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Chapter 8

Section 8.4

R

Nuclear Waste Policy Act
(Section 113)

Consultation Draft

PLANNED SITE PREPARATION ACTIVITIES

Site Characterization Plan

Yucca Mountain Site, Nevada Research and Development Area, Nevada

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8.4 PLANNED SITE PREPARATION ACTIVITIES

The objectives of this section are (1) to describe the activities required to prepare the site for characterization and (2) to describe the design and construction plans for the exploratory shaft facility (ESF) in sufficient detail to evaluate if a) the ESF will adequately support the tests defined in Section 8.3, b) the planned sequencing of tests is consistent with the construction sequence, c) adequate flexibility has been incorporated into the ESF design and construction plans, and d) construction of, or testing in, the exploratory shafts or in the underground test facilities will adversely impact the waste isolation integrity of the site. An integral link exists between the plans presented here and the planned tests and studies in Section 8.3. Therefore, there is extensive cross referencing between the two sections.

The preparations necessary before surface-based testing and underground construction and testing are implemented are discussed in Section 8.4.1. The design and construction plans for the exploratory shafts and underground test facilities are discussed in Section 8.4.2.

Recent changes to the ESF are currently being developed into design criteria for preliminary design. Therefore, the descriptions provided in Section 8.4.2 are conceptual, and further details will be provided in semi-annual progress reports to the SCP and the subsystem design requirements document. Designs will be available for review before the start of each construction activity.

The final design of the repository is not available at this time. However, the requirements for the ESF design state that interfaces between the repository and the ESF should be considered so that ESF configurations that could impact a future repository design are avoided and configurations that could be potentially incorporated into the repository design are preferred.

Section 8.4.2 also presents summary descriptions of the underground tests planned as part of the site characterization program and provides a layout of planned excavations, including preliminary design dimensions. In addition, it discusses the flexibility to be incorporated into design and construction plans and the potential impact of the ESF construction and testing on the waste isolation integrity of the site. This section is based on conceptual design although it reflects ongoing design development.

8.4.1 SURFACE SITE PREPARATION ACTIVITIES

This section discusses the activities on the surface that are necessary to prepare the land for site characterization and testing. Section 8.4.1.1 describes the activities to be performed before surface-based testing. Section 8.4.1.2 describes the activities required at the ESF site before shaft sinking.

8.4.1.1 Preparations for surface-based testing

Surface-based tests consist of geologic, geophysical, hydrologic, and other tests and surveys that will be performed at both the surface and in exploratory boreholes. Descriptions of these planned tests and surveys are given in Sections 8.3.1 and 8.3.2. The purpose of this section is to describe the surface work that is necessary to prepare the land for these activities. Potential environmental effects of conducting surface-based tests have been addressed in Chapter 4 of the final environmental assessment for Yucca Mountain (DOE, 1986b) and in the preliminary analysis of proposed changes to the ESF design and construction schedule (Spaeth, 1987).

Geologic, geophysical, and hydrologic tests will be performed from the surface by measuring the physical characteristics of the rock through magnetic, gravity, or electrical surveys; obtaining samples of outcrop rock for laboratory analysis; measuring properties of core obtained from exploratory holes; measuring properties of rock at depth from boreholes by logging; recording the pattern and speed of sound waves generated and transmitted through the rock; and examining and mapping features exposed by trenches and pavements. Surface preparation is not necessary to measure magnetic, gravity, or electrical properties of the rock nor to obtain samples of rock from outcrops for later analysis. These activities will, therefore, not be addressed in this section.

Many of the geologic, geophysical, and hydrologic tests will be performed by using core from exploratory holes or by measuring physical or chemical characteristics of the subsurface rock by lowering equipment (i.e., logging tools) into the exploratory holes. The type and amount of surface preparation for these tests depend on the type of exploratory hole to be drilled. Shallow holes typically 50 ft (15 m) deep and generally less than 150 ft (50 m) such as neutron holes and shallow infiltration test holes can be drilled by using truck-mounted drill rigs. Current plans call for drilling approximately 300 to 350 of these holes. The rigs are mounted on all-terrain trucks and may not require a bladed access road nor the clearing and grading of drill pads. Therefore, surface preparations for these tests are expected to be minimal and may include the disturbance of small areas for equipment laydown or disposal of cuttings from the drilling operation, as shown in Figure 8.4-1.

Other exploratory holes may require more extensive surface preparation, including clearing and grading the site and staging area, blading a parking area and equipment yard, blading and leveling a drill pad, excavating fill dirt from adjacent or nearby areas, and constructing a mud-and-cuttings pit. Current plans call for drilling 45 to 80 exploratory holes that would require such surface preparation activities. Figure 8.4-2 shows a typical drill site, which requires such surface preparation activities. An average of 2.5 acres per drill site would be disturbed by site preparation activities including such activities as construction of access roads from existing roads to the drill sites. Roads would be bladed smooth and sprinkled with water to aid in soil compaction and to provide dust control.

To examine and map features a short distance below the surface, trenches will be dug with a bulldozer or backhoe. Current plans call for excavating several trenches during site characterization; the locations and number of

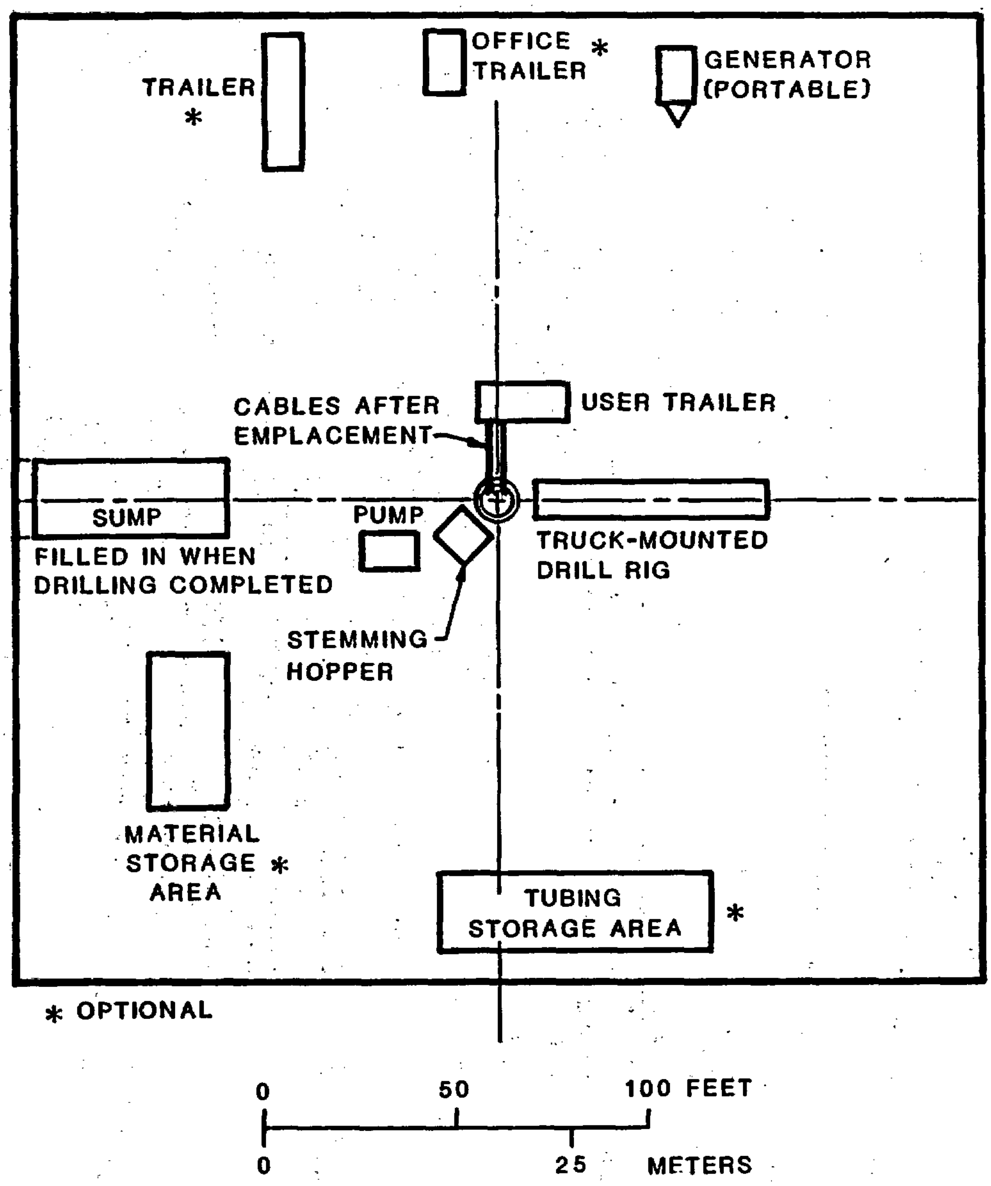
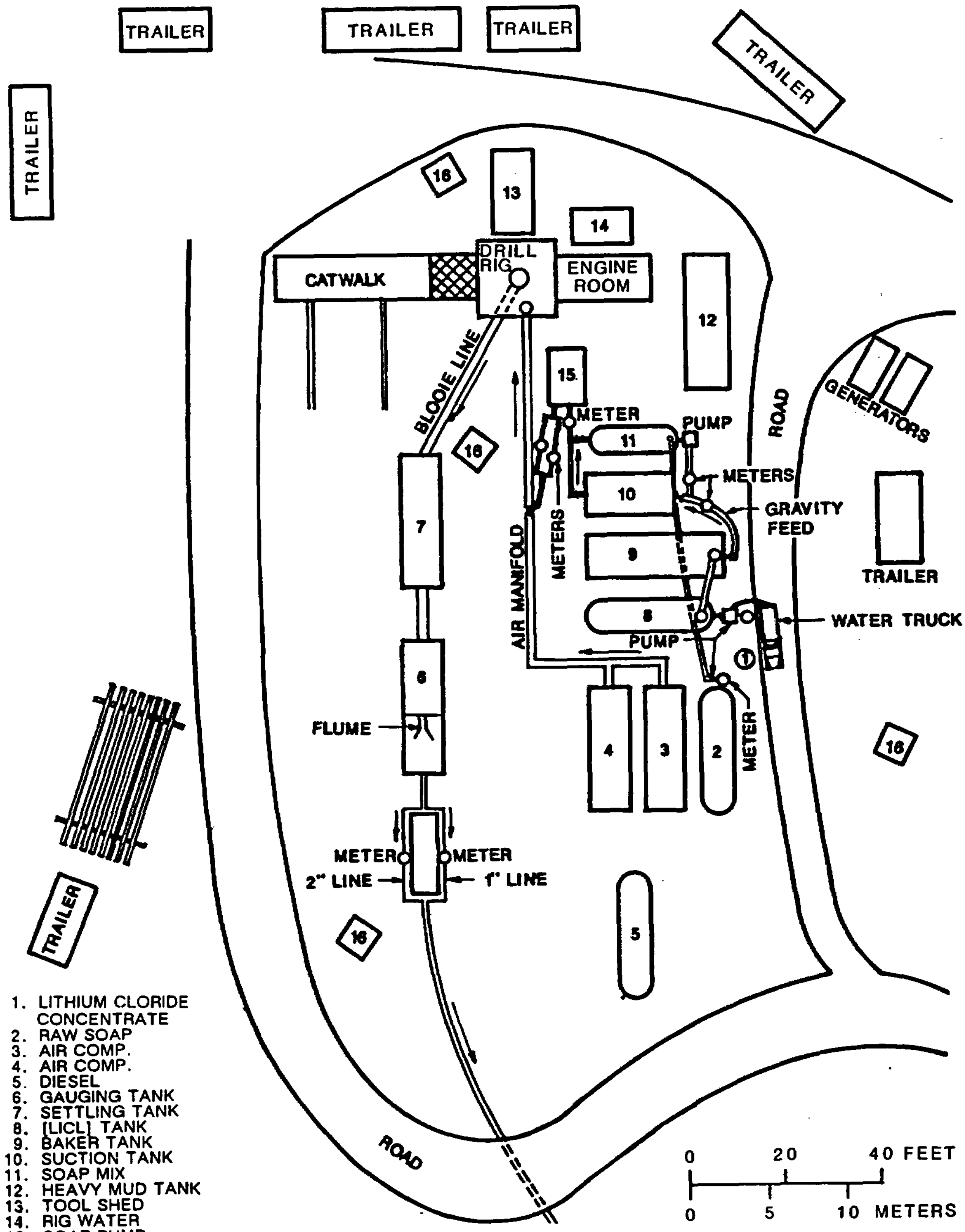


Figure 8.4-1. Typical site plan for shallow geologic exploratory holes.



1. LITHIUM CLORIDE CONCENTRATE
2. RAW SOAP
3. AIR COMP.
4. AIR COMP.
5. DIESEL
6. GAUGING TANK
7. SETTLING TANK
8. [LICL] TANK
9. BAKER TANK
10. SUCTION TANK
11. SOAP MIX
12. HEAVY MUD TANK
13. TOOL SHED
14. RIG WATER
15. SOAP PUMP
16. LIGHT

Figure 8.4-2. Typical site plan for deep geologic exploratory holes.

these trenches (to the extent that they are known now) can be found in Section 8.3.1.17. Excavated material will be stored on the surface next to the trench. An access road may be bladed to the trench site if a road is necessary for either the studies planned at the site or the equipment to be used to excavate the trench.

To perform detailed studies of bedrock features, water or air under moderately high pressure will be sprayed on the surface to remove the regolith and expose the bedrock. These exposed areas of bedrock are called pavements. A one-lane dirt track from the nearest existing road to the pavement site will be cleared and leveled for access so that the area can be cleared and studied.

As discussed in Section 8.3.1.17, a variety of seismic reflection and refraction surveys may be conducted at and near the site. These surveys would be conducted by using 50- to 4,000-lb (23- to 1,800-kg) dynamite charges in shot holes from 20 to several hundred feet deep, drilled in a linear array. Some seismic reflection surveys will be done by using above-surface detonations. These drillholes do not require drill pads; however, off-road vehicle access may be necessary.

8.4.1.2 Preparations for underground construction and testing

The exploratory shaft facility (ESF) consists of surface facilities and underground facilities. Preparations for underground construction and testing require construction and installation of the surface facilities described in this section. The underground facilities, which include exploratory shaft 1 (ES-1), exploratory shaft 2 (ES-2), the main test level operations area, and the exploratory drifts, are described in Section 8.4.2. The surface facilities include the pads and roads, utilities, buildings, shaft collars, shaft hoist, and headframes and equipment necessary to support the construction and operation of the facility. Each of these facilities is discussed in the following sections.

The ESF will be located at Coyote Wash (Bertram, 1984) on the eastern side of Yucca Mountain at an elevation of approximately 1,260 m. Figure 8.4-3 shows the location of the ESF in relation to the Nevada Test Site. It also shows the administrative boundaries of the NTS, the Nellis Air Force Range (NAFR), and the Bureau of Land Management (BLM). Figure 8.4-4 shows the location of facilities such as utility lines, access roads, and buildings to be used during ESF construction. A conceptual illustration of the ESF is presented in Figure 8.4-5 and the conceptual surface layout is shown in Figure 8.4-6. The road, power lines, and water lines have been built to the NTS boundary. There are currently no other facilities or utilities in place to support the planned ESF construction activities. The first tasks will concentrate on the preparation of surface areas, completion of roads and utilities, and construction of support facilities.

The layout of the ESF is currently in conceptual design; the requirements call for minimizing the impact of construction while providing an efficient arrangement of mining equipment laydown areas, hoists, and support buildings. These requirements specify that facilities that involve the use

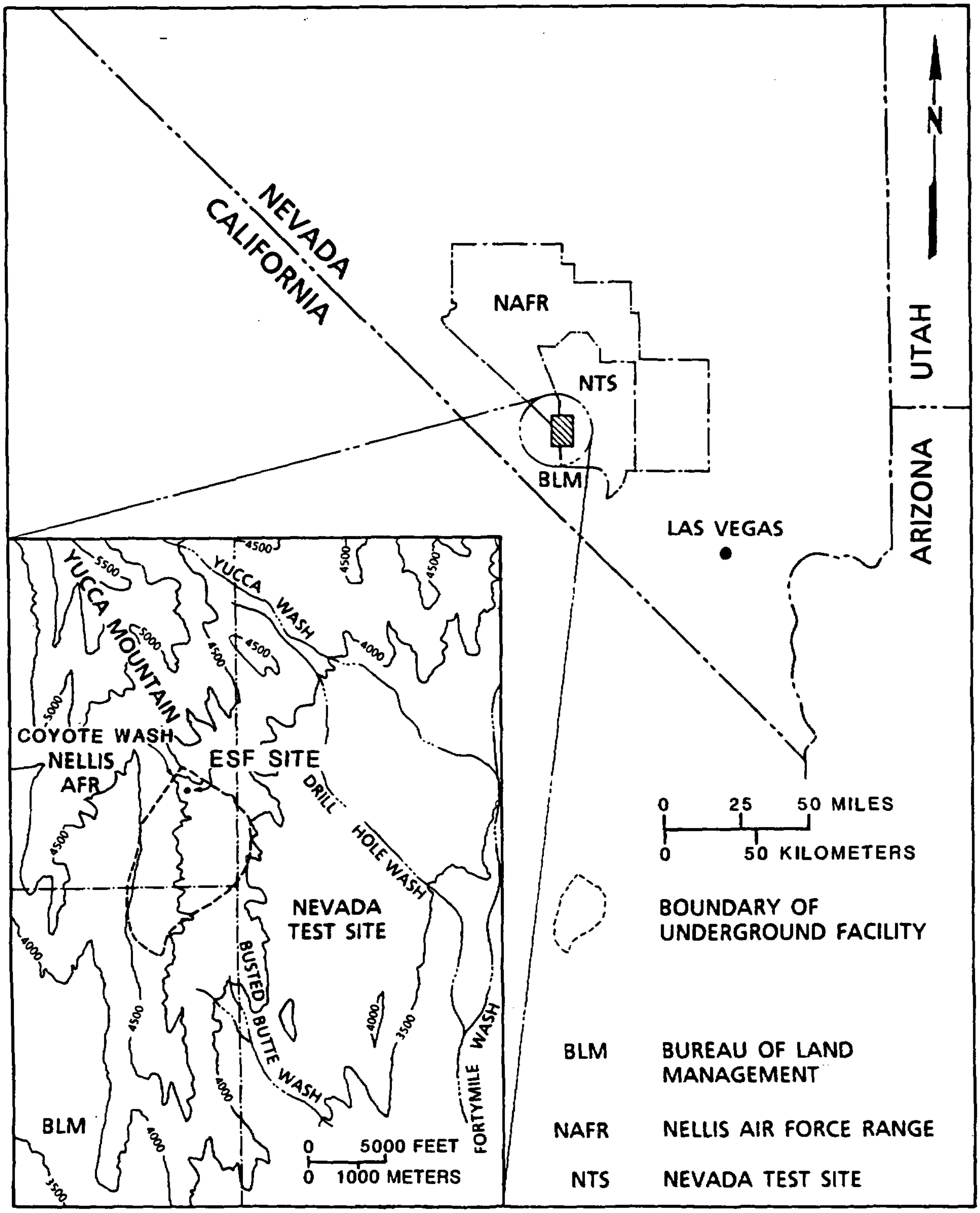


Figure 8.4-3. Relationship of Yucca Mountain site to exploratory shaft facility.

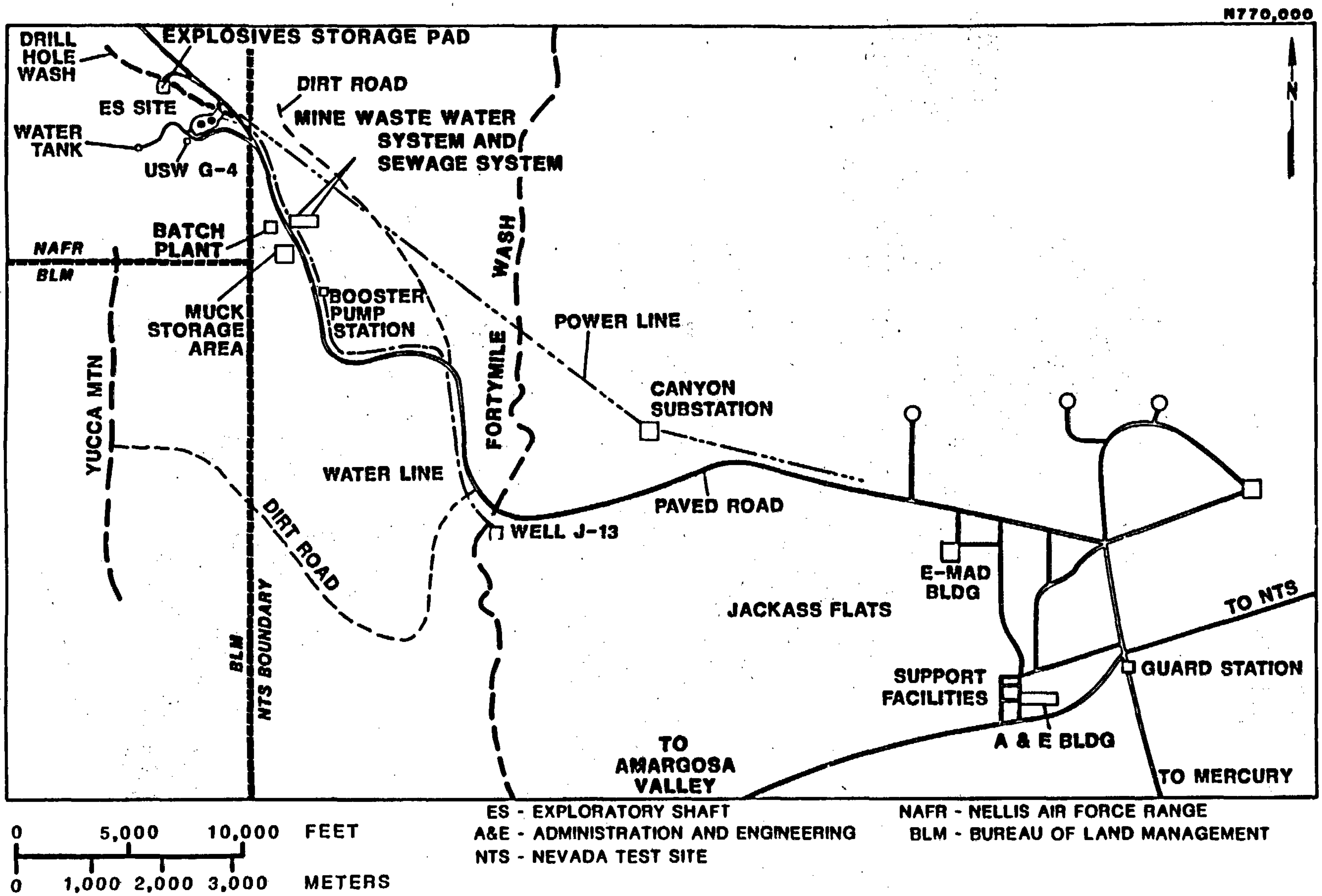


Figure 8.4-4. Location of facilities required during construction of the exploratory shaft facility.

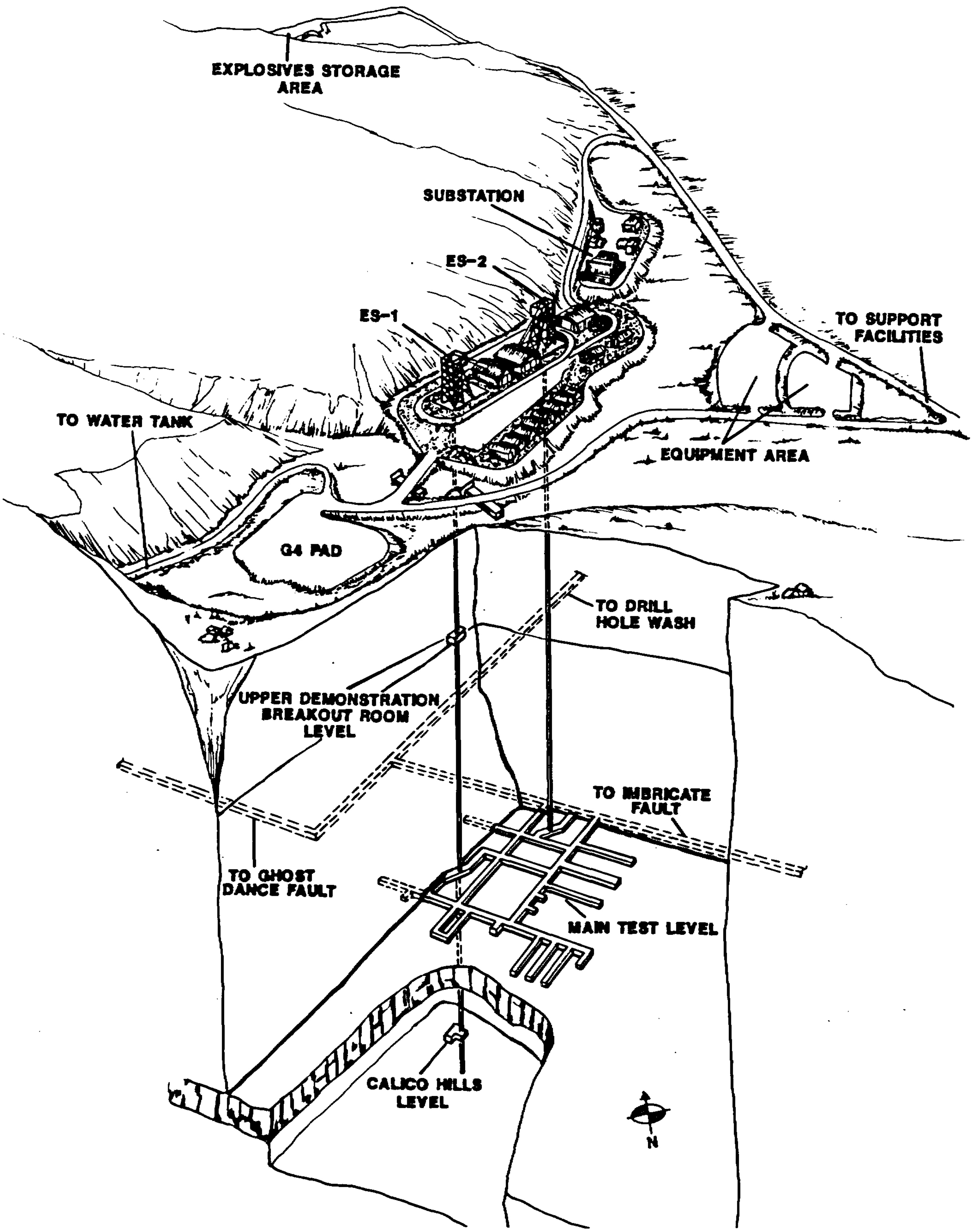


Figure 8.4-5. Conceptual illustration of the exploratory shaft facility.

