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Design Analysis Cover Sheet

Complete only applicable items.

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1. PURPOSE

The purpose of this analysis is to develop a repository subsurface layout for the statutory capacity of 70,000 metric tons of uranium (MTU), or equivalent, with a degree of flexibility to accommodate potential changes in site conditions or programmatic requirements.- The objective of this analysis is to provide a repository subsurface layout for the Viability Assessment (VA) design in accordance with the current waste isolation strategy.

The scope of this analysis covers:

1. Evaluation of Exploratory Studies Facility (ESF) openings and their integration into the repository layout design.
2. Identification and incorporation of factors influencing repository layout design such as site volume available for emplacement, thermal loading, constructibility, subsurface ventilation, waste package transportation, waste emplacement/retrieval method, drainage control, ground support system, utilities, radiological considerations, and performance confirmation. Emplacement drift backfill and remote handling of equipment may also influence the layout but are considered outside the scope of this analysis.
3. Geometry and configuration of the repository openings.
4. Development of a layout showing the emplacement area required for 70,000 metric tons of uranium or heavy metal equivalent (MTU).
5. Evaluation of the VA layout compared to the concept presented in the *Mined Geologic Disposal System Advanced Conceptual Design Report* (MGDS ACD Report) (Reference 5.1).
6. Identification of available emplacement areas for potential expansion.

This analysis was performed as part of the scope of work described in Summary Account number TR47FB5, Subsurface Layout Design.

2. QUALITY ASSURANCE

The quality assurance classification of repository structures, systems, and components has not yet been performed in accordance with QAP-2-3, *Classification of Permanent Items*. However, the repository underground openings are on the *Q-List* (Reference 5.2) by direct inclusion.

This design analysis activity has been evaluated in accordance with QAP-2-0, *Conduct of Activities*, and has been determined to be quality affecting and subject to the requirements of the *Quality Assurance Requirements and Description* (QARD) (Reference 5.3). This analysis is subject to quality assurance controls in accordance with NLP-3-18, *Documentation of QA Controls on Drawings, Specifications, Design Analyses, and Technical Documents*.

3. METHOD

The analytical method is used in this analysis. A purpose, objective, and scope were established for the layout analysis. Requirements that were specific to the repository layout were identified and criteria were developed based on those requirements. Parameters and assumptions relative to the repository layout were determined. The various functions of the repository were identified. Based on the functions, inputs, practical excavation methods, and bounding limits, a repository layout for VA design was generated.

Geologic modeling was used for compliance check of the layout with respect to inputs. Spreadsheets were used for basic mathematical calculations.

4. DESIGN INPUTS

Some of the input data used in this analysis are preliminary and unqualified. Therefore, the outputs based on these inputs are also unqualified and may not be used for construction, procurement, or fabrication without being controlled in accordance with NLP-3-15.

4.1 DESIGN PARAMETERS

4.1.1 Geology

The geologic volume available for repository siting is described in the *Determination of Available Volume for Repository Siting* analysis. Geologic factors that influence the location of the repository are the required minimum overburden thickness, repository host rock stratigraphy, fault locations, and minimum depth to groundwater table (Reference 5.4). The geologic model developed for the repository siting analysis was used to determine the interface between the site volume available and the VA design layout (Reference 5.7). This parameter is used throughout the analysis. [TBV]

4.1.2 Exploratory Studies Facility (ESF) Openings

The ESF openings will be incorporated into the repository [TBV]. The following information is used in this analysis:

a). ESF loop physical configuration
- Arrangement as shown in Figure 4-1 (Reference 5.5)
- North Ramp, Main Drift, and South Ramp are 7.62 m in diameter (Reference 5.5)
- Starter Tunnel at the beginning of the North Ramp is horseshoe-shaped at 8991 mm wide x 9857 mm high x 60960 mm long (References 5.9 and 5.10) along the main portion of the opening. The Starter Tunnel is considered part of the North Ramp in this analysis.

b). ESF loop gradients, coordinates, elevations, and azimuths as shown in Figure 4-1 (Reference 5.5).

c). The seven ESF testing alcoves are shown as designed in Figure 4-1
- Starter Tunnel Test Alcove (References 5.9 and 5.11)
- Bow Ridge Fault Test Alcove (References 5.12 and 5.13)
- Contact Radial Borehole Testing (RBT) Test Alcove #1 (References 5.13 and 5.14)
- Contact RBT Test Alcove #2 (References 5.13 and 5.14)
- Thermal Testing Facility (References 5.15, 5.16, and 5.17)
- Northern Ghost Dance Fault Alcove (References 5.18 and 5.19)
- Southern Ghost Dance Fault Alcove (References 5.20 and 5.21)

d). Two test niches are being excavated in the ESF on the west side of the Main Drift and are shown as designed in Figure 4-2 (Reference 5.22).

4.1.3 ESF Loop Opening Arrangements

a). Utilities within the opening: vent ducts, waste water, supply water, compressed air, electrical power, trolley lines, and instrumentation/communication lines (Reference 5.6)

b). Inverts are pre-cast concrete segments: 3887 mm wide by 633 mm high x 1220 mm long (Reference 5.23)

c). Conveyor consists of a 915 mm (36 inch) belt (Reference 5.24)

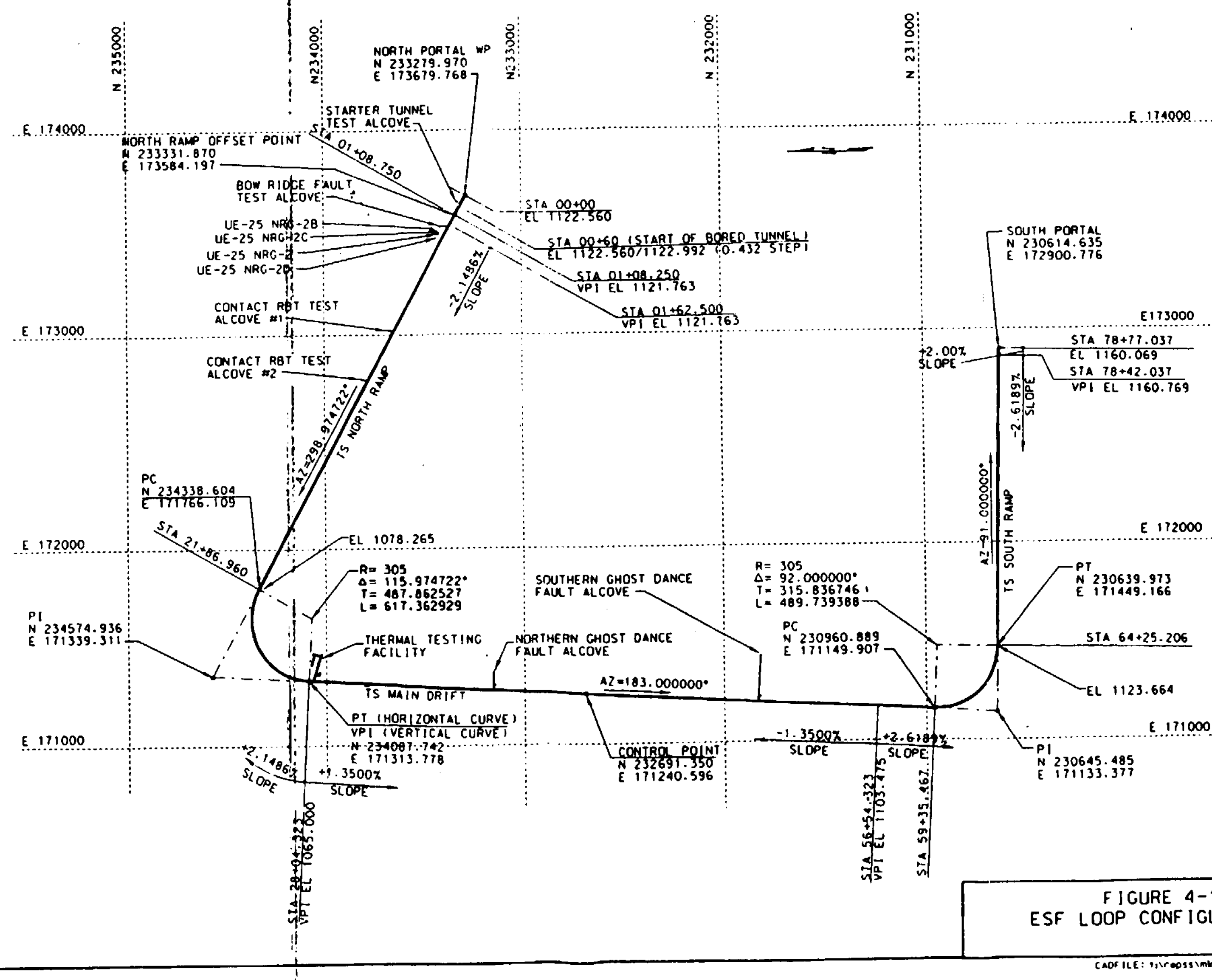

FIGURE 4-1
ESF LOOP CONFIGURATION

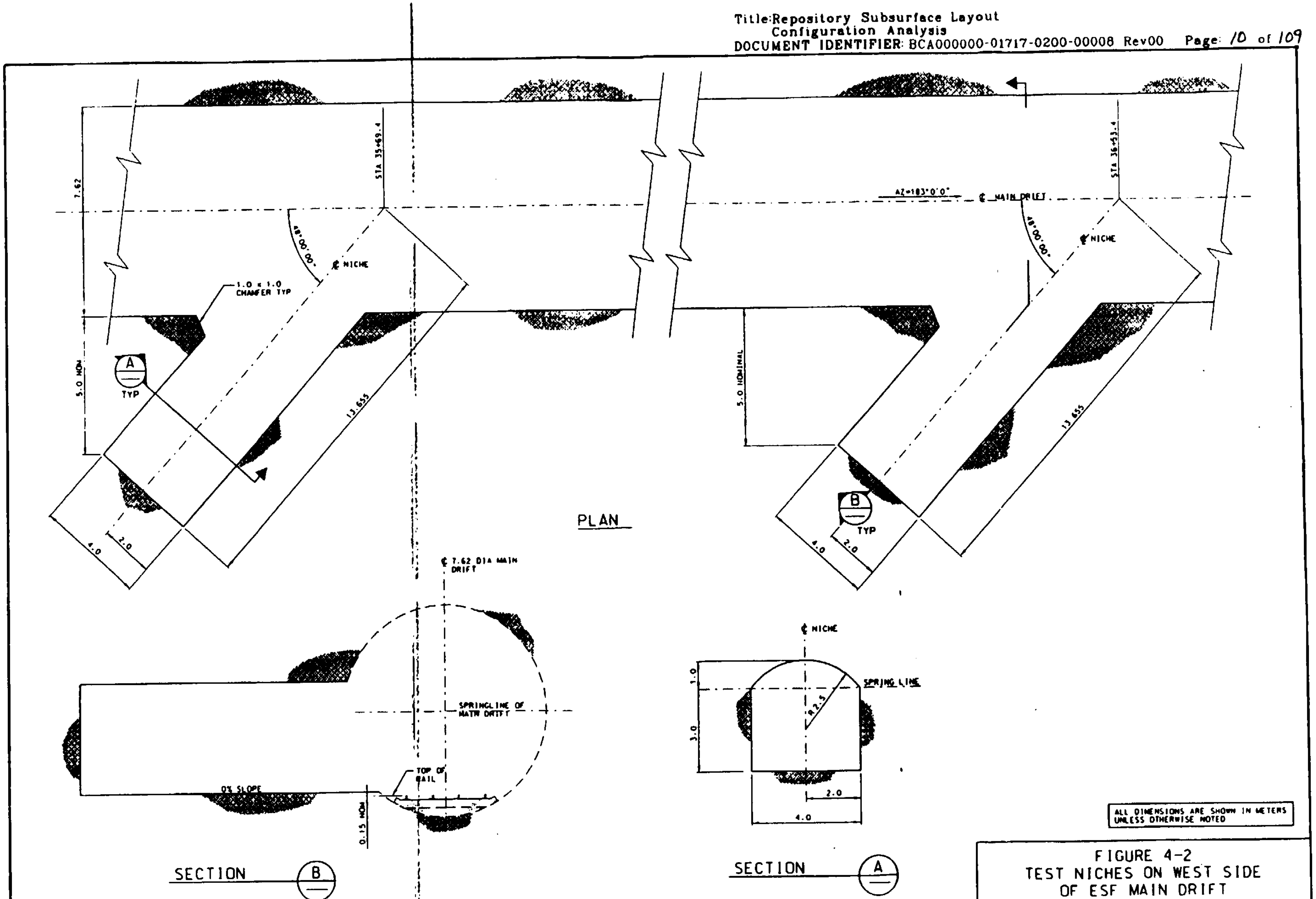

FIGURE 4-2
TEST NICHES ON WEST SIDE
OF ESF MAIN DRIFT

d). Rail gage is 915 mm; two sets of tracks; 42.44 kg/m (85 lb/yd) rail (Reference 5.23)

e). Transportation equipment envelope: 3657 mm wide by 3657 mm high (Reference 5.6)

f). Maximum ground support thickness: 203 mm (8 inches) (Reference 5.25)

4.1.4 Emplacement Drift Inverts and Rail

The emplacement drift invert used in this analysis is as shown in Figure 14 of Attachment II of the *Emplacement Drift Invert Structural Design Analysis* (Reference 5.26). Rail gage for gantry track is 2850 mm. Rail type is 44.64 kg/m for gantry. [TBV]

4.1.5 Areal Mass Loading

The areal mass loading of waste package emplacement is described in the *Repository Thermal Loading Management Analysis* (Reference 5.27). The areal mass loading is 85 MTU/acre for the commercial spent nuclear fuel (SNF) waste packages only. The high-level waste (HLW) waste packages have little heat output and can be emplaced between the commercial SNF waste packages so no space is specifically allotted for them. [TBV]

4.1.6 Emplacement Drift Spacing

The spacing of the emplacement drifts is described in the *Repository Thermal Loading Management Analysis* (Reference 5.27). The drift spacing is 28 m center to center. [TBV]

4.1.7 Personnel/Refuge Chamber

The repository multipurpose personnel/refuge chambers will utilize the same dimensions and locations as designed for the ESF refuge chambers. The designed ESF refuge chamber is 3700 mm wide x 3700 mm high x 21000 mm long (Reference 5.28). The designed spacing of the refuge chambers in the ESF is 2100 m from an adjacent refuge chamber or nearest escapeway (Reference 5.29).

4.1.8 Collection Sump/Tank Alcove

The repository collection sump/tank alcoves will utilize the same dimensions as the collection sump/tank alcoves designed for the ESF (Reference 5.30). The designed ESF collection sump/tank alcove has two sections. The first section is the tank alcove which accommodates approximately an 18,900 liter (5000 gallon) tank. The alcove is 3458.5 mm deep at midpoint x 3350 mm high x 9500 mm long. The second section is the sump which removes one precast concrete invert segment to modify the excavation. The sump is 10310 mm wide x 1580 mm high x 1200 mm long.

4.1.9 Layout Geometry

The coordinates and elevations of key points of the repository layout and the azimuths and slopes of the major drifts are described in the *Repository Subsurface Slopes* analysis (Reference 5.39) and are shown in Figure 7-1. [TBV]

4.2 CRITERIA

The design criteria that specifically apply to this analysis were developed based on requirements from the *Repository Design Requirements Document* (RDRD) (Reference 5.31) and the *Engineered Barrier Design Requirements Document* (EBDRD) (Reference 5.32). Specific RDRD and EBDRD requirements are cited as reference for each criteria. Other criteria that apply to this analysis are listed with specific references cited.

4.2.1 Statutory Limit

The repository shall be designed to incorporate the statutory limit of 70,000 metric tons of uranium or heavy metal equivalent (MTU) and accommodate the waste receipt schedule shown in Table 3-3 of the RDRD. [RDRD 3.2.1.2.A, 3.2.1.2.B [TBR], 3.2.1.3 (first paragraph only), 3.2.3.1.1.A] [EBDRD 3.2.1.2.A, 3.2.1.2.B, 3.2.1.3 (first paragraph only)]

NOTE: See Section 4.3.4 for clarification of requirements RDRD 3.2.1.2.B.

4.2.2 Openings

The openings within the repository layout shall be sized and arranged to accommodate equipment, personnel, waste package transportation and emplacement, and ventilation requirements. To the extent practical, the repository layout shall maintain the flexibility to accommodate changes in the configuration should circumstances dictate including, but not limited to, expansion of the basic mission. Emplacement drift spacing shall accommodate the indicated thermal loading management strategy. [RDRD 3.2.5.2.2.A, 3.2.8, 3.7.5.H, 3.7.5.N.1 [TBV], 3.7.5.N.2 [TBV], 3.7.5.O.1, 3.7.5.O.2 [TBV], 3.7.5.O.3, 3.7.5.P.1, 3.7.5.P.2] [EBDRD 3.2.3.3.A.8 [TBD], 3.2.3.3.A.14 [TBD], 3.2.5.2.2, 3.2.8, 3.7.1.J.1 [TBD]]

NOTE: See 4.3.12 for clarification of requirement EBDRD 3.7.1.J.1 and Section 4.3.26 for clarification of requirements RDRD 3.7.5.N.1, 3.7.5.N.2, and 3.7.5.O.2.

4.2.3 Deleterious Rock Movement

The repository layout shall be designed such that the potential for deleterious rock movement of the overlying or surrounding rock is reduced by limiting the extraction ratio of the excavation of the openings and considering the fracture system when determining the orientation of the openings. By reducing deleterious rock movement, the opportunity for creating potential pathways for water is decreased. [RDRD 3.7.5.E.2, 3.7.5.E.3, 3.7.5.G.2, 3.7.5.I] [EBDRD 3.2.3.3.A.14 [TBD], 3.2.3.3.A.15 [TBD]]

4.2.4 Excavation

Where practicable, the repository layout shall incorporate mechanical excavation methods using currently available technology. The layout shall accommodate the needs and requirements for such construction methods and activities. [RDRD 3.2.5.2.2.A, 3.7.5.E.1, 3.7.5.G.2, 3.7.5.N.2 [TBV], 3.7.5.O.1, 3.7.5.O.2 [TBV], 3.7.5.O.3, 3.7.5.P.2] [EBDRD 3.2.3.3.A.15 [TBD], 3.2.5.2.2]

NOTE: See Section 4.3.26 for clarification of requirements RDRD 3.7.5.N.2 and 3.7.5.O.2.

4.2.5 Emplacement

The repository layout design shall accommodate the needs and requirements for emplacement operations without compromising safety, the ability to isolate waste, or the ability to retrieve any or all of the emplaced waste. [RDRD 3.2.3.2.2.A.7 [TBD], 3.2.5.2.2.A, 3.7.5.E.1, 3.7.5.N.1 [TBV], 3.7.5.P.2, 3.7.5.P.3 [TBD]] [EBDRD 3.2.3.3.A.2, 3.2.3.3.A.8 [TBD], 3.2.3.3.A.14 [TBD], 3.2.5.2.2, 3.7.1.J.1 [TBD]]

NOTE: See Section 4.3.1 for clarification of requirement RDRD 3.2.3.3.A.7, Section 4.3.12 for clarification of requirement EBDRD 3.7.1.J.1, and Section 4.3.26 for clarification of requirement RDRD 3.7.5.N.1.

4.2.6 Retrieval

The repository layout shall be designed to permit the retrieval of any or all waste packages during the life of repository operations. Retrieval operations shall be performed in reverse order of emplacement operations under normal conditions. [RDRD 3.2.1.3 (first paragraph only), 3.2.1.4.A (first paragraph only), 3.2.1.4.B, 3.2.5.2.2.A, 3.7.5.D, 3.7.5.E.1] [EBDRD 3.2.1.3 (first paragraph only), 3.2.1.4.A, 3.2.1.4.B, 3.2.5.2.2]

4.2.7 Ventilation

The repository layout design shall accommodate the ventilation requirements for all modes of repository construction/development and emplacement operations. The repository shall maintain separate ventilation systems for excavation and emplacement operations. [RDRD 3.7.5.B.3, 3.7.5.B.6 [TBD], 3.7.5.N.1 [TBV], 3.7.5.N.2 [TBV], 3.7.5.N.5 [TBD], 3.7.5.O.1, 3.7.5.O.3, 3.7.5.P.2]

NOTE: See Section 4.3.10 for clarification of requirement RDRD 3.7.5.N.5 and Section 4.3.26 for clarification of requirements RDRD 3.7.5.N.1 and 3.7.5.N.2.

4.2.8 Shafts

The repository layout design shall locate shaft collars and ramp portals such that the maximum possible flood (probable maximum flood) does not intrude into the subsurface operations. The design shall be such that water will not be able to flow into the shafts or ramps at the surface. [RDRD 3.7.5.E.4, 3.7.5.I, 3.7.5.N.3, 3.7.5.N.4]

4.2.9 Drainage

The repository layout shall be designed such that any water entering the repository during preclosure will be collected and removed. The emplacement drifts shall be designed to assist in keeping water from collecting around the waste packages. The layout shall be arranged such that water in the mains shall not be able to enter the emplacement drifts due to disruptive events, such as flooding. The layout shall facilitate post-closure drainage under normal conditions. [RDRD 3.2.3.2.2.A.11.a [TBV], 3.7.5.F.2, 3.7.5.G.2, 3.7.5.I] [EBDRD 3.2.3.3.A.8.a [TBV], 3.2.3.3.A.8.b, 3.2.3.3.A.8.c [TBV], 3.2.3.3.A.15 [TBD]]

NOTE: See Section 4.3.13 for clarification of requirement RDRD 3.2.3.2.2.A.11.a.

4.2.10 Utilities

The repository layout shall be designed to accommodate the space required for utilities. [RDRD 3.7.5.N.5 [TBD], 3.7.5.O.2 [TBV]]

NOTE: See Section 4.3.26 for clarification of requirement RDRD 3.7.5.O.2.

4.2.11 Waste Isolation

The repository layout shall be designed such that the ability of the site to isolate waste is not compromised. [RDRD 3.2.3.2.2.A.2, 3.2.3.2.2.A.11.a [TBV], 3.2.3.2.3.A, 3.7.5.E.2, 3.7.5.E.3, 3.7.5.G.2, 3.7.5.I] [EBDRD 3.2.3.3.A.2, 3.2.3.3.A.8.c [TBV], 3.2.3.3.A.14 [TBD], 3.2.3.3.A.15 [TBD]]

NOTE: See Section 4.3.13 for clarification of requirement RDRD 3.2.3.2.2.A.11.a.

4.2.12 Geologic Setting

The repository layout shall be designed such that the geologic setting of the site is not compromised. [RDRD 3.2.3.2.2.A.2, 3.2.3.2.3.A, 3.7.5.G.2] [EBDRD 3.2.3.3.A.2, 3.2.3.3.A.15 [TBD]]

4.2.13 Performance Confirmation

The repository layout shall accommodate a performance confirmation program, developed by the project, in the development of the design. The layout shall provide alcoves, drifts, and other facilities as necessary to fulfill the needs of the performance confirmation program. [RDRD 3.2.1.3 (first paragraph only), 3.2.1.4.B, 3.7.5.P.3 [TBD], 3.7.6.A.5] [EBDRD 3.2.1.3 (first paragraph only), 3.2.1.4.B]

4.2.14 Interfaces

The repository layout design shall interface with other segments of the repository design that have an impact on the configuration of the layout. [RDRD 3.2.3.2.1 (first paragraph only), 3.3.1.E] [EBDRD 3.2.3.2 (first paragraph only), 3.3.1.F]

4.2.15 Alcoves

The repository layout design shall accommodate alcoves for operational uses. The size, location, and configuration of alcoves will be function dependent. [RDRD 3.2.4.2.6, 3.2.5.2.8.F, 3.5.3.1, 3.7.5.F.7, 3.7.7.D] [EBDRD 3.5.3.1]

4.2.16 California Tunnel Safety Orders

California Tunnel Safety Orders [RDRD 3.2.1.1.C] are no longer applicable to the Yucca Mountain Project (Reference 5.33). Requirements in 29 CFR 1910, 29 CFR 1926, and 30 CFR 57 shall be used as applicable.

4.3 ASSUMPTIONS

The assumptions and justification for the assumptions used in this analysis are listed below. Most of the assumptions are cited from the *Controlled Design Assumptions Document* (CDA) (Reference 5.34) and are so referenced. The rationale for the CDA assumptions can be found in the CDA. All CDA assumptions will require substantiation as discussed in Section 2.5 of the CDA. Other assumptions used in this analysis are listed with their own rationale and justifications.

4.3.1 Waste Emplacement Method

a). "Waste packages will be emplaced in-drift in a horizontal mode." (Key 011, Reference 5.34)

b). "The Repository Segment shall accommodate horizontal, in-drift emplacement of waste packages." (RDRD 3.2.3.2.2.A.7, Reference 5.34)

c). "Waste packages will be placed center in-drift, on pedestals, using gantry emplacement." (Key 066, Reference 5.34)

This assumption is used in Sections 7.1.7 and 7.2.2. [TBV]

4.3.2 Transportation Method

a). "Rail transport will be used for subsurface transport of waste packages." (Key 010, Reference 5.34)

b). "Rail will be used for transporting underground supplies and personnel to the extent practical." (Key 030, Reference 5.34)

c). "Repository material handling equipment:

- Supplies: rail transport.
- Excavated Rock: conveyor belt, or conveyor belt variation preferred when practical." (DCSS 010, Reference 5.34)

This assumption is used throughout the analysis where transportation methods are discussed. [TBV]

4.3.3 Permanent Invert

A permanent concrete invert is planned in all openings. In the ramps and mains, the invert is a 300 mm cap placed on top of the initial precast concrete inverts, installed during construction of the openings, to aid in stabilizing the precast inverts for emplacement equipment transportation. A 300 mm permanent concrete invert is installed in the secondary openings and alcoves at the time of construction, with exception of the turnouts. The permanent invert will not be installed until after construction because there is a height differential between construction and emplacement operations. This assumption is used throughout the analysis where inverts are discussed. [TBV]

4.3.4 Waste Receipt Schedule

a). "The Waste Package emplacement scenario at the Mined Geologic Disposal System (MGDS) is as indicated in Table 3-9. This emplacement scenario is consistent with MGDS-RD Table 3-3, which shows a steady state emplacement rate of commercial spent nuclear fuel (SNF) of 3,000 MTU/year. The commercial SNF disposed of in this scenario totals 63,000 MTU. The high-level waste (HLW) totals approximately 7,000 MTU equivalent . . . .

Table 3-9. Waste Package Emplacement Schedule [per year]

Cask Name Capacity Fuel Type	LG-WP 44 BWR	LG-WP 21 PWR	SM-WP 24 BWR	SM-WP 12 PWR	4 HLW*	Total Waste Packages
2010	13	21	0	1	0	35
2011	30	40	0	2	0	72
2012	65	74	0	5	0	144
2013	89	134	0	18	0	241
2014	118	211	0	38	0	367
2015	142	186	0	37	199	564
2016	110	203	0	53	202	568
2017	129	190	0	56	200	575
2018	131	189	0	51	200	571
2019	126	179	0	70	199	574
2020	130	186	0	53	200	569
2021	116	193	0	65	200	574
2022	154	167	0	53	200	574
2023	114	197	0	66	202	579
2024	173	155	0	46	200	574
2025	136	177	0	69	200	582
2026	189	185	0	0	199	573
2027	158	205	0	0	200	563
2028	150	204	0	0	200	554
2029	138	208	0	0	200	546
2030	146	214	0	0	47	407
2031	115	234	0	0	109	458
2032	129	224	0	0	102	455
2033	58	161	0	0	0	219
Total	2859	4137	0	683	3259	10938

* HLW quantities are tentative. DOE SNF design implementation is to be determined . . . ." (Key 003, Reference 5.34)

b). "Design of Waste Handling Operations are presently based on tables in Key Assumptions . . . 003 . . . ." (RDRD 3.2.1.2.B, Reference 5.34)

This assumption is used in Section 7.1.3.2 and Attachment I. [TBV]

4.3.5 Average MTU/WP

"... This is based on youngest fuel first (YFF) acceptance scenario, accepting no fuel younger than 10 years old [removed from the reactor for a minimum of 10 years].

Table 3-10 provides the average MTU/WP on a yearly basis. . . ." (Key 004, Reference 5.34)

Table 3-10. Average MTU/WP [per year]

Cask Name Capacity Fuel Type	LG-WP 44 BWR	LG-WP 21 PWR	SM-WP 24 BWR	SM-WP 12 PWR
2010	7.82	9.28	0	1.84
2011	7.85	9.03	0	4.60
2012	7.74	8.94	0	6.08
2013	7.80	9.00	0	5.60
2014	7.79	8.96	0	5.31
2015	7.74	8.98	0	5.56
2016	7.89	9.05	0	5.53
2017	7.86	8.91	0	5.50
2018	7.91	8.94	0	5.36
2019	7.94	9.04	0	5.52
2020	8.01	9.02	0	5.42
2021	7.81	9.05	0	5.29
2022	7.85	9.06	0	5.35
2023	7.88	8.95	0	5.40
2024	7.79	9.03	0	5.39
2025	7.72	8.94	0	5.36
2026	7.57	8.42	0	0
2027	7.61	8.68	0	0
2028	7.91	8.92	0	0
2029	7.95	9.09	0	0
2030	7.75	8.82	0	0
2031	7.77	8.97	0	0
2032	7.72	9.00	0	0
2033	7.69	9.00	0	0

This assumption is used in Section 7.1.3.1 and Attachment I. [TBV]

4.3.6 Excavation Method

a). "The primary method of tunnel excavation will be mechanical." (Key 027, Reference 5.34)

b). "Where it is impractical to use mechanical methods, drill-and-blast may be used to a limited degree primarily in non-emplacement areas of the repository." (Key 028, Reference 5.34)

c). "Drift excavation methods:

- Primary: tunnel boring machine (TBM)
- Secondary: other mechanical methods, and drill-and-blast where mechanical methods are impractical." (DCSS 005, Reference 5.34)

d). "Shaft excavation method: Mechanical where practical." (DCSS 014, Reference 5.34)

For VA design, the following excavation methods will be used for all repository openings other than the existing ESF openings: TBM for ramps, mains, emplacement drifts, and performance confirmation drifts; roadheader for secondary openings and alcoves; down reamer for shafts; drill-and-blast for sump at bottom of shaft; and raise borer for ventilation raises. Actual excavation for each opening will be determined by other analyses. This assumption is used in Sections 7.1.5 and 7.2. [TBV]

4.3.7 Fault Standoff Distances

"To the extent practical, repository openings will be located to avoid Type 1 faults. For unavoidable Type 1 faults that intersect emplacement drifts, allow a 15 m stand off [sic] from the edge of the fault zone to the nearest waste package.

"Avoidance is assumed to be adequate by using a 60 m offset from the main trace of a fault at the repository level. Exception: 120-m stand off [sic] should be used on the west side of the Ghost Dance Fault because the Exploratory Studies Facility (ESF) Topopah Spring Main drift will be excavated before the Ghost Dance Fault characteristics are fully investigated." (Key 023, Reference 5.34)

For those faults that cross into the emplacement area that are not considered Type 1 faults, a 5 m standoff distance is allotted on both sides of the fault. If waste packages are located to avoid Type 1 faults within the emplacement area because of possible seismic movement or because the faults represent potential pathways, then engineering judgement assumes the same circumstances are justified for other fault types. Since the other fault types are not as critical, only a 5 m standoff distance is used. This assumption is used in Sections 7.1.1.1 and 7.1.3.2 and in Attachments I and II. [TBV]

4.3.8 Radiological Shielding

a). "... Additional shielding for personnel protection will be provided...in subsurface facilities." (Key 031, Reference 5.34)

Shadow shields will be incorporated into the design of the emplacement drifts. The door to the emplacement drift will also provide some measure of radiological protection (see Section 4.3.18). This assumption is used in Section 7.1.6. [TBV]

4.3.9 Location of Shafts

a). "... Flood considerations for locating surface facilities are included in Assumption TDS 008. . . ." (Key 047, Reference 5.34) TDS 008 shown in part b for clarification.

b). "The Design Basis Flood shall be based on the Probable Maximum Flood Boundaries identified in Tables 2.6.2-1 and 2.6.2-2 of the *Technical Basis Report for Surface Characteristics, Preclosure Hydrology and Erosion*, Document No.: YMP/TBR-001, Rev. 0." (TDS 008, Reference 5.34)

This assumption is meant for locating the shaft collars. The shafts shall be located such that they are out of the flood boundaries and to minimize the amount of excavation and/or fill required for pad and road construction. The location of the shafts must also be coordinated with ventilation requirements. The shaft locations will be as follows: Development Shaft at N 230890, E 170360; and Emplacement Shaft at N 235580, E 170790. This assumption is used in Section 7.2.4 and Attachment IV. [TBV]

4.3.10 Opening Sizes

a). "The following diameters are assumed for underground openings [other than the existing ESF openings].

Underground Opening	Diameter (m)
Ramps	7.62
Shafts	6.1 (finished inside diameter)
Access/Service Main	7.62
Central Exhaust Main	7.62
Emplacement Drift	TBD" (Key 070, Reference 5.34)

b). "If shafts are used, the shaft size shall be determined by the size of the conveyances needed to move materials, personnel, and equipment underground; the volume of ventilation flow needed; and the space required for utility lines." (RDRD 3.7.5.N.5, Reference 5.34)

The minimum excavated diameter of the shafts is 6.7 m (Reference 5.1). The emplacement drifts are 5.5 m in diameter to accommodate waste emplacement operations utilizing a gantry system (Reference 5.1). The performance confirmation drifts are 5.5 m in diameter to maintain the same size as the emplacement drifts for simplicity (Reference 5.38). The ventilation raises are 2.0 m in diameter which was assumed to be an appropriate size to accommodate ventilation requirements. Secondary openings will be horseshoe-shaped at various sizes as discussed in Section 7.2. Opening sizes may vary to accommodate ground support design but will not significantly impact the configuration of the layout. This assumption is used throughout the analysis. [TBV]

4.3.11 Layout Features

"The current subsurface repository layout contains the following features:

- Long parallel emplacement drifts
- Only upper emplacement block (no lower emplacement block)
- In-drift waste package emplacement
- Central exhaust main below emplacement drifts
- Two shafts and two ramps
- One upper block perimeter/access drift. . . ." (Key 072, Reference 5.34)

The layout also features performance confirmation drifts located above the repository (see Section 4.33.29). This assumption is used throughout the analysis. [TBV]

4.3.12 Waste Package Dimensions

a). "The external dimensions of the waste package for a) commercial SNF that is repackaged and for b) uncanistered commercial SNF shall not exceed:
Outer Diameter: 1850 mm
Outer Length: 5850 mm" (EBDRD 3.7.1.J.1, Reference 5.34)

b). ". . . The external dimensions of the waste package containing DOE SNF that is co-disposed with defense HLW shall not exceed:
Outer Diameter: 1970 mm
Outer Length: 5350 mm" (DCWP 005, Reference 5.34)

Since the actual size of the waste package is unknown at this point, this analysis uses a 2.0 m diameter for contingency purposes as a maximum bounding limit. The 44-BWR, 21-PWR, 24-BWR, and 12-PWR waste packages in Section 4.3.4 are assumed to be those described in part a, above. The HLW waste packages in Section 4.3.4 are assumed to be the same as those in part b, above. This assumption is used in Sections 7.1.3.1 and 7.2.2. [TBV]

4.3.13 Drainage

". . . The repository layout shall be designed so that a combination of characteristics will limit the amount of liquid water allowed to come into contact with the waste packages . . . ." (RDRD 3.2.3.2.2.A.11.a, Reference 5.34)

The emplacement drifts will be sloped down from the midpoint of the drift out to each main. The mains will then slope down from south to north to a common area. This assumption is used in Section 7.1.4. [TBV]

4.3.14 Drift Orientation

a). "Preferred drift orientation:

- Orientation of emplacement drifts will be at least 30 degrees from dominant joint orientations. Using the latest information on joint orientations, the emplacement drift orientation will generally fall between N70W and S75W.
- Orientation of maintainable access drifts, mains, ramps, etc. will be as needed to complement emplacement drift orientation, generally forming intersections of 70-90 degrees where practicable. . . ." (DCSS 001, Reference 5.34)

b). "Rock joint orientation:

	Strike	Dip
Major Joint Set	N10-12W	75-90 NE/SW
Minor Joint Sets	N25E	10 SE
	N-N45E	80-90 SE/NW

Rock joint frequency: TSw2: 2.51/m for 70-80 degree joints, 11.28/m for 80-90 degree joints (mean value)" (TDSS 017, Reference 5.34)

The bearing of emplacement drifts will be N72W from the East Main. The rationale for this assumption can be found in Section 8.6.1, of the *Initial Summary Report for Repository/Waste Package Advanced Conceptual Design* (Reference 5.35). This assumption is used in Sections 7.1.1.2 and 7.2.2. [TBV]

4.3.15 Extraction Ratio

"Maximum excavation extraction ratio for emplacement drifts: 30 percent." (DCSS 006, Reference 5.34)

This assumption is used in Sections 7.1.3.1 and 7.2.2. [TBV]

4.3.16 Layout Gradients

"Maximum grade in ramps: ≤3 percent to accommodate rail transport.

Maximum grade in mains: minimize, but ≤2 percent in mains used for emplacement drift access.

Maximum grade in emplacement drifts: minimize within 0.25 to 0.75 percent range for drainage." (DCSS 009, Reference 5.34)

The emplacement drifts use a 0.5 percent gradient in this analysis. Access drifts, turnouts, and performance confirmation drifts use the same slope as the emplacement drifts. This assumption is used in Sections 7.1, 7.1.2.1, 7.1.11, and 7.2.2 and in Attachment IV. [TBV]

4.3.17 Thermal and Radiological Standoff Distances

"The greater of two standoff distances in the emplacement drifts for thermal and radiological concerns will be utilized for calculating the usable emplacement area as follows:

- A 35 m thermal standoff distance is used to limit the surface rock temperature of the adjacent main drift. This thermal standoff is defined as the perpendicular distance from the center of the closest emplaced waste package to the nearest edge of the main drift.
- a 13 m radiological standoff distance is used for limiting the radiological dose in the adjacent main drift. This radiological standoff is defined as the distance from the center of the closest emplaced waste package to the door of the emplacement drift. This distance is equal to the sum of the distances from the door to the edge of the waste package (10 m) plus half the length of the waste package (approximately 3 m)." (DCSS 033, Reference 5.34)

The Exhaust Main is not included in the thermal standoff assumption. The East and West Mains will provide access to the emplacement drifts and have a great deal of activity going on during the Emplacement and Caretaker Modes so they will have to be kept cooler. The Exhaust Main, however, will only have activity if the need arises (i.e., maintenance and monitoring); although, it will receive the combined airflow from the mains and must be kept at an accessible temperature. This assumption is used in Section 7.1.3.1 and Attachments I and II. [TBV]

4.3.18 Emplacement Drift Doors

"Doors are required at entrances to emplacement drifts." (DCSS 036, Reference 5.34)

The doors control access, regulate ventilation, and enhance radiological protection. This assumption is used in Section 4.3.8, 7.1.6, 7.1.7, and 7.1.8. [TBV]

4.3.19 Waste Handling Facilities and Access

a). "The proposed repository waste handling and administrative surface facilities will be located adjacent to the north portal. . . ." (Key 047, Reference 5.34)

b). "The North Ramp will be used for waste transport." (Key 068, Reference 5.34)

c). "Underground construction will not use the north portal for access once emplacement operations begin." (DCSS 032, Reference 5.34)

This assumption is used in Sections 7.1.7, 7.1.8, and 7.2.1. [TBV]

4.3.20 Ground Control

a). "A single ground support type will be used in emplacement drifts..

Candidate ground support types under consideration:

- Precast concrete
- Cast In Place concrete
- Steel sets" (DCSS 034, Reference 5.34)

For VA design the ground support design assumes reasonable thicknesses and types that may require that the opening sizes vary to accommodate the ground support but will not significantly impact the configuration of the layout. Ground support thicknesses for the openings are as follows: 300 mm in ramps, mains, and shafts; 200 mm in emplacement drifts and secondary openings; and 150 mm in ventilation raises. Permanent ground support types for the openings are as follows: cast-in-place concrete lining for ramps, mains, shafts, and secondary openings; pre-cast concrete segment lining for emplacement drifts; and cast-in-place concrete lining for ventilation raises. Final ground support design will be determined by other analyses. This assumption is used throughout the analysis where ground support is discussed. [TBV]

4.3.21 Site Characterization Boreholes

Ten Site Characterization boreholes are located within, or closely adjacent to, the proposed layout of the repository area. 10 CFR 60.15(c)(3) requires that boreholes, to the extent practical, are planned to be located in "large unexcavated pillars" in the underground facility. It is assumed that the intent of this requirement is to reduce the potential of creating preferential pathways. Although it has not been determined on how to deal with this situation, one solution that this analysis presents is to locate the boreholes in an unexcavated pillar. There is no indication on how large the pillar should be, so this analysis assumes a minimum standoff of at least 14 m from the center of the borehole to the center of a main or emplacement drift. This is based on the emplacement drift spacing and is assumed adequate for a standoff from the mains also.

The coordinates of the boreholes at the repository level are as follows:

	Northing	Easting
G-1	234845.81	170992.96
H-1	234774.62	171415.88
H-5	233667.04	170353.53
UZ-1	235084.82	170755.29
UZ-6	231567.92	170179.44
UZ-14	235095.18	170731.14
SD-6 (proposed)	232346	170277
SD-7	231329.87	171064.72
SD-9	234084.74	171241.52
SD-12	232243.63	171173.30

The SD-6 coordinates are for the proposed surface location. These coordinates are used for the location of SD-6 at the repository level assuming a vertical borehole with no deviation. This assumption is used in Section 7.1.2.2. [TBV]

4.3.22 Standoff Distance from Ventilation Raises

The ventilation raises are located at the midpoint of the emplacement drifts along the centerline of the Exhaust Main. A 2 m horizontal standoff distance is used from the centerline of the ventilation raise to the end of the closest emplaced waste package to help alleviate interference with ventilation and/or radiological monitoring around the ventilation raises. This assumption is used in Section 7.1.3.2 and Attachment I. [TBV]

4.3.23 Curves Within Drifts

A minimum 305 m radius curve along the centerline of the drift is used in the ramps and mains for conveyor muck handling. The curved section of the turnouts have a 20 m radius from the centerline of the turnouts to the tangent with the centerline of the mains for the turning radii of the construction/development and emplacement operations equipment using rail transportation. Final radii of the turnout walls will be dependent on equipment clearances and track requirements. Other openings in the repository that are not used for conveyor muck handling will have at least a 100 m radius curve for rail transportation. This assumption is used in Sections 7.2.1 and 7.2.5. [TBV]

4.3.24 Ventilation

"The ventilation systems for the development and emplacement areas will be provided by two separate and independent systems that are physically separated in the underground." (DCSS 035, Reference 5.34)

The ventilation design used for the VA repository layout is based on preliminary information provided in Attachment III. This assumption is used in Sections 7.1.8 and 7.2.1. [TBV]

4.3.25 Ventilation Raise Length

This analysis uses a nominal length of 10 m for the ventilation raises that connect the emplacement drifts to the Exhaust Main below. The distance is measured from the invert of the emplacement drift excavation to the crown of the Exhaust Main excavation. This assumption is used in Sections 7.2.3 and 7.5.3. [TBV]

4.3.26 RDRD Requirements Not Applicable

"The corresponding Repository Design Requirements Document (RDRD) requirement is considered to be not applicable." (RDRD 3.7.5.N.1, RDRD 3.7.5.N.2, and RDRD 3.7.5.O.2; Reference 5.34) [TBV]

4.3.27 Operational Alcoves

The electrical equipment alcoves will be of two different sizes. The larger one will house a trolley rectifier, substation, and switchgear box. It will be 4.5 m wide x 4.5 m high x 14 m long. The smaller one will house a substation and switchgear box. It will be 4.5 m wide x 4.5 m high x 8.5 m long. The dimensions of the electrical alcoves are based on preliminary information (Reference 5.44). The dimensions were given in English units, converted to SI units, and then rounded to the nearest half meter for simplicity. There will be 5 large and 6 small electrical alcoves located throughout the repository. The number and locations (shown in Figure 7-32 in Section 7.2.6) of the electrical alcoves are based on preliminary estimates. This assumption is used in Section 7.2.6. [TBV]

Decontamination chambers will also be provided in the repository: one for equipment and one for personnel. The equipment chamber will be approximately 7.5 m wide x 7 m high x 21 m long. This accommodates the largest piece of equipment for emplacement operations, the waste package gantry atop the gantry carrier. The chamber has an airlock door, approximately 2 m of clearance around the top and sides of the equipment, and approximately 6 m of clearance in the back for a small sump to collect and remove contaminated liquids from the chamber. The personnel chamber will be the same cross-sectional area as a refuge chamber but shorter; this equates to 3.7 m wide x 3.7 m high x 4.0 m long. The dimensions of the decontamination chambers are based on preliminary estimates. This assumption is used in Section 7.2.6. [TBV]

4.3.28 Emplacement Equipment Envelope

The emplacement equipment envelope in the ramps and mains is 4.1 m high x 5.25 m wide. This is based on the current emplacement strategy and the corresponding equipment requirements being determined by the waste emplacement equipment personnel. The envelope accommodates the height required for a trolley locomotive and the width is determined by the available distance at the top of the rail plus 300 mm clearance along the edges. This assumption is used in Sections 7.1.7.2 and 7.2.2. [TBV]

4.3.29 Performance Confirmation Drifts

The *Subsurface Repository Performance Confirmation Facilities* analysis recommended 5-10 performance confirmation (PC) drifts at a range of 10 to 20 m above the block (Reference 5.38). For VA design, five PC drifts seem reasonable as there are fewer drifts with a larger drift spacing than the layout shown in the PC analysis. The drifts are excavated by a 5.5 m diameter TBM to keep them the same size as the emplacement drifts for simplicity. They are located 15 m above the block and follow the orientation and slope of the emplacement drifts. The PC drifts will be located directly above the following emplacement drifts: PC Drift #1 above #3, PC Drift #2 above #33, PC Drift #3 above #56, PC Drift #4 above #80, and PC Drift #5 above #103. The majority of the PC Main parallels and is at the same slope as the East Main. This assumption is used in Sections 7.1.11 and 7.2.7, and in Attachment V. [TBV]

4.3.30 Empty Drifts During Emplacement

A certain number of drifts will be left empty during emplacement operations. Some of the empty drifts will be cross-block drifts for ventilation, monitoring, emergency egress, and/or performance confirmation. These will be located to split the block into similar size areas. Other empty drifts will be emplacement stand-by drifts for possible relocation of emplaced waste packages. They will be located within the first half of emplacement drifts to be available early on. In VA design there are three cross-block drifts located at emplacement drifts #30, #60, and #105. The stand-by drifts are located at emplacement drifts #15 and #45. This assumption used in Section 7.1.3.2 and Attachment I. [TBV]

In the potential expansion layout, there are five cross-block drifts in the upper block and three cross-block drifts in the lower block. The cross-block drifts are located at emplacement drifts #35, #70, #105, #140, and #174 in the upper block and at emplacement drifts #35, #70, and #105 in the lower block. There are two emplacement stand-by drifts in both the upper and lower blocks at emplacement drifts #20 and #50 in the upper block and at emplacement drifts #20 and #50 in the lower block. This assumption is used in Attachment II. [TBV]

4.3.31 Emplacement Operations Rail

Rail gage in the ramps, mains, secondary openings, and access drifts is 1.44 m during emplacement operations. Rail type is 57.05 kg/m. This assumption is used in Section 7.2. [TBV]

4.3.32 Areal Mass Loading Range

"Surface, subsurface and waste package designs will be based on a reference mass loading range of 80-100 metric tons of uranium (MTU) per acre." (Key 019, Reference 5.34)

This assumption is used in Section 7.1.3.1. [TBV]

4.4 CODES AND STANDARDS

4.4.1 **10 CFR 960.** "General Guidelines for the Recommendation of Sites for Nuclear Waste Repositories," *Title 10, Code of Federal Regulations, Part 960*, January 31, 1996.

a). "*Disqualifying Condition.* The site shall be *disqualified* if site conditions do not allow all portions of the underground facility to be situated at least 200 meters below the directly overlying ground surface." [10 CFR 960.4-2-5(d)]

b). "'Underground facility' means the underground structure and the rock required for support, including mined openings and backfill materials, but excluding shafts, boreholes, and their seals." [10 CFR 960.2] The term "ramps" is not specifically called out in this criteria, but it is considered that the term "shafts", in the regulatory sense, encompasses ramps.

