \frac{60{,}226.7 \text{ meters} \times 38 \text{ meters}}{43{,}560 \text{ ft}^2/\text{acre}} \times \frac{1}{0.0929 \text{ m}^2/\text{ft}^2}$$

$$\text{Acreage} = 565.5 \text{ acres}$$

The scenario 70,000 MTHM inventory using a drift spacing of 38 meters and WP end-to-end spacing of 0.1 meters will require approximately 565.5 acres.

The AML is calculated with the amount of MTHM from CSNF only. The AML of the repository layout can then be calculated as:

$$\text{AML} = \frac{\text{CSNF (MTHM)}}{\text{Acreage}}$$

Where: CSNF = 63,000 MTHM (see Section 4.1.1.3)
Acreage = 565.5 acres

$$\text{AML} = \frac{63{,}000 \text{ MTHM}}{565.5 \text{ acres}}$$

$$\text{AML} = 111.4 \ \text{MTHM}/\text{acre}$$

These calculations can be repeated for a number of different drift and WP spacings. The results of these calculations are listed in Table VII-4.

Table VII-4. Areal Mass Loading at Various Waste Package/Drift Spacing

| Drift Spacing (meters) | AML at Various WP Spacing (meters) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0.1 | 1.0 | 2.0 | 3.0 | 4.0 | 5.0 | 6.0 | 7.0 | 8.0 |
| 20 | 211.7 | 180.1 | 154.5 | 135.3 | 120.3 | 108.3 | 98.5 | 90.3 | 83.4 |
| 21 | 201.6 | 171.5 | 147.1 | 128.8 | 114.5 | 103.1 | 93.8 | 86.0 | 79.4 |
| 22 | 192.4 | 163.7 | 140.4 | 123.0 | 109.3 | 98.4 | 89.5 | 82.1 | 75.8 |
| 23 | 184.1 | 156.6 | 134.3 | 117.6 | 104.6 | 94.2 | 85.6 | 78.5 | 72.5 |
| 24 | 176.4 | 150.1 | 128.7 | 112.7 | 100.2 | 90.2 | 82.1 | 75.2 | 69.5 |
| 25 | 169.3 | 144.1 | 123.6 | 108.2 | 96.2 | 86.6 | 78.8 | 72.2 | 66.7 |
| 26 | 162.8 | 138.5 | 118.8 | 104.0 | 92.5 | 83.3 | 75.7 | 69.5 | 64.1 |
| 27 | 156.8 | 133.4 | 114.4 | 100.2 | 89.1 | 80.2 | 72.9 | 66.9 | 61.7 |
| 28 | 151.2 | 128.6 | 110.3 | 96.6 | 85.9 | 77.3 | 70.3 | 64.5 | 59.5 |
| 29 | 146.0 | 124.2 | 106.5 | 93.3 | 82.9 | 74.7 | 67.9 | 62.3 | 57.5 |
| 30 | 141.1 | 120.1 | 103.0 | 90.2 | 80.2 | 72.2 | 65.6 | 60.2 | 55.6 |
| 31 | 136.6 | 116.2 | 99.7 | 87.3 | 77.6 | 69.9 | 63.5 | 58.3 | 53.8 |
| 32 | 132.3 | 112.6 | 96.6 | 84.5 | 75.2 | 67.7 | 61.5 | 56.4 | 52.1 |
| 33 | 128.3 | 109.1 | 93.6 | 82.0 | 72.9 | 65.6 | 59.7 | 54.7 | 50.5 |
| 34 | 124.5 | 105.9 | 90.9 | 79.6 | 70.8 | 63.7 | 57.9 | 53.1 | 49.0 |
| 35 | 121.0 | 102.9 | 88.3 | 77.3 | 68.7 | 61.9 | 56.3 | 51.6 | 47.6 |

Table VII-4. Areal Mass Loading at Various Waste Package Spacing/Drift (continued)

| Drift Spacing (meters) | AML at Various WP Spacing (meters) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0.1 | 1.0 | 2.0 | 3.0 | 4.0 | 5.0 | 6.0 | 7.0 | 8.0 |
| 36 | 117.6 | 100.0 | 85.8 | 75.1 | 66.8 | 60.2 | 54.7 | 50.2 | 46.3 |
| 37 | 114.4 | 97.3 | 83.5 | 73.1 | 65.0 | 58.5 | 53.2 | 48.8 | 45.1 |
| 38 | 111.4 | 94.8 | 81.3 | 71.2 | 63.3 | 57.0 | 51.8 | 47.5 | 43.9 |
| 39 | 108.5 | 92.4 | 79.2 | 69.4 | 61.7 | 55.5 | 50.5 | 46.3 | 42.7 |
| 40 | 105.8 | 90.0 | 77.2 | 67.6 | 60.1 | 54.1 | 49.2 | 45.1 | 41.7 |
| 41 | 103.3 | 87.8 | 75.4 | 66.0 | 58.7 | 52.8 | 48.0 | 44.0 | 40.7 |
| 42 | 100.8 | 85.8 | 73.6 | 64.4 | 57.3 | 51.6 | 46.9 | 43.0 | 39.7 |
| 43 | 98.5 | 83.8 | 71.9 | 62.9 | 55.9 | 50.4 | 45.8 | 42.0 | 38.8 |
| 44 | 96.2 | 81.9 | 70.2 | 61.5 | 54.7 | 49.2 | 44.8 | 41.0 | 37.9 |
| 45 | 94.1 | 80.0 | 68.7 | 60.1 | 53.5 | 48.1 | 43.8 | 40.1 | 37.0 |
| 46 | 92.0 | 78.3 | 67.2 | 58.8 | 52.3 | 47.1 | 42.8 | 39.3 | 36.2 |
| 47 | 90.1 | 76.6 | 65.7 | 57.6 | 51.2 | 46.1 | 41.9 | 38.4 | 35.5 |
| 48 | 88.2 | 75.0 | 64.4 | 56.4 | 50.1 | 45.1 | 41.0 | 37.6 | 34.7 |
| 49 | 86.4 | 73.5 | 63.1 | 55.2 | 49.1 | 44.2 | 40.2 | 36.9 | 34.0 |
| 50 | 84.7 | 72.0 | 61.8 | 54.1 | 48.1 | 43.3 | 39.4 | 36.1 | 33.3 |
| 51 | 83.0 | 70.6 | 60.6 | 53.0 | 47.2 | 42.5 | 38.6 | 35.4 | 32.7 |
| 52 | 81.4 | 69.3 | 59.4 | 52.0 | 46.3 | 41.6 | 37.9 | 34.7 | 32.1 |
| 53 | 79.9 | 68.0 | 58.3 | 51.0 | 45.4 | 40.9 | 37.2 | 34.1 | 31.5 |
| 54 | 78.4 | 66.7 | 57.2 | 50.1 | 44.5 | 40.1 | 36.5 | 33.4 | 30.9 |
| 55 | 77.0 | 65.5 | 56.2 | 49.2 | 43.7 | 39.4 | 35.8 | 32.8 | 30.3 |
| 56 | 75.6 | 64.3 | 55.2 | 48.3 | 43.0 | 38.7 | 35.2 | 32.2 | 29.8 |
| 57 | 74.3 | 63.2 | 54.2 | 47.5 | 42.2 | 38.0 | 34.6 | 31.7 | 29.2 |
| 58 | 73.0 | 62.1 | 53.3 | 46.6 | 41.5 | 37.3 | 34.0 | 31.1 | 28.7 |
| 59 | 71.8 | 61.0 | 52.4 | 45.8 | 40.8 | 36.7 | 33.4 | 30.6 | 28.3 |
| 60 | 70.6 | 60.0 | 51.5 | 45.1 | 40.1 | 36.1 | 32.8 | 30.1 | 27.8 |
| 61 | 69.4 | 59.0 | 50.6 | 44.3 | 39.4 | 35.5 | 32.3 | 29.6 | 27.3 |
| 62 | 68.3 | 58.1 | 49.8 | 43.6 | 38.8 | 34.9 | 31.8 | 29.1 | 26.9 |
| 63 | 67.2 | 57.2 | 49.0 | 42.9 | 38.2 | 34.4 | 31.3 | 28.7 | 26.5 |
| 64 | 66.1 | 56.3 | 48.3 | 42.3 | 37.6 | 33.8 | 30.8 | 28.2 | 26.1 |
| 65 | 65.1 | 55.4 | 47.5 | 41.6 | 37.0 | 33.3 | 30.3 | 27.8 | 25.6 |
| 66 | 64.1 | 54.6 | 46.8 | 41.0 | 36.4 | 32.8 | 29.8 | 27.4 | 25.3 |
| 67 | 63.2 | 53.8 | 46.1 | 40.4 | 35.9 | 32.3 | 29.4 | 27.0 | 24.9 |
| 68 | 62.3 | 53.0 | 45.4 | 39.8 | 35.4 | 31.8 | 29.0 | 26.6 | 24.5 |
| 69 | 61.4 | 52.2 | 44.8 | 39.2 | 34.9 | 31.4 | 28.5 | 26.2 | 24.2 |
| 70 | 60.5 | 51.5 | 44.1 | 38.6 | 34.4 | 30.9 | 28.1 | 25.8 | 23.8 |
| 71 | 59.6 | 50.7 | 43.5 | 38.1 | 33.9 | 30.5 | 27.7 | 25.4 | 23.5 |
| 72 | 58.8 | 50.0 | 42.9 | 37.6 | 33.4 | 30.1 | 27.4 | 25.1 | 23.2 |
| 73 | 58.0 | 49.3 | 42.3 | 37.1 | 33.0 | 29.7 | 27.0 | 24.7 | 22.8 |
| 74 | 57.2 | 48.7 | 41.8 | 36.6 | 32.5 | 29.3 | 26.6 | 24.4 | 22.5 |
| 75 | 56.4 | 48.0 | 41.2 | 36.1 | 32.1 | 28.9 | 26.3 | 24.1 | 22.2 |
| 76 | 55.7 | 47.4 | 40.7 | 35.6 | 31.7 | 28.5 | 25.9 | 23.8 | 21.9 |
| 77 | 55.0 | 46.8 | 40.1 | 35.1 | 31.2 | 28.1 | 25.6 | 23.5 | 21.7 |
| 78 | 54.3 | 46.2 | 39.6 | 34.7 | 30.8 | 27.8 | 25.2 | 23.2 | 21.4 |
| 79 | 53.6 | 45.6 | 39.1 | 34.2 | 30.4 | 27.4 | 24.9 | 22.9 | 21.1 |
| 80 | 52.9 | 45.0 | 38.6 | 33.8 | 30.1 | 27.1 | 24.6 | 22.6 | 20.8 |
| 81 | 52.3 | 44.5 | 38.1 | 33.4 | 29.7 | 26.7 | 24.3 | 22.3 | 20.6 |
| 82 | 51.6 | 43.9 | 37.7 | 33.0 | 29.3 | 26.4 | 24.0 | 22.0 | 20.3 |
| 83 | 51.0 | 43.4 | 37.2 | 32.6 | 29.0 | 26.1 | 23.7 | 21.8 | 20.1 |
| 84 | 50.4 | 42.9 | 36.8 | 32.2 | 28.6 | 25.8 | 23.4 | 21.5 | 19.8 |
| 85 | 49.8 | 42.4 | 36.3 | 31.8 | 28.3 | 25.5 | 23.2 | 21.2 | 19.6 |
| 86 | 49.2 | 41.9 | 35.9 | 31.5 | 28.0 | 25.2 | 22.9 | 21.0 | 19.4 |
| 87 | 48.7 | 41.4 | 35.5 | 31.1 | 27.6 | 24.9 | 22.6 | 20.8 | 19.2 |