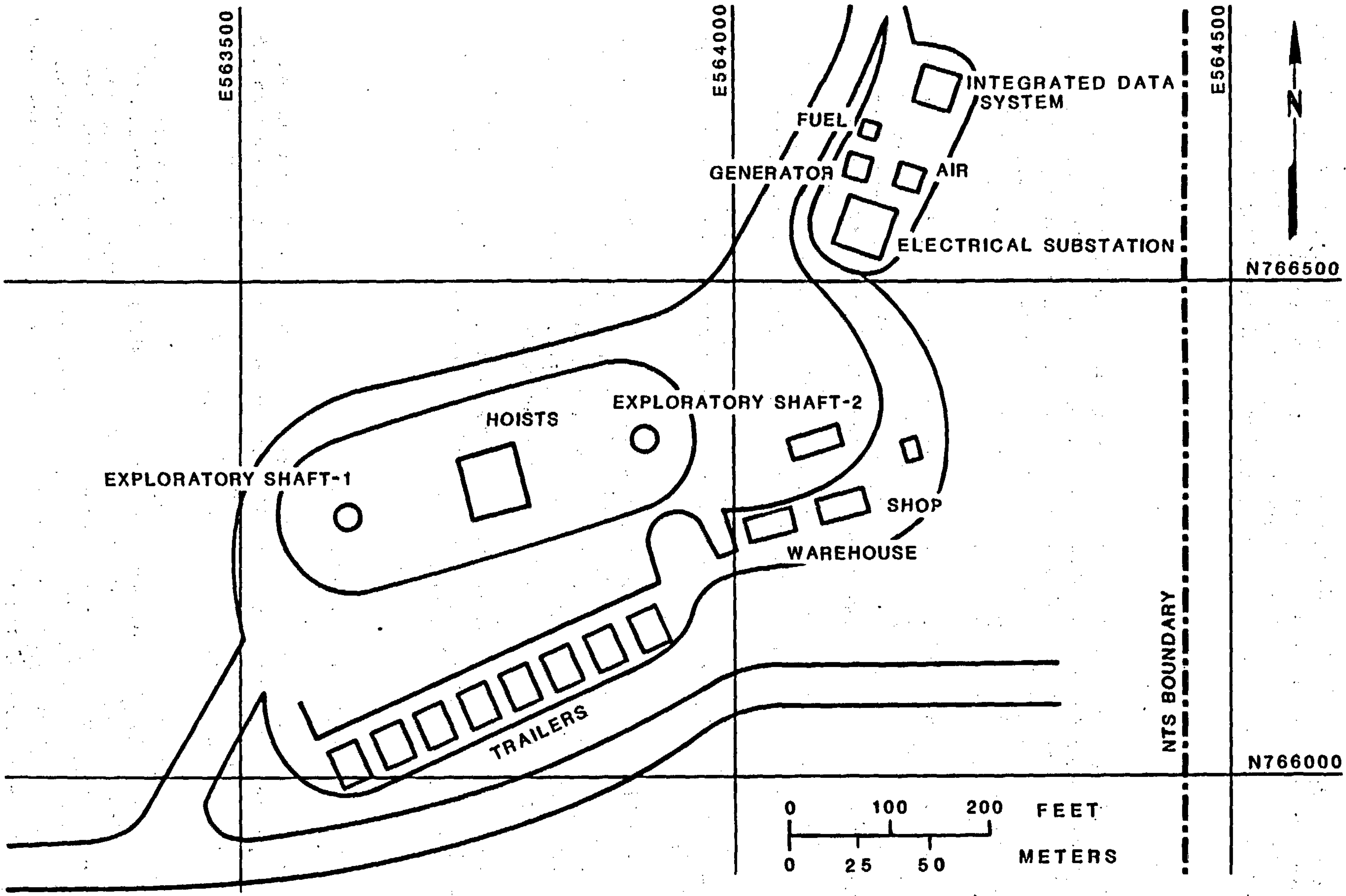


Figure 8.4-6. Conceptual surface layout of the exploratory shaft facility site.

or disposal of liquids be located beyond the proposed repository boundary to minimize the impact of site characterization on natural behavior of that area. Existing office facilities located approximately 13 miles (21 km) from the ESF at Jackass Flats will be used to the extent practical (Figure 8.4-4).

8.4.1.2.1 Pads and roads

Several leveled pads will be required to accommodate the various facilities needed for ESF construction and operations. These include the pads for the exploratory shafts with their associated buildings, water tank, equipment storage areas, explosive storage area, mine waste water pond, sewage collection system, and muck-storage area. An existing pad will be used for the concrete batch plant.

The pad for ES-1 and ES-2 will be situated on a cut-and-fill rock shelf approximately 200 ft (60 m) north of and above the confluence of two small ephemeral stream channels that are tributaries of the Coyote Wash drainage system. The location of Coyote Wash is shown in Figure 8.4-3. Site preparation will require cut and fill to provide level pads for the two exploratory shafts, the surface structures, and the parking and storage areas. Additional fill material will be obtained from "borrow" areas.

Surface preparation for the other pads includes clearing vegetation and grading the site into a level pad large enough to accommodate the particular facility.

The access road from Jackass Flats has been improved to the boundary of the NTS to accommodate heavy equipment. The road is 24 ft (7 m) wide, has 8-ft (2.5-m) shoulders, and is surfaced with a double oil-and-chip layer. Additional roads to the exploratory shaft site pad, the explosives storage area, and the water storage tank will be constructed.

Access to the ESF from the east will be controlled by a chain-link fence and gates. Where appropriate, the natural terrain will be used as a barrier to vehicle access from elsewhere on the site.

8.4.1.2.2 Utilities and communications systems

The utility systems will provide electrical power, water, and sewage facilities necessary to support surface and subsurface operations at the ESF. The communications systems will provide surface communications facilities and fire protection and life safety support system monitoring.

The aboveground electrical supply and power for the underground distribution systems will be provided by a surface substation to be constructed at the exploratory shaft site. The substation will be supplied from an existing 69-kV overhead power line that extends from the canyon substation in Jackass Flats to the NTS boundary (Figure 8.4-4). The substation will be equipped with transformers to supply power to the hoists, air compressors, ventilation fans, and the balance of the site.

A power line will be added to the existing power poles to provide power to the water supply booster pump station from the site substation. Night lighting will be provided by pole-mounted area floodlights. Standby electrical supply will be provided by diesel generators.

The water supply will be distributed from well J-13 on the NTS through an existing 6-mile-long, 6-in.-diameter polyvinyl-chloride pipe buried about 2 ft (0.6 m) below grade. The pipeline, which has been constructed in the bed of the old access road to the NTS boundary, is adjacent to the new paved road and will be extended to the ESF site. Well J-13 is located approximately 5 km from the proposed repository boundary. One pumping station is at well J-13, and a booster pumping station is about halfway (based on elevation) to the site. Water will be pumped to a 150,000-gal (600-m^3) water tank, which will be located west of the site at an elevation of approximately 4330 ft (1,320 m). The water distribution system from the tank will supply water for all needs at the ESF, including fire protection. The fire protection system is designed to meet the requirements of the subsystem design requirements document (SDRD) (DOE, 1987c). The water supply system will be designed to accommodate reasonable changes in the surface and underground facilities.

Sanitary waste will be collected and disposed of in a sewage system located east of the proposed repository boundary. The sewage system will be designed to accommodate sewage from approximately 200 persons during a 24-h period.

The communications systems include telephone service, monitoring systems, integrated data system interfaces, and equipment for transmitting data to the existing Administration and Engineering (A&E) Building at Jackass Flats.

8.4.1.2.3 Buildings

Temporary buildings will be assembled or moved onto the ESF site as they are needed during the construction and operations phases. The site pad will accommodate a limited number of buildings, and, as one construction phase is complete, buildings may be converted for different uses or removed from the site. Prefabricated metal buildings will be constructed to provide space for a shop with adequate repair facilities, a warehouse, and a hoist house. Trailers will be located on the ESF pad and used for change rooms, office and sample preparation space, and a first aid station. Most functions not directly in support of construction will be conducted from the A&E Building (Figure 8.4-4), which will provide a visitors' center and office space.

Three magazines will be required for storing explosive materials: one for explosives, one for detonators, and one for primer makeup. The magazines will be located away from the exploratory shaft site (Figure 8.4-4).

Appropriate codes, standards, and specifications for the surface facilities will be identified and specified in the ESF SDRD (DOE, 1987). The surface facilities will be designed for a 5-yr minimum life unless otherwise specified. Design bases are defined in the ESF SDRD.

8.4.1.2.4 Shaft collars

The purpose of the shaft collar is to provide a stable upper foundation for (1) supporting the shaft concrete liner, (2) anchoring the hoist and headframe assembly (Figure 8.4-7), and (3) mounting the pipes and vents needed for the underground facility services. The collars for both ES-1 and ES-2 will be constructed by using similar design and construction methods. The collars will be in bedrock and consist of reinforced concrete extending from the surface to approximately 88 ft (27 m) below the surface. Drill and blast techniques will be used to excavate the solid rock for the shaft collars. The rock will be removed mechanically by a crane with a clamshell bucket.

8.4.1.2.5 Mine plant and support facilities

The mine plant and support facilities provide the aboveground equipment and systems to support the subsurface construction. Major equipment provided in the mine plant includes ventilation fans with controls, as well as surface ductwork in the shaft collar; air compressors with controls and supply lines to the shaft collar; water-supply piping with controls and waste-water piping from the shaft collar to the mine waste-water pond; and other equipment as required. Major construction support facilities include the concrete batch plant, muck-storage area, mine waste-water storage pond, laydown areas for supplies and equipment, and other facilities as required.

The ventilation system will be designed according to the ESF SDRD (DOE, 1987c). Intake, exhaust, and distribution facilities will supply and exhaust required quantities of air to and from underground working areas for personnel health and safety. Systems will be provided to monitor the underground facilities for radon, methane, oxygen, carbon monoxide, temperature, humidity, and air speed.

Details on the balance of the mine plant systems are currently in conceptual design and will be available in future updates of the SDRD and the conceptual design report.

A concrete batch plant will provide for the storage and mixing of materials for concrete and grout during the ESF construction activities. Concrete will be used for building foundations and the shaft collars and liners. Approximately 1 acre (4,047 m^2) will be used for the batch plant at a location (Figure 8.4-4) beyond the proposed repository boundary. Crushed rock, sand, and cement will be stored in this area.

The mine waste-water pond, located east of the exploratory shaft (Figure 8.4-4) and beyond the repository boundary, will be bermed and lined. Drilling fluids that will be used underground, including air-water mist, bentonitic mud with water control agents, and polymer foam, as well as other waste fluids will be pumped from the underground facility to this pond. The design life of the pond will be a minimum of 25 yr. The pond will be able to hold approximately 375,000 gal (1.4×10^6 L) of waste water.

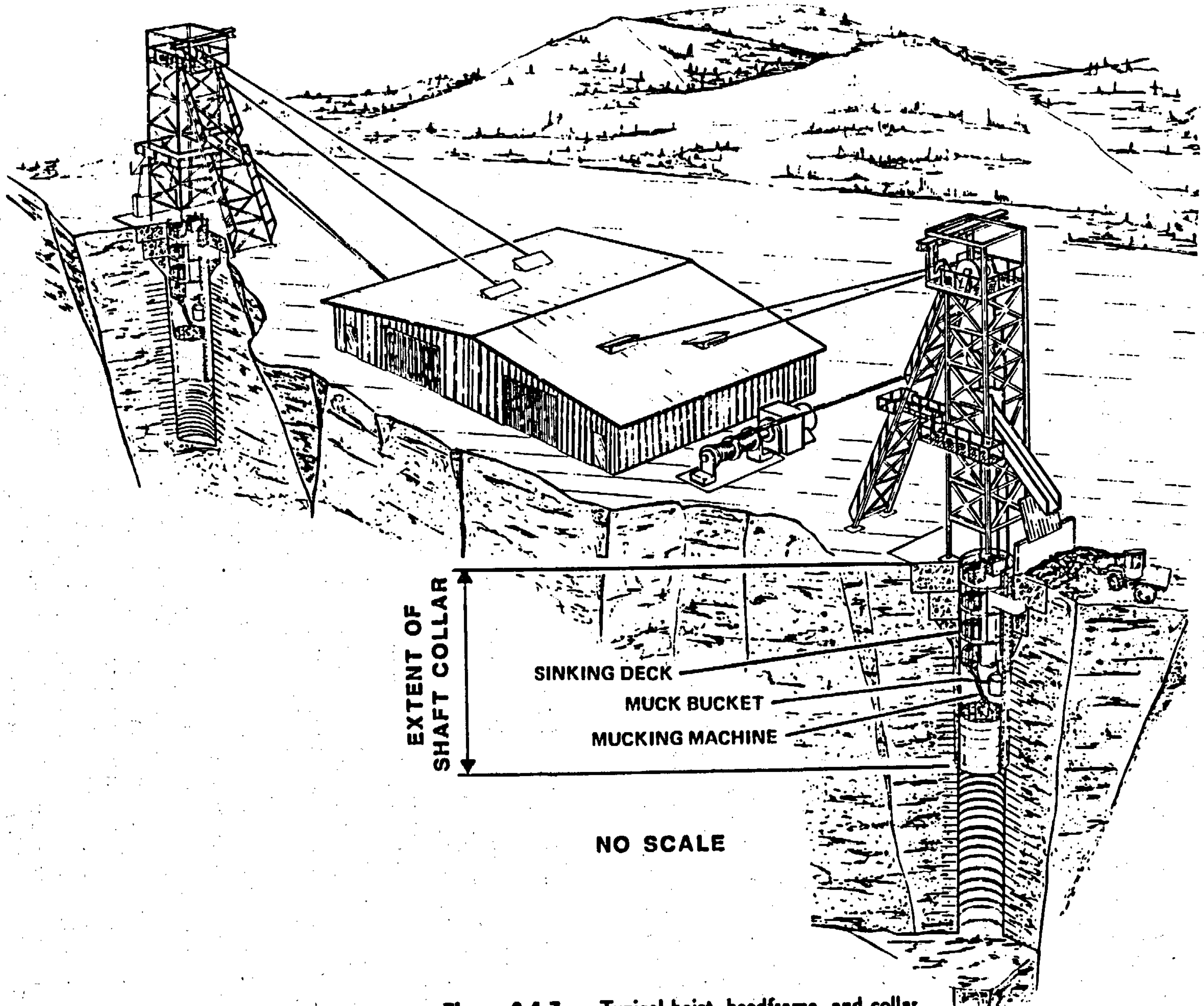


Figure 8.4-7. **Typical hoist, headframe, and collar.**

The muck-storage area will be located east of the exploratory shaft (Figure 8.4-4) and beyond the proposed repository boundary. The rock debris removed during the construction of the shafts, the main test level operations area, and the exploratory drifts will be transported to the surface and hauled to the muck-storage area. This area was selected because it would not constrain the size of the muck-storage pile if additional mining were necessary. The area will accommodate more than the 160,000 yd^3 (122,300 m^3) of rock debris that is currently planned to be produced during shaft and drift mining of the ESF. Dust from the dumping operation will be controlled by appropriate dust suppression techniques.

8.4.1.2.6 Hoist and headframe

The hoists, hoist house, and headframes for both ES-1 and ES-2 shafts will be erected and installed following the construction of the shaft collars (Figure 8.4-7). The hoists will provide the necessary hoisting capacity for muck removal, personnel conveyance, and movement of materials to and from the surface. The hoists will be outfitted with standard controls, brakes, and other safety systems. Details of the hoist systems will be developed as part of the preliminary design, and information will be included in updates of the SDRD. Emergency exit is provided through multiple backup systems. At the first level, two hoists are provided and each can serve as a backup to the other. At the next level, standby power systems are available to both hoists in the event of a power failure. If neither hoist is functional, the ladder in ES-1 can be used for emergency exit.

8.4.2 UNDERGROUND TEST FACILITIES

This section presents an overview description of the underground portion of the ESF as currently planned and designed. The design concepts for the major elements of the design (elements such as the location, dimensions and features of the two exploratory shafts, the location and extent of the lateral exploration drifts driven for investigating certain geologic features, the underground boundary of the ESF, and the design of the central facility) as presented in this section are not expected to change significantly. The more specific details of the design may change as the design progresses or is modified to better meet the goals for site characterization.

The design process for the ESF is consistent with that typically used for major DOE construction projects and the systematic development of designs being used by the Office of Geologic Repositories (OGR). Basic program requirements are established in the generic requirements document (DOE, 1987). These requirements ensure compliance with major regulations and functional requirements for the system. Site specific requirements are then determined based on the physical characteristics and design approach taken at a particular site. The specific design, functional, and performance requirements for the ESF at Yucca Mountain are provided by the NNWSI Project ESF SDRD (DOE, 1987). Additional detailed design criteria will be developed during the conduct of the design and revisions to this document made accordingly. Likewise, even more detailed information will be developed by the designer and used to support the basis for the design.

The location of the ESF within the underground facilities of the conceptual repository is shown on Figures 8.4-8 and 8.4-10. The interfaces between the ESF and the repository are shown on Figure 8.4-9, including the coordinates and elevations of important interface locations that are being used as a common basis for both repository and ES design.

Figure 8.4-10 presents the interface between the ESF and the repository in greater detail and allows information pertinent to other features of both the ESF and the repository to be identified. Specific features identified on Figure 8.4-10 include:

1. The boundary coordinates for the "Dedicated Testing Area." The coordinates C', D, H, and J on the figure locate the corners of an approximately square area in which the facilities of the ESF and any drillholes or drifts supporting testing will be contained (excluding the lateral exploration drifts used for investigating geological features). This area was established as an area of independence in which the designers of the ESF have flexibility to make design modifications without impacting the design of the repository (potential impacts on waste isolation are addressed in Section 8.4.6).

2. The coordinates and elevations of the common points of the ESF and the repository, points C' and D.

3. The estimated coordinates of the locations where the lateral exploration drifts will intersect the target geological features; namely, the Ghost Dance fault to the northwest, the Drill Hole Wash structure to the northeast, and the imbricate normal fault zone to the southeast of the ESF core facility. The coordinates are given for the range of potential intersections resulting from the tolerance applied to the subsurface projection from the surface indication for these structures.

4. The drainage philosophy that is to be used in the dedicated testing area (see Note 4 on Figure 8.4-10).

5. The slopes for the repository drifts in the vicinity of the ESF. This includes the long lateral drifts in the ESF that will become a part of the repository, if it is constructed.

6. The areas where waste will be stored if the repository is constructed. This information is presented to show the proximity of the waste to the ESF.

Approximately 3,000 ft of drifting (mining) are required to construct the central area of the ESF. An additional 5,000 ft of drifting will be required to construct the lateral exploration drifts.

Figure 8.4-11 presents the current design for the central area of the ESF. The arrangement of the central area, as shown on this figure, is not

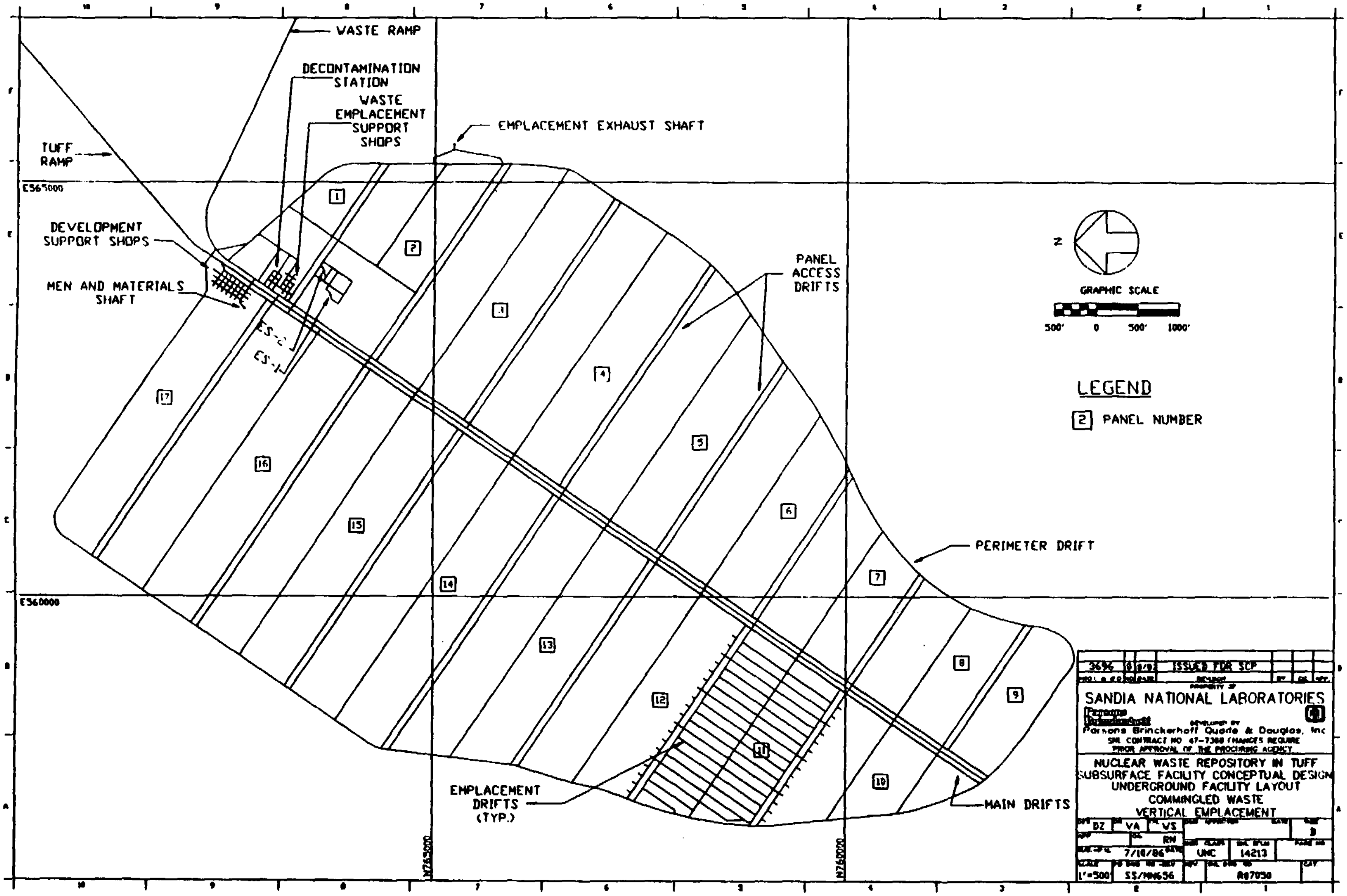


Figure 8.4-8. Location of the ESF within the underground facilities of the repository.

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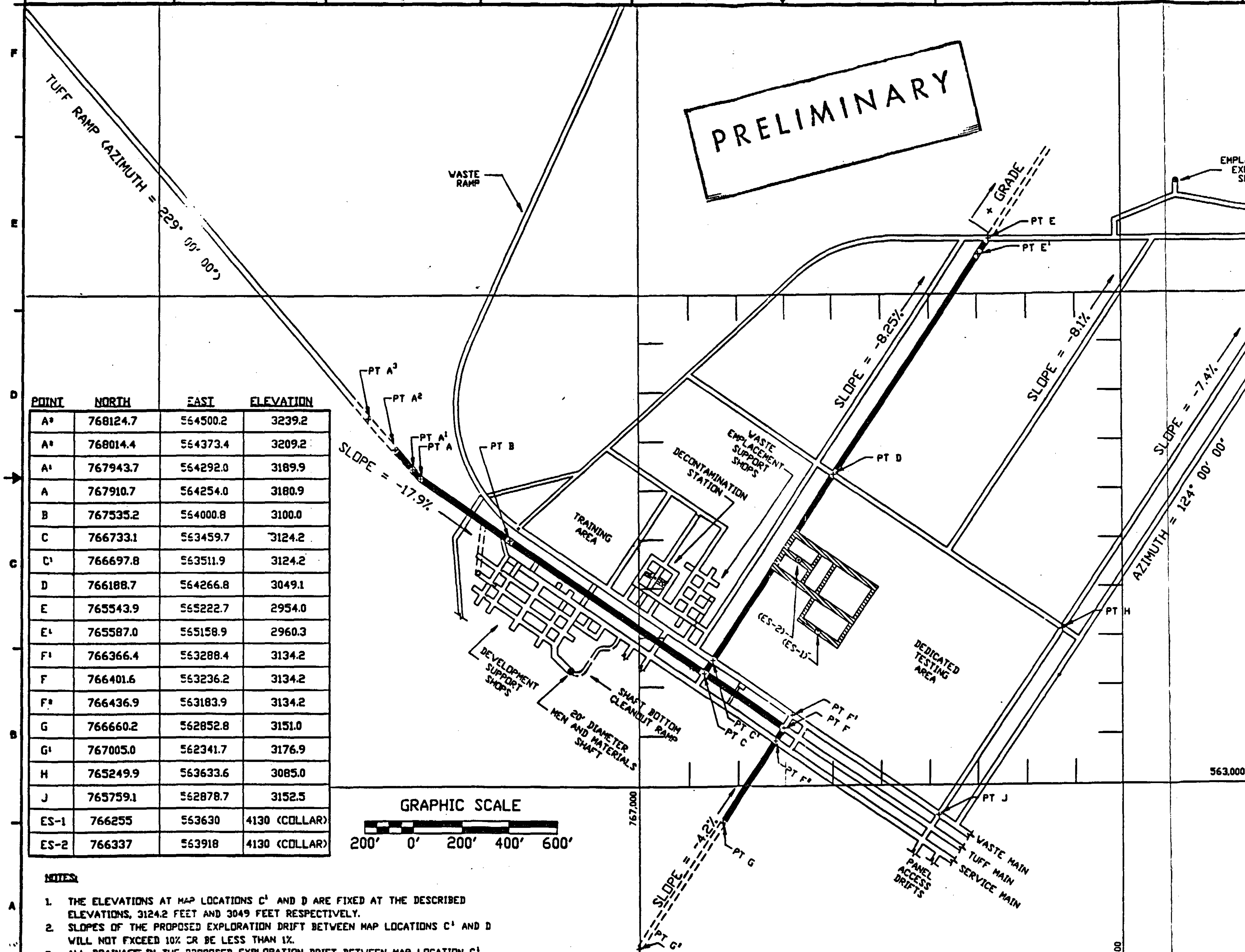

POINT	NORTH	EAST	ELEVATION
A^3	768124.7	564500.2	3239.2
A^2	768014.4	564373.4	3209.2
A^1	767943.7	564292.0	3189.9
A	767910.7	564254.0	3180.9
B	767535.2	564000.8	3100.0
C	766733.1	563459.7	3124.2
C^1	766697.8	563511.9	3124.2
D	766188.7	564266.8	3049.1
E	765543.9	565222.7	2954.0
E^1	765587.0	565158.9	2960.3
F^1	766366.4	563288.4	3134.2
F	766401.6	563236.2	3134.2
F^2	766436.9	563183.9	3134.2
G	766660.2	562852.8	3151.0
G^1	767005.0	562341.7	3176.9
H	765249.9	563633.6	3085.0
J	765759.1	562878.7	3152.5
ES-1	766255	563630	4130 (COLLAR)
ES-2	766337	563918	4130 (COLLAR)

NOTES:

1. THE ELEVATIONS AT MAP LOCATIONS C^1 AND D ARE FIXED AT THE DESCRIBED ELEVATIONS, 3124.2 FEET AND 3049 FEET RESPECTIVELY.
2. SLOPES OF THE PROPOSED EXPLORATION DRIFT BETWEEN MAP LOCATIONS C^1 AND D WILL NOT EXCEED 10% OR BE LESS THAN 1%.
3. ALL DRAINAGE IN THE PROPOSED EXPLORATION DRIFT BETWEEN MAP LOCATION C^1 AND D WILL BE TOWARD POINT D.
4. ALL DRAINAGE WITHIN THE PROPOSED ESF TEST BED WILL BE TOWARD ES-1.

Figure 8.4-9. Exploratory shaft facility-repository interface control drawing.