This code is used in Sections 7.1.1 and 7.3.

5. REFERENCES

5.1 *Mined Geological Disposal System Advanced Conceptual Design Report*, B00000000-01717-5705-00027 REV 00, Volume II of IV, Civilian Radioactive Waste Management System (CRWMS) Management and Operating Contractor (M&O).

5.2 *Q-list*, YMP/90-55Q Rev. 4, U.S. Department of Energy Yucca Mountain Site Characterization Project Office.

5.3 *Quality Assurance Requirements and Description*, DOE/RW-0333P Rev. 7, U.S. Department of Energy Office of Civilian Radioactive Waste Management.

5.4 *Determination of Available Volume for Repository Siting*, BCA000000-01717-0200-00007 REV 00, CRWMS M&O.

5.5 *ESF Layout Calculation*, BABEAD000-01717-0200-00003 REV 04, CRWMS M&O.

5.6 *Exploratory Studies Facility Package 2C TS North Ramp Equipment & Utilities GA Plan & Section*, BABFA0000-01717-2100-40173 REV 01, CRWMS M&O.

5.7 *Archive Tape for LYNX Design Model YMP.MO3Q*, BCA000000-01717-0200-00007 REV 00, Batch Number MOY-970414-09, CRWMS M&O.

5.8 Code of Federal Regulations, Title 10, *Energy*, Part 60, "Disposal of High-Level Radioactive Waste in Geologic Repositories", January 31, 1996.

5.9 *Exploratory Studies Facility Package 1A Starter Tunnel Gen Arrangement Plan (Sht. 2)*, BABEA0000-01717-2100-10121 REV 03, CRWMS M&O.

5.10 *Exploratory Studies Facility Package 1A Starter Tunnel Gen Arrangement Sections*, BABEA0000-01717-2100-10125 REV 03, CRWMS M&O.

5.11 *Exploratory Studies Facility Package 1A Starter Tunnel Test Alcove Elevation & Section*, BABED0000-01717-2100-10128 REV 03, CRWMS M&O.

5.12 *Exploratory Studies Facility Package 2C TS North Ramp Bow Ridge Fault Test Alcove GA Plan*, BABEAF000-01717-2100-40147 REV 02, CRWMS M&O.

5.13 *Exploratory Studies Facility Package 2C TS North Ramp Bow Ridge Fault Test Alcove GA Sections*, BABEAF000-01717-2100-40148 REV 02, CRWMS M&O.

5.14 *Exploratory Studies Facility Package 2C TS North Ramp Contact RBT Test Alcove GA Plan & Sections*, BABEAF000-01717-2100-40149 REV 01, CRWMS M&O.

5.15 *Exploratory Studies Facility TS Main Drift Thermal Testing Facility Alcove Plan Sht. 1 of 3*, BABEAF000-01717-2100-40230 REV 01, CRWMS M&O.

5.16 *Exploratory Studies Facility TS Main Drift Thermal Testing Facility Alcove Sections Sht 2 of 3*, BABEAF000-01717-2100-40231 REV 01, CRWMS M&O.

5.17 *Exploratory Studies Facility TS Main Drift Thermal Testing Facility TS Main Drift Thermal Testing Facility Alcove Sections Sht 3 of 3*, BABEAF000-01717-2100-40250 REV 00, CRWMS M&O.

5.18 *Exploratory Studies Facility TS Main Drift Northern Ghost Dance Fault Alcove Plan*, BABEAF000-01717-2100-40232 REV 01, CRWMS M&O.

5.19 *Exploratory Studies Facility TS Main Drift Northern Ghost Dance Fault Alcove Sections & View*, BABEAF000-01717-2100-40233 REV 01, CRWMS M&O.

5.20 *Exploratory Studies Facility TS Main Drift Southern Ghost Dance Fault Alcove Enlarged Plan*, BABEAF000-01717-2100-40247 REV 00, CRWMS M&O.

5.21 *Exploratory Studies Facility TS Main Drift Southern Ghost Dance Fault Alcove Sections & View*, BABEAF000-01717-2100-40248 REV 00, CRWMS M&O.

5.22 *Exploratory Studies Facility TS Main Drift Drift Scale Flow Test Niches Plan & Sections*, BABEAF000-01717-2100-40255 REV 00, CRWMS M&O.

5.23 *Exploratory Studies Facility Package 2B Rail Placement Invert - Segment A Plan, Sections & Details*, BABFCC000-01717-2100-40179 REV 02, CRWMS M&O.

5.24 *Exploratory Studies Facility Package 2C Subsurface Cnvr W-T03 General Arrangement Sections*, BABFCB000-01717-2100-45047 REV 00, CRWMS M&O.

5.25 *Exploratory Studies Facility 7.62 m Tunnel Ground Support Master Sections*, BABEE0000-01717-2100-40151 REV 00, CRWMS M&O.

5.26 *Emplacement Drift Invert Structural Design Analysis*, BBDC00000-01717-0200-00001 REV 00, CRWMS M&O.

5.27 *Repository Thermal Loading Management Analysis*, B00000000-01717-0200-00135 REV 00, CRWMS M&O.

5.28 *Exploratory Studies Facility Package 2C TS North Ramp Refuge Chamber Alcove GA Plan & Sections*, BABEAE000-01717-2100-40144 REV 01, CRWMS M&O.

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5.30 *Exploratory Studies Facility Package 2C TS North Ramp Collection Sump/Tank Alcove GA Plan & Sections*, BABEAE000-01717-2100-40142 REV 01, CRWMS M&O.

5.31 *Repository Design Requirements Document*, YMP/CM-0023 Rev. 0, ICN 1, U.S. Department of Energy Yucca Mountain Site Characterization Project Office.

5.32 *Engineered Barrier Design Requirements Document*, YMP/CM-0024 Rev. 0 ICN 1, U.S. Department of Energy Yucca Mountain Site Characterization Project Office.

5.33 O'Toole, Tara, *Approval of Yucca Mountain Site Characterization Project (YMP) Exemption From California Tunnel Safety Orders*, Memorandum I-369048, U.S. Department of Energy Office of Occupational Safety and Health Policy, March 22, 1995.

5.34 *Controlled Design Assumptions Document*, B00000000-01717-4600-00032 REV 04, ICN 1, CRWMS M&O.

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5.36 McConnel, K.I., M.E. Blackford, and A-K Ibrahim. *Staff Technical Position on Investigations to Identify Fault Displacement Hazards and Seismic Hazards at a Geologic Repository*, U.S. Nuclear Regulatory Commission, NUREG-1451, 1992.

5.37 Albin, A.L., W.L. Singleton, T.C. Moyer, A.C. Lee, R.C. Lung, G.L.W. Eatman, and D.L. Barr, *Geology of the Main Drift - Station 28+00 to 55+00, Exploratory Studies Facility, Yucca Mountain Project, Yucca Mountain, Nevada*, Bureau of Reclamation and U.S. Geological Survey, 1997.

5.38 *Subsurface Repository Performance Confirmation Facilities*, BCA000000-01717-0200-00011 REV 00, CRWMS M&O.

5.39 *Repository Subsurface Slopes*, BCAA00000-01717-0200-00007 REV 00, CRWMS M&O.

5.40 *Figure 7-40a Expansion of Upper Block w/ Respect to Geologic Boundaries*, BCA000000-01717-0200-00008 REV 00, Batch Number MOY-970708-04, CRWMS M&O.

5.41 *Figure 7-41a Expansion of Lower Block w/ Respect to Geologic Boundaries*, BCA000000-01717-0200-00008 REV 00, Batch Number MOY-970708-04, CRWMS M&O.

5.42 *Figure 7-1a Subsurface Repository Layout for VA Design*, BCA000000-01717-0200-00008 REV 00, Batch Number MOY-970708-04, CRWMS M&O.

5.43 *Figure 7-11a Performance Confirmation Facilities for VA Design*, BCA000000-01717-0200-00008 REV 00, Batch Number MOY-970708-04, CRWMS M&O.

5.44 Fernandez, L.J., *Subsurface Repository Electrical Alcoves*, Interoffice Correspondence LV.ESSD.LJF.06/97-046, June 2, 1997, Batch Number MOY-970630-01, CRWMS M&O.

5.45 *Figure 7-40b Expansion of Upper Block w/ Respect to Geologic Boundaries*, BCA000000-01717-0200-00008 REV 00, Batch Number MOY-970708-04, CRWMS M&O.

6. USE OF COMPUTER SOFTWARE

6.1 LYNX

The representative cross sections of the layout with respect to the site volume available used the Lynx Geoscience Modeling software (LYNX), version 3.06. This software is a three-dimensional, volume-based geology and engineering computer modeling system developed by Lynx Geosystems, Inc. of Vancouver, B.C., Canada. LYNX was qualified in 1995 and carries the Computer Software Configuration Item (CSCI) number B00000000-01717-1200-30018. The software is installed on a Silicon Graphics Indigo2 workstation running the IRIX 5.3 operating system. The workstation is equipped with High Impact graphics, 250 MHZ R4400 processor, and 256 Megabytes of RAM. It is located in the Subsurface Repository Design Department and has the CRWMS-M&O tag #700709. The software was originally obtained to specifically perform this type of work and was qualified with that intent in mind. The software is appropriate for the application used in this design analysis, was not used outside the range of qualification, and was obtained from Software Configuration Management (SCM) according to procedures.

6.2 Lotus 1-2-3

Spreadsheets used in this analysis were done using Lotus 1-2-3, Release 4. The software is installed on a Gateway 2000 P5-75.

7. DESIGN ANALYSIS

7.1 LAYOUT FACTORS

The repository layout for VA design is shown in Figure 7-1. It will feature long, parallel emplacement drifts and long, continuous mains that will accommodate TBM excavation. The Exhaust Main will be located below the level of the emplacement drifts with ventilation raises connecting the Exhaust Main and the emplacement drifts. There will be a shaft and ramp for access to each end of the emplacement area for a total of four access locations. The upper block will be sufficient for the statutory limit of 70,000 MTU for VA design. The coordinates, elevations, azimuths, and slopes were identified in the *Repository Subsurface Slopes* analysis (Reference 5.39).

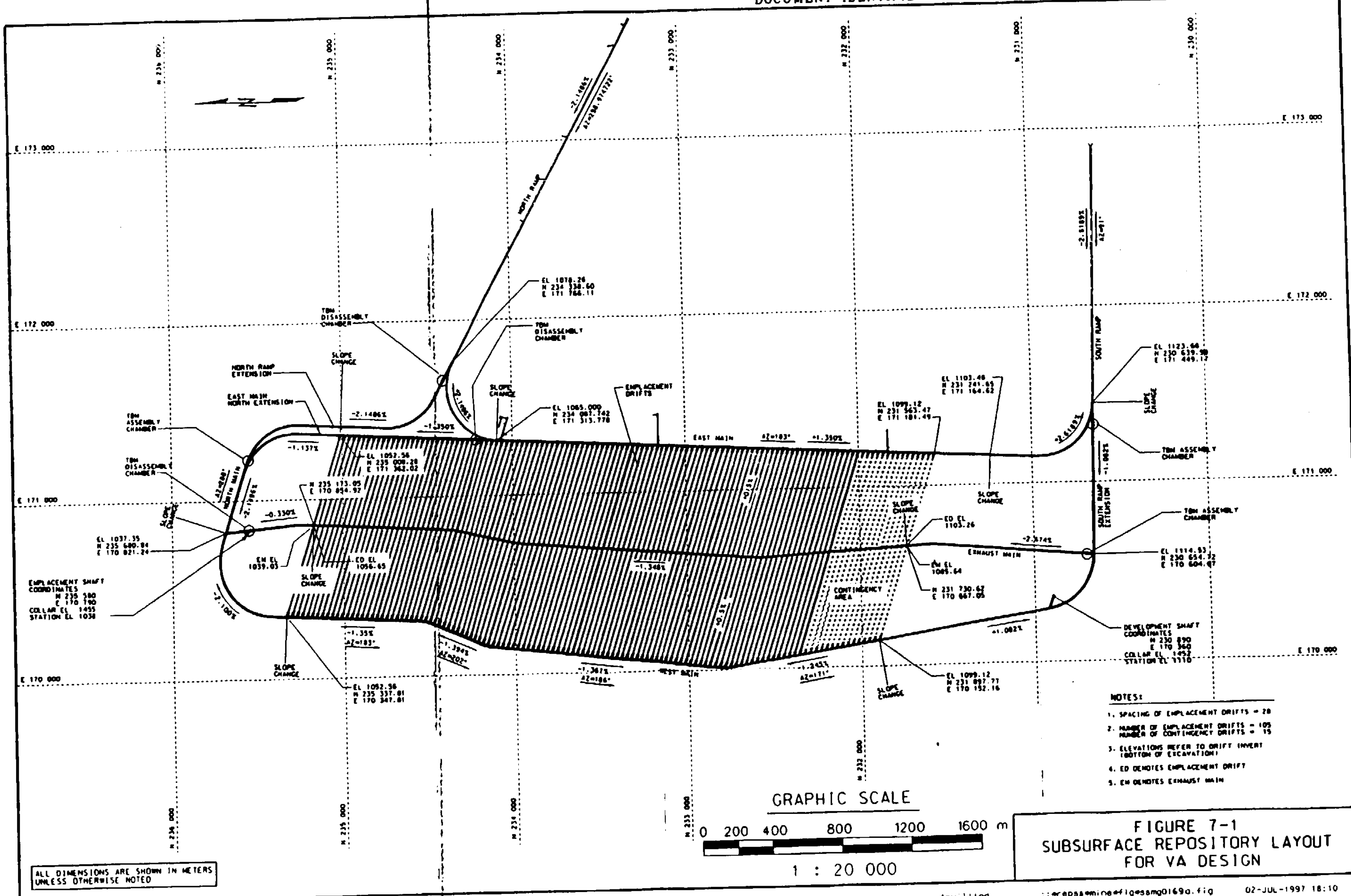

FIGURE 7-1
SUBSURFACE REPOSITORY LAYOUT
FOR VA DESIGN

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The configuration and extent of the subsurface facilities is determined by a number of key factors. These factors are listed below and discussed in Sections 7.1.1 through 7.1.12.

1. Site geology and available volume for emplacement
2. Existing site characterization facilities
3. Emplacement drift area
4. Drainage control
5. Constructibility requirements and construction method
6. Radiological safety requirements
7. Emplacement and retrieval method
8. Ventilation system for construction, development, and emplacement operations
9. Ground control in the subsurface openings
10. Utilities for construction, development, and emplacement operations
11. Performance confirmation facilities
12. Operational alcoves and support areas

7.1.1 Geology

The geology plays a very important role in the siting and configuration of the repository. It sets almost all of the physical three dimensional spatial boundaries of the underground facility. The repository siting volume was recently identified in the design analysis *Determination of Available Volume for Repository Siting*. This volume is the three-dimensional space within which the repository could be located. The identified limits for repository siting include the following: top of Repository Host Horizon (RHH), bottom of RHH, 200 m minimum overburden limit, groundwater table limit, and faults (Reference 5.4).

The geologic boundaries as they relate to the VA repository layout in plan view, based on a defined reference plane used in the *Determination of Available Volume for Repository Siting* analysis (Reference 5.4), are shown in Figure 7-2. The reference plane is a flat plane drawn through the East and West Mains and extended out from the repository area in all directions to define the lateral limits of the repository. East-West cross sections of the layout with respect to geologic boundaries are shown along the North Main, Emplacement Drift #1, Emplacement Drift #40, Emplacement Drift #80, Emplacement Drift #120, and the South Ramp/South Ramp Extension in Figures 7-3, 7-4, 7-5, 7-6, 7-7, and 7-8, respectively. The purpose of the cross sections is to show that all parts of the underground facility fit within the specified site volume.

7.1.1.1 Faults

Type I faults, as defined by the Nuclear Regulatory Commission (Reference 5.36), are those faults or fault zones that may have the potential for displacement that impacts repository design and/or performance and, as a result, should undergo detailed investigation. Although no faults have been officially classified as Type 1, the Ghost Dance Fault, the Solitario Canyon Fault, the Abandoned Wash Fault, and major splays from these faults are identified in the *Determination of Available Volume for Repository Siting* analysis as Type 1 faults (Reference 5.4) and are the major faults that impact the VA design layout. The Ghost Dance and the Abandoned Wash

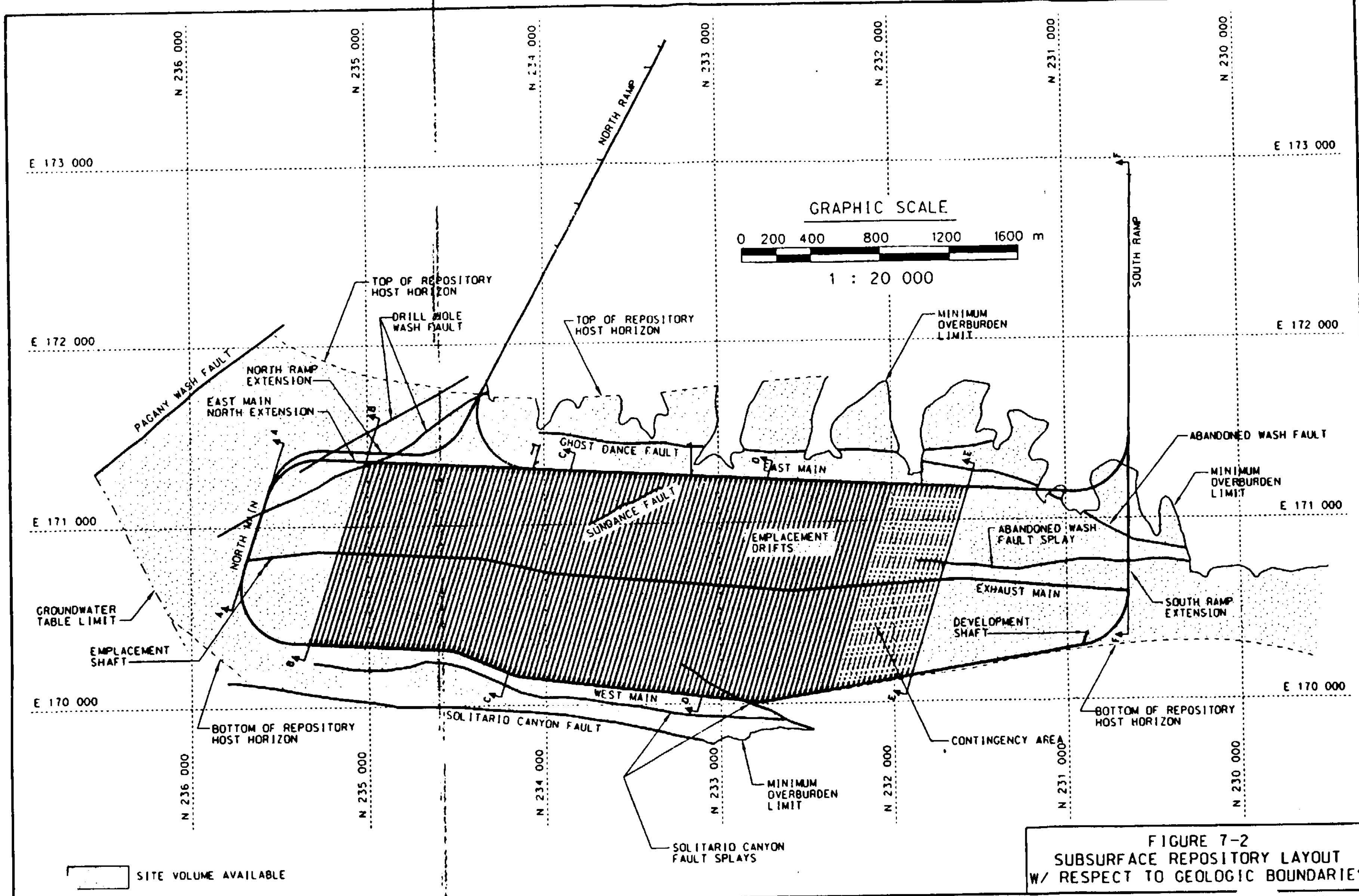

FIGURE 7-2
SUBSURFACE REPOSITORY LAYOUT
W/ RESPECT TO GEOLOGIC BOUNDARIES

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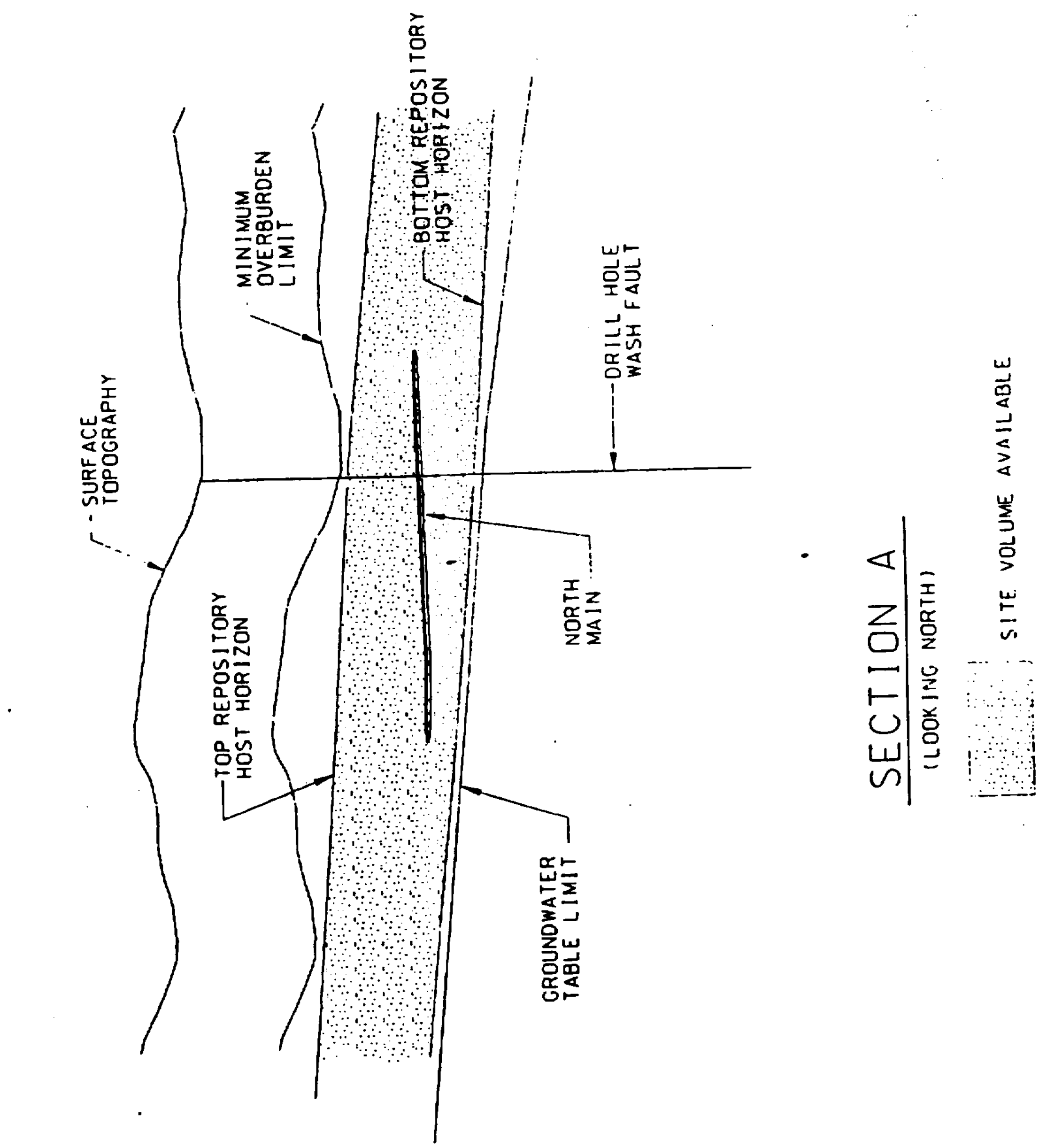

FIGURE 7-3
SECTION OF LAYOUT ALONG
NORTH MAIN

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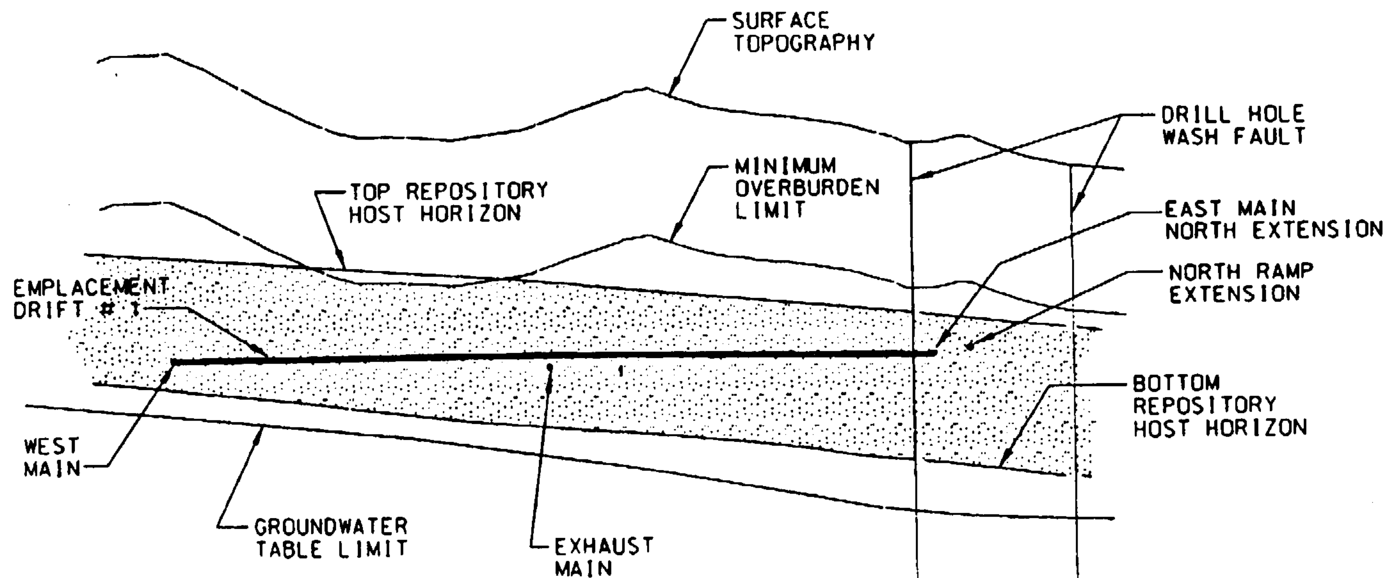

SECTION B

(LOOKING NORTH)


SITE VOLUME AVAILABLE

FIGURE 7-4
SECTION OF LAYOUT ALONG
EMPLACEMENT DRIFT # 1

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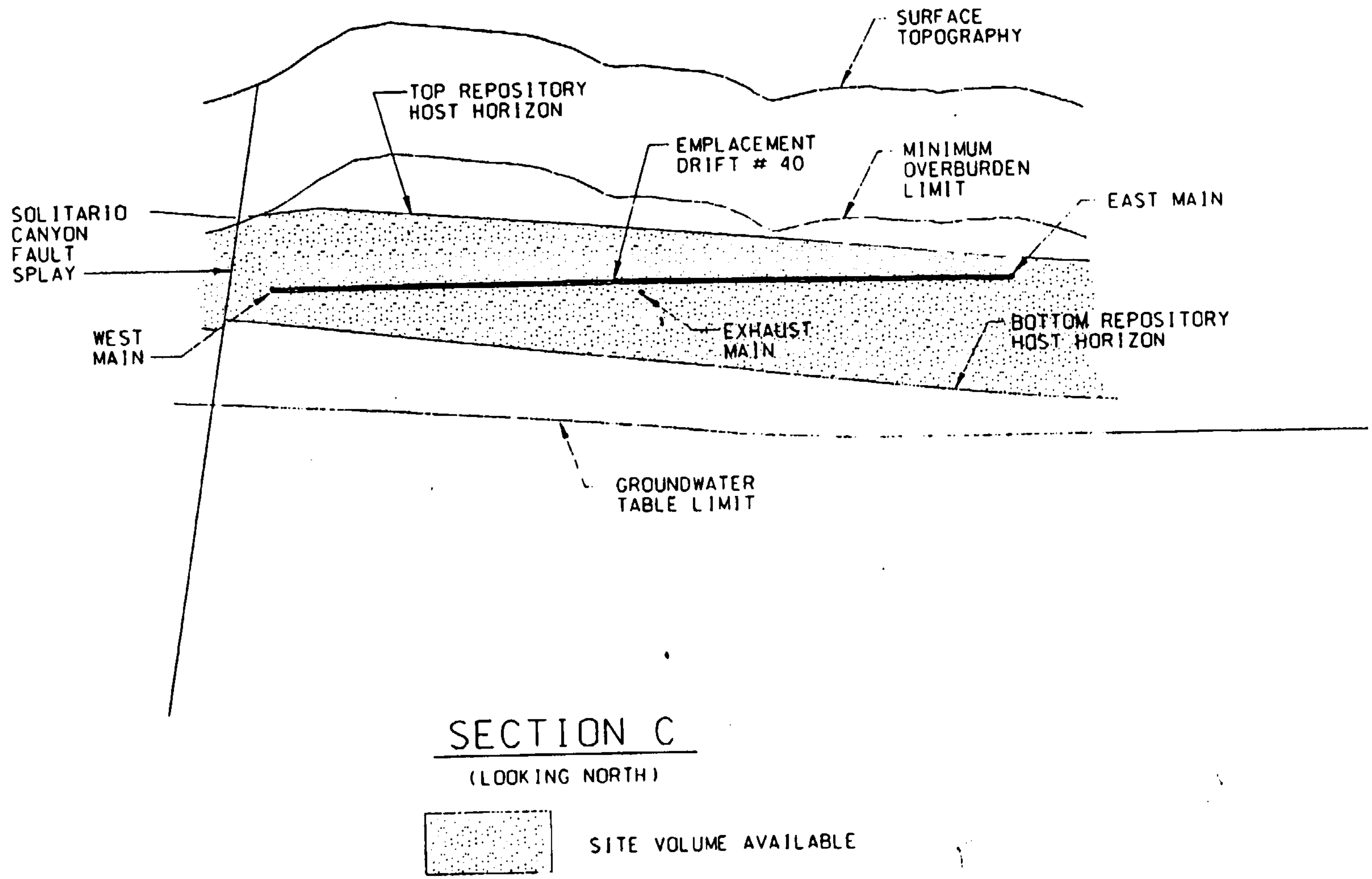

FIGURE 7-5
SECTION OF LAYOUT ALONG
EMPLACEMENT DRIFT # 40

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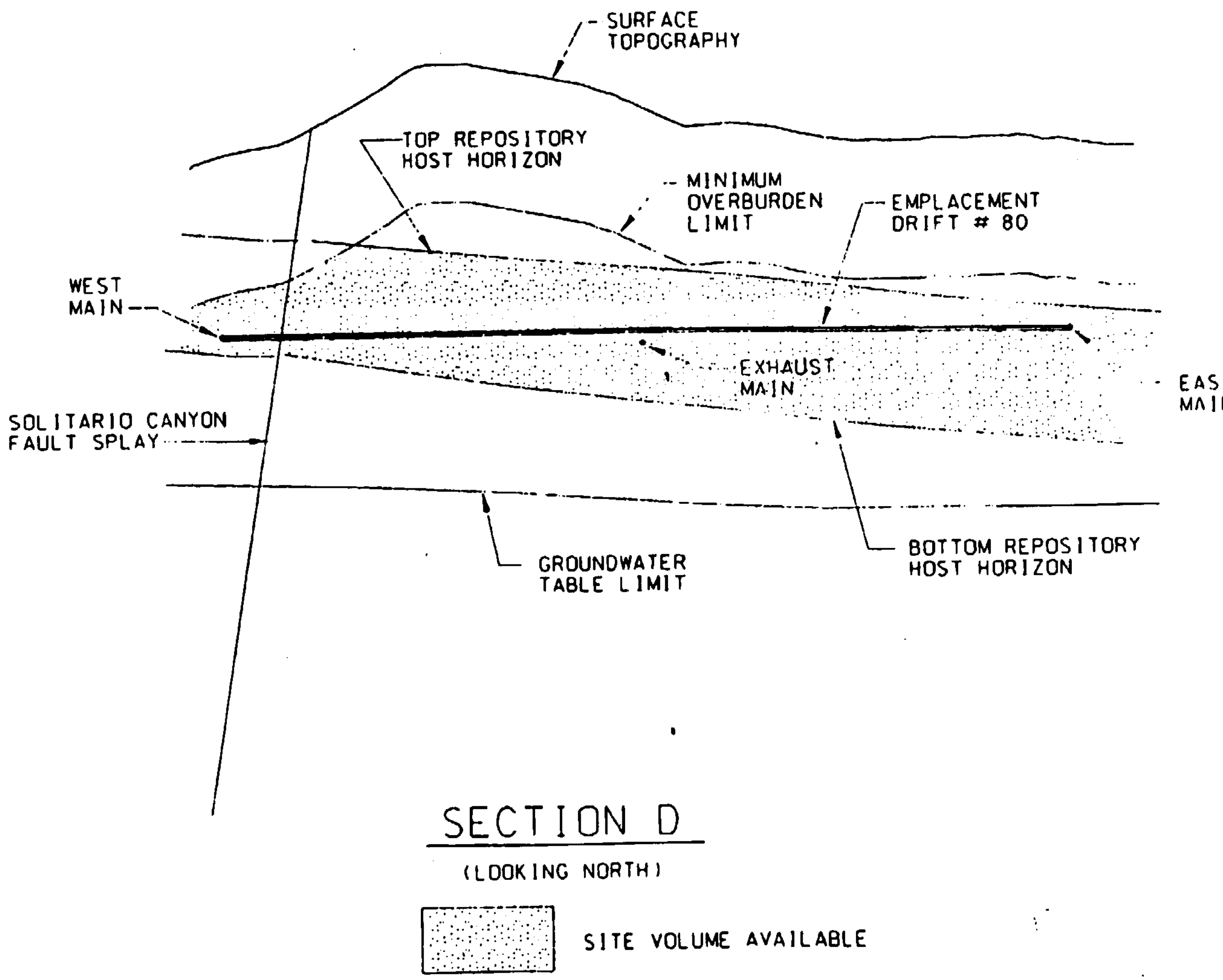

FIGURE 7-6
SECTION OF LAYOUT ALONG EMPLACEMENT DRIFT # 80

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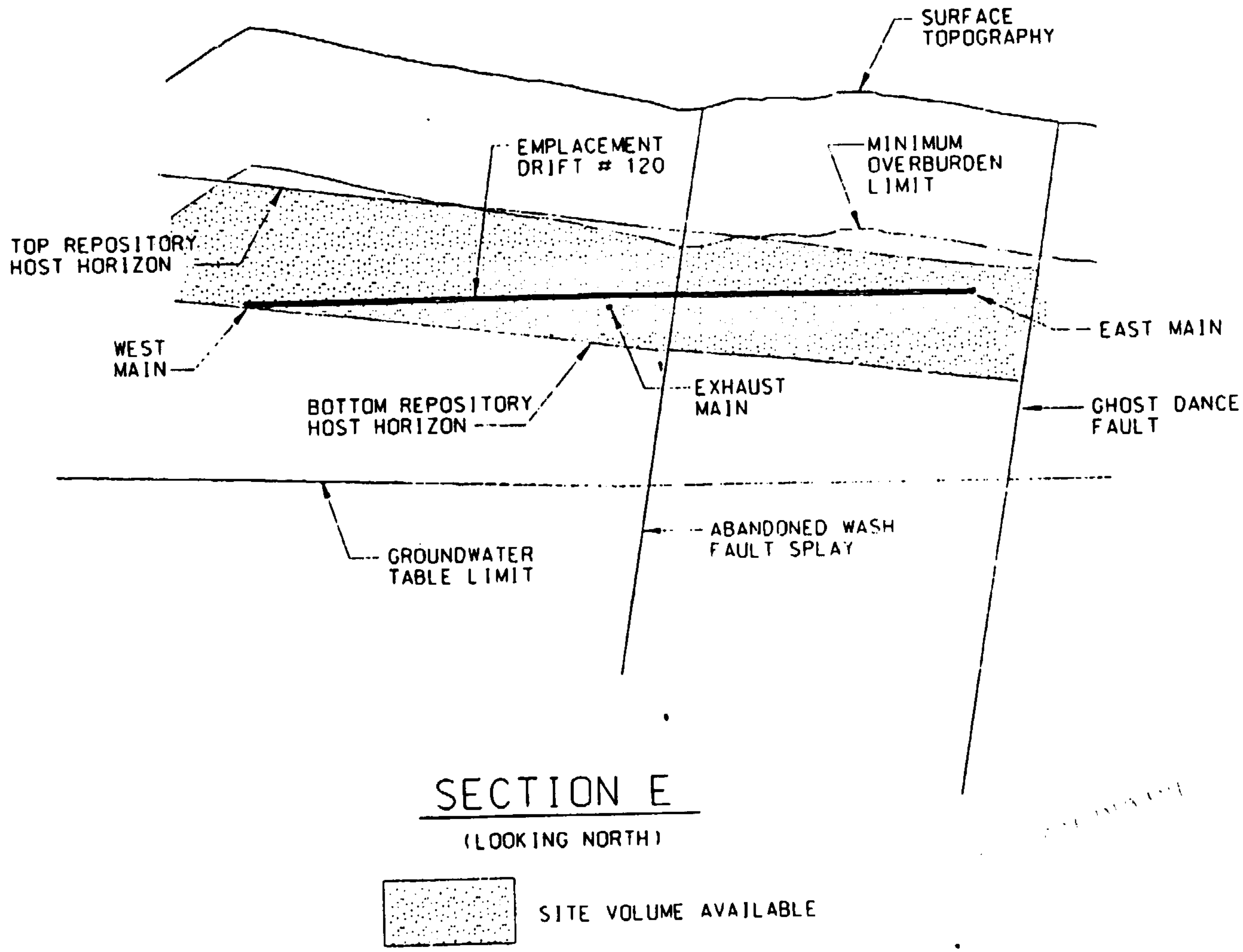

SECTION E
(LOOKING NORTH)

FIGURE 7-7
SECTION OF LAYOUT ALONG EMPLACEMENT DRIFT # 120

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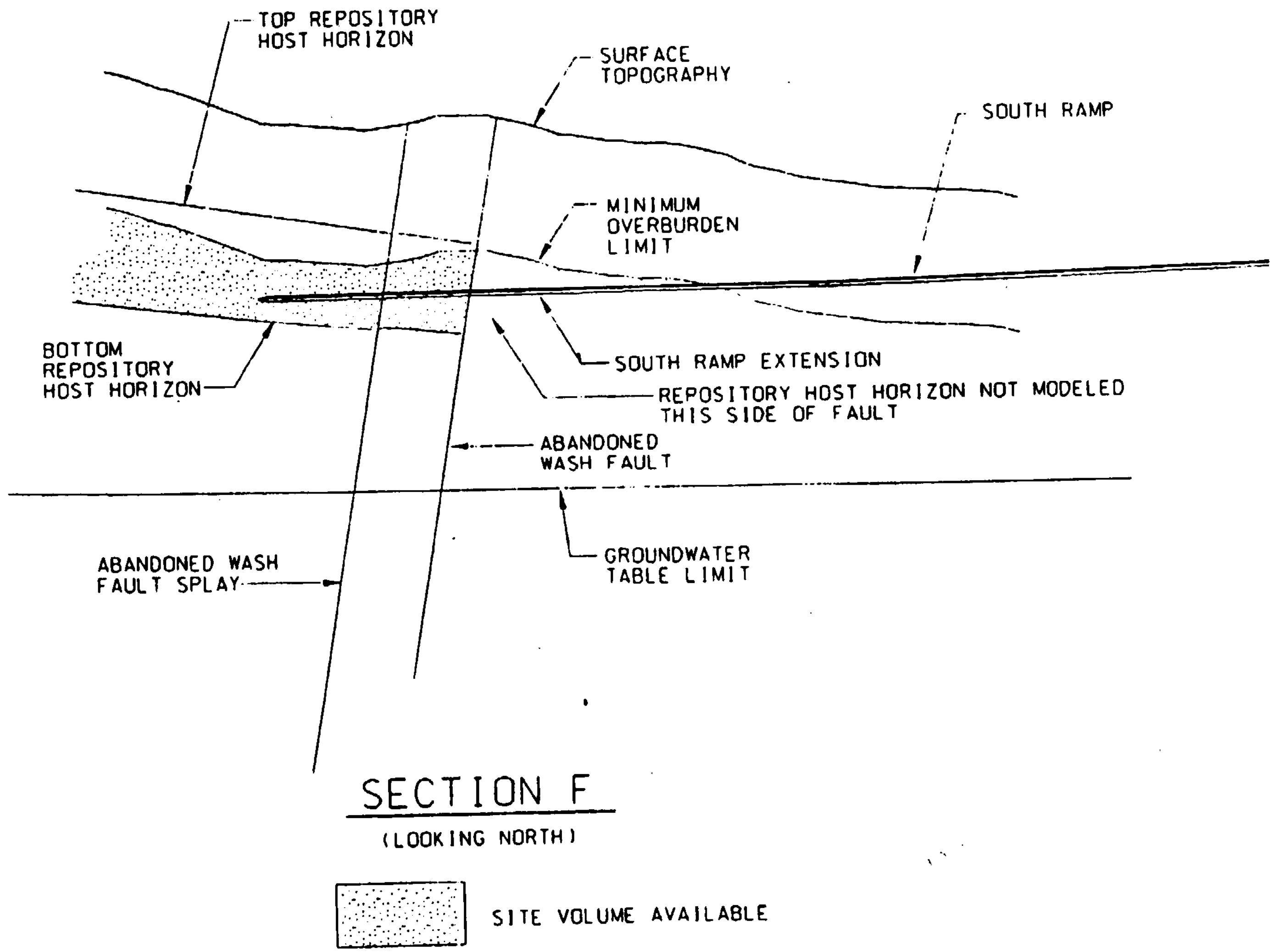

FIGURE 7-8
SECTION OF LAYOUT ALONG S RAMP /S RAMP EXTENSION

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Faults merge toward the south end of the repository. A 60 m minimum standoff distance will be used along the main drifts where it is possible or practical to avoid a Type 1 fault or splay. The East Main has a 120 m standoff distance from the Ghost Dance Fault because the ESF Main Drift, that will be incorporated into the repository as the East Main, was completed during the Site Characterization Mode before the Ghost Dance Fault was fully investigated. The West Main will use a 60 m standoff distance from the main splay of the Solitario Canyon Fault. There are two other assumed Type 1 fault splays, one on the Abandoned Wash Fault and the other on the Solitario Canyon Fault, that penetrate the emplacement drift area. Avoidance of these fault splays is not practical without extensive loss of emplacement area, so allowances will be made within the affected emplacement drifts for locating waste packages. There is one other fault that penetrates the emplacement drift area that is not considered a Type 1 fault (Reference 5.4) but may still pose similar circumstances as a Type 1 although not as great: the Sundance Fault. Avoidance of this fault is also not practical so allowances will be made within the affected emplacement drifts for locating waste packages.