Table VII-4. Areal Mass Loading at Various Waste Package/Drift Spacing (continued)

| Drift Spacing (meters) | AML at Various WP Spacing (meters) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0.1 | 1.0 | 2.0 | 3.0 | 4.0 | 5.0 | 6.0 | 7.0 | 8.0 |
| 88 | 48.1 | 40.9 | 35.1 | 30.7 | 27.3 | 24.6 | 22.4 | 20.5 | 18.9 |
| 89 | 47.6 | 40.5 | 34.7 | 30.4 | 27.0 | 24.3 | 22.1 | 20.3 | 18.7 |
| 90 | 47.0 | 40.0 | 34.3 | 30.1 | 26.7 | 24.1 | 21.9 | 20.1 | 18.5 |
| 91 | 46.5 | 39.6 | 34.0 | 29.7 | 26.4 | 23.8 | 21.6 | 19.8 | 18.3 |
| 92 | 46.0 | 39.1 | 33.6 | 29.4 | 26.1 | 23.5 | 21.4 | 19.6 | 18.1 |
| 93 | 45.5 | 38.7 | 33.2 | 29.1 | 25.9 | 23.3 | 21.2 | 19.4 | 17.9 |
| 94 | 45.0 | 38.3 | 32.9 | 28.8 | 25.6 | 23.0 | 21.0 | 19.2 | 17.7 |
| 95 | 44.6 | 37.9 | 32.5 | 28.5 | 25.3 | 22.8 | 20.7 | 19.0 | 17.5 |
| 96 | 44.1 | 37.5 | 32.2 | 28.2 | 25.1 | 22.6 | 20.5 | 18.8 | 17.4 |
| 97 | 43.6 | 37.1 | 31.9 | 27.9 | 24.8 | 22.3 | 20.3 | 18.6 | 17.2 |
| 98 | 43.2 | 36.8 | 31.5 | 27.6 | 24.5 | 22.1 | 20.1 | 18.4 | 17.0 |
| 99 | 42.8 | 36.4 | 31.2 | 27.3 | 24.3 | 21.9 | 19.9 | 18.2 | 16.8 |
| 100 | 42.3 | 36.0 | 30.9 | 27.1 | 24.1 | 21.7 | 19.7 | 18.1 | 16.7 |
| 101 | 41.9 | 35.7 | 30.6 | 26.8 | 23.8 | 21.4 | 19.5 | 17.9 | 16.5 |
| 102 | 41.5 | 35.3 | 30.3 | 26.5 | 23.6 | 21.2 | 19.3 | 17.7 | 16.3 |
| 103 | 41.1 | 35.0 | 30.0 | 26.3 | 23.4 | 21.0 | 19.1 | 17.5 | 16.2 |
| 104 | 40.7 | 34.6 | 29.7 | 26.0 | 23.1 | 20.8 | 18.9 | 17.4 | 16.0 |
| 105 | 40.3 | 34.3 | 29.4 | 25.8 | 22.9 | 20.6 | 18.8 | 17.2 | 15.9 |
| 106 | 39.9 | 34.0 | 29.1 | 25.5 | 22.7 | 20.4 | 18.6 | 17.0 | 15.7 |
| 107 | 39.6 | 33.7 | 28.9 | 25.3 | 22.5 | 20.2 | 18.4 | 16.9 | 15.6 |
| 108 | 39.2 | 33.3 | 28.6 | 25.0 | 22.3 | 20.1 | 18.2 | 16.7 | 15.4 |
| 109 | 38.8 | 33.0 | 28.3 | 24.8 | 22.1 | 19.9 | 18.1 | 16.6 | 15.3 |
| 110 | 38.5 | 32.7 | 28.1 | 24.6 | 21.9 | 19.7 | 17.9 | 16.4 | 15.2 |
| 111 | 38.1 | 32.4 | 27.8 | 24.4 | 21.7 | 19.5 | 17.7 | 16.3 | 15.0 |
| 112 | 37.8 | 32.2 | 27.6 | 24.2 | 21.5 | 19.3 | 17.6 | 16.1 | 14.9 |
| 113 | 37.5 | 31.9 | 27.3 | 23.9 | 21.3 | 19.2 | 17.4 | 16.0 | 14.8 |
| 114 | 37.1 | 31.6 | 27.1 | 23.7 | 21.1 | 19.0 | 17.3 | 15.8 | 14.6 |
| 115 | 36.8 | 31.3 | 26.9 | 23.5 | 20.9 | 18.8 | 17.1 | 15.7 | 14.5 |
| 116 | 36.5 | 31.0 | 26.6 | 23.3 | 20.7 | 18.7 | 17.0 | 15.6 | 14.4 |
| 117 | 36.2 | 30.8 | 26.4 | 23.1 | 20.6 | 18.5 | 16.8 | 15.4 | 14.2 |
| 118 | 35.9 | 30.5 | 26.2 | 22.9 | 20.4 | 18.4 | 16.7 | 15.3 | 14.1 |
| 119 | 35.6 | 30.3 | 26.0 | 22.7 | 20.2 | 18.2 | 16.6 | 15.2 | 14.0 |
| 120 | 35.3 | 30.0 | 25.7 | 22.5 | 20.0 | 18.0 | 16.4 | 15.0 | 13.9 |
| 121 | 35.0 | 29.8 | 25.5 | 22.4 | 19.9 | 17.9 | 16.3 | 14.9 | 13.8 |
| 122 | 34.7 | 29.5 | 25.3 | 22.2 | 19.7 | 17.8 | 16.1 | 14.8 | 13.7 |
| 123 | 34.4 | 29.3 | 25.1 | 22.0 | 19.6 | 17.6 | 16.0 | 14.7 | 13.6 |
| 124 | 34.1 | 29.0 | 24.9 | 21.8 | 19.4 | 17.5 | 15.9 | 14.6 | 13.4 |