DOCUMENT CONTROL CONCURRENCE

DATE	ORGANIZATION	DESCRIPTION	APP.
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6/2/87	F&S		[illegible]
6/2/87	P&SED		[illegible]
6/2/87	LANL		[illegible]
6/2/87	H&N		[illegible]
6/02/87	REECO		[illegible]
6/02/87	DOE/WMPO		[illegible]

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NUCLEAR WASTE REPOSITORY IN TUFF
SUBSURFACE FACILITY CONCEPTUAL DESIGN

ESF-REPOSITORY INTERFACE CONTROL DRAWING

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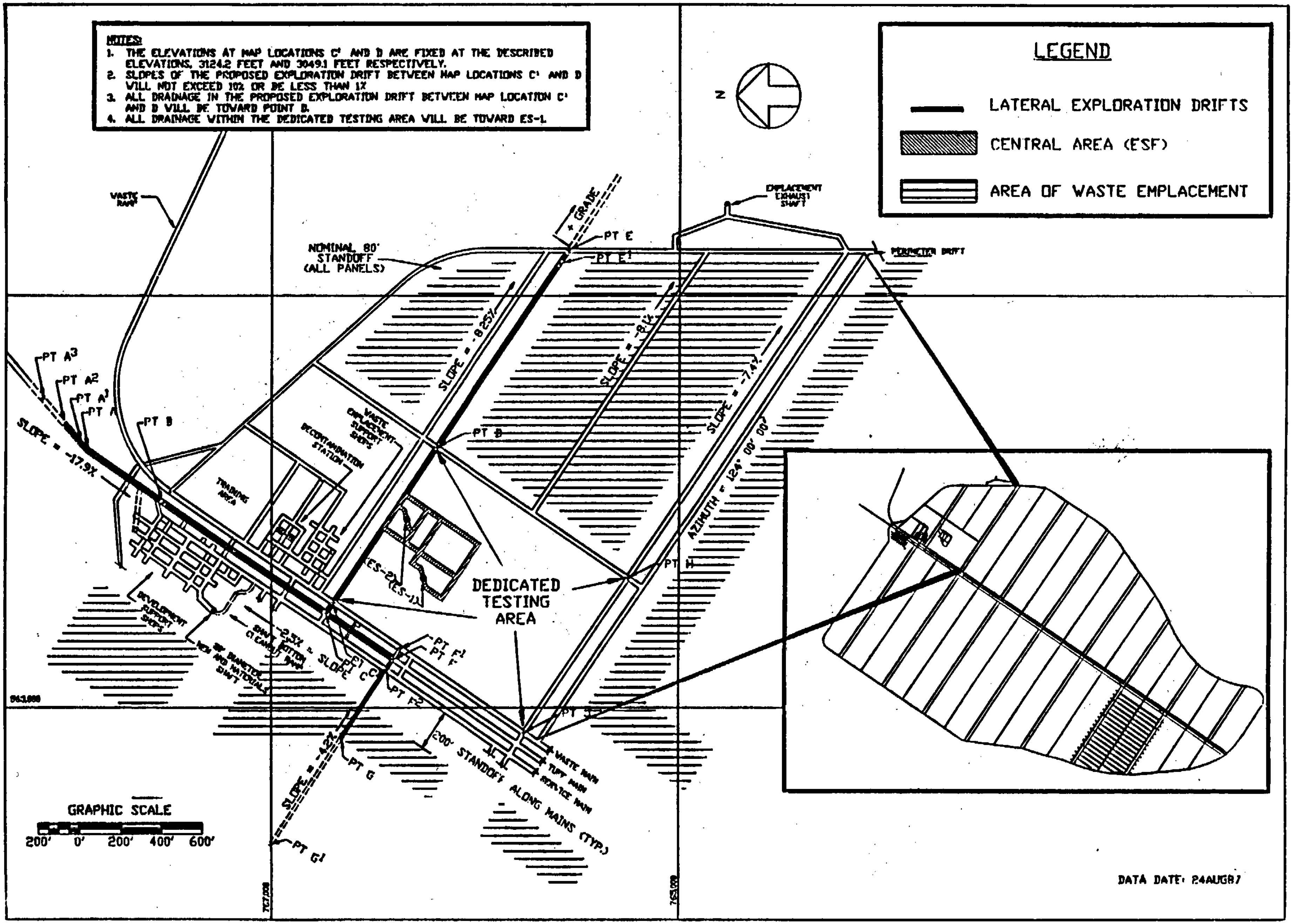

Figure 8.4-10. Detailed repository layout in vicinity of exploratory shaft facility.

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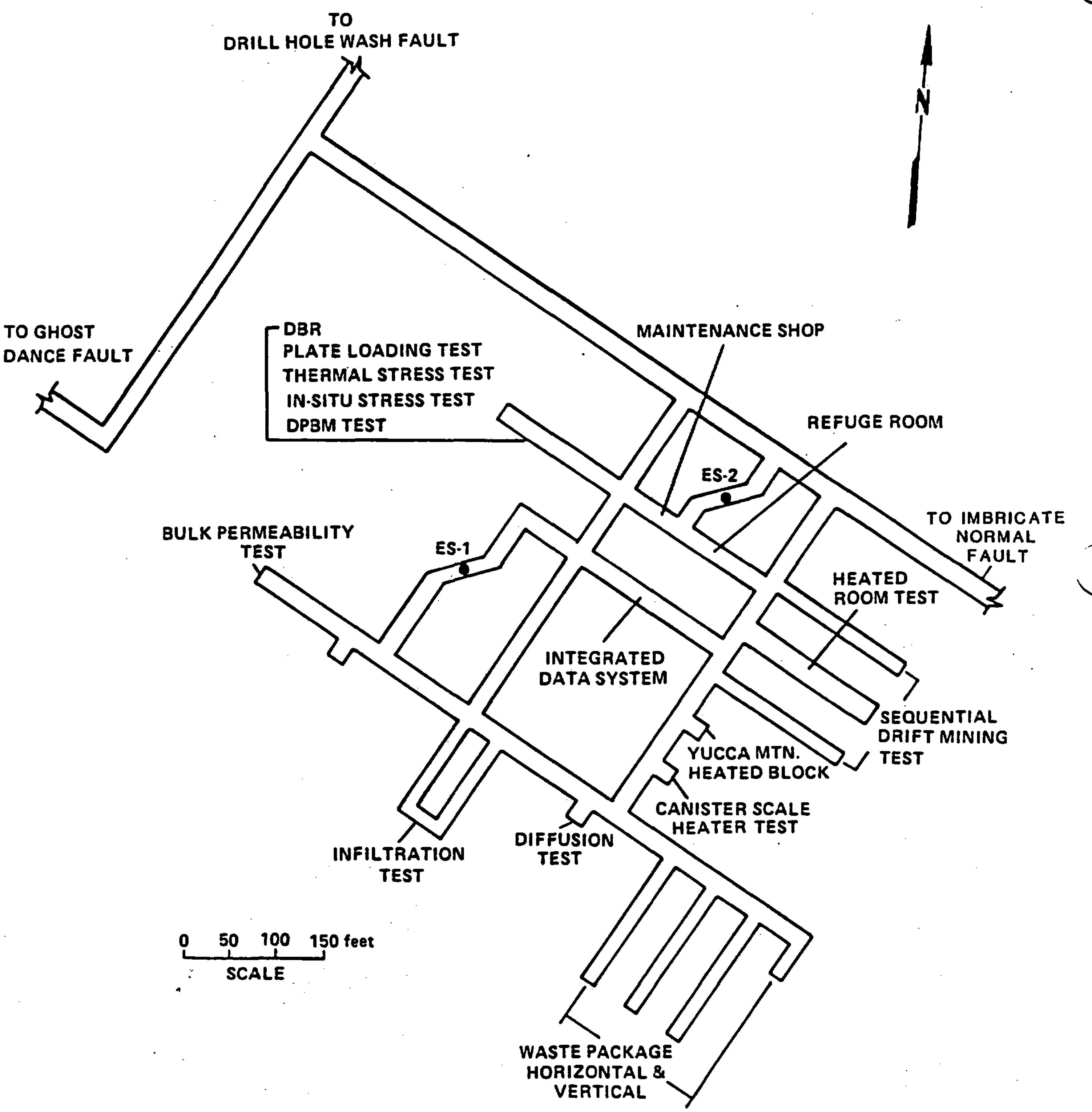

Figure 8.4-11. Central area of the exploratory shaft facility

expected to change significantly; however, the dimensions of the various openings may change as design analyses are completed. The location and orientation may be modified as the interaction between characterization activities and construction phasing are considered further.

A schematic cross-section of ES-1 and ES-2 is presented on Figure 8.4-12. The underground facilities, as shown in Figure 8.4-12, consist of the following:

1. Exploratory shaft 1 (ES-1) with a 12-ft (3.66-m) finished inside diameter and a depth of approximately 1,430 ft (436 m).

2. A landing and a demonstration breakout room (DBR) off ES-1 at the upper DBR level located at an approximate depth of 600 ft (183 m).

3. Landings and approximately 4,000 ft (1,219 m) of drifts at the main test level located at an approximate depth of 1,055 ft (320 m), including test alcoves, test drifts, and the core operations area that provides flexibility for shops and support facilities.

4. A drill room at the Calico Hills level off ES-1 located at a depth of approximately 1,360 ft (415 m).

5. Exploratory shaft 2 (ES-2), with a 12-ft (3.66-m) finished diameter and a depth of approximately 1,100 ft (335 m) for ventilation, materials handling, and emergency exit.

6. Three exploratory drifts having a combined length of about 5,600 ft (1,700 m) from the main test level core operations area to various geologic structures.

The approximate depths of the underground facilities were selected to meet specific characterization objectives. Of these, the main test level selection is the most critical. Chapter 6 describes the proposed repository design and the placement of the emplacement drifts within the tuff media. Since it is important that the ESF characterize tuff representative of the repository media, the main test area should be in the same stratum in which the repository will be located. Because the strata of Yucca Mountain dip from west to east, the repository will also be similarly inclined. As a result of the effort to reduce the degree of inclination along which the repository would be constructed, the repository conceptual design indicates that the level at which the repository actually crosses the ESF would be about 1,055 ft (320 m) below the surface at that location.

This section also briefly describes the construction and in situ tests that will be performed, discusses the potential impact of the ESF on the waste isolation integrity of the site and the relationship between the ESF and the repository, and presents the general requirements and a summary schedule for construction.

Mapping, sampling, and testing within the shaft(s) are designed to (1) obtain geologic information about the units overlying the repository horizon, (2) provide hydrologic information on the overlying units and at the stratigraphic boundaries, (3) provide information on rates of downward water

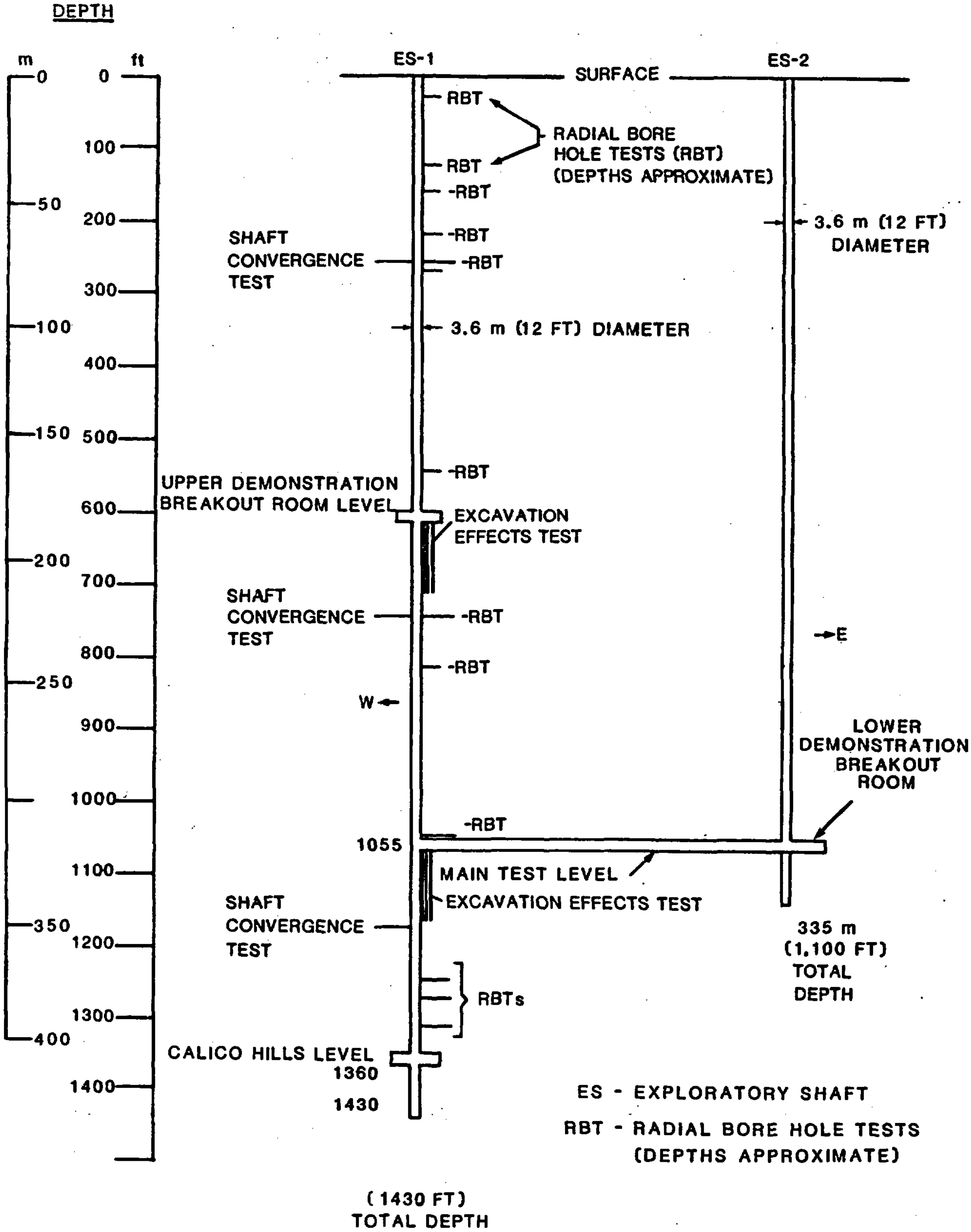

Figure 8.4-12. Schematic cross-section of exploratory shafts 1 and 2.

movement, and (4) provide for geomechanical testing of the overlying units to assist in design engineering, design confirmation, or both. The major focus of ESF testing, however, is to characterize the Topopah Spring unit within the prospective repository horizon.

Because the rock at Yucca Mountain is dominated by near-vertical fracturing, vertical shafts would not be expected to intersect a large fracture population. Therefore, testing within the vertical shafts is not designed to provide detailed information concerning (1) horizontal drift stability in a vertically fractured media, (2) horizontal variability or homogeneity in the Topopah Spring Member, (3) fracture spacing, characteristics, and relationships, and (4) hydrologic parameters and characteristics within the Topopah Spring Member.

It is planned that most of the mapping and testing in the exploratory shafts will be performed in ES-1, primarily to provide a complete and complementary suite of tests in the overlying rock units. Minimal testing is planned in ES-2; however, unanticipated structural or hydrologic features and stratigraphic contacts will be mapped as they are encountered in ES-2.

The facilities listed in this section will be constructed according to a sequence dictated by operational, testing, and safety criteria. Current plans call for starting construction of ES-1 first, then ES-2. When ES-1 reaches the upper DBR level, the upper DBR will be mined. Since there will be little or no testing during the sinking of ES-2, this shaft is expected to be completed first. Construction of the ES-2 is unlikely to affect any of the tests in ES-1. Plausible mechanisms by which the construction of ES-2 could impact testing in ES-1 have not been identified. The impacts, if they were to occur, likely would be in either the areas of mechanical interference or hydrologic interference. Mechanical interference would be manifested by either effects on stress state or displacements. The separation of approximately 300 ft (88 m) is over 20 times the unfinished shaft diameter. Excavation-induced effects in an elastic medium become insignificant at distances of approximately three shaft diameters away from the excavation (Brady and Brown, 1985). The actual situation at Yucca Mountain involves fractured rock masses. However, the shaft lining provides confinement to the rock mass. The degree to which construction of ES-2 could have a mechanical impact on tests in ES-1 is expected to be roughly comparable to that predicted on the basis of elastic behavior. Accordingly, there is no expectation for mechanical interference between the shafts.

Unsaturated-zone hydrologic tests to be conducted in ES-1 are not expected to be influenced by the presence of ES-2. Over the distance involved (300 ft), ES-2 is expected to cause only negligible alterations, if any, to the potential fields (e.g., pressure, temperature, moisture content) in the vicinity of ES-1. In any event, these potentials, which control the movement of moisture in both the vapor and liquid phases, will likely be overshadowed by the artificially induced potentials developed over the course of the various experiments. As the radius of influence of the experiments is expected to be relatively small when compared with the inter-shaft distance, the presence of ES-2 is not expected to affect, hydrologically, any experimental results.

In the unexpected event that any indications are observed that sinking ES-2 might impact tests in ES-1, the schedule for ES-2 construction could be modified. When ES-2 is completed, some drift space for equipment and materials staging may be developed at the bottom of the shaft. Next, the connecting drift between the two shafts will be constructed in time to effect the connection when ES-1 reaches the main test level. When ES-1 and ES-2 are connected, the balance of the core operations area drifts will be mined, and then the individual test alcoves and drifts will be mined. Mining of the long exploratory drifts will begin when the test facilities are complete.

Certain items in the ESF have been classified as permanent items that could be incorporated into a repository at Yucca Mountain. These items will be designated to have the same maintainable life and quality as specified for the repository. They include:

1. Underground openings. All spaces created by mining or drilling, including those zones within the rock altered by that process.

2. Shaft liners. All components placed between the inside limits of the shaft and the accessible extent of the underground opening.

3. Operational seals. Any material placed in an underground opening or the peripheral rock to control the flow of water or gas (the NNWSI Project position is that operational seals will not be required for the Yucca Mountain ESF).

4. Ground support. Any means used to reinforce rock or control the movement of rock, except for removable or replaceable hardware.

Design details and the construction sequencing for ES-1 and ES-2 are described in detail in Sections 8.4.2.1 and 8.4.2.2 respectively. Section 8.4.2.3 describes the main test level and Section 8.4.2.4 describes the lateral exploratory drifts. The tests to be conducted in the shafts and the main test level are described in Section 8.4.2.5.

8.4.2.1 Exploratory shaft 1

This section describes the exploratory shaft 1 (ES-1) and the various steps in its construction. ES-1 is the shaft where most of the in-shaft-related site characterization tests, which are briefly described in Section 8.4.2.5, will be performed. Additional testing at any depth may be done in ES-1, if necessary.

The completed ES-1 (Figure 8.4-12), will be a concrete-lined, 12-ft (3.66-m) finished-diameter vertical hole extending about 1,430 ft (436 m) from a leveled pad located at about the 4,130-ft (1,260 m) elevation on the east flank of Yucca Mountain. The shaft will provide access to breakout rooms and stations at three specific depths: the upper demonstration break-out room (DBR) level, the main test level, and the Calico Hills level. The completed shaft will be equipped with the necessary internal structures, conduits, piping, ventilation ducts, and conveyances to move people and materials in and out of the underground facilities and to support the mining and testing activities.

Because the water table is 280 to 404 ft (85 to 123 m) below any planned excavation, no ground water is expected during shaft sinking and mining of the test areas. Any water encountered during shaft sinking will be collected, measured, and disposed of at the surface in the mine waste water pond. The portable water removal system planned for the water introduced during shaft mining is considered adequate to handle any unanticipated perched water. The shaft will also be equipped with water control features (e.g., water rings, sumps, and discharge pumps) as determined appropriate by ongoing design studies.

The upper DBR level will be located near the upper boundary of the potential repository horizon. The upper DBR will be a horizontal drift that, during construction, will accommodate a number of rock mechanics tests. These tests are described briefly in Section 8.4.2.5.

At the main test level, ES-1 will intersect a lateral drift that will be mined following the sinking of exploratory shaft 2 (ES-2). The main test level stations in ES-1 and ES-2 will provide access to the operations area and the exploratory drifts, described in Sections 8.4.2.3 and 8.4.2.4, where a majority of underground site characterization testing will take place.

ES-1 will extend through the lower boundary of the potential repository horizon and into a transition zone between the Topopah Spring Member and the Calico Hills tuff. At the Calico Hills level a station and drill room will be constructed within the nonwelded Calico Hills tuff. The Calico Hills drill room will be used to study rock characteristics as described in Section 8.3.1.4.2.2.3.

The shaft will extend approximately 80 ft (24 m) below the Calico Hills drill room to its total depth (Figure 8.4-12) to provide access to, and characterization of, the zeolitic zone of the Calico Hills unit. At its total depth, ES-1 will penetrate about 50 ft (15 m) into the nonwelded zeolitic interior of the tuffaceous beds of Calico Hills and will leave about 280 ft (85 m) of the Calico Hills tuff undisturbed above the static water level. The bottom of the shaft will have a sump for collecting and pumping out any water that may be present during the construction or operations of the ESF. The extension of the shaft below the Calico Hills level will also provide space required to accommodate requirements for mine hoisting safety such as conveyance overrun and rope stretch.

Descriptions of the construction activities are presented in the following sections for each construction phase. ES-1 construction is subdivided into construction phases that are separated by major test activities.

8.4.2.1.1 Construction of exploratory shaft 1 to the upper demonstration breakout room

After the headframe, sinking deck, and associated equipment are in place, the shaft-sinking operation will be generally routine, except for testing, down to the upper DBR level. A typical sequence of operations will commence by drilling a number of small-diameter blast holes into the rock. The number, depth, and location of the holes will be determined by the rock conditions and previous blasting results. The blast holes will then be loaded with explosives and the detonation timed so that the blast is controlled (i.e., to enhance the vertical advance, limit damage to rock zone, and produce acceptable-sized rock fragments). Procedures to control blasts will be developed before ESF construction begins.

Controlled blasting techniques are used to improve contour conditions about an opening by reducing overbreak and minimizing crack propagation. Several specific blasting techniques fall under the term controlled blasting: line drilling, cushion blasting, presplitting, and smooth blasting. The first two methods are specialized and have limited practical use underground. Presplitting, also called preshearing, involves detonating lightly loaded charge in closely spaced perimeter holes before the adjacent interior area is excavated by blasting. When executed properly, presplitting creates a fracture plane between the holes that limits the subsequent transfer of energy to the final shaft or drift wall. Smooth blasting, also called contour blasting, is similar to presplitting except that the perimeter holes are detonated after the main blast, breaking a relatively thin slab of rock to the newly created interior free face.

For both of these methods, the linear charge concentration in the perimeter holes is relatively small compared with fully loaded conventional blastholes. The resultant shock waves from adjacent perimeter holes cause localized stress concentrations in the rock and at the blasthole surfaces, and influence the direction and magnitude of a propagating fracture plane. The end result is a plane of weakness between holes that outlines and limits the extent of the blast activity.

Regardless of the techniques used, the results of any blast excavation primarily are dependent on the characteristics of the rock encountered. Although controlled blasting works well in some formations, in others it does not work at all. Trial and error is the best method for determining a practical controlled blast design. When successfully executed, the remainder of perimeter blastholes (half-hole casts) can be seen about the contour of the opening.

The controlled blasting technique considered most suitable for underground development at Yucca Mountain is smooth blasting. Smooth blasting, when compared with presplitting, requires fewer holes and one less step in the mining cycle. Five factors influence the performance of smooth blasting: geology and rock characteristics, drill precision, blast pattern layout, charge concentration, and detonators and sequencing.

After the blast holes are prepared, the sinking deck and associated equipment will be raised to protect them from damage. The miners will then exit the shaft and the explosives will be detonated. Following each blast, air will be exhausted to remove smoke, dust, and fumes before the miners enter the shaft to muck out the rubble. Mechanical mining, a postulated technique for use in repository construction, will not be used in ESF construction because it is not necessary or justified given the limited amount of excavation to be done.

Normally, the shaft miners will spray the rubble with water for additional dust control before mucking. Water usage will be controlled in ES-1, however, to limit any potential impact on testing. All water used for dust suppression will be tagged with a suitable tracer to distinguish water introduced during drilling or testing from natural water. Humidity in the supply and exhaust ventilation will be monitored and recorded.

After venting of smoke, dust, and fumes, the miners will reenter the shaft and will start to remove the muck with a mucking machine hung below the sinking deck and a muck bucket suspended from the main hoist (Figure 8.4-7). After the shaft has been advanced 6 ft (2 m) or more, all rubble has been mucked out and any loose rock cleaned off the walls, the miners will stow their equipment. Then the scientists can enter and conduct shaft-wall mapping, sampling, and other tests in the freshly exposed interval of wall rock. The primary purpose of ES-1 is to provide access for scientific investigations; therefore, the time devoted to testing will be as long as the scientists require to successfully accomplish the mapping, sampling, or other testing objectives using methods and procedures that are as efficient as reasonably possible. These testing activities are described briefly in Section 8.4.2.5.1 and in detail in Sections 8.3.1.2, 8.3.1.3, 8.3.1.4, and 8.3.1.15.

When the scientists have completed their work, they will exit the shaft and the miners will prepare the next blasting round. After several blasting rounds, the shaft-liner concrete will typically be placed in 20-ft (6-m) segments. Where specified by the scientists, blockouts will be installed to protect extensometer anchors, piping to control water seepage (if present), and pressure-cell instrument lines before the liner is poured. The unreinforced concrete liner is expected to be at least 1 ft (0.3 m) thick through the welded tuff units. While the freshly placed concrete is setting, the miners will move up the shaft approximately 60 ft (18 m) and install a 20-ft (6-m) section of shaft internal fittings and other equipment, including manway ladders and landings, conveyance guides, utility piping, and instrument conduits (Figure 8.4-13). When this work is completed, the miners will move back to the shaft bottom and muck out the rubble remaining from the previous blasting round. The scientists will then conduct their tests, and the sequence of activities will be repeated down to the proposed depth of the upper DBR. At selected depths, radial-borehole and shaft convergence tests will be conducted as described in Section 8.4.2.5.1.

At about 50 ft (15 m) above the selected breakout depth, the shaft wall will be bolted and reinforced to provide a secure anchor into the bedrock for added support to the reinforced liner interval (brow) located immediately above the breakout. The brow will be reinforced with both rock bolts and vertical steel tendon rods set within the concrete from the anchor down to the breakout level. The purpose of the reinforcement is to remove heavy vertical loading on the wall rock at the breakout level so that mining of the

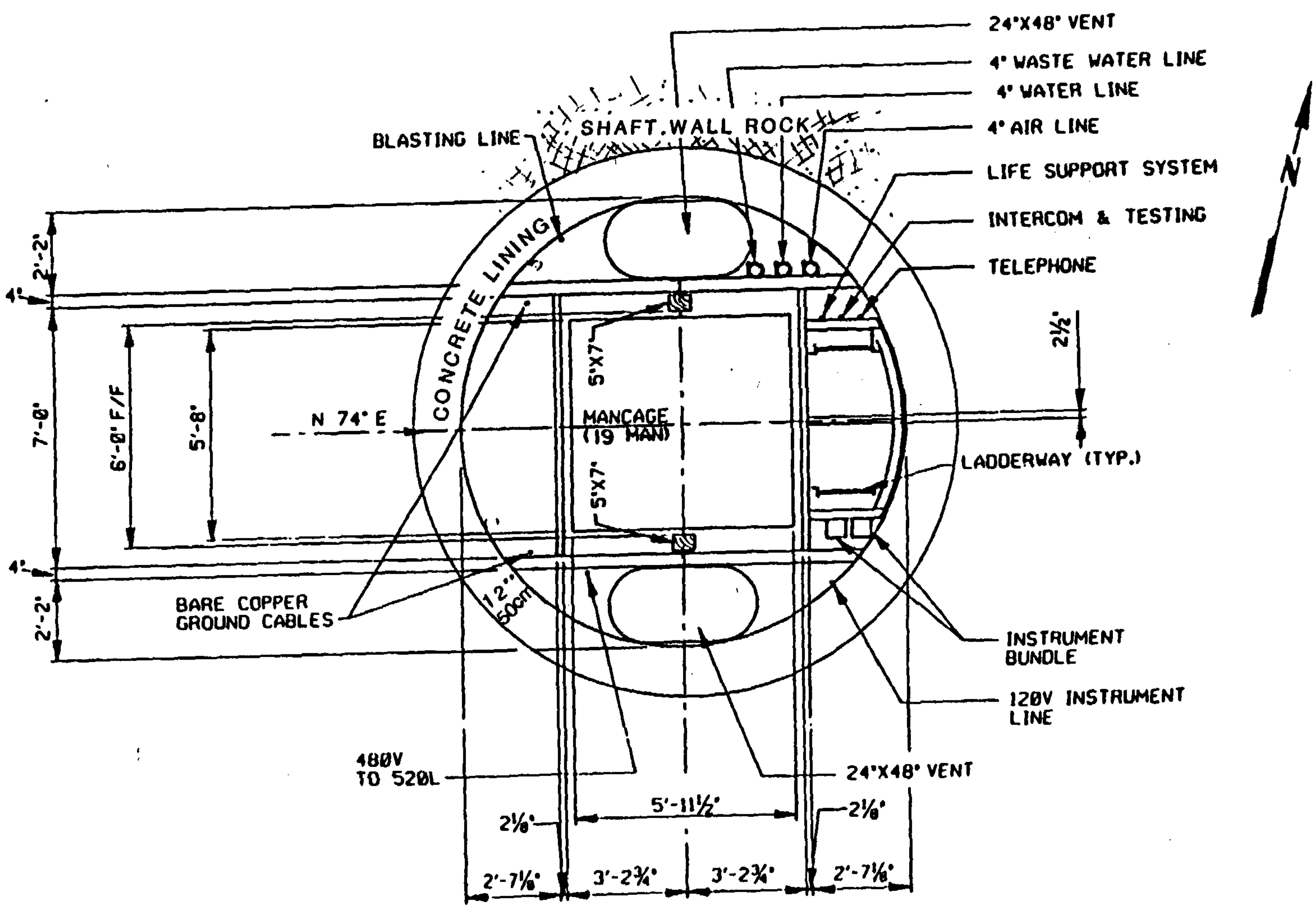

Figure 8.4-13. Conceptual illustration of exploratory shaft 1 internal structure.