7.1.1.2 Joints

Joints are naturally occurring fractures that are generally planar and commonly occur in parallel sets. Because joint planes introduce a strong directional weakness that increases the potential for the formation of blocky ground, the orientation of joint sets is potentially important to drift stability. At Yucca Mountain the majority of joints are steeply dipping with fracture densities as great as 12 per meter. A drift aligned perpendicular to a zone of jointed rock encounters the least amount of potentially unstable rock blocks, whereas, the potential for the formation of blocky ground is greater for drifts oriented close to the strike of the joints.

To increase the inherent (i.e., in the absence of ground support) stability of emplacement drifts it has been determined that drift alignment should be at least 30 degrees to that of the dominant joint sets, which results in an alignment of N72W, based on borehole information (Reference 5.35). Favorable drift alignments are expected to lie within a 35 degree window, between N70W and S75W (Section 4.3.14). Additional mapping data from the completed ESF Main Drift shows that joint orientations within the upper stratum of the Repository Host Horizon may not be consistent with the borehole information (Reference 5.37). However, without an exploratory drift across the repository horizon to examine the middle and lower strata, the mapping data are insufficient to warrant a change to the current orientation for VA design. Variations may be found upon further investigation of the repository horizon and, if needed, changes to the drift alignment can be accommodated within the current approach to layout design.

7.1.2 Site Characterization

7.1.2.1 Exploratory Studies Facility (ESF)

The existing ESF loop is located such that it can become an integral part of the repository. The ramps in the ESF loop provide access to the specified site volume (Reference 5.4) at gradients that accommodate rail transportation. The entire Main Drift lies within the site volume, is situated near the upper bound of the site volume, and runs parallel to the Ghost Dance Fault.

Since the site volume dips up toward the west, the Main Drift logically provides the eastern boundary for the repository, thereby becoming the East Main in repository design.

Two minor deviations of line and grade have occurred in the ESF as a result of problems with TBM guidance in extremely blocky ground. The first occurred in the North Ramp at approximately Station 1+08 and the second in the South Ramp at approximately Station 71+35. The first deviation resulted in a minor correction to horizontal alignment. The second deviation was somewhat more severe in that it resulted in a relatively major (>1 m) deviation in vertical alignment. Some remediation may be necessary at the time of repository construction in order to ensure that minimum equipment clearance is maintained.

7.1.2.2 Site Characterization Boreholes

There are ten Site Characterization boreholes (including the proposed SD-6) that are within, or closely adjacent to, the underground facility in the current layout. The boreholes of concern are G-1, H-1, H-5, UZ-1, UZ-6, UZ-14, SD-6 (proposed), SD-7, SD-9, and SD-12. The locations of the boreholes at the repository level (based on available borehole deviation surveys) are shown in Figure 7-1. Section 4.3.21 says to leave a pillar around the boreholes to reduce the potential for creating preferential pathways. However, the Site Characterization Mode is not complete and additional boreholes may yet be drilled through the block. For this preliminary phase of design, it was not considered necessary to adjust the layout to account for all of the boreholes. Only boreholes H-1 and UZ-6 will be accommodated at this time because they may influence the mains. It is important to establish the location of the mains because they define the emplacement area. The other boreholes will be considered in the layout during design for License Application.

Boreholes H-1 and UZ-6 may influence the North Ramp Extension and the West Main, respectively. At least a 14 m standoff distance from the center of the borehole to the center of the main drift will be utilized to locate the main drift within the layout.

When the VA repository layout is revised for submittal with the License Application, the in-block boreholes will need to be addressed. This analysis presents two ways to account for the boreholes, although other options may be possible. The first method is to start by locating emplacement drifts on either side of all in-block boreholes at the minimum standoff distance. This will define space between the boreholes where other emplacement drifts will then be laid out. The drifts in between the boreholes will then be laid out at even intervals at a spacing as close as possible to 28 meters, the currently planned emplacement drift spacing, so that the usable area is consumed. If, however, it is considered important to maintain the drift spacing at exactly 28 meters, a second method can be utilized. This method involves forcing the drift spacing to 28 meters, except for those drifts which have a borehole between them. The spacing of such drifts will be increased to meet the standoff requirements. Either method should produce an acceptable layout, and it is anticipated that a loss of emplacement area of no more than 5% will result unless the minimum size of the required pillar becomes large.

7.1.2.3 ESF Test Niches

In addition to the boreholes discussed above, there are two small test alcoves ("niches") designed for the west side of the ESF Main drift, at Stations 35+69 and 36+53 (see Figure 4-2 in Section 4.1.2) . Like the boreholes, these niches will require consideration when the VA repository layout is updated for License Application. The most preferable option would be to locate emplacement drift turnouts such that the niches are completely removed by the excavation of the turnouts. This option has been preserved by stipulating that the two niches be located a distance apart which is divisible by 28 meters, the currently planned emplacement drift spacing. In this way, if the drift spacing can be worked out, the niches would be "erased" during the development of the repository. The niche and borehole locations will have to be considered together when the final emplacement drift arrangement is developed. If the niches cannot be placed within planned turnouts, they may be backfilled with concrete; or, if suitable and stable, they may be used as alcoves for storage, electrical components, or some other use.

7.1.3 Definition of Emplacement Area

The total amount of waste to be emplaced and the areal mass loading (MTU/acre) determine the size of the required emplacement area. The emplacement drift spacing and waste package spacing, in turn, define the total length of emplacement drifting needed.

7.1.3.1 Emplacement Drift Spacing

This analysis uses a drift spacing of 28 m determined in another analysis (Section 4.1.6). However, due to the fact that the emplacement drifts are largely independent of each other, the VA layout concept is valid for a wide range of drift spacings. There are, however, upper and lower limits on drift spacing caused by the areal mass loading and maximum extraction ratio criteria, respectively.

The minimum drift spacing is based on a maximum emplacement drift extraction ratio of 30 percent and an emplacement drift diameter of 5.5 m. The extraction ratio per drift is the ratio of excavated area to total area in plan view and can be reduced to the following relationship:

$$(\text{emplacement drift diameter} / \text{emplacement drift spacing}) \times 100 \leq 30\%.$$

Using an emplacement drift diameter of 5.5 m yields a minimum drift spacing of 18.33 m. This method simply uses the emplacement drift spacing without accounting for the turnouts at the end of the emplacement drifts. If it is decided at some point to place the emplacement drifts this closely, an analysis will be needed to determine if this minimum drift spacing interferes with the stability of the main and turnout area.

The maximum emplacement drift spacing is dependent on the waste receipt schedule (number and type of waste packages), physical dimensions of the waste packages, and areal mass loading of the waste packages. All waste packages, including the HLW packages, must be accounted for in the maximum drift spacing because this method is a "line-load" that places each package essentially end-to-end with a uniform 1.0 m between them. The total numbers of each type of waste package are included in the waste receipt schedule for the 70,000 MTU inventory in Section 4.3.4: 2,859 44-BWR; 4,137 21-PWR; 0 24-BWR; 683 12-PWR; and 3,259 HLW. Section 4.3.12 depicts the lengths of each type of waste package: 5.85 m for 44-BWR, 21-PWR, 24-BWR, and 12-PWR; and 5.35 m for HLW. Allowing 1.0 m clearance for each waste package, the total drift length for all the waste packages is:

$$[(1+5.85)(2859+4137+0+683) + (1+5.35)(3259)] = 73{,}295.8 \text{ m.}$$

The maximum drift spacing for the areal mass loading range in Section 4.3.32 is determined by the following formula:

acreage = total waste inventory / mass loading
DS = (acreage x 4047 sq m/acre) / total drift length

For 80 MTU/acre:

acreage = 70,000 MTU / (80 MTU/acre) = 875 acres
DS = (875 acres x 4,047 sq m/acre) / 73,295.8 m = 48.3 meter spacing.

For 100 MTU/acre:

acreage = 70,000 MTU / (100 MTU/acre) = 700 acres
DS = (700 acres x 4,047 sq m/acre) / 73,295.8 m = 38.6 meter spacing.

The maximum drift spacing for VA design (see Section 7.1.3.2) using a mass loading of 85 MTU/acre and a total waste inventory of 63,000 MTU can be found by the following formula:

acreage = (63,000 MTU / 85 MTU/acre = 741.2 acres
DS = (741.2 acres x 4,047 sq m/acre) / 73,295.8 m = 40.9 meter spacing.

If it is decided to have a drift spacing greater than that for VA design for the same areal mass loading, an analysis would be needed to determine the impact on thermal goals.

7.1.3.2 Number of Emplacement Drifts

Section 4.3.4 shows the waste emplacement schedule for each type of waste package received each year at the MGDS for emplacement into the repository. The average MTU/package for each waste package type received each year is shown in Section 4.3.5. Based on a drift spacing of 28 m (Section 4.1.6) and a mass loading of 85 MTU/acre (Section 4.1.5), the drift length required per year for each waste package type can be calculated using an average of 1.70 m of drift/MTU (see Section I.1 in Attachment I). The spacing between the large commercial spent nuclear fuel (SNF) waste packages is enough that the high-level waste (HLW) waste packages can be physically emplaced between them. The HLW waste packages generally have low and short-lived heat output. Therefore, only the commercial SNF waste packages are used in the calculations to find the emplacement area for 85 MTU/acre. Table I-1 in Attachment I shows the length of emplacement drift needed per year for each waste package type and the total cumulative length for the entire inventory, which equates to 107,144 m. However, the total cumulative length of drift needed for emplacement does not include unusable area in the repository attributed to fault, physical, thermal, and/or radiological standoff distances or drifts left empty for operational purposes. These factors which influence usable emplacement area are discussed below.

The layout is such that the main trace of a Type 1 fault is avoided by at least 60 m. Splays from the main trace of a Type 1 fault may also be classified as Type 1. However, it is not practical to attempt to avoid all splays of the major faults. Where a Type 1 fault splay passes through the emplacement area, a 15 m standoff distance from the edge of the fault to the nearest waste package on either side of the fault would be implemented during emplacement. A 5 m standoff distance from faults not classified as Type 1 will be implemented because they still have the potential for the same circumstances as a Type 1 although not as great. The Abandoned Wash Fault has a major splay located at the south end of the block slightly to the east of the Exhaust Main intersects several drifts on the east side. The Solitario Canyon Fault has a major splay located toward the southern end of the West Main where the main bends slightly back to the east and intersects several drifts on the west side. A total of 30 m per affected emplacement drift for each Type 1 fault splay is assumed to be unusable emplacement area. The Sundance Fault is not considered a Type 1 fault but impacts several drifts on the east side near the middle of the block. A total of 10 m per affected emplacement drift for this fault is assumed to be unusable emplacement area.

The ventilation raises are located at the midpoint of the emplacement drifts along the centerline of the Exhaust Main. Emplaced waste packages must be set back from the raises in the emplacement drifts so as not to interfere with ventilation and/or radiological monitoring around the raise. A 2 m standoff distance from the centerline of the ventilation raise to the end of the closest emplaced waste package on either side will be applied.

All waste package emplacement operations use the East and West Mains for access to the emplacement drifts. Equipment and personnel will be in the mains frequently. To limit the temperature in the East and West Mains during emplacement operations, a thermal standoff distance of 35 m will be applied. The thermal standoff is the perpendicular distance from the center of the last waste package in the emplacement drift to the edge of the main. However, the Exhaust Main presents a special case. The only reason for any personnel to be in the Exhaust Main is for maintenance purposes or emergency situations. Therefore, the thermal standoff will not be imposed on the Exhaust Main. The Exhaust Main will receive the combined airflow from the mains and must be kept at an accessible temperature for personnel if the need arises.

To limit the amount of radiological exposure to personnel working or traveling in the East and West Mains during emplacement operations, a 13 m radiological standoff distance will be applied. The radiological standoff is the distance from the center of the last waste package in the emplacement drift to the door of the emplacement drift. This concept assumes that there will be radiation, or "shadow", shields placed inside and/or outside the door to the emplacement drift to reduce the direct radiation leaving the emplacement drift.

Because of the various lengths of the turnouts, the radiological and thermal standoffs must be compared to see which one governs the location of the last waste package nearest the door in the emplacement drifts. Only one of the standoffs will govern, they are not cumulative. In most cases, the radiological standoff will govern because most of the turnouts are long enough to push the first waste package location beyond 35 m from the main. Where the turnouts are shorter, the thermal standoff will govern. The turnouts vary in length, up to about 10 m, because the angle of intersection of the centerline of the emplacement drift and the main changes with the azimuth of the main.

Five emplacement drifts will be excavated but left empty during emplacement operations. These drifts will serve two purposes. First, three of the drifts will be designated as cross-block drifts and left empty to facilitate ventilation, emergency egress, and, possibly, to assist with performance confirmation monitoring. The cross-block drifts will be one of the only paths for cool, fresh air to get into the Exhaust Main. The Exhaust Main will be heated up by conductive heat from the emplacement drifts. Once the cool air arrives in the Exhaust Main, it will blend with the hotter air and make the overall air that exhausts into the Emplacement Shaft cooler. These drifts can also function as emergency egress routes for personnel either from the Exhaust Main into the repository area or from the repository area to the Exhaust Main if the major routes are blocked. A ladder system will be provided in the raises. The performance confirmation program may also use the cross-block drifts to monitor the adjacent emplacement drifts. The other two drifts that will be left empty will be for relocating waste packages, if needed. These two drifts are designated as emplacement stand-by drifts. They will be finished to the same standards as the emplacement drifts but will only be used if needed. If, for some reason, waste packages must be removed from a loaded emplacement drift, the emplacement stand-by drifts will serve as receiving locations instead of removing the waste packages to the surface. Relocated waste packages can remain in the emplacement stand-by drifts or be moved back to their original location depending on the situation that caused the relocation.

Taking into account the emplacement drift lengths plus all the exclusions and standoffs yields the total amount of emplacement drift excavation actually required to emplace 70,000 MTU of waste. Since 107,144 m are needed for emplacement, 104 drifts will be sufficient for the amount with the 105th drift being excavated as a cross-block drift. The usable emplacement drift length for 105 emplacement drifts is 108,003 m. This equates to approximately 747 acres as calculated in Attachment I. Table I-2 in Attachment I shows the drift length available for each emplacement drift. There is a contingency area shown in the layout that encompasses another 15 drifts, bringing the total to 120 drifts. The area is an approximate 15% emplacement area contingency in case conditions during development are found to be such that intended emplacement area cannot be used or in case additional space is needed during emplacement for exceptionally hot waste packages (Reference 5.27). The usable emplacement area in the contingency area is approximately 107 acres as calculated in Attachment I. The total amount of excavation for 105 drifts is 116,957 m. Table I-3 in Attachment I shows the drift length excavated for each emplacement drift. The usable emplacement area for the statutory capacity of 70,000 MTU is shown in Figure 7-9. The contingency area would only be developed if needed.

7.1.4 Drainage Control

7.1.4.1 Overall Drainage Strategy

Section 4.2.9 states that water is to be kept from collecting around waste packages inside the emplacement drifts To accomplish this, the emplacement drifts will be excavated at a slight gradient up from the mains to the midpoint of the drift where the ventilation raise will be located. Any water will flow out of the emplacement drift, down the turnout, and into the East and West Mains. The East and West Mains will, in turn, be sloped down from the south to the north with the lowest point in the repository being along the North Main where it intersects the Exhaust Main. Any water collected along the route during preclosure will be pumped to the surface. Figure 7-10 shows the repository drainage patterns based on the slopes shown in Figure 7-1 in Section 7.1. Possible locations for water collection are shown in Figure 7-32 in Section 7.2.6. The effects of this drainage strategy on the performance of the repository will be determined in other analyses.

7.1.4.2 Control of Water Events

The repository will be designed to control water inflow. Such inflows could come from the host rock, but are much more likely to occur as a result of broken water lines or fire fighting activities during preclosure. Since the East and West Mains will be designed with a slope to make water flow in one direction from south to north, a sump will be installed with every block of emplacement drifts being excavated during construction/development to collect water and pump it to the surface. The sump will be left in place when each block of emplacement drifts is turned over for emplacement operations. An invert segment in the mains will be removed and a sump installed. The down slope side of the sump will contain a seal on the bottom part of the invert to impede water flow. Any water that did get past a sump would be available for collection at the next sump, and so on down the main. If any water were to make it past the first emplacement drift at the north end, it would flow to the lowest point in the repository, the intersection of the North Main and the Exhaust Main, to be collected and pumped to the surface.

7.1.5 Constructibility

7.1.5.1 Construction/Development Approach

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 construction equipment can determine the size and shape of excavated openings and the general arrangements possible for the layout. The construction methods and equipment, construction sequence, and equipment productivity must be considered to ensure the overall constructibility of the planned layout. The repository layout design seeks to minimize the number and size of openings needed to

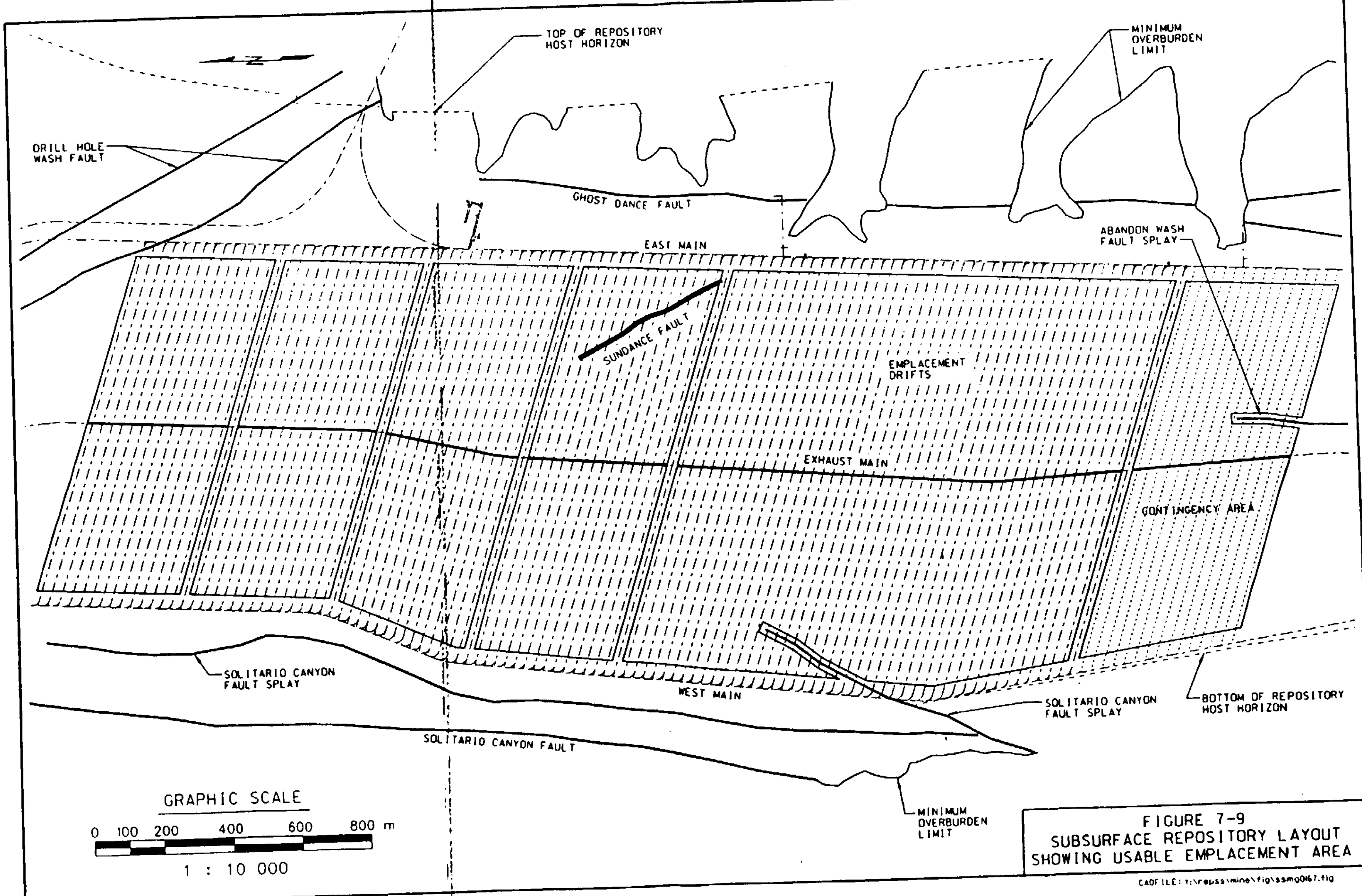

FIGURE 7-9
SUBSURFACE REPOSITORY LAYOUT
SHOWING USABLE EMPLACEMENT AREA

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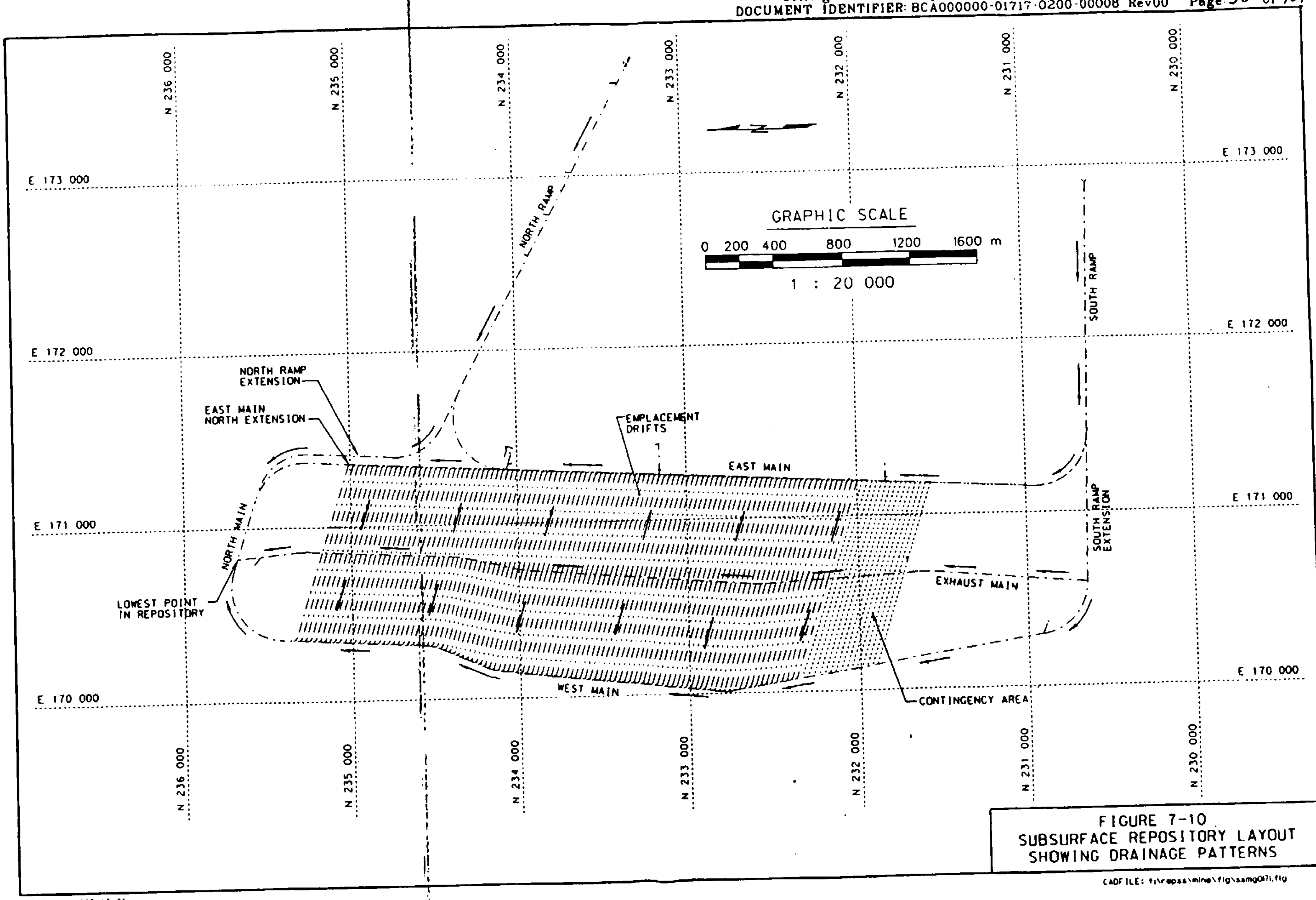

FIGURE 7-10
SUBSURFACE REPOSITORY LAYOUT
SHOWING DRAINAGE PATTERNS

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accomplish the mission (i.e., emplacement of 70,000 MTU of waste) and to utilize completed drifts in an efficient manner to help the construction process. For example, completed emplacement drifts will serve as ventilation airways during construction, for materials transfer between the East and West Mains, and to support multiple construction activities at one time, such as boring ventilation raises and final equipping of the drifts. This section discusses the planned construction and development approach and its influence on the repository layout. Other analyses will address repository construction and development and the schedule for this work in more detail.

The main ESF openings (North Ramp, Main Drift, and South Ramp) were excavated by a 7.62 m diameter TBM (Section 4.1.2); and the alcoves were excavated by drill-and-blast and by roadheader. Similar methods will be used for repository construction and development, although drilling and blasting will be strictly limited to where mechanical methods are clearly impractical and in non-emplacement areas. The majority of the repository openings will be excavated by TBM, which require long and relatively straight headings (tunnels) for efficient operation. The TBM excavates a circular cross-sectional opening and relies on weight, power, and stability to excavate the rock. The TBM is consequently a large heavy machine (estimated weight of a 7.62 m diameter TBM is about 450-550 tonnes and a 5.5 m TBM is about 180 tonnes) and is completely immobile unless set up in the tunnel to excavate. Both the 7.62 m and 5.5 m TBMs will be designed for transportation through completed tunnels. This function may require partial disassembly and the use of transportation dollies.

Pre-excavated chambers are required to assemble/launch and recover/disassemble the 7.62 m TBM, which will excavate the ramps and mains, and the 5.5 m TBMs which will excavate the emplacement drifts and performance confirmation (PC) drifts. For the ramps and mains, the assembly and disassembly chambers are located to support the desired construction sequence. The emplacement drift turnouts required for the waste emplacement operations will serve as the launch chambers on the east side and recovery chambers on the west side for the 5.5 m TBM. For the PC drifts located above the repository block, assembly chambers will be excavated as needed. The 5.5 m TBM will be designed to back out from a completed PC drift so disassembly chambers will not be required.

The TBM assembly and disassembly chambers, the emplacement drift turnouts, and other miscellaneous access drifts will be excavated by roadheader. Roadheaders are traditionally soft rock machines, although recent developments have improved their hard rock cutting capability. Roadheader productivity is low compared to that of a TBM and, for this reason, 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 and are ideally suited to excavating turnouts and similar openings. These machines can be moved on a flat car between headings or, if close by, moved under their own power.

7.1.5.2 Construction Sequence

The construction sequence and schedule for the subsurface facilities are planned to complete the pre-emplacement construction between 2005 and 2009 to ensure that the facilities will be ready in time to begin waste emplacement in 2010. The remaining development of the repository will occur concurrently with emplacement from 2010 to approximately two years before the end of the emplacement in 2033. Construction and development of the repository will be accomplished in two phases. The first, the Construction Mode, will occur prior to the beginning of emplacement operations; and the second, the Development Mode, will occur concurrently with emplacement operations.

The Construction Mode will cover excavation of the ramps, mains, shafts, and a panel of several emplacement drifts and ventilation raises. Isolation airlocks will be erected after the first panel of emplacement drifts is finished so that simultaneous emplacement and development operations can proceed. Emplacement operations will use the first panel of emplacement drifts on the north side of the isolation airlocks while the next panel of emplacement drifts and ventilation raises is under development on the south side of the isolation airlocks. As a panel of emplacement drifts is completed, a new set of isolation airlocks will be erected, the panel turned over to emplacement operations, and the previous set of isolation airlocks dismantled and stored for future use or left in place as emergency air control devices.

During the Construction Mode, the ramps and mains will be excavated by a 7.62 m TBM. The TBM will be assembled at the top of the curve on the South Ramp and excavate its way through the South Ramp Extension, West Main, North Main, and East Main North Extension to the bottom of the North Ramp. It will then be partially disassembled and backed out of the East Main North Extension into the North Main and continue by excavating the North Ramp Extension. On completion of this work, the TBM will be disassembled and refurbished as necessary. It will be transported to the South Ramp Extension and reassembled to excavate the Exhaust Main from south to north. The TBM will then be disassembled and removed to the surface.

The first excavation in the repository after construction is authorized, though, will be the turnout for the southern-most cross-block drift. As the main drift TBM is being assembled, a 5.5 m diameter emplacement drift TBM will be assembled in a selected turnout and the cross-block drift then excavated. After completion of the first cross-block drift, the 5.5 m TBM will be partially disassembled and backed out to the East Main and moved to the next cross-block drift location near the middle of the repository. The first cross-block drift will need to be scheduled for completion before the 7.62 m main drift TBM reaches the curve along the South Ramp Extension to establish an accurate target for alignment of the West Main along the bottom of the Repository Host Horizon. Similarly on completion of the second cross-block drift, the 5.5 m TBM will be moved to the last cross-block drift at the north end of the repository. The second and third cross-block drift excavations will confirm the location of the Solitario Canyon Fault and its splays along the west edge of the block. To define the geology along the west side, the cross-block drifts will continue approximately 100 m past the proposed intersection point with the West Main. Alternatively, stopping the TBM short of the planned West Main location and borehole drilling to the area of interest may be adequate to confirm the geology. The cross-block drifts will also serve as ventilation airways to deliver fresh air to the 7.62 m TBM as it continues to excavate the mains.

The ramps and mains will be concrete lined to ensure a long and low maintenance requirement life for the duration of the subsurface preclosure activities. Installation of the concrete lining will be scheduled to avoid interference with other construction activities in the mains. On completion of the lining in the mains, a roadheader will begin excavating the emplacement drift turnouts. Upon completion of several turnouts, the emplacement drift TBMs will start excavating the first panel of emplacement drifts at the north end. The emplacement drift TBMs will start from the turnouts along the East Main, excavate across the block into the turnouts on the West Main, be partially disassembled, and backed out through the excavated and lined emplacement drifts to start the next drift in the East Main.

As surface pads are built and access to the bottom of the shaft locations is gained, excavation of the shafts will begin. The Development Shaft/South Ramp Extension Connector will be started only after the 7.62 m TBM passes the first cross-block drift to ensure an alternative supply of fresh air for the TBM so that the roadheader excavating the shaft connector will not contaminate the TBM air supply. Similarly, the Emplacement Shaft/Exhaust Main Connector will start after the 7.62 m TBM finishes all excavation in the north end of the block.

7.1.5.3 Equipment Envelope Requirements for Construction/Development Operations

The excavation equipment envelope is a determining factor in sizing the openings. The exact equipment sizes have not been determined yet, and additional analyses may be required to establish these. However, since the ESF loop has already been excavated to a diameter of 7.62 m and will become part of the repository, the construction equipment should be sized to fit within the limits of this opening. The transportation equipment envelope in the ESF is 3.657 m x 3.657 m (Section 4.1.3), although this could be increased where circumstances dictate. To increase the equipment envelope will require an analysis of the impacts of all aspects of the construction operations. Final layout dimensions will be determined by equipment sizes and manufacturers recommendations for equipment selected.

7.1.6 Radiological Safety

7.1.6.1 Radiological Strategy

Radiological safety is one of the most important aspects of the repository. Radiological exposure should be kept as low as reasonably achievable (ALARA) for personnel. Since personnel will frequently be traveling in the mains, potential exposures there should be ALARA. The turnouts will aid in increasing radiological protection in the mains in most cases because the curved section provides some blockage of direct shine from the emplacement drifts to the mains. The length of the turnout also provides an increase in radiological protection as distance is one of the best sources of protection.

7.1.6.2 Shadow Shields

Once an emplacement drift has been filled to capacity with waste packages, it will be secured and only opened for monitoring, retrieval, or off-normal situations. Shadow shields will be incorporated into the design of the emplacement drifts in order to support ALARA radiological exposure in the mains.

7.1.6.3 Radiological Standoff

Distance from the source helps to minimize radiological exposure. Locating the waste packages back from the door of the emplacement drift will help to support this concept. Preliminary information suggests that the center of the closest emplaced waste package should be set back at least 13 m from the door.

7.1.6.4 Decontamination Chambers

Section 4.2.15 dictates that operational alcoves be accommodated. This includes decontamination chambers for equipment and personnel. The chambers will include a shower mechanism that uses water for personnel and water or other methods for the decontamination of equipment. A sump will be installed in the chambers to collect contaminated water for treatment. An airlock door will be provided at the entrance to the chambers and an independent fan system with HEPA filters to pull air from the main will be installed in the chambers. The personnel chamber will be room-sized and the equipment chamber will be sized to fit the largest piece of emplacement equipment that has the potential for contamination.

7.1.7 Emplacement/Retrieval

7.1.7.1 Emplacement/Retrieval Strategy

The waste package emplacement strategy will consist of the following sequence which is similar to the method of emplacement identified in the MGDS ACD Report (Reference 5.1, Section 8.6). A waste package will be loaded into a shielded waste package transporter in the surface Waste Handling Building at the North Portal. The waste package transporter will be moved into the repository via the North Ramp to East Main, North Ramp to North Ramp Extension to East Main North Extension, or North Ramp to North Ramp Extension to North Main to West Main. The waste package transporter will stop at an active emplacement drift and be pushed into the emplacement drift turnout. It will stop just short of the emplacement drift door so the doors on the waste package transporter and the emplacement drift can be opened. It will then continue into the turnout until the waste package transporter comes up against the emplacement transfer dock at the emplacement drift door. An internal mechanism inside the waste package transporter will push the waste package out of the waste package transporter onto the emplacement transfer dock. A waste package gantry will then straddle the waste package, pick it up by the ends, and carry it to a specified emplacement location within the emplacement drift. Once the gantry has taken possession of the waste package, the unloading mechanism retracts back into the waste package transporter, and the waste packaged transporter will move away from the emplacement drift door. The emplacement drift door and the waste package transporter doors will then close. The waste package transporter will be pulled back out into the main and travel back to the surface for another waste package.

Inside the emplacement drift, the gantry will carry the waste package to a specified location. The waste package will be emplaced in-drift, along the axis parallel to the centerline of the drift. The gantry will set the waste package down onto waste package support assemblies that rest on top of the invert at the intended location. The gantry will release the waste package and travel back to the emplacement drift entrance to await another waste package.

The ability to retrieve any or all of the waste packages will be maintained throughout the preclosure of the repository (Section 4.2.6). Under normal conditions, retrieval of waste packages will be accomplished in reverse order of emplacement. Off-normal conditions are special situations that will be accomplished on a case-by-case basis. Off-normal retrieval is out of the scope of this analysis.

7.1.7.2 Equipment Envelope Requirements for Emplacement Operations

The emplacement equipment envelope is a determining factor in sizing the openings. The exact equipment sizes have not been determined yet, and additional analyses may be required to establish these. The transportation equipment envelope in the ramps and mains during emplacement operations must accommodate trolley-locomotives and emplacement equipment. The envelope is currently planned to be 4.1 m x 5.25 m high. Final layout dimensions will be determined by equipment sizes and manufacturers recommendations for equipment selected.

The emplacement drift and turnout sizes are mostly dependent on the emplacement operations. The operating envelope required inside the emplacement drifts must fit within the space left by the ground support and the invert. The waste package emplacement method and the equipment necessary for that method will determine this envelope. The waste emplacement method will be center-in-drift on pedestal using gantry emplacement. This method will also have the capability to carry a waste package over an emplaced waste package. Therefore, the gantry will be the main driver of this constraint.

7.1.8 Ventilation Strategy

7.1.8.1 Construction Mode

During excavation of the Perimeter Construction Loop (see Section 7.2.1), fresh air will be brought down the North Ramp, into the East Main, and into the Perimeter Construction Loop. At first the fresh air will be taken all the way to the south end where the Perimeter Construction Loop begins, but when the Cross-Block Drifts are excavated, fresh air will be directed across the block to intersect the Perimeter Construction Loop closer to the TBM. All exhaust air will be taken through ventilation duct back through the Perimeter Construction Loop, into the South Ramp, to be released at the South Portal. Residual exhaust air along the system will be directed through to the South Ramp. During excavation of the Exhaust Main, the ventilation system will work the same as the Perimeter Construction Loop since the Exhaust Main begins and ends along the Perimeter Construction Loop.

7.1.8.2 Simultaneous Development and Emplacement Modes

Sections 4.2.7 and 4.3.24 state that the repository be divided into two separate systems during simultaneous development and emplacement operations. On the emplacement side, fresh air will be brought down the North Ramp, split evenly between the East Main and West Main, flow into the emplacement drifts with most going to open emplacement drifts and a small amount through the door into each emplacement drift that is fully emplaced and secured, join together to flow down the ventilation raises into the Exhaust Main, and exhaust through the Emplacement Shaft. On the development side, fresh air will be brought down the Development Shaft, split between the West Main and the Exhaust Main with most of the air going into the West Main, flow into open emplacement drifts across to the East Main, and exhaust through the South Ramp.

7.1.9 Ground Control

7.1.9.1 Ramps and Main Drifts

The ground support system in the North Ramp, East Main, and the South Ramp was installed during construction of the ESF loop and was classified as quality affecting. The ground support includes Swellex and Williams rock bolts, cementitious grout, shotcrete, welded wire fabric, steel channel, and steel sets with lagging. Although quality affecting, the ESF ground support is considered an initial support system that will be incorporated into the ground support planned for the repository. Permanent ground support in the ramps and mains will be a 300 mm cast-in-place concrete lining.

The ground support system in all ramps and mains will consist of the same basic type of system as the ESF loop. Initial support will be installed to make a safe and stable excavation, followed by a permanent system for repository operations.

7.1.9.2 Emplacement Drifts

The goal for the ground support system in the emplacement drifts is to minimize required maintenance during the life of the repository operations. The environment in the emplacement drifts will be hostile to personnel and normal maintenance equipment while waste packages are present because of high heat and radiation. Because of this, maintaining ground support will be very difficult. The approach to maintenance will be explained in other analyses.

As explained in Section 7.2.2, emplacement drifts are oriented with respect to joint patterns in a direction that lessens the effect of the joints on the stability of the opening. The ground support in the emplacement drifts will be a 200 mm full concrete lining made of precast segments, although issues regarding the use of cementitious materials and the extent of the need for geologic mapping are currently being studied and may result in a change to this strategy.

7.1.9.3 Secondary Openings

The ground support system in the secondary openings will consist of initial support for construction/development operations and permanent support for emplacement operations. The initial support will include combinations of rock bolts, mesh, steel channel, or steel sets depending on ground conditions. The permanent support will include a 200 mm cast-in-place concrete lining.

7.1.9.4 Alcoves

Alcoves will serve various functions in the repository. Some alcoves will be dedicated to the performance confirmation program, others will be dedicated to operational activities. The ground support in the performance confirmation alcoves will be dependent on the testing to be conducted. The exact testing requirements have not yet been developed. It is assumed that the ground support will be installed as testing requirements necessitate.

Ground support in the alcoves for operational activities will follow the same method for design as the ESF alcoves. Initial support in the repository will include appropriate combinations of rock bolts, mesh, or steel channel depending on ground conditions. Permanent support will consist of a 200 mm cast-in-place concrete lining.

7.1.9.5 Ventilation Raises

Ventilation raises will be supported with a permanent 150 mm cast-in-place concrete lining.

7.1.9.6 Shafts

The ground support system in the shafts will consist of initial support for stability and construction safety followed by permanent support. Initial support will include combinations of rock bolts, mesh, and steel channel depending on ground conditions. Permanent support will consist of a 300 mm cast-in-place concrete lining.

7.1.9.7 Performance Confirmation Drifts

The ground support in the performance confirmation drifts will be dependent on the testing to be conducted. The exact testing requirements have not yet been developed. It is assumed that the ground support will be installed as testing requirements necessitate.

7.1.10 Utilities

The utilities needed for repository operations are similar to those in the ESF (Section 4.1.3) and will include: potable water, waste water, fire water, compressed air, electrical power, communication lines, and monitoring lines. The utilities needed for construction/development operations will be temporary and will be removed as these operations are concluded. The utilities needed for emplacement operations will be permanent and will remain throughout the operating life of the repository. All repository openings will be sized such that the space for utilities will be accommodated without interference with other operations (Section 4.2.10). The utility requirements for each mode of operations will be determined in future analyses.

7.1.11 Performance Confirmation

Section 4.2.13 dictates that a performance confirmation (PC) program is to be established, which will begin during the Site Characterization Mode and continue throughout the preclosure period, to confirm that the design objectives are accomplished. This pertains to the long-term isolation of waste. The PC program may require observation drifts, observation alcoves, and/or other testing facilities. Neither the number nor the location of such facilities has yet to be determined.

The *Subsurface Repository Performance Confirmation Facilities* analysis (Reference 5.38) recommends that the PC observation drifts be located above the repository block at an elevation that will keep the PC drifts within the repository host horizon. The analysis identified a range of 10 to 20 m above the block. The number and orientation of the PC drifts will depend on the amount of coverage needed for monitoring purposes. The analysis presented a scenario for excavating the drifts with a TBM at a minimum size of 4.5 m in diameter. For VA design, the layout utilizes TBM excavation for the drifts but at 5.5 m in diameter. This size is the same size as the emplacement drifts and one of those TBMs could be used to excavate the PC drifts or a separate machine may be acquired to do the work but the same specifications would be utilized. Five PC drifts will be shown for VA design as represented in Figure 7-11. The PC drifts will be located 15 m above the block and follow the orientation and slope of the emplacement drifts. Ventilation raises will be excavated between the PC drifts and the East Main, West Main, and Exhaust Main. They will be the same size as the ventilation raises that connect the emplacement drifts and the Exhaust Main. Actual location and configuration of the PC ventilation raises or their connections to the mains has yet to be determined.

The performance confirmation analysis also indicates that any of the seven alcoves excavated as part of the ESF may be utilized for alcove-based testing which is part of the performance confirmation program in non-emplacement areas. Any additional alcoves needed for performance confirmation will be excavated. It is unknown what size, configuration, or location these alcoves will be. Those parameters are testing dependent. Therefore, this analysis only provides possible locations for the PC alcoves. Figure 7-11 shows an area all the way around the outside of the South Ramp, around the block, and outside the North Ramp where the alcoves could be located. The alcoves could also be located anywhere along the PC drifts above the block. The size and configuration of the alcoves is not anticipated to have a significant impact on the configuration of the layout.