# ATTACHMENT VIII

# AIRFLOW ALLOCATION

## ATTACHMENT VIII

## AIRFLOW ALLOCATION

The following air allocation tables follow the logic and restrictions discussed in the *Site Recommendation Subsurface Layout* (BSC 2001a, Attachment IV). Airflows are allocated for the repository layout; allocations to other possible layout cases would be similar. The Design Airflow Volumes are from Section 4.1.2.2 (15 m³/s and 19.63 m³/s) and Section 6.2.8.2 (16.26 m³/s). The airflow capacities for the North Ramp (217.02 m³/s), South Ramp (289.36 m³/s), Intake Shaft (578.72 m³/s), and Exhaust Shaft (733.51 m³/s) are from Section 4.1.2.4.

### Intake Airflow Allocations

Tables VIII-1 through VIII-11 detail the allocations for the intake airflow. The "Extra Capacity" value in each table is determined by subtracting the component's airflow capacity from the "Total" airflow volume. For example: the "Extra Capacity" of 18.5 m³/s in Table VIII-1 is determined by the component's airflow capacity (North Ramp = 217.02 m³/s) minus the 'Total' airflow volume (198.52 m³/s).

Table VIII-1. North Ramp Intake Airflow Volume Allocation

| Heading Description | Number of Splits | Design Airflow Volume ($m^3/s$) | Total Airflow Volume ($m^3/s$) |
|---|---|---|---|
| ECRB | 1 | 19.63 | 19.63 |
| Test and Evaluation Facility ODs | 3 | 19.63 | 58.89 |
| Standby Drifts | 0 | 15.00 | 0.00 |
| Cross-block Drifts | 0 | 19.63 | 0.00 |
| PCTDs | 2 | 15.00 | 30.00 |
| Emplacement Drifts | 6 | 15.00 | 90.00 |
| Total | | | 198.52 |
| Extra Capacity | | | 18.5 |

Table VIII-2. Intake Shaft 1 Intake Airflow Volume Allocation

| Heading Description | Number of Splits | | | | Design Airflow Volume ($m^3/s$) | Total Airflow Volume ($m^3/s$) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | NE | SE | NW | SW | | NE | SE | NW | SW |
| ECRB | 0 | 0 | 0 | 0 | 19.63 | 0.00 | 0.00 | 0.00 | 0.00 |
| Test and Evaluation Facility ODs | 0 | 0 | 0 | 0 | 19.63 | 0.00 | 0.00 | 0.00 | 0.00 |
| Standby Drifts | 1 | 0 | 1 | 0 | 15.00 | 15.00 | 0.00 | 15.00 | 0.00 |
| Cross-block Drifts | 0 | 1 | 0 | 1 | 19.63 | 0.00 | 19.63 | 0.00 | 19.63 |
| PCTDs | 0 | 0 | 0 | 0 | 15.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Emplacement Drifts | 6 | 10 | 6 | 10 | 15.00 | 90.00 | 150.00 | 90.0 | 150.00 |
| Total | | | | | | 105.00 | 169.63 | 105.00 | 169.63 |
| Total per Access | | | | | | 274.63 | | 274.63 | |
| Shaft Total | | | | | | 549.26 | | | |
| Extra Shaft Capacity | | | | | | 29.46 | | | |

Table VIII-3. Intake Shaft 2 Intake Airflow Volume Allocation

| Heading Description | Number of Splits | | | | Design Airflow Volume ($m^3/s$) | Total Airflow Volume ($m^3/s$) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | NE | SE | NW | SW | | NE | SE | NW | SW |
| ECRB | 0 | 0 | 0 | 0 | 19.63 | 0.00 | 0.00 | 0.00 | 0.00 |
| Test and Evaluation Facility ODs | 0 | 0 | 0 | 0 | 19.63 | 0.00 | 0.00 | 0.00 | 0.00 |
| Standby Drifts | 1 | 0 | 1 | 0 | 15.00 | 15.00 | 0.00 | 15.00 | 0.00 |
| Cross-block Drifts | 1 | 0 | 1 | 0 | 19.63 | 19.63 | 0.00 | 19.63 | 0.00 |
| PCTDs | 0 | 0 | 0 | 0 | 15.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Emplacement Drifts | 10 | 6 | 10 | 6 | 15.00 | 150.00 | 90.00 | 150.00 | 60.00 |
| Total | | | | | | 184.63 | 90.00 | 184.63 | 90.00 |
| Total per Access | | | | | | 274.63 | | 274.63 | |
| Shaft Total | | | | | | 549.26 | | | |
| Extra Shaft Capacity | | | | | | 29.46 | | | |

Table VIII-4. Intake Shaft 3 Intake Airflow Volume Allocation

| Heading Description | Number of Splits | | | | Design Airflow Volume ($m^3/s$) | Total Airflow Volume ($m^3/s$) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | NE | SE | NW | SW | | NE | SE | NW | SW |
| ECRB | 0 | 0 | 1 | 0 | 19.63 | 0.00 | 0.00 | 19.63 | 0.00 |
| Test and Evaluation Facility ODs | 1 | 0 | 1 | 0 | 19.63 | 19.63 | 0.00 | 19.63 | 0.00 |
| Standby Drifts | 0 | 0 | 0 | 0 | 15.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cross-block Drifts | 1 | 0 | 1 | 0 | 19.63 | 19.63 | 0.00 | 19.63 | 0.00 |
| PCTDs | 0 | 0 | 0 | 0 | 15.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Emplacement Drifts | 8 | 7 | 8 | 7 | 15.00 | 120.00 | 105.00 | 120.00 | 105.00 |
| Total | | | | | | 159.26 | 105 | 178.89 | 105 |
| Total per Access | | | | | | 264.26 | | 283.89 | |
| Shaft Total | | | | | | 548.15 | | | |
| Extra Shaft Capacity | | | | | | 30.57 | | | |

Table VIII-5. South Ramp Intake Airflow Volume Allocation

| Heading Description | Number of Splits | | | | Design Airflow Volume ($m^3/s$) | Total Airflow Volume ($m^3/s$) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | NE | SE | NW | SW | | NE | SE | NW | SW |
| ECRB | 0 | 0 | 0 | 0 | 19.63 | 0.00 | 0.00 | 0.00 | 0.00 |
| Test and Evaluation Facility ODs | 0 | 0 | 0 | 0 | 19.63 | 0.00 | 0.00 | 0.00 | 0.00 |
| Standby Drifts | 0 | 0 | 0 | 0 | 15.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cross-block Drifts | 1 | 0 | 0 | 0 | 19.63 | 19.63 | 0.00 | 0.00 | 0.00 |
| PCTDs | 0 | 0 | 0 | 0 | 15.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Emplacement Drifts | 10 | 3 | 0 | 0 | 15.00 | 150.00 | 45.00 | 0.00 | 0.00 |
| Total | | | | | | 169.63 | 45.00 | 0.00 | 0.00 |
| | | | | | | 214.63 | | 0.00 | |
| Ramp Total | | | | | | 214.63 | | | |
| Extra Ramp Capacity | | | | | | 74.73 | | | |