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upper DBR can proceed safely and with assured long-term stability of the drift opening near the shaft.

8.4.2.1.2 Construction of the upper demonstration breakout room and station

The rationale for the location of the upper DBR is to characterize rock having approximately 15 percent lithophysal void content that may be encountered at places in the proposed repository horizon. This information will help site modeling efforts to predict the thermal and mechanical response within high lithophysal zones of the proposed repository horizon. In addition, the constructability and stability of the drifts will be established for both vertical and horizontal emplacement modes. Work on the upper DBR will actually include mining two types of rooms: (1) the station excavated directly off the exploratory shaft and (2) the upper DBR excavated off the station (Figure 8.4-14).

The station will provide a reinforced area for off-loading equipment and handling muck produced by upper DBR construction. It will provide the flexibility to implement future drifting if required, including a blockout for the installation of a muck pocket. The station excavation will not be greater than an 11-ft (3.3-m) radius east and west from the shaft (Figure 8.4-14) and will be reinforced with rock bolts, wire mesh, steel sets, and lagging. Fractures and other features exposed in the walls and roof of the station will be mapped during construction.

The upper DBR will probably be mined in a single pass. The excavation will be accomplished by drilling rounds of small-diameter shot holes about 7 ft (2 m) into the face, loading them with explosives, and blasting. The hole patterns, explosive loads, and detonation timing will all be designed to enhance the advance, reduce blast damage to the drift walls, and produce acceptable-size rock fragments. Following each blasting round, the drift will be ventilated to remove smoke, dust, and fumes before the miners reenter the drift to muck the rubble. The muck will be transported to the shaft and loaded directly into the muck bucket for removal to the surface.

After the newly excavated drift space is cleaned out and made safe for entry, the scientists will map the fresh surface exposures. Some of the geomechanical tests will begin concurrently with upper DBR mining so initial responses of the rock mass can be measured. Instrumentation used for the upper DBR tests will be wired into the integrated data system. Data collection and analysis can, therefore, begin immediately and will continue while the shaft is mined to its total depth. Stress and permeability test holes will be drilled and data instrumentation installed in the upper DBR before shaft sinking resumes.

8.4.2.1.3 Construction of exploratory shaft 1 to the main test level station

After the test holes described in the previous section have been drilled, the shaft sinking will resume until the main test level is reached. The same construction and testing sequence described in Section 8.4.2.1.1

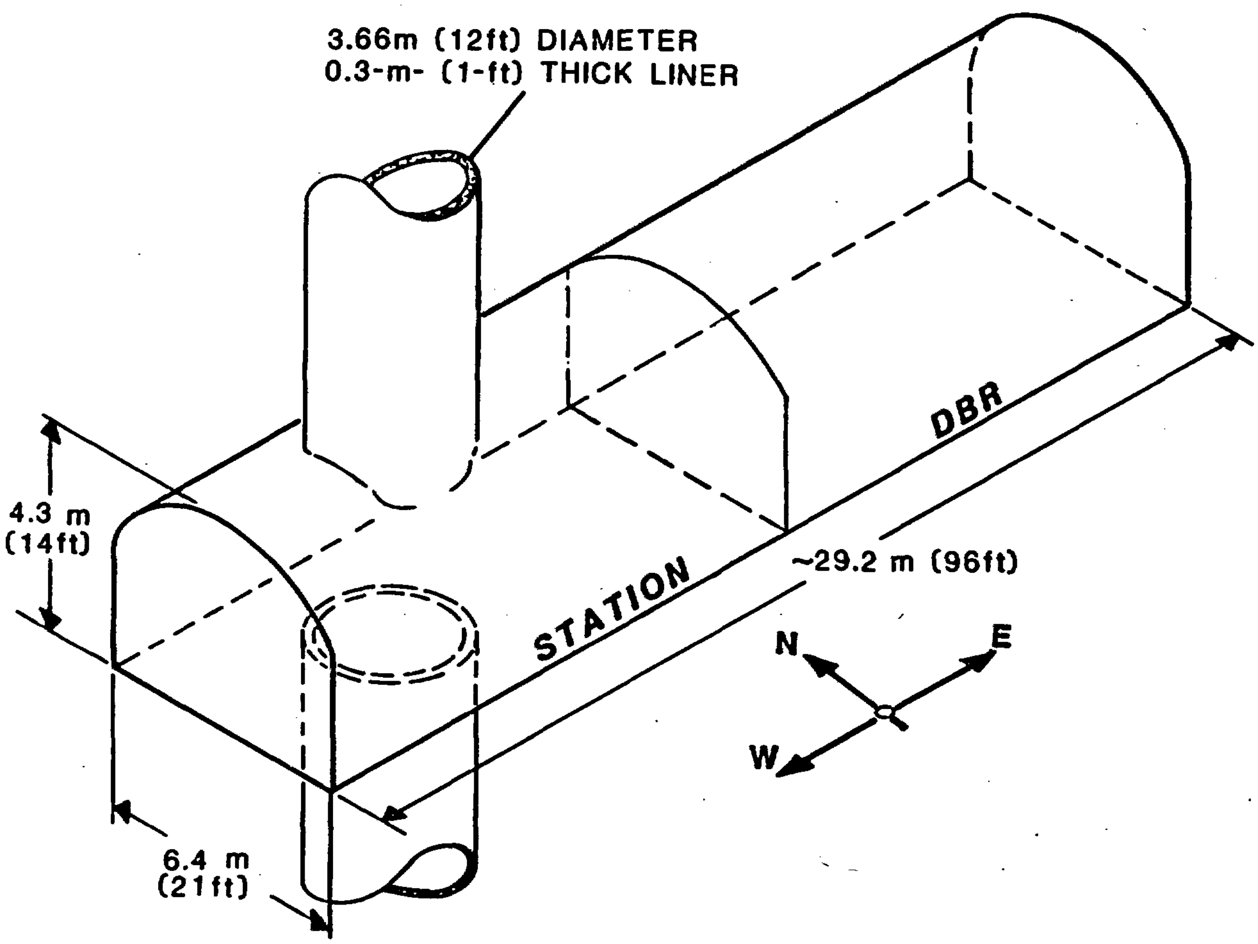

Figure 8.4-14. Upper demonstration breakout room.

will be used. In addition to the regular mapping and sampling activities, shaft-sinking operations will be interrupted periodically for other tests described in Section 8.4.2.5.1.

8.4.2.1.4 Construction of the main test level station

At about 50 ft (15 m) above the main test level, a reinforced brow liner will be constructed (discussed in Section 8.4.2.1.1) to reinforce the main test level station. This station will be constructed in essentially the same manner as the upper DBR station described in Section 8.4.2.1.2. The shaft will be deepened approximately 40 ft (12 m) below the station level so that the blockout for the muck pocket can be constructed. Upon completion of the station, the connecting drift from ES-2 will be completed.

8.4.2.1.5 Construction of exploratory shaft 1 to the Calico Hills station

With completion of the main test level station and certain test preparations described in Section 8.4.2.5.1, the miners will continue sinking the shaft through the lower boundary of the potential repository horizon and into the transition zone between the Topopah Spring Member and the Calico Hills tuff. The shaft will be mined by using the same techniques described in Section 8.4.2.1.1.

8.4.2.1.6 Construction of the Calico Hills station

The construction of the Calico Hills station will be essentially the same as that for the upper DBR station and the main test level described in Sections 8.4.2.1.2 and 8.4.2.1.4. A conceptual layout of the Calico Hills station is shown in Figure 8.4-15. A reinforced brow liner (discussed in Section 8.4.2.1.1) will be constructed from 50 ft (15 m) above the breakout. Drill rooms will be excavated from the shaft for testing in the Calico Hills tuff. A slash-out for a small muck pocket will be mined as part of the Calico Hills station development.

8.4.2.1.7 Construction of exploratory shaft 1 to total depth

With completion of the Calico Hills station, ES-1 will be sunk to its total depth of about 1,430 ft (436 m). The shaft will penetrate about 75 ft (23 m) into the tuffaceous beds of Calico Hills, and the lower 50 ft (15 m) will be in the pervasively zeolitized zone. Penetration into the Calico Hills tuff by the ESF is thus minimized, but the zeolitic zone is accessible for in situ testing to investigate the potential for retarding radionuclides by various physical and chemical sorption processes. The shaft-liner thickness may be increased (for structural support) within the nonwelded Calico Hills tuff.

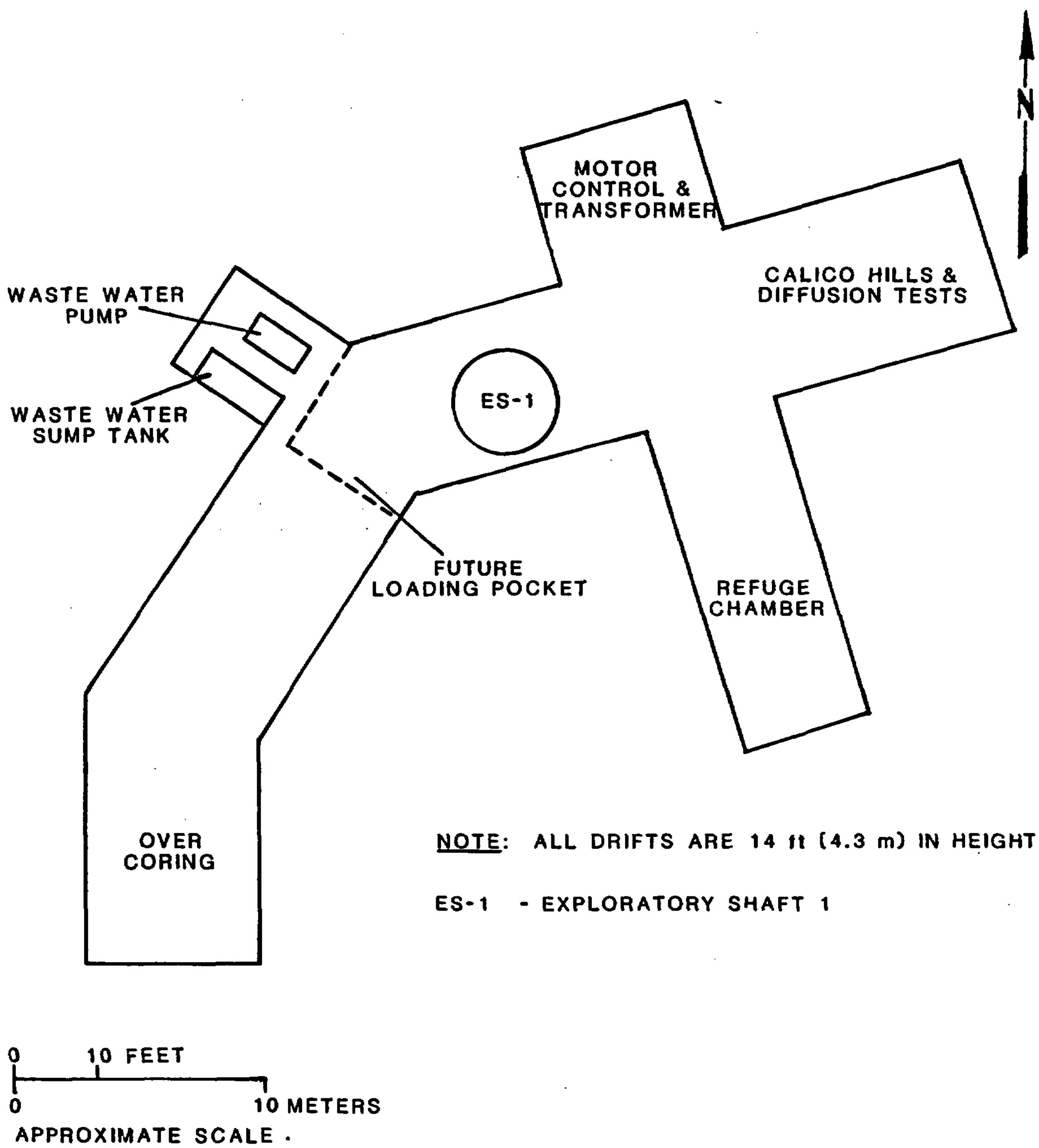

Figure 8.4-15. Conceptual view of the 1,360-ft level (Calico Hills station) of exploratory shaft 1.

At the shaft bottom, a sump pit will be excavated and pumps installed for water removal. Although water is not expected in the underground facilities, it is possible that perched-water zones, percolation seepages, or water used for dust control at working headings could release a small amount of water to the underground facilities during construction and testing. If a seep or perched-water zone is encountered, the water will be collected as discussed in Section 8.3.1.2.2.4.7. Excess water will be collected in the sump and then pumped to the surface and discharged in the mine waste-water pond. A backup sump pump will also be provided. The quantity of water removed from the shafts will be measured and recorded. The details and capacities of the waste-water removal system are currently being developed as part of a conceptual design study and will be included in future updates of the subsystem design requirements document.

8.4.2.2 Exploratory shaft 2

This section describes ES-2 and the various steps in its construction. ES-2 will be used to provide secondary emergency exit from the facility, to transport people and materials in and out of the underground test facilities, to provide for muck removal, and to provide additional ventilation capacity to the long exploratory drifts. The construction of ES-2 will proceed continuously until it reaches its design depth. A connecting drift to ES-1 and a lower demonstration breakout room (DBR) will also be constructed on the main test level after ES-2 is completed. No specific tests are planned while mining ES-2. The majority of tests are to be carried out in ES-1 and in the horizontal drifts; however, significant structural or hydrologic features and stratigraphic contacts may be mapped if encountered or as needed to verify data obtained in ES-1.

ES-2 is also a 12-ft (3.66-m) finished diameter, concrete-lined vertical hole extending from a leveled pad at the same elevation as ES-1 and to just below the main test level. The completed shaft includes the internal fittings, ventilation duct and plenum area, and conveyances shown in Figure 8.4-16. At the main test level, a station with a muck pocket and equipment staging area will be constructed. The drift space for equipment staging may initially be used for conducting some of the geomechanics tests planned for the lower DBR. The connecting drift to ES-1, located about 300 ft (91 m) southwest, will be mined from ES-2 in time to complete the connection as soon as ES-1 reaches the main test level. When the two shafts are connected, ES-2 will be used to support mining of the test areas and exploratory drifts.

8.4.2.2.1 Construction of exploratory shaft 2 to total depth

The current plan is to construct ES-2 using similar drill, blast, muck, and lining methods as used for ES-1; they are described in Section 8.4.2.1.1. The shaft internal fittings, however, will be installed after the shaft is sunk and lined to its total depth.

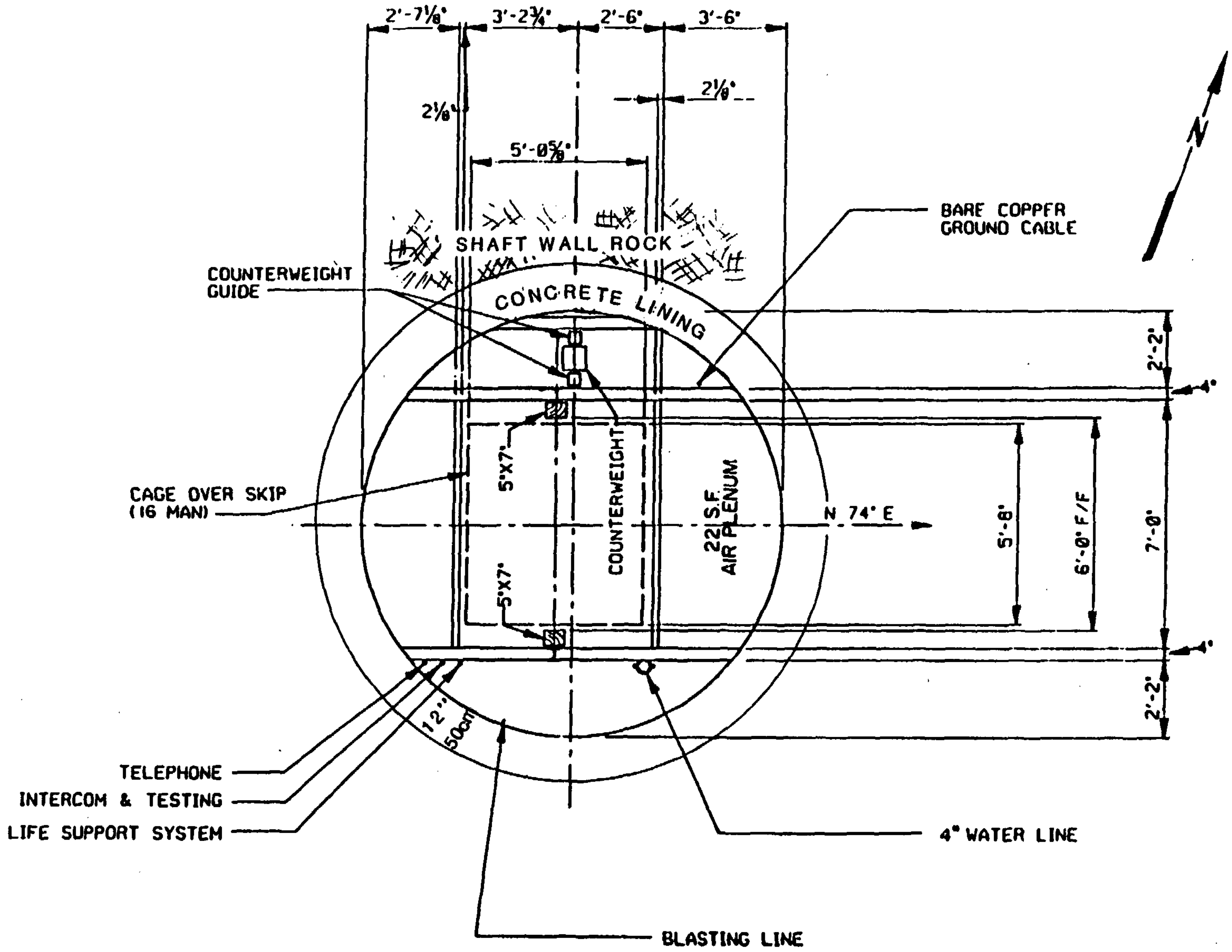

Figure 8.4-16. Conceptual illustration of the internal structure of exploratory shaft 2.

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8.4.2.2.2 Construction of the exploratory shaft 2 station and the connecting drift to exploratory shaft 1

The construction of the ES-2 station at the main test level will be essentially the same as that for the ES-1 main test level station described in Section 8.4.2.1.4. A reinforced brow liner will be constructed by using tendon rods and rock bolts. An additional feature at this breakout level will be the construction of a muck pocket and chute adjacent to, but outside, the shaft diameter. The chute will discharge stored muck directly into the skip in the shaft. After the station and equipment staging area have been completed, the drift that will connect ES-2 with ES-1 will be mined by the drill, blast, and muck technique. If ES-1 has not reached the main test level, the connecting drift will be stopped before it reaches the ES-1 intercept point so that the connection can be made after completion of the ES-1 station. Detailed design information about the ES-2 station and the connecting drift will be made available in semiannual progress reports for this document.

8.4.2.2.3 Construction of the lower demonstration breakout room at the main test level

Like the upper DBR (in ES-1), the lower DBR (in ES-2) will be mined to obtain rock mechanics data related to mining methods and constructibility in welded tuff. The mining (Section 8.4.2.1.2) and testing methods (Section 8.3.1.15.1.5.2) will be the same as for the upper DBR. When the DBR testing is completed, the drift space will be available for other testing or mining operations uses. The DBR tests are planned to be performed from ES-2 before extensive drifting operations are started because they will provide engineering data useful for mining the main test level operations area.

8.4.2.3 <u>The main test level operations area</u>

The design of the main test level operations area has been developed to meet several objectives. The overriding objective is to design the facility such that the waste isolation integrity of the site is not compromised (See Section 8.4.2.6). A primary design objective is to provide maximum flexibility within the area of the proposed repository horizon set aside for exploratory shaft testing. The concept consists of having a dedicated testing area (Figure 8.4-10) that will permit the scientists to select the areas for constructing their test alcoves and drifts in the surrounding rock mass. This objective is important for several tests that have special requirements such as orientation relative to rock stress or predominant fracture patterns, minimized induced water, isolation from other mining or drilling operations, and separation from other mined openings. Figure 8.4-11 shows the current design for developing test areas off the core operations drift area to accommodate the scientific objectives.

A second objective is to ensure that the main test level operations area design will be compatible with the design of a repository. In this regard, the core operations area drifts are designed to minimize constraints on future repository uses such as ventilation or other repository operations.

A third objective is to ensure that the proposed drifts out to the boundary structures to the north and east and to Ghost Dance fault to the west will not compromise site integrity and will not jeopardize future repository emplacement space. This will be accomplished by locating the exploratory drifts along the alignments of the current conceptual repository drifts.

A fourth objective is to provide a centrally located data acquisition system, convenient to the test areas and shafts but adequately isolated from the mining operations.

A fifth objective is to provide a sufficient utilities operations area and dedicated test area to accommodate later performance confirmation tests from the same facility.

A sixth objective is to ensure that the site has been characterized for both the vertical and horizontal emplacement concepts identified in Chapter 6.

Other objectives relate to operational and safety considerations like traffic flow, equipment maintenance, shop space, and ventilation and underground utility requirements. The core operations area concept incorporates all these factors into its design and should, therefore, be operationally efficient, safe, and very flexible in supporting the test effort.

As shown in Figures 8.4-5 and 8.4-10, the main test level will consist of the core area drifts that will provide access to both shafts; access to and between the test areas, equipment maintenance, and shop space; space for the integrated data system with uninterrupted power supply; utility runs; and ventilation. The drifts in the core operations area will be sized (design studies are ongoing) to allow two-way traffic plus all utilities and ventilation ducts. The drifts will be reinforced with rock bolts, wire mesh, and shotcrete as required by design or encountered rock conditions.

8.4.2.3.1 Construction of the main test level

The main test level will be mined by conventional drill, blast, and muck methods. These operations consist of drilling many small-diameter blast holes in the drift face, loading them with explosives, and timing the charges to produce a sequential, controlled blast pattern that will meet the design specifications. The resulting rock rubble (muck) will be loaded and transported to the shaft muck pocket and then transported to the surface in the skip.

After blasting and muck removal and after ensuring safe conditions, the freshly exposed rock will be mapped and photographed (Section 8.3.1.4.2.2.4), and then reinforced with rock bolts, wire mesh, and shotcrete, as required, before preparations are started for the next blast round.

The actual sequence of mining the drifts is still under consideration, but the connecting drift between ES-1 and ES-2 is a high-priority activity for reasons of safety. Since the ES-2 operations shaft may reach the 1,055-ft (320-m) level several months before the ES-1, drift space for equipment and material staging and possibly a room for certain design experiments (i.e., lower DBR tests (Section 8.3.1.15.1.5.2) and stress testing (Section 8.3.1.4.3.1.1)) may be completed first, followed by construction of the connecting drift in time to effect the connection when ES-1 reaches the main test level.

When ES-1 and ES-2 are connected, the balance of the core operations area drifts will be mined, followed by the individual test alcoves and drifts. The details of these test alcoves and drifts will be provided in future design documents. Mining of the long exploratory drifts will begin about the time the test facilities are completed. Operational constraints may be a determining factor in scheduling the drift mining activities.

8.4.2.4 Exploratory drifts

Exploratory drifts are planned to gain access to three specific features within the proposed repository block: (1) the Ghost Dance fault, (2) the Drill Hole Wash structure, and (3) the imbricate normal fault zone to the east. These drifts are necessary to obtain information on the various structures to be encountered at the ends of each drift. The locations of the three drifts are shown in Figures 8.4-5 and 8.4-10. The lengths of the drifts have been estimated based on projections of the fault planes from the surface to the intercept elevations. The uncertainty in the length estimates is about ±200 ft (60 m) for each of the three drifts. The lengths of the drifts could be slightly less than the estimates provided in the following sections if the intercept locations occur as projected.

Each drift will be mined by the same techniques used for the main test level operations area described in Section 8.4.2.3.1. The exploratory drift layout is shown in Figure 8.4-10. The ribs and the back will be rock bolted and covered with wire mesh as required. Tests described in Section 8.4.2.5 will be conducted during the mining and site characterization periods.

8.4.2.4.1 Drift to the Ghost Dance fault

The drift to the Ghost Dance fault will examine features potentially important to the design and performance of a repository. First, the fault is a potential transmissive zone for movement of water from the surface to the water table. The drift will allow direct observation, collection of samples, and other measurements needed to model the hydrologic environment. Other information that can be obtained by this drift includes the nature of the fault zone and possibly the degree of fault offset.

To reach the Ghost Dance fault area, a drift approximately 1,200 ft (370 m) long heading northwest from the main test level operations area will be constructed by using the drill, blast, and muck technique previously described. The tests to be performed during construction and site characterization are briefly described in Section 8.4.2.5.

8.4.2.4.2 Drift to the Drill Hole Wash structure

The drift to the Drill Hole Wash structure will examine characteristics potentially important to the construction and performance of the repository. There will be examination of structural features, such as faulting, that have been postulated based on surface mapping and drill holes. If the investigation shows little or no faulting, then the area of the formation that can potentially be used for a repository will be substantially increased.

The hydrologic character of the rock structures below Drill Hole Wash will also be studied from this drift. Because the wash tends to concentrate surface waters and channel them along a specific path, higher than average infiltration rates could occur in this area. Studying this area may resolve concerns about seasonal change and movement of water down a fracture zone.

To reach the Drill Hole Wash structure area, a drift heading northeast from the main test level operations area will be constructed by using the drill, blast, and muck technique previously described. The tests to be performed during construction and site characterization are briefly described in Section 8.4.2.5.

8.4.2.4.3 Drift to the imbricate normal fault zone

The drift to the imbricate normal fault zone is planned to study the width of the fault zone, the strike and dip of the faults, and the location of these faults at the proposed repository depth. These studies will aid in determining the eastern boundary and the total size of the repository. Hydrologic studies will also be performed to determine whether this fault zone is transmitting water.

A drift heading southeast from the main test level operations area will be constructed by using the drill, blast, and muck technique previously described. The tests to be performed during construction and site characterization are briefly described in Section 8.4.2.5.