7.1.12 Operational Alcoves and Support Areas

Section 4.2.15 states that alcoves shall be provided for operational uses. These alcoves include, but are not limited to: personnel/refuge chambers, decontamination chambers, electrical alcoves, and collection sump/tank alcoves. Personnel/refuge chambers can serve multiple personnel functions other than emergency refuge, such as first aid stations, temporary offices, and

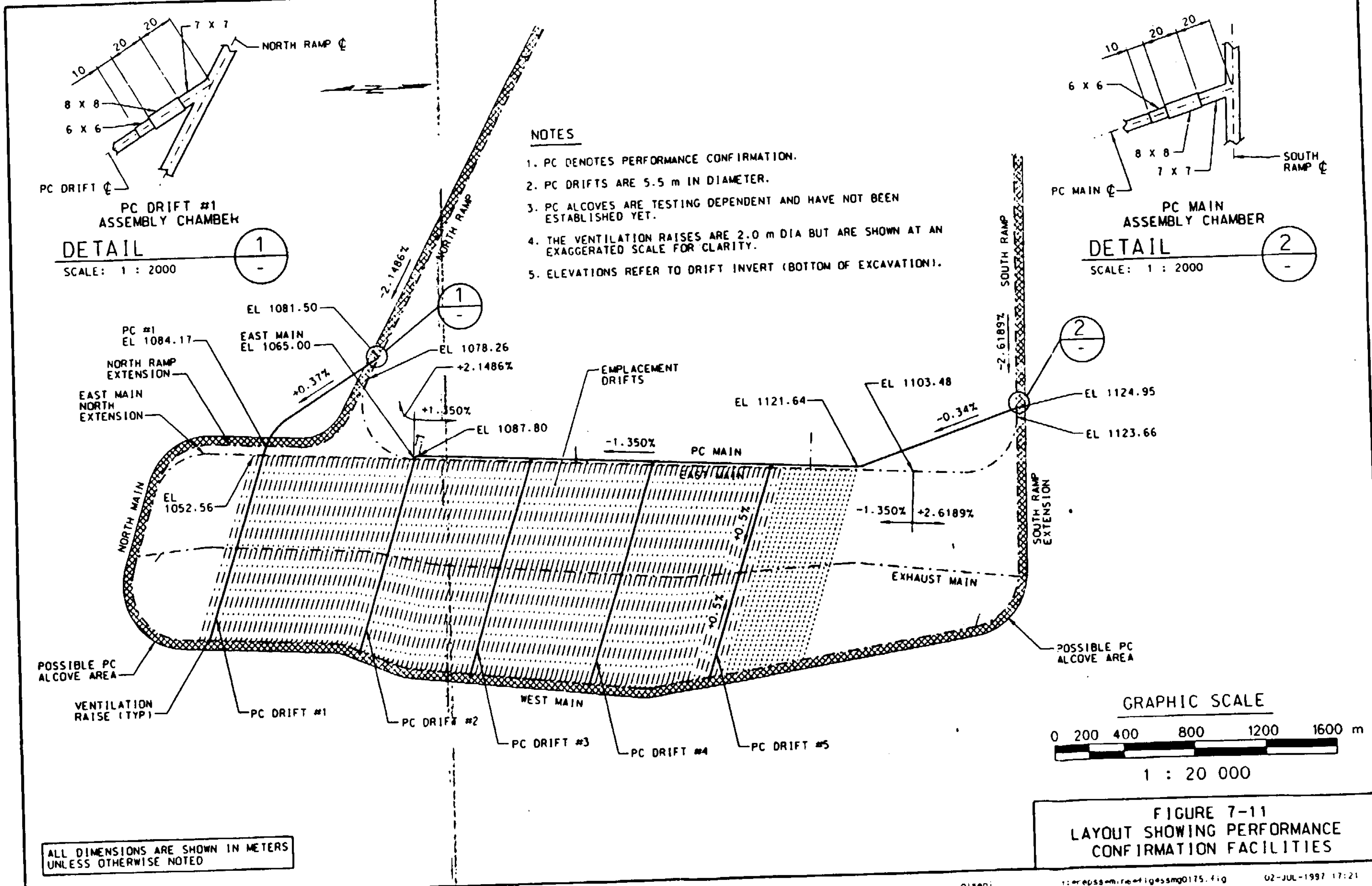

FIGURE 7-11
LAYOUT SHOWING PERFORMANCE CONFIRMATION FACILITIES

lunchrooms. They will be located a maximum of 2,100 m from an adjacent personnel/refuge chamber or nearest escapeway. Decontamination chambers were discussed in Section 7.1.6. Electrical alcoves will be provided to enhance the electrical power distribution throughout the repository. They will include a trolley rectifier, substation, and/or switchgear box and will be located at various intervals around the repository. Collection sump/tank alcoves will be provided to collect water at various points around the repository to reduce water inflows from spreading through the repository. They will include a sump and a water tank. Operational alcove sizes and locations are further discussed in Section 7.2.6.

Support areas include, but are not limited to: warehouse, operational equipment storage area, safety equipment storage area, and maintenance shop. No space will be allocated underground for warehousing or maintenance as these functions can be more efficiently handled on the surface. Servicing and breakdown maintenance of large equipment would be done at the equipment location and overhaul maintenance would be done either on the surface or off site. Equipment storage, both operational and safety equipment, will utilize empty emplacement drifts, turnouts, or other locations not being utilized and do not interfere with operations.

7.2 LAYOUT DESCRIPTION

The extent and complexity of the subsurface facilities preclude any attempt to complete them in their entirety before commencement of waste emplacement in 2010. The current schedule calls for start of the pre-emplacement construction (referred to as construction) in 2005 with sufficient amount of the subsurface completed and with associated control and monitoring systems in place to support emplacement start up in 2010 (Sections 4.2.1 and 4.3.4). The balance of the subsurface facilities (referred to as development) will be completed during the emplacement period, with completion paced to stay a reasonable distance ahead of the emplacement schedule. The emplacement and development activities will be separated by isolation airlocks (which are the subject of other analysis).

To facilitate construction and development of the subsurface facilities, many of the repository openings will serve various functions throughout the Construction, Development, and Emplacement Modes. The Construction Mode, which commences prior to the beginning of emplacement operations, covers the excavation and equipping of the mains, the shafts, and a sufficient number of emplacement drifts to support start up of emplacement operations. The Development Mode will run concurrently with emplacement operations and involves the excavation and finishing of the remaining emplacement drifts. The Emplacement Mode covers emplacement of waste packages in the finished emplacement drifts. The geometry, configuration, and functions of the repository openings during each phase are described in the following subsections.

7.2.1 Ramps and Mains

The North and South Ramps (excavated as part of the Site Characterization Mode), the North Ramp Extension, and the South Ramp Extension will provide access from surface to the emplacement horizon for all preclosure subsurface activities. The mains connect with the ramps and provide access throughout the repository at the emplacement level. The mains include the East Main (also constructed during the Site Characterization Mode as the Main Drift), the East Main North Extension, the North Main, the West Main, and the Exhaust Main. The ramps and mains serve as travelways, muck handling routes, and primary airways for the subsurface ventilation system at various times throughout the repository operations. The North Ramp Extension serves two purposes: to facilitate emplacement operations in the East Main North Extension during concurrent emplacement and development operations and as a by-pass route to the West Main so as to not interfere with operations in the East Main or East Main North Extension. The purpose of the Exhaust Main is to provide a ventilation flow path between the emplacement drifts and the shafts and to provide access for installation, inspection and maintenance of the ventilation raise bottom structures, exhaust air ducts, and monitoring and control systems. The North Ramp, East Main (ESF Main Drift), and South Ramp are referred to as the ESF Loop when addressed collectively because they have already been constructed; and the South Ramp Extension, West Main, North Main, and East Main North Extension are referred to as the Perimeter Construction Loop when addressed collectively because they will be constructed as part of the repository. The Perimeter Construction Loop is located around the boundary of the 70,000 MTU emplacement area (Section 4.2.1) as shown in Figure 7-1. The North and South Mains are located outside the north and south limits of the 70,000 MTU emplacement area and aligned to facilitate TBM construction with conveyor muck removal and rail haulage service, i.e, a minimum 305 m radius of curvature, gradients less than 3% as shown in Figure 7-1, and straight alignments to the extent practical. The South Ramp Extension and the West Main follow the bottom of the Repository Host Horizon in the southwest corner of the block, and the West Main follows a 60 m offset from the Solitario Canyon Fault along the remainder of its length. The Exhaust Main follows the midpoints of the emplacement drifts within constraints imposed by TBM excavation as stated above.

The ESF Loop was excavated by TBM and is 7.62 m in diameter. This diameter ensures an adequate tunnel cross section for ESF ventilation and clearances for construction equipment. To minimize the penetrations into the repository from surface, the ESF loop will be incorporated into the repository facility and used for repository access. The relatively flat gradients (North Ramp 2.1486%, South Ramp 2.619%, and Main Drift 1.3500%) and large diameter of the ramps and mains make them suitable for repository use, both for construction and emplacement operations. (See Section 4.1.2.) Equipment envelopes are discussed in Sections 7.1.5 and 7.1.7, and this topic and repository ventilation system design will be addressed further in other analyses. The ramp and mains locations are defined in Table 7-1 and illustrated in Figure 7-1. The sizes and lengths of the ramps and mains are summarized in Table 7-2.

Table 7-1 Location Definitions of Ramps and Mains

Ramp/Main	Location Definition
North Ramp	From the North Portal to the bottom of the northern curve of the ESF loop.
East Main	From the bottom of the northern curve of the ESF loop to the slope inflection point below the southern curve of the ESF loop.
South Ramp	From the inflection point below the southern curve of the ESF loop to the South Portal.
North Ramp Extension	From top of the northern curve of the ESF loop to the North Main.
East Main North Extension	From the bottom of the northern curve of the ESF loop to the North Main.
North Main	From the North Ramp Extension to the centerline of the first emplacement drift at the northern end of the West Main.
West Main	From the centerline of the first emplacement drift at the northern end of the west side to the centerline of the last emplacement drift at the southern end of the west side.
South Ramp Extension	From the centerline of the last emplacement drift at the southern end of the west side to the southern curve of the ESF loop.
Exhaust Main	From the South Ramp Extension to the North Main.

Table 7-2 Geometry of Ramps and Mains

Drift	Size	Length (m)*	Comments
North Ramp	7.62 m Dia.	2804	Reference 5.5
East Main	7.62 m Dia.	2850	Reference 5.5
South Ramp	7.62 m Dia.	2223	Reference 5.5
North Main	7.62 m Dia.	1137	Reference 5.39
West Main	7.62 m Dia.	3486	Reference 5.39
Exhaust Main	7.62 m Dia.	5048	Reference 5.39
East Main North Extension	7.62 m Dia.	1576	Reference 5.39
North Ramp Extension	7.62 m Dia.	1491	Reference 5.39
South Ramp Extension	7.62 m Dia.	2269	Reference 5.39

* The drift lengths have been rounded to whole numbers.

7.2.1.1 Operational Functions of Ramps and Mains

The operational functions of the ramps and mains will change during the various modes of the repository preclosure period.

7.2.1.1.1 Construction Mode

All ramps and mains will serve as primary airways for ventilation. The South Ramp, East Main, Perimeter Construction Loop, and Exhaust Main during the Construction Mode will serve as muck handling routes from active excavations to the surface muck handling facilities at the South Portal. Personnel, materials, and equipment will use either the North Ramp or South Ramp for access, depending on where particular subsurface construction support facilities are located on the surface and on the specific location of the subsurface construction activities. During the early part of the construction period access via the North Ramp will be necessary for efficient scheduling of construction activities. As construction of surface facilities advances, subsurface support at the North Portal will be eliminated and construction access restricted to the South Ramp.

7.2.1.1.2 Concurrent Development and Emplacement Modes

The periods for the Development and Emplacement Modes will overlap and, during this period, the repository will be divided into separated development and emplacement sides (Sections 4.2.7 and 4.3.24). On the development side, the South Ramp will be a primary airway for the development ventilation system and the primary muck handling route from development operations to surface. Construction personnel, materials, and equipment will enter and leave through the South Ramp. The development-side mains will serve as primary airways for ventilation, as muck handling routes, and as access routes for men, materials, and equipment.

On the emplacement side, the North Ramp will be a primary ventilation airway and, as the waste handling facilities will be located at the North Portal, the access for the waste package transporter from the surface facilities to the repository horizon. Other analyses will address the design of the waste handling equipment. Personnel, materials, and other miscellaneous emplacement operations equipment will also use the North Ramp for access into the repository. The emplacement-side mains will serve as primary airways for ventilation and for access to, from, and between the emplacement drifts for the waste package transporter, waste package gantry, operations personnel, and miscellaneous materials and equipment needed for support of the emplacement operations.

7.2.1.2 Sizes of Ramps and Mains

The sizes of the ramps and mains must accommodate the operational functions. As these functions vary between the repository modes, the sizes must consider all activities that will normally take place. The largest pieces of equipment to travel through these openings under normal operating conditions will be for construction and emplacement.

The North Ramp, Main Drift (East Main), and South Ramp, were excavated for site characterization by a 7.62 m diameter TBM. As the ESF facilities will be integrated into the repository, equipment used for other repository activities, including construction/development and emplacement operations, will be designed to fit within the existing 7.62 m diameter opening either intact or disassembled to be reassembled in a location underground. The largest pieces of equipment for the various modes of repository operations are as follows: 7.62 m TBM, 5.5 m TBM, and roadheaders during the Construction and Development Modes; and waste package transporter and waste package gantry atop the gantry carrier during the Emplacement Mode.

7.2.1.3 Configuration of Ramps and Mains

This section describes the configuration of the ramps and mains. Configuration is defined as the ground support and equipment installed in the openings during each repository mode. The ground support thicknesses can be found in Section 7.1.9.

7.2.1.3.1 Construction Mode

At the start of the Construction Mode, the North Ramp contains the configurations existing from ESF operations and includes: initial ground support, precast concrete inverts, a double 915 mm gage construction track with 42.44 kg/m rail, utility lines, and a 915 mm conveyor system. The conveyor will be removed from the North Ramp as all the muck will be removed through the South Ramp. Later in the construction period, a 300 mm cast-in-place concrete lining and 300 mm cast-in-place concrete invert cap will be installed. The South Ramp will be similar to the North Ramp, since they are both existing ESF openings. However, the cast-in-place concrete lining and cast-in-place concrete invert cap will be omitted from the South Ramp during the Construction, Development, and Emplacement Modes, although both could be installed during the Caretaker Mode if required at that time. The North Ramp Extension and North Main configurations will follow the same sequence as the North Ramp except the conveyor will be left in place until the Emplacement Shaft is completed.

The East Main also contains the configurations existing from ESF operations and includes: initial ground support, precast concrete inverts, a double 915 mm gage construction track with 42.44 kg/m rail, utility lines, and a 915 mm conveyor system. A 300 mm cast-in-place concrete lining will be installed over the initial ground support. The East Main North Extension configuration will be the same as the East Main. During the construction of the emplacement drifts, a 300 mm temporary invert cap will be installed over the precast concrete inverts in both the East Main and East Main North Extension to adjust the height of the track for excavation of the emplacement drift turnouts and emplacement drifts. A ventilation duct will be installed to remove exhaust air from roadheader excavation of the turnouts and from emplacement drift TBM excavation. A permanent 300 mm cast-in-place concrete invert cap will be installed in the East Main and East Main Extension upon completion of emplacement drifts.

The West Main configuration will be similar to the East Main. However, the conveyor will be removed once the construction of the Perimeter Construction Loop, North Ramp Extension, and Emplacement Shaft are complete. The conveyor will not be needed during construction of the emplacement drifts because the emplacement drifts will be excavated from east to west and the TBM muck transported by rail car to the East Main conveyor system for removal to surface. Ventilation duct will be required for the roadheader excavation of the turnouts along the West Main. The South Ramp Extension configuration will follow the configuration of the West Main except it will only have temporary ground support, no cast-in-place concrete invert cap, and no ventilation duct. The cast-in-place concrete invert cap could be installed during the Caretaker Mode if required at that time. The Exhaust Main will have the same configuration as the West Main, except that no permanent concrete invert cap will be installed. Ventilation duct will be installed in the Exhaust Main to remove exhaust air from raise borer excavation of the ventilation raises.

Figures 7-12, 7-13, 7-14, 7-15, and 7-16 show typical cross sections of the North Ramp, South Ramp, East Main, West Main, and Exhaust Main during the Construction and/or Development Modes.

7.2.1.3.2 Concurrent Development and Emplacement Modes

During the concurrent Development and Emplacement Modes, the ramps and mains on the development side will have the same configuration as in the Construction Mode. These ramps and mains include the South Ramp, East Main, West Main, South Ramp Extension, and Exhaust Main. See Figures 7-12, 7-13, 7-14, 7-15, and 7-16 for similar configurations of these openings.

On the emplacement side, the North Ramp, North Ramp Extension, East Main, East Main North Extension, and West Main will contain a cast-in-place concrete lining installed over initial ground support, a 300 mm cast-in-place concrete invert cap, a single 1.44 m gage track with 57.05 kg/m rail for the emplacement operations, and utility lines. Figure 7-17 shows a typical cross section of the North Ramp and the East and West Mains during the Emplacement Mode. The Exhaust Main is different from the other mains in that it will also contain ventilation ducting connected to the ventilation raises to carry hot air from the emplacement drifts to the emplacement side exhaust shaft. The ventilation ducting will retard hot air from heating the primary air flow in the Exhaust Main and will help to contain any potential radiation leaks. Figure 7-18 shows a typical cross section of the Exhaust Main during the Emplacement Mode.

7.2.2 Emplacement Drifts

The primary purpose of the emplacement drifts is to accommodate the waste packages; however, these drifts will also have various functions throughout the different repository modes. During the Construction and Development Modes, the empty emplacement drifts will serve as ventilation airways, muck handling routes, and personnel/materials access. During the Emplacement Mode, the emplacement drifts will contain emplaced waste packages and will be loaded from both the East and West Mains. Emplacement will start from the midpoint of the drifts and work out towards the mains. Empty emplacement drifts and the three cross-block drifts will serve as ventilation airways to the Exhaust Main.

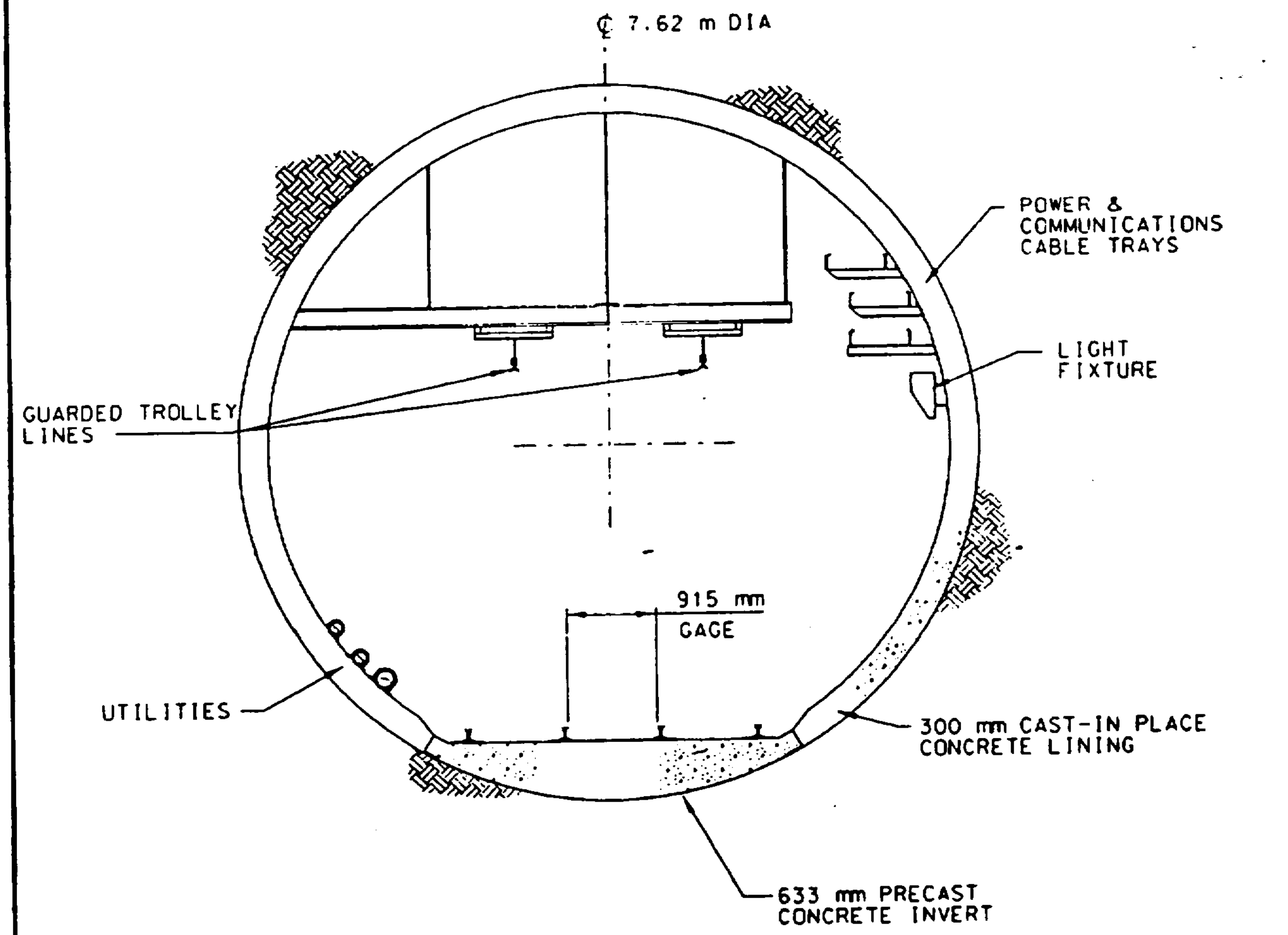

FIGURE 7-12
TYP SECTION OF NORTH RAMP
CONSTRUCTION MODE

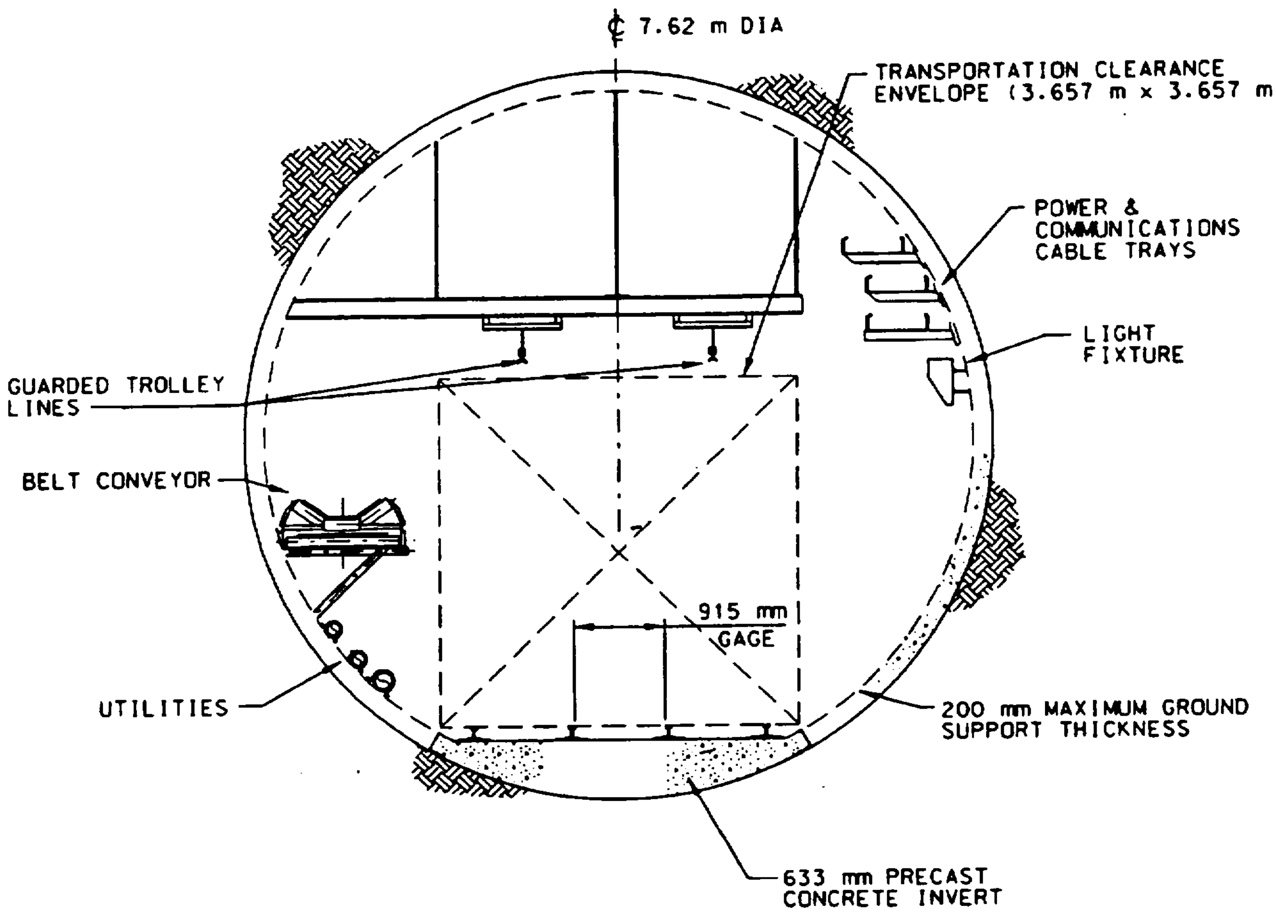

FIGURE 7-13
TYP SECTION OF SOUTH RAMP
CONST/DEVELOPMENT MODES

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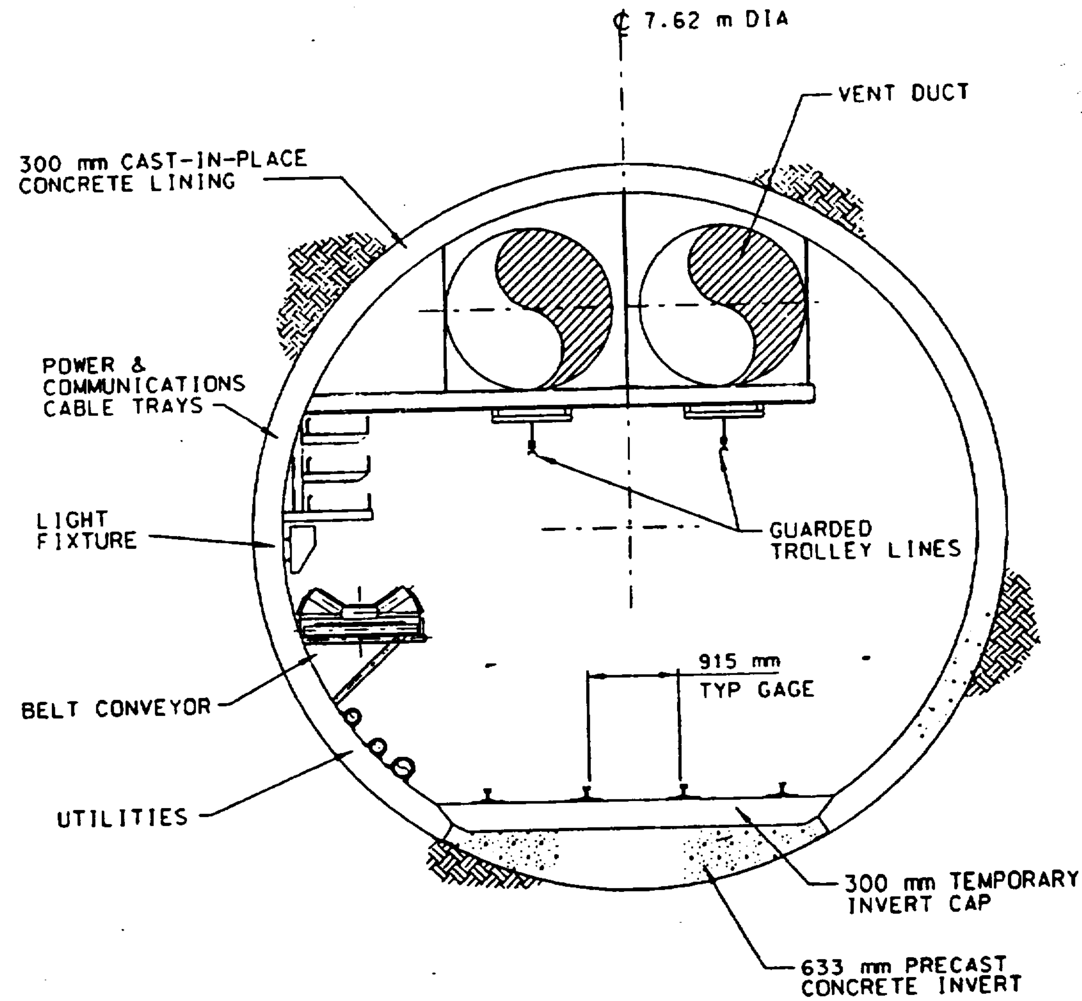

FIGURE 7-14
TYP SECTION OF EAST MAIN
CONST/DEVELOPMENT MODES

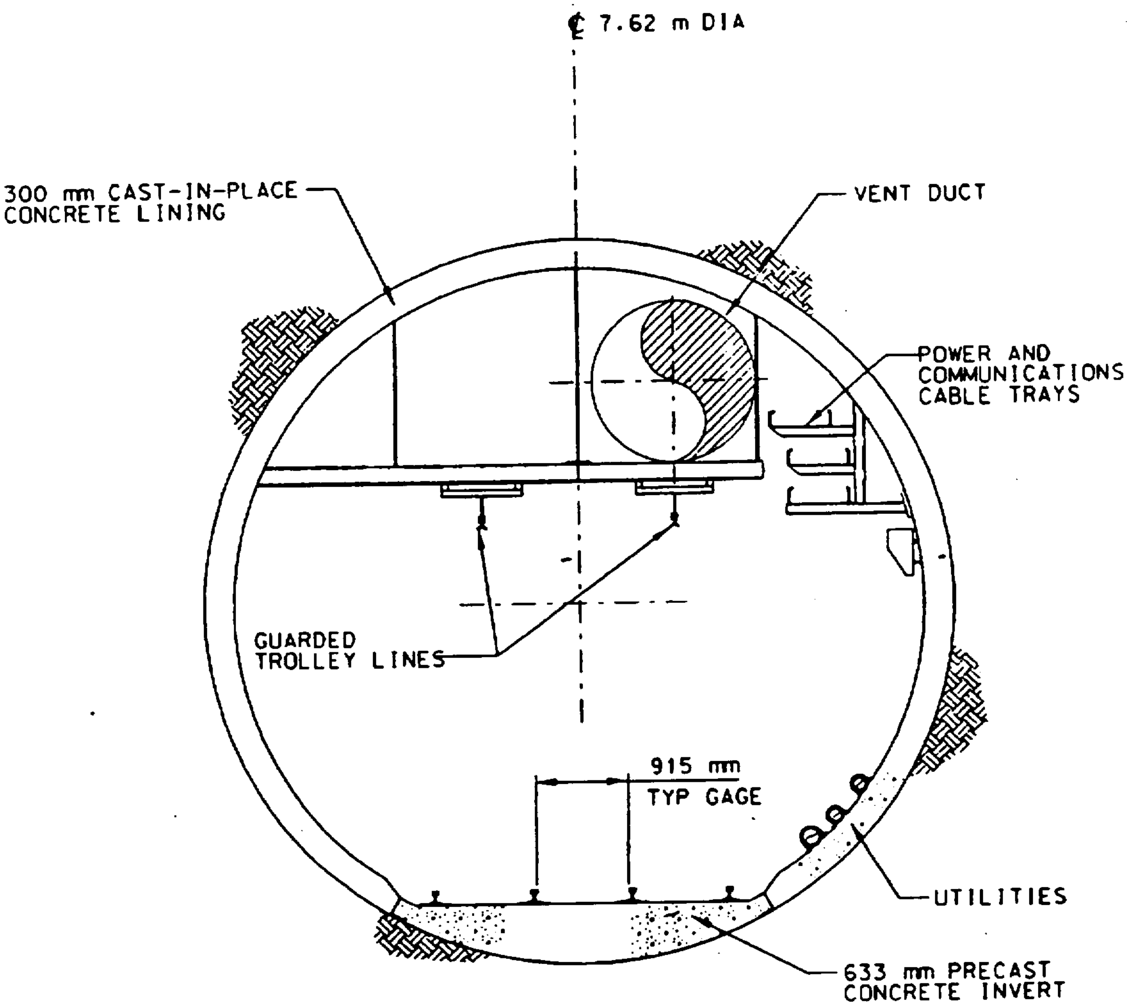

FIGURE 7-15
TYP SECTION OF WEST MAIN
DEVELOPMENT MODE

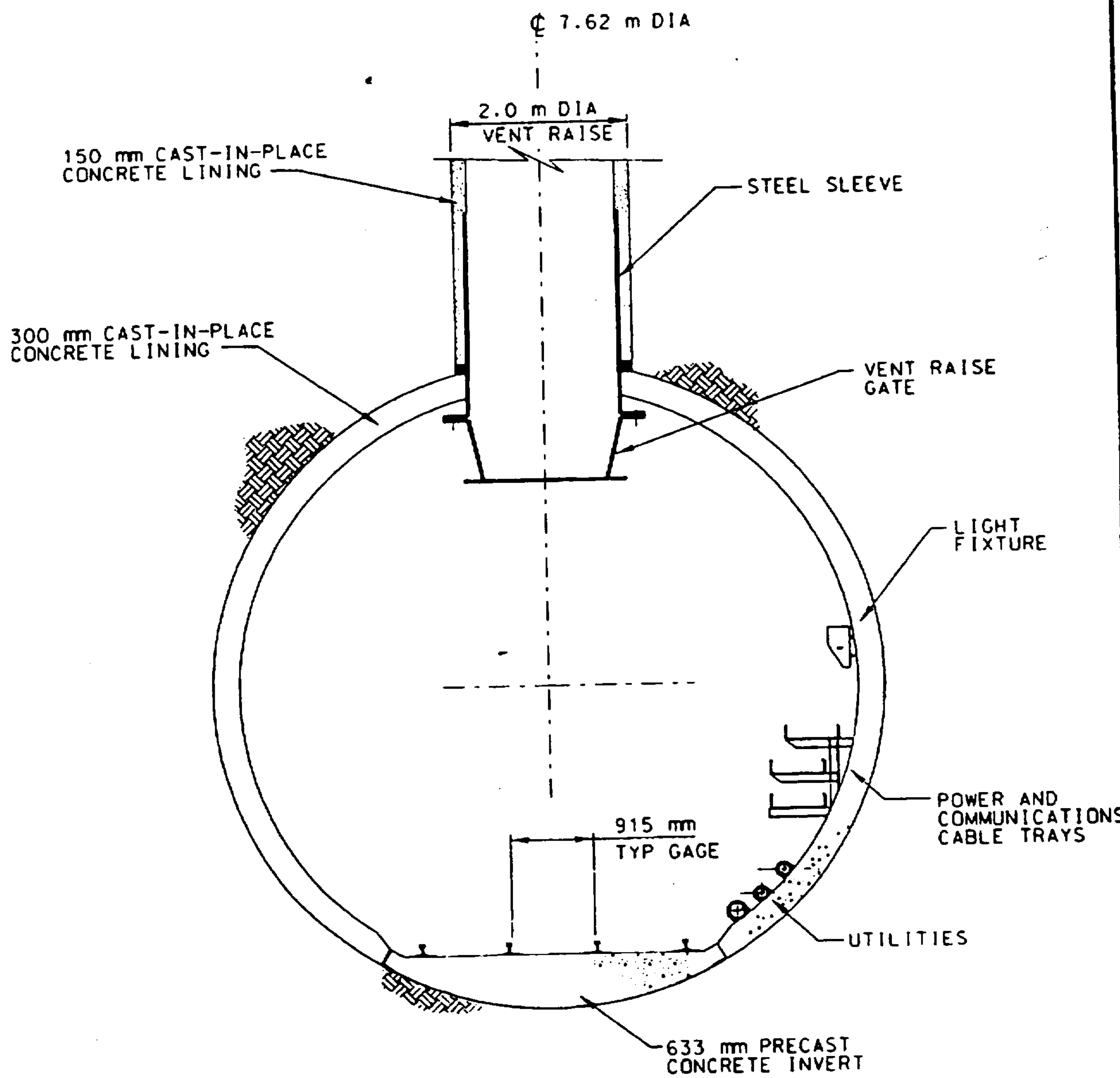

FIGURE 7-16
TYP SECTION/EXHAUST MAIN
DEVELOPMENT MODE

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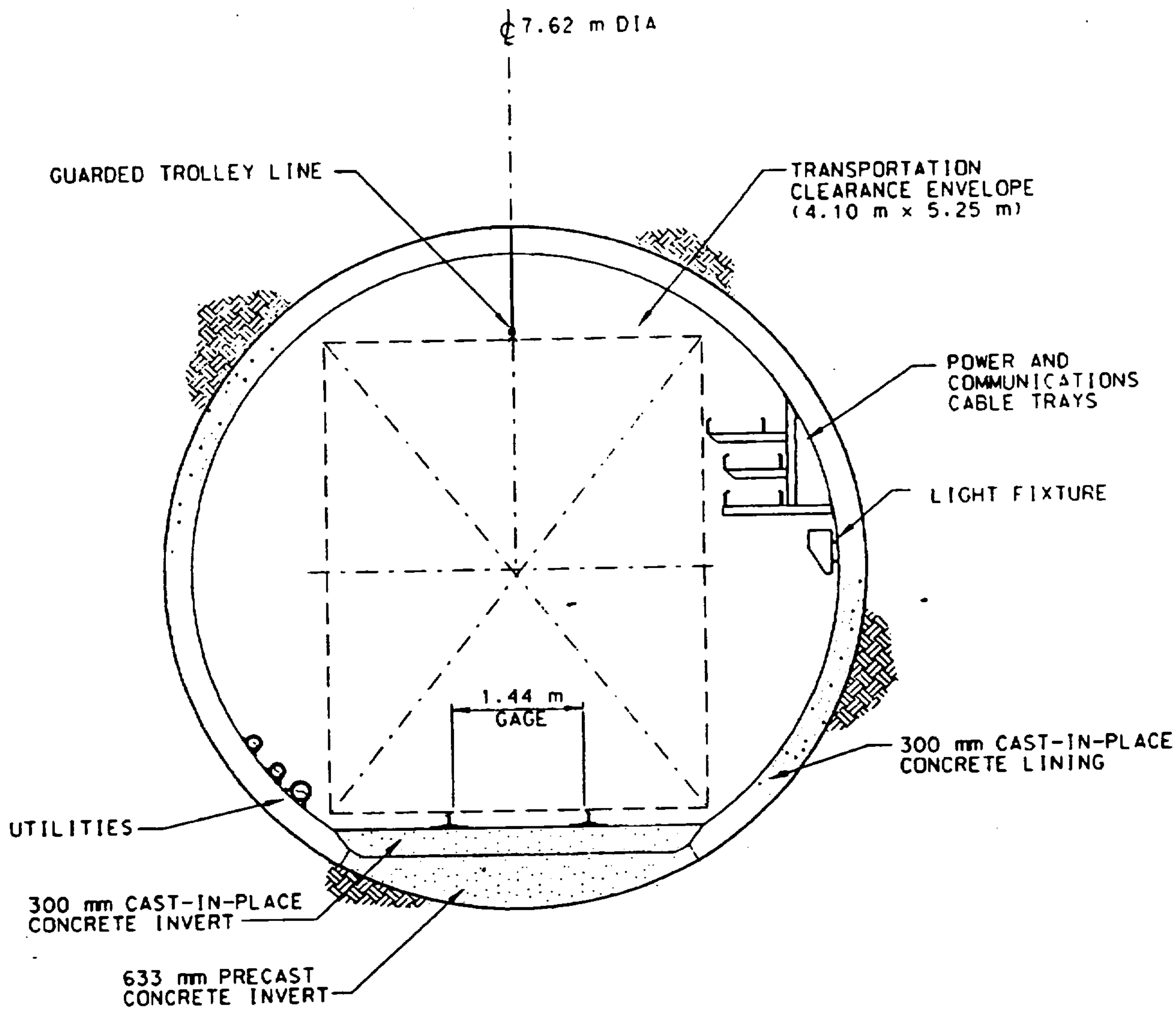

FIGURE 7-17
SECTION OF RAMPS AND MAINS
EMPLACEMENT MODE

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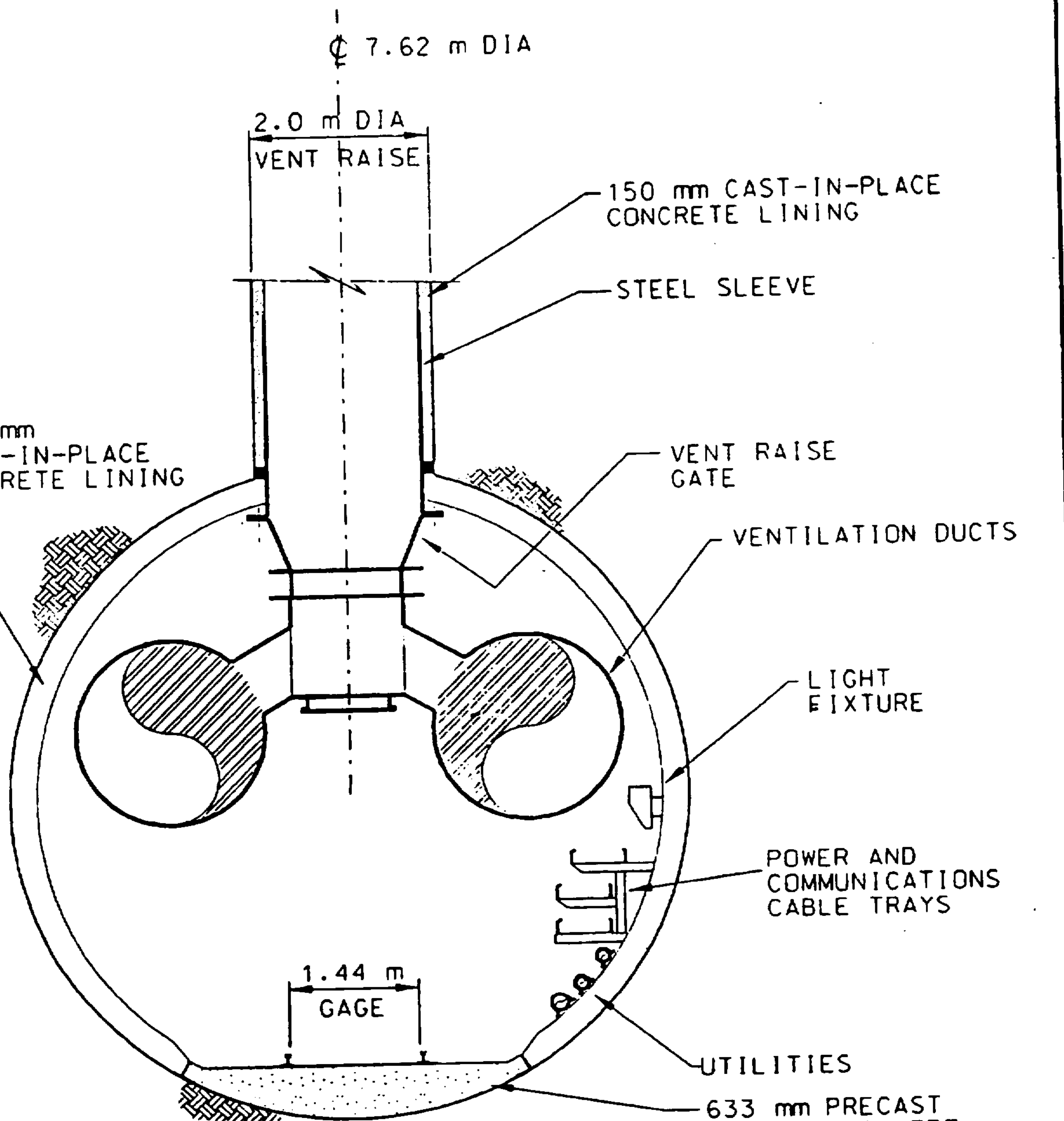

FIGURE 7-18
SECTION OF EXHAUST MAIN
EMPLACEMENT MODE

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The size of the emplacement drifts is determined by the equipment operating envelope required by the waste package gantry. The emplacement method and equipment sizes will be addressed in other analyses. The emplacement drifts will be excavated to 5.5 m diameter by TBM and, with the precast segmented concrete lining installed, will have an internal diameter of 5.1 m. The emplacement drifts are inclined upward at a 0.5% gradient towards the center for drainage. It is unlikely that preclosure water inflows will occur; if they do, the gradient will allow any water encountered during that period to drain back towards the mains. The elevation at the intersection of the centerline of an emplacement drift with the East Main will be the same as the intersection of the centerline of the same emplacement drift with the West Main.

For layout design, it is desirable to have the orientation of the centerlines of emplacement drifts intersect the main drifts at angles between 70 and 90 degrees. The curved turnouts at these intersections are set by the centerline intersection angles. For an emplacement drift alignment of N72W, the centerline intersects the East Main at 75 degrees. Emplacement drift/main intersections vary along the West Main because the West Main alignment is established by geologic boundaries with different orientations. The orientations and emplacement drift intersection angles of portions of the West Main will be as follows (from north to south): portion 1 will be S3W with intersections at 75 degrees; portion 2 will be S22W with intersections at 94 degrees; portion 3 will be S6W with intersections at 78 degrees; and portion 4 will be S9E with intersections at 63 degrees (Reference 5.39).

During the Construction and Development Modes, the emplacement drifts will contain a single 915 mm construction track with 42.44 kg/m rail, ventilation duct, and utility lines. The precast concrete invert and segmented lining, installed behind the TBM, will serve as the permanent ground support throughout the preclosure period. Figure 7-19 shows a typical cross section of the emplacement drifts during the Construction/Development Modes.

For the Emplacement Mode, a 2.58 m gage gantry track with 42.44 kg/m rail, reinforced concrete waste package piers and waste package steel support structures (collectively called waste package support assemblies), electric power supply, and control and monitoring systems will be installed in the emplacement drifts. The design and placement of the waste package support assemblies will be covered in other analyses. The waste package support assemblies could be installed at every invert segment or at other intervals to match the waste package emplacement plan, if available at the time of construction. An emplacement transfer dock, doors, and radiation shadow shields will be installed at the entrance to the emplacement drifts on both the east and west sides. Figure 7-20 shows a typical cross section of the emplacement drifts during the Emplacement Mode. Figure 7-21 shows a typical cross section of the emplacement drifts during emplacement operations which features the waste package gantry emplacing a waste package. Figure 7-22 presents a longitudinal section through Emplacement Drift #1 during the Emplacement Mode.