Table VIII-6. Development/Intake Shaft Intake Airflow Volume Allocation

| Heading Description | Number of Splits | | | | Design Airflow Volume ($m^3/s$) | Total Airflow Volume ($m^3/s$) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | NE | SE | NW | SW | | NE | SE | NW | SW |
| ECRB | 0 | 0 | 0 | 0 | 19.63 | 0.00 | 0.00 | 0.00 | 0.00 |
| Test and Evaluation Facility ODs | 0 | 0 | 0 | 0 | 19.63 | 0.00 | 0.00 | 0.00 | 0.00 |
| Standby Drifts | 0 | 0 | 0 | 0 | 15.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cross-block Drifts | 0 | 0 | 1 | 0 | 19.63 | 0.00 | 0.00 | 19.63 | 0.00 |
| PCTDs | 0 | 0 | 0 | 0 | 15.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Emplacement Drifts | 0 | 10 | 13 | 10 | 15.00 | 0.00 | 150.00 | 195.00 | 150.00 |
| Total | | | | | | 0.00 | 150.00 | 214.63 | 150.00 |
| Total per Access | | | | | | 150.00 | | 364.63 | |
| Shaft Total | | | | | | 514.63 | | | |
| Extra Shaft Capacity | | | | | | 64.09 | | | |

Table VIII-7. Intake Shaft 4 Intake Airflow Volume Allocation

| Heading Description | Number of Splits | | | | Design Airflow Volume ($m^3/s$) | Total Airflow Volume ($m^3/s$) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | NE | SE | NW | SW | | NE | SE | NW | SW |
| ECRB | 0 | 0 | 0 | 0 | 19.63 | 0.00 | 0.00 | 0.00 | 0.00 |
| Test and Evaluation Facility ODs | 1 | 0 | 1 | 0 | 19.63 | 19.63 | 0.00 | 19.63 | 0.00 |
| Standby Drifts | 0 | 0 | 0 | 0 | 15.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cross-block Drifts | 0 | 0 | 0 | 0 | 19.63 | 0.00 | 0.00 | 0.00 | 0.00 |
| PCTDs | 0 | 0 | 0 | 0 | 15.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Emplacement Drifts | 9 | 8 | 9 | 8 | 15.00 | 135.00 | 120.00 | 135.00 | 120.00 |
| Total | | | | | | 154.63 | 120.00 | 154.63 | 120.00 |
| Total per Access | | | | | | 274.63 | | 274.63 | |
| Shaft Total | | | | | | 549.26 | | | |
| Extra Shaft Capacity | | | | | | 29.46 | | | |

Table VIII-8. Intake Shaft 5 Intake Airflow Volume Allocation

| Heading Description | Number of Splits | | | | Design Airflow Volume ($m^3/s$) | Total Airflow Volume ($m^3/s$) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | NE | SE | NW | SW | | NE | SE | NW | SW |
| ECRB | 0 | 0 | 0 | 0 | 19.63 | 0.00 | 0.00 | 0.00 | 0.00 |
| Test and Evaluation Facility ODs | 0 | 1 | 0 | 1 | 19.63 | 0.00 | 19.63 | 0.00 | 19.63 |
| Standby Drifts | 0 | 0 | 0 | 0 | 15.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cross-block Drifts | 1 | 0 | 1 | 0 | 19.63 | 19.63 | 0.00 | 19.63 | 0.00 |
| PCTDs | 0 | 0 | 0 | 0 | 15.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Emplacement Drifts | 0 | 7 | 0 | 7 | 15.00 | 0.00 | 105.00 | 0.00 | 105.00 |
| Total | | | | | | 19.63 | 124.63 | 19.63 | 124.63 |
| | | | | | | 144.26 | | 144.26 | |
| Ramp Total | | | | | | 288.52 | | | |
| Extra Ramp (Shaft) Capacity | | | | | | 0.84 (290.20) | | | |

Note: Intake Shaft 5 airflow feeds down ramp 3 to the Lower Block. The ramp 3 air volume capacity uses the south ramp design air volume (289.36 $m^3/s$); the Intake Shaft 5 air volume capacity (578.72 $m^3/s$) exceeds the ramp air volume capacity by 290.20 $m^3/s$ (i.e. shaft is not utilized fully).

Table VIII-9. Intake Shaft 6 Intake Airflow Volume Allocation

| Heading Description | Number of Splits | | | | Design Airflow Volume ($m^3/s$) | Total Airflow Volume ($m^3/s$) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | NE | SE | NW | SW | | NE | SE | NW | SW |
| ECRB | 0 | 0 | 0 | 0 | 19.63 | 0.00 | 0.00 | 0.00 | 0.00 |
| Test and Evaluation Facility Ods | 1 | 0 | 1 | 0 | 19.63 | 19.63 | 0.00 | 19.63 | 0.00 |
| Standby Drifts | 1 | 0 | 1 | 0 | 15.00 | 15.00 | 0.00 | 15.00 | 0.00 |
| Cross-block Drifts | 0 | 0 | 0 | 0 | 19.63 | 0.00 | 0.00 | 0.00 | 0.00 |
| PCTDs | 0 | 0 | 0 | 0 | 15.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Emplacement Drifts | 8 | 7 | 8 | 7 | 15.00 | 120.00 | 105.00 | 120.00 | 105.00 |
| Total | | | | | | 154.63 | 105.00 | 154.63 | 105.00 |
| Total per Access | | | | | | 259.63 | | 259.63 | |
| Shaft Total | | | | | | 519.26 | | | |
| Extra Shaft Capacity | | | | | | 59.46 | | | |

Table VIII-10. Intake Shaft 7 Intake Airflow Volume Allocation

| Heading Description | Number of Splits | | | | Design Airflow Volume ($m^3/s$) | Total Airflow Volume ($m^3/s$) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | NE | SE | NW | SW | | NE | SE | NW | SW |
| ECRB | 0 | 0 | 0 | 0 | 19.63 | 0.00 | 0.00 | 0.00 | 0.00 |
| Test and Evaluation Facility ODs | 0 | 0 | 0 | 0 | 19.63 | 0.00 | 0.00 | 0.00 | 0.00 |
| Standby Drifts | 0 | 1 | 0 | 1 | 15.00 | 0.00 | 15.00 | 0.00 | 15.00 |
| Cross-block Drifts | 1 | 0 | 1 | 0 | 19.63 | 19.63 | 0.00 | 19.63 | 0.00 |
| PCTDs | 0 | 0 | 0 | 0 | 15.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Emplacement Drifts | 11 | 5 | 11 | 5 | 15.00 | 165.00 | 75.00 | 165.00 | 75.00 |
| Total | | | | | | 184.63 | 90.00 | 184.63 | 90.00 |
| Total per Access | | | | | | 274.63 | | 274.63 | |
| Shaft Total | | | | | | 549.26 | | | |
| Extra Shaft Capacity | | | | | | 29.46 | | | |

Table VIII-11. Intake Shaft 8 Intake Airflow Volume Allocation

| Heading Description | Number of Splits | | | | Design Airflow Volume ($m^3/s$) | Total Airflow Volume ($m^3/s$) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | NE | SE | NW | SW | | NE | SE | NW | SW |
| ECRB | 0 | 0 | 0 | 0 | 19.63 | 0.00 | 0.00 | 0.00 | 0.00 |
| Test and Evaluation Facility ODs | 0 | 0 | 0 | 0 | 19.63 | 0.00 | 0.00 | 0.00 | 0.00 |
| Standby Drifts | 0 | 0 | 0 | 0 | 15.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cross-block Drifts | 0 | 0 | 0 | 0 | 19.63 | 0.00 | 0.00 | 0.00 | 0.00 |
| PCTDs | 0 | 0 | 0 | 0 | 15.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Emplacement Drifts | 6 | 8 | 6 | 8 | 15.00 | 90.00 | 120.00 | 90.00 | 120.00 |
| Total | | | | | | 90.00 | 120.00 | 90.00 | 120.00 |
| Total per Access | | | | | | 210.00 | | 210.00 | |
| Shaft Total | | | | | | 420.00 | | | |
| Extra Shaft Capacity | | | | | | 158.72 | | | |

The intake airflow allocations outlined in Table VIII-1 through Table VIII-11 are depicted in Figure VIII-1 for the repository layout. These airflow zones are for planning purposes only. Ventilation simulations will provide a more accurate representation of airflow distribution.