8.4.2.5 <u>Exploratory shaft facility testing</u>

The various tests planned for the exploratory shaft facility (ESF) are designed to acquire data on geologic, hydrologic, geomechanical, geochemical, and waste package environment characteristics. Strictly speaking, all tests performed in the ESF will be done in situ. However, the DOE has classified those test activities that are initiated during construction of exploratory shaft 1 (ES-1) as construction phase tests. Tests initiated on the main test level after ES-1 and ES-2 are connected, or elsewhere in the ESF after the shaft sinking subcontractor has departed the site, are termed in situ phase tests.

The construction phase and in situ phase tests are listed in Table 8.4-1 along with references to their discussion locations in Section 8.3. Section 8.3 provides the rationale for each test and information about how the resulting data will be used. The following sections provide a summary of how each test will be developed and implemented.

The extent of testing in the exploratory shafts and underground testing facilities possibly could change from tests described here. Most notably, the drifts or exploratory holes from the Calico Hills level to the Ghost Dance fault are not described here pending an analysis of possible impacts to the waste isolation capabilities of the site. Other tests described as contingency tests in Section 8.3 are likewise not discussed here. Decisions on whether to proceed with a contingency test will be based on criteria developed for each test. If it is decided to proceed with any test that is currently described as a contingency test, an analysis of the impacts of the test on waste isolation will be completed and available for review before proceeding with the test.

8.4.2.5.1 Exploratory shaft facility studies

The studies to be conducted in the ESF are outlined in the following subsections.

<u>Activity: Geologic mapping of exploratory shaft and drifts (Section 8.3.1.4.2.2.4)</u>

The activities that make up this task include cleaning the shaft or drift wall areas, surveying in reference points, and marking significant structural features. Geologists will map the exposed wall interval as described in Section 8.3 and make a permanent record of the exposed interval by using a camera to obtain high-resolution, stereo photographs referenced to the surveyed bearings. Finally, the geologists will collect, package, and label hand specimen samples for geologic, mineralogic, petrologic, geochemical, geomechanical, or hydrochemical analyses and for archival storage.

<u>Activity: Fracture mineralogy studies of exploratory shaft and drifts (Section 8.3.1.3.2.1.3)</u>

In addition to mineralogic sampling in the shaft at the working face and in the drifts, samples will be collected on the surface from the muck resulting from each blast round. The muck will be segregated, either in a temporary surface storage bin or at the muck storage area, and the geologists will hand pick samples for fracture-coating mineralogy studies. The samples will be packaged and labeled for shipment to a laboratory for detailed analyses, including age determinations.

Table 8.4-1. Exploratory shaft facility tests and the sections in which they are discussed

Title	Section
EXPLORATORY SHAFT FACILITY TESTS	
Geologic mapping of the exploratory shaft and drifts	8.3.1.4.2.2.4
Fracture mineralogy studies of exploratory shaft and drifts	8.3.1.3.2.1.3
Seismic tomography and vertical seismic profiling	8.3.1.4.2.2.5
Shaft convergence	8.3.1.15.1.5.1
Demonstration breakout rooms	8.3.1.15.1.5.2
Sequential drift mining	8.3.1.15.1.5.3
Heater experiment in unit TSw1	8.3.1.15.1.6.1
Canister-scale heater experiment	8.3.1.15.1.6.2
Yucca Mountain heated block	8.3.1.15.1.6.3
Thermal stress measurements	8.3.1.15.1.6.4
Heated room experiment	8.3.1.15.1.6.5
Development and demonstration of required equipment	8.3.2.5.6
Plate loading tests	8.3.1.15.1.7.1
Rock-mass strength experiment	8.3.1.15.1.7.2
Overcore stress experiments in the exploratory shaft facility	8.3.1.15.2.1.2
Matrix hydrologic properties testing	8.3.1.2.2.3.1
Intact-fracture test in the exploratory shaft facility	8.3.1.2.2.4.1
Infiltration tests in the exploratory shaft facility	8.3.1.2.2.4.2

Table 8.4-1. Exploratory shaft facility tests and the section in which they are discussed (continued)

Title	Section
Bulk-permeability test in the exploratory shaft facility	8.3.1.2.2.4.3
Radial borehole tests in the exploratory shaft facility	8.3.1.2.2.4.4
Excavation effects test in the exploratory shaft facility	8.3.1.2.2.4.5
Calico Hills test in the exploratory shaft facility	8.3.1.2.2.4.6
Perched water test in the exploratory shaft facility	8.3.1.2.2.4.7
Hydrochemistry tests in the exploratory shaft facility	8.3.1.2.2.4.8
Diffusion tests in the exploratory shaft shaft facility	8.3.1.2.2.5
Chloride and chlorine-36 measurements of percolation at Yucca Mountain	8.3.1.2.2.2.1
Repository horizon near-field hydrologic properties	8.3.4.2.4.4.1
Repository horizon rock-water interaction	8.3.4.2.4.4.2
LABORATORY TESTS USING SAMPLES OBTAINED FROM THE EXPLORATORY SHAFT FACILITY	
Density and porosity characterization	8.3.1.15.1.1.1
Volumetric heat capacity characterization	8.3.1.15.1.1.2
Thermal conductivity characterization	8.3.1.15.1.1.3
Thermal expansion characterization	8.3.1.15.1.2.1

Table 8.4-1. Exploratory shaft facility tests and the section in which they are discussed (continued)

Title	Section
Compressive mechanical properties of intact rock at baseline experiment conditions	8.3.1.15.1.3.1
Effects of variable environmental conditions on compressive-mechanical properties	8.3.1.15.1.3.2
Tensile strength of unit TSw2 (portion of the welded Topopah Spring unit proposed for the repository)	8.3.1.15.1.3.3
Mechanical properties of fractures at baseline experiment conditions	8.3.1.15.1.4.1
Effects of variable environmental conditions on mechanical properties of fractures	8.3.1.15.1.4.2

Activity: Seismic tomography and vertical seismic profiling (Section 8.3.1.4.2.2.5)

When fracture domains are selected in the shaft or drifts as described in Section 8.3.1.4.2.2.5, short boreholes will be drilled for geophone or similar instrumentation installation. When the sensor arrays are in place, seismic stimuli will be initiated by using explosives or vibroseis techniques at locations to be selected by the investigators.

Activity: Shaft convergence (Section 8.3.1.15.1.5.1)

Using standard overcore techniques (Section 8.3.1.15.2.1.2), horizontal stress measurements will be made at each of three test locations as the exploratory shaft is being sunk. In the shaft wall, three radially arrayed multipoint borehole extensometers (MPBXs) will be installed in each location (Figure 8.4-17) to measure shaft wall convergence when mining resumes. Hydraulic pressure cells will be installed behind the shaft liner to monitor radial stress changes over time as shaft sinking continues below the test location. In addition to MPBX measurements, deformations will be measured with rod extensometers at each of the three levels.

Activity: Demonstration breakout rooms (Section 8.3.1.15.1.5.2)

At the upper demonstration breakout room (DBR) and the main test level, full-size repository openings will be mined. Optimum blasting methods in each DBR horizon and rock stabilization requirements will be determined.

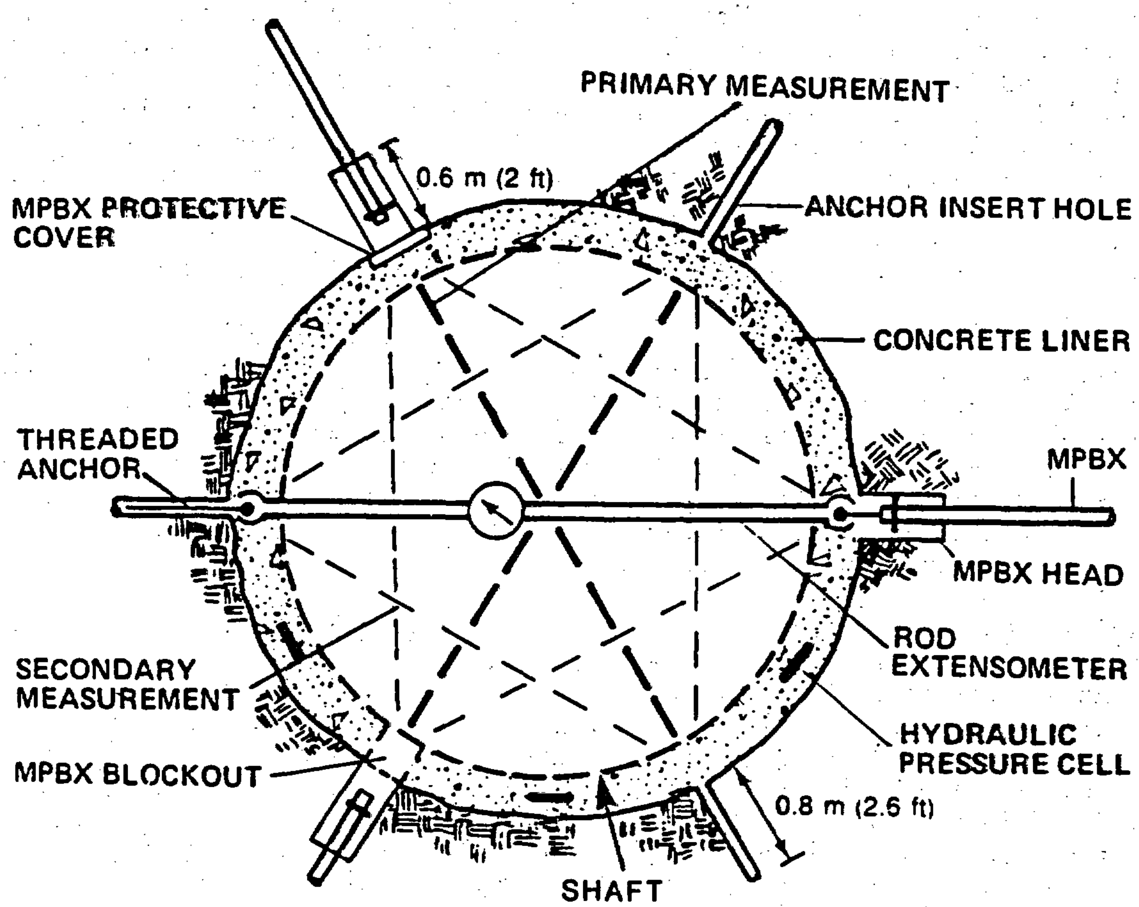


Figure 8.4-17. Measurement details of the shaft convergence test.

Rock mass response will also be measured in the DBR excavations by using extensometers and convergence anchors.

Activity: Sequential drift mining (Section 8.3.1.15.1.5.3)

At the main test level, an instrumentation drift will be mined. Instrumentation holes to monitor above, below, and adjacent to a second parallel drift as shown in Figures 8.4-18 and 8.4-19 will be drilled. Borehole sensors will be installed to monitor stress release, rock permeability changes, and deformation. Baseline data before mining will be obtained, and a parallel drift will be mined while the rock mass responses to mining are monitored. Air and water permeability in boreholes adjacent to the new drift opening (Figure 8.4-20) will be measured after mining. Stress changes around the mined opening will continue to be monitored.

Activity: Heater experiment in unit TSw1 (Section 8.3.1.15.1.6.1)

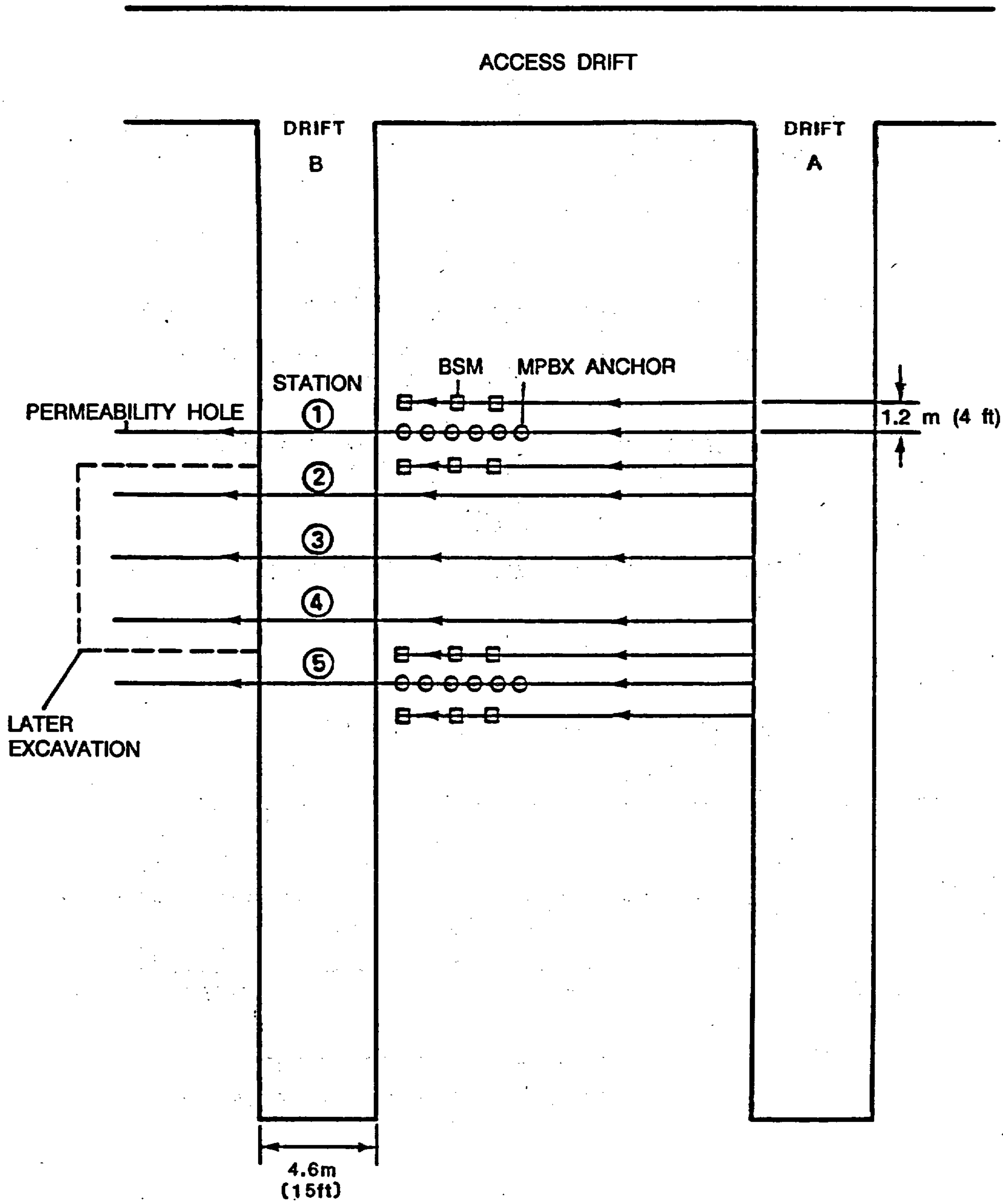
In the upper DBR, a heater emplacement hole will be drilled approximately into the wall (Figure 8.4-21). Several instrumentation holes parallel to the heater hole will be drilled and then heater and instruments (multipoint borehole extensometers (MPBX) and thermocouples) will be installed. In a borehole below the heater, neutron logs will be run before, during, and after the heating cycle to monitor moisture content changes. After the heater is started, the rock response to thermal loading, heat flow, and moisture changes will be monitored.

Activity: Canister-scale heater experiment (Section 8.3.1.15.1.6.2)

At a location in the lower DBR or a location to be determined within the main test area, a hole will be drilled into the drift wall. Parallel small-diameter instrumentation holes (Figures 8.4-22 and 8.4-23) will be drilled. Baseline moisture data in neutron probe holes will be recorded. Heater and instrumentation (thermocouples, MPBXs, hole deformation gauges, and radon monitors) will be installed. Finally, cyclic heating steps will be initiated and thermal, thermomechanical, hydrothermal, and radon release rates at increasing heat loads will be monitored.

Activity: Yucca Mountain heated block (Section 8.3.1.15.1.6.3)

At a selected location on the main test level a 6 ft by 6 ft (2 m by 2 m) area of rock will be defined, baseline fracture permeabilities will be measured, reference survey pins will be established, and crosshole ultrasonics measurements will be made. Next, slots will be cut on each side of the block to a depth of approximately 6 ft (2 m) and flatjacks will be inserted. An array of heaters will be installed in holes on opposite sides of the block as shown in Figure 8.4-24. Other instrumentation holes will be drilled and instrumented with thermocouples, MPBXs, and deformation gauges. Finally, cyclic tests will be conducted at various stress loads (using flatjacks) and thermal load (heaters). The rock responses and permeability changes under induced conditions will be monitored.



BSM = BOREHOLE STRESS METER
MPBX = MULTIPOINT BOREHOLE EXTENSOMETER

Figure 8.4-18. Sequential drift mining tests.

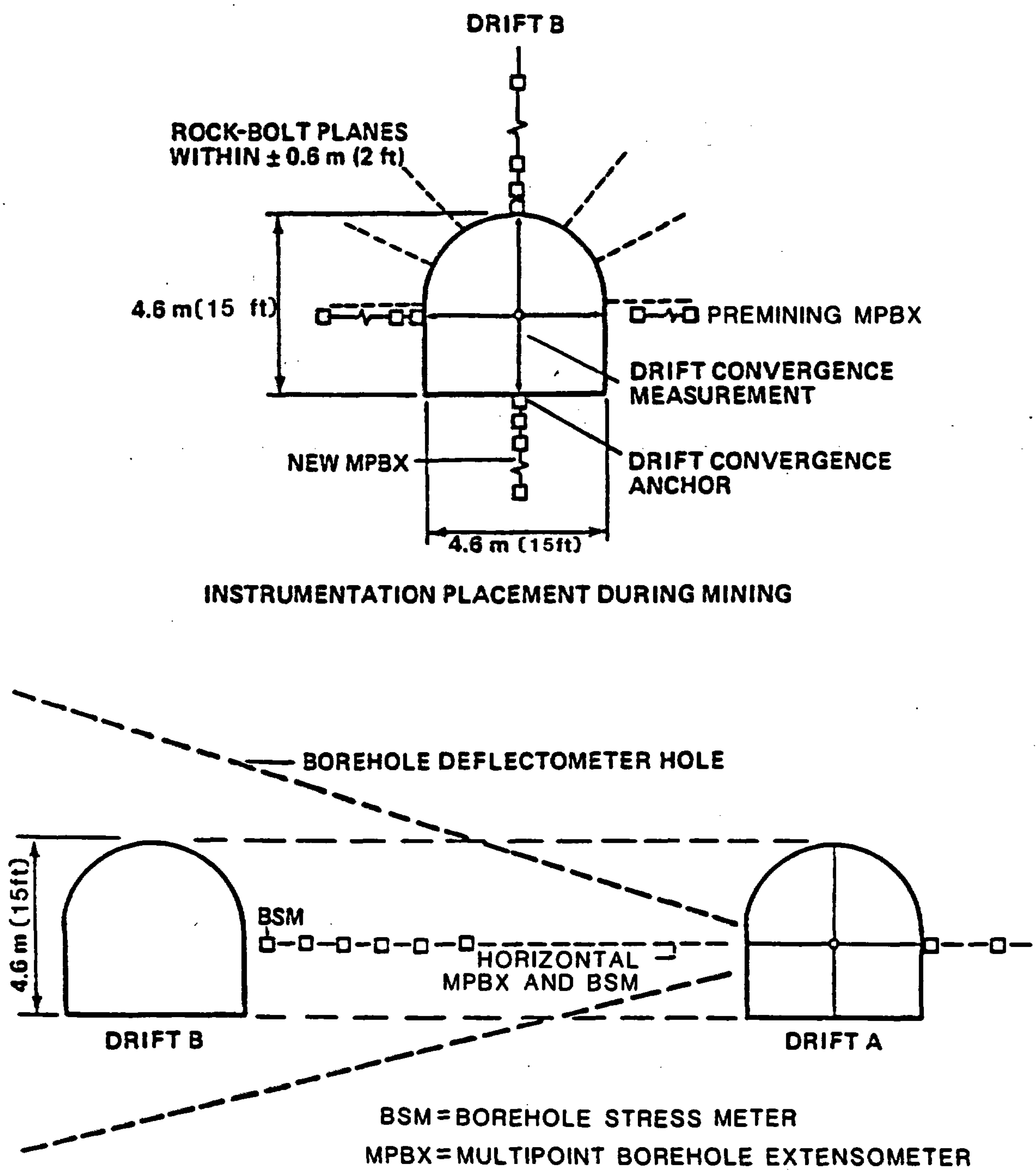


Figure 8.4-19. Instrumentation arrangements for sequential drift mining tests.

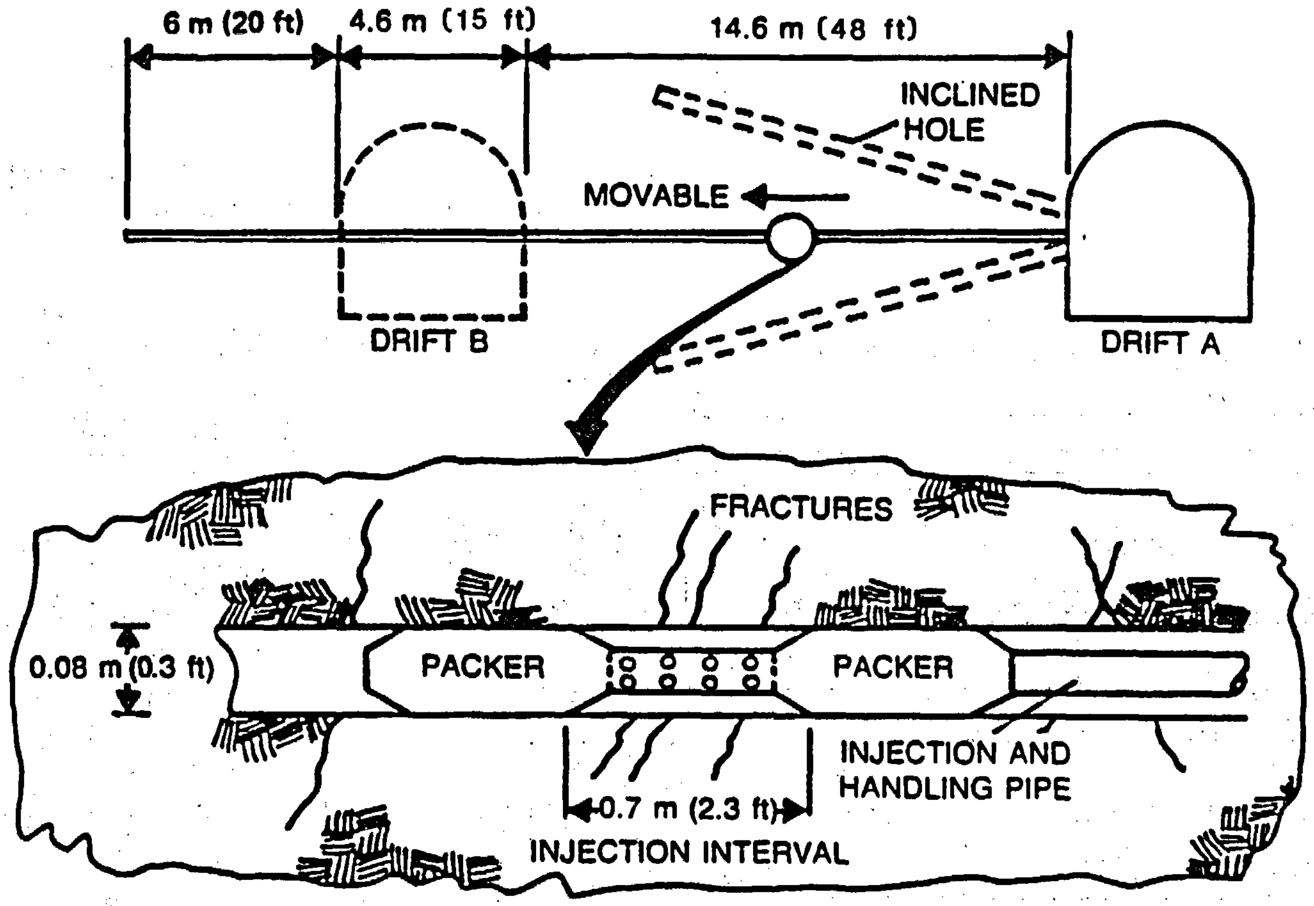
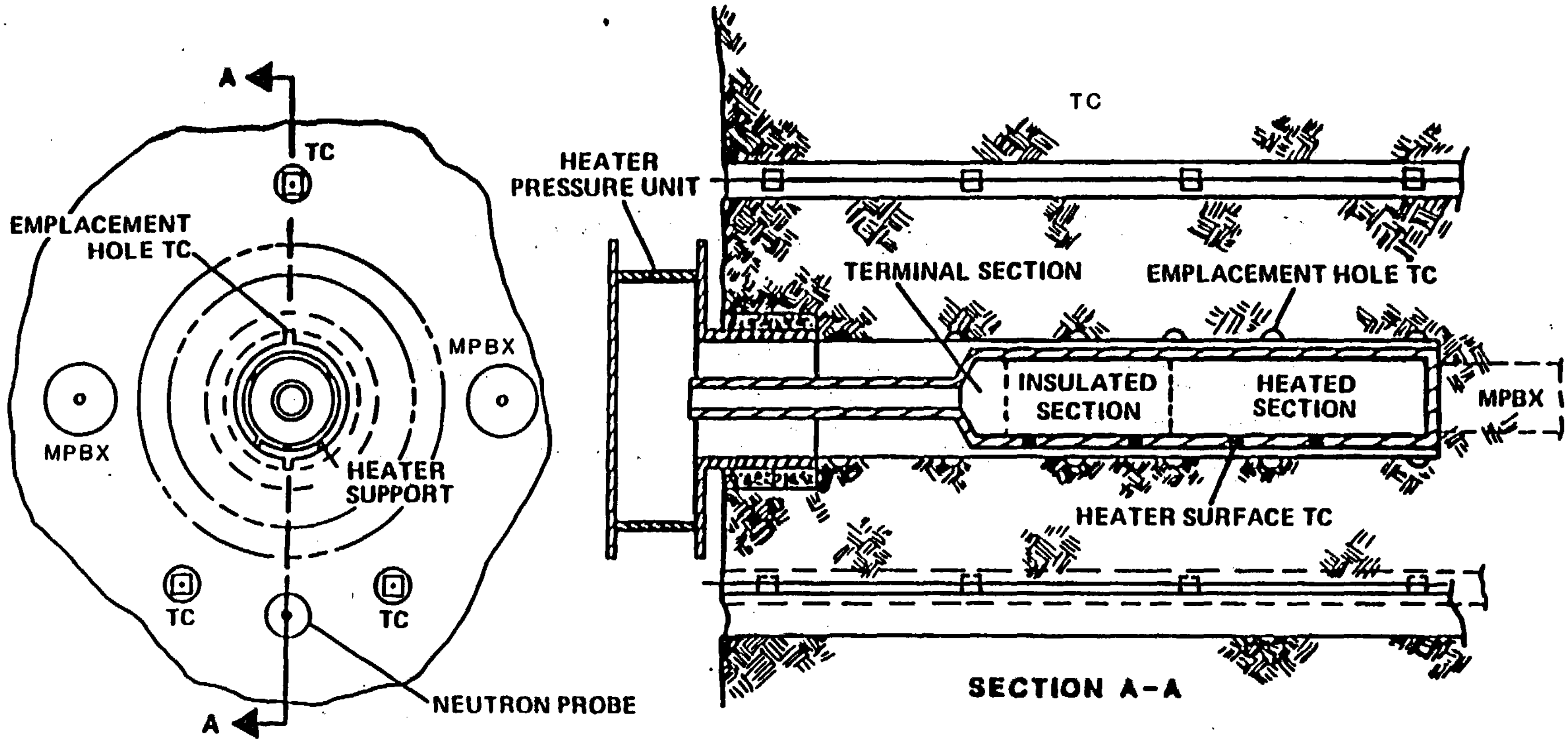


Figure 8.4-20. Permeability testing scheme for sequential drift mining test.