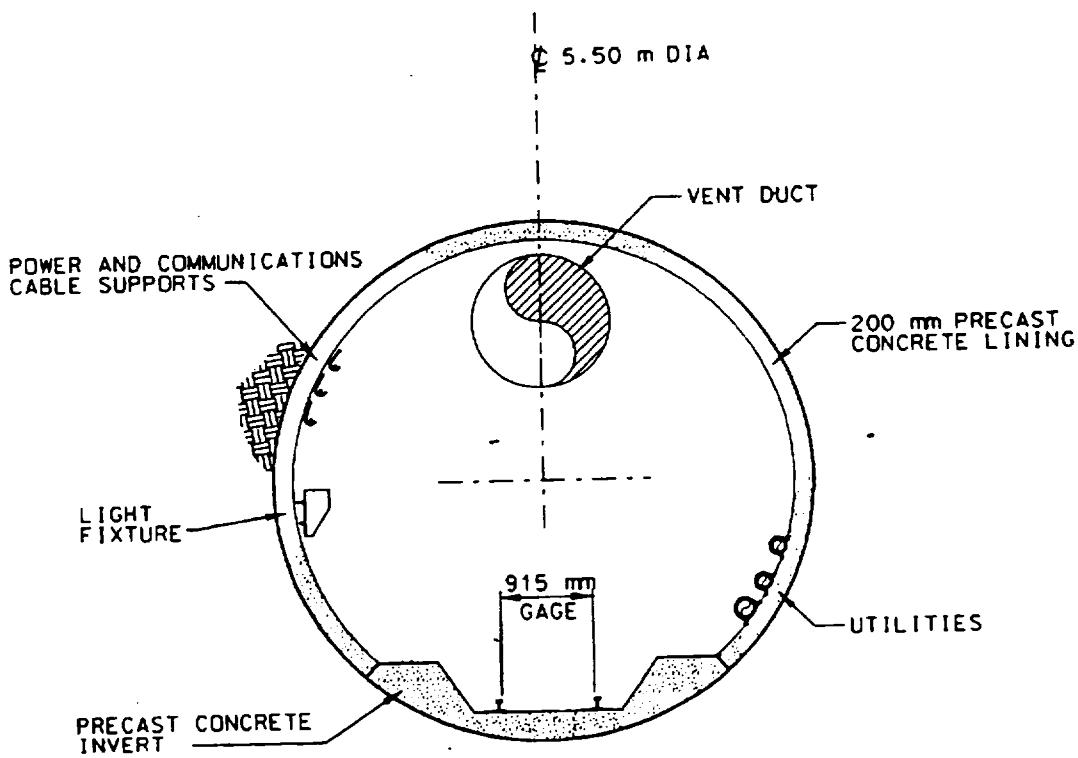

FIGURE 7-19
TYP SECTION OF EMPL DRIFTS
CONST/DEVELOPMENT MODES

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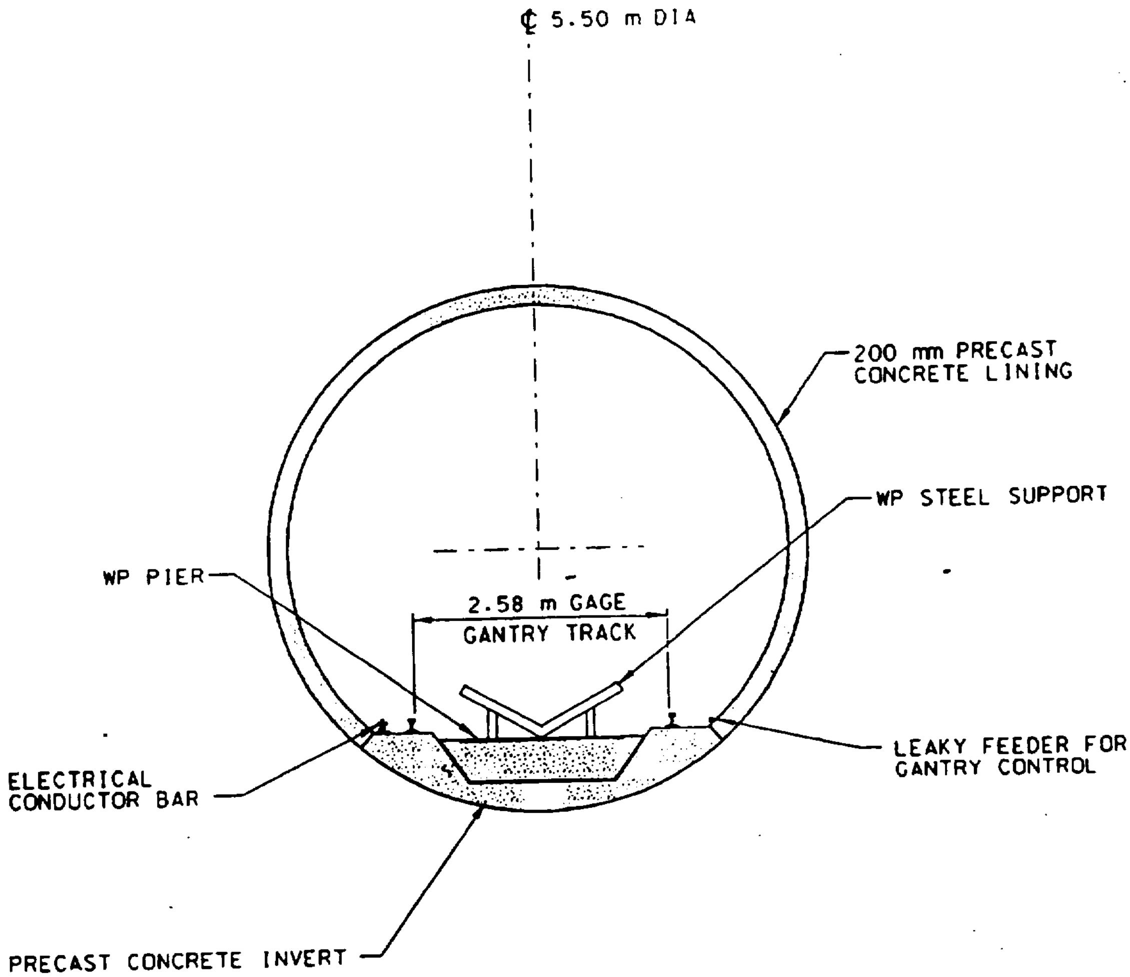

FIGURE 7-20
SECTION OF EMPL DRIFTS
EMPLACEMENT MODE

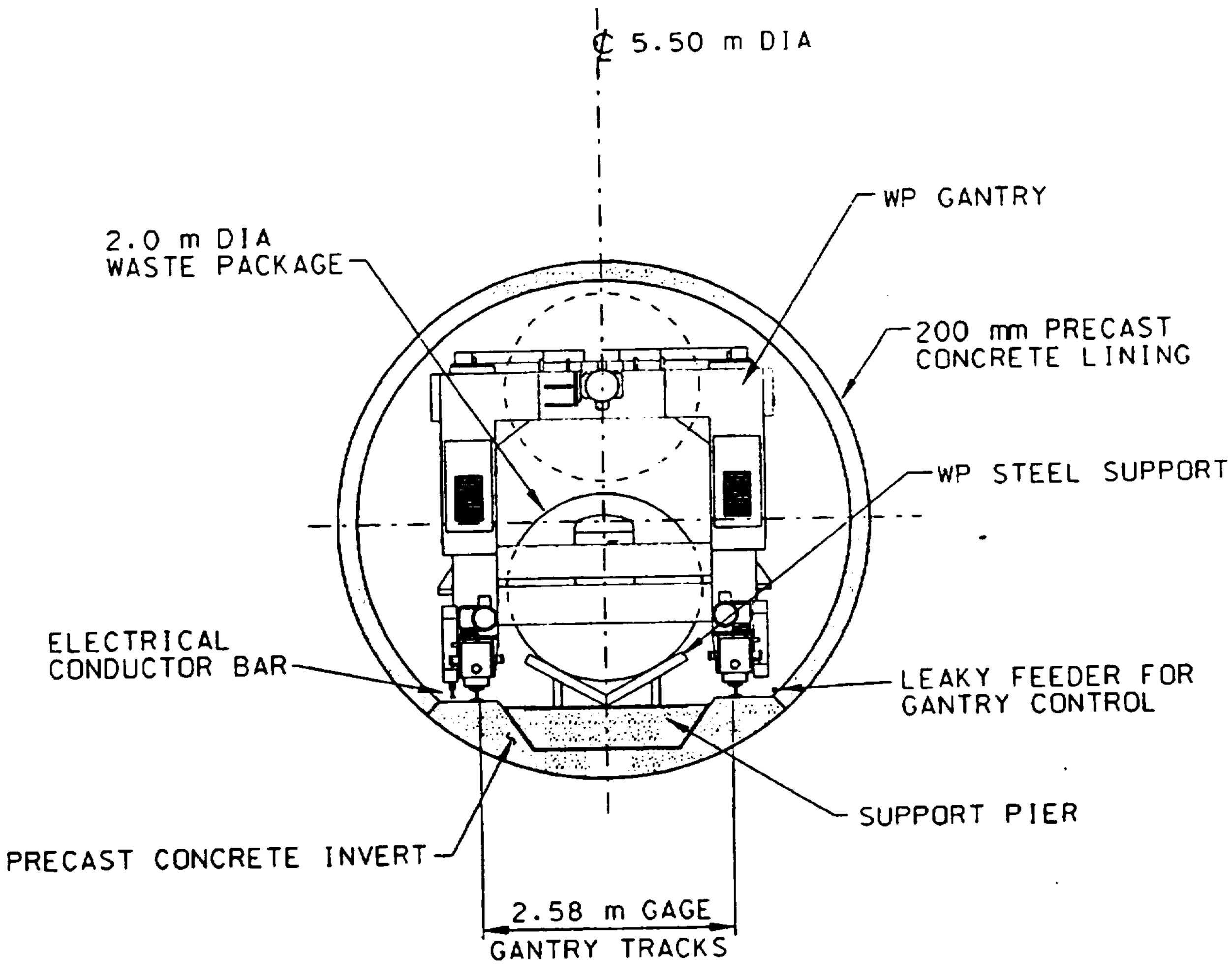

FIGURE 7-21
SECTION OF EMPL DRIFTS
EMPLACEMENT OPERATIONS

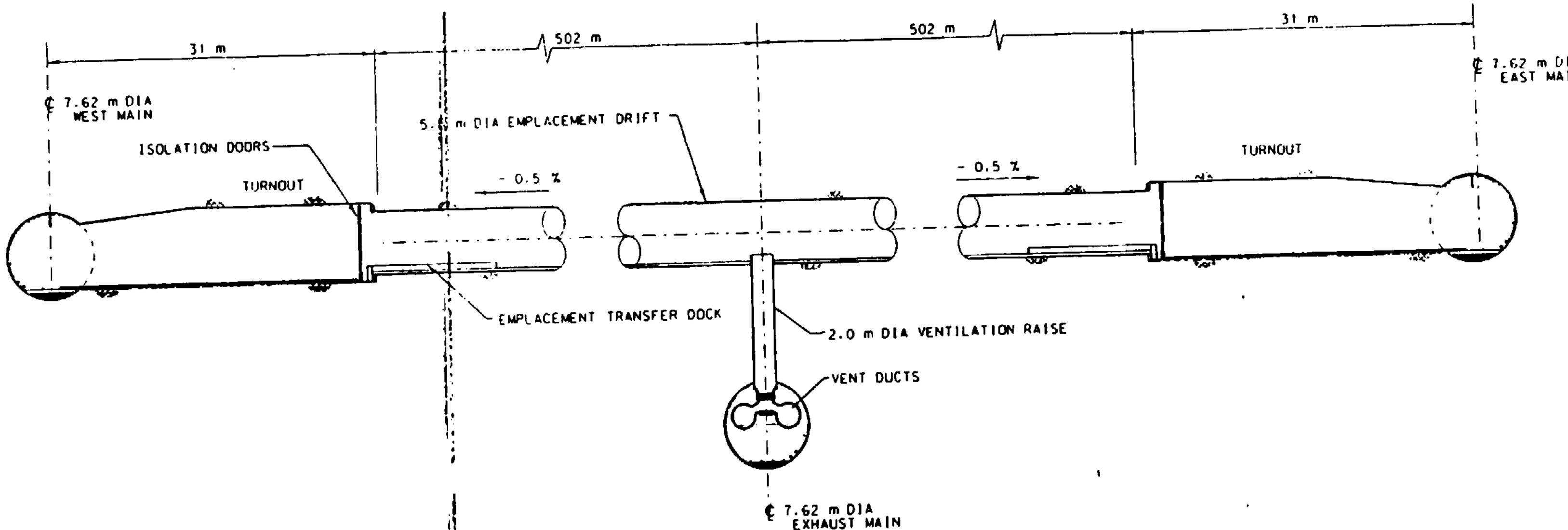

FIGURE 7-22
SECTION THROUGH EMPLACEMENT DRIFT #1 DURING EMPLACEMENT MODE

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Section 4.2.3 states that limiting the extraction ratio reduces the potential for deleterious rock movement and, therefore, decreases the opportunity for creating potential pathways for water. The maximum extraction ratio of the emplacement drifts is 30 percent. For the VA layout, the extraction ratio can be found by the following formula:

extraction ratio = (emplacement drift diameter / emplacement drift spacing) x 100

Using an emplacement drift diameter of 5.5 m and an emplacement drift spacing of 28 m yields an extraction ratio of 19.6 percent, which is well below the maximum allowed.

7.2.3 Ventilation Raises

The ventilation raises, located at the midpoint of the emplacement drifts, will connect the emplacement drifts to the Exhaust Main below. The 2.0 m diameter raises will be excavated by raise borer from the emplacement drifts, with a nominal length of 10 m from the invert of the emplacement drift to the crown of the Exhaust Main. The raises will serve as ventilation airways for emplacement operations and for performance confirmation monitoring activities. In establishing the length of the ventilation raises, several factors have been considered. Shorter raises, such as 5 to 10 m, will cause the Exhaust Main to heat up faster from the emplaced waste, but they have the advantage of shorter construction times and, consequently, lower costs compared to longer raises. The shorter raise helps reduce the ramp length connecting the North Main and South Ramp Extension to the Exhaust Main. A longer raise may require a longer curving ramp or shorter spiral ramp from the upper level to the Exhaust Main. Thermal analysis performed for locating the PC drifts above the emplacement block indicated that a 10-20 m separation between the emplacement drifts and the PC drifts was adequate provided sufficient air flow was maintained in the PC drifts (Reference 5.38). Provided adequate airflow can be provided to the Exhaust Main, the 10 m raises appear adequate. Future analyses will need to be performed on this topic.

The raises will be concrete lined with a steel transition section at the bottom. The transition section connects to a bifurcated steel section, which in turn connects to two circular ventilation ducts in the Exhaust Main. Instrumentation, sampling points, and control system devices will be installed for Emplacement Mode performance monitoring and ventilation control. Figure 7-23 shows a typical cross section and elevation view of the ventilation raises.

7.2.4 Shafts

Two shafts are required for the subsurface ventilation system. The Development Shaft located at the south end of the block will provide intake air for development, and the Emplacement Shaft located at the north end will carry exhaust air from the emplacement side. Both shafts will be equipped with ventilation fans. The shafts are sized to handle the required airflow for the subsurface operations. Final shaft diameters will be addressed by other analyses and could change from that stated in this analysis. The repository ventilation system design will be addressed in other analyses.

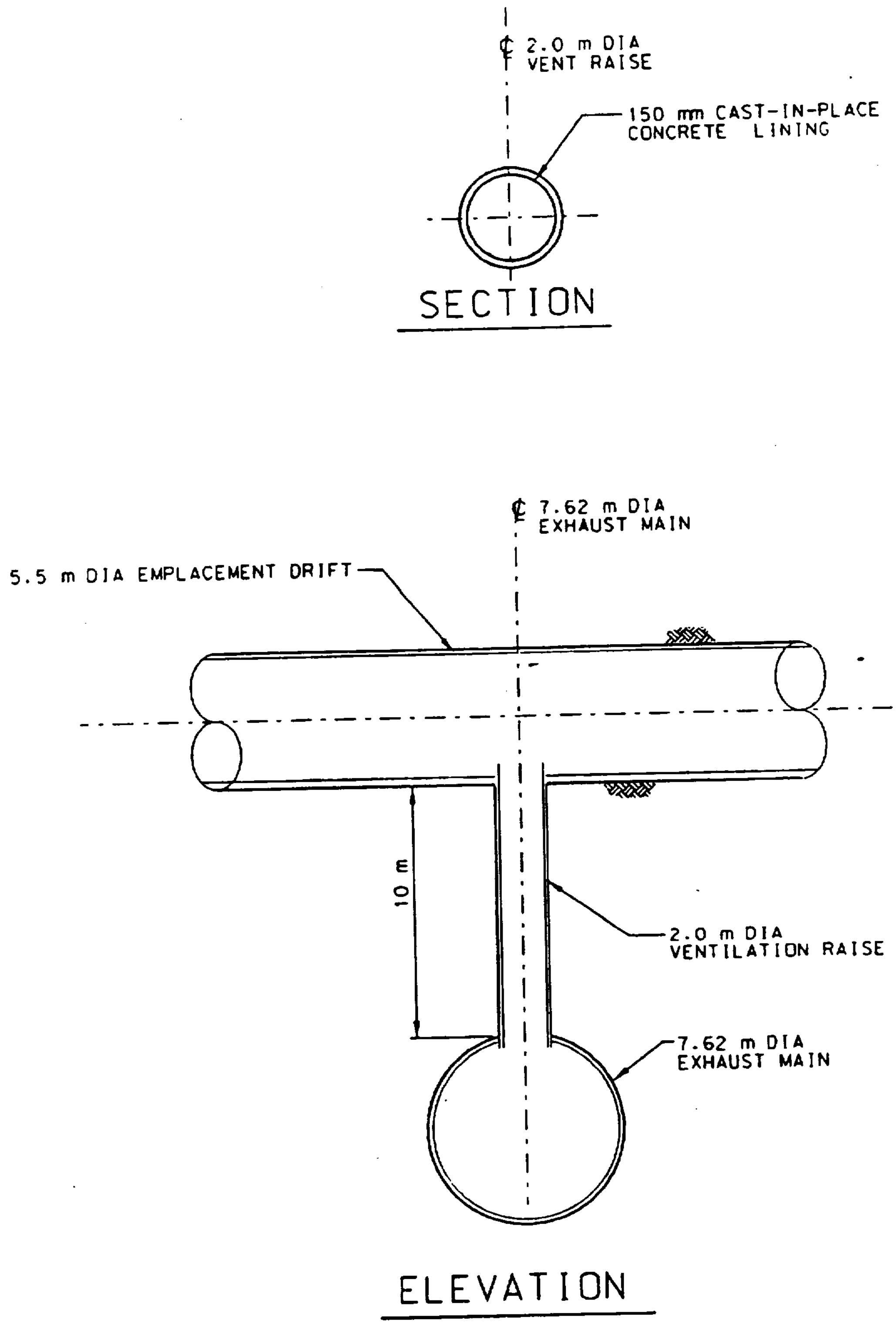

FIGURE 7-23
TYP SECTION AND ELEVATION
OF VENTILATION RAISES

Both shafts will be excavated by mechanical means in multiple phases. Shaft excavation will utilize a raise borer to first drill a pilot hole and then back ream a raise from the repository horizon to surface. A down reamer will enlarge the raise to the full excavated diameter and a cast-in-place concrete lining will be installed either concurrently with down reaming or from the bottom up on completion of the down reaming. The cast-in-place concrete lining will be placed over initial ground support installed for construction safety. Detailed shaft construction methods will be addressed in other analyses, which may consider alternative excavation approaches.

The shaft collars will be located to avoid steep terrain that would require extensive earth moving for pad and road construction, and to avoid potential flood areas (Section 4.2.8). The collar and subsurface locations must also be compatible. The Emplacement Shaft is located close to the Exhaust Main and inside the outline of the Perimeter Construction Loop. The Development Shaft is located close to the South Ramp Extension at the southwest corner of the emplacement block. The location of the shafts are as follows: Emplacement Shaft N 235580, E 170790; and Development Shaft N 230890, E 170360. The rugged topography above the repository location severely limits potential shaft locations; although, for the selected subsurface locations for both shafts in the VA design layout, suitable shaft collar pads are available on surface. Figures 7-24 and 7-25 show the surface locations of the Development Shaft and Emplacement Shaft with respect to the topography (Reference 5.7).

The shafts will be 6.1 m inside diameter. Based on the ground support thickness in Section 7.1.9.6, they will have a minimum 6.7 m excavated-diameter. The Emplacement Shaft will be 422 m in depth and the Development Shaft will be 347 m in depth with a 5 m sump included at the bottom of each shaft. Attachment IV contains the calculations for the depths of the shafts. Emergency hoisting systems will also be installed in both shafts. An access area around the bottom of the shaft will be provided for each shaft to accommodate operations. It will be the same height as the access drifts (Section 7.2.5). Figures 7-26 and 7-27 show typical cross sections and elevation views of the Development and Emplacement Shafts.

7.2.5 Secondary Openings

The secondary openings will be excavated by roadheader and will have a horseshoe-shaped cross section. In general these openings are too short for TBM excavation and require something other than a circular cross section. Secondary openings include the TBM assembly and disassembly chambers, emplacement drift turnouts, and access drifts. Alcoves are discussed separately in Section 7.2.6.

The TBM assembly chambers will serve as areas to assemble and launch the 7.62 m diameter TBM that will excavate the mains. The TBM disassembly chambers will serve as areas to recover the 7.62 m TBM when it finishes excavation and disassemble it. The lead-in and assembly/disassembly sections will contain a 200 mm cast-in-place concrete lining for ground support. The launch section in the assembly chambers will not have any ground support initially as the excavation will be just large enough to launch the TBM with it's own grippers. A 200 mm cast-in-place concrete lining will be added later to match the rest of the chamber. The TBM assembly and disassembly chambers are shown in Figures 7-28 and 7-29.

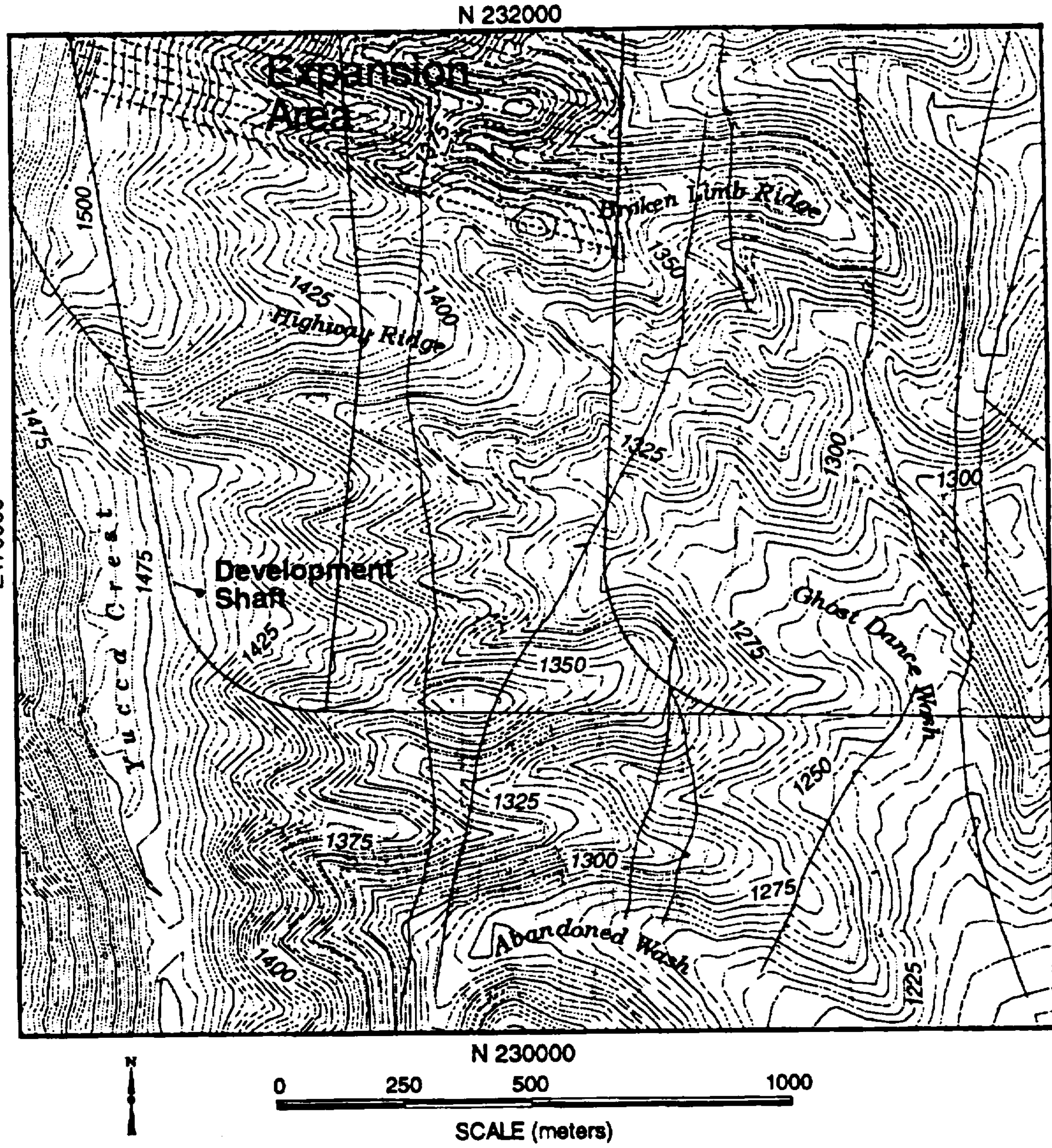

FIGURE 7-24
SURFACE LOCATION
DEVELOPMENT SHAFT

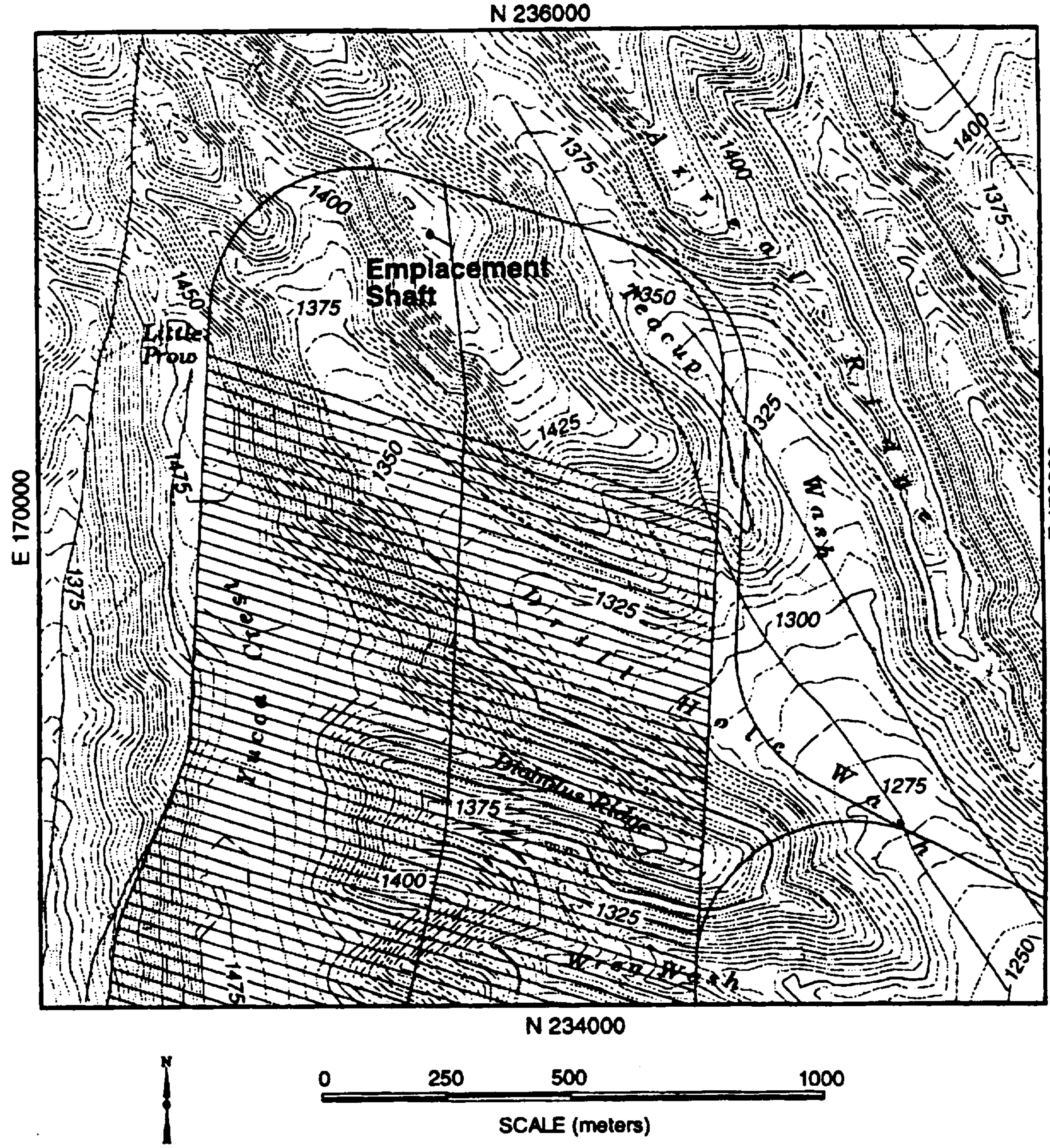

FIGURE 7-25
SURFACE LOCATION
EMPLACEMENT SHAFT

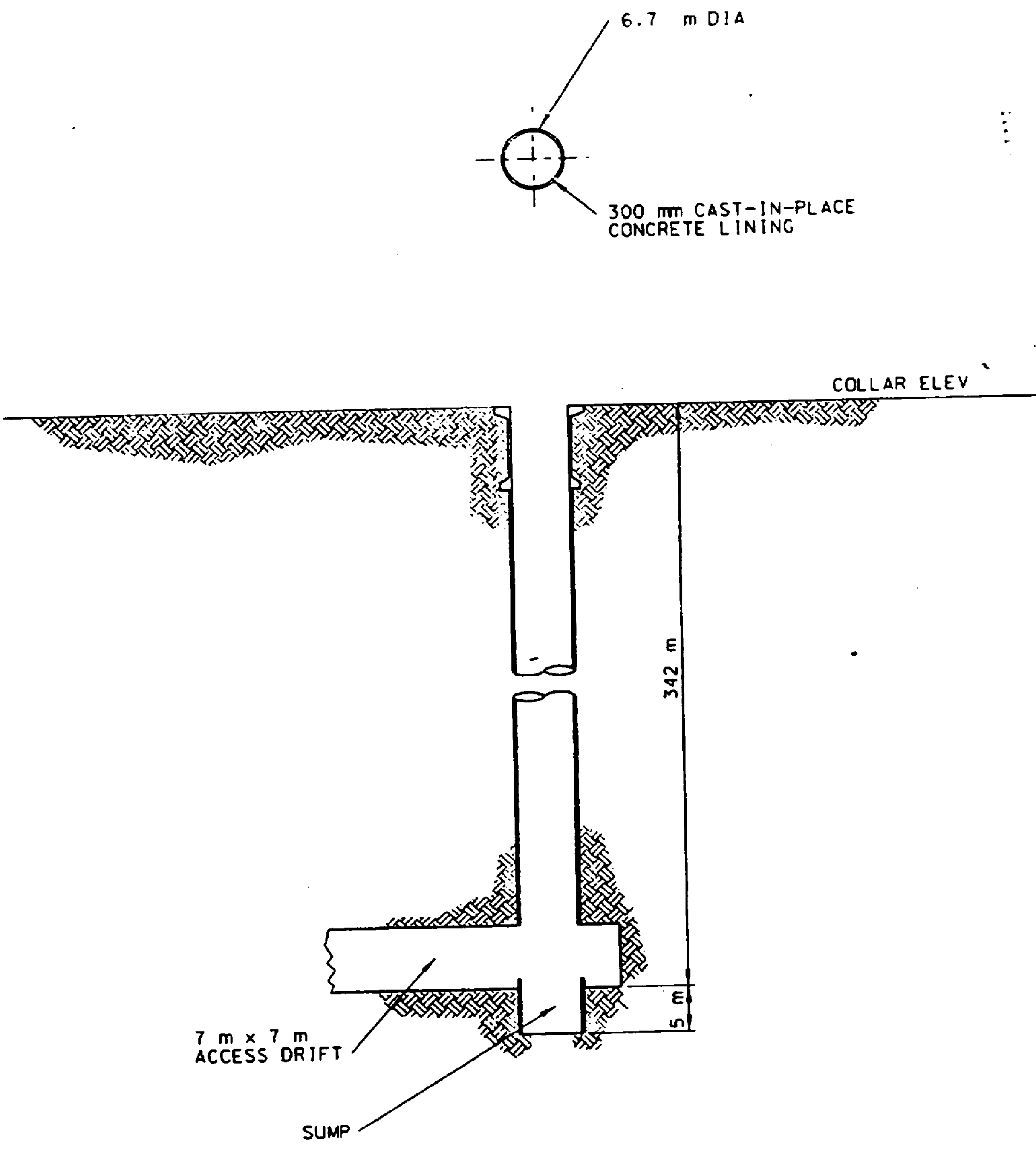

FIGURE 7-26
TYP SECTION AND ELEVATION
OF DEVELOPMENT SHAFT

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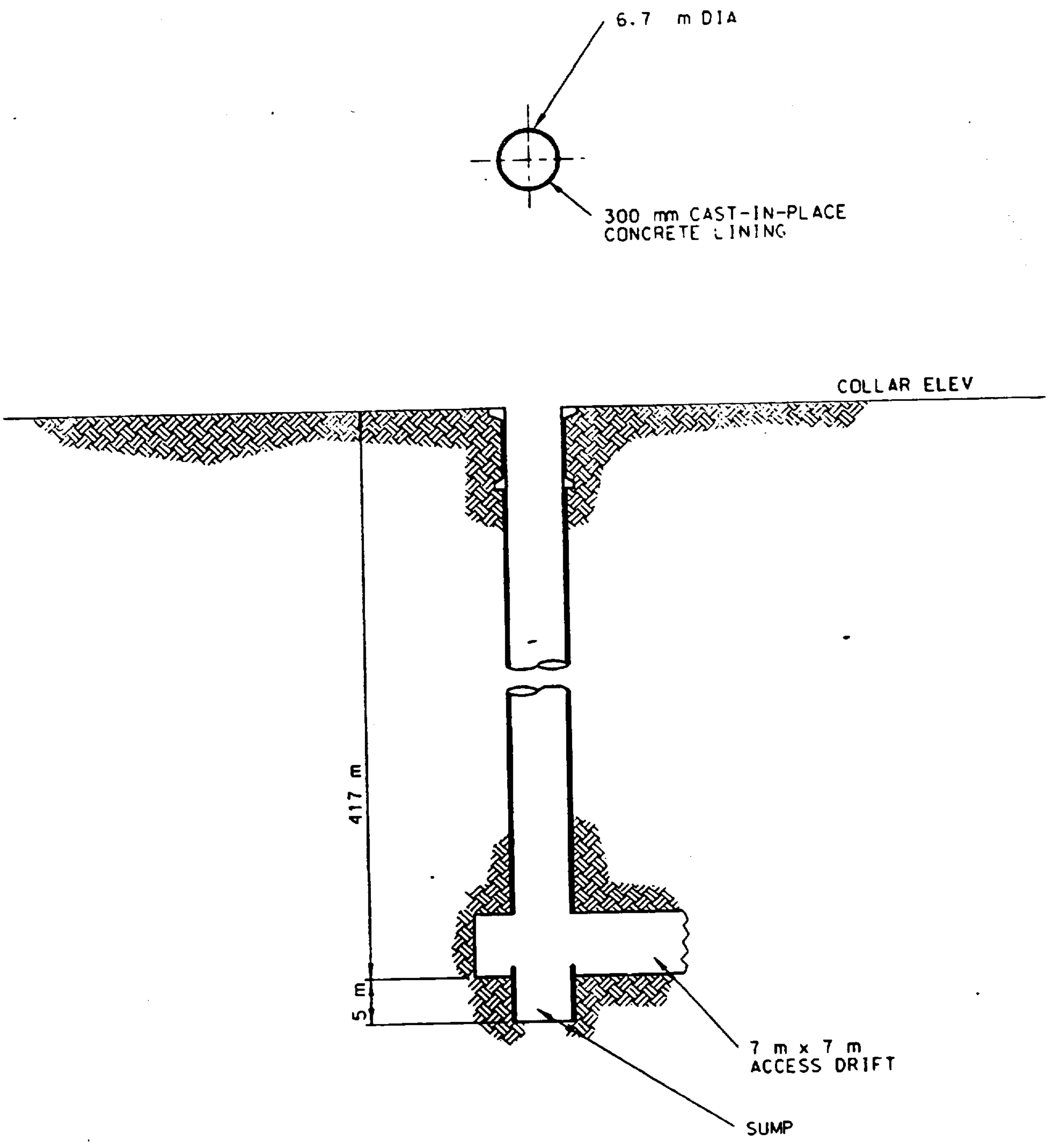

FIGURE 7-27
TYP SECTION AND ELEVATION
OF EMPLACEMENT SHAFT

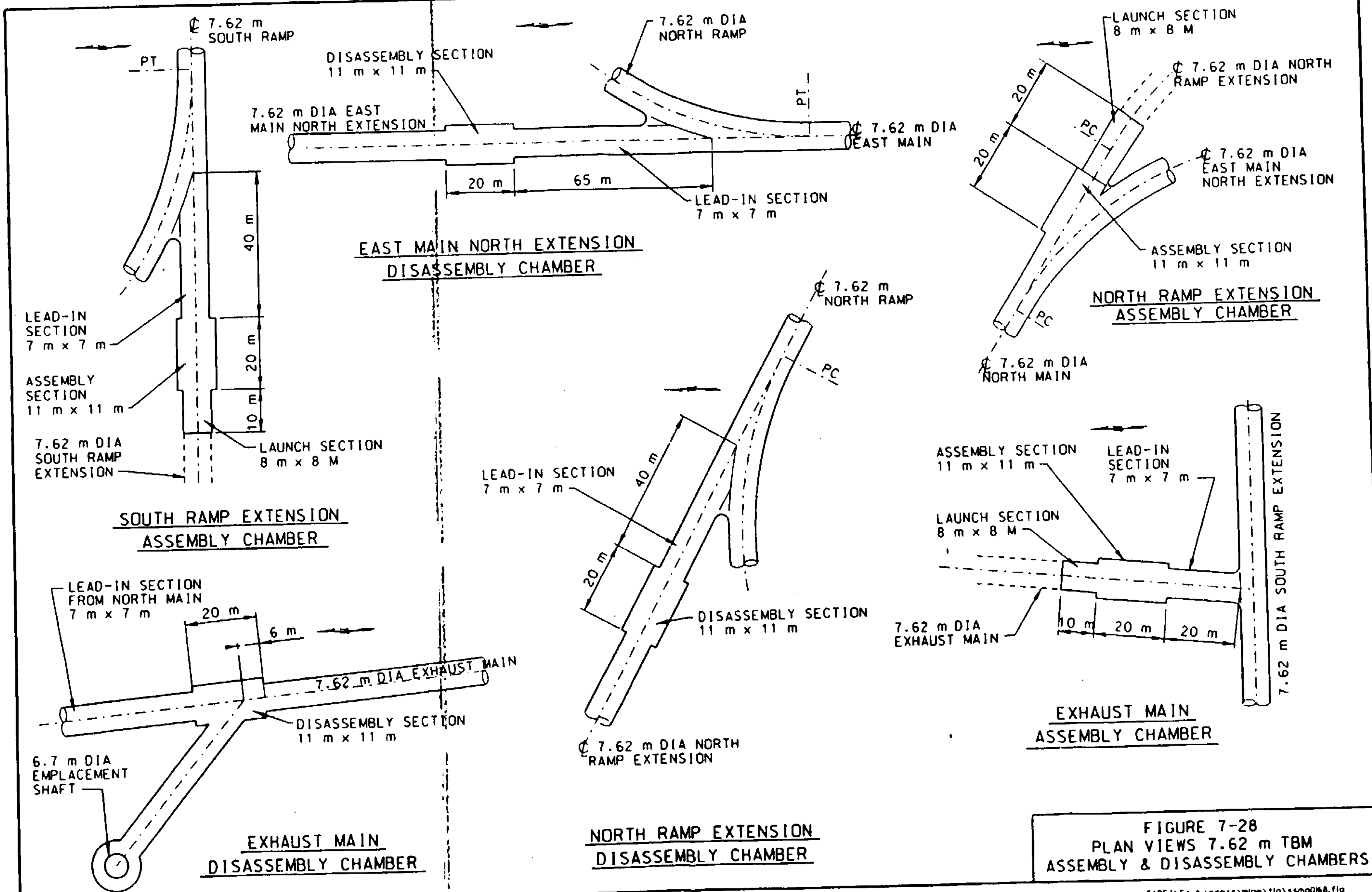

FIGURE 7-28
PLAN VIEWS 7.62 m TBM
ASSEMBLY & DISASSEMBLY CHAMBERS

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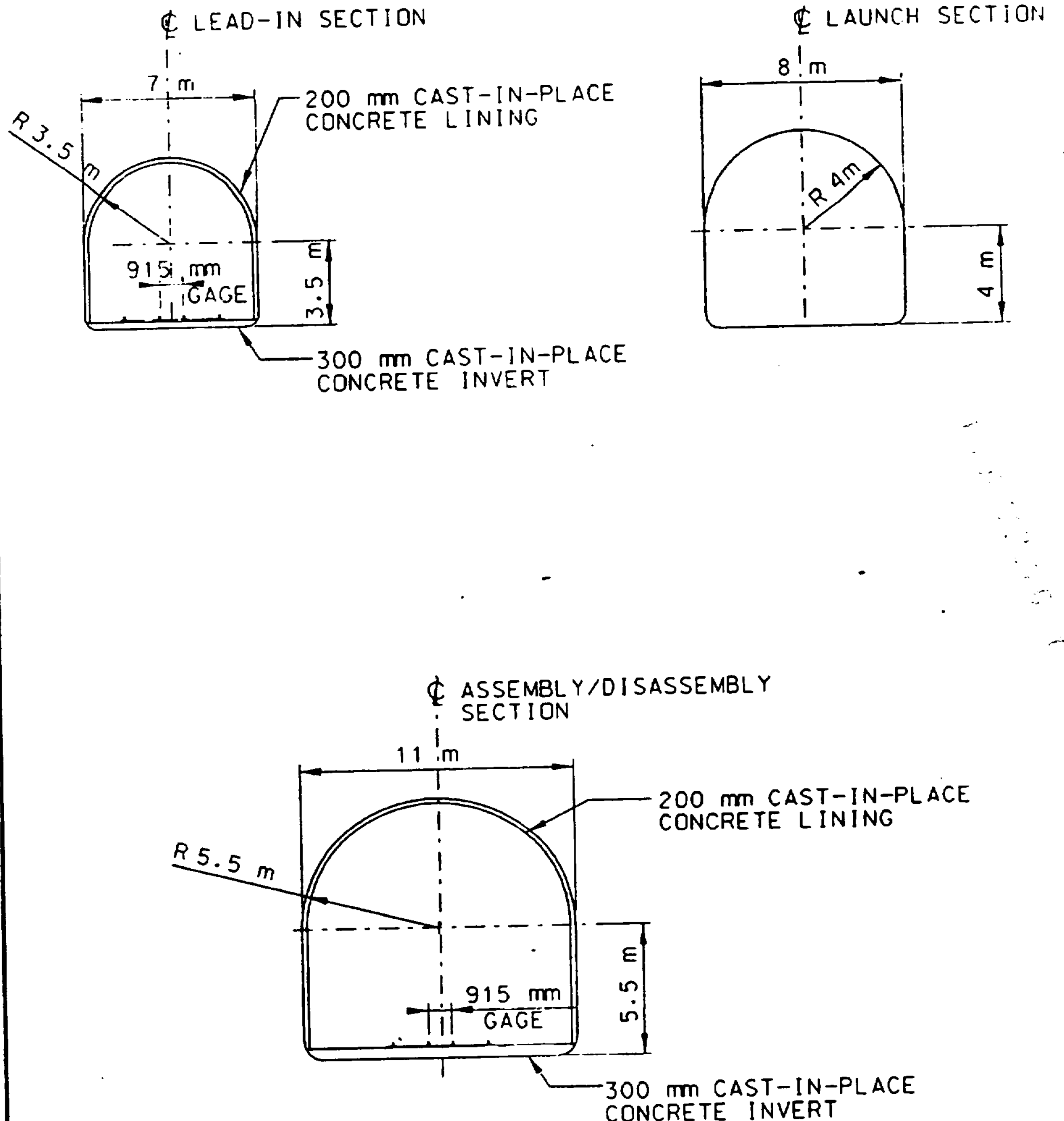

FIGURE 7-29
ASSEMBLY & DISASSEMBLY CHAMBERS
TYPICAL SECTIONS

The emplacement drift turnouts will function as a transition from the East and West Mains into the emplacement drifts. They will have a curved section with a 20 m radius along the centerline of the turnout that will allow rail haulage for both construction and emplacement; and they will have a straight section for launching the TBM and unloading the waste package transporter in line with the emplacement drift. Final radii of the turnout walls will be dependent on equipment clearances and track requirements. The excavation of the turnouts originates from the top of the precast concrete invert in the mains. The step between the invert of the turnout and the invert of the emplacement drift at the entrance to the emplacement drift will be to accommodate waste emplacement operations. The step is estimated to be 0.8 m high for the current emplacement strategy. The slope of the turnouts will be the same as the emplacement drifts for simplicity. The actual slope of the turnouts will be dependent on the drainage of the turnouts into the mains. The length of the turnouts depends on the angle of intersection of the mains and the centerline of the emplacement drifts. The size of the turnouts will be dependent on equipment operations for construction/development and emplacement operations. The equipment that impact the size of the turnouts will be the 5.5 m TBM during construction/development and the waste package transporter and gantry carrier during emplacement operations. The geometry of the turnouts is summarized in Table 7-3. The turnouts are illustrated in Figures 7-30 and 7-31. Figure 7-32 shows the East Main turnouts with a TBM, waste package transporter, and gantry carrier for comparison. The ground support in the turnouts will be initial ground support for construction and development operations. A 200 mm cast-in-place concrete lining will be added prior to emplacement operations. A temporary invert will also be used during construction and development operations because of the height requirements for the step. A 300 mm permanent concrete cap will be installed prior to emplacement operations.