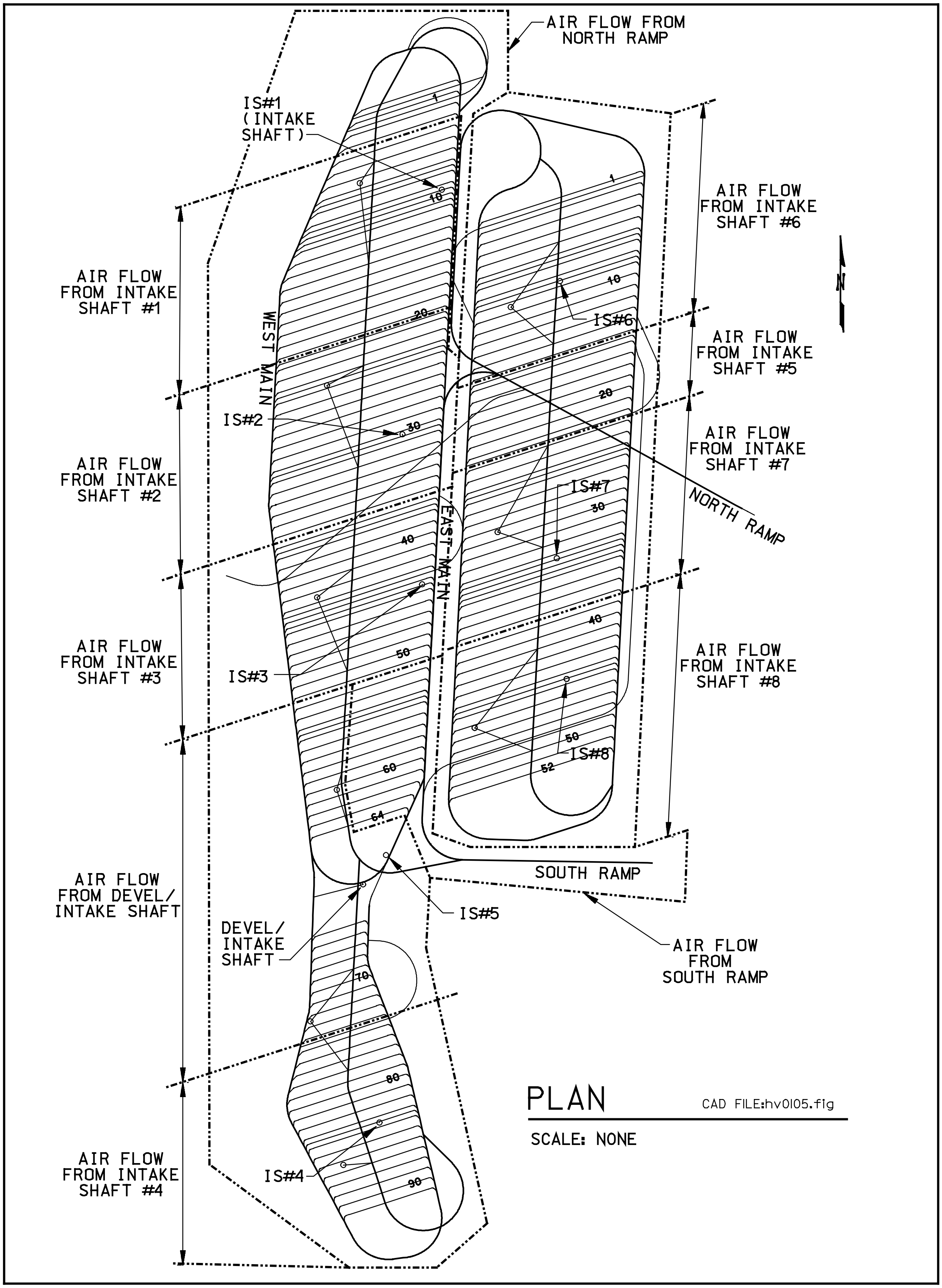



Figure VIII-1. Intake Airflow Allocations

## Exhaust Airflow Allocations

Tables VIII-12 through VIII-20 detail the allocations for the exhaust airflow. The exhaust shaft design capacity is 733.51 $m^3/s$ (see Section 4.1.2.4). Airflows are allocated to maintain the total exhaust volume below the deign capacity. In the Table headings, Access = Acc.

Table VIII-12. Exhaust Shaft 1 Exhaust Airflow Volume Allocation

| Heading Description | Number of Splits | | | | | | Design Airflow Volume ($m^3/s$) | Total Airflow Volume ($m^3/s$) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Acc 1 From North | Acc 1 from South | Access 1 Direct | Acc 2 from North | Acc 2 from South | Acc 2 Direct | | Acc 1 from North | Acc 1 from South | Acc 1 Direct | Acc 2 from North | Acc 2 from South | Acc 2 Direct |
| ECRB | 0 | 0 | 0 | 0 | 0 | 0 | 19.63 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Test and Evaluation Facility Ods | 3 | 0 | 0 | 0 | 0 | 0 | 19.63 | 58.89 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Standby Drifts | 0 | 2 | 0 | 0 | 0 | 0 | 16.26 | 0.00 | 32.52 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cross-block Drifts | 0 | 0 | 0 | 2 | 0 | 0 | 19.63 | 0.00 | 0.00 | 0.00 | 39.26 | 0.00 | 0.00 |
| Test and Evaluation Facility Postclosure Drifts | 2 | 0 | 0 | 0 | 0 | 0 | 16.26 | 32.52 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Emplacement Drifts | 6 | 8 | 2 | 8 | 8 | 2 | 16.26 | 97.56 | 130.08 | 32.52 | 130.08 | 130.08 | 32.52 |
| Total | | | | | | | | 188.97 | 162.60 | 32.52 | 169.34 | 130.08 | 32.52 |
| Total per Access | | | | | | | | 384.09 | | | 331.94 | | |
| Shaft Total | | | | | | | | 716.03 | | | | | |

Table VIII-13. Exhaust Shaft 2 Exhaust Airflow Volume Allocation

| Heading Description | Number of Splits | | | | | | Design Airflow Volume ($m^3/s$) | Total Airflow Volume ($m^3/s$) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Acc 1 From North | Acc 1 from South | Acc 1 Direct | Acc 2 from North | Acc 2 from South | Acc 2 Direct | | Acc 1 from North | Acc 1 from South | Acc 1 Direct | Acc 2 from North | Acc 2 from South | Acc 2 Direct |
| ECRB | 0 | 0 | 0 | 0 | 2 | 0 | 19.63 | 0.00 | 0.00 | 0.00 | 0.00 | 39.26 | 0.00 |
| Test and Evaluation Facility ODs | 0 | 0 | 0 | 0 | 0 | 0 | 19.63 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Standby Drifts | 2 | 0 | 0 | 0 | 0 | 0 | 16.26 | 32.52 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cross-block Drifts | 0 | 2 | 0 | 0 | 0 | 0 | 19.63 | 0.00 | 39.26 | 0.00 | 0.00 | 0.00 | 0.00 |
| Test and Evaluation Facility Postclosure Drifts | 0 | 0 | 0 | 0 | 0 | 0 | 16.26 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Emplacement Drifts | 8 | 8 | 2 | 8 | 8 | 2 | 16.26 | 130.08 | 130.08 | 32.52 | 130.08 | 130.08 | 32.52 |
| Total | | | | | | | | 162.60 | 169.34 | 32.52 | 130.08 | 169.34 | 32.52 |
| Total per Access | | | | | | | | 364.46 | | | 331.94 | | |
| Shaft Total | | | | | | | | 696.40 | | | | | |

Table VIII-14. Exhaust Shaft 3 Exhaust Airflow Volume Allocation

| Heading Description | Number of Splits | | | | | | Design Airflow Volume ($m^3/s$) | Total Airflow Volume ($m^3/s$) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Acc 1 from North | Acc 1 from South | Acc 1 Direct | Acc 2 from North | Acc 2 from South | Acc 2 Direct | | Acc 1 from North | Acc 1 from South | Acc 1 Direct | Acc 2 from North | Acc 2 from South | Acc 2 Direct |
| ECRB | 0 | 0 | 0 | 0 | 0 | 0 | 19.63 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Test and Evaluation Facility ODs | 0 | 2 | 0 | 0 | 0 | 0 | 19.63 | 0.00 | 39.26 | 0.00 | 0.00 | 0.00 | 0.00 |
| Standby Drifts | 0 | 0 | 0 | 0 | 0 | 0 | 16.26 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cross-block Drifts | 2 | 0 | 0 | 0 | 0 | 0 | 19.63 | 39.26 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Test and Evaluation Facility Postclosure Drifts | 0 | 0 | 0 | 0 | 0 | 0 | 16.26 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Emplacement Drifts | 8 | 8 | 2 | 8 | 8 | 2 | 16.26 | 130.08 | 130.08 | 32.52 | 130.08 | 130.08 | 32.52 |
| Total | | | | | | | | 169.34 | 169.34 | 32.52 | 130.08 | 130.08 | 32.52 |
| Total per Access | | | | | | | | | 371.20 | | | 292.68 | |
| Shaft Total | | | | | | | | | | 663.88 | | | |