MPBX - MULTIPOINT BOREHOLE EXTENSOMETER
TC - THERMOCOUPLE

NOT TO SCALE

Figure 8.4-21. Elevation view of heater experiment in TSw1 (lithophysal Topopah spring unit).

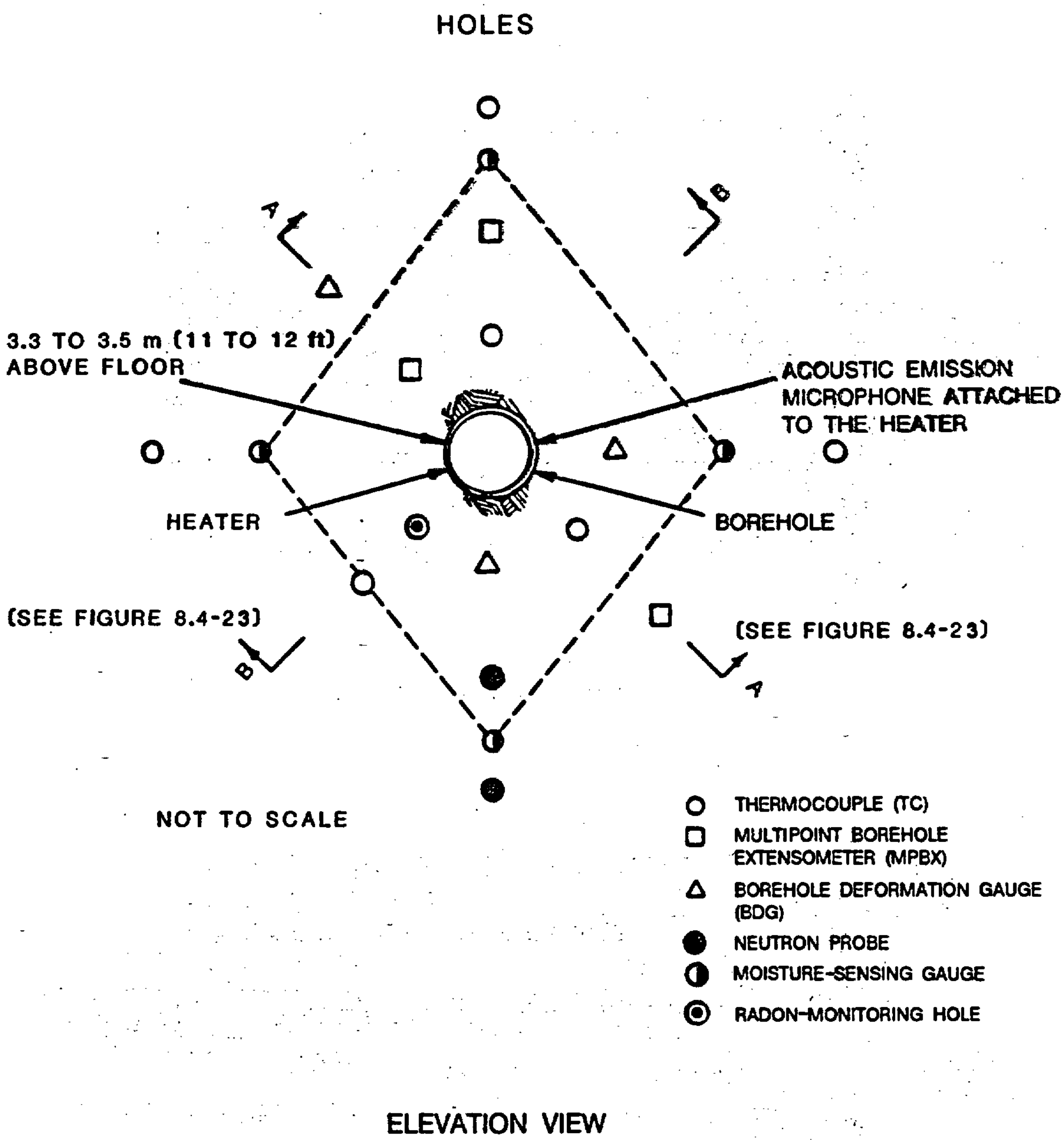
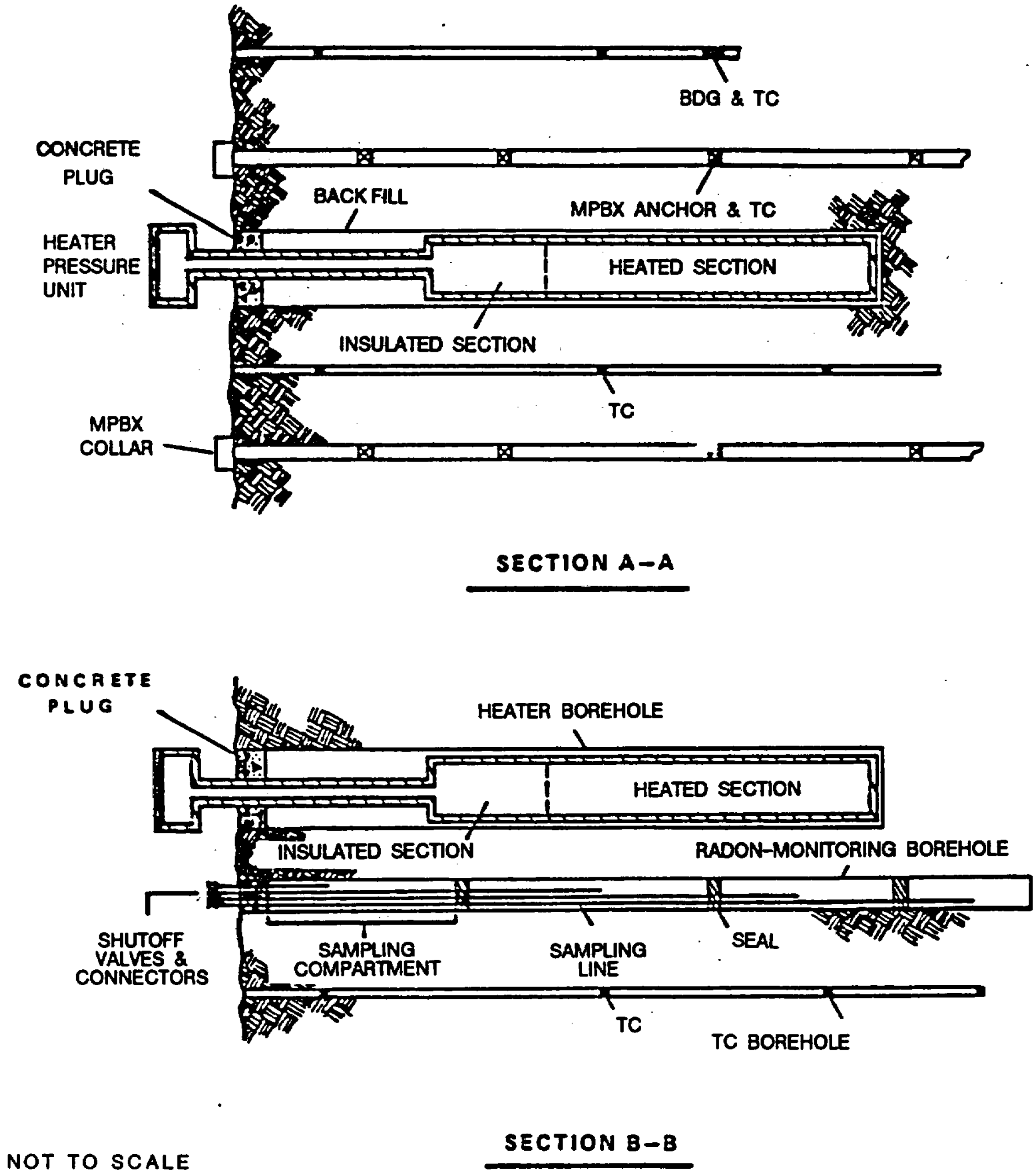


Figure 8.4-22. Canister-scale heater experiment showing heater and instrumentation holes.

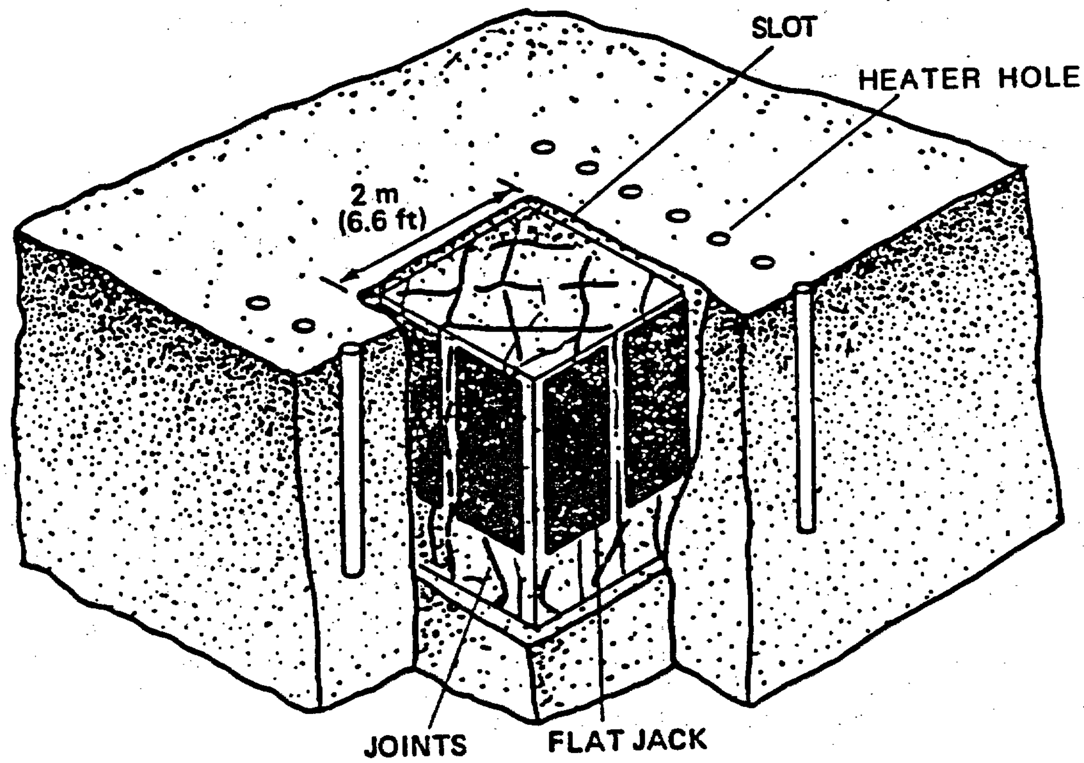


TC - THERMOCOUPLE

BDG - BOREHOLE DEFORMATION GAUGE

MPBX - MULTIPOINT BOREHOLE EXTENSOMETER

Figure 8.4-23. Canister-scale heater experiment showing location of sections shown in Figure 8.4-22.



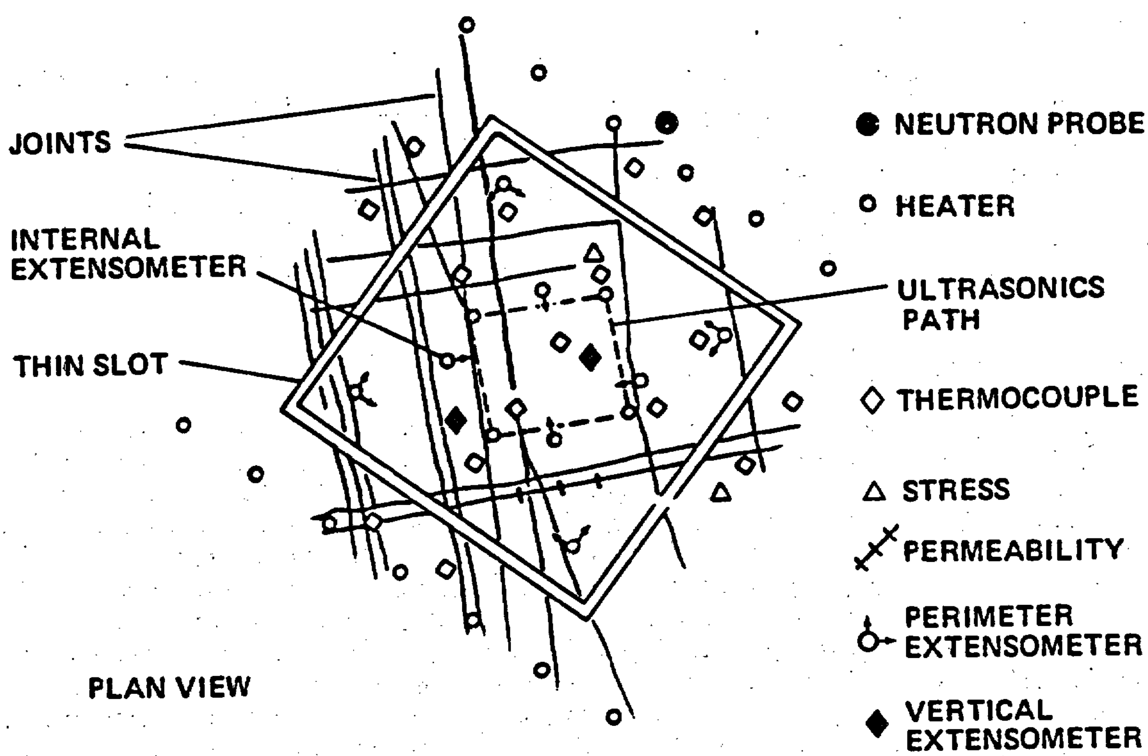


Figure 8.4-24. Conceptual layout for Yucca Mountain heated block experiment.

Activity: Thermal stress measurements (Section 8.3.1.15.1.6.4)

In the upper DBR and at a location in the main test level, single slots will be cut in both the back (roof) and rib (wall) 6 ft (2 m) long and 6 ft (2 m) deep after reference pins are established on either side. Flatjacks will be installed in the slots, and heaters will be installed in the holes drilled on either side of the slots (Figure 8.4-25). An insulating blanket will be installed over the test area of the drift to reduce heat loss. Heaters will be started and stress changes in the near-field area will be monitored as thermal loading increases.

Activity: Heated room experiment (Section 8.3.1.15.1.6.5)

In the main test level or lower DBR, a drift representative of repository-size drifts will be excavated, and the rock around it will be heated. Either a preexisting drift will be used or a drift will be constructed specifically for this experiment. The drift will be instrumented to provide data on rock mass deformation, rib stress change, thermal conductivity, heat capacity and thermal expansion coefficient, ground-support loading and deformation, and an estimate of the region in which the stress state is changed by elevation of temperature. The experiment may involve more than one opening so that temperatures around and between drifts more nearly represent those expected in the repository.

Information Need 4.4.6: Development and demonstration of required equipment (Section 8.3.2.5.6)

A development prototype boring machine (DPBM) is being investigated for use in underground demonstration testing. The DPBM would be capable of drilling and installing a metal lining in long, horizontal boreholes. Tests currently under consideration in the ESF involve the drilling and lining of two 250-ft (76.2-m) deep horizontal holes at the main test level or lower DBR. The drilling of these holes will be highly instrumented so that data on drill performance can be obtained for use in predicting drill performance in the repository.

Activity: Plate loading tests (Section 8.3.1.15.1.7.1)

Plate loading experiments will be performed at numerous locations in the upper DBR and in the main test level. Rock deformations will be measured with a multipoint borehole extensometer oriented parallel to the load axis in the center of the plate area. Deformation of the loading column will be monitored with rod extensometers. Values of the rock deformation modulus will be calculated by using the rock deformation and the applied stresses. Moduli from different stations will be compared to evaluate spatial variability within unit TSw2 (nonlithophysal Topopah Spring). These data primarily will be applicable to the material around an opening that has been affected by the presence of the opening and by the excavation process. As such, the moduli will represent lower bounds on the modulus of the undistributed rock mass.

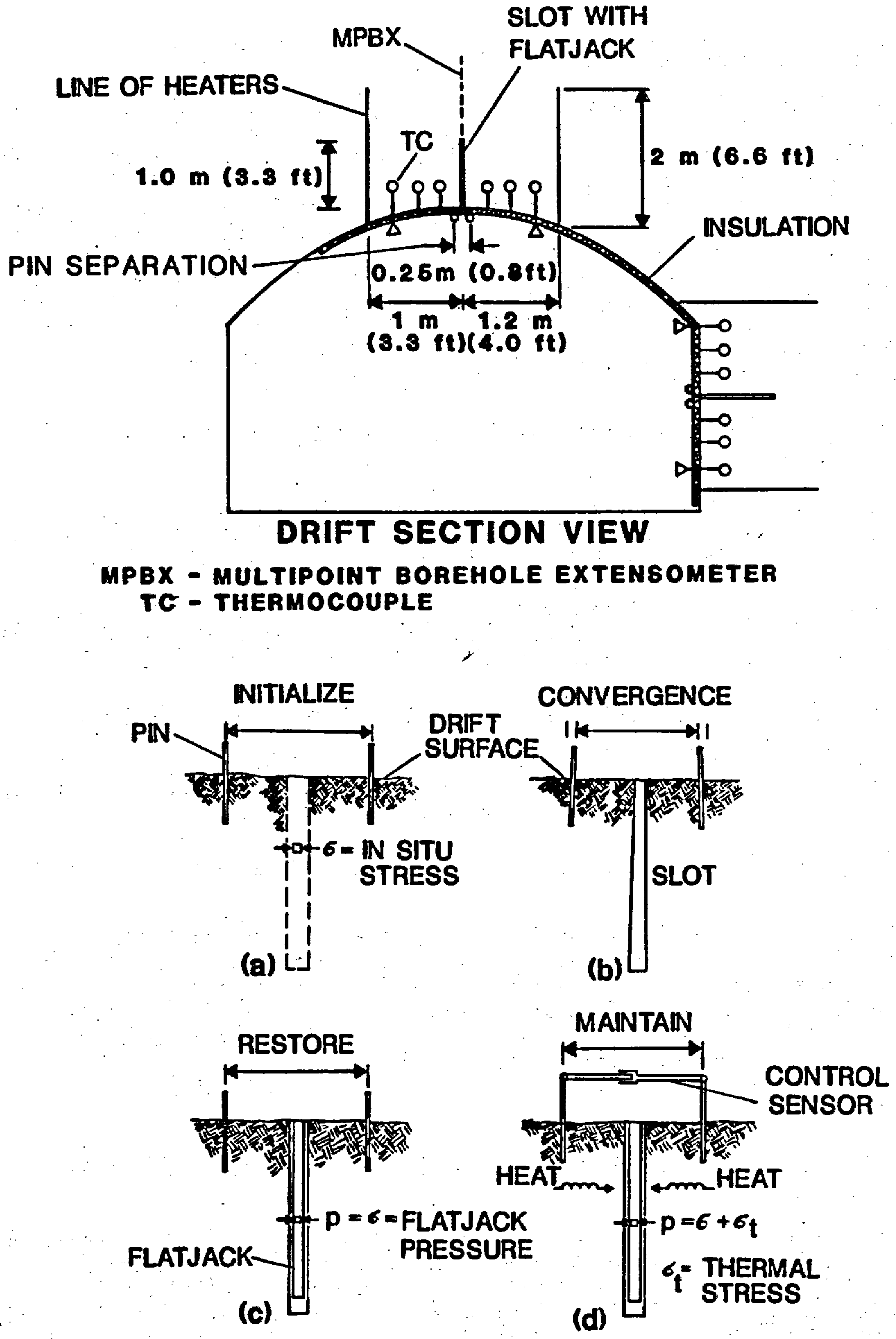


Figure 8.4-25. Conceptual layout for thermal stress measurement.

Activity: Rock-mass strength experiment (Section 8.3.1.15.1.7.2)

Experiments will be conducted in several areas of the ESF chosen to be representative of the range of geologic conditions expected in the repository. The experiments will be conducted in stages. The joint shear strength stage will be performed on samples of field-scale size, where field-scale is considered the expected in situ joint length. If random jointing is encountered in the ESF, then another stage of the experiment will be performed in which a representative volume of randomly jointed rock will be loaded to failure. The final stage of this experiment will require a block of jointed rock to be carefully characterized as to joint spacing, aperture, properties, etc., and then loaded to predetermined stress levels. This stage of the experiment will provide information on joint loading and closure characteristics for evaluating and validating a jointed-rock model.

Activity: Overcore stress experiments in the exploratory shaft facility (Section 8.3.1.15.2.1.2)

Soon after access is available at the upper DBR and the main test levels, small-diameter holes will be drilled to prescribed orientations and lengths (longer than three shaft or drift diameters). Stress sensors (dilatometers) will then be installed, and the instrumented center hole will be overcored in stages. Stress data will be taken as the core from each stage is retrieved. At the Calico Hills level, similar measurements will be made in packed-off boreholes to obtain verification stress data.

Activity: Matrix hydrologic properties testing (Section 8.3.1.2.2.3.1)

Bulk and core samples collected after selected blasting rounds during ES-1 and drift construction and from core holes will be collected, packaged, and labeled. The analyses will be performed in a laboratory.

Activity: Intact-fracture test in the exploratory shaft facility (Section 8.3.1.2.2.4.1)

Fracture-sampling locations will be selected at each breakout horizon (upper DBR, main test level, Calico Hills level) on the basis of detailed fracture maps. At about 12 locations (to be determined), a small pilot hole will be drilled across the fracture, a rock bolt anchor will be installed, the pilot hole will be overcored, and the sample will be withdrawn. The sample will be packaged, labeled, and transported to an onsite field laboratory for intact-fracture analyses as described in Section 8.3.1.2.2.4.1.

Activity: Infiltration tests in the exploratory shaft facility (Section 8.3.1.2.2.4.2)

In a test alcove on the main test level (location to be determined), an elevated test bed will be constructed as shown conceptually in Section 8.3.1.2.2.4.2. A trickle system and sand bed will be installed after 4 vertical and 12 or more horizontal instrumentation holes have been air-cored, surveyed, tested for air permeability, and instrumented. The room will be lined with an impermeable (plastic) liner and sealed off from other test areas. The infiltration test will involve trickling tracer-tagged water through the sand bed and monitoring flow rates and pathways over time in the underlying rock mass.

Activity: Bulk-permeability test in the exploratory shaft facility (Section 8.3.1.2.2.4.3)

A test location on the main test level will be selected on the basis of detailed fracture maps. A small-diameter pilot hole 100 to 200 ft (30 to 60 m) deep, parallel to but 12 ft (3 m) outside the wall of the proposed test room, will be air-cored and logged. Air permeability will be measured in packed-off intervals. If the rock is suitable for the test, two additional holes parallel to the first, but 4 ft (1.2 m) and 8 ft (2.4 m) outside the wall of the proposed test room, will be air-cored and then logged and tested as the pilot hole was. The test room will be excavated using controlled blasting and dry mining techniques (Section 8.3.1.2.2.4.3). The wall rock fractures will be mapped in detail. Up to nine holes parallel to principal permeability axes will be air-cored. Crosshole air permeability (injection) tests followed by crosshole water injection tests will be conducted. A double bulkhead to isolate the test room will be constructed. Pressure, temperature, and humidity sensors will be installed in the test room and adjacent boreholes. The room will then be pressurized, and the air movement outward to the borehole sensors will be monitored. The procedure will be repeated as required by using positive or negative pressure in the test room.

Activity: Radial borehole tests in the exploratory shaft facility (Section 8.3.1.2.2.4.4)

At approximately 12 locations in ES-1 (Section 8.3.1.2.2.4.4) two small-diameter holes will be air-cored diagonally from each other 30 ft (10 m) or more radially from the shaft. Core will be collected, packaged, labeled, and transported to an onsite laboratory for hydrologic analyses (fracture and matrix properties). The holes will be logged and surveyed for fracture and moisture data. Nitrogen injection tests in packed-off intervals will be conducted to obtain gas permeability data. Across stratigraphic contacts, crosshole permeability tests will be run with both gas and water. Short-term monitoring for moisture resulting from shaft mining will be done when mining resumes. Long-term monitoring of matrix water potential, pressure, and temperature and periodic sampling of formation gases will be done.

Activity: Excavation effects test in the exploratory shaft facility (Section 8.3.1.2.2.4.5)

At the upper DBR and main test level stations, six vertical, small-diameter holes will be drilled parallel to the unexcavated shaft wall but set back 4, 8, and 12 ft (1.2, 2.4, and 3.5 m) from it. All holes will be logged and surveyed; three will be instrumented to monitor stress changes, and the other three will monitor permeability changes as the shaft is advanced. Pre-excavation (baseline) stress and permeability data will also be taken. Long-term permeability measurements will be made and temperature and moisture data collected. (Additional holes will be drilled to handle the instrumentation arrays if they are determined to be necessary during prototype testing.)

Activity: Calico Hills test in the exploratory shaft facility (Section 8.3.1.2.2.4.6)

At the Calico Hills station, a small drill room will be constructed to support the drilling of an approximately 250-ft (76-m) horizontal drillhole and a long (approximately 800-ft (250-m) drillhole out to Ghost Dance fault. All drillholes will be cored with air as the circulating fluid. Core samples will be collected, packaged, labeled, and analyzed for matrix, rock mass, and chemical parameters in a laboratory as described in Section 8.3.1.2.2.4.6. The holes will be logged and surveyed and then tested for permeability with gas-injection techniques in packed-off intervals. Air and water crosshole tests will be conducted in both drillholes at the stations and in holes drilled as part of the radial borehole tests (Section 8.3.1.2.2.4.4) above and below the Topopah Spring and Calico Hills contact.

Activity: Perched water test in the exploratory shaft facility (Section 8.3.1.2.2.4.7

If perched water is encountered while mining ES-1, a small-diameter hole will be drilled to enhance drainage, facilitate collection of water samples, and allow flow measurements to be made. The holes will also be instrumented and sealed to obtain data on hydraulic pressure and water potential over time.

Activity: Hydrochemistry tests in the exploratory shaft facility (Section 8.3.1.2.2.4.8)

During shaft sinking at selected locations, large block (≥6 in. (16 cm) diameter if possible) samples will be collected from the blast rubble, packaged, labeled, and then transported to a surface laboratory for analysis of pore and fracture fluid chemistry. Core from selected shaft, drift, and test alcove drillholes will also be collected and analyzed as described in Section 8.3.1.2.2.4.8.

Study: Diffusion tests in the exploratory shaft facility (Section 8.3.1.2.2.5)

Four small-diameter holes will be air-drilled to a vertical (or horizontal) depth of 33 ft (10 m), a suitable nonsorbing tracer will be injected at the bottom in a packed-off zone, then the holes will be capped and left undisturbed for periods of 3 to 12 months. Finally, the test intervals will be overcored, and the core will be removed to a laboratory for analysis of tracer diffusivity.

Activity: Chloride and chlorine-36 measurements of percolation at Yucca Mountain (Section 8.3.1.2.2.2.1)

As the ES-1 shaft is being excavated, large bulk samples (from up to 30 locations) will be periodically collected, packaged, and labeled for laboratory analysis as described in Section 8.3.1.2.2.2.1. Because of the requirement to extract pore water to conduct the chlorine-36 test, several hundred pounds of rubble may be needed at each sampling location.

Activities: Repository horizon near-field hydrologic properties (Section 8.3.4.2.4.4.1) and repository horizon rock-water interaction (Section 8.3.4.2.4.4.2)

These tests will provide thermal, hydrologic, mechanical, and limited chemical information during an abbreviated thermal cycle (of at least 1-yr duration) in the very near field emplacement environment. In test alcoves on the main test level, horizontal and vertical heater emplacement holes and small-diameter parallel and perpendicular instrumentation holes will be drilled as shown in Figures 8.4-26 and 8.4-27. Heater canisters and associated instrumentation packages will be inserted to monitor thermal, moisture, and stress and strain parameters during a thermal cycle in each test. In selected tests, water will be injected during heating and cooling stages while monitoring takes place. Core from the rock mass adjacent to the heater hole will be recovered and petrologic, petrographic, mineralogic, and related laboratory analyses will be performed to identify thermally induced alterations.