Table 7-3 Geometry of Emplacement Drift Turnouts

Opening	Size (width x height)	Length (m)
East Main Turnouts		
Curved Section	8 m x 6-7 m	17.6
Straight Section	8 m x 7 m	16.0
West Main Turnouts 1-29		
Curved Section	8 m x 6-7 m	17.6
Straight Section	8 m x 7 m	16.0
West Main Turnouts 30-43		
Curved Section	8 m x 6-7 m	22.4
Straight Section	8 m x 7 m	16.0
West Main Turnouts 44-91		
Curved Section	8 m x 6-7 m	18.7
Straight Section	8 m x 7 m	16.0
West Main Turnouts 92-120		
Curved Section	8 m x 6-7 m	13.4
Straight Section	8 m x 7 m	16.0

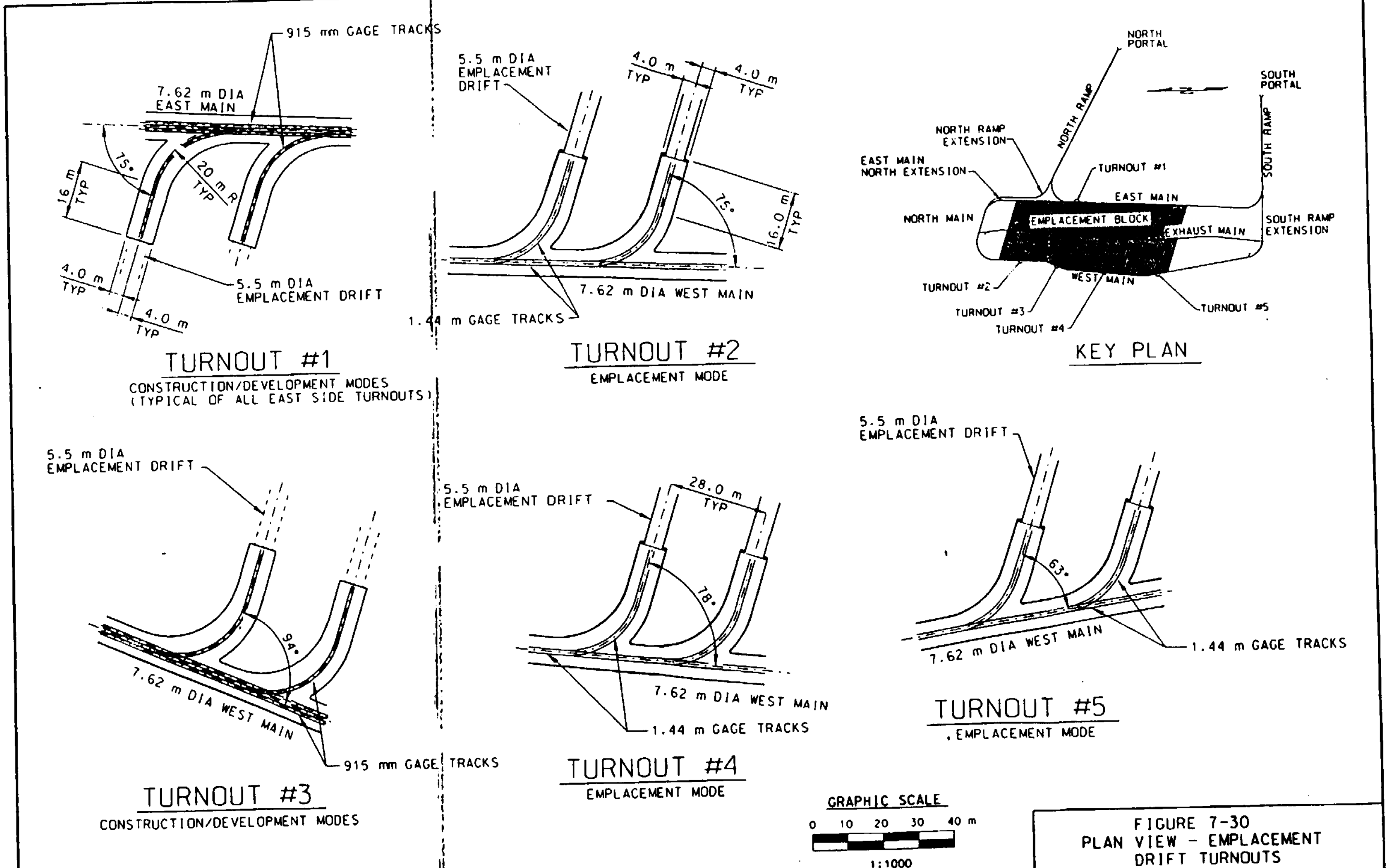

FIGURE 7-30
PLAN VIEW - EMPLACEMENT
DRIFT TURNOUTS

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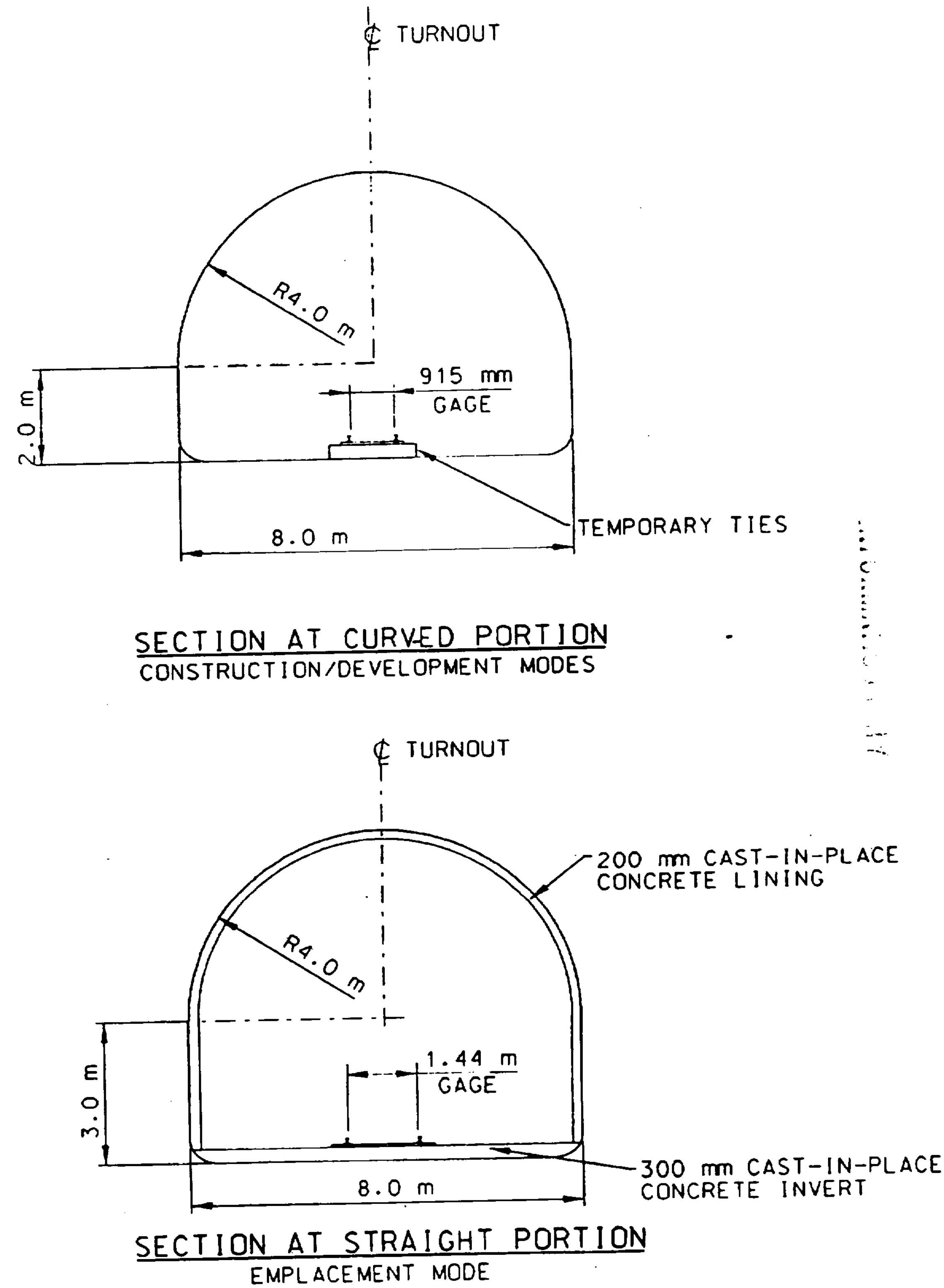

FIGURE 7-31
EMPLACEMENT DRIFT TURNOUTS
TYPICAL SECTIONS

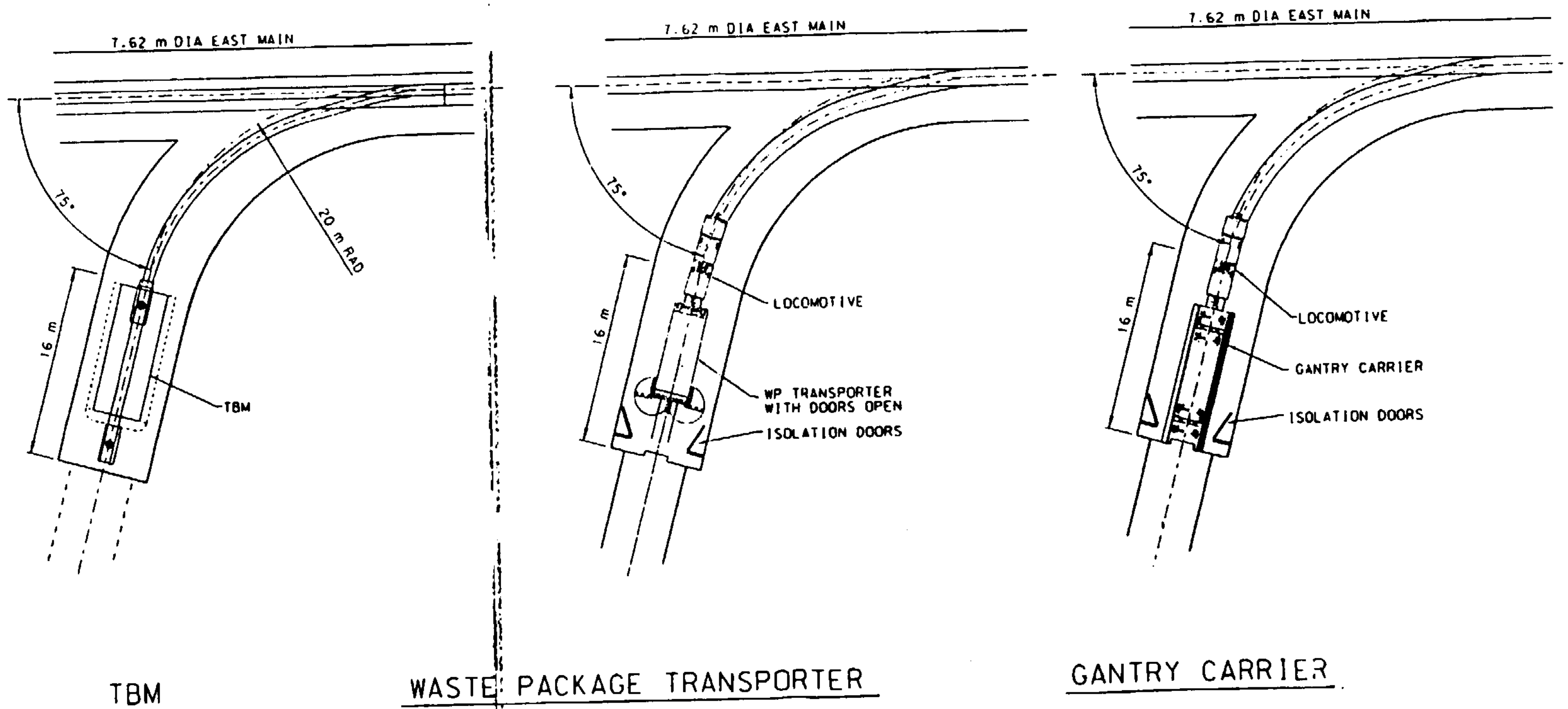

FIGURE 7-32
PLAN VIEW EAST MAIN TURNOUTS
WITH VARIOUS EQUIPMENT

The access drifts connect the main drifts to the shafts. These drifts include the Development Shaft/South Ramp Extension Connector and the Emplacement Shaft/Exhaust Main Connector. Access drift configurations are shown conceptually, the actual configuration of the access drifts will be determined by other analyses because the ventilation strategy may have a significant impact on them. The access drifts are horseshoe shaped at 7 m wide x 7 m high. The access drifts are depicted in Figure 7-33 with the cross section depicted as during emplacement operations.

7.2.6 Alcoves

The alcove sizes, shapes, and configurations will depend on their functions. Some alcoves will be dedicated to performance confirmation while others will serve operational needs. The geometry, location, and quantity of the alcoves is not anticipated to have a significant impact on the configuration of the layout.

Performance confirmation alcoves will contain testing and monitoring equipment to gather information used to determine the performance of the natural and engineered barrier systems in the repository. These alcoves are discussed in Section 7.1.11.

Operational alcoves include: personnel/refuge chambers, which can serve multiple personnel functions; electrical equipment alcoves; water collection/sump alcoves; equipment decontamination chamber; and personnel decontamination chamber. The preliminary locations of the operational alcoves are shown in Figure 7-34. The actual locations and sizes will be determined in future analyses.

Preliminary sizing of personnel/refuge chambers for the repository will follow the sizing and location determination used in the ESF. Section 4.1.7 states that the personnel/refuge chambers should be 3.7 m x 3.7 m x 21.0 m long. The ESF alcoves were sized for 56 persons, a number based on projected ESF personnel expected to be underground. Further analysis will be required to determine the size and capacity of repository personnel/refuge chambers. Figure 7-35 shows a typical personnel/refuge chamber.

Electrical equipment alcoves will be required in the repository for electrical support. There will be two different size alcoves for this purpose. The large alcoves will support a trolley rectifier, substation, and switchgear box. They will be 4.5 m wide x 4.5 m high x 14 m long. The smaller alcoves will support a substation and switchgear box. They will be 4.5 m wide x 4.5 m high x 8.5 m long. There will be 5 large and 6 small electrical equipment alcoves distributed throughout the repository. Figure 7-36 shows typical views of the electrical equipment alcoves.

The repository will utilize collection sump/tank alcoves for controlling water inflow (Section 4.1.8). The collection sump/tank alcove has two sections. The first section is the tank alcove which accommodates a 18,900 liter tank. It will be 3.46 m deep at midpoint x 3.35 m high x 9.5 m long. The second section is the sump which will be formed by removing one precast concrete invert segment and modifying the excavation. It will be 10.31 m wide x 1.58 m high x 1.2 m long. Water will be collected in the sump first and then pumped into the tank for storage before

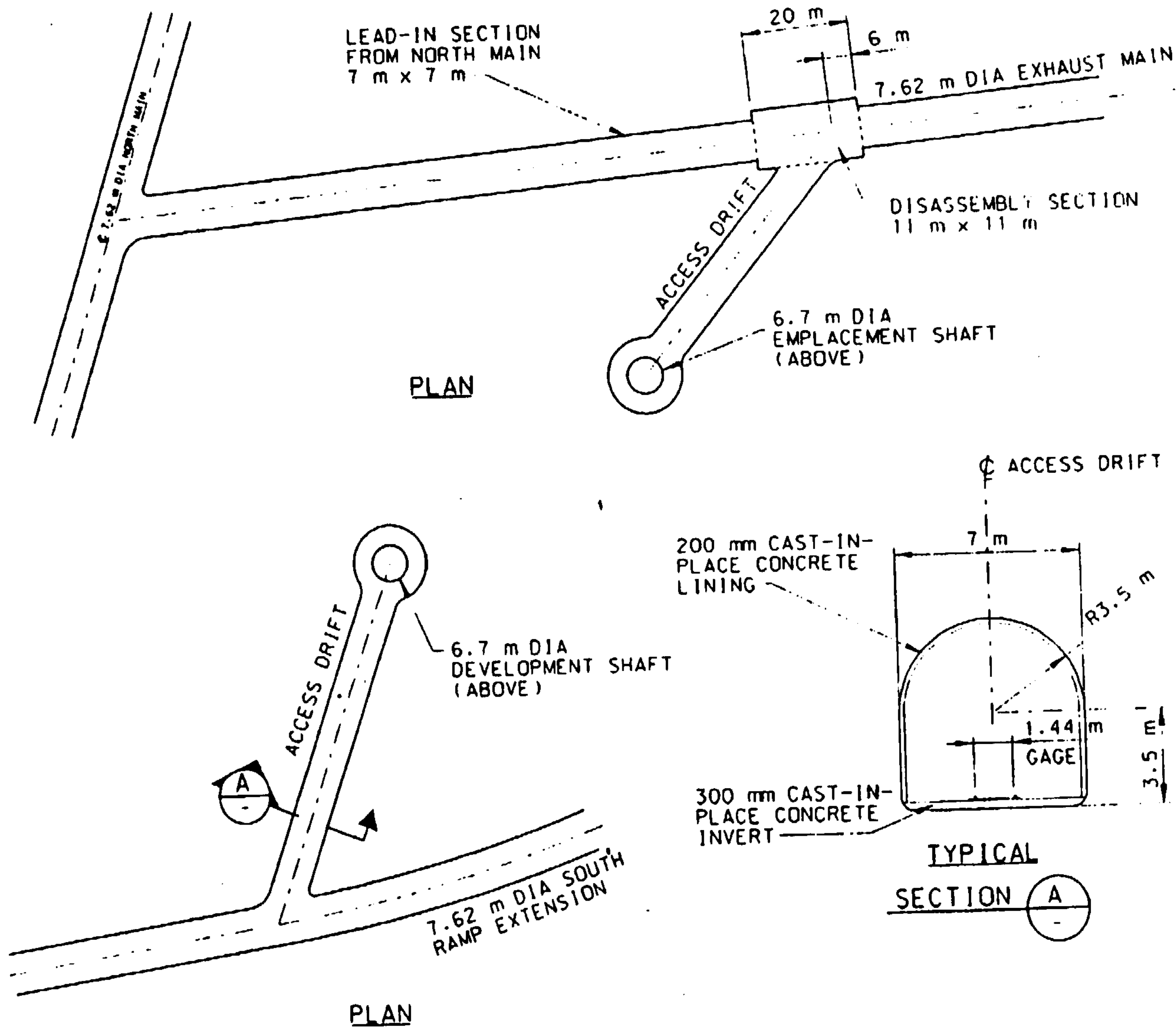

FIGURE 7-33
PLAN AND SECTIONAL VIEWS OF ACCESS DRIFTS

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The access drifts connect the main drifts to the shafts. These drifts include the Development Shaft/South Ramp Extension Connector and the Emplacement Shaft/Exhaust Main Connector. Access drift configurations are shown conceptually, the actual configuration of the access drifts will be determined by other analyses because the ventilation strategy may have a significant impact on them. The access drifts are horseshoe shaped at 7 m wide x 7 m high. The access drifts are depicted in Figure 7-33 with the cross section depicted as during emplacement operations.

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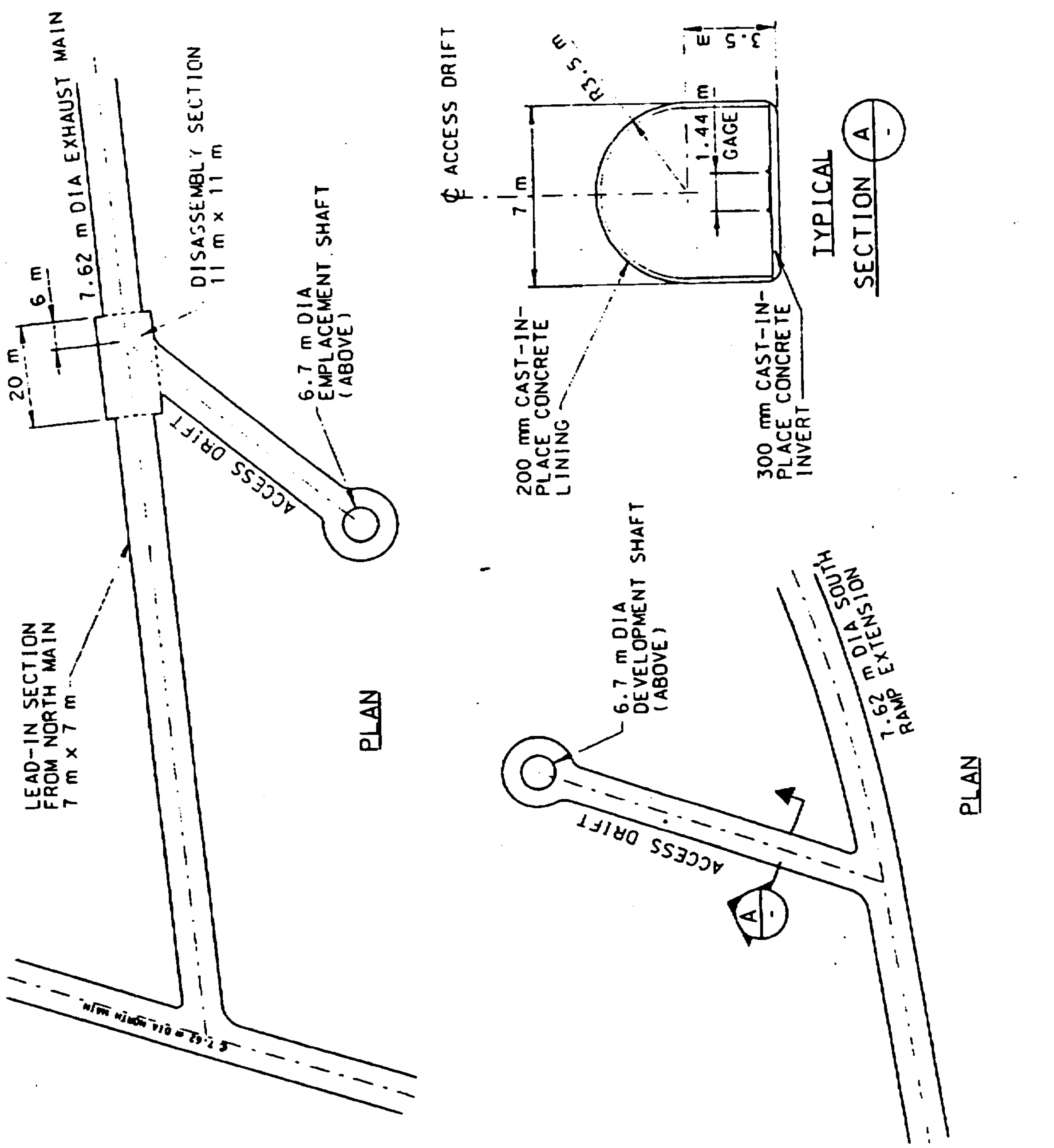

FIGURE 7-33
PLAN AND SECTIONAL
VIEWS OF ACCESS DRIFTS

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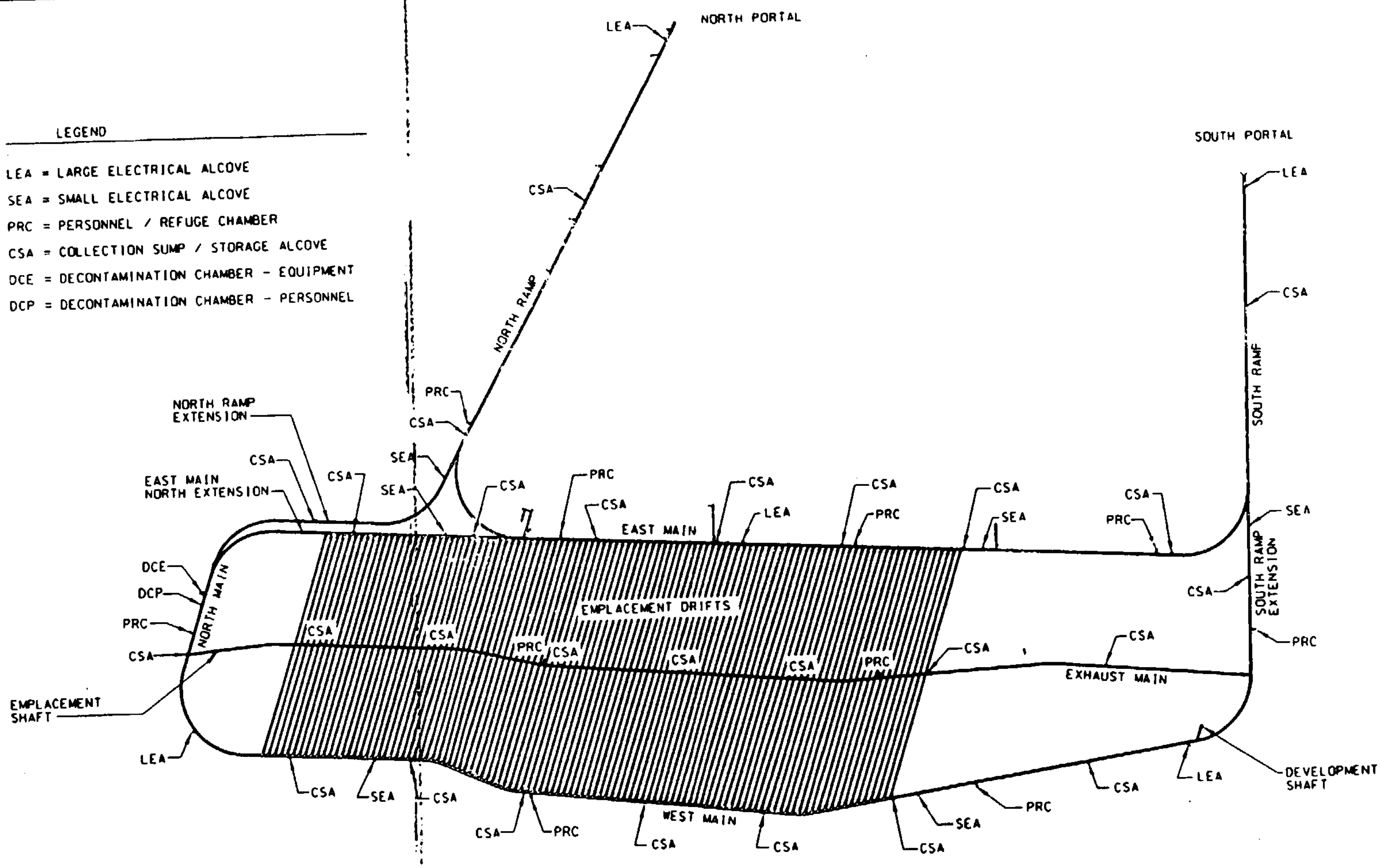

FIGURE 7-34
SUBSURFACE REPOSITORY LAYOUT
LOCATION OF OPERATIONAL ALCOVES

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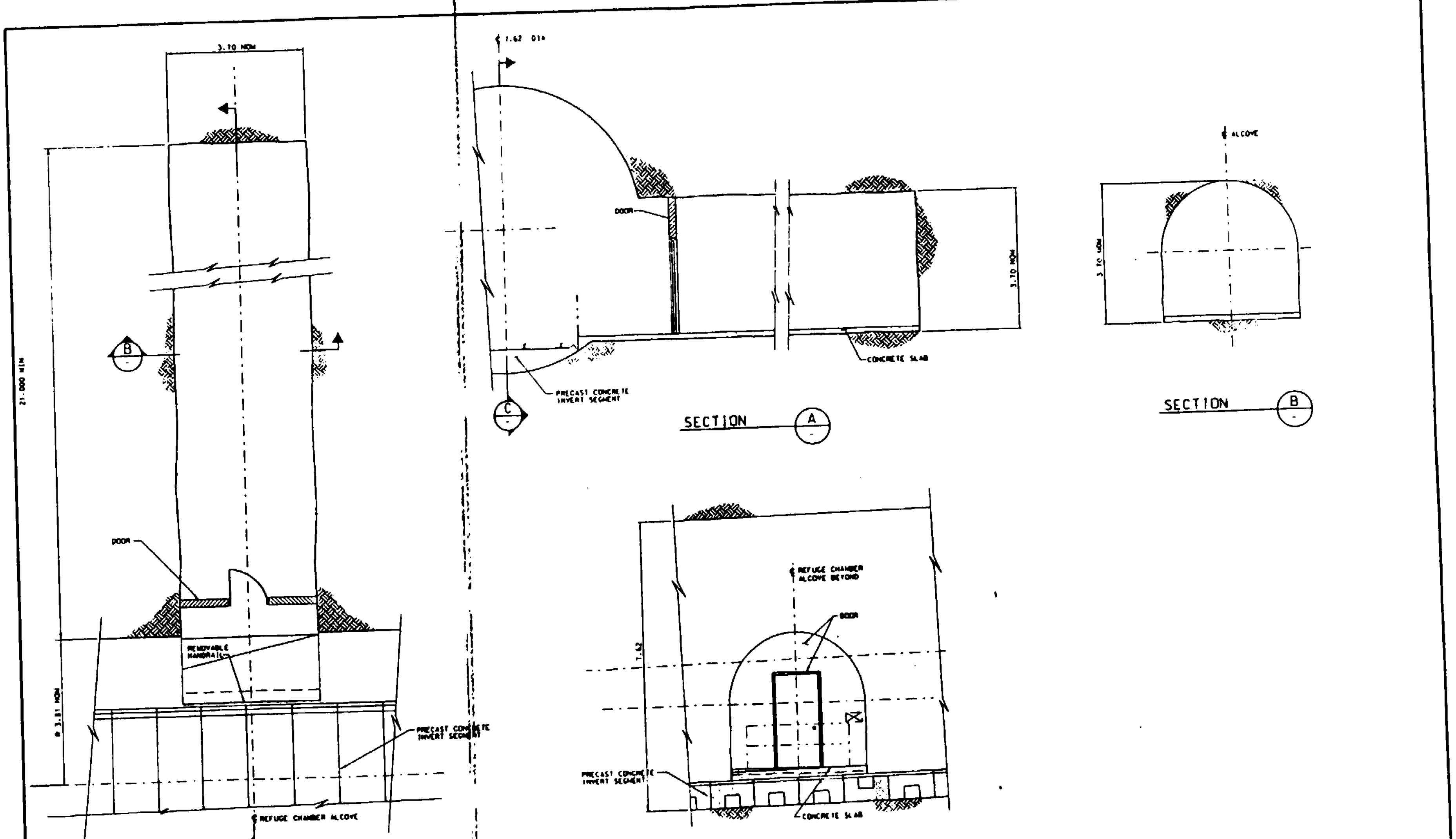

FIGURE 7-35
TYPICAL PERSONNEL/REFUGE CHAMBER

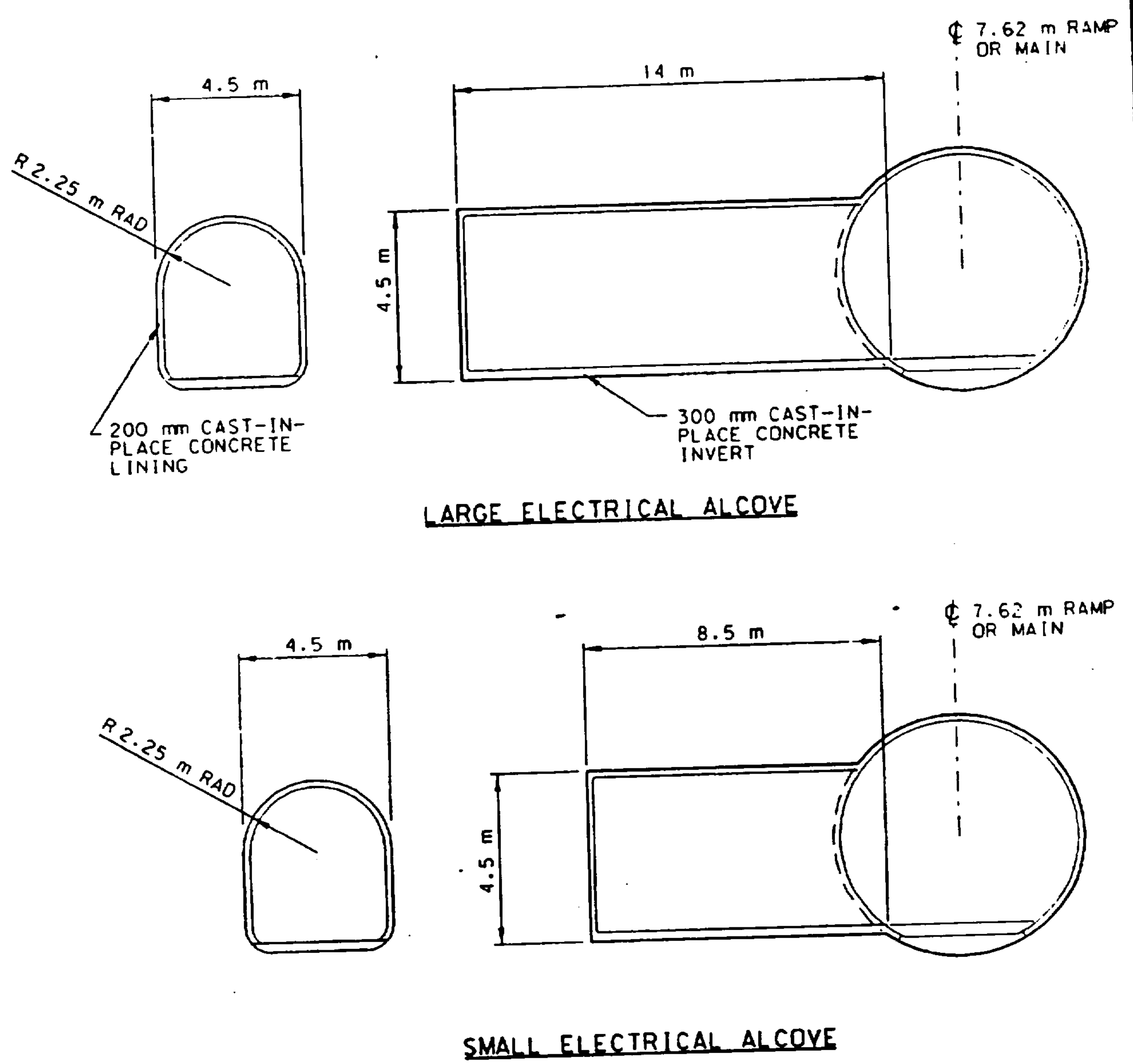

FIGURE 7-36
TYPICAL ELECTRICAL
EQUIPMENT ALCOVES

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being removed to the surface. There will be 27 collection sump/tank alcoves in the repository. They are located at various intervals in the ramps and are located to match emplacement panels in the East, West, and Exhaust Mains. Figure 7-37 shows a typical collection sump/tank alcove.

Decontamination chambers will also be provided in the repository during emplacement operations: one for equipment and one for personnel. The equipment chamber will be approximately 7.5 m wide x 7 m high x 21 m long to support the largest piece of equipment for emplacement operations that has the potential for becoming contaminated: the waste package gantry atop the gantry carrier. The personnel chamber will be the same cross-sectional area as a refuge chamber but shorter; this equates to 3.7 m wide x 3.7 m high x 4.0 m long. Both decontamination chambers are located at the north end of the block along the North Main, which is a non-emplacement area. Figures 7-38 and 7-39 depict the decontamination chambers for equipment and personnel, respectively.

The ESF alcoves may be used as performance confirmation testing facilities in the repository. These alcoves will not be considered for use as personnel/refuge chambers or for other operational purposes at this time. There may be a time when these particular alcoves have served their purpose and can be turned over for operational use, but repository design does not rely on this at this time.

7.2.7 Performance Confirmation Drifts

The performance confirmation (PC) drifts and main will be located approximately 15 m above the repository block. They will be 5.5 m in diameter and excavated by a TBM so are the same size and shape as the emplacement drifts for simplicity. There are five PC drifts that are approximately equally spaced across the block. They will follow the orientation and slope of the emplacement drifts. The first PC drift originates from the North Ramp. The other four PC drifts are connected by the PC Main. The PC Main originates from the South Ramp to a location 20 m perpendicular from the East Main where it will then run parallel and at the same slope as the East Main. PC Drift #1 and the PC Main must have a TBM assembly chamber to launch from. The assembly chambers for the PC drifts will be similar to the 7.62 m TBM chambers in the mains, although proportionally smaller. Since the TBM will be the same type as the one for the emplacement drifts, it will be designed to be partially disassembled and backed out through the PC drift to it's origination point, so no disassembly chamber will be needed.

Ventilation raises will connect the PC drifts to the East, West, and Exhaust Mains. They will be the same size, 2.0 m diameter, as the ventilation raises connecting the emplacement drifts to the Exhaust Main. The actual location and configuration of the PC ventilation raises or their connections to the mains has yet to be determined.

Figure 7-11 in Section 7.1.11 depicts the PC drift arrangements. The elevations and slopes were determined in Attachment V. The ventilation raises are shown at the intersection of the mains for simplicity. Table 7-4 summarizes the geometry of the PC drifts. The lengths were determined in Attachment V.

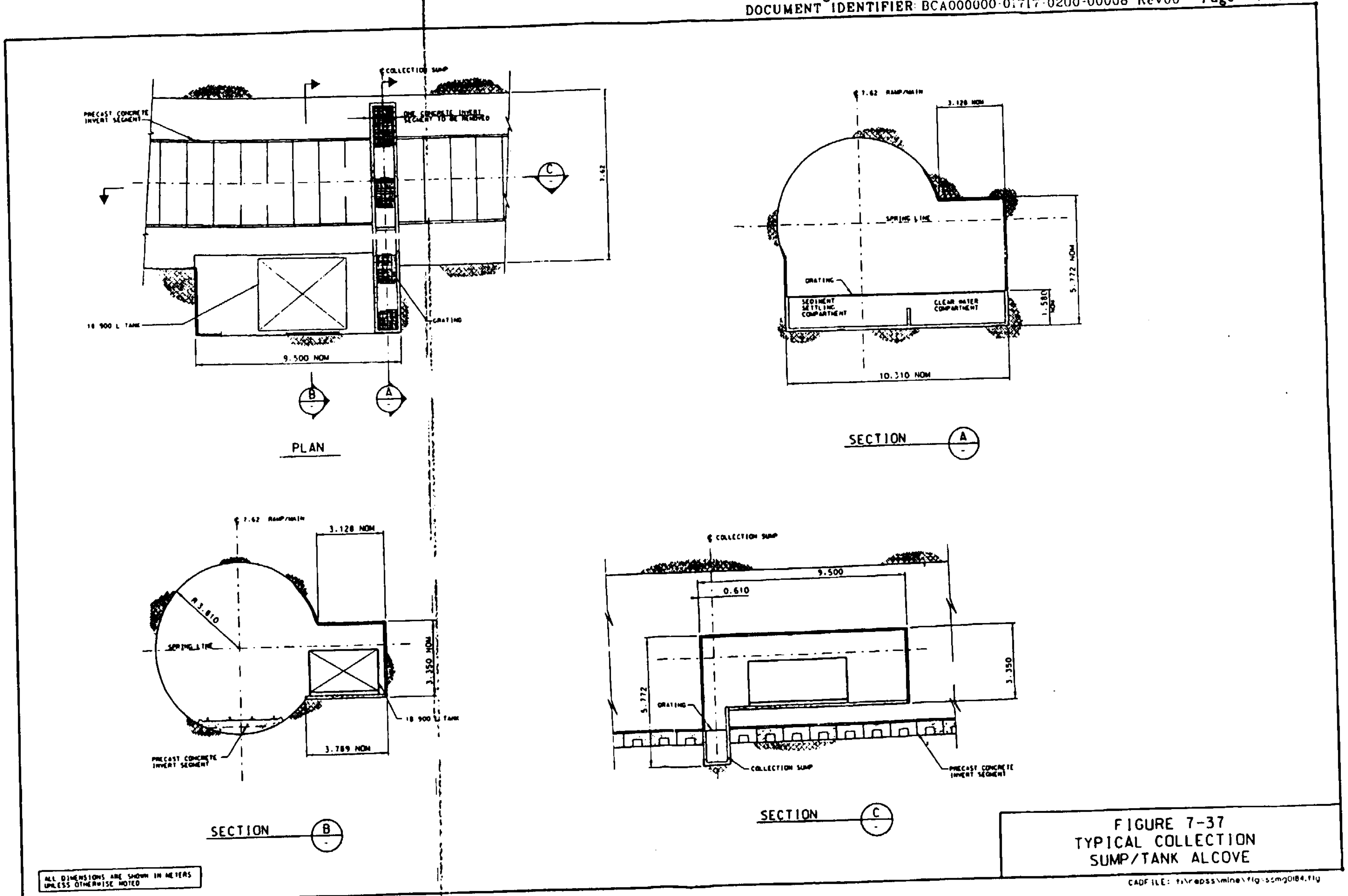

FIGURE 7-37
TYPICAL COLLECTION
SUMP/TANK ALCOVE

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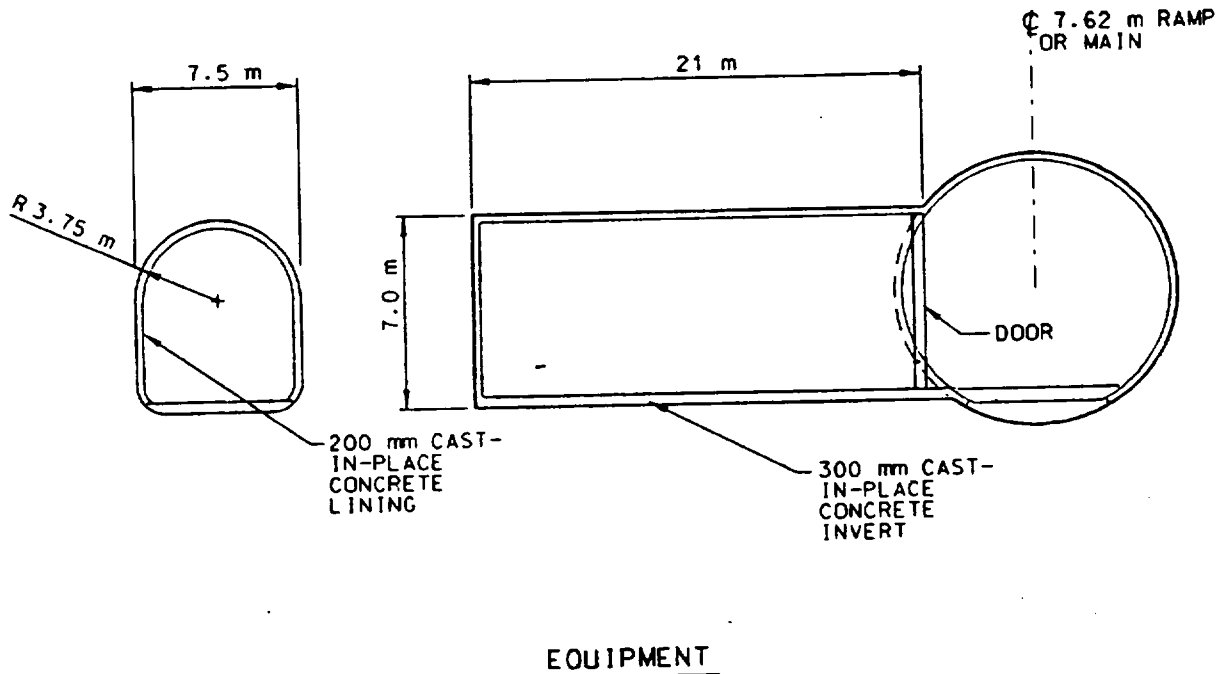

FIGURE 7-38
EQUIPMENT
DECONTAMINATION CHAMBER

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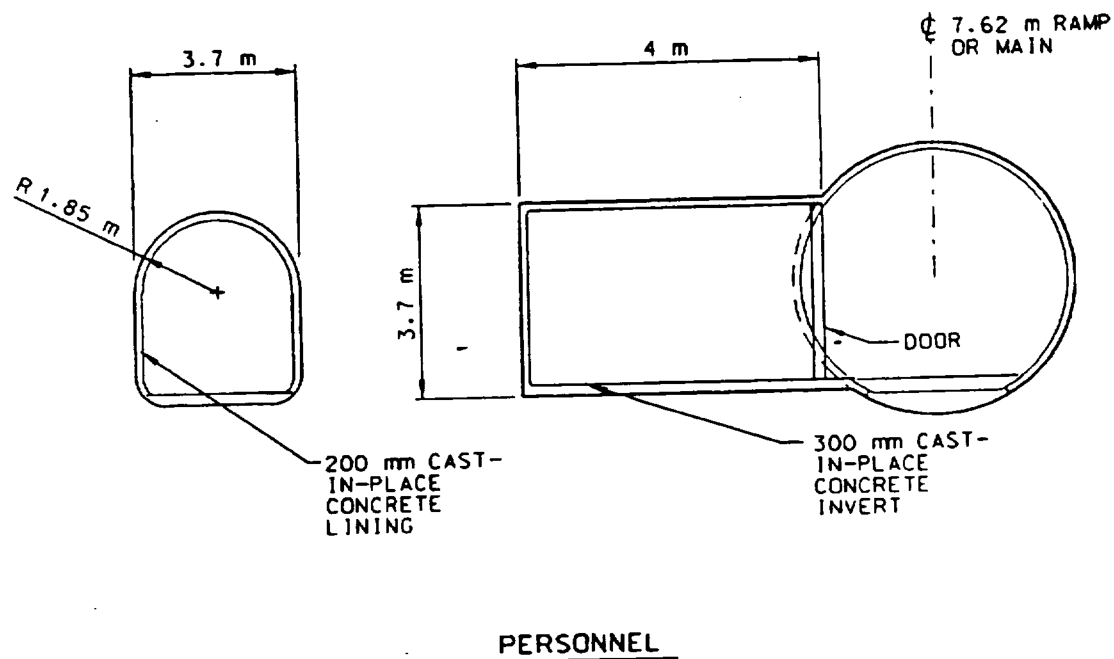

FIGURE 7-39
PERSONNEL
DECONTAMINATION CHAMBER

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Table 7-4 Geometry of PC Drifts

Drift	Size	Length (m)
PC Main	5.5 m Dia.	3,473
PC Drift #1	5.5 m Dia.	1,963
PC Drift #2	5.5 m Dia.	1,156
PC Drift #3	5.5 m Dia.	1,275
PC Drift #4	5.5 m Dia.	1,312
PC Drift #5	5.5 m Dia.	1,257

7.3 EXPANSION

Given the current geologic information (Reference 5.4), the repository layout has the ability to expand in area to maintain flexibility. Some examples of situations that may affect the layout include: an increase in the statutory capacity of the repository; a decrease in the thermal loading; an increase in the number of waste packages without changing the capacity; or site conditions in the repository, found during construction/development, such that area meant for emplacement cannot be used.