Table VIII-15. Exhaust Shaft 4 Exhaust Airflow Volume Allocation

| Heading Description | Number of Splits | | | | | | Design Airflow Volume ($m^3/s$) | Total Airflow Volume ($m^3/s$) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Acc 1 from North | Acc 1 from South | Acc 1 Direct | Acc 2 from North | Acc 2 from South | Acc 2 Direct | | Acc 1 from North | Acc 1 from South | Acc 1 Direct | Acc 2 From North | Acc 2 from South | Acc 2 Direct |
| ECRB | 0 | 0 | 0 | 0 | 0 | 0 | 19.63 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Test and Evaluation Facility ODs | 0 | 0 | 0 | 0 | 0 | 0 | 19.63 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Standby Drifts | 0 | 0 | 0 | 0 | 0 | 0 | 16.26 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cross-block Drifts | 2 | 0 | 0 | 0 | 0 | 0 | 19.63 | 39.26 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Test and Evaluation Facility Postclosure Drifts | 0 | 0 | 0 | 0 | 0 | 0 | 16.26 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Emplacement Drifts | 8 | 4 | 2 | 4 | 0 | 2 | 16.26 | 130.08 | 65.04 | 32.52 | 65.04 | 0.00 | 32.52 |
| Total | | | | | | | | 169.34 | 65.04 | 32.52 | 65.04 | 0.00 | 32.52 |
| Total per Access | | | | | | | | | 266.90 | | | 97.56 | |
| Shaft Total | | | | | | | | | | 364.46 | | | |

Table VIII-16. Exhaust Shaft 5 Exhaust Airflow Volume Allocation

| Heading Description | Number of Splits | | | | | | Design Airflow Volume ($m^3/s$) | Total Airflow Volume ($m^3/s$) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Acc 1 from North | Acc 1 from South | Acc 1 Direct | Acc 2 from North | Acc 2 from South | Acc 2 Direct | | Acc 1 from North | Acc 1 from South | Acc 1 Direct | Acc 2 From North | Acc 2 from South | Acc 2 Direct |
| ECRB | 0 | 0 | 0 | 0 | 0 | 0 | 19.63 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Test and Evaluation Facility ODs | 0 | 0 | 0 | 2 | 0 | 0 | 19.63 | 0.00 | 0.00 | 0.00 | 39.26 | 0.00 | 0.00 |
| Standby Drifts | 0 | 0 | 0 | 0 | 0 | 0 | 16.26 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cross-block Drifts | 0 | 0 | 0 | 0 | 0 | 0 | 19.63 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Test and Evaluation Facility Postclosure Drifts | 0 | 0 | 0 | 0 | 0 | 0 | 16.26 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Emplacement Drifts | 8 | 8 | 2 | 8 | 8 | 2 | 16.26 | 130.08 | 130.08 | 32.52 | 130.08 | 130.08 | 32.52 |
| Total | | | | | | | | 130.08 | 130.08 | 32.52 | 169.34 | 130.08 | 32.92 |
| Total per Access | | | | | | | | 292.68 | | | 331.94 | | |
| Shaft Total | | | | | | | | 624.62 | | | | | |

Table VIII-17. Exhaust Shaft 6 Exhaust Airflow Volume Allocation

| Heading Description | Number of Splits | | | | | | Design Airflow Volume ($m^3/s$) | Total Airflow Volume ($m^3/s$) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Acc 1 from North | Acc 1 from South | Acc 1 Direct | Acc 2 from North | Acc 2 from South | Acc 2 Direct | | Acc 1 from North | Acc 1 from South | Acc 1 Direct | Acc 2 From North | Acc 2 from South | Acc 2 Direct |
| ECRB | 0 | 0 | 0 | -- | -- | -- | 19.63 | 0.00 | 0.00 | 0.00 | -- | -- | -- |
| Test and Evaluation Facility ODs | 0 | 0 | 0 | -- | -- | -- | 19.63 | 0.00 | 0.00 | 0.00 | -- | -- | -- |
| Standby Drifts | 0 | 0 | 0 | -- | -- | -- | 16.26 | 0.00 | 0.00 | 0.00 | -- | -- | -- |
| Cross-block Drifts | 0 | 0 | 0 | -- | -- | -- | 19.63 | 0.00 | 0.00 | 0.00 | -- | -- | -- |
| Test and Evaluation Facility Postclosure Drifts | 0 | 0 | 0 | -- | -- | -- | 16.26 | 0.00 | 0.00 | 0.00 | -- | -- | -- |
| Emplacement Drifts | 8 | 8 | 2 | -- | -- | -- | 16.26 | 130.08 | 130.08 | 32.52 | -- | -- | -- |
| Total | | | | | | | | 130.08 | 130.08 | 32.52 | -- | -- | -- |
| Total per Access | | | | | | | | 292.68 | | | -- | | |
| Shaft Total | | | | | | | | 292.68 | | | | | |

Table VIII-18. Exhaust Shaft 7 Exhaust Airflow Volume Allocation

| Heading Description | Number of Splits | | | | | | Design Airflow Volume ($m^3/s$) | Total Airflow Volume ($m^3/s$) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Acc 1 from North | Acc 1 from South | Acc 1 Direct | Acc 2 from North | Acc 2 from South | Acc 2 Direct | | Acc 1 from North | Acc 1 from South | Acc 1 Direct | Acc 2 from North | Acc 2 from South | Acc 2 Direct |
| ECRB | 0 | 0 | 0 | 0 | 0 | 0 | 19.63 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Test and Evaluation Facility ODs | 2 | 0 | 0 | 0 | 0 | 0 | 19.63 | 39.26 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Standby Drifts | 0 | 2 | 0 | 0 | 0 | 0 | 16.26 | 0.00 | 32.52 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cross-block Drifts | 0 | 0 | 0 | 0 | 2 | 0 | 19.63 | 0.00 | 0.00 | 0.00 | 0.00 | 39.26 | 0.00 |
| Test and Evaluation Facility Postclosure Drifts | 0 | 0 | 0 | 0 | 0 | 0 | 16.26 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Emplacement Drifts | 8 | 8 | 2 | 8 | 8 | 2 | 16.26 | 130.08 | 130.08 | 32.52 | 130.08 | 130.08 | 32.52 |
| Total | | | | | | | | 169.34 | 162.60 | 32.52 | 130.08 | 169.34 | 32.52 |
| Total per Access | | | | | | | | 364.46 | | | 331.94 | | |
| Shaft Total | | | | | | | | 696.40 | | | | | |

Table VIII-19. Exhaust Shaft 8 Exhaust Airflow Volume Allocation

| Heading Description | Number of Splits | | | | | | Design Airflow Volume ($m^3/s$) | Total Airflow Volume ($m^3/s$) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Acc 1 from North | Acc 1 from South | Acc 1 Direct | Acc 2 from North | Acc 2 from South | Acc 2 Direct | | Acc 1 from North | Acc 1 from South | Acc 1 Direct | Acc 2 From North | Acc 2 from South | Acc 2 Direct |
| ECRB | 0 | 0 | 0 | 0 | 0 | 0 | 19.63 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Test and Evaluation Facility ODs | 2 | 0 | 0 | 0 | 0 | 0 | 19.63 | 39.26 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Standby Drifts | 0 | 0 | 0 | 0 | 2 | 0 | 16.26 | 0.00 | 0.00 | 0.00 | 0.00 | 32.52 | 0.00 |
| Cross-block Drifts | 0 | 2 | 0 | 0 | 0 | 0 | 19.63 | 0.00 | 39.26 | 0.00 | 0.00 | 0.00 | 0.00 |
| Test and Evaluation Facility Postclosure Drifts | 0 | 0 | 0 | 0 | 0 | 0 | 16.26 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Emplacement Drifts | 8 | 8 | 2 | 8 | 8 | 2 | 16.26 | 130.08 | 130.08 | 32.52 | 130.08 | 130.08 | 32.52 |
| Total | | | | | | | | 169.34 | 169.34 | 32.52 | 130.08 | 162.60 | 32.52 |
| Total per Access | | | | | | | | 371.20 | | | 325.20 | | |
| Shaft Total | | | | | | | | 696.40 | | | | | |