In addition to the geomechanical and thermomechanical field tests planned in the ESF, a number of laboratory activities will use bulk rock and core samples collected in the ESF. These activities are listed in Table 8.4-1.

These brief descriptions of the ESF testing are based on current test concepts and plans. Design modifications and more detailed planning will undoubtedly result in changes before the tests are actually conducted in the ESF. Study plans and the NNWSI Project Exploratory Shaft Test Plan will provide much more detailed information about all of the planned ESF tests. The study plans, which will be periodically updated with the site characterization plan, provide the official source of reference testing information.

8.4.2.5.2 Performance confirmation tests

At present, the NNWSI Project does not have a fully defined performance confirmation testing program. The overall approach to performance confirmation developed by the DOE is described in Section 8.3.5.16. The results of surface-based and ESF testing will help to define what testing will be needed as part of performance confirmation. The design of the ESF incorporates ample space and operational flexibility to support follow-on performance confirmation tests at full repository scales.

8.4.2.6 Potential impacts of exploratory shaft construction and testing on the waste isolation integrity of the site

The purpose of this section is to discuss whether the construction of the exploratory shaft facility (ESF) and operation of tests in the ESF could affect the waste isolation integrity of the site by providing a preferential pathway for radionuclide transport. Both the Nuclear Waste Policy Act and 10 CFR Part 60 request an analysis of characterization activities that could affect the waste isolation capabilities of the site. To determine whether

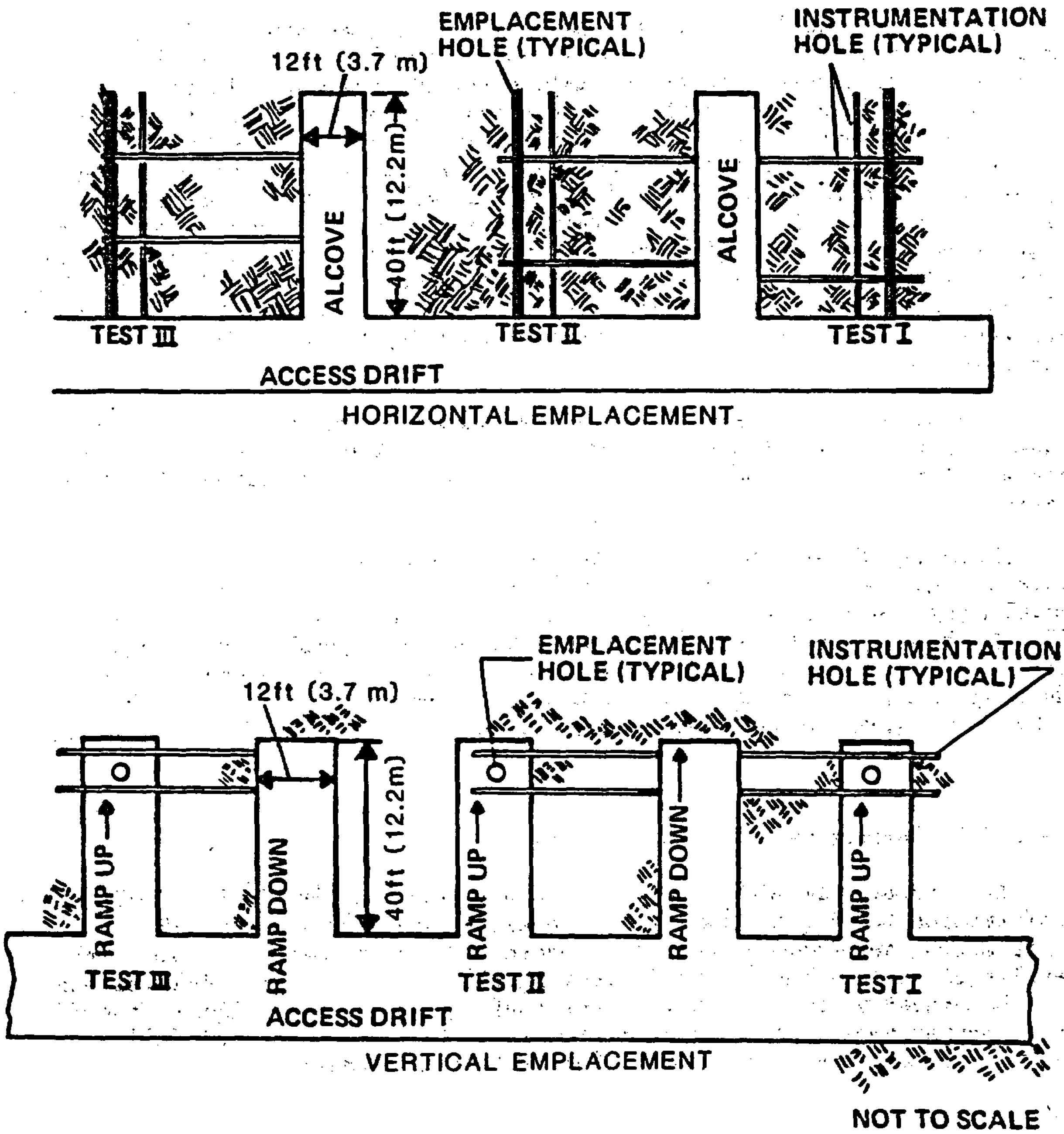


Figure 8.4-26. Typical layout for horizontal and vertical emplacement holes for the engineered barrier system field tests

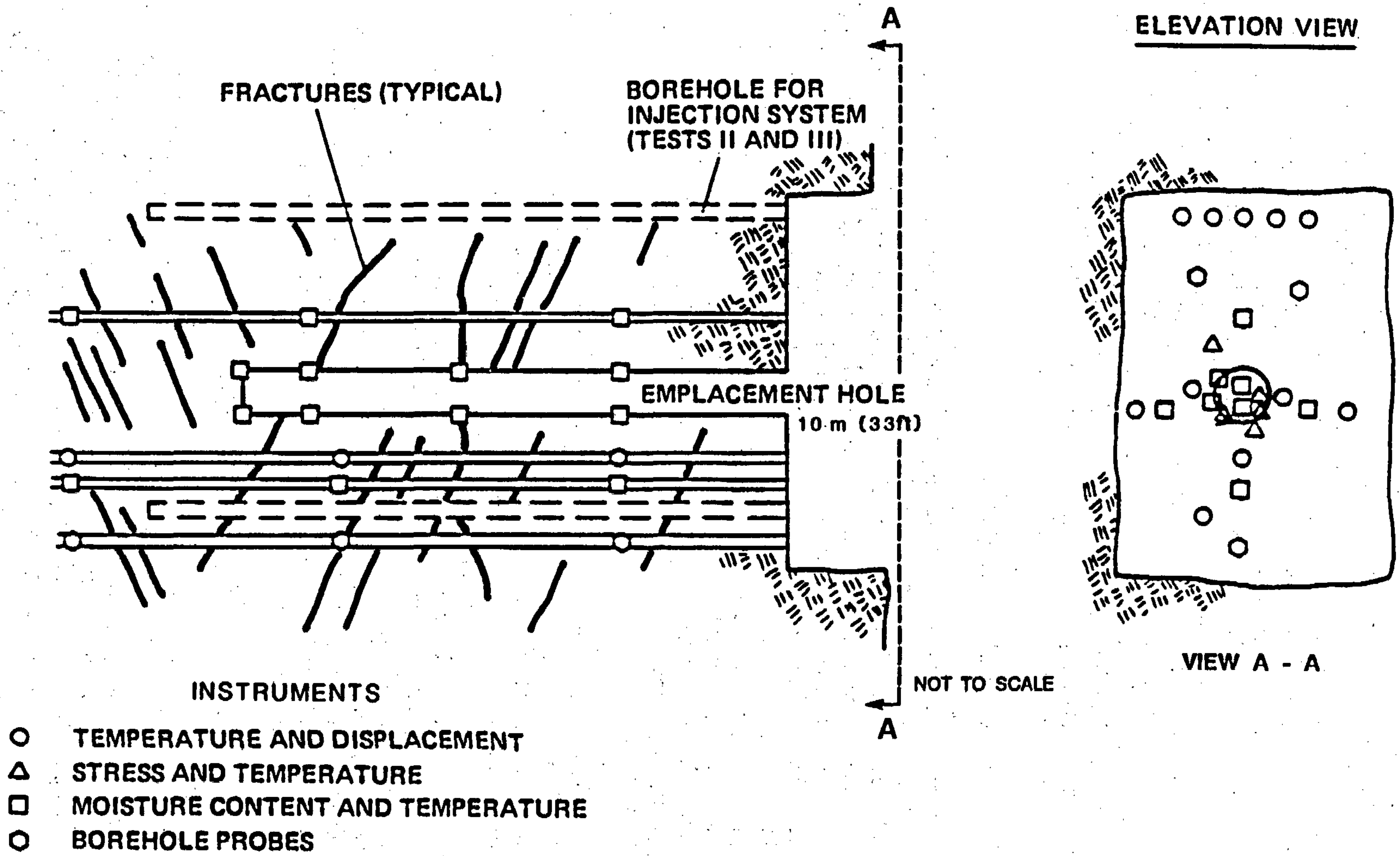


Figure 8.4-27. Typical instrumentation array for the engineered barrier field test.

the construction of, or the testing in, the ESF could affect the waste isolation integrity of the site, it is first necessary to identify the elements of the system that are important to waste isolation. The DOE has defined items important to waste isolation to be "those barriers, structures, systems, and components which are relied on to meet 10 CFR 60, Subpart E postclosure performance objectives" (DOE, 1987c). Subpart E describes four postclosure performance objectives related to (1) total system performance assessment of release of radionuclides to the accessible environment, (2) containment requirements for the waste package, (3) engineered barrier system (EBS) release rate, and (4) pre-waste-emplacement ground-water travel time (GWTT). These performance objectives are addressed in Section 8.3.5.13, 8.3.5.9, 8.3.5.10, and 8.3.5.12, respectively, of this document. In addition to the general discussion here, the specific potential impacts of ESF construction and testing on each of these performance objectives are addressed in the subsections that follow.

Description of exploratory shaft facility

The ESF comprises a small fraction of the total repository area and is separate from potential waste emplacement panels (see Figures 8.4-8 and 8.4-10). The ESF is located in the northeastern portion of the potential repository, with ES-1 penetrating the unsaturated portion of the Calico Hills nonwelded unit and ES-2 extending only slightly below the repository level (Figure 8.4-12). Three long exploratory drifts are planned to allow access to the Ghost Dance fault, the Drill Hole Wash structure, and the imbricate normal fault zone (Figure 8.4-10). These drifts are permanent items that could be included as part of the underground facility. They will be constructed using the same methods that are expected to be used for drifts in the rest of the underground facility. Fluids in the testing area will drain away from these drifts.

The dedicated testing area occurs at the repository level and consists of an area dedicated for currently planned site-characterization testing and an area dedicated for performance-confirmation testing and other site-characterization testing that may be defined in the future. As shown in Figure 8.4-10, the ESF is physically separate from potential waste emplacement panels by a minimum of approximately 30 m of rock, with the area currently dedicated to site-characterization testing (Figure 8.4-11) generally separated from the panels by at least 60 m of rock. The ESF testing area is designed to drain any fluids that might enter the shafts or drifts toward ES-1 (see Figure 8.4-28) and away from the emplacement areas. Information on shaft and drift dimensions and penetration depths of the exploratory shafts is given in Section 8.4.2.

General approach to evaluation of potential impacts

Conceptual models of present hydrologic conditions are described in Chapter 3 and Section 8.3.1.2 of this document. Briefly, it is believed that within each unsaturated-zone rock unit, water will flow vertically downward and will travel mainly in the matrix of the rock units, with spatially averaged percolation flux not exceeding 0.5 mm/yr. Some lateral diversion of flux may occur at the interfaces between distinct hydrogeologic rock units. This diverted water may be directed down-dip along the interface (as matrix flow, given the present recharge rates) to the water table or to downward

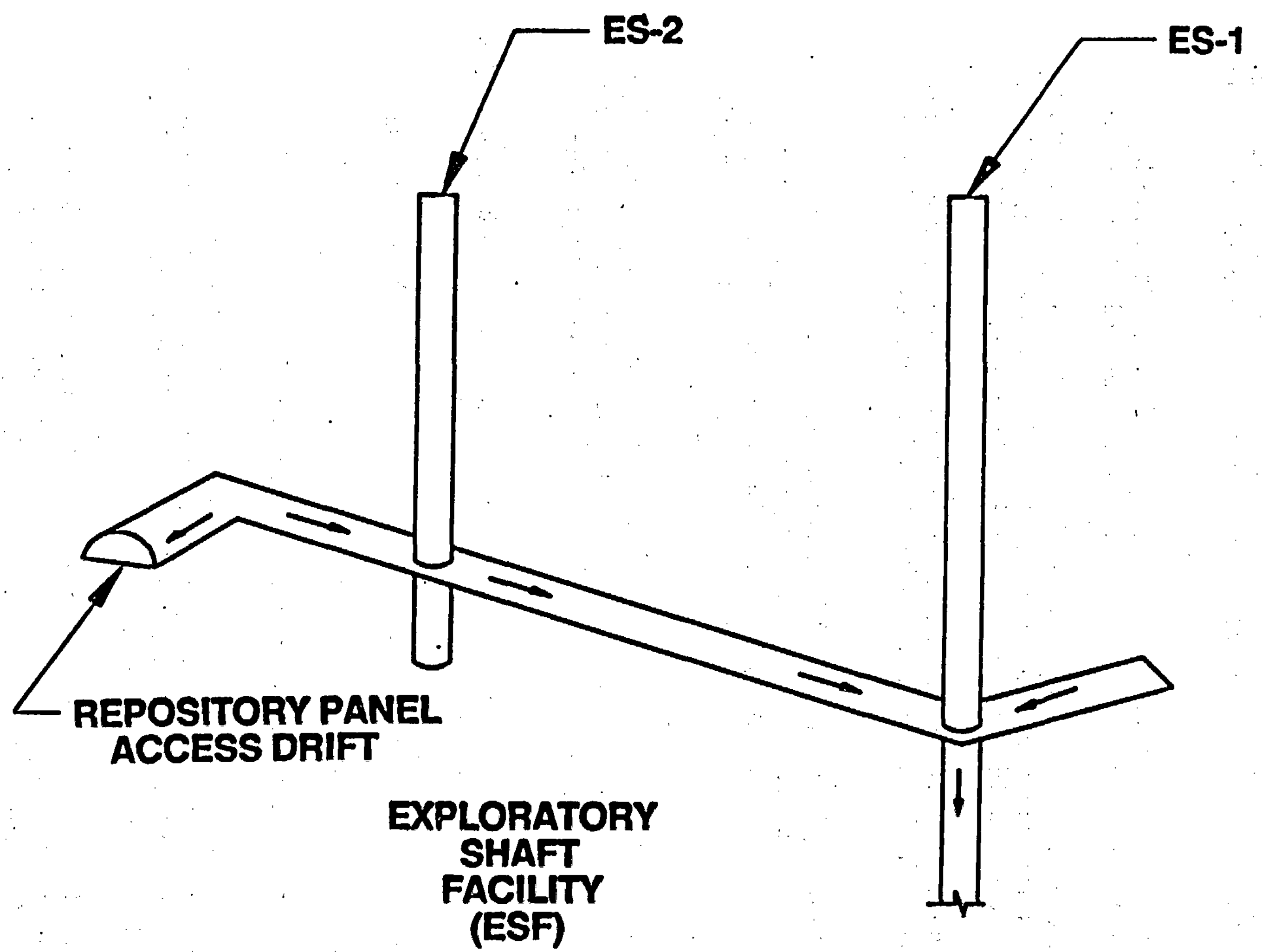


Figure 8.4-28. Illustration of the planned drainage pattern towards exploratory shaft 1 in the exploratory shaft facility.

drainage points in the highly faulted zone southeast from the edge of the emplacement zone. Water reaching the water table will then flow in a roughly horizontal direction to the accessible environment boundary. As discussed in Section 8.3.5.13, the units of the unsaturated zone below the proposed repository level (especially the Calico Hills unit) and the saturated zone are expected to provide the primary barrier to radionuclide release to the accessible environment.

The conceptual model for the transport of gas (carbon-14 dioxide) through the partially saturated overburden has three principal features:

1. Gas-phase carbon-14 dioxide would move upward through air-filled pores and fractures of the unsaturated tuffs by molecular diffusion and by advection in a thermally driven air convection cell.

2. An isotopic equilibrium would exist between carbon dioxide in the gas phase, which is mobile, and dissolved bicarbonate, which is immobile.

3. Precipitation of calcite would irreversibly remove carbon-14 from the system. As discussed in Section 8.3.5.13, the engineered barrier system, especially the container, is expected to act as the primary barrier to gaseous radionuclide release to the accessible environment.

Given the above understanding of the hydrologic conditions at the site, ESF construction and testing could potentially impact the primary barriers and, therefore, the performance of the Yucca Mountain site through four primary mechanisms:

1. Create openings that remain after construction and potentially could furnish pathways for movement of liquids and gases.

2. Induce changes in the rock characteristics around these openings.

3. Introduce solid materials to the site.

4. Introduce fluids, both liquids and gases, to the site.

The potential impacts caused by these mechanisms are generally addressed in the paragraphs below. The potential impacts to each of the four postclosure performance objectives identified previously are specifically evaluated in the subsections that follow the general discussion.

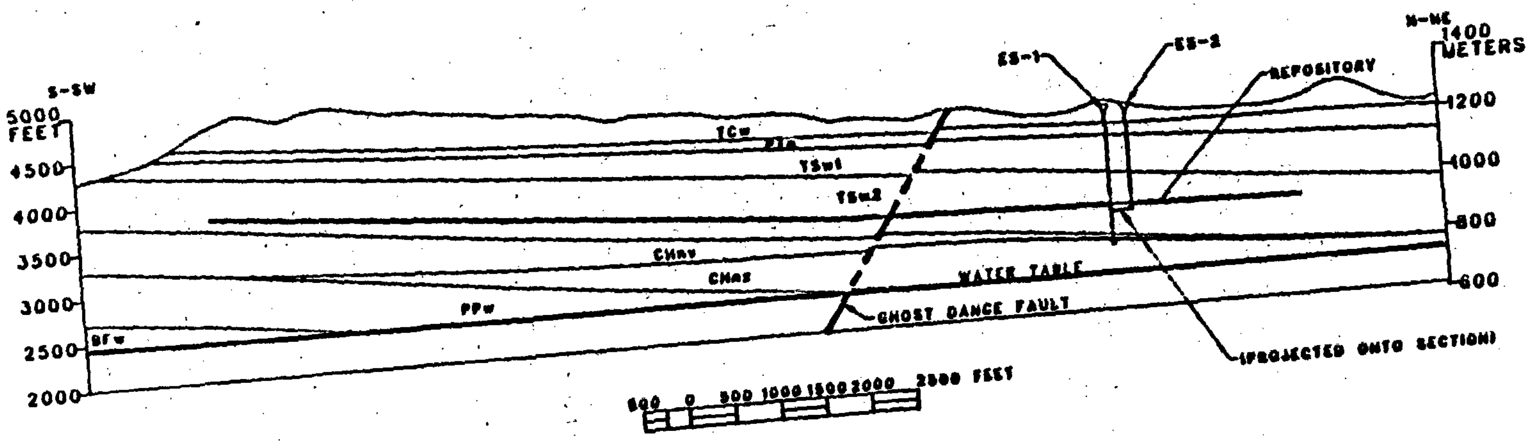
Creation of openings. The openings and surrounding disturbed rock provide potential pathways for radionuclide travel in both the liquid and gaseous phases. These pathways include not only the shafts and drifts themselves but also the rock damage zone caused by excavation of openings. Fernandez et al. (1987) have analyzed the potential for both gaseous and liquid flow through a shaft and the damaged zone around a shaft and concluded that the presence of the shafts, damaged zone, and liner will not significantly impact the long-term isolation capability of the repository. The analysis results would be similar for the evaluation of potential performance impacts caused by the construction of the long exploratory drifts and the testing area. Additionally, the shafts and drifts will be backfilled to reduce the potential for flow of gases and liquids through these openings. Fernandez et al. (1987) also described methods to remove the liner, to mitigate the damaged zone, and to emplace a seal in the event that future analyses suggest that these actions are necessary. Again, it should be pointed out that the ESF was designed to be physically separate from potential waste emplacement panels.

Induced changes to rock characteristics. Case and Kelsall (1987) examined the significance of construction-induced changes in the hydrologic characteristics of the rock mass surrounding an opening and found that significant changes to rock-mass permeability were limited to a few meters. As can be noted from Figure 8.4-29, the ESF comprises only an extremely small volume compared with the volume of rock mass over the entire repository. Therefore, the ESF induced changes in rock characteristics are not expected to significantly change the overall hydrologic flow characteristics at the site, especially near waste emplacement panels which are horizontally separated from the ESF. This is primarily because liquid water generally moves slowly vertically downward in the unsaturated zone at the site (see Section 3.9.3). Therefore, only localized effects on the flow patterns are expected.

Introduction of solid materials. Solid materials introduced to the site through the ESF include the shaft liner and those materials used for testing purposes. The chemical interactions of the shaft liner with the surrounding rock mass are expected to be limited in extent (a few meters) and are not likely to have any significant effect on performance. The current plans are for the liner to be removed below the waste emplacement level. Other materials (such as test instrumentation and cementitious materials) generally will be removed and, because all materials will be in regions separated by at least 30 m laterally from waste packages, are not expected to have any influence on the isolation integrity of the site. Potential chemical interactions of these materials with the site are now being evaluated, with preliminary results indicating no significant impacts on waste isolation.

Introduction of Fluids. A variety of fluids will be introduced to the site, both organic and inorganic. The fluids introduced in the largest quantities will be liquid water, introduced during ESF construction and testing, and air, primarily introduced through ventilation. The expected volume of water introduced by construction and testing is an order of magnitude smaller than the 20,000 m^3 considered in scenarios by Fernandez et al. (1987). No significant impacts on performance were found in their analyses. The majority of water (approximately 80-90%) introduced is expected to be recovered, with the amount of water permanently lost to the rock mass at least one to two orders of magnitude larger than the amounts of other fluids lost. The other fluids are primarily small amounts of organics (such as lubricants and oils) lost by machinery. All water introduced will be tagged with a tracer to permit evaluation of the extent of the water movement.

The fluid injection pressures used in construction and testing are low, generally a few atmospheres or less, with the pressure applied only for a short time. Preliminary analyses indicate that water (or other liquids) will move only a short distance (several meters) into the rock mass because of the



SECTION THROUGH TUFF MAIN

Figure 8.4-29. Projection of exploratory shaft facility onto stratigraphic cross-section of the site along repository mains.

low injection pressures, the low matrix permeability, and the high capillary forces within the matrix. The analyses indicate that water movement in fractures under low pressure gradients will be significantly retarded by the high capillary forces in the adjacent rock matrix. The analyses also indicate that, at equilibrium with the rock mass, saturation of the rock mass will not change by significant amounts (only a few percent). Therefore, it is not expected that the flow field will be altered except in very localized areas around the water injection locations. Also, because water is expected to move slowly vertically downward, any liquid (organic or inorganic) entering the rock mass is expected to move vertically through the rock matrix after passing through the main test level. The ESF testing area is designed to drain any fluids that enter the shafts or drifts toward ES-1 and away from the emplacement areas (Figure 8.4-28). In addition, the physical separation of the ESF from potential waste emplacement locations, located at approximately the same elevation as the ESF testing area, suggests that fluids introduced into the ESF will not interact with the waste, nor will fluids that might contact the waste interact with the ESF fluids.

A significant amount of air will enter the ESF through ventilation. Analyses by Hopkins et al. (1987) indicate that a volume of water comparable to that estimated to be lost during ESF construction and testing can potentially be removed from the rock mass in 3-4 years of ventilation. The analyses suggest that more water would be removed by ventilation than introduced by ESF construction and testing and, hence, the rock-mass saturation could actually be reduced. The analyses indicate that the ventilation effect occurs only within a few meters of the exposed rock surfaces. These factors, combined with the considerations noted above, indicate that the fluids introduced into the ESF during construction and testing will not significantly impact the waste isolation integrity of the site. The investigation of fluid movement at the site is an integral part of the planned site characterization activities, and future data and analyses will be evaluated to determine the validity of this conclusion.

Summary. In summary, potential impacts of ESF construction and testing on performance are not expected to be significant because 1) the exploratory shafts will be located where water is not likely to enter, 2) any water entering the shafts will drain from the sump of ES-1, 3) liquid movement is expected to be vertically downward, 4) the drainage pattern in the ESF is away from waste-emplacement panels, 5) damage to the rock mass surrounding openings is limited to a few meters, 6) liquids introduced by construction and testing are expected to move only a short distance (several meters) into the rock, 7) the ESF is laterally separated from waste-emplacement panels by at least 30 m, 8) a significant volume of water will be removed by ventilation, 9) air and water flow through the shaft can be controlled effectively by the emplacement of a shaft fill, and 10) deposition of solids from chemical interactions of the shaft liner with ground water will be a localized phenomena and should not decrease the drainage capacity of the rock at the base of the shaft. These findings are based on current knowledge of the site and preliminary results of some ongoing studies. These findings are used in the following subsections to evaluate the potential impacts of ESF construction and testing on the performance of the site.

8.4.2.6.1 Potential impacts on the pre-waste-emplacement ground-water travel time postclosure performance objective

Summary of issue resolution strategy

One of the postclosure performance objectives described in 10 CFR 60, Subpart E addresses pre-waste-emplacement ground-water travel time (GWTT) and places a minimum criterion of 1,000 yr for ground-water travel time from the disturbed zone to the accessible environment along the fastest path of likely radionuclide travel. The draft generic position paper on GWTT issued by the Nuclear Regulatory Commission (NRC) (NRC, 1986) states that "Pre-waste-emplacement pertains to conditions at the site prior to any significant disturbance of the hydrological or geological setting such as construction activities or the effects of radioactive wastes." The position paper also states that the GWTT objective should be viewed as a conceptually simple measure of the overall quality of the geologic setting.

Section 8.3.5.12 (Issue 1.6) describes the Issue Resolution Strategy (IRS) proposed for determining if the site meets the performance objective for GWTT as required by 10 CFR 60.113(a)(2). The IRS considers liquid water movement along the fastest path of likely radionuclide travel from the disturbed zone to the accessible environment. The flow path will include portions of both the unsaturated zone and the saturated zone at the site. The strategy for demonstrating compliance with the GWTT performance objectives is to rely on each hydrogeologic unit from the disturbed zone to the accessible environment as a barrier to flow, with the primary barrier designated as the unsaturated Calico Hills nonwelded unit. Current understanding of flow in the unsaturated zone is that, under present conditions, water moves predominantly vertically downward and through pores in the rock matrix, with the possibility of lateral water movement along hydrogeologic unit interfaces (see Section 3.9.3). The flow path through the saturated zone is generally horizontal and through the fractures. Preliminary estimates of GWTT through the unsaturated zone, based on an upper-bound estimate of flux (see Section 3.9), indicate travel times of tens of thousands of years (Sinnock et al., 1986). The travel time through the unsaturated Calico Hills nonwelded unit alone was estimated to be over 10,000 yr. These preliminary estimates suggest that the pre-waste-emplacement GWTT objective can be met with reasonable assurance at the Yucca Mountain site.

Evaluation of potential impacts

None of the four potential impacts of ESF construction or testing on the waste isolation integrity of the site listed previously have been identified as significant, with respect to the GWTT performance objective. The GWTT performance objective addresses performance of the site under pre-waste-emplacement conditions. Therefore, the impacts of ESF construction and testing are relevant to this performance objective only in how the boundary of the disturbed zone might be altered (i.e., how the hydrologic characteristics and performance of the site might be significantly changed by ESF construction or testing).