The area immediately north of the current layout appears potentially suitable for expansion based on sparse data. An expansion of up to 650 m may be possible while maintaining consistent gradients for drainage. Additional exploratory work is needed to confirm this area. Because of the construction sequence, this area must be included in the layout prior to the start of construction. If it is not, it will be eliminated by the construction of the North Main and Emplacement Shaft.

Expansion to the south in the upper block will be determined by boundary limits as well as excavation limitations. The 200 m minimum overburden limit and the Abandoned Wash Fault influence expansion on the east side. The bottom of the Repository Host Horizon is already a boundary limit on the west side. The practical minimum excavation by the emplacement drift TBM has been set at 500 m in the upper block. This limitation has been set as the shortest drift that a TBM can excavate that can still incorporate the Exhaust Main and a ventilation raise at the midpoint and have two sides to the emplacement drift.

In the VA design layout, the entire lower block becomes an expansion area. The lower block can be modified and expanded from that shown in the MGDS ACD Report (Reference 5.1). The lower block area is controlled by both boundary limits and excavation limitations. The faults have an influence on the locations of the mains on the north, south, and west sides of the block.

The 200 m minimum overburden limit has a small influence on the southeast side of the block. The east side limits are governed more by excavation limitations. The maximum excavation by the emplacement drift TBM has been set at 625 m and the minimum set at 300 m in the lower block. The maximum limit of 625 m has been set as the longest drift excavated without incorporating an Exhaust Main and ventilation raise. This is approximately the same length as one side of the emplacement drifts in the upper block. The minimum limit of 300 m has been set as the shortest drift excavated by a TBM that does not incorporate an Exhaust Main and ventilation raise.

If the layout were to utilize all the expansion area available, the total usable emplacement area in all the upper and lower blocks at an emplacement drift spacing of 28 m would be 1541 acres (see Attachment II) at 85 MTU/acre considering that the defense high level waste packages are emplaced between the 63,000 MTU of commercial spent nuclear fuel. This includes any or all of the contingency area not excavated during repository development. For VA design, it is assumed that all of the contingency area will become part of the available expansion area. Figure 7-40 presents the expansion available in the upper block, shown with the geologic boundaries at the upper block level. Figure 7-41 presents the expansion available in the lower block, shown with the geologic boundaries at the lower block level. The usable emplacement area in the North Expansion Area in the upper block will be approximately 140 acres for 22 drifts (see Attachment II). The usable emplacement area in the South Expansion Area in the upper block will be approximately 253 acres for 47 drifts (see Attachment II). The usable emplacement area in the entire lower block will be approximately 392 acres for 109 drifts (see Attachment II).

7.4 VA DESIGN LAYOUT VS. ACD LAYOUT

The MGDS ACD Report (Reference 5.1) presented the layout shown in Figure 7-42 which had the following ramps and main drifts as part of the layout: North Ramp, North Ramp Extension, South Ramp, South Ramp Extension, East Main, Upper Block TBM Launch Main, West Main, Upper Block Exhaust Main, North Lower Block Access Ramp, South Lower Block Access Ramp, Lower Block Main, Lower Block TBM Launch Main, and Lower Block Exhaust Main. The ramps and ramp extensions were 7.62 m diameter openings. The main drifts had two different diameters: the East Main, West Main, and Lower Block Main were 7.62 m diameter openings; and the Upper and Lower Block TBM Launch Mains and the Lower Block Exhaust Main were 9.0 m diameter openings. The need for 9.0 m drifts has been re-examined to see if this size could be changed to 7.62 m diameter. These drifts were sized at 9.0 m because of the launch tube construction method for the emplacement drift TBM. Utilizing the crosscuts between the launch main and service main for space, a tube was used to launch the emplacement drift TBM from the TBM Launch Main. By using a turnout with 20 m radius curves, the 9.0 m TBM Launch Main can be eliminated and the emplacement drift TBM can be launched from the turnout with a launch cradle installed at the face. The MGDS ACD Report described turnouts on the west side of the block for recovering the emplacement drift TBM and a transporter to carry the TBM around the block for relaunching. The current concept for excavating the emplacement drifts is to use turnouts on both sides of the block. The emplacement drift TBM will be launched from the east side and recovered on the west side. However, instead of being transported around

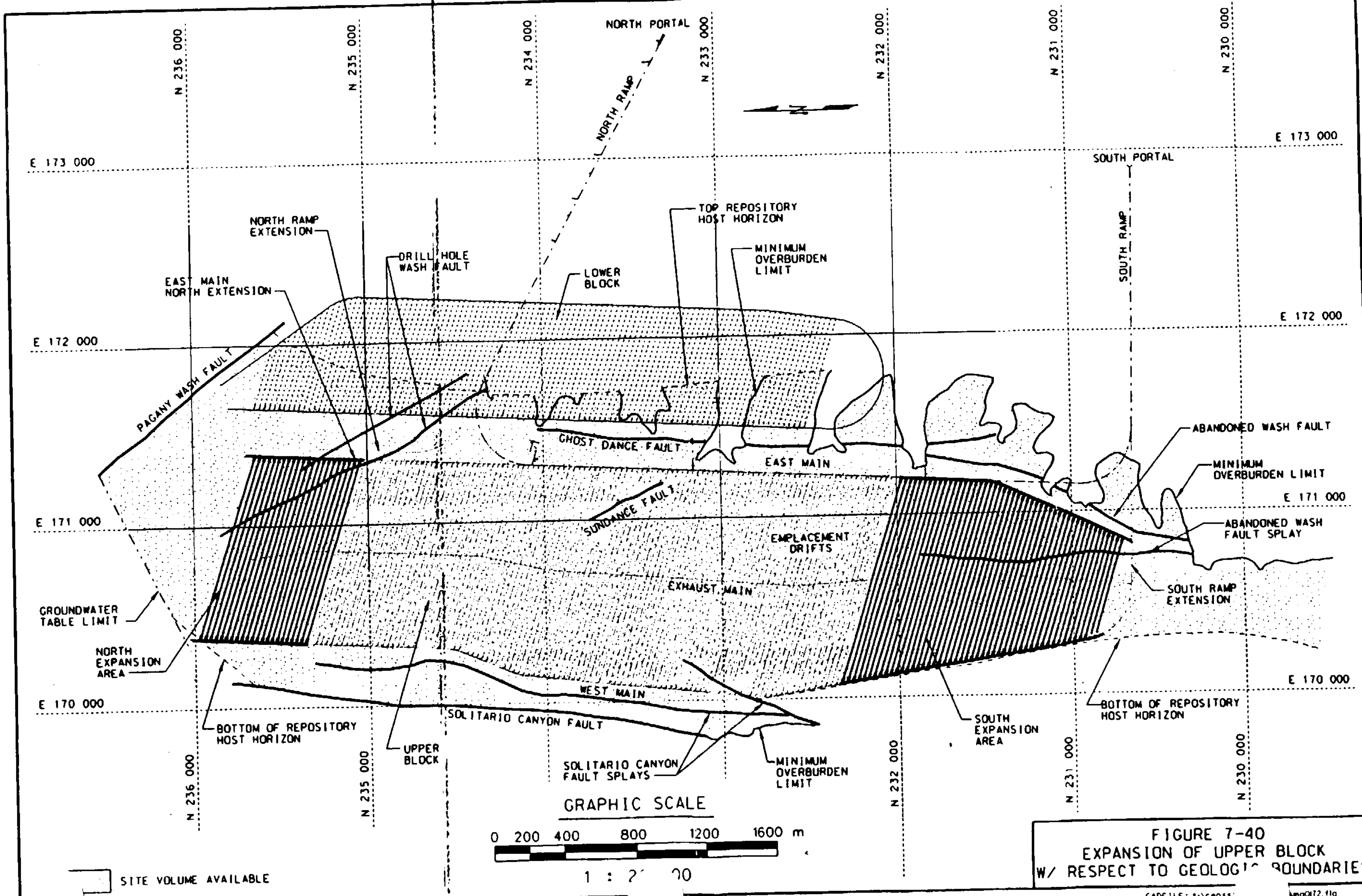

FIGURE 7-40
EXPANSION OF UPPER BLOCK
W/ RESPECT TO GEOLOGIC BOUNDARIES

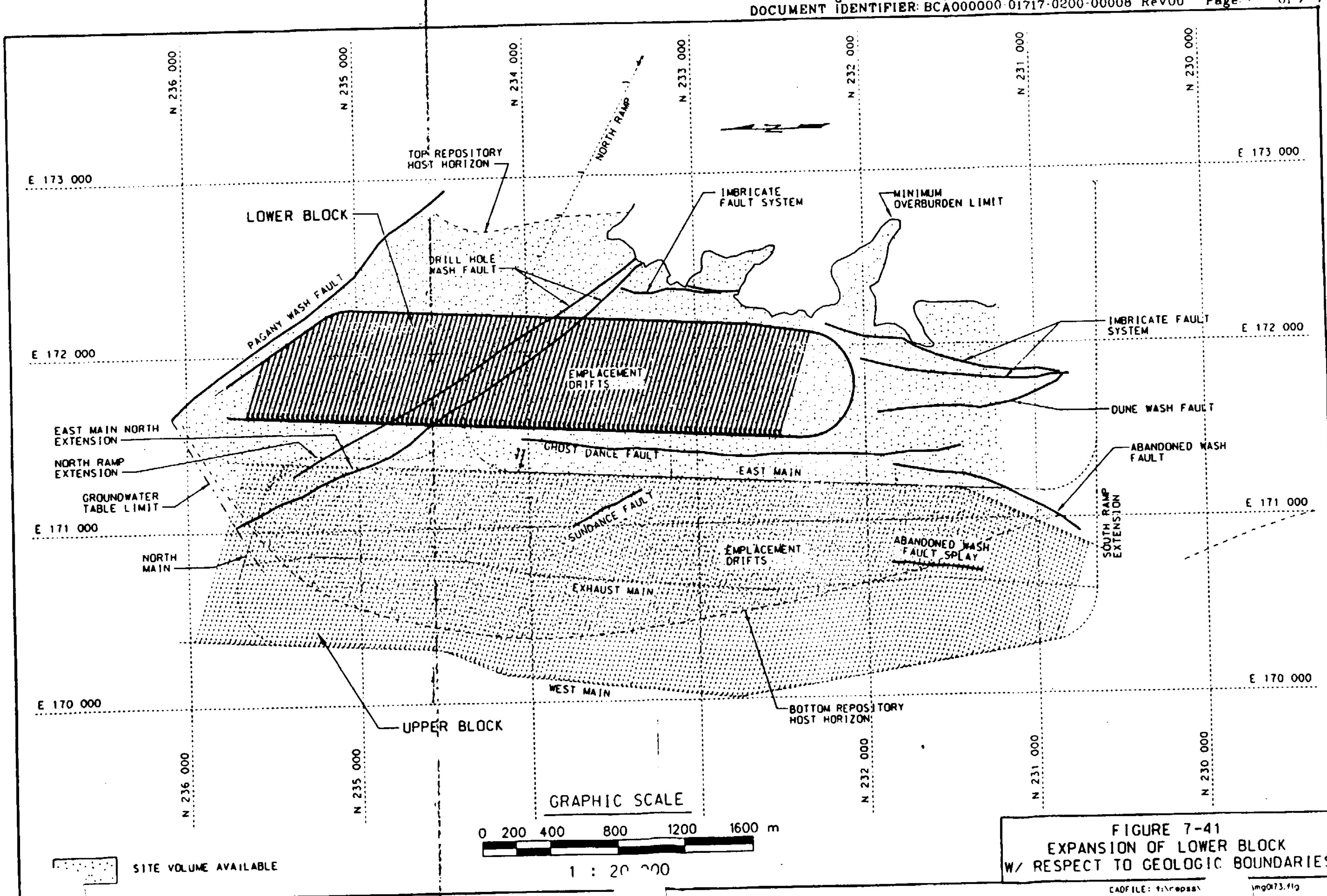

FIGURE 7-41
EXPANSION OF LOWER BLOCK
W/ RESPECT TO GEOLOGIC BOUNDARIES

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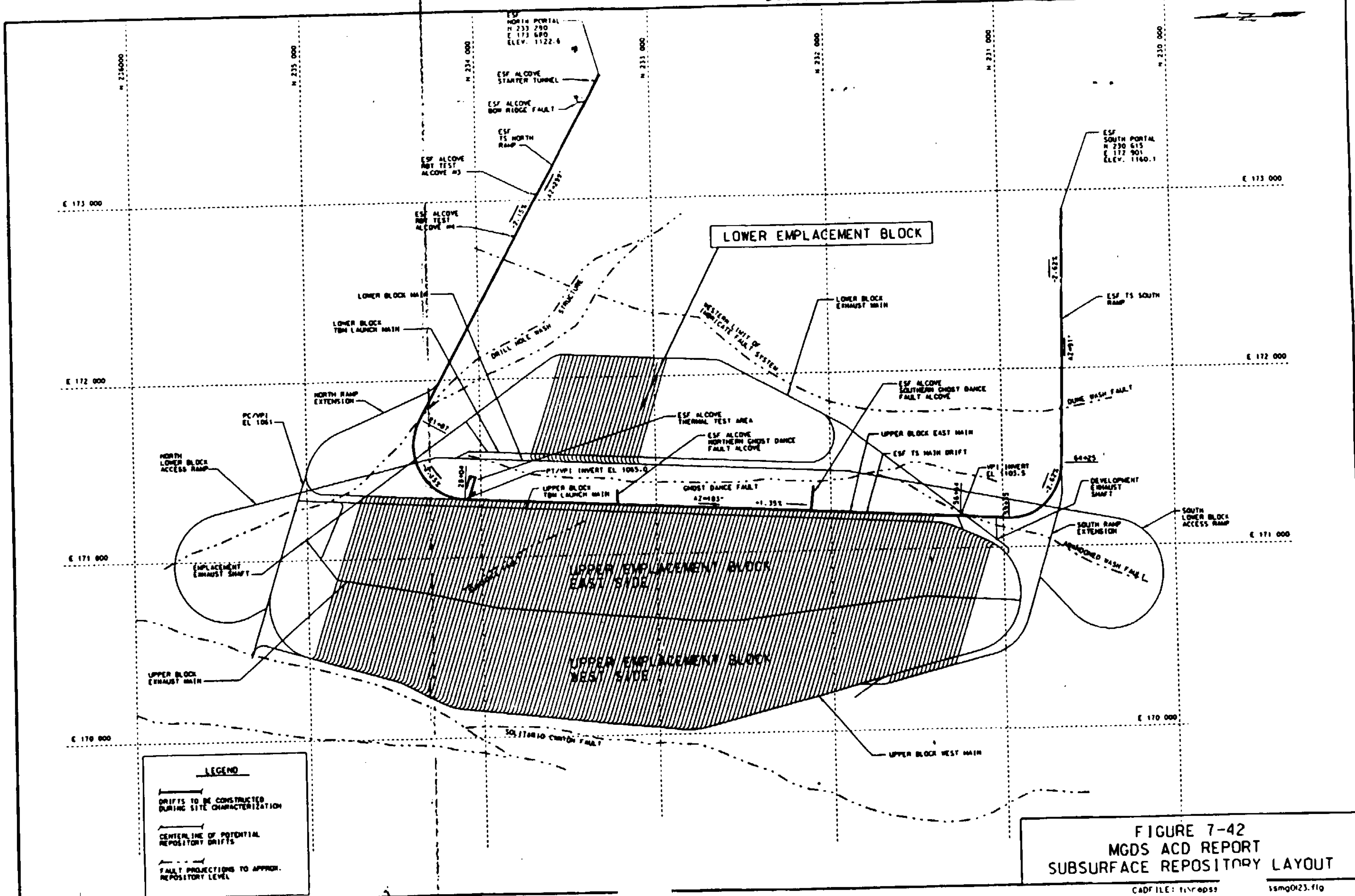

FIGURE 7-42
MGDS ACD REPORT
SUBSURFACE REPOSITORY LAYOUT

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the block as in the ACD concept, the emplacement drift TBM will be partially disassembled and moved back through the completed emplacement drift to the next drift for relaunching. The turnouts also enhance waste package emplacement operations as they can be accomplished from both sides of the repository block.

Since the emplacement drift TBM can be launched from a turnout off a 7.62 m diameter opening, the TBM Launch Main becomes unnecessary. Therefore, all 9.0 m diameter openings that were shown in the MGDS ACD Report have been either replaced by 7.62 m diameter openings (e.g., Lower Block Exhaust Main) or deleted all together (e.g., both Upper and Lower Block TBM Launch Mains). The Upper Block Exhaust Main has been relocated below the block and will be excavated by a 7.62 m diameter TBM instead of a 6.75 m x 6.75 m square-shaped opening excavated by a roadheader as shown in the ACD concept. Ventilation raises will be excavated between the Exhaust Main to each emplacement drift. Locating the Exhaust Main below the emplacement drifts permits easier access to the Exhaust Main for monitoring and maintenance purposes and frees the space in the middle of the block for emplacement. The latest geologic information (Reference 5.4) extends the usable emplacement area of the block approximately 300 m further to the north than the MGDS ACD layout depicted, allowing additional emplacement drifts for VA design.

The emplacement drifts in the MGDS ACD Report were 5.0 m in diameter. For VA design, the emplacement drifts will be 5.5 m in diameter. The difference being that the MGDS ACD Report used a center-in-drift on rail car emplacement method for the waste packages. The VA design will use a center-in-drift on pedestal using a gantry for emplacement of waste packages. The gantry requires a larger diameter opening for operation. The emplacement drifts will also have a full segmental concrete lining for ground support in VA design, whereas, the MGDS ACD Report described a combination of bolts, mesh, and steel sets.

As discussed in Section 7.1.3, the areal mass loading strategy for VA design involves emplacement of waste packages at 85 MTU/acre in emplacement drifts spaced 28 m center-to-center, considering only commercial SNF waste packages in the calculation because the HLW waste packages can be emplaced between the commercial SNF waste packages. The strategy in the MGDS ACD Report used 83 MTU/acre as an assumed mass loading and set the drift spacing at 22.5 m. This geometry was dictated by a desire to maintain the ability to emplace at up to 100 MTU/acre (the upper limit of the areal mass loading in Key Assumption 019, Reference 5.34) and by early thermal models which indicated that a spacing of about 16 m center-to-center between large PWR waste packages was the minimum to prevent violation of the drift wall and fuel cladding thermal goals (EBDRD 3.7.G.2 and DCWP 001, Reference 5.34). The combination of the 100 MTU/acre value and the 16 m minimum package spacing lead to the 22.5 m drift spacing. Subsequent work as described in the *Repository Thermal Loading Management Analysis* (Reference 5.27) has resulted in determining the mass loading at 85 MTU/acre and increasing the emplacement drift spacing to 28 m.

Since the TBM Launch Main was eliminated, the Exhaust Main was relocated below the upper block, the upper block was extended approximately 300 m to the north, the emplacement drift spacing was increased, and the emplacement strategy was modified to only include the commercial spent nuclear fuel in the areal mass loading, the entire lower block becomes an available expansion area.

7.5 ISSUES THAT IMPACT THE LAYOUT

7.5.1 Geology

As discussed in section 7.1.1, the site geology largely determines the boundaries of the repository layout. These boundaries are, primarily, the Solitario Canyon and Ghost Dance Faults and, in the southwest area, the underlying TSw3 unit. A change in the perceived location of these boundaries could cause the layout to change in response.

The orientation of major joint sets is another factor which could influence the layout. The emplacement drifts are oriented such that they do not run parallel, or sub-parallel, to the assumed major joint sets described in Section 7.1.1.2. However, the repository will be constructed across three distinct sub-units of the TSw2 unit, and these sub-units may exhibit different characteristics. The lower two of these sub-units have not yet been explored in the ESF and little is known of their characteristics. When additional information is acquired, the subject of emplacement drift orientation may be re-visited. The layout is flexible in this regard and even relatively large changes in drift orientation could be accommodated without major changes to the operating concepts or construction methodology.

7.5.2 Change in Project Thermal Goals

Since the thermal goals determine the areal mass loading of the repository, a change in the project thermal goals can have an impact on the layout. For instance, if the thermal loading were to change to a significantly lower value, the layout would have to accommodate the increased space required to emplace the statutory limit of waste. This may require the use of the proposed expansion areas and possibly other areas that were identified in the MGDS ACD Report (Reference 5.1) but have not yet been characterized.

7.5.3 Ventilation Raise Length

The ventilation raise length is currently set at a nominal 10 m from the invert of the emplacement drifts to the crown of the Exhaust Main. It has yet to be determined what thermal impacts there may be on the stability and operability of the Exhaust Main being only 10 m from the emplacement drifts. It could be that the Exhaust Main may have to be located further away from the emplacement drifts if the thermal impacts show this to be necessary. If the ventilation raises were to increase in length, then it would impact the location and configuration of the Exhaust Main and its connections to the other mains at the north and south ends of the block.

7.5.4 Openings

The drift sizes are generally driven by either the space required for equipment transportation, or by a cross-sectional area requirement derived from planned ventilation flow quantities and maximum airflow velocity criteria. Any change in repository design parameters which increases airflow requirements, or involves the use of larger-than-anticipated equipment, could reasonably be expected to prompt a change in the affected openings' size requirement. With the exception of the existing ESF openings, small changes in required size would not invalidate the layout as depicted in this analysis.

The emplacement drifts are currently assumed to slope upward at a slight (0.5%) grade from the East and West Mains toward the center of the block. This slope is intended to promote post-closure drainage from the drifts. A change in this assumption would have very little effect on the layout or concept of operation unless the slope were to be increased enough to affect the operation of the rail-mounted emplacement gantry. Changing the slope from rising from the mains to the center of the block to dipping from the mains to the center of the block would not have much impact on the layout. It has yet to be determined what type of slope--rising, dipping, or flat--is best for the emplacement drift environment.

The mains are currently assumed to slope downward from south to north to a common point to limit the accumulation of water in the emplacement area. A change in this assumption could have a significant impact on the layout if it were determined that flatter mains (<1.35% gradient) were to be utilized, the East Main would have to be abandoned and a new main excavated.

7.5.5 Performance Confirmation

The extent to which dedicated performance confirmation drifts will be utilized in the repository is not yet known. This layout is based on an assumption that a total of five performance confirmation drifts will be sufficient to provide the needed coverage. Increases in the required coverage would likely require additional drifts. The primary impact to the repository would be in the area of construction sequencing, and in the size of the resulting data acquisition effort required to support the additional monitoring.

Some facets of the PC program are planned to be carried out in alcoves. The impact of adding alcoves to the layout is generally small, as long as the alcoves are located in non-emplacement, relatively low traffic areas. Figure 7-11 indicates those areas of the layout where alcoves can be located with relatively minimal impact.

8. CONCLUSIONS

Based on an areal mass loading of 85 MTU/acre and an emplacement drift spacing of 28 m, the VA design layout shown in Figure 7-1 will support the statutory limit of 70,000 MTU within the upper block alone, provided that the HLW waste packages are emplaced between the commercial

SNF waste packages. If either the mass loading or drift spacing were to change, the layout is flexible enough to accommodate moderate changes using expansion areas identified in Figures 7-40 and 7-41. These expansion areas also provide potential emplacement areas should the statutory limit increase beyond 70,000 MTU or areas intended for emplacement are found unsuitable during repository construction/development.

The VA layout is located within the available site volume as estimated from current geologic information (Reference 5.4). If the available site volume were to change, the layout would have to be modified to accommodate the changes. Changes to the identified locations of faults or the actual determination of the effect of the faults on the repository could have a significant impact on the layout as it would affect the emplacement area available.

The VA design layout complies with all the criteria as stated in Section 4.2.

The ESF loop will be integrated into the VA design layout. The North Ramp will become the access for the emplacement side of the subsurface repository, and the South Ramp will become the access for the development side. The ESF Main Drift will become the East Main. All other subsurface repository openings will be developed from the ESF loop. The size and configuration of the ESF loop will provide clearance for repository construction and emplacement operations. ESF alcoves will be incorporated as needed for performance confirmation testing.

The VA design layout has changed from that shown in the MGDS ACD Report (Reference 5.1) by: elimination of the lower block, elimination of the TBM Launch Main, increasing the emplacement drift spacing from 22.5 m to 28 m, locating the Exhaust Main below the emplacement drifts and using ventilation raises to connect the Exhaust Main with the emplacement drifts, and increasing the areal mass loading to 85 MTU/acre from 83 MTU/acre based on emplacing the HLW waste packages between the commercial SNF waste packages.

The VA layout facilitates preclosure and post-closure drainage by sloping the emplacement drifts back to the mains and the mains sloping to a common drainage area at the north end of the block.

The VA design layout accommodates the assumptions in Section 4.3 in regards to the proposed waste package transportation, emplacement/retrieval methods, constructibility, subsurface ventilation, ground support systems, radiological considerations, performance confirmation, operational alcoves and support areas, and utilities. Design confirmation of these activities is the subject of other analyses.

The TBVs identified in Section 4 are carried through to the outputs of this analysis. Therefore, the outputs with TBVs may not be used for construction, procurement, or fabrication without being controlled in accordance with NLP-3-15.

9. ATTACHMENTS

ATTACHMENT I
DETERMINATION OF EMPLACEMENT AREA FOR VA DESIGN

I.1 DETERMINATION OF DRIFT LENGTH PER MTU

Mass Loading = 85 MTU/acre (Section 4.1.5)
Drift Spacing = 28 m (Section 4.1.5)

Calculation:

Find # sq ft / MTU:
(43560 sq ft/acre) / (mass load) = 512.471 sq ft/MTU

Find # sq m / MTU:
(sq ft/MTU) * (0.09290304 sq m/sq ft) = 47.61 sq m/MTU

Find # m / MTU:
(sq m/MTU) / (drift spacing) = 1.7 m/MTU

I.2 DETERMINATION OF DRIFT LENGTH REQUIRED PER YEAR

Table I-1 shows the drift length required per year for each type of waste package. The table uses as inputs: the waste receipt schedule in Section 4.3.4, the average MTU per waste package in Section 4.3.5, the waste package lengths in Section 4.3.12, a minimum clearance between waste packages of 1.0 m, and the drift length per MTU in Section I.1 above. It also assumes that the HLW packages will fit in between the other packages, so no length is allotted to them.

The cells for each waste package type use the following formula:

```
IF (#MTU * m/MTU) < (length WP + 1.0)
    THEN (#WP * (length WP + 1.0)
    ELSE (#WP * #MTU * m/MTU)
```

I.3 DETERMINATION OF DRIFT LENGTH AVAILABLE FOR EMPLACEMENT

Table I-2 shows the drift length available for emplacement. The table uses as inputs: the excavation length of the drift on both sides from Section I.4 below; thermal standoff distance of 15 m from door for drifts 92-120 on west side; radiological standoff distance of 13 m from door for all drifts on east side and drifts 1-91 on west side; total fault standoff distance of 10 m for drifts 48-60 on east side, 30 m for drifts 114-120 on east side, and 30 m for drifts 74-85 on west side; physical standoff distance of 2 m from midpoint of emplacement drift for all drifts on both sides; three cross-block drifts left empty on both sides at drifts #30, #60, and #105; and two emplacement stand-by drifts left empty on both sides at drifts #15 and #45.

I.4 DETERMINATION OF DRIFT LENGTH EXCAVATION

Table I-3 shows the drift length excavation from door of emplacement drift on east side to midpoint to door of emplacement drift on west side. The table uses as inputs: the emplacement drift length from the intersection of the main to the midpoint of the emplacement drift as measured from a scaled plot of the VA layout (Reference 5.42); and the length of the turnouts from the intersection of the main to the door of the emplacement drift along the centerline of the emplacement drift as measured from the turnouts depicted in Figure 7-30 (31 m for east drifts 1-120, 31 m for west drifts 1-29, 38 m for west drifts 30-43, 32 m for west drifts 44-91, and 28 m for west drifts 92-120).

I.5 DETERMINATION OF AVAILABLE EMPLACEMENT ACREAGE

The available emplacement acreage can be determined by the following formula:

ACREAGE = (total drift length available for emplacement) * (drift spacing) / (0.09290304 sq m/sq ft) / (43560 sq ft/acre)

For the VA design layout, the available acreage can be found using the total length of drift for 105 drifts from Table I-2:

ACREAGE = (108004 m) * (28 m) / (0.09290304 sq m/sq ft) / (43560 sq ft/acre)
ACREAGE = 747 acres

For the contingency area, the available acreage can be found using the total length of drift for 120 drifts minus the total length of drift for 105 drifts from Table I-2:

ACREAGE = (123469 m - 108004 m) * (28 m) / (0.09290304 sq m/sq ft) / (43560 sq ft/acre)
ACREAGE = 107 acres

Table I-1 Drift Length Required for Each Waste Package Type Per Year

LENGTH OF EMPLACEMENT DRIFT REQUIRED FOR EACH PACKAGE TYPE EACH YEAR
(DRIFT SPACING = 28 METERS / THERMAL LOAD = 85 MTU/ACRE ; YFF WASTE ACCEPTANCE)
(Assume DHLW packages will fit in between other packages, so no length is allotted to them)

YEAR	44 BWR	21 PWR	24 BWR	12 PWR	HLW	TOTAL METERS/YEAR	CUM. USAGE
2010	173	331	0	7	0	511	511
2011	400	614	0	16	0	1,030	1,541
2012	855	1,125	0	52	0	2,032	3,573
2013	1,180	2,051	0	171	0	3,402	6,976
2014	1,563	3,215	0	343	0	5,121	12,097
2015	1,869	2,840	0	350	0	5,059	17,155
2016	1,476	3,124	0	498	0	5,098	22,253
2017	1,724	2,879	0	524	0	5,126	27,379
2018	1,762	2,873	0	465	0	5,100	32,479
2019	1,701	2,751	0	657	0	5,110	37,589
2020	1,771	2,853	0	488	0	5,112	42,701
2021	1,540	2,970	0	585	0	5,095	47,796
2022	2,056	2,573	0	482	0	5,110	52,906
2023	1,527	2,998	0	606	0	5,131	58,037
2024	2,292	2,380	0	422	0	5,093	63,130
2025	1,785	2,691	0	629	0	5,105	68,235
2026	2,433	2,649	0	0	0	5,081	73,317
2027	2,044	3,026	0	0	0	5,070	78,387
2028	2,017	3,094	0	0	0	5,112	83,498
2029	1,865	3,215	0	0	0	5,080	88,579
2030	1,924	3,209	0	0	0	5,133	93,712
2031	1,519	3,569	0	0	0	5,088	98,800
2032	1,693	3,428	0	0	0	5,121	103,922
2033	758	2,464	0	0	0	3,222	107,144
TOTALS	37,930	62,920	0	6,294	0		
AVE/PKG	13.27	15.21	0.00	9.22	0.00		13.95

NOTE: ADDITIONAL DRIFTING REQUIRED FOR THERMAL BUFFERS AND ACCESS
TO CENTRAL EXHAUST DRIFT IS NOT INCLUDED IN THIS TABLE

1.700 METERS OF DRIFT PER MTU

Table I-2 Drift Length Available for Emplacement

EMPLACEMENT

East Section				West Section						
Drift #	Excavation Length (m)	Emplacement Adjustment Length (m)	Usable Emplacement Length (m)	Drift #	Excavation Length (m)	Emplacement Adjustment Length (m)	Usable Emplacement Length (m)	Total Excavation Length (m)	Total Usable Emplacement Length (m)	Emplacement Cumulative Length (m)
1	502	-15	487	1	502	-15	487	1004	974	974
2	502	-15	487	2	502	-15	487	1004	974	1948
3	502	-15	487	3	502	-15	487	1004	974	2921
4	502	-15	487	4	502	-15	487	1004	974	3895
5	502	-15	487	5	502	-15	487	1004	974	4869
6	502	-15	487	6	502	-15	487	1004	974	5843
7	502	-15	487	7	502	-15	487	1004	974	6817
8	502	-15	487	8	502	-15	487	1004	974	7791
9	502	-15	487	9	502	-15	487	1004	974	8764
10	502	-15	487	10	502	-15	487	1004	974	9738
11	502	-15	487	11	502	-15	487	1004	974	10712
12	502	-15	487	12	502	-15	487	1004	974	11686
13	502	-15	487	13	502	-15	487	1004	974	12660
14	502	-15	487	14	502	-15	487	1004	974	13633
15	502	-502	0	15	502	-502	0	1004	0	13633
16	502	-15	487	16	502	-15	487	1004	974	14607
17	502	-15	487	17	502	-15	487	1004	974	15581
18	502	-15	487	18	502	-15	487	1004	974	16555
19	502	-15	487	19	502	-15	487	1004	974	17529
20	502	-15	487	20	502	-15	487	1004	974	18503
21	502	-15	487	21	502	-15	487	1004	974	19476
22	502	-15	487	22	502	-15	487	1004	974	20450
23	502	-15	487	23	502	-15	487	1004	974	21424
24	502	-15	487	24	502	-15	487	1004	974	22398
25	502	-15	487	25	502	-15	487	1004	974	23372
26	502	-15	487	26	502	-15	487	1004	974	24346
27	502	-15	487	27	502	-15	487	1004	974	25319
28	502	-15	487	28	502	-15	487	1005	975	26294
29	504	-15	489	29	504	-15	489	1008	978	27272
30	507	-507	0	30	507	-507	0	1014	0	27272
31	511	-15	496	31	511	-15	496	1022	992	28264
32	516	-15	501	32	516	-15	501	1032	1002	29266
33	521	-15	506	33	521	-15	506	1042	1012	30278
34	526	-15	511	34	526	-15	511	1051	1021	31299
35	530	-15	515	35	530	-15	515	1061	1031	32330
36	535	-15	520	36	535	-15	520	1071	1041	33371
37	540	-15	525	37	534	-15	519	1074	1044	34415
38	545	-15	530	38	539	-15	524	1084	1054	35468
39	550	-15	535	39	544	-15	529	1093	1063	36532
40	555	-15	540	40	548	-15	533	1103	1073	37605
41	559	-15	544	41	553	-15	538	1113	1083	38687
42	564	-15	549	42	558	-15	543	1122	1092	39779
43	567	-15	552	43	561	-15	546	1129	1099	40878
44	570	-15	555	44	563	-15	548	1133	1103	41981
45	571	-571	0	45	564	-564	0	1135	0	41981
46	571	-15	556	46	565	-15	550	1137	1107	43087
47	572	-15	557	47	566	-15	551	1138	1108	44196
48	573	-25	548	48	567	-15	552	1140	1100	45295
49	574	-25	549	49	568	-15	553	1141	1101	46397
50	575	-25	550	50	568	-15	553	1143	1103	47500
51	575	-25	550	51	569	-15	554	1145	1105	48605
52	576	-25	551	52	570	-15	555	1146	1106	49711
53	577	-25	552	53	571	-15	556	1148	1108	50819
54	578	-25	553	54	577	-15	562	1155	1115	51934
55	579	-25	554	55	578	-15	563	1157	1117	53050
56	580	-25	555	56	579	-15	564	1158	1118	54168
57	580	-25	555	57	579	-15	564	1160	1120	55288
58	581	-25	556	58	580	-15	565	1161	1121	56410
59	582	-25	557	59	581	-15	566	1163	1123	57533
60	583	-583	0	60	582	-582	0	1165	0	57533
61	584	-15	569	61	583	-15	568	1166	1136	58669
62	584	-15	569	62	584	-15	569	1168	1138	59807
63	585	-15	570	63	584	-15	569	1170	1140	60947
64	586	-15	571	64	585	-15	570	1171	1141	62088
65	587	-15	572	65	586	-15	571	1173	1143	63231

Table I-2 Drift Length Available for Emplacement (Continued)

EMPLACEMENT

East Section				West Section						
Drift #	Excavation Length (m)	Emplacement Adjustment Length (m)	Usable Emplacement Length (m)	Drift #	Excavation Length (m)	Emplacement Adjustment Length (m)	Usable Emplacement Length (m)	Total Excavation Length (m)	Total Usable Emplacement Length (m)	Emplacement Cumulative Length (m)
66	588	-15	573	66	587	-15	572	1174	1144	64375
67	589	-15	574	67	588	-15	573	1176	1146	65521
68	589	-15	574	68	588	-15	573	1178	1148	66669
69	590	-15	575	69	589	-15	574	1179	1149	67818
70	591	-15	576	70	590	-15	575	1181	1151	68969
71	592	-15	577	71	591	-15	576	1183	1153	70122
72	593	-15	578	72	592	-15	577	1184	1154	71276
73	593	-15	578	73	592	-15	577	1186	1156	72432
74	594	-15	579	74	593	-45	548	1187	1127	73559
75	595	-15	580	75	594	-45	549	1189	1129	74689
76	596	-15	581	76	595	-45	550	1191	1131	75819
77	597	-15	582	77	596	-45	551	1192	1132	76952
78	597	-15	582	78	597	-45	552	1194	1134	78086
79	598	-15	583	79	597	-45	552	1196	1136	79221
80	599	-15	584	80	598	-45	553	1197	1137	80358
81	600	-15	585	81	599	-45	554	1199	1139	81497
82	601	-15	586	82	600	-45	555	1201	1141	82638
83	602	-15	587	83	601	-45	556	1202	1142	83780
84	602	-15	587	84	601	-45	556	1204	1144	84924
85	603	-15	588	85	602	-45	557	1205	1145	86069
86	604	-15	589	86	603	-15	588	1207	1177	87246
87	605	-15	590	87	604	-15	589	1209	1179	88425
88	606	-15	591	88	605	-15	590	1210	1180	89605
89	606	-15	591	89	606	-15	591	1212	1182	90787
90	607	-15	592	90	606	-15	591	1214	1184	91971
91	608	-15	593	91	607	-15	592	1214	1184	93155
92	607	-15	592	92	606	-17	589	1213	1180	94335
93	604	-15	589	93	603	-17	586	1208	1175	95511
94	601	-15	586	94	600	-17	583	1201	1169	96680
95	598	-15	583	95	597	-17	580	1194	1162	97842
96	594	-15	579	96	593	-17	576	1188	1156	98997
97	591	-15	576	97	590	-17	573	1181	1149	100146
98	588	-15	573	98	587	-17	570	1174	1142	101289
99	584	-15	569	99	583	-17	566	1168	1136	102424
100	581	-15	566	100	580	-17	563	1161	1129	103554
101	578	-15	563	101	577	-17	560	1155	1123	104676
102	574	-15	559	102	574	-17	556	1148	1116	105792
103	571	-15	556	103	570	-17	553	1141	1109	106901
104	568	-15	553	104	567	-17	550	1135	1103	108004
105	565	-565	0	105	564	-564	0	1128	0	108004
106	561	-15	546	106	560	-17	543	1122	1089	109093
107	558	-15	543	107	557	-17	540	1115	1083	110176
108	555	-15	540	108	554	-17	537	1108	1076	111252
109	551	-15	536	109	550	-17	533	1102	1070	112322
110	548	-15	533	110	547	-17	530	1095	1063	113385
111	545	-15	530	111	544	-17	527	1089	1056	114441
112	541	-15	526	112	541	-17	523	1082	1050	115491
113	538	-15	523	113	537	-17	520	1075	1043	116534
114	535	-45	490	114	538	-17	521	1073	1011	117545
115	532	-45	487	115	535	-17	517	1066	1004	118549
116	528	-45	483	116	531	-17	514	1059	997	119546
117	525	-45	480	117	528	-17	511	1053	991	120537
118	522	-45	477	118	525	-17	507	1046	984	121521
119	518	-45	473	119	521	-17	504	1040	977	122498
120	515	-45	470	120	518	-17	501	1033	971	123469
	66627		61845		66488		61624	133115	123469	

Emplacement distance actually needed for 70,000 MTU is 107,144 m at 85 MTU/acre and 28 m drift spacing which equates to 104 drifts (includes 2 drifts that are left empty for ventilation/monitoring and 2 drifts for emplacement standby within the block– however, the 105th drift will also be left empty for ventilation/monitoring)

Table I-3 Drift Length Excavation

EMPLACEMENT DRIFT EXCAVATION

East Section				West Section						
Drift #	Length (m)	Excavation Adjustment Length (m)	Excavation Length (m)	Drift #	Length (m)	Excavation Adjustment Length (m)	Excavation Length (m)	Total Length (m)	Total Excavation Length (m)	Excavation Cumulative Length (m)
1	533	-31	502	1	533	-31	502	1067	1004	1004
2	533	-31	502	2	533	-31	502	1067	1004	2008
3	533	-31	502	3	533	-31	502	1067	1004	3011
4	533	-31	502	4	533	-31	502	1067	1004	4015
5	533	-31	502	5	533	-31	502	1067	1004	5019
6	533	-31	502	6	533	-31	502	1067	1004	6023
7	533	-31	502	7	533	-31	502	1067	1004	7027
8	533	-31	502	8	533	-31	502	1067	1004	8031
9	533	-31	502	9	533	-31	502	1067	1004	9034
10	533	-31	502	10	533	-31	502	1067	1004	10038
11	533	-31	502	11	533	-31	502	1067	1004	11042
12	533	-31	502	12	533	-31	502	1067	1004	12046
13	533	-31	502	13	533	-31	502	1067	1004	13050
14	533	-31	502	14	533	-31	502	1067	1004	14053
15	533	-31	502	15	533	-31	502	1067	1004	15057
16	533	-31	502	16	533	-31	502	1067	1004	16061
17	533	-31	502	17	533	-31	502	1067	1004	17065
18	533	-31	502	18	533	-31	502	1067	1004	18069
19	533	-31	502	19	533	-31	502	1067	1004	19073
20	533	-31	502	20	533	-31	502	1067	1004	20076
21	533	-31	502	21	533	-31	502	1067	1004	21080
22	533	-31	502	22	533	-31	502	1067	1004	22084
23	533	-31	502	23	533	-31	502	1067	1004	23088
24	533	-31	502	24	533	-31	502	1067	1004	24092
25	533	-31	502	25	533	-31	502	1067	1004	25096
26	533	-31	502	26	533	-31	502	1067	1004	26099
27	533	-31	502	27	533	-31	502	1067	1004	27103
28	534	-31	502	28	534	-31	502	1067	1005	28108
29	535	-31	504	29	535	-31	504	1071	1008	29116
30	538	-31	507	30	538	-31	507	1077	1014	30129
31	543	-31	511	31	543	-31	511	1085	1022	31152
32	547	-31	516	32	547	-31	516	1095	1032	32184
33	552	-31	521	33	552	-31	521	1104	1042	33226
34	557	-31	526	34	557	-31	526	1114	1051	34277
35	562	-31	530	35	562	-31	530	1124	1061	35338
36	567	-31	535	36	567	-31	535	1133	1071	36408
37	571	-31	540	37	571	-38	534	1143	1074	37482
38	576	-31	545	38	576	-38	539	1153	1084	38566
39	581	-31	550	39	581	-38	544	1162	1093	39659
40	586	-31	555	40	586	-38	548	1172	1103	40762
41	591	-31	559	41	591	-38	553	1182	1113	41875
42	595	-31	564	42	595	-38	558	1191	1122	42997
43	599	-31	567	43	599	-38	561	1198	1129	44126
44	601	-31	570	44	601	-38	563	1202	1133	45259
45	602	-31	571	45	602	-38	564	1204	1135	46394
46	603	-31	571	46	603	-38	565	1205	1137	47530
47	604	-31	572	47	604	-38	566	1207	1138	48668
48	604	-31	573	48	604	-38	567	1209	1140	49808
49	605	-31	574	49	605	-38	568	1210	1141	50949
50	606	-31	575	50	606	-38	568	1212	1143	52092
51	607	-31	575	51	607	-38	569	1214	1145	53237
52	608	-31	576	52	608	-38	570	1215	1146	54383
53	608	-31	577	53	608	-38	571	1217	1148	55531
54	609	-31	578	54	609	-32	577	1219	1155	56686
55	610	-31	579	55	610	-32	578	1220	1157	57843
56	611	-31	580	56	611	-32	579	1222	1158	59001
57	612	-31	580	57	612	-32	579	1223	1160	60161
58	613	-31	581	58	613	-32	580	1225	1161	61322
59	613	-31	582	59	613	-32	581	1227	1163	62485
60	614	-31	583	60	614	-32	582	1228	1165	63650
61	615	-31	584	61	615	-32	583	1230	1166	64816
62	616	-31	584	62	616	-32	584	1232	1168	65984
63	617	-31	585	63	617	-32	584	1233	1170	67154
64	617	-31	586	64	617	-32	585	1235	1171	68325
65	618	-31	587	65	618	-32	586	1236	1173	69498

Table I-3 Drift Length Excavation (Continued)

EMPLACEMENT DRIFT EXCAVATION

East Section				West Section						
Drift #	Length (m)	Excavation Adjustment Length (m)	Excavation Length (m)	Drift #	Length (m)	Excavation Adjustment Length (m)	Excavation Length (m)	Total Length (m)	Total Excavation Length (m)	Excavation Cumulative Length (m)
66	619	-31	588	66	619	-32	587	1238	1174	70672
67	620	-31	589	67	620	-32	588	1240	1176	71848
68	621	-31	589	68	621	-32	588	1241	1178	73026
69	621	-31	590	69	621	-32	589	1243	1179	74206
70	622	-31	591	70	622	-32	590	1245	1181	75387
71	623	-31	592	71	623	-32	591	1246	1183	76569
72	624	-31	593	72	624	-32	592	1248	1184	77753
73	625	-31	593	73	625	-32	592	1249	1186	78939
74	626	-31	594	74	626	-32	593	1251	1187	80127
75	626	-31	595	75	626	-32	594	1253	1189	81316
76	627	-31	596	76	627	-32	595	1254	1191	82507
77	628	-31	597	77	628	-32	596	1256	1192	83699
78	629	-31	597	78	629	-32	597	1258	1194	84893
79	630	-31	598	79	630	-32	597	1259	1196	86089
80	630	-31	599	80	630	-32	598	1261	1197	87286
81	631	-31	600	81	631	-32	599	1262	1199	88485
82	632	-31	601	82	632	-32	600	1264	1201	89685
83	633	-31	602	83	633	-32	601	1266	1202	90887
84	634	-31	602	84	634	-32	601	1267	1204	92091
85	635	-31	603	85	634	-32	602	1269	1205	93296
86	635	-31	604	86	635	-32	603	1271	1207	94503
87	636	-31	605	87	636	-32	604	1272	1209	95712
88	637	-31	606	88	637	-32	605	1274	1210	96922
89	638	-31	606	89	638	-32	606	1276	1212	98134
90	639	-31	607	90	639	-32	606	1277	1214	99348
91	639	-31	608	91	639	-32	607	1278	1214	100562
92	638	-31	607	92	638	-32	606	1276	1213	101775
93	636	-31	604	93	636	-32	603	1271	1208	102982
94	632	-31	601	94	632	-32	600	1265	1201	104183
95	629	-31	598	95	629	-32	597	1258	1194	105378
96	626	-31	594	96	626	-32	593	1251	1188	106565
97	622	-31	591	97	622	-32	590	1245	1181	107746
98	619	-31	588	98	619	-32	587	1238	1174	108921
99	616	-31	584	99	616	-32	583	1231	1168	110089
100	612	-31	581	100	612	-32	580	1225	1161	111250
101	609	-31	578	101	609	-32	577	1218	1155	112405
102	606	-31	574	102	606	-32	574	1212	1148	113553
103	603	-31	571	103	603	-32	570	1205	1141	114694
104	599	-31	568	104	599	-32	567	1198	1135	115829
105	596	-31	565	105	596	-32	564	1192	1128	116957
106	593	-31	561	106	593	-32	560	1185	1122	118079
107	589	-31	558	107	589	-32	557	1179	1115	119194
108	586	-31	555	108	586	-32	554	1172	1108	120302
109	583	-31	551	109	583	-32	550	1165	1102	121404
110	579	-31	548	110	579	-32	547	1159	1095	122499
111	576	-31	545	111	576	-32	544	1152	1089	123588
112	573	-31	541	112	573	-32	541	1146	1082	124670
113	569	-31	538	113	569	-32	537	1139	1075	125745
114	566	-31	535	114	566	-28	538	1132	1073	126818
115	563	-31	532	115	563	-28	535	1126	1066	127884
116	560	-31	528	116	560	-28	531	1119	1059	128943
117	556	-31	525	117	556	-28	528	1112	1053	129996
118	553	-31	522	118	553	-28	525	1106	1046	131042
119	550	-31	518	119	550	-28	521	1099	1040	132082
120	546	-31	515	120	546	-28	518	1093	1033	133115
	70389		66627		70388		66488	140777	133115	

ATTACHMENT II
DETERMINATION OF EMPLACEMENT AREA AVAILABLE FOR EXPANSION

II.1 DETERMINATION OF DRIFT LENGTH AVAILABLE FOR EMPLACEMENT IN UPPER BLOCK

Table II-1 shows the total drift length available for emplacement in the upper block. The table uses as inputs: the excavation length of the drift on both sides of upper block from Section II.3 below; thermal standoff distance of 15 m from door for drifts 113-174 on west side; radiological standoff distance of 13 m from door for all drifts on east side and drifts 1-112 on west side; total fault standoff distance of 10 m for drifts 1-21 on east side, 10 m for drifts 10-11 on east side, 10 m for drifts 69-81 on east side, 30 m for drifts 135-174 on east side, and 30 m for drifts 95-106 on west side; physical standoff distance of 2 m from midpoint of emplacement drift for all drifts on both sides; five cross-block drifts left empty on both sides at drifts #35, #70, #105, #140, and #174; and two emplacement stand-by drifts left empty on both sides at drifts #20 and #50.