Table VIII-20. Exhaust Shaft 9 Exhaust Airflow Volume Allocation

| Heading Description | Number of Splits | | | | | | Design Airflow Volume ($m^3/s$) | Total Airflow Volume ($m^3/s$) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Acc 1 from North | Acc 1 from South | Acc 1 Direct | Acc 2 From North | Acc 2 from South | Acc 2 Direct | | Acc 1 from North | Acc 1 from South | Acc 1 Direct | Acc 2 From North | Acc 2 from South | Acc 2 Direct |
| ECRB | 0 | 0 | 0 | 0 | 0 | 0 | 19.63 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Test and Evaluation Facility ODs | 0 | 0 | 0 | 0 | 0 | 0 | 19.63 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Standby Drifts | 0 | 0 | 0 | 0 | 0 | 0 | 16.26 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cross-block Drifts | 0 | 0 | 0 | 0 | 0 | 0 | 19.63 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Test and Evaluation Facility Postclosure Drifts | 0 | 0 | 0 | 0 | 0 | 0 | 16.26 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Emplacement Drifts | 8 | 8 | 2 | 8 | 4 | 2 | 16.26 | 130.08 | 130.08 | 32.52 | 130.08 | 65.04 | 32.52 |
| Total | | | | | | | | 130.08 | 130.08 | 32.52 | 130.08 | 65.04 | 32.52 |
| Total per Access | | | | | | | | 292.68 | | | 227.64 | | |
| Shaft Total | | | | | | | | 520.32 | | | | | |

The exhaust airflow allocations outlined in Table VIII-12 through Table VIII-20 are depicted in Figure VIII-2 for the repository layout. These airflow zones are conceptual estimates.

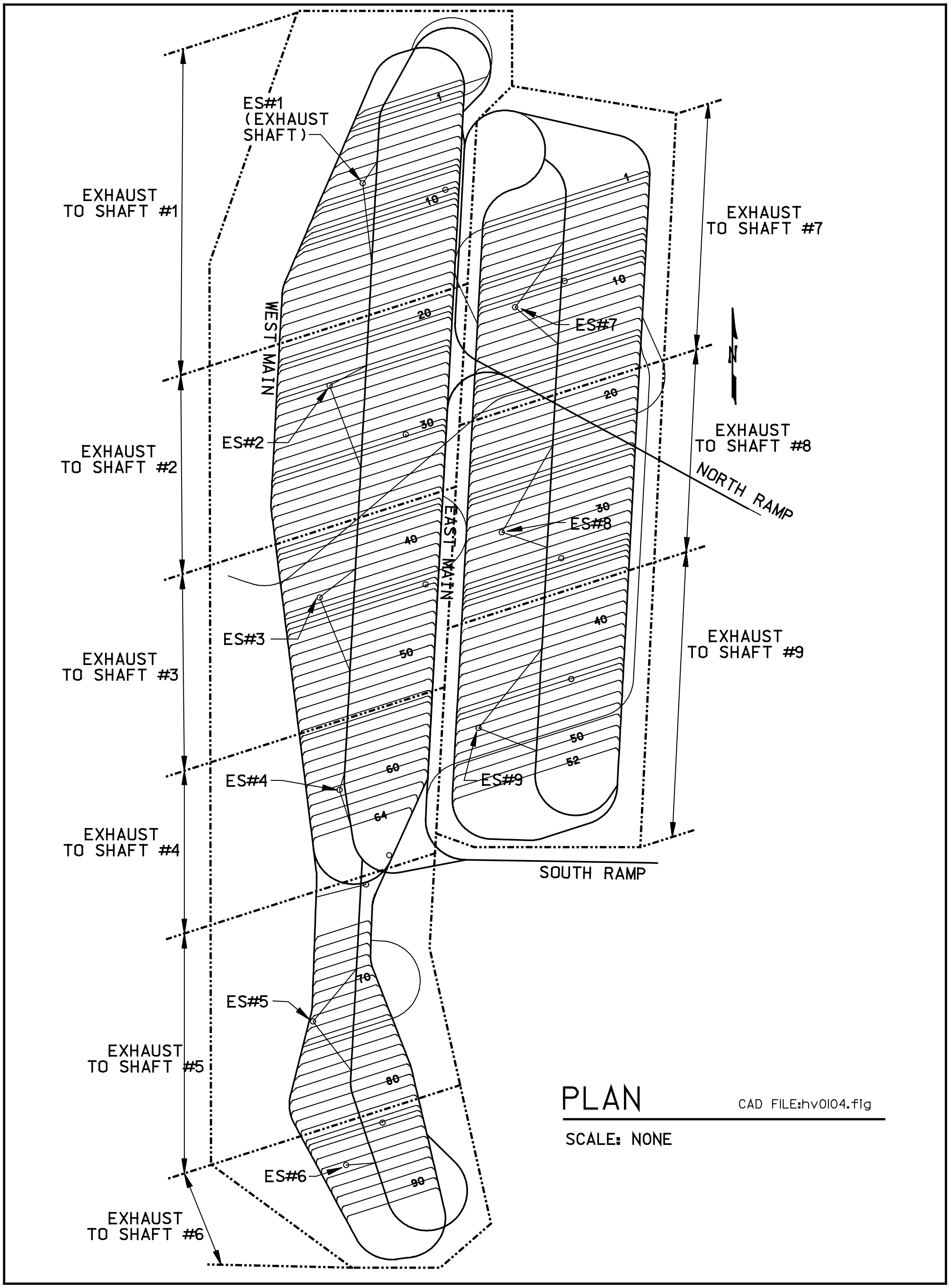



Figure VIII-2. Exhaust Airflow Allocations

# ATTACHMENT IX

# HISTORY OF THE VARIOUS OPERATING MODES

## ATTACHMENT IX

## HISTORY OF THE VARIOUS OPERATING MODES

### IX.1 VIABILITY ASSESSMENT OF A REPOSITORY AT YUCCA MOUNTAIN

The Viability Assessment of the Yucca Mountain site included descriptions of the following (DOE 1998d, p. 1):

- The preliminary design concepts for the critical elements of the repository and the WP.
- A total system performance assessment based on the design concept and the scientific data and analyses available.
- A plan and cost estimate for the remaining work required to complete and submit a license application.
- An estimate of the costs to construct and operate a repository.

### IX.1.1 Engineering and Performance Assessment

The engineering analysis and the performance assessment for the Viability Assessment provided evaluations of a design that would accommodate the 70,000 MTHM waste inventory. The Viability Assessment design (DOE 1998b, pp. 3-30 to 3-31) consisted of:

- Emplacement drifts spaced at 28 meters from center-to-center.
- Point-loading emplacement, meaning that the WPs are far enough apart that there is little direct thermal communication between the packages. This point loading arrangement resulted in an average effective end-to-end WP spacing of 3.9 meters (CRWMS M&O 1997c, p. 42).
- The emplacement drift ventilation rate was limited to 0.1 $m^3/s$ after waste emplacement.
- The AML of 85 MTHM/acre was based in the CSNF only.

### IX.1.2 Total System Life Cycle Cost

The MGR – Viability Assessment cost estimate also referred to as the Total System Life Cycle Costs is a detailed, point-in-time estimate of the costs to design, construct, operate, monitor, close, and decommission a radioactive waste disposal facility at Yucca Mountain. The Total System Life Cycle Cost was based on the reference design for the Viability Assessment (DOE 1998e, p. O-1) as described in Section 6.1.6.1.1.

### IX.1.3 Environmental Impact Statement

The *Draft 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 1999) was published in July of 1999. This document incorporated two waste inventories, the 70,000 MTHM inventory and a larger inventory case (DOE 1999, Appendix A, p. A-1). The larger inventory case is considered a bounding case that consists of approximately 105,000 MTHM of CSNF (CRWMS M&O 1999i, p. 3-3). The Draft EIS uses the repository operating and design concepts presented in the Viability Assessment design analyses. The design features for evaluating the environmental impacts (CRWMS M&O 1999i, p. 3-3) included the following for the base case and the larger inventory case:

- Emplacement drifts spaced at 28 meters from center-to-center.
- Point-loading emplacement, meaning that the WPs are far enough apart that there is less direct thermal communication between the packages. This point loading arrangement resulted in an average effective end-to-end WP spacing of approximately 3.9 meters (CRWMS M&O 1997c, p. 42).
- The emplacement drift ventilation rate was limited to 0.1 $m^3$/s after waste emplacement.
- AML of 85 MTHM/acre based on CSNF.