The creation of openings or the introduction of materials are not expected to alter the dimensions of the disturbed zone discussed below. Openings are explicitly a part of the disturbed zone, excluding shafts, boreholes, and their seals. The introduction of materials is not likely to impact the current conservatively assumed boundary of the disturbed zone of 50 m below the repository midplane. Therefore, these two potential impacts are not expected to affect the GWTT performance objective.

As part of the IRS of Section 8.3.5.12 and the GWTT estimates by Sinnock et al. (1986), a preliminary definition for the boundary of the disturbed zone was conservatively assumed to be a plane 50 m below the repository midplane. This assumption is in accordance with the recommendations made in the NRC draft technical position paper on the disturbed zone (June 1986), where significant construction-induced changes to rock-mass hydrologic characteristics were estimated to extend no more than 50 m from any underground opening.

Construction-induced modification of rock-mass permeability could impact the definition of the boundary of the disturbed zone. Case and Kelsall (1987) examined the significance of construction-induced changes to the hydrologic characteristics in the rock mass surrounding an opening (such as the exploratory shaft) and found significant changes to rock-mass permeability to be limited to much less than 50 m. Thus, not only are the exploratory shafts not part of the disturbed zone by definition, the potential modification of hydrologic characteristics of the rock around the shafts and drifts is of limited extent and within the assumption made in estimates of GWTT. As stated above, these estimates indicate that the construction of the ESF is unlikely to impact the ability of the site to comply with the GWTT performance objective.

The introduction of fluids by ESF construction and testing could change the rock-mass saturation, hydrologic properties, and flow paths; thereby impacting the definition of the boundary of the disturbed zone. The ESF testing area is designed to drain any fluids that enter the shafts or drifts toward ES-1 and away from the emplacement areas (Figure 8.4-28). The previous section suggests that introduction of fluids into the rock mass will be limited to much less than 50 m of the ESF because of the low fluid pressures used and the hydrologic properties of the rock, and therefore would not alter the current conservatively assumed value for the boundary of the disturbed zone. Moreover, ventilation through the facility will remove, in a few years, a volume of water comparable to the amount lost in the rock by construction and testing. Finally, the ESF is separated by a minimum of approximately 30 m from the waste emplacement drifts (see Figure 8.4-9). Because fluids introduced into the facility are expected to move vertically downward, the fluids will not interact with the flow paths that are directly below the waste emplacement areas. Therefore, even if some fluids could move more than 50 m vertically from the ESF, the fluids will not affect likely paths of radionuclide travel and will not affect performance relative to the GWTT performance objective. Because of these factors, current knowledge supports the conclusion that no significant impacts on the GWTT performance objective are expected to result from exploratory shaft construction or testing.

The basis for this conclusion is the current design of the ESF and test program. Although not currently a part of the ESF design, a long, lateral drift in the unsaturated Calico Hills unit has been proposed and described in Section 8.3.1.2.2.4.1 (Calico Hills test in the ESF). The current understanding, based on the intent of the GWTT performance objective to be a conceptually simple measure of performance, is that this drift would be excluded in defining the boundary of the disturbed zone. Moreover, the NNWSI Project believes that activities described in Section 8.3.5.12.5 will justify a definition for the disturbed zone as a boundary 10 m or less below any underground opening, which would still provide almost 85 m of unsaturated rock to the water table. This thickness of Calico Hills rock would be more than the minimum expected at other locations below the repository. Based on preliminary GWTT estimates by Sinnock et al. (1986), 85 m of unsaturated Calico Hills rock would still yield travel times well in excess of the 1,000-yr criterion specified by 10 CFR 60.113.

8.4.2.6.2 Potential impacts on container lifetime

Summary of issue resolution strategy

This section discusses containment requirements for the waste package and the impact of the construction of and testing in the ESF on the waste package. Issue 1.4 (Section 8.3.5.9) addresses the performance of the waste package as required by 10 CFR 60.113. The performance objective for containment is as follows: "The engineered barrier system shall be designed, assuming anticipated processes and events, so that containment of high-level waste (HLW) within the waste package will be substantially complete for a period to be determined by the Commission, taking into account factors specified in 60.113(b) provided that such a period shall not be less than 300 yr nor more than 1,000 yr after permanent closure of the geologic repository."

A precise interpretation of the regulatory term "substantially complete containment" depends in large part on the level of waste-package performance needed at the site. Therefore, a specific interpretation of the general requirements cannot be made until additional information regarding site condition and the characteristics of alternative materials and waste package design subject to these conditions is available. To guide testing and design programs to obtain the information needed to assess the performance of the set of waste packages, three quantitative design objectives have been set. These objectives state that (1) 80 percent or more of the waste packages will retain all their radioactivity for a containment period of 1,000 yr after permanent closure, (2) at any time during the containment period, at least 99 percent of the radioactivity resulting from original waste emplaced in the underground facility will be retained within the set of waste packages, and (3) releases from the EBS in any one year during this period should not exceed one part in 100,000 of the total inventory of the radionuclide activity present in the geologic repository system in that year.

The NNWSI Project has chosen to use the components of the waste package, together with the near-field environment as altered through engineering design, as a basis for the strategy to demonstrate that the containment performance objective has been met. The system elements relied upon are (1) the postemplacement environment of the waste package, as altered by the engineered aspects of the waste package, (2) the waste container and its properties under those conditions, and (3) the waste form and its properties under those environmental conditions. Section 8.3.5.9 provides a detailed discussion of the regulatory basis and resolution strategy for Issue 1.4.

Evaluation of potential impacts

The container can be breached by two mechanisms: mechanical damage to the container or corrosion of the container through contact with water. With respect to the potential impacts listed in the introduction, the creation of openings and rock-induced damage are the only impacts that could result in mechanical damage. Mechanical damage to a container as a result of ESF construction and operation is not a credible scenario because of the separation of the ESF from waste emplacement areas and because the excavation of the ESF will meet the same general standards as the rest of the underground facility (SCP-CDR, 1987). A significant failure of the drifts in the ESF during the containment period is highly unlikely because of the planned methods of mining and methods of supporting the drifts (SCP-CDR Section 3.3). However, even if a failure were assumed to occur, any deformation in those drifts would be isolated from the waste-emplacement areas by a minimum of 30 m (Figure 8.4-8 and Figure 8.4-10). This is well beyond the range of significant effects of deformation.

During construction of and testing in the ESF, materials such as experiment instrumentation, concrete, and other construction materials will be introduced into the host rock. A large portion of these materials will be retrieved. For those materials not expected to be removed, it is expected that they will have no impact on the performance of the repository. Any movement of the solids away from the shaft would be by dissolution in the ground water and subsequent ground-water flow through the rock. Since, as discussed above, the water is expected to flow predominantly vertically, the water and dissolved solids are not expected to contact the waste packages.

Water introduced during ESF construction and testing is not expected to significantly impact performance with respect to container lifetime. The basic strategy for limiting the potential for corrosion of the container is to limit the liquid water that can contact the container and limit any changes in water chemistry. Construction and operation of the ESF will not significantly change the hydrology and geochemistry of waste emplacement areas. During construction of the ESF, water will be used for dust control, drilling and mining, and testing. Most of this water will be removed to the surface by mucking operations. Preliminary estimates indicate that only a small fraction of the water used in the ESF during construction will be retained in the host rock. This water will be retained in the rock mass around the shaft and drifts. Retained water may flow into fractures and move away from exposed rock surfaces or be retained in the rock matrix near the surfaces.

If water flows in the vertically oriented fractures, it would increase the distance that the water moved (generally several meters); however, the effect on the equilibrium saturation level in the rock mass would be quite small (a few percent). If the water moved primarily into the matrix, there would be a somewhat larger local effect on the saturation level, but the distance of the effect from the surface would be short (generally tens of centimeters or less). As water moves away from the walls of the shafts and drifts, its effect on the equilibrium saturation level is decreased simply because there is an increase in the volume of rock containing the fixed volume of water.

Since the injection pressure of the water used during construction will be low, retained water is expected to be a local effect near shafts and drifts. Since flow in the potential repository unit is expected to be essentially vertical (see Section 3.9.3), water from ESF construction and testing is not expected to flow laterally through the 30 m or more of rock that separates the ESF from a waste package and reach emplacement boreholes and the waste package. A modified permeability zone (MPZ) around an exploratory shaft, due to excavation of the shaft, was calculated by Case and Kelsall (1987). The MPZ was estimated to have a radius twice the radius of the shaft and considered as a preferential pathway for radionuclide travel by Fernandez et al. (1987). The permeability in the MPZ was estimated to be substantially larger than the undisturbed rock permeability. This increase in permeability will allow easier movement of fluids into that limited region but the fluids would still be retained near the shaft wall. Fernandez et al. (1987) have analyzed the potential for both gaseous and liquid radionuclide transport through the exploratory shaft and damaged zone around the shaft and concluded that the presence of the shafts, damaged zone, and liner will not significantly impact the isolation capability of the repository. The analysis results would be similar in the evaluation of potential performance impacts caused by the construction of the long exploratory drifts and in the testing area.

As an additional measure, the ventilation system will remove water from the exposed walls in the ESF during construction and testing. Hopkins et al. (1987) have performed analyses that show that ventilation will reduce the saturation level several meters into the wall. Specifically, the ventilation system will remove, in a few years, a volume of water comparable to that retained from construction and testing before emplacement of waste, thereby reducing the potential for construction water reaching a waste package.

Further, drainage in the ESF is designed for water to flow toward ES-1 (see Figure 8.4-10 and 8.4-28) reducing the potential for water to reach a waste package. If surface water were to enter the exploratory shafts, this water is also expected to drain vertically and not flow horizontally for the 100 m or more necessary to reach waste packages. Fernandez et al. (1987) have performed analyses that indicate that if a large quantity of water, estimated to be an order of magnitude or more larger than the water retained during construction, entered the exploratory shaft, this water would be contained within the shaft sump and subsequently drain.

Therefore, the conclusion is that potential impacts of ESF construction and testing on the containment capability of the packages will not be significant. Water and other materials will be introduced into the host rock during construction and testing of the ESF. However, injection pressure for construction water is so low and the quantity is so small that the change in the saturation level at equilibrium will be small. The quantity of the other materials that will remain in the ESF is also small. Because of the relatively small amount of water and materials that will remain in the ESF, the relatively short distance into the rock mass that they will penetrate, the horizontal distance separating the ESF from the emplaced waste packages, and the expected predominant vertical flow of water, the fluids and materials introduced into the ESF and the construction-induced changes to the rock-mass permeability in the few meters surrounding the shafts and drifts are not expected to contact and affect performance of the waste packages.

8.4.2.6.3 Potential impacts on releases from the engineered barrier system (EBS)

Summary of issue resolution strategy

This section discusses the postclosure performance objective related to the engineered barrier system (EBS) release rate and the impact of the construction and testing in the ESF on the releases from the EBS. Issue 1.5 (Section 8.3.5.10) addresses the performance of the EBS as required by 10 CFR 60.113(a)(1)(ii), which states in part that the EBS shall be designed, assuming anticipated processes and events, so that: "(B) the release rate of any radionuclide from the engineered barrier system following the containment period shall not exceed one part in 100,000 per year of the inventory of that radionuclide calculated to be present at 1,000 years following permanent closure, or such other fraction of the inventory as may be approved or specified by the Commission; provided that this requirement does not apply to any radionuclide which is released at a rate less than 0.1 percent of the calculated total release rate limit. The calculated total release rate limit shall be taken to be one part in 100,000 per year of the inventory of radioactive waste, originally emplaced in the underground facility, that remains after 1,000 years of radioactive decay."

The strategy for resolution of Issue 1.5 is based on present knowledge of the repository emplacement environment, data gathered on waste form performance in environments that can be related to the projected repository environment, and the use of models to assess the performance of various system elements. The system elements relied upon to limit releases are (1) the engineered environment that limits the quantity and quality of water that can contact the containers and (2) the waste form that controls the release rate from inside failed containers. Strategies are developed for the expected case of no liquid water contacting waste packages and for a bounding case that allows all containers to experience the maximum water flux, even though this latter case is not expected to occur.

Current data (see Section 7.4) indicate that it is very likely that the performance objective for control of the release rate from the EBS can be met by the waste form in an unprotected condition, i.e., without relying upon the presence of a container. The unprotected conditions that will be assumed will be different for the two basic waste forms because of intrinsic differences. The glass waste form will be assumed to be in its pour canister, with the canister degraded to the point that water can flow freely into and out of the canister. The spent fuel waste form will be assumed to consist of bare fuel pellets that have been exposed because of cladding rupture. For both waste forms, the container will be assumed to be substantially intact, thereby providing a means to accumulate water in contact with the waste form. Section 8.3.5.10 provides a detailed discussion of the regulatory basis and resolution strategy for Issue 1.5.

Evaluation of potential impacts

No significant impacts of ESF construction and testing on the waste isolation integrity of the site, with respect to container lifetime, were identified in Section 8.4.2.6.2. The system elements relied upon for container lifetime include two of the same elements that are relied upon to limit releases from the EBS: the engineered environment and the waste form. Therefore, the discussion presented in Section 8.4.2.6.2 is applicable to the impact on the EBS releases and will not be totally repeated in this section.

As discussed in Section 8.4.2.6.2, a significant failure of drifts in the ESF is highly unlikely. Furthermore, even in the event of a failure, the waste-emplacement areas are beyond the range of significant effects of deformation.

Transport of small amounts of other materials retained from construction and testing will be primarily by ground-water flow. Since the water is expected to flow predominantly vertically, these materials should also neither contact waste packages or affect releases from the EBS.

As described in Section 8.4.2.6.2, the amount of water retained in the walls and ceilings of the ESF will be small since the injection pressure of water used during construction will be low. It is expected that retained water will be a local effect near the shafts and drifts will probably drain vertically down through rock of the unsaturated zone. The ventilation system will remove some of water retained during construction and testing before emplacement of waste, further reducing the potential for construction water to affect the performance of the EBS. As explained in Section 8.4.2.6, the drifts are designed so that fluids in the drifts will drain toward ES-1. Therefore, fluids that enter the host rock during construction and testing are expected to remain well within 30 m of the ESF and not move laterally into the vicinity of the waste package.

Water and other materials will be introduced into the host rock during construction of and testing in the ESF. Because of the small amount of water and materials that will remain in the ESF, the relatively short distance into the rock mass that they will penetrate, the relatively long horizontal distance from the ESF to the waste packages, and the expected predominant vertical flow of the water in the unsaturated zone; the fluids and materials introduced into the ESF and the construction-induced changes in permeability of the rock mass surrounding the shafts and drifts are not expected to affect releases from the EBS.

8.4.2.6.4 Potential impacts on release to accessible environment

Summary of issue resolution strategy

This section discusses the postclosure performance objective related to the assessment of total system releases to the accessible environment. Issue 1.1 (Section 8.3.5.13) addresses the performance of the total system as required by 10 CFR 60.112 and 10 CFR 60.115. These regulations specify cumulative release limits for radionuclides to the accessible environment from all significant processes and events that may affect the geologic repository for 10,000 years following permanent closure.

The strategy for the resolution of Issue 1.1 is to determine the contribution to total radionuclide releases to the accessible environment during the next 10,000 yr of all scenarios involving processes and events which are sufficiently credible to warrant consideration and to construct a complementary cumulative distribution function (CCDF) for the cumulative radioactivity (in curies) released to the accessible environment in the 10,000-yr period following closure. Generic lists of processes and events that could affect a repository system are evaluated together with site-specific information to identify the significant process and events. Significant processes and events are those that could have a significant impact on the characteristics of the system important to waste isolation and that are sufficiently credible to warrant consideration. Scenarios, based on the set of significant process and events, are then developed for both undisturbed and disturbed conditions. Undisturbed conditions are the natural processes and events that are likely to occur given the modifications that result from the repository construction and waste emplacement. Disturbed conditions are the natural processes and conditions and human activities that are considered unlikely yet sufficiently credible to warrant consideration. Mathematical models for each scenario class are constructed to calculate the cumulative normalized releases from the occurrence of each scenario. The release values are then used to construct the CCDF as advocated by the regulations.

Because of the variety of scenarios that must be addressed, various barriers are relied upon. In general, the primary barriers to be relied upon for release scenarios involving liquid-water transport include the unsaturated zone beneath the repository (primarily the Calico Hills nonwelded unit), with the saturated zone used as a backup. For release scenarios involving gaseous transport, the EBS is the primary barrier, with the overburden as a backup.

Evaluation of potential impacts

Construction and operations of the ESF are not expected to alter the physical characteristics of the natural geologic setting so as to have a significant effect on releases to the accessible environment. As discussed in the introduction, the primary potential impacts to performance of the total system are the creation of openings and the associated disturbed zone, thereby creating potential pathways for water and air flow after construction, and the introduction of solid materials and fluids during ESF construction and testing.

Fernandez et al. (1987) have analyzed the potential for both gaseous and liquid flow through the exploratory shafts and the construction-induced zone of modified rock characteristics surrounding the openings. The potential impacts of drifts in the testing area of the ESF and the long exploratory drifts are expected to be similar, but not greater, than the impacts caused by the exploratory shafts. Therefore, much of the following discussion focuses on the exploratory shafts. The features of the exploratory shaft that should be considered during the postclosure phase are the shaft fill, the shaft liner, and the zone of increased rock permeability around the shaft (the Modified Permeability Zone, MPZ) is discussed in Case and Kelsall (1987). Determinations of both expected and maximum increases in permeability.

Fernandez et al. (1987) address the potential for the exploratory shafts to create preferential pathways for water and air flow. Scenarios have been considered in which water enters the top of the exploratory shafts and migrates downward through the shaft backfill and the MPZ to a sump at the base of ES-1. Water entering the ESF will drain away from the waste emplacement areas and toward the ES-1 (Figure 8.4-28) and flow from there to the sump at the base of ES-1. The long exploratory drifts that will be mined within the ESF are a special case and will be designed to meet permanent repository standards. These drifts will be graded to control any water entering them (see Figure 8.4-9) and hydraulically isolate the ESF from the rest of the underground facility (see Figure 8.4-10). Fernandez et al. (1987) show that, for the majority of scenarios analyzed, no water enters the ESF test area or drifts because the water can be effectively drained at the base of the shafts. Water was able to enter the ESF drifts and test area for only two of the scenarios analyzed, and the flow was computed to be low and easily contained within the ESF, not reaching any waste. It was assumed by Fernandez et al. (1987) that the saturated hydraulic conductivity of the shaft fill is 10^{-2} m/s and the shaft liner below the repository station would be removed. Hence, analysis suggests that the exploratory shafts, as currently designed, will not affect releases to the accessible environment by allowing surface water to enter repository areas.

The worse-case scenario considered by Fernandez et al. (1987) assumes that all water from a probable maximum flooding event is restricted in an alluvial basin adjacent to the shaft allowing water to drain into the shaft. Because water entering the shaft is contained within the shaft sump and the ESF, water does not enter the emplacement panels. Therefore, it is concluded that the exploratory shafts do not affect the repository performance by allowing surface water to enter repository areas. This worst-case scenario is considered highly unlikely since the currently planned exploratory shaft locations are well above flood levels for a probable maximum flooding event and are not located in alluvium. These considerations further reduce the likelihood that the ESF will have any effect on repository performance.

Convective air transport of gases through drifts and shaft was also evaluated in Fernandez et al (1987). Gaseous transport may be induced by either thermal energy differences within the repository or barometric pressure variations.

The first convective air flow analysis modeled the temperature variation within the repository and determined that air would rise up the exploratory shaft and be drawn in through peripheral ramps and shafts. The analyses also considered flow through rock above the waste disposal area. For several combinations of host rock air conductivity above the repository, the fraction of the flow through the shaft fill and the MPZ to the total flow through the rock mass above the waste disposal areas, as well as through the shaft fill and the MPZ, was determined. It was concluded from the analysis that shafts and ramps, in general, and the exploratory shafts in particular, are not preferential pathways for gaseous radionuclide release if air conductivity of the shaft fill is less than 3 x 10^{-4} m/min or an equivalent hydraulic conductivity of 10^{-2} cm/s. This condition is expected to be met.

The second air flow analysis considered barometric pressure changes and modeled air flow both in and out of the repository in response to these changes. Possible flow paths included all shafts and ramps in addition to the host rock. As before, conductivities were varied to determine the magnitude of the air flow as well as the ratio of air flow through the shafts and MPZ to the total flow. Because of the total volume of air mass and the cyclic nature of barometric pressure changes, it was concluded that this mechanism contributes negligibly to any airborne radioactive release.

The primary impact of solid materials introduced to the site is expected to be from chemical interactions of the shaft liner with ground water. There exists a potential to form precipitates in the MPZ and the shaft fill. This precipitation is a consequence of water chemistry changes as alkali is leached from the concrete liner. Analyses presented in Fernandez et al. (1987) indicate that these precipitates will be deposited very near to the point of their nucleation so that these effects will be very localized. Additionally, the deposited precipitates will tend to reduce the hydraulic conductivity of both the MPZ and the shaft backfill, to further reduce air flow and water entry into the ES. As discussed in Section 8.4.6.2, transport of small amounts of other materials retained from construction and testing will be primarily by ground-water flow. Since the water is expected to flow predominantly vertically, these materials also should neither contact waste packages nor affect releases from the EBS.

It is expected that fluids introduced by ESF construction and testing will have no significant impact on the performance of the total system, for reasons similar to those presented in section 8.4.2.6.2. As described in that section, the amount of water retained in the walls and ceilings of the ESF will be small since the injection pressure of water used during construction will be low. It is expected that retained water will be a local effect near the shafts and drifts and will probably drain vertically down through the unsaturated zone. The ventilation system will remove some of the water retained during construction and testing before emplacement of waste, further reducing the potential for construction water to affect the performance of the EBS. Also, the drifts are designed so that fluids in the drifts will drain toward ES-1. Fluids that enter the host rock during construction and testing are expected to remain well within 30 m of the ESF, not move laterally into the vicinity of the waste package, and not affect releases from the total system.

In summary, potential impacts of ESF construction and testing on performance are not expected to be significant because (1) the exploratory shafts will be located where water is not likely to enter, (2) any water entering the shafts will drain from the sump of ES-1, (3) liquid movement is expected to be vertically downward, (4) the drainage pattern in the ESF is away from waste-emplacement panels, (5) damage to the rock mass surrounding openings is limited to a few meters, (6) liquids introduced by construction and testing are expected to move only a short distance (several meters) into the rock, (7) the ESF is laterally separated from waste-emplacement panels by at least 30 m, (8) a significant volume of water will be removed by ventilation, (9) air and water flow through the shaft can be controlled effectively by the emplacement of a shaft fill, and (10) deposition of solids from chemical interactions of the shaft liner with ground water will be a localized phenomena and should not decrease the drainage capacity of the rock at the base of the shaft.

8.4.2.7 Relationship of the exploratory shaft facility and the conceptual repository design

If the Yucca Mountain site is shown to be suitable and is selected for the waste repository, the exploratory shaft facility (ESF) will be incorporated into the repository. The relationship between the ESF and the repository is shown in Figure 8.4-30. It is likely that both shafts will be used as a source of intake air for the Phase I repository operations. It is currently envisioned that exploratory shaft 1 (ES-1) will be used as the primary source of intake air for the waste-emplacement operations. For this provision, all ES-1 internals would be removed before these operations, leaving only the concrete liner and provisions for shaft and liner inspection conveyances. Likewise, exploratory shaft 2 (ES-2) would be used as a source of intake air during repository operations to ventilate the repository shop facilities supporting waste-emplacement operations. However, since the volume of air required to ventilate these areas from ES-2 would be minimal, the internal features and the hoist hardware could be left in place without hindering the ventilation function during repository operations. Both shafts would continue to have scheduled inspections. Additionally, if the shaft internals for ES-2 are left in place, the shaft could continue to be used as an emergency exit.

8.4.2.8 Exploratory shaft facility construction and testing summary schedule

A logic diagram which shows the relative duration and sequencing of major exploratory shaft construction- and testing-related activities is provided in Section 8.5.1.2. The summary schedule is provided to show approximately when each of the ESF tests will begin relative to the construction operations. The sequencing of tests on the main test level is still under evaluation and is based on complex construction operations, scientific considerations, and probable test durations.

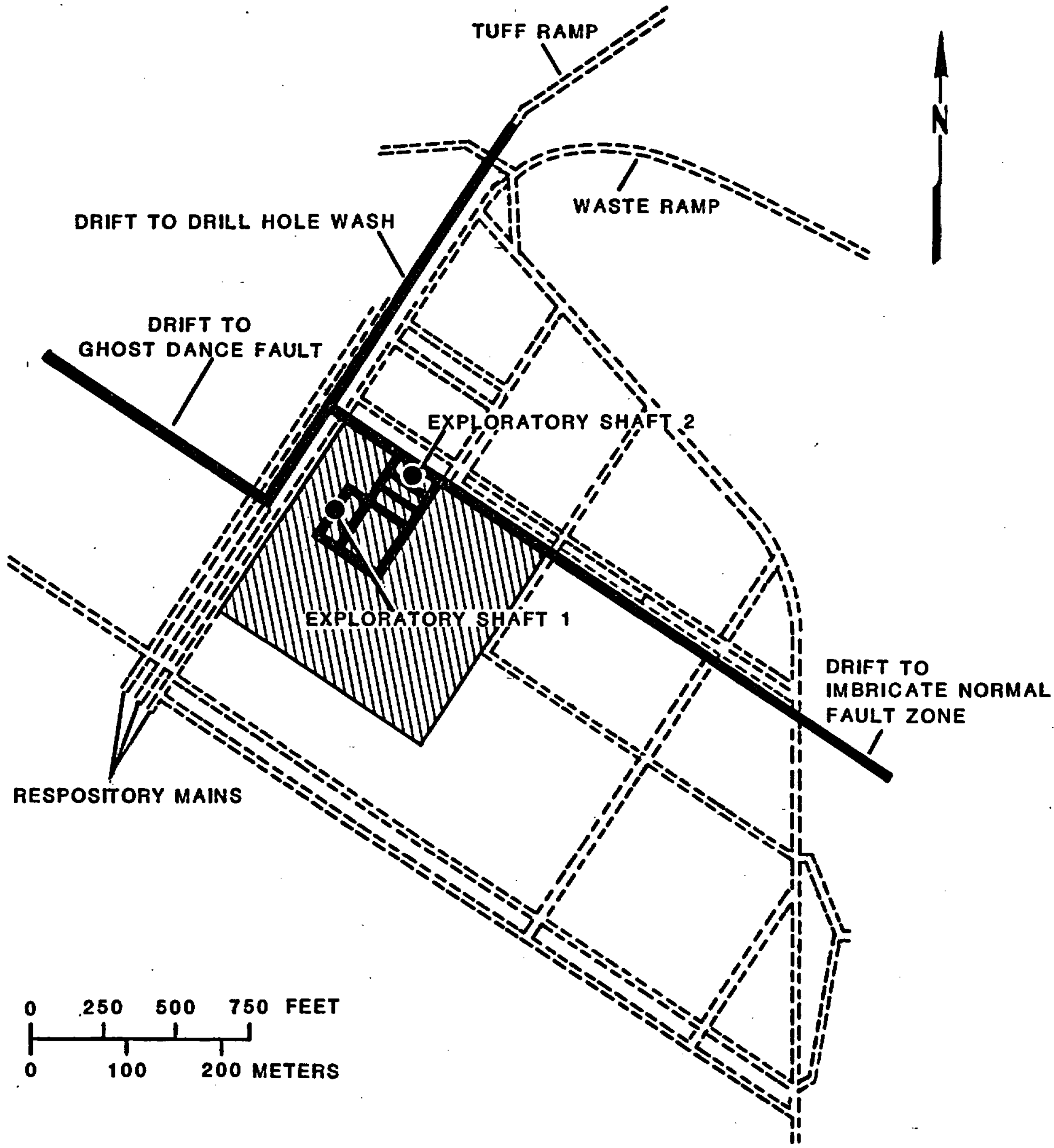


Figure 8.4-30. Relationship of exploratory shaft facility and the conceptual repository design. Dashed line shows the conceptual layout of the repository.