II.2 DETERMINATION OF DRIFT LENGTH AVAILABLE FOR EMPLACEMENT IN LOWER BLOCK

Table II-2 shows the total drift length available for emplacement in the lower block. The table uses as inputs: the excavation length of the drift in lower block from Section II.4 below; thermal standoff distance of 57 m on east side from door for drifts 1-12, 36 m on east side for drifts 13-95, and 35 m on east side for drifts 96-109; radiological standoff distance of 13 m on west side from door for drifts 1-109; total fault standoff distance of 10 m for drifts 32-40, 10 m for drifts 57-62, and 30 m for drifts 41-56; no physical standoff distance in lower block; three cross-block drifts left empty at drifts #35, #70, and #105; and two emplacement stand-by drifts left empty at drifts #20 and #50.

II.3 DETERMINATION OF DRIFT LENGTH EXCAVATION IN THE UPPER BLOCK

Table II-3 shows the drift length excavation from door of emplacement drift on east side to midpoint to door of emplacement drift on west side. The table uses as inputs: the emplacement drift length from the intersection of the main to the midpoint of the emplacement drift as measured from a scaled plot of the expanded layout (References 5.40 and 5.45); and the length of the turnouts from the intersection of the main to the door of the emplacement drift along the centerline of the emplacement drift as measured from the turnouts depicted in Figures 7-30 and II-1 (31 m for east drifts 1-145, 38 m for east drifts 146-174, 31 m for west drifts 1-50, 38 m for west drifts 51-64, 32 m for west drifts 65-112, and 28 m for west drifts 113-174).

II.4 DETERMINATION OF DRIFT LENGTH EXCAVATION IN THE LOWER BLOCK

Table II-4 shows the drift length excavation from door of emplacement drift on west side to edge of main on east side. The table uses as inputs: the emplacement drift length from the intersection of the main on the west side and on the east side as measured from a scaled plot of the expanded layout (Reference 5.41); the length of the turnouts from the intersection of the main on the west side to the door of the emplacement drift along the centerline of the emplacement drift as measured from the turnouts depicted in Figure II-1 (42 m for drifts 1-109); and the length of the adjustment from the intersection of the main on the east side to the edge of the main (6 m for drifts 1-12, 4 m for drifts 13-95, and 4 m for drifts 96-109).

I.5 DETERMINATION OF AVAILABLE EMPLACEMENT ACREAGE

The available emplacement acreage can be determined by the following formula:

ACREAGE = (total drift length available for emplacement) * (drift spacing) / (0.09290304 sq m/sq ft) / (43560 sq ft/acre)

For the entire expansion of the upper block, the available acreage can be found by summing up the three areas using the total length of drift for the first 22 drifts (north expansion), the next 105 drifts (VA area during expansion), and the last 47 drifts (south expansion) from Table II-1:

ACREAGE = [(20230 m) * (28 m) / (0.09290304 sq m/sq ft) / (43560 sq ft/acre)] + [(129436 m - 20230 m) * (28 m) / (0.09290304 sq m/sq ft) / (43560 sq ft/acre] + [(166017 m - 129436 m) * (28 m) / (0.09290304 sq m/sq ft) / (43560 sq ft/acre)]
ACREAGE = 140 acres + 756 acres + 253 acres
ACREAGE = 1149 acres

For the entire expansion of the lower block, the available acreage can be found using the total length of drift for 109 drifts from Table II-2:

ACREAGE = (56721 m) * (28 m) / (0.09290304 sq m/sq ft) / (43560 sq ft/acre)
ACREAGE = 392 acres

Total acreage available for the upper block and lower block together is:

ACREAGE = (1149 acres + 392 acres)
ACREAGE = 1541 acres

Table II-1 Drift Length Available for Emplacement in Upper Block

EMPLACEMENT Entire Upper Block				
Drift #	Excavation Length (m)	Emplacement Adjustment Length (m)	Usable Emplacement Length (m)	Emplacement Cumulative Length (m)
1	1004	-40	964	964
2	1004	-40	964	1928
3	1004	-40	964	2891
4	1004	-40	964	3855
5	1004	-40	964	4819
6	1004	-40	964	5783
7	1004	-40	964	6747
8	1004	-40	964	7711
9	1004	-40	964	8674
10	1004	-50	954	9628
11	1004	-50	954	10582
12	1004	-40	964	11546
13	1004	-40	964	12510
14	1004	-40	964	13473
15	1004	-40	964	14437
16	1004	-40	964	15401
17	1004	-40	964	16365
18	1004	-40	964	17329
19	1004	-40	964	18293
20	1004	-1004	0	18293
21	1004	-40	964	19256
22	1004	-30	974	20230
23	1004	-30	974	21204
24	1004	-30	974	22178
25	1004	-30	974	23152
26	1004	-30	974	24126
27	1004	-30	974	25099
28	1004	-30	974	26073
29	1004	-30	974	27047
30	1004	-30	974	28021
31	1004	-30	974	28995
32	1004	-30	974	29968
33	1004	-30	974	30942
34	1004	-30	974	31916
35	1004	-1004	0	31916
36	1004	-30	974	32890
37	1004	-30	974	33864
38	1004	-30	974	34838
39	1004	-30	974	35811
40	1004	-30	974	36785
41	1004	-30	974	37759
42	1004	-30	974	38733
43	1004	-30	974	39707
44	1004	-30	974	40680
45	1004	-30	974	41654
46	1004	-30	974	42628
47	1004	-30	974	43602
48	1004	-30	974	44576
49	1005	-30	975	45550
50	1008	-1008	0	45550
51	1014	-30	984	46534
52	1022	-30	992	47527
53	1032	-30	1002	48529
54	1042	-30	1012	49540
55	1051	-30	1021	50562
56	1061	-30	1031	51592
57	1071	-30	1041	52633
58	1074	-30	1044	53677
59	1084	-30	1054	54731
60	1093	-30	1063	55794

Table II-1 Drift Length Available for Emplacement in Upper Block (Continued)

EMPLACEMENT
Entire Upper Block

Drift #	Excavation Length (m)	Emplacement Adjustment Length (m)	Usable Emplacement Length (m)	Emplacement Cumulative Length (m)
				56867
61	1103	-30	1073	57950
62	1113	-30	1083	59042
63	1122	-30	1092	60140
64	1129	-30	1099	61243
65	1133	-30	1103	62348
66	1135	-30	1105	63455
67	1137	-30	1107	64563
68	1138	-30	1108	65663
69	1140	-40	1100	65663
70	1141	-1141	0	66766
71	1143	-40	1103	67870
72	1145	-40	1105	68977
73	1146	-40	1106	70085
74	1148	-40	1108	71200
75	1155	-40	1115	72316
76	1157	-40	1117	73434
77	1158	-40	1118	74554
78	1160	-40	1120	75676
79	1161	-40	1121	76799
80	1163	-40	1123	77923
81	1165	-40	1125	79060
82	1166	-30	1136	80198
83	1168	-30	1138	81337
84	1170	-30	1140	82478
85	1171	-30	1141	83621
86	1173	-30	1143	84766
87	1174	-30	1144	85912
88	1176	-30	1146	87059
89	1178	-30	1148	88209
90	1179	-30	1149	89360
91	1181	-30	1151	90512
92	1183	-30	1153	91667
93	1184	-30	1154	92822
94	1186	-30	1156	93950
95	1187	-60	1127	95079
96	1189	-60	1129	96210
97	1191	-60	1131	97342
98	1192	-60	1132	98476
99	1194	-60	1134	99612
100	1196	-60	1136	100749
101	1197	-60	1137	101888
102	1199	-60	1139	103028
103	1201	-60	1141	104171
104	1202	-60	1142	104171
105	1204	-1204	0	105316
106	1205	-60	1145	106493
107	1207	-30	1177	107672
108	1209	-30	1179	108852
109	1210	-30	1180	110034
110	1212	-30	1182	111217
111	1214	-30	1184	112402
112	1214	-30	1184	113582
113	1213	-32	1180	114758
114	1208	-32	1175	115926
115	1201	-32	1169	117089
116	1194	-32	1162	118244
117	1188	-32	1156	119393
118	1181	-32	1149	120535
119	1174	-32	1142	121671
120	1168	-32	1136	

Table II-1 Drift Length Available for Emplacement in Upper Block (Continued)

EMPLACEMENT
Entire Upper Block

Drift #	Excavation Length (m)	Emplacement Adjustment Length (m)	Usable Emplacement Length (m)	Emplacement Cumulative Length (m)
121	1161	-32	1129	122800
122	1155	-32	1123	123923
123	1148	-32	1116	125039
124	1141	-32	1109	126148
125	1135	-32	1103	127251
126	1128	-32	1096	128347
127	1122	-32	1089	129436
128	1115	-32	1083	130519
129	1108	-32	1076	131595
130	1102	-32	1070	132665
131	1095	-32	1063	133728
132	1089	-32	1056	134784
133	1082	-32	1050	135834
134	1075	-32	1043	136877
135	1073	-62	1011	137888
136	1066	-62	1004	138892
137	1059	-62	997	139889
138	1053	-62	991	140880
139	1046	-62	984	141864
140	1040	-1040	0	141864
141	1033	-62	971	142834
142	1026	-62	964	143799
143	1020	-62	958	144756
144	1013	-62	951	145707
145	1007	-62	944	146652
146	985	-62	923	147574
147	968	-62	906	148480
148	951	-62	889	149369
149	934	-62	872	150240
150	917	-62	855	151095
151	900	-62	837	151932
152	883	-62	820	152753
153	866	-62	803	153556
154	848	-62	786	154343
155	831	-62	769	155112
156	814	-62	752	155864
157	797	-62	735	156599
158	780	-62	718	157317
159	744	-62	681	157999
160	741	-62	678	158677
161	729	-62	667	159344
162	712	-62	650	159994
163	695	-62	633	160627
164	678	-62	616	161242
165	661	-62	599	161841
166	644	-62	582	162423
167	627	-62	565	162987
168	610	-62	548	163535
169	593	-62	531	164066
170	576	-62	513	164579
171	559	-62	496	165075
172	542	-62	479	165555
173	524	-62	462	166017
174	507	-507	0	166017
	179874		166017	

Table II-2 Drift Length Available for Emplacement in Lower Block

EMPLACEMENT
Expansion Lower Block

Drift #	Excavation Length (m)	Emplacement Adjustment Length (m)	Usable Emplacement Length (m)	Emplacement Cumulative Length (m)
1	308	-70	238	238
2	337	-70	267	505
3	366	-70	296	800
4	395	-70	325	1125
5	423	-70	354	1479
6	452	-70	383	1861
7	481	-70	412	2273
8	510	-70	441	2713
9	539	-70	470	3183
10	568	-70	498	3681
11	587	-70	518	4199
12	602	-70	532	4731
13	613	-49	564	5295
14	619	-49	570	5865
15	622	-49	572	6437
16	622	-49	573	7009
17	622	-49	573	7582
18	622	-49	573	8154
19	622	-49	573	8727
20	622	-622	0	8727
21	622	-49	573	9299
22	622	-49	573	9872
23	622	-49	573	10445
24	622	-49	573	11017
25	622	-49	573	11590
26	622	-49	573	12162
27	622	-49	573	12735
28	622	-49	573	13307
29	622	-49	573	13880
30	622	-49	573	14452
31	622	-49	573	15025
32	622	-59	563	15587
33	622	-59	563	16150
34	622	-59	563	16712
35	622	-622	0	16712
36	622	-59	563	17275
37	622	-59	563	17837
38	622	-59	563	18400
39	622	-59	563	18962
40	622	-59	563	19525
41	622	-69	553	20077
42	622	-69	553	20630
43	622	-69	553	21182
44	622	-69	553	21735
45	622	-69	553	22287
46	622	-69	553	22840
47	622	-69	553	23392
48	622	-69	553	23945
49	622	-69	553	24498
50	622	-622	0	24498
51	622	-69	553	25050
52	622	-69	553	25603
53	622	-69	553	26155
54	622	-69	553	26708
55	622	-69	553	27260
56	622	-69	553	27813
57	622	-59	563	28375
58	622	-59	563	28938
59	622	-59	563	29500
60	622	-59	563	30063

Table II-2 Drift Length Available for Emplacement in Lower Block (Continued)

EMPLACEMENT Expansion Lower Block				
Drift #	Excavation Length (m)	Emplacement Adjustment Length (m)	Usable Emplacement Length (m)	Emplacement Cumulative Length (m)
61	622	-59	563	30625
62	622	-59	563	31188
63	622	-49	573	31760
64	622	-49	573	32333
65	622	-49	573	32905
66	622	-49	573	33478
67	622	-49	573	34050
68	622	-49	573	34623
69	622	-49	573	35195
70	622	-622	0	35195
71	622	-49	573	35768
72	622	-49	573	36340
73	622	-49	573	36913
74	622	-49	573	37485
75	622	-49	573	38058
76	622	-49	573	38631
77	622	-49	573	39203
78	622	-49	573	39776
79	622	-49	573	40348
80	622	-49	573	40921
81	622	-49	573	41493
82	622	-49	573	42066
83	622	-49	573	42638
84	622	-49	573	43211
85	622	-49	573	43783
86	622	-49	573	44356
87	622	-49	573	44928
88	622	-49	573	45501
89	622	-49	573	46073
90	622	-49	573	46646
91	622	-49	573	47218
92	622	-49	573	47791
93	622	-49	573	48363
94	622	-49	573	48936
95	622	-49	573	49508
96	621	-48	573	50081
97	618	-48	570	50651
98	616	-48	567	51218
99	613	-48	564	51783
100	610	-48	561	52344
101	607	-48	559	52903
102	604	-48	556	53459
103	601	-48	553	54011
104	598	-48	550	54561
105	596	-596	0	54561
106	593	-48	544	55106
107	590	-48	541	55647
108	587	-48	539	56185
109	584	-48	536	56721
	65601		56721	

Table II-3 Drift Length Excavation in Upper Block

EMPLACEMENT DRIFT EXCAVATION
Entire Upper Block

Drift #	Length (m)	Excavation Adjustment Length (m)	Excavation Length (m)	Excavation Cumulative Length (m)
1	1067	-63	1004	1004
2	1067	-63	1004	2008
3	1067	-63	1004	3011
4	1067	-63	1004	4015
5	1067	-63	1004	5019
6	1067	-63	1004	6023
7	1067	-63	1004	7027
8	1067	-63	1004	8031
9	1067	-63	1004	9034
10	1067	-63	1004	10038
11	1067	-63	1004	11042
12	1067	-63	1004	12046
13	1067	-63	1004	13050
14	1067	-63	1004	14053
15	1067	-63	1004	15057
16	1067	-63	1004	16061
17	1067	-63	1004	17065
18	1067	-63	1004	18069
19	1067	-63	1004	19073
20	1067	-63	1004	20076
21	1067	-63	1004	21080
22	1067	-63	1004	22084
23	1067	-63	1004	23088
24	1067	-63	1004	24092
25	1067	-63	1004	25096
26	1067	-63	1004	26099
27	1067	-63	1004	27103
28	1067	-63	1004	28107
29	1067	-63	1004	29111
30	1067	-63	1004	30115
31	1067	-63	1004	31118
32	1067	-63	1004	32122
33	1067	-63	1004	33126
34	1067	-63	1004	34130
35	1067	-63	1004	35134
36	1067	-63	1004	36138
37	1067	-63	1004	37141
38	1067	-63	1004	38145
39	1067	-63	1004	39149
40	1067	-63	1004	40153
41	1067	-63	1004	41157
42	1067	-63	1004	42160
43	1067	-63	1004	43164
44	1067	-63	1004	44168
45	1067	-63	1004	45172
46	1067	-63	1004	46176
47	1067	-63	1004	47180
48	1067	-63	1004	48183
49	1067	-63	1005	49188
50	1071	-63	1008	50196
51	1077	-63	1014	51210
52	1085	-63	1022	52232
53	1095	-63	1032	53264
54	1104	-63	1042	54306
55	1114	-63	1051	55357
56	1124	-63	1061	56418
57	1133	-63	1071	57489
58	1143	-69	1074	58563
59	1153	-69	1084	59646
60	1162	-69	1093	60740

Table II-3 Drift Length Excavation in Upper Block (Continued)

EMPLACEMENT DRIFT EXCAVATION
Entire Upper Block

Drift #	Length (m)	Excavation Adjustment Length (m)	Excavation Length (m)	Excavation Cumulative Length (m)
61	1172	-69	1103	61843
62	1182	-69	1113	62955
63	1191	-69	1122	64077
64	1198	-69	1129	65206
65	1202	-69	1133	66339
66	1204	-69	1135	67474
67	1205	-69	1137	68610
68	1207	-69	1138	69748
69	1209	-69	1140	70888
70	1210	-69	1141	72030
71	1212	-69	1143	73173
72	1214	-69	1145	74317
73	1215	-69	1146	75464
74	1217	-69	1148	76612
75	1219	-64	1155	77767
76	1220	-64	1157	78923
77	1222	-64	1158	80081
78	1223	-64	1160	81241
79	1225	-64	1161	82403
80	1227	-64	1163	83566
81	1228	-64	1165	84730
82	1230	-64	1166	85897
83	1232	-64	1168	87065
84	1233	-64	1170	88234
85	1235	-64	1171	89405
86	1236	-64	1173	90578
87	1238	-64	1174	91753
88	1240	-64	1176	92929
89	1241	-64	1178	94106
90	1243	-64	1179	95286
91	1245	-64	1181	96467
92	1246	-64	1183	97649
93	1248	-64	1184	98834
94	1249	-64	1186	100019
95	1251	-64	1187	101207
96	1253	-64	1189	102396
97	1254	-64	1191	103587
98	1256	-64	1192	104779
99	1258	-64	1194	105973
100	1259	-64	1196	107169
101	1261	-64	1197	108366
102	1262	-64	1199	109565
103	1264	-64	1201	110765
104	1266	-64	1202	111967
105	1267	-64	1204	113171
106	1269	-64	1205	114377
107	1271	-64	1207	115584
108	1272	-64	1209	116792
109	1274	-64	1210	118003
110	1276	-64	1212	119215
111	1277	-64	1214	120428
112	1278	-64	1214	121643
113	1276	-64	1213	122855
114	1271	-64	1208	124063
115	1265	-64	1201	125264
116	1258	-64	1194	126458
117	1251	-64	1188	127646
118	1245	-64	1181	128827
119	1238	-64	1174	130001
120	1231	-64	1168	131169

Table II-3 Drift Length Excavation in Upper Block (Continued)

EMPLACEMENT DRIFT EXCAVATION
Entire Upper Block

Drift #	Length (m)	Excavation Adjustment Length (m)	Excavation Length (m)	Excavation Cumulative Length (m)
121	1225	-64	1161	132330
122	1218	-64	1155	133485
123	1212	-64	1148	134633
124	1205	-64	1141	135774
125	1198	-64	1135	136909
126	1192	-64	1128	138038
127	1185	-64	1122	139159
128	1179	-64	1115	140274
129	1172	-64	1108	141382
130	1165	-64	1102	142484
131	1159	-64	1095	143579
132	1152	-64	1089	144668
133	1146	-64	1082	145750
134	1139	-64	1075	146825
135	1132	-60	1073	147898
136	1126	-60	1066	148964
137	1119	-60	1059	150023
138	1112	-60	1053	151076
139	1106	-60	1046	152122
140	1099	-60	1040	153162
141	1093	-60	1033	154195
142	1086	-60	1026	155221
143	1079	-60	1020	156241
144	1073	-60	1013	157254
145	1066	-60	1007	158261
146	1051	-67	985	159246
147	1034	-67	968	160214
148	1017	-67	951	161164
149	1000	-67	934	162098
150	983	-67	917	163015
151	966	-67	900	163914
152	949	-67	883	164797
153	932	-67	866	165662
154	915	-67	848	166511
155	898	-67	831	167342
156	881	-67	814	168157
157	864	-67	797	168954
158	847	-67	780	169734
159	810	-67	744	170478
160	807	-67	741	171218
161	796	-67	729	171947
162	779	-67	712	172660
163	762	-67	695	173355
164	744	-67	678	174032
165	727	-67	661	174693
166	710	-67	644	175337
167	693	-67	627	175964
168	676	-67	610	176574
169	659	-67	593	177166
170	642	-67	576	177742
171	625	-67	559	125822
172	608	-67	542	126364
173	591	-67	524	126888
174	574	-67	507	127395
	191020		179874	

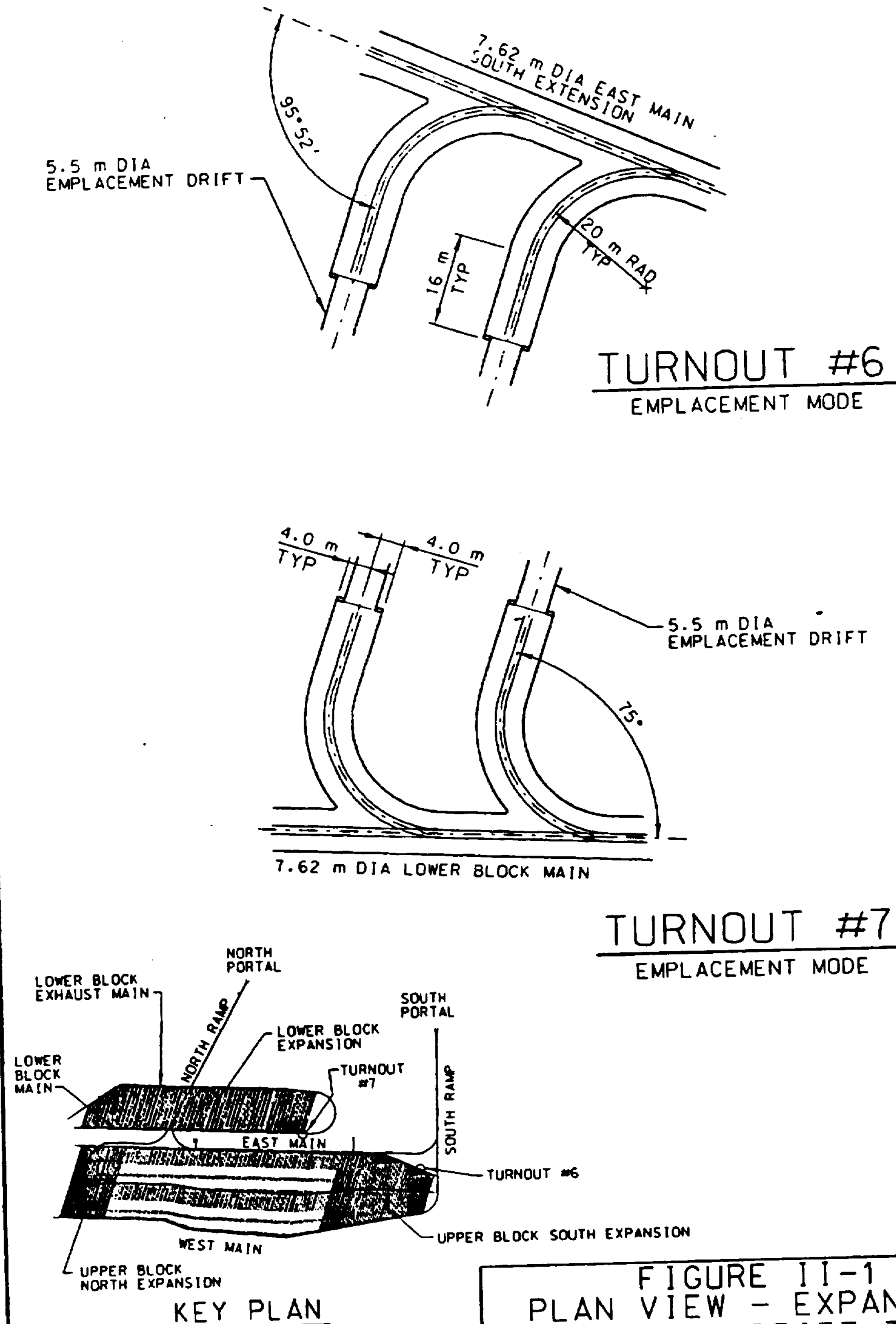

FIGURE II-1
PLAN VIEW - EXPANSION
EMPLACEMENT DRIFT TURNOUTS

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Table II-4 Drift Length Excavation in Lower Block

EMPLACEMENT DRIFT EXCAVATION
Expansion Lower Block

Drift #	Length (m)	Excavation Adjustment Length (m)	Excavation Length (m)	Excavation Cumulative Length (m)
1	356	-48	308	308
2	385	-48	337	644
3	414	-48	366	1010
4	443	-48	395	1404
5	472	-48	423	1828
6	501	-48	452	2280
7	530	-48	481	2762
8	559	-48	510	3272
9	588	-48	539	3811
10	617	-48	568	4380
11	636	-48	587	4967
12	650	-48	602	5569
13	659	-46	613	6182
14	665	-46	619	6801
15	668	-46	622	7423
16	668	-46	622	8045
17	668	-46	622	8666
18	668	-46	622	9288
19	668	-46	622	9910
20	668	-46	622	10532
21	668	-46	622	11153
22	668	-46	622	11775
23	668	-46	622	12397
24	668	-46	622	13019
25	668	-46	622	13640
26	668	-46	622	14262
27	668	-46	622	14884
28	668	-46	622	15506
29	668	-46	622	16127
30	668	-46	622	16749
31	668	-46	622	17371
32	668	-46	622	17993
33	668	-46	622	18614
34	668	-46	622	19236
35	668	-46	622	19858
36	668	-46	622	20480
37	668	-46	622	21101
38	668	-46	622	21723
39	668	-46	622	22345
40	668	-46	622	22967
41	668	-46	622	23588
42	668	-46	622	24210
43	668	-46	622	24832
44	668	-46	622	25454
45	668	-46	622	26075
46	668	-46	622	26697
47	668	-46	622	27319
48	668	-46	622	27941
49	668	-46	622	28562
50	668	-46	622	29184
51	668	-46	622	29806
52	668	-46	622	30428
53	668	-46	622	31049
54	668	-46	622	31671
55	668	-46	622	32293
56	668	-46	622	32915
57	668	-46	622	33536
58	668	-46	622	34158
59	668	-46	622	34780
60	668	-46	622	35402

Table II-4 Drift Length Excavation in Lower Block (Continued)

EMPLACEMENT DRIFT EXCAVATION
Expansion Lower Block

Drift #	Length (m)	Excavation Adjustment Length (m)	Excavation Length (m)	Excavation Cumulative Length (m)
61	668	-46	622	36023
62	668	-46	622	36645
63	668	-46	622	37267
64	668	-46	622	37889
65	668	-46	622	38510
66	668	-46	622	39132
67	668	-46	622	39754
68	668	-46	622	40376
69	668	-46	622	40997
70	668	-46	622	41619
71	668	-46	622	42241
72	668	-46	622	42863
73	668	-46	622	43484
74	668	-46	622	44106
75	668	-46	622	44728
76	668	-46	622	45350
77	668	-46	622	45971
78	668	-46	622	46593
79	668	-46	622	47215
80	668	-46	622	47837
81	668	-46	622	48458
82	668	-46	622	49080
83	668	-46	622	49702
84	668	-46	622	50324
85	668	-46	622	50945
86	668	-46	622	51567
87	668	-46	622	52189
88	668	-46	622	52811
89	668	-46	622	53432
90	668	-46	622	54054
91	668	-46	622	54676
92	668	-46	622	55298
93	668	-46	622	55919
94	668	-46	622	56541
95	668	-46	622	57163
96	667	-46	621	57784
97	664	-46	618	58403
98	662	-46	616	59018
99	659	-46	613	59631
100	656	-46	610	60241
101	653	-46	607	60848
102	650	-46	604	61452
103	647	-46	601	62053
104	644	-46	598	62652
105	641	-46	596	63247
106	639	-46	593	63840
107	636	-46	590	64430
108	633	-46	587	65017
109	630	-46	584	65601
	70641		65601	

ATTACHMENT III
VENTILATION JUSTIFICATION

The following was received by Repository Subsurface Design Ventilation personnel to support the justification for ventilation strategies in the VA design layout:

To: Chris Gorrell
cc: Kalyan Bhattacharya, Daniel McKenzie, Robert Saunders, Jim Taipale, David Rasmussen, Mihail Grigore
From: Romeo Jurani RJ
Date: 05/30/97 06:37:53 PM
Subject: Draft Record of Vent Interface

This is to concur that the **current repository layout** attached in your draft analysis DI:BCA000000-01717-0200-00008, Repository Subsurface Layout Configuration Analysis has been used in my ventilation analysis DI:BCA000000-01717-0200-00015, Overall Development and Emplacement Ventilation Systems.

Early Construction Ventilation

The ventilation flow path for early construction phase has the following primary airways:

> Surface intake through the North Ramp then through the East Main, the South Ramp and exhaust to the surface. Temporary exhausting fans with airlock doors will be installed at the South Portal to power this ventilation mode. Auxiliary ventilation to launch the 7.62m TBM drive for the South Main, West Main and North Main perimeter drifts will be supported by this system along with the 5.5m TBM drive for the three cross block drifts and Exhaust Main.

The need to drive the cross block drifts will explore the Solitario Canyon fault for West Main drift orientation, characterize the bedding of the repository host horizon, and will establish an early flow through ventilation of the West Main drift through the cross block drifts. The flow through ventilation of the West Main drift at this stage will alleviate potential dust problems and will also provide the ventilation of early Development Shaft construction.

The configuration, size and length of the primary airways in the early construction phase has been used to predict the subsequent ventilation support of the repository construction and operation. The results of the preliminary ventilation models are indicating that the current repository layout and sizes of airways are viable to support the overall ventilation strategy of the repository.

Development Ventilation

The ventilation flow path for the development area has the following primary airways:

> Surface intake through the Development Shaft and split into West Main and Exhaust Main, then through emplacement drift construction activities and exhaust through East Main, South Ramp and surface. The primary fan location is near the Development Shaft Collar pushing the air into the development subsurface activities.

The configuration, size and length of the primary airways in the development area shown in your repository layout have been used for computer models to predict ventilation of the overall repository construction and operation. The results of the preliminary ventilation network models have indicated that the current repository layout and size of airways are viable to support the overall development ventilation strategy of the repository.

Emplacement Ventilation

Concurrent with development area construction, the ventilation flow path for the emplacement area has the following primary airways:

> Surface intake through the North Ramp and split into West and East Mains, then through the active or non-active emplacement drifts. The air downcast through raises and into the exhaust main drift or exhaust main auxiliary ducts with optional HEPA filter system. Both return air from exhaust main and exhaust main auxiliary ducts are directed into the emplacement shaft and surface. The primary fan location is near the Emplacement Shaft Collar pulling the air from the subsurface activities.

The configuration, size and length of the primary airways in the emplacement area shown in your repository layout have been used for computer models to predict ventilation of the overall repository emplacement and operation. The results of the preliminary ventilation network models have indicated that the current repository layout and size of airways are viable to support the overall emplacement ventilation strategy of the repository.

If you have any question, please call me at 295-4535.

ATTACHMENT IV
SHAFT DEPTH CALCULATIONS

IV.1 DEVELOPMENT SHAFT

Figure 7-24 depicts the surface location of the Development Shaft with respect to the topography. Based on the topography and the layout, the location of the shaft was assumed to be at N 230890, E1 70360. A block 300 m x 200 m was assumed to determine the elevation of the Development Shaft surface station. In plan view, the topography is steep and the block covers elevations 1435 m to 1470 m. To accommodate the size of the block, the elevations were averaged and the topography was assumed to be cut and filled down to an elevation of 1452 m.

The elevation at the intersection of the South Ramp Extension and South Ramp Extension/Development Shaft Connector (referred to as Point A in this calculation) is 1109.92 m (Reference 5.39). The horizontal length from Point A to the Development Shaft bottom station is 70 m as measured from Figure 7-33. The slope of this segment is +0.5% from Point A to the shaft. To determine the elevation of the Development Shaft bottom station, the following calculation is used:

change in elevation = horizontal length x (slope / 100)
= (70 m) x (+0.5% / 100)
= +0.35 m

elevation of Development Shaft bottom station = Point A + change in elevation
= 1109.92 m + (+0.35 m)
= 1110.27 m

Subtracting the elevation of the shaft bottom station from the shaft surface station yields a depth of 342 m. However, since there will be a 5 m sump located at the bottom of the shaft, the final depth of the Development Shaft will be 347 m.

IV.2 EMPLACEMENT SHAFT

Figure 7-25 depicts the surface location of the Emplacement Shaft with respect to the topography. Based on the topography and the layout, the location of the shaft was assumed to be at N 235580, E 170790. A block 300 m x 200 m was assumed to determine the elevation of the Emplacement Shaft surface station. In plan view, the shaft location is on top of a hill. To accommodate the size of the block, the topography was assumed to be excavated down to an elevation of 1455 m.

The elevation at the intersection of the Exhaust Main and North Main (referred to as Point B in this calculation) is 1037.35 m (Reference 5.39). The horizontal length from Point B to the intersection of the Exhaust Main and Exhaust Main/Emplacement Shaft Connector (referred to as

Point C in this calculation) is 138 m as measured from Figure 7-33. The slope of this segment is +0.331% from Point B to Point C. To determine the elevation of Point C, the following calculation is used:

change in elevation = horizontal length x (slope / 100)
= (138 m) x (+0.331% / 100)
= +0.46 m

elevation of Point C = Point B + change in elevation
= 1035.35 m + (+0.46 m)
= 1037.81 m

The horizontal length from Point C to the Emplacement Shaft is 57 m (Figure 7-33). The slope of this segment is +0.5% from Point C to the shaft. The elevation of the Emplacement Shaft bottom station is calculated as follows:

change in elevation = horizontal length x (slope / 100)
= (57 m) x (+0.5% / 100)
= +0.28 m

elevation of Emplacement Shaft bottom station = Point C + change in elevation
= 1037.81 m + (+0.28 m)
= 1038.09 m

Subtracting the elevation of the shaft bottom station from the shaft surface station yields a depth of 417 m. However, since there will be a 5 m sump located at the bottom of the shaft, the final depth of the Emplacement Shaft will be 422 m.

ATTACHMENT V
PERFORMANCE CONFIRMATION DRIFT CALCULATIONS

V.1 DETERMINATION OF KEY POINTS

The key points of the performance confirmation (PC) drifts were identified as follows:

- Intersection PC Drift #1/North Ramp
- Intersection PC Drift #1/North Ramp Extension at PC drift level
- Intersection PC Main/South Ramp
- PC Main Point #1 located above and to the east of Emplacement Drift #120
- PC Main Point #2 located at the end of the PC Main at PC Drift #2

The elevations of key points along the PC drifts were calculated based on elevations, slopes, and lengths determined in Section 4.1.9. The lengths of the drifts and various segments needed for determining elevations were measured from a scaled plot of Figure 7-11 (Reference 5.43). The PC drifts will be located directly above the following emplacement drifts: PC Drift #1 above #3, PC Drift #2 above #33, PC Drift #3 above #56, PC Drift #4 above #80, and PC Drift #5 above #103. Table V-1 shows the lengths of the PC drifts.

Table V-1 Lengths of PC Drifts (m)

PC Drift #1	PC Main	PC Drift #2	PC Drift #3	PC Drift #4	PC Drift #5
825	966	584	644	662	634
585	2507	572	631	650	623
553					
1963	3473	1156	1275	1312	1257

The slopes for the North Ramp, North Ramp Extension, and South Ramp were determined in Section 4.1.9. The orientation of the second segment of the PC Main is parallel to the East Main but has a 20 m perpendicular distance offset to the east. It's slope along that portion will be the same as the East Main: -1.35% from south to north. The orientation of the PC drifts will parallel the emplacement drifts and their slope will be the same as the emplacment drifts: +0.5% from PC Main to the midpoint of the emplacement drifts and -0.5% from midpoint of the emplacement drifts to the west end of the PC drifts. The elevations, slopes, and horizontal distance lengths of the key points are found in Table V-2. The explanations of the calculations are found in Sections V.1.1 and V.1.2 below.

Table V-2 Calculation of Key Points for PC Drifts

From	To	Length (m)	Slope (%)	Starting Elevation	Change In Elevation (m)	Ending Elevation
South Ramp PT	Int PC Main/South Ramp	49	2.6189	1123.66	1.29	1124.95
Empl Drift 120 E	Empl Drift 120 E (above)			1099.12	22.62	1121.74
Empl Drift 120 E (above)	PC Main Point #1	20	-0.5	1121.74	-0.10	1121.64
Int PC Main/South Ramp	PC Main Point #1	966	-0.34	1124.95	-3.31	1121.64
PC Main Point #1	PC Main Point #2	2507	-1.35	1121.64	-33.84	1087.80
North Ramp PC	Int PC Drift #1/North Ramp	135	2.1486	1078.26	2.89	1081.15
North Ramp Extension PT	Int PC Drift #1/NRE	196	-2.1486	1065.75	-4.20	1061.55
Int PC Drift #1/NRE	Int PC Drift #1/NRE (above)			1061.55	22.62	1084.17
Int PC Drift #1/North Ramp	Int PC Drift #1/NRE (above)	825	0.37	1081.15	3.01	1084.17

V.1.1 PC Drift #1 Key Points

The elevation of the Intersection PC Drift #1/North Ramp Extension (NRE) at the NRE level is determined from the location of the North Ramp Extension PT of the first curve in Section 4.1.9. The elevation of this point is found by the following formula:

EL = (EL NRE PT) + (change in elevation between NRE PT and Int PC Drift #1/NRE)

change in elevation = length x (slope of NRE / 100)

The elevation of the Intersection PC Drift #1/NRE at the PC drift level is determined from the following formula:

EL = (EL Int PC Drift #1/NRE + height of NRE + vertical location of PC drifts above block)

The elevation of the Intersection PC Drift #1/North Ramp is determined from the North Ramp PC in Section 4.1.9 and is found by the following formula:

EL = (EL North Ramp PC) + (change in elevation between North Ramp PC and Int PC Drift #1/North Ramp)

change in elevation = length x (slope of North Ramp / 100)

The slope between the intersection PC Drift #1/NRE at the PC drift level and the Intersection PC Drift #1/North Ramp can be found by the following formula:

slope = (EL Int PC Drift #1/NRE [above] - EL Int PC Drift #1/North Ramp) / (length) x 100

V.1.2 PC Main Key Points

The elevation of PC Main Point #1 is determined from the location of Emplacement Drift #120 in the East Main. The elevation of this point is found by the following formula:

EL = (EL #120 + height of East Main + vertical location of PC drifts above block) - (20 m perpendicular offset from East Main x slope of PC drifts)

The elevation of the Intersection PC Main/South Ramp is determined from the South Ramp PT in Section 4.1.9 and is found by the following formula:

EL = (EL South Ramp PT) + (change in elevation between South Ramp PT and Int PC Main/South Ramp) change in elevation = length x (slope of South Ramp / 100)

The slope between PC Main Point #1 and Intersection PC Main/South Ramp can be found by the following formula:

slope = (EL PC Main Point #1 - EL Int PC Main/South Ramp) / (length) x 100

The elevation of PC Main Point #2 is determined by the following formula:

EL = (EL PC Main Point #2) + (change in elevation between PC Main Point #1 and PC Main Point #2)

change in elevation = length x (slope of PC Main / 100)