Additional case studies are also included in the draft EIS. These cases included impact evaluations of intermediate and low thermal loading scenarios resulting in AMLs ranging from 25 to 60 MTHM/acre.

## IX.2 HIGHER TEMPERATURE OPERATING MODE

Subsequent direction (Wilkins and Heath 1999, Enclosure 2) during the License Application Design Selection (CRWMS M&O 1999d, Overview, pp. O-21 to O-26) and Enhanced Design Alternative II studies (CRWMS M&O 1999e, Executive Summary) lead to evaluations that defined thermal goals for a higher-temperature operating mode repository design. This concept would keep the boiling fronts from coalescing in the rock pillars between the emplacement drifts. To achieve this goal a sufficient portion of the pillars must be maintained at temperatures below the boiling point of water at the elevation of the emplacement horizon. This increase in the range of operations introduced the concept of line-loading the WPs. Line-loading is spacing WPs very closely together end-to-end to achieve a more uniform thermal profile along the length of the emplacement drifts. The concentration of heat sources resulting from line loading required that the emplacement drifts be spaced farther apart to distribute the thermal load over a larger area. Also in this concept, the ventilation system must remove approximately 70 percent of the heat generated by the WPs during the preclosure period.

### IX.2.1 Engineering

The engineering analysis for the higher-temperature operating mode, *Site Recommendation Subsurface Layout* (BSC 2001a, Section 6.2), developed a layout that would accommodate both a 70,000 MTHM waste inventory and a 97,000 MTHM waste inventory. This analysis also supported the design efforts of the performance assessment organization, the Total System Life Cycle Cost, and the proposed Final EIS Update. The higher temperature operating mode design consisted of:

- Emplacement drifts spaced at 81 meters from center-to-center.
- WPs spaced at 0.1 meters end-to-end.
- A linear thermal loading of approximately 1.45 kW/m.
- Forced ventilation of 15 $m^3$/s for 50 years from the start of emplacement (heat removal efficiency of 70 percent).

- Resulting AML of approximately 56 MTHM/acre.

### IX.2.2 Performance Assessment

The performance assessment work that supported the higher-temperature operating mode was documented in *Total System Performance for the Site Recommendation* (CRWMS M&O 2000o, p. 1-47). An intermediate layout configuration was used as the basis for the performance assessment evaluations. A set of boundary coordinates for this layout configuration was documented in an input transmittal and subsequently placed in the technical data management system (DTN: MO9911MWDEBSWD.000, directory: drainageAMR, file: dft1.dat). The basis for this work was:

- Waste inventory of 70,000 MTHM (63,000 MTHM of CSNF and 7,000 MTHM of DOE SNF and high level waste).
- Emplacement drifts spaced at 81 meters from center-to-center.
- WPs spaced at approximately 0.1 meters end-to-end.
- A linear thermal loading of approximately 1.35 kW/m.
- Forced ventilation of 15 $m^3/s$ for 50 years from the start of emplacement (heat removal efficiency of 70 percent).
- AML of approximately 55 MTHM/acre.

### IX.2.3 Total System Life Cycle Cost

The *FY2000 Monitored Geologic Repository Total System Life Cycle Cost Report* (CRWMS M&O 2000p, pp. 1 to 2) provides the cost basis for the higher-temperature operating mode design. This cost estimate was based on the 97,000 MTHM waste inventory layout as developed in the *Site Recommendation Subsurface Layout* (BSC 2001a, Section 6.4) and described in Section 6.1.6.2.1.

### IX.2.4 Environmental Impact Statement

The higher-temperature operating mode for the Final EIS is documented in the *FEIS Update to Engineering File – Subsurface Repository* (CRWMS M&O 2000n, p. 3-2). This case study incorporated the following features:

- Consideration of the 70,000 MTHM waste inventory, as well as the larger inventory inventory.
- Emplacement drifts spaced at 81 meters from center-to-center.
- WPs spaced at 0.1 meters end-to-end.
- A linear thermal loading of approximately 1.45 kW/m.
- Forced ventilation of 15 $m^3/s$ for 50 years from the start of emplacement (heat removal efficiency of 70 percent).
- AML of approximately 56 MTHM/acre.

## IX.3 LOWER TEMPERATURE OPERATING MODE

Current project efforts provide the basis for a lower-temperature operating mode that achieves lower drift wall and WP surface temperatures (see Section 6.1). These evaluations also provide the basis for the discussion of operating and design flexibility (see Section 6.1.5). The objective of this analysis is to use this information, along with prior information, to evaluate various scenarios that demonstrate the operating flexibility of the design over a range of thermal modes. This is demonstrated by evaluating various scenarios within the range and, where appropriate, performing sensitivity evaluations that provide information pertinent to this range of operating modes.

### IX.3.1 Engineering

The engineering analysis for the lower-temperature operating mode is contained in this analysis (see Section 6.1). A layout configuration for the potential repository development area is developed that would be sufficient to accommodate the 70,000 and 97,000 MTHM waste inventories. The layout configuration also supports the design efforts of the performance assessment organization, the Total System Life Cycle Cost, and the proposed FEIS update. The lower-temperature operating mode case studies presented in this analysis consist of:

- Emplacement drifts spaced at 81 meters from center-to-center.
- WPs spaced at approximately 2.0 meters end-to-end.
- A linear thermal loading of approximately 1.00 kW/m.
- Forced ventilation of 15 $m^3$/s for 75 years (25 years during emplacement followed by 50 years after emplacement.
- Natural ventilation for 250 years after the forced ventilation period.
- AML of approximately 40 MTHM/acre.

Other implementation scenarios are evaluated by the engineering analyses to demonstrate the variety of parameter adjustments that can be made to achieve a given set of thermal objectives.

### IX.3.2 Performance Assessment

The performance assessment work that supports the lower-temperature operating mode is documented in the *Supplemental Science and Performance Analysis*. The basis for this work, documented in the input transmittal *Bases for the Supplemental Science and Performance Analyses (SSPA) Vol 1 calculations* (BSC 2001c, Item 1, p. 1), is:

- The 70,000 MTHM waste inventory (63,000 MTHM of CSNF and 7,000 MTHM of DOE SNF and high level waste),
- Emplacement drifts spaced at 81 meters from center-to-center,
- WPs spaced at approximately 1.1 meters end-to-end,
- A linear thermal loading of approximately 1.13 kW/m,
- Forced ventilation at 15 $m^3$/s for 300 years from the start of emplacement (heat removal efficiency of 80 percent),

- AML of approximately 45 MTHM/acre.

The objective of this evaluation is to assess performance over a range of thermal modes. This is accomplished by using updated models and best available information on uncertainties to assess performance for a scenario at the lower-end of the thermal range and then performing sensitivity evaluations by varying operational parameters to obtain the assessment of performance over the range of thermal modes. The sensitivity evaluations capture the range of performance characteristics for the variety of scenarios evaluated in the engineering analyses, including evaluations covering the higher-temperature operating modes.

### IX.3.3 Total System Life Cycle Costs

The FY2001 MGR Total System Life Cycle Cost Report is currently under development. It is anticipated that this cost estimate will use the FY2000 Total System Life Cycle Cost estimate (CRWMS M&O 2000p) to determine unitized costs that can be applied to a case study that addresses the range of thermal operating modes. This case study would use the 97,000 MTHM case study (see Section 6.1.4) as its basis.

### IX.3.4 Environmental Impact Statement

Currently, the two waste inventories options (70,000 MTHM and the larger inventory case) are being developed to address the lower-temperature operating mode concept. Information provided to the EIS contractor is based on the following and the engineering analyses described previously for the lower- temperature operating mode.

- Emplacement drifts spaced at 81 meters from center-to-center.
- WPs spaced at approximately 2.0 meters end-to-end.
- A linear thermal loading of approximately 1.00 kW/m.
- Forced ventilation of 15 $m^3$/s for 75 years (25 years during emplacement followed by 50 years after emplacement.
- Natural ventilation for 250 years after the forced ventilation period.
- AML of approximately 40 MTHM/acre.